Synopsis of Research

Conducted under the 2017–2018 Northern Contaminants Program:

Full Report

Résumé de la recherche

effectuée en 2017–2018 dans le cadre du
Programme de lutte contre les contaminants dans le Nord :

rapport complet

Synopsis of Research Conducted under the 2017-2018 Northern Contaminants Program: Full Report

Résumé de la recherche effectuée en 2017-2018 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This is an unpublished document created internally by the Northern Contaminants Program (NCP) Secretariat.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 2017-2018 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 2017-2018 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 2017-2018 Northern Contaminants Program: Full Report* provides a detailed report of the activities and preliminary results of each project funded under the NCP between April 1, 2017 and March 31, 2018.

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 2017-2018), included dietary contaminant exposure, food 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; the benefits/risk evaluation of country food consumption; and environmental microplastics monitoring. Projects were carried out using a variety of methodologies including fieldwork, laboratory analysis, community based monitoring, and workshops.

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 effectuée en 2017-2018 dans le cadre du Programme de lutte contre les contaminants dans le Nord : rapport complet* présente un résumé des activités et des résultats préliminaires de chaque projet financé dans le cadre du PLCN entre le 1 avril 2017 et le 31 mars 2018.

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 : 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 2017-2018), 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, et les ateliers.

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 sur les contaminants de

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 is part of the NCPs usual activities, 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 2017-2018 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 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.

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 intitule Résumé de Recherche effectuées en 2017-2018 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 la Recherche, les futures publications liées aux projets financés par le PLCN (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 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 that are transported to the Canadian 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 five federal departments (Environment and Climate Change Canada, Fisheries and Oceans Canada, Health Canada, Polar Knowledge Canada 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 Canada), five regional contaminants committees, and Canada's 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. The Regional Contaminants Committees in Yukon, Northwest Territories, Nunavut, Nunavik and

Le Programme de lutte contre les contaminants dans le Nord (PLCN) mobilise les résidants du Nord et les scientifiques pour qu'ils participent à la recherche et à la surveillance axées sur les contaminants dans l'Arctique canadien, c'est-à-dire les contaminants qui sont transportés jusque dans l'Arctique par voie aérienne ou par les océans, et qui proviennent d'ailleurs dans le monde; ces contaminants demeurent dans l'environnement arctique et s'accumulent dans la chaîne alimentaire. Les données produites par le PLCN servent à évaluer la santé des écosystèmes et la santé humaine, et les conclusions de ces évaluations permettent d'assurer la salubrité et la sécurité des aliments traditionnels qui sont importantes pour la santé et le mode de vie traditionnels des 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 RCAANC), 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, 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).

la Nation dénée, Inuit Tapiriit Kanatami et le Conseil 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 de RCAANC 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

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

Contexte

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

Le Programme a pour objectif premier de réduire et, dans la mesure du possible, d'éliminer les contaminants présents dans le Nord dans les aliments traditionnels ou prélevés dans la nature tout en fournissant aux individus et aux collectivités de l'information leur permettant de prendre des décisions éclairées au sujet de leur alimentation.

to determine the levels, geographic extent, and source of contaminants in the northern atmosphere, environment and its people, and the probable duration of the problem. The data enabled us to understand the spatial patterns and temporal trends of contaminants in the North, and confirmed our suspicions that the major sources of contaminants were other countries. The data, which included information on the benefits from continued consumption of traditional/ country foods, was also used to carry out assessments of human health risks resulting from contaminants in those foods. Results were synthesized in the first Canadian Arctic Contaminants Assessment Report (1997).

Extensive consultations were conducted in 1997-1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, research priorities were developed based on an understanding of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

In 1998, initiatives got under way to redesign the NCP, and implement new program features which continue to this day: 1) the NCP blueprints that represent the long-term vision and strategic direction for the NCP; and 2) an open and transparent proposal review process. These features ensure that the NCP remains scientifically defensible and socio-culturally aware, while at the same time, achieving real progress in terms of the Program's broad policy objectives.

In 1998-1999, the NCP began its second phase, which continued until 2002-2003. Results of this phase were synthesized in the 5-part (1, 2, 3, 4, 5) 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

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

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

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

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

Since 2003, the NCP has continued to lead and 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 Canadian Arctic Contaminants Assessment Reports 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 *CACAR III: Mercury in Canada's North* publication reported on the scientific progress made under the projects supported by ArcticNet, NCP and International Polar Year. The report also evaluated the current understanding of the environmental fate of mercury in the Canadian Arctic. Its key scientific recommendations were: 1) Continue research and monitoring of atmospheric mercury, with an enhanced focus on deposition measurements to facilitate quantification of atmospheric contributions of mercury to Arctic ecosystems. 2) Continue temporal trend monitoring of mercury in Arctic biota, and identify the processes that are changing mercury concentrations in some species. 3) Further characterize the key processes acting on mercury after atmospheric deposition and

dans le RECAC II, en 5 parties (Partie 1, 2, 3, 4, 5) 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.

La publication intitulée *Troisième rapport d'évaluation des contaminants dans l'Arctique canadien : le mercure dans le Nord canadien* fait their effects on the fate of mercury in the Arctic environment. 4) Better characterize the processes that link climate change with mercury transport, cycling and bioaccumulation. 5) Increase efforts to determine the biological effects of methylmercury exposure on Arctic fish and wildlife.

The *CACAR III: Persistent Organic Pollutants in Canada's North* publication reported research on POPs in the Canadian Arctic over the period of 2003 to 2011. It drew on results from the NCP (2003-2011) as well as on any other published or unpublished studies up to early 2013. This reporting period saw much new knowledge developed on temporal trends of POPs in air and biota, new POPs in many environmental compartments, and on ocean transport to the Arctic. The possible influence of climate warming on trends of POPs has was also investigated. The report made recommendations in relation to the transition from science to policy action, how the expansion of information on the chemical of interest impacts future research directions, how the improved knowledge of time trends of POPs impacts future research directions, the importance of local sources of new POPs, knowledge of factors influencing levels and trends or POPs, and the on-going challenge of assessing the biological effect of POPs.

The *CACAR III Contaminants In Canada's North: Summary for Policy Makers* publication gives an overview of where contaminants originate, how they are transported, and how they interact with the Arctic and Northern environment and ecosystems. The report explores NCP's current knowledge to action initiatives, including a look at the key scientific studies taking place across the Arctic. Finally, the report details the 10 key findings of NCP research to date (Box 1) and the future directions of research in the Arctic (Box 2).

The most recent reports in the CACAR series, Contaminants in Canada's North: State of Knowledge and Regional Highlights, and Human Health 2017 were released in 2018.

état des progrès scientifiques réalisés dans le cadre des projets financés par ArcticNet et dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN) et de l'Année polaire internationale. Ce rapport visait également à évaluer notre compréhension actuelle du devenir du mercure dans l'Arctique canadien. Il propose les recommandations scientifiques clés suivantes : 1) Poursuivre la recherche et la surveillance sur le mercure atmosphérique, en mettant l'accent sur la mesure des dépôts afin de faciliter la quantification de la contribution du mercure atmosphérique dans les écosystèmes arctiques; 2) Continuer de surveiller les tendances temporelles des concentrations de mercure dans le biote de l'Arctique et déterminer les processus qui entraînent une variation des concentrations de mercure chez certaines espèces; 3) Continuer de caractériser les principaux processus agissant sur les dépôts atmosphériques de mercure ainsi que leurs effets sur le devenir du mercure dans l'environnement arctique; 4) Améliorer la caractérisation des processus liant le changement climatique au transport, au cycle et à la bioaccumulation du mercure; 5) Consacrer plus d'efforts à la détermination des effets biologiques de l'exposition au méthylmercure sur les poissons et les autres espèces sauvages de l'Arctique.

Le *Troisième rapport d'évaluation des contaminants dans l'Arctique canadien : Polluants organiques persistants dans le Nord canadien* présente les résultats des recherches menées sur les polluants organiques persistants (POP) dans l'Arctique canadien au cours de la période de 2003 à 2011. Il s'appuie sur les résultats du PLCN (de 2003 à 2011), de même que sur toutes les études publiées ou non publiées réalisées jusqu'au début de 2013. Cette période de référence a permis d'en apprendre beaucoup sur les tendances temporelles des POP dans l'air et dans le biote, sur les nouveaux POP dans de nombreux compartiments de l'environnement, et sur le transport océanique vers l'Arctique. L'influence possible du réchauffement climatique sur les tendances des POP a également été étudiée. Le rapport contient des recommandations sur la transition des données scientifiques aux mesures stratégiques; l'influence qu'exerce l'expansion

As part of the 25th anniversary of NCP, the report on *Contaminants in Canada's North: State of Knowledge and Regional Highlights* synthesizes the detailed scientific results presented in a series of technical reports produced from 2011 to 2017 by the NCP on the issue of long-range contaminants in the Canadian Arctic. This report elaborates further on the 10 key findings reported in the *CACAR III Contaminants In Canada's North: Summary for Policy Makers* publication, and provides details of NCP's activities and a summary of contaminants related issues in the 5 regions of its geographic scope.

In Nunatsiavut, the Nunatsiavut Government Research Advisory Committee (NGRAC) and the Nain Research Centre coordinate the implementation of NCP activities and are the main points of contact for information about long-range contaminants in Nunatsiavut. In Nunavik, NCP activities are coordinated through the Nunavik Nutrition and Health Committee (NNHC). In Nunavut, NCP activities are coordinated by the Nunavut Environmental Contaminants Committee (NECC). In the Northwest Territories (NWT), the NWT Regional Contaminants Committee (NWTRCC) coordinates NCP-related activities. In Yukon, the Yukon Contaminant Committee (YCC) coordinates all NCP-related activities in the territory. Each regional highlight describes information on country foods, health and contaminants; mercury and country food; and POPs and food. The regional highlights also include information on relevant health advisories and scientific studies in the respective regions.

The *CACAR IV: Human Health Assessment 2017* is a Canadian-specific summary of an Arctic Council report from the Arctic Monitoring and Assessment Programme (AMAP) on human health in the Arctic published in 2015. The NCP undertook this assessment to address concerns about potential human health risks associated with exposure to environmental contaminants from a diet that includes traditionally prepared and harvested foods from local northern ecosystems. Traditional food, also known as country food, is central to the social, cultural, economic, and spiritual well-being of Inuit, Dene, and Métis in the North and, for many,

des connaissances sur les substances chimiques d'intérêt et les tendances temporelles des POP sur les orientations futures de la recherche; l'importance des sources locales de nouveaux POP; la connaissance des facteurs influant sur les concentrations et les tendances des POP, et le défi constant que représente l'évaluation des effets biologiques des POP.

La publication intitulée *Les contaminants dans le nord du Canada : sommaire à l'intention des décideurs* présente un aperçu des sources de contaminants, de la façon dont ils sont propagés et de leurs effets sur l'environnement et les écosystèmes de l'Arctique et du Nord. Ce rapport fait état des initiatives du PLCN en cours sur la mise en application des connaissances, notamment les principales études scientifiques menées dans l'Arctique. Enfin, ce document précise les 10 principales conclusions tirées des études menées dans le cadre du PLCN à ce jour (Encadré 1) et les orientations futures de la recherche dans l'Arctique (Encadré 2).

Les plus récents rapports de la série de rapports d'évaluation des contaminants ans l'Arctique canadien, Les contaminants ans le Nord canadien : État des connaissances et synthèse régionale et Santé humaine (2017), ont été publiés en 2018

Le rapport *Les contaminants dans le Nord canadien : État des connaissances et synthèse régionale*, qui s'inscrit dans le cadre du 25e anniversaire du PLCN, constitue une synthèse des résultats scientifiques détaillés présentés dans une série de rapports techniques produits entre 2011 et 2017 par le PLCN sur les contaminants de longue portée dans l'Arctique canadien. Ce rapport traite de façon plus approfondie les 10 principales conclusions énoncées dans le rapport *Les contaminants dans le nord du Canada : sommaire à l'intention des décideurs* et fournit des détails sur les activités du PLCN, ainsi qu'un résumé des enjeux liés aux contaminants dans les cinq régions visées.

Au Nunatsiavut, le Comité de recherche sur la santé et l'environnement du Nunatsiavut et le Centre de recherches de Nain coordonnent la mise en œuvre des activités du PLCN dans la is essential for their overall food security. The key finding of the report were that: levels of many contaminants have decreased over time, however, there is still a strong need for additional data to ascertain contaminants trends among pregnant women and women of childbearing age in many regions of the Canadian Arctic; contaminants such as PBDEs and PFAS are also found in people and wildlife and further data is needed to understand human exposure to these contaminants and potential health outcomes; dietary advice should be regionally specific; there is a strong need for co-location of biomonitoring and wildlife monitoring studies, along with dietary assessment work to create stronger data linkage between exposure sources and contaminant levels measured in humans.

région et constituent les principaux points de contact pour obtenir des renseignements sur les contaminants transportés à longue distance. Au Nunavik, la coordination des activités du PLCN relève du Comité de la nutrition et de la santé du Nunavik. Au Nunavut, cette responsabilité revient au Comité des contaminants de l'environnement du Nunavut. Dans les Territoires du Nord-Ouest, le Comité régional des contaminants des Territoires du Nord-Ouest est chargé de la coordination des activités liées au PLCN, tandis qu'au Yukon, c'est le Comité des contaminants du Yukon. Chaque synthèse régionale contient des renseignements sur des sujets comme les aliments traditionnels, la santé et les contaminants; le mercure et les aliments traditionnels, et les POP et l'alimentation. Ces synthèses présentent aussi des renseignements sur les études scientifiques et les avis sanitaires pertinents pour chaque région.

Le *Rapport sur l'évaluation des contaminants dans l'Arctique canadien : Santé humaine (2017)* est un résumé des données canadiennes tirées du rapport du Conseil de l'Arctique publié en 2015 dans le cadre du Programme de surveillance et d'évaluation de l'Arctique et qui porte sur la santé humaine. Cette évaluation, entreprise dans le cadre du PLCN, aborde les préoccupations relatives aux risques potentiels pour la santé humaine de l'exposition aux contaminants environnementaux consécutive à un régime comprenant des aliments prélevés et préparés de manière traditionnelle dans les écosystèmes du Nord. Les aliments traditionnels, aussi connus sous le nom d'aliments prélevés dans la nature, sont essentiels au bienêtre social, culturel, économique et spirituel des Inuits, des Dénés et des Métis dans le Nord et, pour de nombreuses personnes, sont un élément crucial de la sécurité alimentaire. Les principales conclusions présentées dans le rapport sont les suivantes : les niveaux de bon nombre de contaminants ont diminué au cours des dernières années, mais une quantité importante de données supplémentaires serait nécessaire pour dégager les tendances des contaminants chez les femmes en âge de procréer et les femmes enceintes dans bon nombre des régions de l'Arctique canadien; des contaminants, comme les polybromodiphényléthers (PBDE) et les substances perfluoroalkyliques, se retrouvent également chez les animaux sauvages de l'Arctique et les humains, et de plus amples données sont nécessaires pour comprendre l'exposition humaine à ces contaminants et les effets potentiels sur la santé; les recommandations alimentaires devraient être propres à chaque région; le regroupement des études de biosurveillance chez les humains et les animaux sauvages et de travaux d'évaluation de l'alimentation est fortement souhaitable, car cela permettrait de créer des liens directs entre les sources d'exposition et les niveaux de contaminants mesurés chez les humains.

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. As of June 2017, in addition to the original 12 POPs included in the convention, there were 16 new POPs. As part of the continued international efforts to address new and emerging POPs, the POP review committee (POPRC) continues to meet regularly to review POPs of emerging concern. The POPRC had its 13th such

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. En juin 2017, 16 nouveaux POP se sont ajoutés, en plus des 12 POP compris dans la Convention.

meeting, in October 2017, since the treaty entered into force. As of April 30th 2018, there are 152 signatories and 182 parties to the treaty.

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. NCP was represented at the COP1 by an Inuit Circumpolar Council (ICC) member who participated in a panel discussion about how Inuit are affected by mercury, and about mercury monitoring in the Arctic.

Dans le cadre des efforts internationaux déployés continuellement pour lutter contre les POP nouveaux et émergents, le Comité d'examen des POP (CEPOP) continue de se réunir sur une base régulière pour discuter des POP qui constituent de nouvelles sources de préoccupation. En octobre 2017, le CEPOP a tenu sa 13e réunion sur le sujet, depuis l'entrée en vigueur du traité. En date du 30 avril 2018, le traité comptait 152 États signataires et 182 parties.

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. Le PLCN était représenté par un membre du Conseil Circumpolaire Inuit à la première réunion de la Conférence des Parties. Il a participé à une discussion en groupe sur les répercussions du mercure sur la population Inuite et la surveillance des concentrations de mercure dans l'Arctique.

Box 1.

10 key findings of the Northern Contaminants Program

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.

Encadré 1.

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

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.

Box 2.

Current direction 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;
- enhancing the measurement of long-term trends of mercury and POPs by filling gaps in geographic coverage;
- carrying out more research to understand the effects of climate change and predict their impacts on contaminant dynamics and ecosystem and human health risks; and,
- supporting the expansion of community-based monitoring projects that build scientific capacity in the North and optimize the use of Indigenous knowledge.

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

- ad\dressing 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

Encadré 2.

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;
- en train d'améliorer la mesure des tendances à long terme du mercure et des POP en comblant les lacunes dans la couverture géographique;
- 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

in collaboration with Northern communities, to provide current information to public health officials.

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; and,
- 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.

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 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

Yukon contaminant biomonitoring seed funding: Investigating the links between contaminant exposure, nutritional status and country food use

Financement de démarrage pour la biosurveillance des contaminants au Yukon : étude des liens qui existent entre l'exposition aux contaminants, l'état nutritionnel et les aliments prélevés dans la nature

- **Project Leader/Chef de projet**
  Mary Gamberg, Gamberg Consulting, 708 Jarvis St., Whitehorse, Yukon.
  Tel: 867-334-3360; E-mail: mary.gamberg@gmail.com
- **Project Team/Équipe de projet**
  Brian Laird and Victoria Leger, University of Waterloo; William Josie and Megan Williams, Vuntut Gwitchin First Nation; Chris Furgal, Trent University; Amanda Boyd, Washington State University; Kelly Skinner, University of Waterloo

- **Project Location/Emplacement(s) du projet**
  Old Crow, YT

Abstract

Wild food is an important part of the diet for many Yukon residents, particularly First Nations, who traditionally harvest caribou, moose, fish, waterfowl, small game and many plants. Although there has been extensive research on contaminants in wild foods and some dietary surveys, there have been no human biomonitoring studies conducted in the territory. The Vuntut Gwitchin First Nation has initiated a human biomonitoring study for their citizens as a pilot project for the Yukon. To explore the possibility of developing broader Yukon Human Biomonitoring Study partnerships among Yukon First Nations, Yukon Government, Health Canada, and

Résumé

De nombreux habitants du Yukon prélèvent une grande partie de leur nourriture dans la nature; c'est le cas particulièrement des membres des Premières Nations, qui récoltent traditionnellement le caribou, l'orignal, le poisson, la sauvagine, le petit gibier et de nombreuses plantes. Bien que des recherches approfondies aient été menées sur les contaminants dans les aliments prélevés dans la nature et que quelques sondages sur l'alimentation aient été menés, aucune enquête de biosurveillance humaine n'a été menée dans le territoire. La Première Nation des Vuntut Gwitchin a entrepris une enquête de biosurveillance humaine auprès de ses

research scientists have been initiated. Focus groups in the community fine-tuned Food Frequency Questionnaires and Health Messages Surveys for Old Crow residents. These surveys were subsequently administered to 65 Old Crow residents. With 100% of participants reporting that they eat traditional foods, the results demonstrated the importance of such foods in Old Crow. Results showed caribou and salmon to be among the most frequently consumed traditional foods in Old Crow. Most participants had heard about the healthfulness of traditional foods and the potential risks from mercury in some fish, while relatively few participants had heard messages about the levels of cadmium in caribou. This project will continue with biomonitoring in Old Crow in the fall of 2018 and the results of Food Frequency Questionnaires and Health Messages Surveys will be used to help interpret the results.

citoyens dans le cadre d'un projet pilote mené pour le Yukon. Ce projet explore la possibilité d'amener les Premières Nations du Yukon, le gouvernement du Yukon, Santé Canada et les chercheurs à établir des partenariats plus vastes en vue de la tenue d'enquêtes de biosurveillance humaine au Yukon. Des groupes de discussion locaux ont adapté le questionnaire sur la fréquence de consommation et les sondages sur les messages en matière de santé pour les résidants d'Old Crow. Par la suite, 65 résidants d'Old Crow ont répondu à ces sondages. Tous les participants ont mentionné qu'ils consomment des aliments prélevés dans la nature, ce qui démontre l'importance de ces aliments à Old Crow. Selon les résultats, le caribou et le saumon font partie des aliments traditionnels les plus consommés à Old Crow. La plupart des participants avaient entendu parler de la valeur nutritive des aliments traditionnels et des risques liés à la présence de mercure dans certains poissons, tandis que relativement peu de participants ont mentionné avoir été informés des concentrations de cadmium chez le caribou. Ce projet se poursuivra par la biosurveillance à Old Crow à l'automne 2018, et les résultats des questionnaires sur la fréquence de la consommation et des sondages sur les messages en matière de santé serviront à interpréter les résultats.

Key Messages

- Consultations with community leaders and territorial representatives led to the creation of a community-research agreement for baseline data collection in Old Crow, YT.
- Dietary and risk perception questionnaires were refined with feedback from focus groups held in October 2017.
- 65 participants took part in baseline data collection in February-March 2017.
- Results showed caribou and salmon to be among the most frequently eaten traditional foods in Old Crow, YT.
- 100% of participants reported eating traditional foods and 98% preferred their diet to include traditional foods.

Messages clés

- Des consultations auprès des dirigeants des collectivités et des représentants du territoire ont mené à la conclusion avec la collectivité d'un accord de recherche sur la collecte de données de référence à Old Crow, au Yukon.
- Des précisions ont été apportées aux questionnaires sur l'alimentation et la perception des risques en fonction des commentaires formulés par les groupes de réflexion qui se sont réunis en octobre 2017.
- Soixante-cinq (65) participants ont pris part à la collecte des données de référence en février et mars 2017.
- Selon les résultats, le caribou et le saumon font partie des aliments traditionnels les plus consommés à Old Crow, au Yukon.

- Most participants had heard about the healthfulness of traditional foods and the potential risks from mercury in some fish.
- Relatively few participants reported receiving messages about the levels of cadmium in caribou.

- Tous les participants (100 %) ont mentionné consommer des aliments traditionnels, et 98 % préféraient que leur régime alimentaire comprenne des aliments traditionnels.
- La plupart des participants avaient entendu parler de la valeur nutritive des aliments traditionnels et des risques liés à la présence de mercure dans certains poissons.
- Relativement peu de participants ont mentionné avoir été informés des concentrations de cadmium chez le caribou.

Objectives

The aims of this project are to:

- create partnerships among Yukon First Nations, Yukon Government and research scientists to facilitate the planning of a human biomonitoring survey in the Yukon;
- engage the Vuntut Gwitchin First Nation (VGFN) in Old Crow, YT as a pilot project in determining the feasibility of a human biomonitoring survey in the Yukon; and,
- survey resident dietary habits and risk perceptions regarding contaminants in Old Crow.

Introduction

Wild food is an important part of the diet for many Yukon residents, particularly First Nations, who traditionally harvest caribou, moose, fish, waterfowl, small game and many plants. Although there has been extensive research on contaminants in those wild foods (Gamberg 2000) and some dietary surveys have been conducted in the past (Receveur et al. 1998), there have been no human biomonitoring studies conducted in the territory.

In their exploration of environmental health risk management in Yukon, Friendship and Furgal (2012) stressed the need for better collaboration between scientists and Yukon First Nation communities. They considered it essential to commit adequate time to build strong and trusting relationships, and facilitate open communication to better address complex benefit-risk issues. To that end, partnerships among Yukon First Nations, Yukon Government, Health Canada, and research scientists have been initiated to explore the possibility of developing a Yukon Human Biomonitoring Study.

Meanwhile, the Vuntut Gwitchin First Nation (VGFN) has initiated a human biomonitoring study for their citizens as a pilot project for the Yukon. VGFN has been integrally involved with ongoing environmental monitoring of the Porcupine caribou and conducted its own project studying mercury in fish in their traditional territory in 2014. In the first year, the pilot project was designed to survey dietary preferences and risk perception of contaminants in traditional foods in the community of Old Crow, Yukon.

Activities in 2017-2018

Partnerships have been initiated and discussions held with Yukon Health (Kim Hickman), the Chief Medical Officer of Health (Brendan Hanley), Health Canada (Cheryl Khoury), Yukon Environment (Matt Clarke), Council of Yukon First Nations (Helen Stappers, James MacDonald), Yukon Contaminants Committee (Ellen Sedlack, Aynslie Ogden, Derek Cooke, Mary Vanderkop), VGFN (William Josie, Megan Williams), Northern Contaminants Program (Jonathan Provost) and a human health researcher (Brian Laird). A meeting was held with this group to discuss if/how to offer the potential of biomonitoring in other Yukon communities. There was a clear consensus within the group to wait for the results from the Old Crow Biomonitoring Project before proceeding with other Yukon communities. Those results are anticipated for the summer of 2019. After such time, we will have conversations about the possibility of this work with other communities. Brendan Hanley will talk to the Health Commissioners about the project at their meeting scheduled for June 2018, and if appropriate, Mary Gamberg will present the Old Crow survey results to the same group in the fall of 2018. Mary Gamberg will include discussion of this work in training modules planned for land guardians from the Nacho Nyuk Dun, White River and Taku River Tlinget First Nations this summer as part of NCP-funded community-based monitoring projects. We will also create a summary of the project for inclusion on the Yukon Contaminants Website that is currently being updated.

In October 2017, Brian Laird and Mary Gamberg conducted focus groups with 14 Old Crow residents to fine-tune a Food Frequency Questionnaire (FFQ) and Health Messages Surveys for this community. They also met with Chief and Council, who decided to continue the project in the coming year to include human biomonitoring in Old Crow.

In February 2018, Victoria Leger, Mary Gamberg and Jenna Lord (community member) administered the revised Food Frequency and Health Messages Surveys to 65 Old Crow residents. The surveys were done using I-pads and assistance in filling out the surveys was offered to those who were not comfortable with the technology. Each participant was given a gift card from a local store or airline for their participation.

Community Engagement

The community of Old Crow was integrally engaged in this project. They initiated the project and were full partners in developing protocols and procedures. 65 residents of Old Crow provided samples and engaged in surveys as part of this project.

Capacity Building and Training

Surveys were conducted (in part) by a northern researcher (Mary Gamberg) who has studied contaminants in wildlife but has previously not had experience with human health-related activities. This work increases capacity within the Yukon for this type of research. In addition, a VGFN citizen (Jenna Lord) was also trained to conduct the surveys, building capacity within Old Crow for further work in this area of research in the future. We expect that this expertise will be used in the anticipated broader Yukon Human Biomonitoring Study.

Communications

Communication has been integral to developing partnerships among First Nations, various governments and scientists. This will continue with the development of a framework and guidelines for future research in human biomonitoring in the Yukon. Communication was also an important part of conducting the surveys in Old Crow, as many participants had questions about contaminants and wildlife, as well as potential future studies, that we were able to answer to their satisfaction.

Indigenous Knowledge Integration

Indigenous Knowledge was integral to the completion of the Food Frequency surveys which gathered information on traditional foods, harvesting methods, times and locations, cooking practices and consumption patterns.

Results

Preliminary results from the baseline data collection for the dietary questionnaire and health messages survey are presented below. Community members who completed the surveys were 52% male and 48% female. The majority of participants (52%) were between 18 and 39 followed by those aged 40-59 (24%) and participants over 60 years (24%).

Dietary Survey Results

A total of 64 participants completed the FFQ. The most often eaten traditional foods (and the percent of participants who reported eating each of those foods) are reported in Table 1. Caribou meat and moose meat were consumed by the majority of participants. The most commonly eaten fish included chinook (king) salmon and whitefish, smoked whitefish (44%) and chum (dog) salmon (41%). Low (grey) blueberries (70%) and low bush cranberries (66%) were the most commonly eaten berries. Of the most commonly consumed traditional foods, 10 of 16 came from caribou. Other commonly consumed country foods include: salmonberries/cloudberries, snowshoe hare, and high (black) blueberries. The Porcupine River was the main waterbody from which fish were harvested. Other waterbodies from which participants harvested fish included: Crow River, Up Porcupine River Lakes, Down Porcupine River Lakes, Crow Flats, Whitefish Wetlands, and wetlands south of Old Crow.

Participants reported eating the meat, organs, and other parts of harvested fish, land animals, and game birds. For example, when land mammals were harvested, participants reported eating the meat, ribs, bone marrow, head, tongue, liver, kidney, bones (in soup/broth), fat, heart, stomach, blood, guts/tripe, blood, brain, fetus, tail and feet. This was also true for birds (meat, gizzard, kidney, heart, fat, liver, eggs) and fish (meat, head, eggs, fish-pipe).

Health Messages Survey Results

A total of 65 participants completed the Health Messages Survey. The results showed the importance of traditional foods to the diets of participants. For example, 100% of the survey participants reported eating traditional foods and most preferred to eat a mix of both traditional and store foods (Figure 1). 75% of participants had heard or seen messages about fish with high levels of mercury, while only 23% had heard or seen messages about caribou liver/kidney with high levels of cadmium. Participants reported hearing these messages from several sources, including friends (51%), researchers or scientists (49%), community meetings (41%) and family (37%). Many participants reported changing their behavior around eating fish and caribou as a result of hearing these messages (Figure 1). Of the participants who had reported hearing messages about fish and mercury (n=49), 30% said that they now eat less fish, and 50% said they eat less of certain kinds of fish (Figure 1, top panel). Fewer participants had changed their behavior for eating caribou; of the participants who had heard messages about caribou and cadmium (n=15), 31% said they now eat less caribou organs (liver/kidney) and 31% said they eat more caribou meat (Figure 1, bottom panel).

Table 1. Traditional Foods Most Often Consumed by Project Participants in the Vuntut Gwitchin Traditional Territory

Food Consumed[a]	Percent Consuming[b]	Average Consumption (days/week)[c]
Caribou Meat	91%	2.2
Moose Meat	88%	1.2
Chinook (King) Salmon	78%	0.7
Whitefish	77%	0.8
Low (Grey) Blueberries	70%	0.7
Caribou Heart	67%	0.8
Caribou Ribs	67%	1.4
Caribou Head	66%	0.9
Low Bush Cranberries	66%	0.7
Caribou Bone Marrow	63%	0.8
Caribou Tongue	63%	0.6
Salmonberries/ Cloudberries	61%	0.6
Caribou Kidney	59%	0.6
Caribou Meat (Smoked)	56%	1.5
Caribou Bones in Soup or Broth	55%	1.1
Caribou Fat	55%	1.1

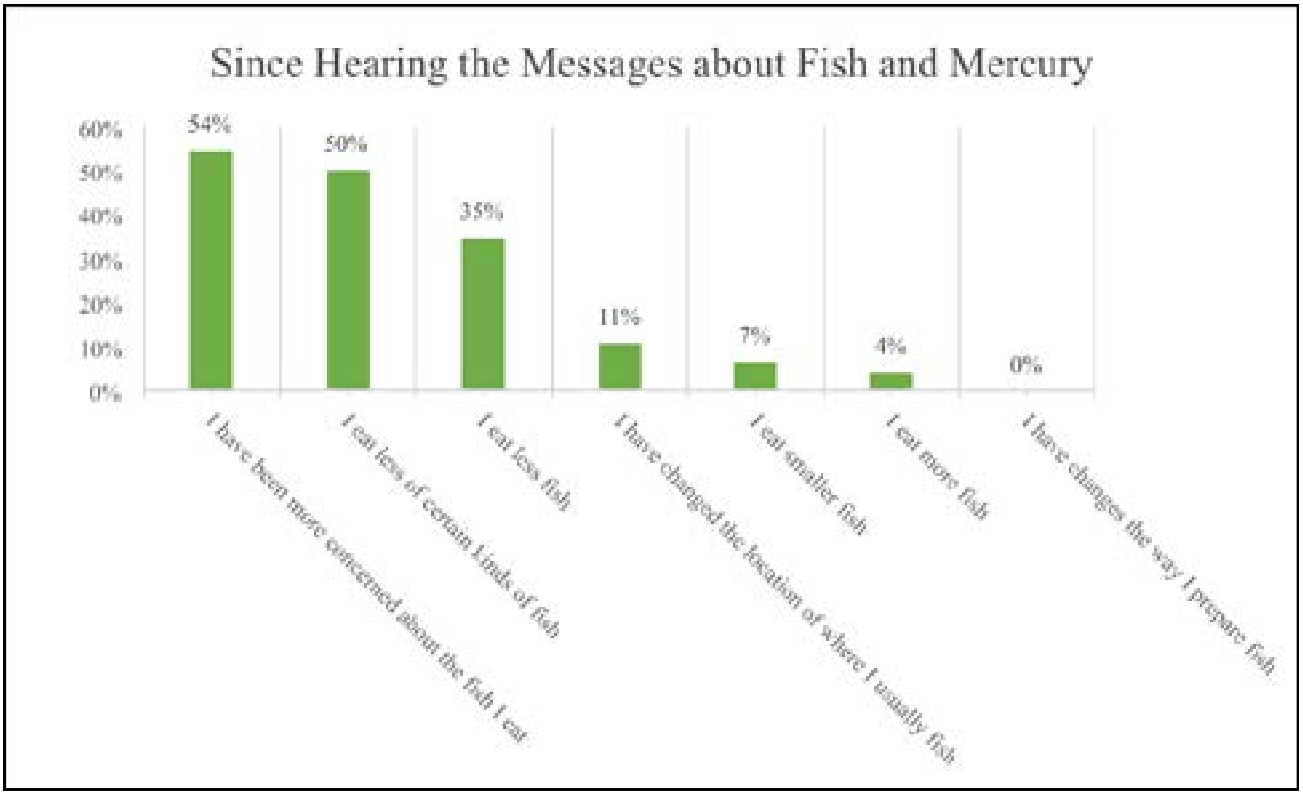
[a] Foods eaten by at least 50% of participants.
[b] This percentage includes the participants who reported eating each food
[c] Among participants who reported eating these foods

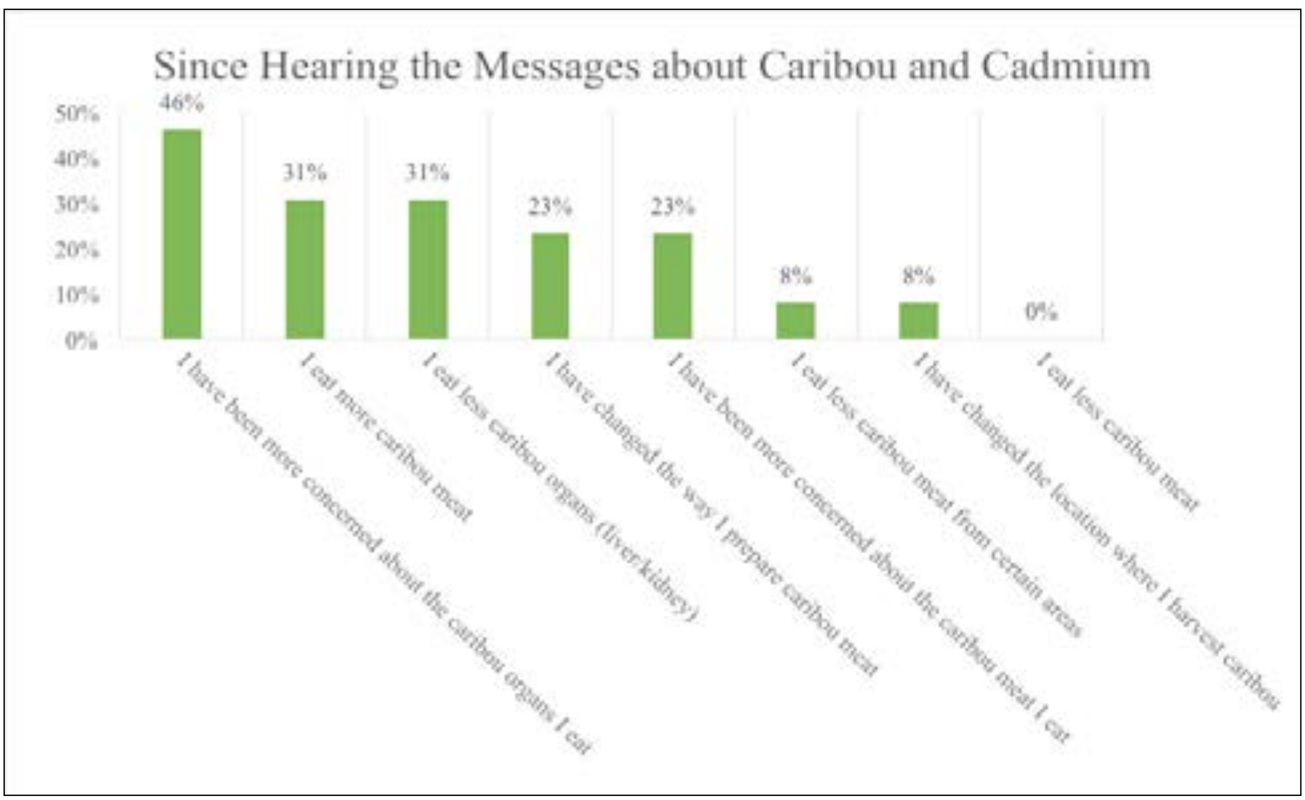
Participants indicated whether they had heard a broad range of contaminant-related health messages related to traditional foods, caribou, fish, radioactivity and contaminant exposure. Nearly all participants had heard the messages: “Eating fish contributes to a healthy, nutritious diet” (85%), “Fish is an excellent source of good omega-3 fatty acids” (82%), and “Traditional foods con provide a significant variety and amount of nutrients” (97%). However, less than a third of participants had heard the messages:

- “Beluga from the Eastern Beaufort Sea stock were not affected by radioactivity from the Fukushima nuclear accident” (11%);
- “Caribou from the Porcupine Herd were not affected by radioactivity from the Fukushima nuclear accident” (17%),
- “Women of child-bearing years should limit the number of large lake trout and burbot they eat” (29%).

In addition, the majority of participants stated that they thought that cigarette smoking (85%), store bought foods (77%) and fish (51%) contributed to the amount of contaminants that they are exposed to. In contrast, 63% of participants did not think that eating caribou would impact the amount of contaminants that they are exposed to. The most trusted sources for information regarding contaminants and traditional food were elders, researchers and scientists, friends and family, doctors, chief and council and other healthcare workers such as nurses.

Figure 1. Behavioral changes reported by participants who heard messages regarding fish and mercury (top panel) and caribou and cadmium (bottom panel). These results are based upon those from participants who indicated that they heard messages about fish and mercury (n=49) and caribou and cadmium (n=15).





Discussion and Conclusions

Survey participants indicated that traditional food remains an important part of the diet, and while most people recognize that traditional food is a good source of nutrients, many are concerned about contaminants in traditional food as well as store-bought food. Most people recognize cigarette smoking to be a significant source of contaminants. The most trusted sources for information regarding contaminants and traditional food were elders, researchers and scientists, friends and family, doctors, chief and council and other healthcare workers, such as nurses.

Many people had heard about the issue of mercury in fish, likely due to the project measuring mercury in fish from Old Crow conducted by VGFN in 2014. This is beneficial, as there is current health advice recommending limiting the consumption of some fish in the Yukon. Fewer participants had heard about the issue of cadmium in caribou, likely because this was first in the media in the early 1990's and has not been an issue of high concern since that time. The recommendation of consuming a maximum of 25 Porcupine caribou kidneys or 12 entire livers does not likely limit consumption for many people.

These results will be used to help interpret results from the Human Biomonitoring Study proposed for Old Crow in 2018/19.

Expected Project Completion Date

The survey portion of this project has been completed. Building partnerships and community consultation will continue with the planning of the Yukon Human Biomonitoring Project.

Project website

The project website is in development.

Acknowledgments

Many thanks to VGFN, particularly William Josie and Megan Williams, for facilitating this project and providing space for the surveys. Thanks also to Jenna Lord who assisted in administering the surveys and all the community members who volunteered their time to participate in the surveys. A special thanks to Victoria Leger who participated in administering the surveys and collated the results. The project team would also like to thank the NCP for their funding and support for this project.

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Exposure to food chain contaminants in Nunavik: Biomonitoring in adult and youth cohorts of the Qanuilirpitaa survey (Year 1 of 3)

Exposition aux contaminants de la chaîne alimentaire au Nunavik : biosurveillance des cohortes d'adultes et de jeunes de l'enquête Qanuilirpitaa? (année 1 de 3)

- **Project Leader/Chef de projet**

Pierre Ayotte, Ph.D., Toxicologist (Acting-PI), Professor, Dept. of social and preventive medicine, Université Laval; Research Scientist, Axe en santé publique et pratiques optimales en santé, Centre de recherche du-CHU de Québec; Head, Research Division, Institut national de santé publique du Québec (INSPQ), 945 Avenue Wolfe, 4e étage, Québec, QC, G1V 5B3. Tel: (418) 650-5115 ext. 4654, Fax: (418) 654-2148; E-mail: pierre.ayotte@inspq.qc.ca

Mélanie Lemire, Ph.D. (co-PI), Assistant Professor and Nasivvik Chair, Dept. of social and preventive medicine, Université Laval; Axe santé des populations et pratiques optimales en santé, Centre de recherche du CHU de Québec, Hôpital du Saint-Sacrement, 1050, chemin Sainte-Foy, Québec, QC G1S 4L8. Tel: (418) 525-4444, ext. 81967, E-mail: melanie.lemire@crchuq.ulaval.ca

- **Project Team/Équipe de projet**

Pierre Dumas, Quebec Toxicology Centre, INSPQ, Quebec, QC; Michel Lucas, Université Laval, Quebec, QC; Gina Muckle, Université Laval, Quebec, QC; Richard Bélanger, Université Laval, Quebec, QC; Benoit Lévesque, Université Laval and INSPQ, Quebec, QC; Chris Furgal, Trent University, Peterborough, ON; Françoise Bouchard, Nunavik Regional Board of Health and Social Services (NRBHSS), Kuujjuaq, QC; Sylvie Ricard, NRBHSS, Kuujjuaq, QC; Marie-Josée Gauthier, NRBHSS, Kuujjuaq, QC

- **Project Location/Emplacement(s) du projet**

Nunavik, QC

Abstract

Inuit are exposed to a wide range of environmental contaminants through their traditional diet, which includes significant amounts of fish and sea mammals. During the past 25 years, our team has monitored the exposure of Nunavimmiut to persistent organic pollutants (POPs) and metals, starting with the Santé Québec Inuit Health Survey in 1992, which was followed by the *Qanuippitaa* 2004 Health Survey. From 1992 to 2004, for most legacy POPs, a significant decreasing trend was confirmed in environmental components, and wildlife and circumpolar Inuit exposure data. Despite a decreasing trend, mostly due to reduced consumption of country foods, mercury and lead exposures remain topical issues, particularly among childbearing and pregnant women in Nunavik. In addition, each year, new chemicals are introduced in the market. These "new POPs and contaminants of emerging concern" now reach the Arctic food chain and very little is known about their concentrations and temporal and regional trends in Inuit Nunangat. In the first year of this project, we aim to provide current data on exposure to toxic metals in a representative sample of the Inuit population of Nunavik, within the framework of the *Qanuilirpitaa?* Nunavik Inuit Health Survey which took place from August 19th to October 5th, 2017, in the 14 communities of Nunavik. In addition, we assembled 30 pooled plasma samples that were analysed using various targeted and untargeted methods, in order to determine which POPs should be selected for analysis in individual samples during the subsequent years of this project. Our results will allow updating long-range environmental contaminants exposure among Nunavimmiut and contribute to better understanding the risks and benefits of country foods consumption in this population.

Résumé

Les Inuits sont exposés à une vaste gamme de contaminants environnementaux en raison de leur régime alimentaire traditionnel, riche en poissons et en mammifères marins. Depuis 25 ans, notre équipe surveille l'exposition des Nunavimmiuts aux polluants organiques persistants (POP) et aux métaux; il y a d'abord eu l'Enquête Santé Québec auprès des Inuits du Nunavik 1992, qui a été suivie de l'Enquête de santé auprès des Inuits du Nunavik (enquête *Qanuippitaa?*) en 2004. De 1992 à 2004, les données relatives aux composantes environnementales et à l'exposition des espèces sauvages et des Inuits des régions circumpolaires ont confirmé une importante tendance à la baisse de la plupart des POP hérités du passé. Malgré une tendance à la baisse surtout attribuable à la réduction de la consommation des aliments prélevés dans la nature, les expositions au mercure et au plomb demeurent des sujets d'actualité, en particulier chez les femmes en âge de procréer et les femmes enceintes du Nunavik. En outre, chaque année, de nouveaux produits font leur entrée sur le marché. Ces « nouveaux POP et nouveaux contaminants préoccupants » atteignent maintenant la chaîne alimentaire arctique, et on connaît encore très peu leur concentration et les tendances temporelles et régionales chez les Inuits. Au cours de la première année de ce projet, nous désirons fournir des données à jour sur l'exposition aux métaux toxiques d'un échantillon représentatif de la population des Inuits du Nunavik, dans l'enquête *Qanuilirpitaa??* sur la santé des Inuits du Nunavik, qui s'est déroulée du 19 août au 5 octobre 2017, dans les 14 collectivités du Nunavik. De plus, nous avons constitué 30 échantillons combinés de plasma qui ont été analysés au moyen de différentes méthodes ciblées et non ciblées, dans le but de sélectionner les POP à analyser dans les échantillons individuels au cours des années subséquentes du projet. Les résultats obtenus nous permettront de mettre à jour l'exposition des Nunavimmiuts aux contaminants environnementaux transportés sur de longues distances, ce qui contribuera à améliorer la compréhension des risques et des avantages de la consommation d'aliments prélevés dans la nature pour cette population.

Key Messages

- A total of 1326 Nunavimmiut aged 16 and over participated to the *Qanuilirpitaa?* Nunavik Inuit Health Survey in 2017.
- Concentrations of cadmium, lead, mercury and selenium were determined in whole blood samples of participants.
- Pooled plasma samples (n = 30) were analysed for polychlorinated biphenyls and organochlorine pesticides, per - and polyfluoroalkyl substances and polychlorinated dibenzo-*p*-dioxins and dibenzofurans.
- Pooled plasma extracts are being analysed for the presence of unsuspected contaminants (non-targeted screening).

Messages clés

- En tout, 1 326 Nunavimmiuts âgés de 16 ans et plus ont participé à l'enquête *Qanuilirpitaa??* sur la santé des Inuits du Nunavik tenue en 2017.
- Des concentrations de cadmium, de plomb, de mercure et de sélénium ont été mesurées dans des échantillons de sang entier des participants.
- On a procédé à une analyse des échantillons combinés de plasma (n = 30) afin d'y détecter la présence de biphényles polychlorés et de pesticides organochlorés, de composés perfluoroalkyliques et polyfluoroalkyliques et de polychlorodibenzoparadioxines et de dibenzofuranes.
- Les échantillons combinés de plasma ont fait l'objet d'analyses qui avaient pour but de détecter la présence de contaminants dont la présence n'était pas soupçonnée (dépistage non ciblé).

Objectives

The main objective of this project is to update data on exposure to food-chain contaminants among Nunavimmiut. This will be achieved in the framework of the *Qanuilirpitaa* Nunavik Inuit Health Survey, which comprises an adult cohort of 752 adults - 31 years and older - and 574 youths between 16 and 30 years of age. Biological samples will be obtained from participants during the fall of 2017 to allow for this major biomonitoring effort.

The specific objectives are:

1. to measure through biomonitoring Nunavimmiut's exposure to toxic metals [mercury (Hg), lead (Pb), and cadmium (Cd)] and legacy persistent organic pollutants (POPs), new POPS and contaminants of emerging concerns (CECs) as well as other new CECs currently investigated only as part of environmental monitoring programs in the Arctic or identified through non-targeted screening;
2. to evaluate the nutritional status of Nunavimmiut including omega-3 polyunsaturated fatty acids (PUFAs), total selenium (Se) and selenoneine, ergothioneine, hemoglobin and iron status, vitamin D, vitamin B12 and folate; and,
3. to account for country and store-bought food consumption of *Qanuilirpitaa* participants, food security, socio-demographic status, lifestyle habits and anthropometric characteristics in explaining biomonitoring data on contaminant exposure and nutritional status.

Introduction

Why continuing efforts on food chain contaminants temporal and spatial trends in the Nunavik population?

Early work conducted on Baffin Island and in Nunavik has demonstrated that due to their traditional dietary habits, Inuit people are exposed to unusually high doses of environmental contaminants, mainly toxic metals and organochlorines (OCs) (Kinloch et al. 1992; Dewailly et al. 1993; Muckle et al. 2001). OCs, a class of persistent organic pollutants also known as legacy POPs, includes polychlorinated biphenyls (PCBs) as well as various chlorinated pesticides and industrial products. Results from most epidemiological and experimental studies on health effects related to toxic metals (Hg and Pb) and OCs exposure (mainly PCBs) suggest that prenatal life is the most susceptible period for adverse effects on physical and neurological development. Indeed, 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 later in childhood (Guo et al. 1994; Guo et al. 1995; Jacobson and Jacobson 1997; Dewailly et al. 2000; Dallaire et al. 2004). 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. 2012a; Ethier et al. 2012; Boucher et al. 2014; Jacobson et al. 2015), whereas exposure to Hg during childhood has been associated to alternated fine motor functions in children (Boucher et al. 2016).

Given the potential health hazards related to these environmental contaminants, worldwide agreements have been adopted to decrease the release of these substances in the environment as well as wildlife and human exposures (i.e. Stockholm Convention on POPs and Minamata Convention on Hg). Included in these conventions are measures that aim at assessing current exposure levels in human populations and to derive spatial and temporal trends for these environmental contaminants. These measures allow researchers to follow and understand contaminant behaviour in the environment and wildlife, as well as to evaluate the efficiency of intervention programs and undertake appropriate actions to efficiently decrease potentially hazardous human exposures (i.e. recommendations on dietary habits).

The Stockholm convention on legacy POPs, which entered into force in 2004, likely contributed to the significant decreasing trend in environmental concentrations and circumpolar Inuit exposure over the last two decades. Studies focusing on temporal trends of OCs and PCBs in the Arctic have identified a decreasing trend during the last decades in several wildlife species (Muir et al. 2001a; Muir et al. 2001b). For more than 10 years, decreases in the body burden of these legacy POPs in Northern human populations have also been reported, for instance in Sweden (Noren and Meironyte 2000) and in Canada, on the Lower North Shore of the St. Lawrence River (Dallaire et al. 2002) and in Nunavimmiut residing in the Hudson Bay area (Dallaire et al. 2002). This decreasing trend was also confirmed over the past years among pregnant women in Nunavik (AMAP 2011, NCP 2013, AMAP 2015, Adamou et al. In preparation).

Similarly, Hg exposure among Inuit of all Arctic regions has also considerably decreased over the last decades (AMAP 2011, AMAP 2015). However, no clear decreasing trend in Hg concentrations has been observed in the Eastern Arctic wildlife, and even an increasing trend in marine mammal Hg concentrations has been recently observed in the Western Arctic (Braune et al. 2015). This suggests that decreasing Hg exposure among Inuit is more likely to be related to the decreasing trend in country food consumption (Adamou et al. In preparation). However, since a high number of pregnant women and childbearing-age women continue to exhibit excessive Hg concentrations in Nunavik (Adamou et al. In preparation), Hg exposure remains a high priority public health issue, particularly in Hudson Strait communities, where most of beluga hunting activities take place in Nunavik (Lemire et al.

2015). Beluga meat is known to contain elevated Hg concentrations, often two-fold higher than the 0.5 µg/g Health Canada guideline (Lemire et al. 2015).

Hg has long been known to be toxic to humans and other organisms. Large public health crises due to Hg poisoning, such as Minamata disease and Niigata disease, drew international attention to the issue in 1956. On 20 February 2009, the 25th Governing Council of UNEP adopted a decision "to initiate international action to manage Hg in an efficient, effective and coherent manner". The Convention was adopted and opened for signature on 10 October 2013, at a Conference in Kumamoto, Japan and entered into force on 16 August 2017. Health research conducted by our team since 1992 has been critical for the adoption of the Convention. These include data from biomonitoring trends among pregnant women in Nunavik, as well as findings from the Nunavik Child Development Study (NCDS) led by Dr. Muckle showing significant and persistent toxic effects of prenatal and postnatal Hg exposure on child development (Pirkle et al. 2016). Eighty-six countries and the European Union signed the Convention on the first day it was open. Currently, 128 countries including Canada and USA have signed, while 121 countries have ratified the Minamata Convention on Mercury (as of November 18, 2018). Considering that the central objective of the convention is to protect human health and, that Arctic people are among those most exposed on earth, the present research project will provide baseline data to evaluate the effectiveness of the Minamata convention following its implementation.

Pb exposure from lead-containing ammunitions also remains significantly more elevated in Nunavik than elsewhere in southern Canada and the USA (Centers for Disease Control 2010; Health Canada 2013). As for Hg, the NCDS has shown significant intellectual, behavioural, visual and motor functions deficits related prenatal and postnatal exposure to Pb in Nunavik children (Boucher et al. 2012b; Boucher et al. 2014; Ethier et al. 2015; Boucher et al. 2016). Lead-shot ammunition were voluntarily banned by Nunavik regional organizations in 1999-2000 (Couture et al. 2012). Between 1992 and 2013, a significant decreasing trend was observed in childbearing and pregnant women Pb exposure, and visual inspection of the trend suggests that the decrease started in 2000, following the adoption of measures to limit the use of lead shots (Donaldson et al. 2010; Adamou et al. In preparation). However, no statistically-significant decline of Pb exposure was observed between 2004 to 2013, and few pregnant women still present Pb exposure above 50 µg/L, the US blood Pb level of intervention which should be adopted by Health Canada in the coming months (Centers for Disease Control 2010; Health Canada 2013). The Institut national de santé publique du Québec (2016) has recently lowered the reporting threshold for blood lead among children aged 11 years and younger to 50 µg/L (INSPQ 2016). A recent study highlighted that hunters consuming game meat hunted with lead bullets may be exposed to Pb since lead fragments are found in the meat a significant distance from the bullet channel (Fachehoun et al. 2015). A project carried out in the summer of 2016 in Nunavik (Pétrin-Desrosiers, Lévesque et al. In preparation) showed that some hunters still use lead shots for hunting and that this type of ammunition is still available in most communities. Regarding lead bullets, their use is still widespread and the availability of lead-free alternatives is excessively restricted. Recent resolutions were adopted in Nunavik to reinforce the voluntary ban of sale and use not only of lead shots but also of lead bullets, and to promote non-toxic alternatives, via information campaigns and eventually by further expending the affordability of lead-free alternatives through subsidized programs (Ricard, personal communication). Therefore, the present project will provide baseline data to evaluate the effectiveness of these interventions in Nunavik, which may be the first region in Canada to officially and strongly promote alternatives to lead bullets across the country.

In addition to legacy POPs, Hg and Pb, each year, a large number of new chemicals are introduced on the market; several of these have emerged as potential threats to the Arctic. New POPs and contaminants of emerging concern (CECs) and even other new ones now reach the Arctic and the Arctic food chain. Very little is known about their concentrations and temporal and regional trends in Inuit people. Those listed as new POPs under the Stockholm convention include brominated flame retardants (BFRs), such as polybrominated diphenyl ethers (PBDEs), which were commonly added in electronic equipment, plastics and textiles; and per- and polyfluoroalkylated substances (PFAS), for example perfluorooctane-sulfonate (PFOS) and related compounds. PFAS have been produced commercially for over 40 years. PFOS is very stable, repels water and oil and was largely used as a stain repellent ("ScotchGuard"). Kannan et al. have reported widespread occurrence of PFOS in fishes, birds and marine mammals from the Mediterranean and Baltic Seas (Kannan et al. 2002). PFOS has also been detected in marine mammals from the North American Arctic (Kannan et al. 2001). In Nunavik, plasma concentrations of PFOS in Inuit adults were positively related with fish and marine mammal consumption (Dallaire et al. 2009).

In recent years, polychlorinated naphthalenes (PCNs), pentachlorophenol (PCP), hexabromocyclododecane (HBCD) and short-chained chlorinated paraffins (SCCPs) were also added to the list of the new POPs under the Stockholm Convention[1]. Other CECs such as new halogenated and organophosphate flames retardants are currently only investigated as part of environmental monitoring programs in southern Canada and the Arctic (Salamova et al. 2014; Su et al. 2015). More data on human exposure to these new CECs in the North are needed. Until today, very little research on exposure and related health effects of these other new POPs and CECs is available in the Arctic and elsewhere.

1 http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx

Why measuring country food nutrients and assessing country and store-bought food consumption, socio-demographic status, lifestyle habits and anthropometric characteristics when measuring biomonitoring data?

Inuit people have very high levels of PUFAs in their blood due to their high consumption of fish and marine mammal (Proust et al. 2014). High PUFAs intake during prenatal life increases birth weight of newborns and cognitive functions in childhood (Boucher et al. 2011; Jacobson et al. 2015). *Qanuippitaa* 2004 data analysis also showed a beneficial association between red blood cell (RBC) PUFA concentrations and different markers of cardiometabolic functions during adulthood (Valera et al. 2009; Ayotte et al. 2011; Valera et al. 2011). With respect to Se, an essential element found in exceptional concentrations in marine country foods of the Arctic, our most recent data reveal that high cord and child Se blood status has protective effects on visual, cognitive and behavioural outcomes in infancy and childhood despite high Hg exposure during pregnancy (see Muckle et al. NCP 2015-2016). Moreover, our recent work on Se speciation in *Qanuippitaa* participants' blood and country foods, shows that selenoneine is the major Se compound in Inuit adult RBCs and beluga mattaaq (Achouba et al. 2016; Achouba et al. Submitted). Selenoneine is a Se-analogue of ergothioneine, a powerful anti-oxidant, and recent experimental data suggests that selenoneine would be involved in Hg detoxification processes (Palmer and Parkin 2015). Several country foods are also known as optimal sources of heme iron (most bioavailable type of dietary iron), folate, vitamin A, vitamin D and zinc (Government of Nunavut 2013).

The contaminants to be monitored in the framework the current research project are known to (e.g. Hg, Pb, PCBs) or could potentially (e.g. new POPs and CECs) endanger human health. The difficulty is that many of the environmental contaminants that pose the greatest risk to human populations are found in some country foods that also have high levels of beneficial nutrients and are of major social/cultural significance (Blanchet et al. 2000; Blanchet and Rochette 2008; Dallaire et al. 2009; Lucas et al. 2010; ITK and ICC 2012; Lemire al. 2015). In addition, some nutrients found in fish and marine mammals are known to negatively confound observed associations between contaminants and health outcomes, and/or to directly mitigate contaminants' toxicity (Chapman and Chan 2000; Rice 2008). Therefore, measuring country food nutrient status is important when assessing health effects of food chain contaminants. Since Hg (and selenoneine) both accumulates in RBCs, hemoglobin concentrations are also newly recognized as an important co-variable for interpreting Hg concentrations in human populations (Kim et al. 2014). Breastfeeding and fat mass are important co-variables when interpreting lipophilic contaminant concentrations such as PCBs. Moreover, biomarkers of nutritional status, country food consumption and anthropometric/breastfeeding data are important to adjust models of time-trends for food chain environmental contaminants and to provide additional information on their sources of exposure, study exposure level among sub-groups and examine possible explanations for the geographical and temporal trends observed.

Since one of the purposes of biomonitoring is ultimately to inform actions that reduce contaminant exposure among at-risk sub-populations, the wider context in which foods are procured, consumed and metabolized, *etc.* is necessary for garnering a fuller picture of these and potential mitigations strategies/actions. For instance, iron deficiency anemia is a growing public health concern for populations in the Canadian Arctic; a third of non-pregnant women in Nunavik have depleted iron stores (Plante el al. 2011). In the context of iron deficiency, elevated Hg and Pb exposures, and since country foods are replete in vitamins and several essential elements (including iron, Se, PUFAs), healthcare providers in the Arctic need to balance multiple health concerns when developing and providing dietary guidance to vulnerable populations (Pirkle et al. 2016).

Low incomes and food insecurity are well-publicized social and health concerns in the Canadian Arctic (Ruiz-Castell et al. 2015). Both influence environmental contaminants exposure and mitigating actions/policies. In the context of limited income and the high cost of market foods in Nunavik, country foods have several advantages (cultural anchor, better dietary quality, etc.) and may help families save money. Not surprisingly, families with a strong social network of country food exchanges, influenced by the presence of active hunters, elders and a life partner, are more food secure (Collings et al. 2016). Conversely, some, but not all of these country foods, contain moderate to elevated environmental contaminant concentrations and may lead to higher contaminant exposures. Poorer education have likewise been associated with higher Hg exposure among childbearing-age women in Nunavik (Adamou et al. 2018). With respect to lead and cadmium exposure, lifestyle habits, such as types of ammunitions used for hunting, game meat preparation practices and smoking habits, are central determinants of these exposure in Nunavik (Rey et al. 1997; Couture et al. 2012). For PCBs, fat mass is an important determinant.

Activities in 2017-2018

Qanuilirpitaa - How are we now? the follow-up of *Qanuippitaa* conducted in 2004, took place onboard the CCGS Amundsen from August 19th to October 5th, 2017. For this new survey, we followed up 305 participants of the 2004 adult cohort now aged 31 and over; we also recruited 447 additional new participants to be representative of the actual Nunavik adult population distribution. Since the youth was repeatedly mentioned by Inuit as one of the most important priority for the future of Nunavik (via different consultations in preparation for the survey conducted since June 2012), we also recruited an additional 574 participants aged 16 to 30. *Qanuilirpitaa* 2017 (n=1326) aims at documenting and studying several physical and mental health issues, as well as their risk and protective factors, chosen as priority by the steering and scientific committees of survey. Moreover, *Qanuilirpitaa* 2017 also fosters a community component aiming at

(i) defining community well-being, and indicators from Inuit perspectives; (ii) monitor change at the community level, by communities; (iii) Map community resources and communities as positive places, with assets to be preserved and enhanced and (iv) Identify actions that communities can take to improve health and social well-being and minimize negative impacts.

Objective 1 and 2 - To measure Nunavimmiut exposure to toxic metals, legacy and new POPs, CECs and other new CECs and to evaluate nutritional status of participants.

Blood puncture and spot urine collection to address objectives 1 and 2 were performed onboard the Amundsen during the clinical session. The present project provided funds to hire three research nurses for biological sample collection and two laboratory technicians who processed the samples onboard the CCGS Amundsen. A ≈40ml whole blood sample was collected from each participant. Whole blood was collected in EDTA vacutainers and an aliquot was transferred into a plastic vial for metal analysis (Hg, Pb, Se, Cd); the remaining blood was centrifuged at 3000 rpm during 10 min and the plasma poured in a glass vial prewashed with hexane for organic compound analyses (POPs, CECs) or in a plastic tube for PFAS analysis. Whole blood and plasma vials were frozen at -80˚C until shipment to the laboratories. Blood mercury, lead, cadmium and selenium concentrations were determined by inductively-coupled plasma mass spectrometry at the CTQ laboratory. With regard to nutritional status, blood hemoglobin was measured in fresh blood using the Beckman Coulter DxH 500 instrument onboard the Amundsen, whereas iron status biomarkers (serum iron, serum total iron-binding capacity, transferrin saturation, serum ferritin level and plasma high-sensitive C-reactive protein) were measured at the biochemistry laboratory of *Institut Universitaire de Cardiologie et de Pneumologie de Québec* using standard methods. RBC PUFA profile and blood selenoneine/ergothioneine levels will be measured during year 2 of the project.

Thirty pooled plasma samples were constituted by adding equal amounts of plasma from participants grouped according to age, sex, and region of residence (5 age groups, 2 sexes, 3 regions of residence). Pooled plasma samples were submitted to a targeted analysis for halogenated POPs using CTQ's E-458 method, PCDD/F using E-510 method and PFAS using E-501 method (specific analytes quantified using isotope labelled standards). The purified extracts prepared for the targeted analyses will be submitted to an untargeted analysis (semi-quantitative method – exposomics screening) using our APGC QTOF-MS instrument. Results of these pooled sample analyses obtained during year 1 will be helpful in selecting compounds to be measured in individual samples during subsequent years of the project.

A spot urine sample (≈ 10 ml) was obtained from most participants and stored in a -80˚C freezer. In the course of a Health Canada funded project (M. Lemire PI), 30 pooled urine samples (by sex, age group and coast –see above) were analysed for a series of contaminants not covered under NCP.
These pooled urine samples are analysed for metabolites of organophosphate ester flame retardants using the newly validated method at the CTQ (year 2).

Objective 3 - To account for participant's country and store-bought food consumption, food security, socio-demographic status, lifestyle habits and anthropometric characteristics in explaining biomonitoring data.

Qanuilirpitaa questionnaires, developed in collaboration with multiple Inuit and scientific experts, were administered to participants by the staff using laptops. Anthropometric measurements (weight, height, fat mass) were performed during the clinical session onboard the Amundsen.

Descriptive statistical analyses of blood metal concentrations were first conducted and included in a report prepared jointly by INSPQ staff and our research group. The report was sent to the NRBHSS in October 2018 and interventions at the community level were set up to reduce exposure of Nunavimmiut to methylmercury, the metal for which exposure guidelines are most often exceeded. A thematic report entitled "Exposure to environmental contaminants: metals" will be prepared in which blood metal levels will be presented according to sex, age groups and sub-region of residence. This report will be submitted in December 2019. Spatial trends for environmental contaminants and nutrients blood concentrations by Nunavik regions will be analysed while taking into account all relevant co-variables documented in Objective 2 and 3, including hemoglobin. Similarly, time trends analysis will be conducted using the adjustment methods previously developed by T. Adamou (PhD student) and E. Anassour-Laouan-Sidi (statistician) at the *Centre de recherche du CHU de Québec*. Nutrient blood measurements and/or country food consumption variables (and other ones) will be used to adjust models of body burdens of environmental contaminants in order to provide additional information on the sources of exposure and possible explanations for the geographical and temporal trends observed. Associations between blood nutritional status and data from the questionnaires will also be examined in order to better understand association between nutritional status, country and market foods consumption, and food security outcomes.

Weights will be applied to pooled samples data in order to calculate statistical parameters for plasma concentrations of PCBs and chlorinated pesticides, PCDD/F and PFAS. Kendrick mass defect analyses (Ubukata et al. 2015) and other chemometric methods will used to identify new halogenated compounds.

Community Engagement, Capacity Building and Communication

The governance structure of the survey calls for the participation of several representatives from Nunavik's communities, reflecting the participatory approach that characterizes this survey. Governance is overseen by a steering committee composed of the main regional leaders and key representatives of the Nunavik community: Kativik Regional Government, Makivik, Kativik School Board and two mayors representing the communities. Representatives of two major organizations, the Institut national de santé publique du Québec (INSPQ) and the CHU de Québec Research Centre/Université Laval, are also key members of the Steering Committee. The NRBHSSS chairs the steering committee and is responsible for the overall survey.

Three core partners are working together toward the realization of this survey: the Nunavik Regional Board of Health and Social Services (NRBHSS), the Institut national de santé publique du Québec (INSPQ) and the CHU de Québec Research Centre/Université Laval. The INSPQ has been mandated to ensure the project's overall coordination and administrative management.

This decision-making body and the active involvement of communities, which is at the core of this project, are intended to allow Nunavimmiut to appropriate all phases of this health survey and its results, thus strengthening Nunavimmiut autonomy and their ability to manage their health.

We have discussed preliminary findings with the NNHC, and provided information to adapt actual guidelines and determine the best communication tools and strategies to use. Dr Mario Brisson, physician responsible for environmental health issues at the NRBHSS, has also been involved at all important decision making steps of the study, and strong efforts have been made to actively involve physicians in charge of the Tulattavik Hospital in Kuujjuaq and Inuulitsivik Hospital in Puvirnituq in the project, in parallel to our pregnant women biomonitoring project.

Data sharing and follow-up of the participants

Haemoglobin values are measured on-board the Amundsen, and if a participant presents haemoglobin values below or above the recommended guidelines for his/her gender, age group and pregnancy status (according to Tulattavik and Inuulitsivik hospital protocols) and if the participant previously agreed to in the informed consent form, the participants are rapidly referred to local health providers for a clinical follow-up. Similarly, iron status analyses are included in the first year so that, as for haemoglobin, if a participant presents iron biomarkers below the recommended guidelines and if participant previously agreed to in the informed consent, the participant's results are sent to local health provider to support the clinical diagnosis of the types of anaemia according to iron deficiency and other biomarkers (measured in Qanuilirpitaa but funded elsewhere). Mechanisms for communication and transmission of the clinical results were discussed with NRBHSS partners to ensure efficient follow-up and prevent the overloading local health system.

Metal analyses were included in the Year 1 of this proposal to also ensure a rapid clinical follow-up of participants exhibiting levels above the Quebec Province Maladie à déclaration obligatoire (MADO) for Hg and Pb exposure. The follow-up of the MADO will be supervised by Sylvie Ricard at the NRBHSS. For Hg, the previous follow-up documents were elaborated based on the Hg guideline document and clinical algorithm elaborated by our team at Université Laval and University of Hawai'I, Manoa (Lemire, Muckle et al. 2016). The document is actually in revision and will be updated in the next few months according to our findings from our NCP project entitled 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 and Year 2). For Pb, the follow-up documents including the clinical follow-up algorithm are planned to be revised in 2017 in collaboration with our team, Sylvie Ricard and Dr Mario Brisson, physician responsible for environmental health issues at the NRBHSS. For Cd, a clinical algorithm is already available. Since there are no toxicological reference values for POPs, participants' results analysed in Year 2 will only be provided in aggregated format.

Indigenous Knowledge

OCAP is an important reference in terms of participatory research by and for indigenous people. The Qanuilirpitaa? 2017 Policy on the Management of Databases and Biological Samples have been designed in conformity with the elements described below. The final document was submitted for adoption at the Qanuilirpitaa Steering Committee Meeting in March 2017.

The Components of OCAP®

Ownership: Ownership refers to the relationship of First Nations to their cultural knowledge, data, and information. This principle states that a community or group owns information collectively in the same way that an individual owns his or her personal information.

Control: The principle of control affirms that First Nations, their communities and representative bodies are within their rights in seeking to control over all aspects of research and information management processes that impact them. First Nations control of research can include all stages of a particular research project-from start to finish. The principle extends to the control of resources and review processes, the planning process, management of the information and so on.

Access: First Nations must have access to information and data about themselves and their communities, regardless of where it is currently held. The principle also refers to the right of First Nations communities and organizations to manage and make decisions regarding access to their collective information. This may be achieved, in practice, through standardized, formal protocols.

Possession: While ownership identifies the relationship between a people and their information in principle, possession or stewardship is more concrete. It refers to the physical control of data. Possession is a mechanism by which ownership can be asserted and protected.

Discussion and Conclusions

The *Qanuilirpitaa* 2017 survey allows continuing our biomonitoring efforts in Nunavik that started 25 years ago with the Santé Québec Inuit Health Survey in 1992. While our attention remains on POPs and toxic metals, methods have been developed to measure new POPs and identify new contaminants of emerging concern in the Nunavik population. This project allows Canada to maintain its role at the forefront of international biomonitoring efforts on long-range environmental contaminants exposure among circumpolar populations and contribute to improve our understanding of the risks and benefits of country foods consumption in the Arctic.

Expected Project Completion Date

March 2020

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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 2 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 (année 2 de 3)

Project Leader/Chef de projet

Chris Furgal PhD (acting PI), Associate Professor, Indigenous Environmental Studies & Sciences Program; Nasivvik Centre for Inuit Health and Changing Environments, Trent University, 1600 West Bank Drive, Peterborough, ON K9J 7B8. Tel: (705) 748-1011 ext.7953; Fax: (705) 748-1416; Email: chrisfurgal@trentu.ca

Mélanie Lemire PhD (co-PI), Assistant Professor and Nasivvik Chair, Department of Social and Preventive Medicine, Université Laval; Axe santé des populations et pratiques optimales en santé, Centre de recherche du CHU de Québec, Hôpital du Saint-Sacrement, 1050 chemin Sainte-Foy, Québec, QC G1S 4L8. Tel: (418) 525-4444 ext. 81967; E-mail: melanie.lemire@crchuq.ulaval.ca

Pierre Ayotte PhD (co-PI), Professor, Department of Social and Preventive Medicine, Université Laval; Axe santé des populations et pratiques optimales en santé, Centre de recherche du CHU de Québec; Head, Biomarker laboratory, Institut national de santé publique du Québec (INSPQ), 945 avenue Wolfe, Québec, QC G1V 5B3. Tel: (418) 650-5115 ext. 4654; Fax: (418) 654-2148; Email: pierre.ayotte@inspq.qc.ca

Catherine Pirkle PhD, Assistant Professor, Health Policy and Management, Office of Public Health Studies, University of Hawai'i at Manoa, 1960 East-West Road, Honolulu, HI, U.S.A. 96822-2319. Tel: (808) 956-8748; Fax: (808) 956-3368; Email: cmpirkle@hawaii.edu

Project Team/Équipe de projet

Amanda D. Boyd, Washington State University, Pullman, WA; Gina Muckle, Université Laval, Québec, QC; Sylvie Ricard, Nunavik Regional Board of Health and Social Services (NRBHSS), Québec, QC; Marie-Josée Gauthier, NRBHSS, Kuujjuaq, QC; Caroline d'Astous, Kuujjuaq, QC; Carole Beaulne, Ilagitsuta Family House, Inuulitsivik Health Center, Puvirnituq, QC; Ellen Avard, Nunavik Research Centre, Kuujjuaq, QC; Michael Kwan Nunavik Research Centre, Kuujjuaq, QC; Suzanne Côté, Université Laval, Québec, QC; Thérèse Adamou, Université Laval, Québec, QC; Annie Turgeon, Université Laval, Québec, QC

Project Location/Emplacement(s) du projet

- All 14 communities of Nunavik
- Quebec City, Quebec
- Peterborough, ON

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, chaque année, de nouveaux produits font leur entrée sur le marché. 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 of Year 2 show that blood Hg and lead (Pb) levels in 2016-2017 have decreased by 16-18% since the last time they were measured in 2013. Exposure levels of legacy and new POPs included in the Stockholm Convention have decreased markedly since they were first measured in 1992 or 2004, and continued to decrease in the recent years. However, more recent perfluorinated compounds (PFNA, PFDA and PFuDA) that were used in replacement of the older ones are now increasing since they were first measured in 2012, and PFNA exposure levels are more than three times higher than those reported for women of the same age in southern Canadian cities. Based on food questionnaire data and methylmercury (MeHg) intake estimations, beluga meat and nikku was the main source of MeHg exposure for pregnant women across seasons in 2016-2017, but primarily in the summer when most beluga products are available. All study results will be available and progressively presented to Nunavimmiut and health professionals over the next year.

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 collectivités du Nunavik ont été recrutées en vue des activités de biosurveillance. Les résultats de l'année 2 montrent que la concentration sanguine de Hg et de plomb (Pb) en 2016-2017 a diminué de 16 à 18 % depuis la dernière fois qu'elle a été mesurée en 2013. Les niveaux d'exposition aux POP hérités du passé et nouveaux visés par la Convention de Stockholm ont diminué de façon marquée depuis qu'ils ont été mesurés pour la première fois en 1992 ou en 2004 et ont continué de diminuer au cours des dernières années. Toutefois, les composés perfluorés plus récents (PFNA, PFDA et PFuDA) qui ont été utilisés pour remplacer les composés plus anciens sont maintenant en hausse depuis qu'ils ont été mesurés pour la première fois en 2012, et les niveaux d'exposition au PFNA sont plus du triple des taux d'exposition enregistrés chez les femmes du même âge dans les villes du Sud du Canada. Selon les données recueillies au moyen du questionnaire sur les habitudes alimentaires et les estimations de l'exposition au méthylmercure (MeHg), la viande et le nikku de béluga ont constitué la principale source d'exposition au MeHg chez les femmes enceintes pendant toutes les saisons de 2016-2017, mais particulièrement en été, lorsque la plupart des produits du béluga sont disponibles. Tous les résultats de l'étude seront rendus publics et seront présentés progressivement aux Nunavimmiuts et aux professionnels de la santé au cours de la prochaine année.

Key Messages

- In 2016-2017, blood Hg and Pb levels have decreased by 16-18% since the last time they were measured in 2013.
- Exposure levels of legacy and new POPs included in the Stockholm Convention continued to decrease since they were first measured in 1992 or 2004.
- More recent perfluorinated compounds (PFNA, PFDA and PFuDA) exposure levels are increasing since they were first measured in 2012.
- PFNA exposure levels are more than three times higher than those reported for women of the same age in southern Canadian cities.
- Beluga meat and nikku are the main source of MeHg exposure for pregnant women across seasons but primarily in the summer, when most beluga products are available.

Messages clés

- Les résultats de 2016-2017 montrent que la concentration sanguine de Hg et de Pb a diminué de 16 à 18 % depuis la dernière fois qu'elle a été mesurée en 2013.
- Les niveaux d'exposition aux POP hérités du passé et nouveaux visés par la Convention de Stockholm ont continué de diminuer depuis qu'ils ont été mesurés pour la première fois en 1992 ou en 2004.
- Les niveaux d'exposition aux composés perfluorés plus récents (PFNA, PFDA et PFuDA) sont en augmentation depuis qu'ils ont été mesurés pour la première fois en 2012.
- Les niveaux d'exposition au PFNA sont plus du triple des taux d'exposition enregistrés chez les femmes du même âge dans les villes du Sud du Canada.
- La viande et le nikku de béluga représentent la principale source d'exposition au MeHg chez les femmes enceintes pendant toutes les saisons, mais particulièrement en été, lorsque la plupart des produits du béluga sont disponibles.

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 (recruitment Year 1, data analysis Years 2 and 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 (Years 2-4)

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:

- to evaluate pregnant women' awareness of health and dietary recommendations provided by caregivers (included in Part A questionnaires);
- 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;
- through the use of 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;
- 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;
- assess pregnant women's understanding of health and dietary recommendations provided by caregivers (nurse, midwives, physician) and pregnant women's information needs to improve future communications; and,
- 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 - 4)

Part C aims to:

- 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,
- 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 4, 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 were exposed to unusually high doses of environmental contaminants, mainly organochlorines (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 as well as other federal regulations, contributed to a significant decrease in POPs environmental concentrations (AMAP 2014). Circumpolar Inuit exposures to POPs have also decreased (AMAP 2015), although most recent trends in legacy POPs exposure among Nunavik pregnant women remain to be documented.

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). Since up to 23% pregnant women in Nunavik continue to be detected with blood Hg above the Health Canada guideline (Lemire et al. 2017), Hg exposure remains a priority public health issue in the region. Moreover, sequential hair Hg analyses show important monthly variations in exposure (Lemire et al. 2017). Beluga meat is known to contain elevated Hg and the 2004 Qanuippitaa Inuit Health Survey showed that beluga meat was the main source of dietary exposure to Hg in Nunavik, 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). Lake trout is also known to accumulate high levels of Hg (Kwan et al. 2014). It is believed to be often consumed by women in other villages, and particularly during winter, although no information was available about the consumption of lake trout in the 2004 Qanuippitaa survey. Thus, further data analysis on pregnant women dietary habits is needed to identify the primary dietary sources of Hg within each season. The Minamata Convention on Hg emissions entered 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 (AMAP 2017). However, little is known about their actual levels of exposure in the Nunavik population.

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 2017-2018

Part A

Data collection is presented in Lemire et al. (2017) and outlines research tools design, ethical approval process, pregnant women recruitment strategies, the clinical follow-up of participants with anemia and/or elevated blood Hg or Pb as well as samples handling and shipping. Capacity building of research nurses and about how hair Hg analyses were conducted in Nunavik and the multiple communication and community engagement activities in Nunavik are also detailed in Lemire et al. (2017).

Biological sample analyses

Results for blood levels for Hg, Pb, Mn, Se and PUFAs, the sequential hair analyses results for Hg as well as iron status and anemia among Nunavik pregnant women in 2016-2017 are detailed in Lemire et al. (2017). Laboratory analyses for POPs (legacy POPs, news POPs and CECs) and selenoneine were completed by fall 2017 and presented in the results section.

Databases and statistical analysis

Temporal trends for contaminants were conducted by an experienced data analyst, Elhadji Anassour Laouan-Sidi, which has worked on this dataset for several years. Detailed statistical analyses to document pregnant women country food consumption in the past year (2016-2017) as well as to identify seasonal local dietary sources of Hg exposure are being conducted as part the MSc project of M. Pontual that started in May 2017. Preliminary results are shown in the result section.

Other capacity building, training, communication and outreach activities in 2017- 2018

Return of individual results to pregnant women

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 to be added to the participant's medical file. At the same time in June 2017, Info-MADO (maladies à déclaration obligatoire) newsletter about the role of health professionals in the research project and clinical follow-up of pregnant women was sent to all health professionals in Nunavik (Ricard and Lemire 2017). 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. All these knowledge sharing and clinical tools were used to inform 2017 Qanuilirpitaa participants' result return and clinical follow-up undertaken in 2018 (Ricard et al. 2018a; Ricard et al. 2018b; Ricard et al. 2018c).

Nunavik Nutrition and Health Committee (NNHC)

Preliminary findings of the project were systematically presented and discussed with NNHC members before being presented to other general or scientific audiences. Preliminary analysis of POPs data and time-trends were presented in November 2017, whereas Mariana Pontual, the MSc student involved in the project, presented her findings on pregnant women seasonal country food consumption and local dietary sources of Hg exposure in May 2018.

Other knowledge mobilization activities in Nunavik

Together with the NNHC, several project team members also 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 2017. A shorter version of this open letter was also published June 27, 2017, in the Air Inuit magazine, and co-signed by Sarah Kalhok Bourque on behalf of the NCP Management Committee (Annex 1).

2017 Arctic Conference: New Lights on Northern Prevention Efforts

Following the recommendation of Drs Bouchard and Brisson, Mélanie 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. Mélanie Lemire has also been recently invited to present the latest project findings at the next conference in Iqaluit in April 2019.

2017 NCP's 25th anniversary and results workshop in Yellowknife & Arctic Change Conference in Quebec City

Nutaratsaliit qunuinggisiarningit niqituinnanut (NQN) project findings detailed in Lemire et al. (2017) were presented at the NCP conference in Yellowknife on September 27, 2017. Time-trends for POPs and metal exposure were presented at the Arctic Change Conference in December 12, 2017. Mariana Pontual also presented a scientific poster outlining a short summary of her preliminary findings on pregnant women seasonal country food consumption and local dietary sources of Hg exposure.

30th anniversary of the Centre de recherche interdisciplinaire sur le bien-être, la santé, la

société et l'environnement (CINBIOSE) at Université du Québec à Montréal (UQÀM)

Mélanie Lemire and Marie-Josée Gauthier, a nutritionist at the NRBHSS and NQN project collaborator, gave a joint presentation on November 9, 2017, untitled: Les recommandations alimentaires quant à l'exposition au méthylmercure au Nunavik: le fruit de la collaboration entre la santé publique et la recherche. This presentation outlined how intersectoral research in Nunavik was critical for informing the NQN research project and public health dietary intervention in this region.

2017-2018 Human Health Assessment Group of Arctic Monitoring and Assessment Programme (AMAP) meetings in Reston and Quebec City

The present project's preliminary findings were presented at the two latest Human Health Assessment Group (HHG)-AMAP meetings in Reston, USA, April 24, 2017, and Quebec City Feb 28, 2018, 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. Similarly, recent data about new POPs and CECs were also shared and discussed. Experts also agreed on the possibility of nominating emerging contaminants for inclusion into the Stockholm Convention together with Inuit Circumpolar Council representatives.

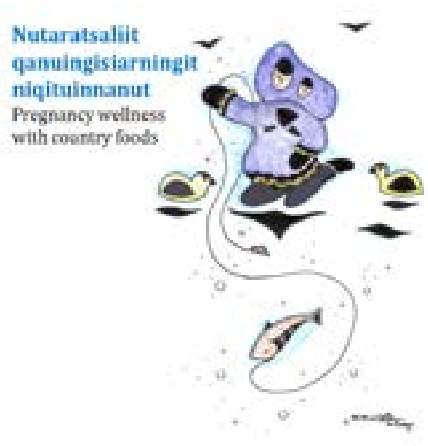
Presentation to several other audiences via the Nasivvik Chair activities

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 the team. This includes the plenary conference: *Conduire des projets de recherche interculturels: enjeux éthiques* in Québec City on May 5, 2017; at the *Institut nordique du Québec's* special session of the *Association francophone pour le savoir* (ACFAS) on May 8, 2017, and for a guest conference on March 28, 2018, at UQAT in Val d'Or.

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 (Figure 1). 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. During the process of developing the questionnaire and preparing the results letter, consultations were held with members of the NNHC and other health professionals in Nunavik. Similarly, when analyzing country food consumption data, consultation with NNHC members and NQN project partners were made to make sure data interpretation were accurate and in accordance with regional partners observations.

Figure 1: Project logo developed together with Ulayu Pilurtuut, an Inuk artist based in Kuujjuaq.



Part B

This year we made moderate progress on the planned activities to meet objectives under Part B of the project. In 2017-18, we met with team members and regional public health representatives to update them on project progress and challenges, 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 2017-2018 the team (i) began analysis of the data on pregnant women' awareness of health and dietary recommendations provided by the caregivers (included in Part A questionnaires); (ii) revised and refined a data extraction form for the review of curriculum material as well as the review of medical school syllabi and reading materials (assigned texts related to prenatal care, nutrition, and contaminants); and (iii) revised our review of Laval nursing school curricula. Based on the initial review of materials done in 2016-17 it was clear that we needed to conduct key informant interviews with instructors at major medical institutions in Quebec to learn what trainees were taught in terms of clinical protocols for addressing environmental contaminant issues during pregnancy. An interview guide for the medical instructors was developed and submitted for ethics review. The clinical vignettes to assess health practitioner's processes and considerations for addressing issues of contaminant exposure during pregnancy were created and reviewed in early 2017-18 and required revision for length and understanding and pre-testing of those tools was initiated.

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, it was deemed that this would not be necessary. Interview / questionnaire questions were adapted to be used with a wider selection of women currently and recently pregnant in the region. These questions 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. Delays with ethics approval and interviewer recruitment for the project influenced planned progress on conducting these interviews in 2017-18.

Results for Part A (Year 2)

Study population

Between October 2016 and March 2017, we succeeded in recruiting 97 pregnant women, among the 231 pregnant women eligible in Nunavik during this period, thus representing about 42% of pregnant women at that time. Recruitment was done in 13 of the 14 communities since in one village, these was no pregnant women during the sampling period. The percentage of participation in each community was quite variable, between 17 to 71%, although globally, it ranged between 38 and 48% among the 3 study regions.

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

Study region	Number of pregnant women eligible (estimated)	Number of pregnant women recruited	% of participation *
Hudson Bay	99	38	38
Hudson Strait	77	37	48
Ungava	55	22	40
TOTAL	231	97	42

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

Time-trends analysis for POPs and metal exposure since the last two decades

Table 2 presents time-trends analysis for contaminant exposure among Nunavik pregnant women since the last two decades. These time-trends analyses 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. Hg, Pb and PFUAs are measured since 1992 whereas total Se is measured since 1996. Almost all OCs and PCBs were measured since 1992, with the exception of Toxaphene Parlar 26 and 50 that are measured only since 2004. PBDEs, OH-PCBs, PCP and PFOS were measured and included in the time-trend analyses since 2004. More recent perfluorinated compounds (also known as PFAS) were later included in the following years: PFOA and PHFxS in 2007 and PFBA, PFHxA and longer chain PFAS, such as PFNA, PFDA and PFUnDA in 2012 (but not measured in 2013). In 2016-2017, POPs were measured in serum, whereas in the previous years they were measured in plasma. According to the CTQ, POPs levels in plasma and serum are fully comparable (Leblanc, comm pers).

Blood Hg and Pb levels in 2016-2017 have decreased by 16-18% since the last time they were measured in 2013. Exposure levels of Legacy and New POPs included in the Stockholm Convention (OCs, PCBs, PBDEs, OH-PCBs and PCP) have decreased markedly since they were first measured in 1992 or 2004, and kept decreasing in the recent years. Moreover, in 2016-2017, several of these were no longer detected or detected in less than 50% of the participants. Figure 1 shows time-trends for Hg and PCB-153 exposure since 1992.

Conversely, time-trend analyses for PFAS show different patterns. Older PFAS that are included in the Convention as a New POPs (PFOS), recommended for listing under the Convention (PFOA) or under review by the POPs Review Committee (PFHxS) are decreasing since the first time they were measured in 2004 or 2007. Conversely, more recent PFAS (PFNA, PFDA and PFuDA) that were used in replacement of the older PFAS are now increasing since they were first measured in 2012. PFNA was the PFAS showing the highest increasing percentage, with average levels just below average levels for PFOS, whereas all other ones were in average four to five time lower. Figure 2 shows time-trends for PFOS and PFNA exposures since 2004 and 2012 respectively. It is to note that PFBS were never detected in Nunavik pregnant women and PFHxA were detected at 84.5% in 2012, but were no longer detected in 2016-2017.

Table 2: Nunavik pregnant women exposure to legacy POPs, new POPs, some CECs, Hg, Pb, Se and PUFAs in 2016-2017 and time-trends since each contaminant was first measured in Nunavik as well as between 2012-2013 and 2016-2017.

	Acronym	% > LOD*	2016-2017 GM [95%CI]**	% of change since 1992[a], 1996[b], 2004[c] or 2007[d]	% of change between 2012-2013 and 2016-2017
Metals and PUFAs (metals: blood, µg/L; PUFAs: red blood cells, ratio)					
Hg		100	4.2 [3.4-4.9]	-66.2% [a]	-18.1%
Pb		100	12 [11-14]	-71.6% [a]	-15.5%
Se		100	232 [211-255]	-40.1% [b]	-25.2%
PUFAs n-3/n-6		100	0.39 [0.36-0.42]	-74.6% [a]	-12.4%
OCs and PCBs (plasma or serum, µg/kg lipids)					
Aldrin		0	-		
alpha-Chlordane	α-chlordane	0	-		
gamma-Chlordane	γ-chlordane	0	-		
Hexachlorobenzene	HCB	99	18 [16-21]	-81.3% [a]	-11.4%
beta-Hexachlorocyclohexane	ß-HCH	73.2	2.1 [1.8-2.4]	-83.4% [a]	-15.5%
gamma-Hexachlorocyclohexane	γ-HCH	0	-		
cis-Nonachlor		95.9	4.5 [3.8-5.4]	-84.2% [a]	-25.2%
trans-Nonachlor		100	32 [27-38]	-72.4% [a]	-24.2%
Oxychlordane		100	16 [14-20]	-79.3% [a]	-26.9%
p,p'-Dichlorodiphenyltrichloroethane	p,p'-DDT	14.4	-		
p,p'- Dichlorodiphenyldichloroethylene	p,p'-DDE	100	97 [84-112]	-85.0% [a]	-25.9%
Mirex		81.4	2.7 [2.3-3.2]	-79.5% [a]	-10.9%
Toxaphene Parlar 26		91.8	3.96 [3.2-4.9]	-54.8% [c]	-34.5%
Toxaphene Parlar 50		96.9	6.53 [5.3-8.1]	-57.9% [c]	-31.8%
Aroclor 1260			226 [192-266]	-85.2% [a]	-27.6%
PCB 28		0	-		
PCB 52		0	-		
PCB 99		69	5.6 [4.9-6.6]	-88.4% [a]	-25.2%
PCB 101		3	-		
PCB 105		43	-		
PCB 118		89.7	5.1 [4.3-5.9]	-82.6% [a]	-24.1%
PCB 128		9	-		
PCB 138		100	14 [12-17]	-87.8% [a]	-26.0%
PCB 153		100	29 [25-34]	-83.4% [a]	-28.5%
PCB 156		45	-		
PCB 170		87	3.9 [3.2-4.6]	-87.9% [a]	-27.9%
PCB 180		100	13 [11-15]	-86.5% [a]	-24.6%
PCB 183		71.1	1.9 [1.7-2.3]	-86.6% [a]	-19.4%
PBDEs, OH-PCBs and PCP (plasma or serum, µg/kg lipids)					
PBB 153		0	-		
PBDE 15		0	-		
PBDE 17		0	-		

	Acronym	% > LOD*	2016-2017 GM [95%CI]**	% of change since 1992[a], 1996[b], 2004[c] or 2007[d]	% of change between 2012-2013 and 2016-2017
PBDE 25		0	-		
PBDE 28		0	-		
PBDE 33		0	-		
PBDE 47		23.7	-		
PBDE 99		5.2	-		
PBDE 100		6.2	-		
PBDE 153		34	-		
OH-PCB 107		9.4	-		
OH-PCB 146		38.1	-		
OH-PCB 187		40.4	-		
Pentachlorophenol	PCP	74.5	0.16 [0.13-0.19]	- 70.9% [c]	-46.5%
PFAS (plasma. µg/L)					
Perfluoro-n-butanoic acid	PFBA	0	-		
Perfluoro-n-hexanoic acid*	PFHxA	0	-		
Perfluoro-n-octanoic acid	PFOA	100	0.6 [0.5-0.6]	- 30.7% [d]	- 23.7%
Perfluoro-n-nonanoic acid*	PFNA	100	2.4 [2.2-2.7]		+ 14.9%
Perfluoro-n-decanoic acid	PFDA	100	0.52 [0.45-0.60]		+ 7.4%
Perfluoro-n-undecanoic acid	PFuDA	100	0.59 [0.49-0.70]		+ 12.9%
Perfluorobutane sulfonate	PFBS	0	-		
Perfluorohexane sulfonate	PFHxS	100	0.26 [0.23-0.3]	- 39.2% [d]	- 27.6%
Perfluorooctane sulfonate	PFOS	100	3.3 [2.9-3.7]	- 64.9% [c]	- 14.0%

* LOD: Limit of Detection. ** The geometric mean (GM) and 95% Confidence intervals (CI) are considered reliable and are reported only when the contaminant is detected in more than 50% of the participants.

Figure 2: Time-trends for Hg and PCB-153 exposure in Nunavik pregnant women since 1992.

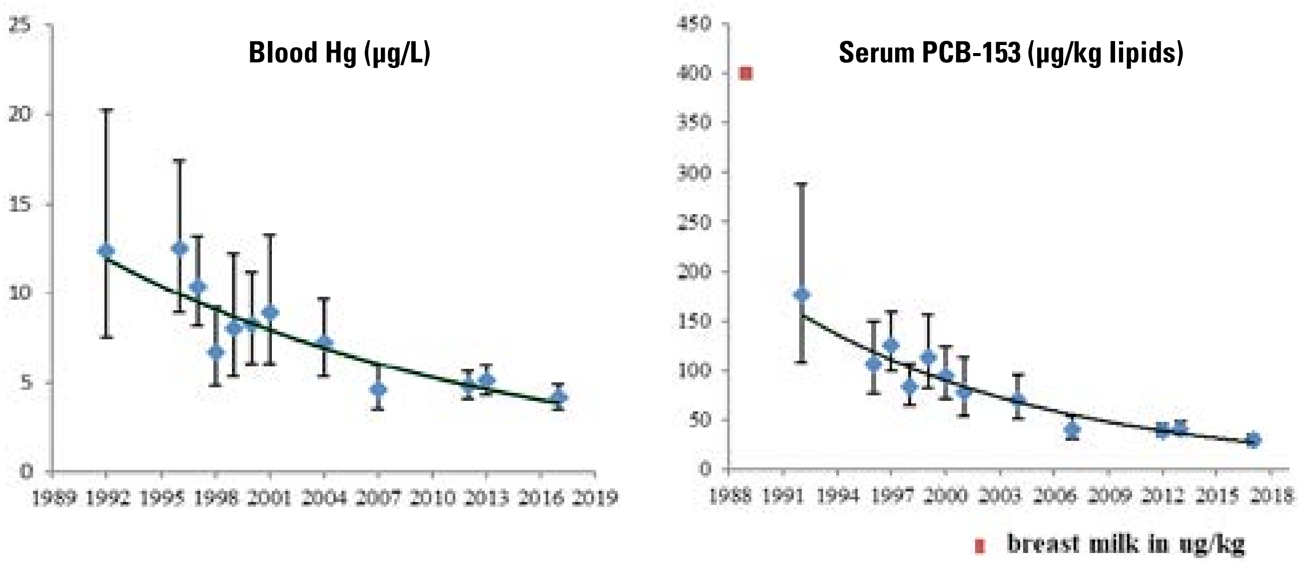
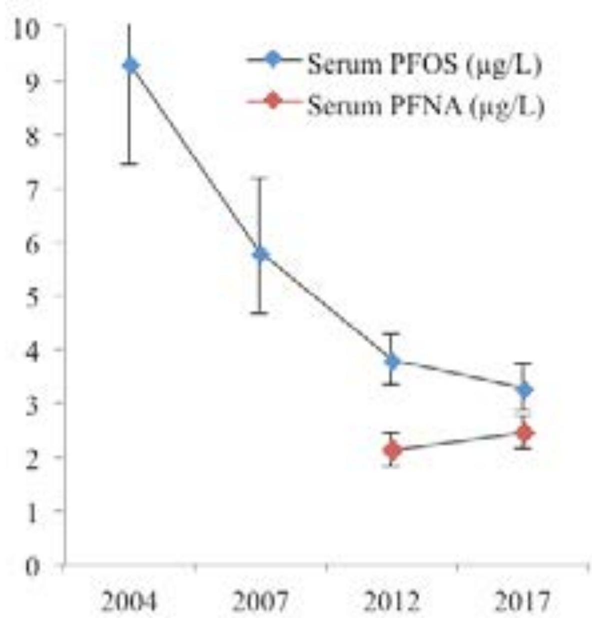


Figure 3: Time-trends for PFOS and PFNA exposure in Nunavik pregnant women since 2004 and 2012 respectively.



Selenoneine levels

The GM of selenoneine concentrations in whole blood was 20.7 µg Se/L (Inter-quartile range (IQR) = 53.0 µg Se/L: range = 1.0 - 1227.8 µg Se/L, n=96). Selenoneine represented in average 9.0% of total Se in whole blood, but for those with the highest total Se levels, up to 55.0% of total Se was in the form of selenoneine. Methylation of selenoneine may be a prerequisite for its excretion in urine (Klein et al. 2011). The GM of methylselenoneine concentrations in whole blood was 3.1 µg Se/L (IQR = 2.6 µg Se/L: range = 2.0 – 14.2 µg Se/L), which represented in average 15.0% of total selenoneine concentrations. No differences in blood selenoneine and methylselenoneine concentrations were found between study regions. Blood selenoneine concentrations were very strongly correlated to blood total Se concentrations ($\rho = 0.91$), and greatly correlated with blood Hg concentrations ($\rho = 0.67$) as was blood Hg with total Se ($\rho = 0.67$). Blood Hg was more strongly correlated to the % of selenoneine than the % of methylselenoneine in blood (ρ=0.64 versus 0.28). Interestingly, hair Hg excretion rate was not correlated to blood Hg concentration (ρ=0.11) and was slightly more correlated to blood methylselenoneine than to selenoneine concentrations (ρ=0.21 versus 0.18). Blood Hg, selenoneine and methylselenoneine were well correlated to hemoglobin concentrations since both selenoneine and Hg are known to accumulate in red blood cells (Yamashita et al. 2013).

Table 3: Non-parametric correlation matrix (Spearman's ρ correlations) between blood Hg, hair Hg, blood Hb, total Se, selenoneine, methylselenoneine, percentage of blood selenoneine and methylselenoneine as well as hair Hg excretion rate among study participants (n=96)

	Hair Hg[a]	Blood hemoglobin	Blood total Se	Blood selenoneine	Blood methyl-selenoneine	% blood selenoneine	% blood methyl-selenoneine	Hair Hg excretion rate[b]
Blood Hg	0.94***	0.32**	0.67***	0.67***	0.64***	0.64***	0.28**	0.11
Hair Hg[a]		0.28**	0.69***	0.67***	0.66***	0.64***	0.28**	0.39***
Blood hemoglobin			0.38**	0.31**	0.37***	0.28**	0.14	-0,19†
Blood total Se				0.91***	0.89***	0.85***	0.25*	0.23*
Blood selenoneine					0.86***	0.99***	0.34**	0.18†
Blood methyl-selenoneine						0.82***	0.62***	0.21*
% Blood selenoneine							0.35**	0.14
% Blood methyl-selenoneine								0.05

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

[a] Average hair Hg concentrations for the two first centimeters;

[b] Calculated as hair Hg/blood Hg

Seasonal country food consumption and dietary sources of Hg exposure

Country food intake was estimated using data from the food frequency questionnaire and estimated portions based on the Qanuilirpitaa 2004 Survey for childbearing age women, using the method detailed in the supplementary material of Lemire et al. (2015). Complete data was available for 93 of the 97 pregnant women recruited. MeHg intake from country food was also estimated using the method in Lemire et al. (2015), using estimated MeHg concentrations in Nunavik country foods that were more recently assessed by the Nunavik Research Centre (Laird et al. unpublished data) and an estimated percentage of 11% of MeHg in seal liver as outlined in in Lemire et al. (2015).

Table 4 show that country food intake was the highest during summer, followed by the fall and winter. The diversity of country food consumed was also higher in the summer. Caribou meat, caribou nikku (dried meat) and Arctic Char were quite similarly consumed across seasons, whereas wild berries and mollusks were primarily eaten in the summer, goose in the spring and ptarmigan in winter. Beluga mattaaq was among the top 5 most consumed country foods in all seasons, but was more importantly consumed in the summer. Conversely, beluga meat (raw and nikku) were not highly consumed except in the summer, but still these two country foods together only represented 5.2% of the total country food intake. Lake trout was not highly consumed in none of the seasons.

Table 5 details estimated MeHg intake of pregnant women recruited in 2016-2017 by season. Although beluga meat (meat and nikku) was not frequently consumed, it was responsible for most of estimated MeHg intake across seasons, and primarily in the summer, where beluga meat and nikku was responsible for almost 50% of total MeHg intake. Their findings are well aligned with Year 1 findings of this project showing higher hair Hg levels in summer months, and particularly in the Hudson Strait villages, where most of beluga hunting takes place in Nunavik (Lemire et al. 2017). These results are also in accordance with those reported by Lemire et al. (2015) based on Qanuippitaa data in 2004. Beluga mattaaq consumption was only responsible for 10 to 20% of MeHg intake, although it was much more consumed than beluga meat and nikku. This can be explained by the fact that beluga nikku and raw meat are considerably higher in Hg (in average 1 and 4 µg/g respectively) compared to beluga mattaaq (in average 0.3 µg/g).

Conversely, our most recent data in Nunavik shows that beluga mattaaq is the main source of selenoneine in Inuit diet (Little et al. In revision). Finally, based on the present results, lake trout consumption was not an important source of MeHg intake among pregnant women in 2016-2017.

Table 4: Pregnant women country food intake by season (in g/day or % of the total) (n=93)

Winter			Spring			Summer			Fall		
	g/day	%		g/day	%		g/day	%		g/day	%
Caribou Meat	18,84	39,50	Caribou Meat	9,98	27,10	Wild Berries	20,32	25,60	Caribou Meat	11,50	20,60
Arctic Char	8,65	18,10	Arctic Char	6,20	16,80	Caribou Meat	14,18	17,90	Arctic Char	4,90	8,80
Caribou Nikku	7,43	15,50	Goose	4,99	13,50	Arctic Char	6,93	8,80	Caribou Nikku	3,80	6,80
Ptarmigan	3,40	7,10	Caribou Nikku	3,63	9,90	Beluga Mattaq	6,44	8,10	Wild Berries	2,20	3,90
Beluga Mattaq	1,34	2,80	Beluga Mattaq	1,93	5,20	Mollusks	6,02	7,60	Beluga Mattaq	1,90	3,50
Seal Meat	1,12	2,30	Ptarmigan	1,28	3,50	Caribou Nikku	5,67	7,20	Goose	1,60	2,90
Beluga Misirak	0,89	1,90	Pitsik	1,11	3,00	Goose	3,78	4,80	Mollusks	1,60	2,80
Beluga Nikku	0,87	1,80	Mollusks	1,05	2,80	Beluga Nikku	2,96	3,70	Beluga Nikku	1,40	2,50
Lake Trout	0,84	1,80	Seal Meat	1,04	2,80	Pitsik	2,85	3,60	Seal Meat	1,40	2,50
Wild Berries	0,64	1,30	Wild Berries	1,03	2,80	Seal Meat	2,60	3,30	Ptarmigan	0,70	1,30
Pitsik	0,61	1,30	Beluga Nikku	0,95	2,60	Beluga Meat	2,17	2,70	Pitsik	0,70	1,20
Brook Trout	0,48	1,00	Lake Trout	0,88	2,40	Lake Trout	0,91	1,10	Beluga Misirak	0,60	1,10
Goose	0,45	1,00	Beluga Meat	0,77	2,10	Beluga Misirak	0,77	1,00	Lake Trout	0,60	1,00
Beluga Meat	0,45	0,90	Beluga Misirak	0,65	1,80	Seaweed	0,73	0,90	Beluga Meat	0,50	1,00
Whitefish	0,41	0,90	Brook Trout	0,37	1,00	Seal Liver	0,70	0,90	Brook Trout	0,40	0,70
Mollusks	0,35	0,70	Seal Ursuk	0,27	0,70	Game Bird Eggs	0,44	0,60	Seal Liver	0,30	0,50
Seal Ursuk	0,34	0,70	Seaweed	0,21	0,60	Brook Trout	0,39	0,50	Seal Ursuk	0,30	0,50
Seal Liver	0,22	0,50	Seal Liver	0,17	0,50	Ptarmigan	0,38	0,50	Seaweed	0,20	0,40
Seaweed	0,15	0,30	Whitefish	0,15	0,40	Whitefish	0,34	0,40	Whitefish	0,10	0,20
Walrus	0,14	0,30	Game Bird Eggs	0,09	0,30	Seal Ursuk	0,31	0,40	Sculpin	0,10	0,10

Winter			Spring			Summer			Fall		
	g/day	%		g/day	%		g/day	%		g/day	%
Sculpin	0,03	0,10	Other Fish	0,06	0,20	Sculpin	0,19	0,20	Other Fish	0,10	0,10
Other Fish	0,03	0,10	Sculpin	0,03	0,10	Walrus	0,08	0,10	Walrus	0,10	0,10
Pike	0,03	0,10	Walrus	0,03	0,10	Other Fish	0,03	0,00	Game Bird Eggs	0,00	0,00
Polar Bear	0,03	0,10	Pike	0,00	0,00	Pike	0,03	0,00	Muskox	0,00	0,00
Muskox	0,03	0,10	Polar Bear	0,00	0,00	Polar Bear	0,00	0,00	Pike	0,00	0,00
Game Bird Eggs	0,00	0,00	Muskox	0,00	0,00	Muskox	0,00	0,00	Polar Bear	0,00	0,00
Total intake	47,76	100,00	Total intake	36,89	100,00	Total intake	79,21	100,00	Total intake	55,87	100,00

Table 5: Pregnant women Hg intake from country food by season (in µg/day or % of the total) (n=93)

Winter			Spring			Summer			Fall		
	µg/day	%		µg/day	%		µg/day	%		µg/day	%
Beluga (Meat+Nikku)	2,45	28,86	Beluga (Meat+Nikku)	2,77	33,78	Beluga (Meat+Nikku)	8,77	46,05	Beluga (Meat+Nikku)	3,27	38,47
Beluga Nikku	1,48	17,38	Beluga Nikku	1,70	20,79	Beluga Nikku	6,29	33,00	Beluga Nikku	2,67	31,44
Caribou Nikku	1,22	14,38	Beluga Mattaq	1,24	15,17	Beluga Mattaq	3,61	18,96	Beluga Mattaq	1,22	14,31
Beluga Meat	0,97	11,47	Beluga Meat	1,07	13,09	Beluga Meat	2,48	13,04	Seal Meat	0,75	8,83
Caribou Meat	0,97	11,40	Lake Trout	0,90	10,95	Seal Meat	1,25	6,54	Caribou Nikku	0,71	8,33
Beluga Mattaq	0,87	10,25	Caribou Nikku	0,68	8,35	Caribou Nikku	1,00	5,25	Caribou Meat	0,68	7,94
Lake Trout	0,86	10,13	Caribou Meat	0,64	7,86	Lake Trout	0,93	4,86	Beluga Meat	0,60	7,11
Arctic Char	0,61	7,14	Seal Meat	0,57	6,99	Caribou Meat	0,78	4,11	Lake Trout	0,59	6,91
Seal Meat	0,59	6,90	Arctic Char	0,53	6,50	Seal Liver	0,78	4,11	Arctic Char	0,45	5,35
Seal Liver	0,24	2,88	Pitsik	0,29	3,51	Char	0,61	3,71	Seal Liver	0,32	3,74
Whitefish	0,18	2,10	Seal Liver	0,19	2,31	Pitsik	0,57	2,98	Pitsik	0,17	1,97
Fish Pitsik	0,17	2,03	BrookTrout	0,13	1,53	Mollusks	0,17	0,89	BrookTrout	0,14	1,59
BrookTrout	0,16	1,83	Ptarmigan	0,08	0,93	Game Bird Eggs	0,16	0,83	Mollusks	0,08	0,92
Ptarmigan	0,13	1,52	Whitefish	0,06	0,77	Whitefish	0,14	0,72	Ptarmigan	0,05	0,61
Walrus	0,02	0,26	Mollusks	0,05	0,58	BrookTrout	0,13	0,68	Whitefish	0,03	0,40
Mollusks	0,02	0,18	Game Bird Eggs	0,04	0,46	Sculpin	0,09	0,47	Sculpin	0,03	0,36
Sculpin	0,01	0,15	Sculpin	0,01	0,15	Ptarmigan	0,03	0,16	Walrus	0,01	0,10
Game Bird Eggs	0,00	0,00	Walrus	0,00	0,05	Pike	0,02	0,11	Game Bird Eggs	0,01	0,10
Pike	0,00	0,00	Pike	0,00	0,00	Walrus	0,01	0,07	Pike	0,00	0,00
Total Hg intake	8,49	100,00	Total Hg intake	8,20	100,00	Total Hg intake	19,04	100,00	Total Hg intake	8,50	100,00

Results for Part B (Year 2)

Awareness of health messages

As shown in Table 6 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.

Table 6: 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?

Discussion and Conclusions

Although pregnant women Hg exposure is still decreasing in Nunavik, 23% of them presented blood Hg levels above 8 µg·L^{-1}, the Health Canada blood guidance value for pregnant women (Legrand et al. 2010; Lemire et al. 2017). In comparison, in the southern Canadian population, the vast majority (98%) 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). It is important to remember that pregnant women for the present study were recruited in Oct 2016 to March 2017, and based on their monthly hair Hg results showing more elevated Hg exposure in the summer months, the percentage of Nunavik pregnant women with elevated levels of Hg in 2016-2017 is likely underestimated on a year-based perspective (Lemire et al. 2017). Further biomonitoring study in the region should focus on recruiting participants for assessing Hg exposure in late summer and early fall, when most country food intake takes place. Our present results also confirm that beluga meat and nikku are the main source of MeHg exposure for pregnant women across seasons but primarily in the summer, when most beluga products are available. Conversely, lake trout consumption and contribution to MeHg intake was negligible. These results are in accordance with MeHg intake estimations based on the Qanuippitaa study involving Nunavik childbearing-age women and conducted in 2004 (Lemire et al. 2015).

The present study shows that Nunavik pregnant women to Legacy and New POPs included in the Stockholm Convention continued to decrease in 2016-2017 since they were first measured in 1992 or 2004. PFOS exposure in Nunavik pregnant women was in the same range, and PFOA and PFHxS were more than twice lower than levels reported for women aged 20 to 39 years old in the Canadian Health Measures Survey (CHMS) Cycle 2 (2009-2011). Conversely, more recent perfluorinated compounds (PFNA, PFDA and PFuDA) exposure levels are increasing since they were first measured in 2012. Moreover, their exposure levels were significantly higher in Nunavik than in CHMS for the same gender and age group, particularly for PFNA, which were more than three times higher than in southern Canadian cities (GM [95%CI]: 2.4 µg/L [2.2 - 2.7 µg/L] versus 0.73 µg/L [0.64 – 0.83 µg/L] respectively).

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), awareness of health messages, and further analyzing associations between country food consumption and other contaminants exposure (PFAS, Pb and others) and nutrient status (iron status, selenoneine, omega-3 fatty acids) will be conducted over the coming months.

Expected Project Completion Date

All laboratory analysis are now completed and in depth statistical analyses are on-going. These will continue over the next year, and we are in discussion with the Nunavik Regional Board of Health and Social Services to plan the next phase of pregnant women biomonitoring, and evaluating the possibility of implementing a systematic biomonitoring of all pregnant women across Nunavik early in their pregnancy. Field implementation of round 2 interviews with pregnant women, women recently pregnant and health care providers is planned to begin in fall/ winter 2018.

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 Hawai'i 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.

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!

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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 et au mercure

- **Project Leader/Chef de projet**
  Frank Wania, University of Toronto Scarborough, Department of Physical and Environmental Sciences, 1265 Military Trail, Toronto ON, M1C 1A4. Tel: (416)-287-7225; E-mail: frank.wania@utoronto.ca
- **Project Team/Équipe de projet**
  James Armitage, University of Toronto Scarborough, Toronto, ON

- **Project Location/Emplacement(s) du projet**
  - Toronto, Ontario
  - Yellowknife, Northwest Territories

Abstract

Our main activity for the 2017-2018 project year was to raise awareness and highlight the potential uses of the dietary mercury (MeHg) exposure assessment tool (MEAT v2.0) we developed with support of the Northern Contaminants Program (NCP). The tool can be used to predict the concentrations of mercury in blood and hair in humans based on the estimated dietary exposure of the individual. The MEAT v2.0 model can also estimate nutrient intakes (e.g., fatty acids, vitamins, minerals) if that information is available.

Résumé

Notre principale activité en 2017-2018 a consisté à faire connaître les utilisations possibles de l'outil d'évaluation de l'exposition au mercure (MeHg) dans l'alimentation (MEAT v2.0) que nous avons conçu avec le soutien du Programme de lutte contre les contaminants dans le Nord (PLCN). Cet outil peut servir à prédire les concentrations de mercure dans le sang et les cheveux des humains en s'appuyant sur l'estimation de l'exposition alimentaire de la personne. Le modèle MEAT v2.0 peut également servir à estimer l'apport en nutriments (p. ex. acides gras, vitamines, minéraux) si cette information est disponible.

To raise awareness and highlight the potential uses of the tool, we attended the NCP Results Workshop in Yellowknife, NWT (Sept 26-28, 2017). The tool was presented as part of the NCP Researcher EXPO and during a special meeting held with researchers and representatives of the Regional Contaminants Committees and Northern Health Authorities.

Key Messages

- Biomonitoring data required for assessing human exposure to organic chemicals such as methylmercury are not always available.
- Exposure models are necessary and useful; they can help answer the fundamental question, "Do I need to be worried about mercury in the food I am eating?"
- The MEAT v2.0 model is freely available to NCP officials, the NCP Regional Committees and representatives of Northern Health Authorities.

Pour mieux faire connaître les utilisations possibles de cet outil, nous avons assisté à l'atelier sur les résultats du PLCN à Yellowknife, dans les Territoires du Nord-Ouest (du 26 au 28 septembre 2017). L'outil a été présenté dans le cadre de l'exposition des chercheurs du PLCN et pendant une réunion spéciale tenue avec les chercheurs et les représentants des comités régionaux des contaminants et des autorités sanitaires du Nord.

Messages clés

- Nous ne disposons pas toujours des données de biosurveillance nécessaires pour évaluer l'exposition humaine à des produits chimiques organiques comme le méthylmercure.
- Il faut disposer de modèles d'exposition, qui peuvent répondre à cette question fondamentale : « Dois-je m'inquiéter du mercure contenu dans ma nourriture? »
- Le personnel du PLCN, les comités régionaux du PLCN et les représentants des autorités sanitaires du Nord peuvent utiliser le modèle MEAT v2.0 gratuitement.

Objectives

To raise awareness and highlight the potential uses of the dietary mercury (MeHg) exposure assessment tool (MEAT v2.0) we developed with support of the Northern Contaminants Program (NCP).

Introduction

We developed the dietary mercury (MeHg) exposure assessment tool (MEAT v2.0) with the support of the Northern Contaminants Program (NCP) in the 2016-2017 project year. A conceptual representation of the MEAT v2.0 exposure assessment model is shown below (Figure 1).

The benefits and potential uses of the MEAT v2.0 model are as follows:

- Provide additional insights and information on dietary advisories and consumption guidelines.
- Identify consumptions scenarios more (or less) likely to result in exposures to methylmercury leading to concern (*Rapid Screening*).
- Investigate food substitution regimes for the impact on exposure to methylmercury and nutrient intakes.
- Provide an organizational framework for identifying key data gaps with respect to monitoring campaigns in Northern communities.

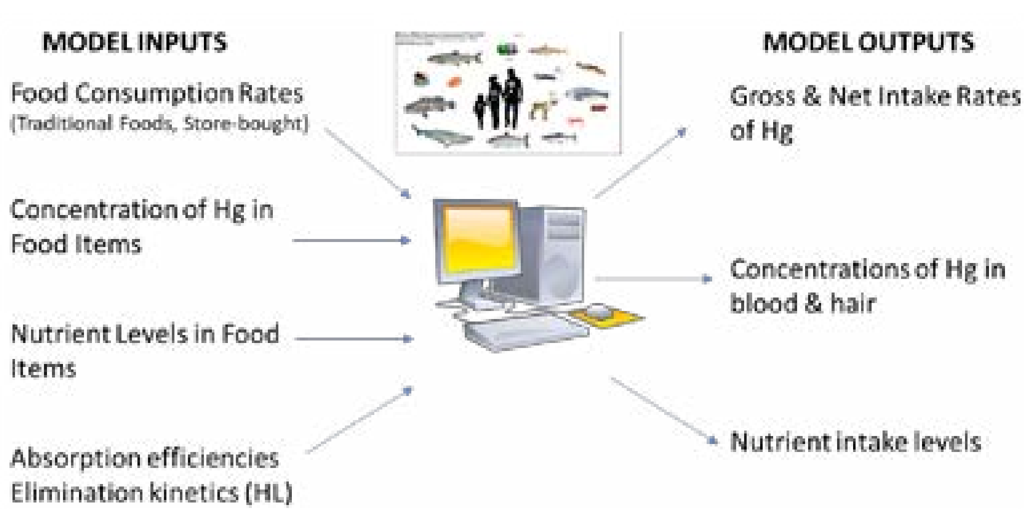
In response to the assessment of our 2017-2018 NCP project proposal, our main activity for this 2017-2018 project year was to raise awareness and highlight the potential uses of the dietary mercury (MeHg) exposure assessment tool (MEAT v2.0).

Activities in 2017-2018

Community Engagement

We attended the NCP Results Workshop in Yellowknife, NWT (Sept 26-28, 2017) and presented the MEAT v2.0 tool as part of the NCP Researcher EXPO, a public event held on the first day of the workshop.

Figure 1. A conceptual representation of the MEAT v2.0 exposure assessment model



Capacity Building and Training

MEAT v2.0 is a user-friendly tool that links dietary exposures of methylmercury to human body burdens and therefore potential risks; by definition, the tool has the potential to improve an organization's ability to engage in contaminants issues.

Communications and Outreach

We attended the NCP Results Workshop in Yellowknife, NWT (Sept 26-28, 2017) and presented the MEAT v2.0 tool to representatives of NCP Regional Committees and Northern Health Authorities during a special meeting.

Indigenous Knowledge

The MEAT v2.0 tool is completely flexible with respect to the dietary exposure scenarios that can be considered; it is therefore able to use Indigenous Knowledge and/or local knowledge about food preferences and seasonal food availabilities to come up with realistic scenarios.

Results and Outputs/Deliverables

We attended the NCP Results Workshop in Yellowknife, NWT (Sept 26-28, 2017). The MEAT v2.0 tool was presented as part of the NCP Researcher EXPO and during a special meeting held with researchers and representatives of the Regional Committees and Northern Health Authorities. Attendees of the special meeting expressed a general interest in the assessment tool and recognized its potential use for assessing human exposure to methylmercury through the diet. We also received some valuable suggestions on options to make the tool more user-friendly and targeted for key exposure and risk assessment scenarios (e.g., women of child-bearing age).

The MEAT v2.0 tool is freely-available to NCP officials and representatives of the NCP Regional Committees and Northern Health Authorities as an MS Excel/VBA application

Discussion and Conclusions

We hope that our efforts to talk about and distribute the MEAT v2.0 model have demonstrated the potential benefits and uses of this tool. We are open to further discussions with NCP officials, NCP Regional Contaminants Committees and representatives of Northern Health Authorities to find specific uses (e.g., worrisome exposure scenarios) for this valuable tool.

Expected Project Completion Date

April 2018

Project website (if applicable)

N/A

Acknowledgments

We acknowledge the Northern Contaminants Program (NCP) and the Regional Contaminants Committees for supporting the development of the Mercury Exposure Assessment Tool.

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 prélevés dans la nature

Project Leader/Chef de projet

Brian Laird, School of Public Health and Health Systems, University of Waterloo, 200 University Ave W, Waterloo, ON N2L 3G1. Tel: 519-888-4567 x 32720; Fax: 519-746-6776; Email: brian.laird@uwaterloo.ca

Project Team/Équipe de projet

Mylène Ratelle, University of Waterloo, Waterloo, ON; Kelly Skinner, University of Waterloo, Waterloo, ON; Rhona Hanning, University of Waterloo, Waterloo, ON; Shannon Majowicz, University of Waterloo, Waterloo, ON; Heidi Swanson, University of Waterloo, Waterloo, ON; Chris Furgal, Trent University, Peterborough, ON; Amanda Boyd, Washington State University, Pullman, WA; Michèle Bouchard, University of Montreal, Montreal, QC; Ken Stark, University of Waterloo, Waterloo, ON; Deborah Simmons, Sahtú Renewable Resources Board, Tulita, NT; George Low, Dehcho Aboriginal Aquatic Resources and Ocean Management (AAROM), Dehcho First Nations, Hay River, NT

Project Location/Emplacement(s) du projet

Year 1/1re année

- Jean Marie River First Nation, NT

Year 2/2e année

- Kakisa (Ka'a'gee Tu), NT
- Fort Providence (Deh Gah Gotie), NT
- West Point First Nation, NT
- Hay River Reserve (K'atl'odeeche), NT
- Deline, NT

Year 3/3e année

- Trout Lake (Samba K'e), NT
- Fort Good Hope (K'asho Got'ine), NT
- Tulita (Tulít'a), NT

Abstract

This study aims to evaluate people's exposure to a variety of contaminants, including metals and persistent organic pollutants, in Dene/Métis communities of the Dehcho and Sahtú regions of the Northwest Territories. In the third sampling year of the project, we collected samples and data in three participating communities and returned results from prior sampling years in six additional communities. Our research team traveled to Jean Marie River First Nation, Fort Providence (Deh Gah Gotie), West Point First Nation, Hay River Reserve (K'atl'odeeche), Deline and Kakisa (Ka'a'gee Tu), NT to discuss results with local leadership as well as return results to participants through public meetings and one-to-one sessions. Building upon prior consultations in 2015-2017, our research team traveled to Tulita (Tulít'a), Trout Lake (Samba K'e) and Fort Good Hope (K'asho Got'ine), NT for data and sample collection. With the assistance of local research coordinators and nurses, we collected blood, urine, and/or hair samples from 202 individuals across the three participating communities (Tulit'a, Samba K'e, and K'asho Got'ine) in 2017-2018. Over the three-year project, 537 participants (between ages of 6 and >80 years) from nine Dehcho and Sahtú communities took part in this research. Participants also completed a health messages survey and two dietary surveys (24-hr Recall, Food Frequency Questionnaire). Data analysis of the Year 3 results (metals in blood/urine; POPs in blood; mercury in hair; dietary surveys) is currently underway. In collaboration with regional, territorial, and federal partners, results will be returned to Year 3 participating communities in Fall 2018.

Résumé

Dans le cadre de cette étude, nous évaluons l'exposition humaine à différents contaminants comme des métaux et des polluants organiques persistants, dans les collectivités dénées et métisses des régions du Dehcho et du Sahtú des Territoires du Nord-Ouest. Au cours de la troisième année de prélèvement d'échantillons du projet, nous avons prélevé des échantillons et recueilli des données dans trois collectivités participantes et avons communiqué les résultats des années d'échantillonnage précédentes dans six autres collectivités. Notre équipe de recherche s'est rendue dans la Première Nation de Jean Marie River, à Fort Providence (Deh Gah Gotie), dans la Première Nation de West Point, dans la Réserve de Hay River (K'atl'odeeche), à Deline et à Kakisa (Ka'a'gee Tu), dans les T.N.-O. pour discuter des résultats avec les chefs locaux et communiquer les résultats aux participants dans le cadre d'assemblées publiques et de rencontres individuelles. Pour faire suite aux consultations menées de 2015 à 2017, notre équipe de recherche s'est rendue à Tulita (Tulít'a), au lac Trout (Samba K'e) et à Fort Good Hope (K'asho Got'ine), dans les Territoires du Nord-Ouest, pour recueillir des données et prélever des échantillons. 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 202 personnes dans les trois collectivités participantes (Tulit'a, Samba K'e et K'asho Got'ine) en 2017 et en 2018. Au cours de ce projet de trois ans, 537 participants (âgés de 6 ans à plus de 80 ans) de neuf collectivités du Dehcho et du Sahtú ont participé à cette recherche. Ces derniers ont aussi rempli un questionnaire sur les messages en matière de santé et deux sondages sur leur alimentation (relevé de 24 h et fréquence de consommation). L'analyse des données recueillies lors de la troisième année (métaux dans le sang et dans l'urine, polluants organiques persistants dans le sang, mercure dans les cheveux, questionnaires sur l'alimentation) est en cours. En collaboration avec les partenaires régionaux, territoriaux et fédéraux, les résultats seront communiqués aux collectivités ayant participé à la troisième année du projet à l'automne 2018.

Key Messages

- Year 2 results were returned to participating individuals and communities in between November 2017 and February 2018.
- For the vast majority of participants (Year 1-2), metal exposures for mercury, cadmium and lead fell below available health-based guidance values.
- Additional consultation with leaders and community members were held in Tulít'a, and K'asho Got'ine to discuss their participation in the biomonitoring project.
- Between November 2017 and March 2018, 202 participants from three NWT communities (i.e., Samba K'e, Tulít'a, and K'asho Got'ine) provided hair, blood, and/or urine samples for biomarker analyses.
- Year 3 samples are currently being analyzed for mercury (hair), metals and metalloids (blood, urine), and POPs (blood).
- Year 3 results will be returned to participating individuals and communities in fall 2018.

Messages clés

- Les résultats obtenus durant la deuxième année ont été communiqués aux personnes et aux collectivités qui ont participé au projet de novembre 2017 à février 2018.
- Pour la grande majorité des participants (première et deuxième années), l'exposition au mercure, au cadmium et au plomb était inférieure aux valeurs admissibles en fonction de critères sanitaires.
- D'autres consultations avec des dirigeants et des membres de la collectivité ont été tenues à Tulít'a et à K'asho Got'ine afin de discuter de leur participation au projet de biosurveillance.
- De novembre 2017 à mars 2018, 202 participants de trois collectivités des Territoires du Nord-Ouest (Samba K'e, Tulít'a et K'asho Got'ine) ont fourni des échantillons de cheveux, de sang ou d'urine à des fins d'analyse des biomarqueurs.
- Les échantillons recueillis au cours de la troisième 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 troisième année du projet à l'automne 2018.

Objectives

The short term objectives for this research project were to:

- evaluate traditional food usage patterns, contaminant exposure profiles, and nutritional biomarkers in participating communities of the Dehcho Region and the Sahtú Region;
- report results to Year 2 participating communities of the Dehcho Region and the Sahtú Region;
- complete the sampling of the communities wanting to take part in the project, consulted previously;
- continue developing the results dissemination strategy with the Scientific Advisory; and,
- work with the Health and Social Service Authorities and participating communities to develop and implement a re-testing strategy and develop/create a follow up process for participants having elevated levels of contaminants.

The long term objectives of this research project are to:

- return results to all individuals and communities who take part in the project;
- characterize the levels and determinants of contaminant exposure among project participants in the Dehcho and Sahtú regions of the Northwest Territories;
- evaluate the impact of public health messages on risk perceptions and awareness of contaminant issues in participating communities; and,
- create a public health screening tool that can be used to characterize those most at risk of facing elevated contaminant exposures 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 traditional food reliance in ways that maximize nutrient status while limiting contaminant exposure in the Northwest Territories. Also, this work is complementing ongoing, co-located environmental contaminant monitoring research underway in the Northwest Territories.

Introduction

Traditional food consumption is integral to the health, wellness, and food security of the Aboriginal communities within the Dehcho and Sahtú Regions of the Northwest Territories (NWT) (Berti et al. 1998; Kuhnlein et al. 2004; Kuhnlein et al. 2007; Nakano et al. 2005). Further, the consumption of such traditional 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 2016). Additionally, elevated Cd levels have been recorded in the organs (e.g. kidneys, livers) of moose from some parts of the Dehcho region (DHSS 2017). 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 (Ratelle et al., 2018). This work incorporates a risk-benefit approach to promote the use of traditional foods in order to improve nutrition and food security while lessening contaminant exposure among Dehcho and Sahtú First Nations communities.

Activities in 2017-2018

NCP funding in 2017-2018 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: Research Partnerships

The Dehcho Health and Social Services Authority (DHSSA) and Sahtú Health and Social Services Authority (SHSSA) have supported our biomonitoring project, making nurses available for blood sample collection whenever possible. In 2015-2018, we built on this agreement through consultations with both the DHSSA and SHSSA in order to clarify responsibilities regarding each organization's role, the supply of materials, sample shipment and handling, nurse training for the project, as well as the return of results to individuals. Following these consultations, we communicated with and provided training materials for clinic staff so that nurses, nurse practitioners, and other health professionals in the region were adequately informed of the biomonitoring project. This process includes both the regular sampling and the re-testing of a few participants.

Component 2: Biomonitoring Implementation

Participant Recruitment and Informed Consent. With NCP support, we provided funds to the band office of each community for the hiring a Local Research Coordinator to assist with participant recruitment 3 weeks in advance of the sample collection. As previously described (Ratelle et al., 2018), in relatively small communities (i.e. ~100 persons or less), given the limited number of potential participants, we have invited all community members to participate in the study. In larger communities, we randomly sampled households and then invited all members of each selected household to participate. In both small and large communities, all members aged 6 years and older are eligible to participate regardless of sex, family or parity status, or other characteristics. Before participating in the project, with the support of a local research coordinator, each participant was required to read an information letter before signing an informed consent form. Importantly, each participant was provided the choice to only take part in the project components in which they were interested. This consent process followed an opt-in framework.

Year 3 sampling was completed in Trout Lake (Samba K'e, November 2017), Tulita (Tulít'a, December 2017), and Fort Good Hope (K'asho Got'ine, March 2018). For this component, six members of the research team, including Brian Laird (Principal Investigator), Mylene Ratelle (Post-doctoral fellow), Matthew Laird (Research Assistant), Sharon Mackintosh (nurse), Sara Packull-McCormick (M.Sc. Candidate), and Danielle Brandow (M.Sc. Candidate) traveled to participating communities to direct the sample and data collection alongside the Local Research Coordinator(s). The team spent between 4 and 8 days to implement the sampling in each participating community. The samples were then sent to collaborating laboratories in Ontario and Quebec for the measurement of metals, POPs, and fatty acids. Additionally, we received supplemental funding from Health Canada to measure other contaminant markers (PAHs, cotinine) from previously collected samples.

Community Engagement

Before Year 1-2 findings were published, results were returned to each participating community and individual. Each study participant that provided a hair, urine, and/or blood sample were hand-delivered a confidential, plain-language letter detailing their contaminant exposure levels by a member of the project team. In parallel with the individual reporting, we hosted public forums in each participating community. These community-level reports only included aggregate data and cannot be used to identify the results of any one individual. The development of messages, materials and presentation approaches be used took into consideration the results of analyses of the contaminants and health awareness, understanding and risk perception questions administered to all participants.

Individuals with exposure levels that exceeded biomonitoring guidelines were offered follow-up on ways to lower exposures and were given the opportunity to do a re-testing to determine whether their level remained elevated or decreased over time. This re-testing was designed in collaboration with the HSSA-Dehcho, and HSSA-Sahtú. Terminology workshops were also held in 2017-2018 in collaboration with the Sahtú Renewable Resources Board to better assess the reception of the results from communities' members and elders. Furthermore, questions developed in collaboration with the Sahtú Renewable Resources Board and discussed during a focus group were integrated into individual interviews with 12 participants from Deline to better understand their relation and perception with and of contaminants and traditional foods.

Capacity Building

NCP funds were used to hire 1 or 2 local research coordinators in participating communities. These coordinators assist with the implementation of the project by overseeing participant recruitment, assisting participants with completing the surveys and supporting the return of the results. These research coordinators' were invaluable to all of the project's components.

Communications and Outreach

We provided our contacts within the Northwest Territories Health and Social Services Authority (NTHSSA), Dehcho AAROM, Sahtú Renewable Resources Board (SRRB), Dehcho Health and Social Services Authority (DHSSA), and other organizations with monthly phone/email updates of the research progress. Additionally, we participated in the monthly Sahtú Environmental Research and Monitoring Forum, providing additional opportunities to liaise with other researchers, local organizations and community leaders. Further, we created and distributed factsheets describing human biomonitoring for exposure assessment and particular contaminants of concern. These factsheets were designed to support Northern medical practitioners who receive questions from patients who heard and/or participated in the project. Plain language brochures detailing the biomonitoring approach used in the project were distributed widely. Dr. Laird also completed an interview with CBC News describing the project and available results to date (CBC News, 2018). Finally, the research team distributed a quarterly newsletter to community partners, local coordinators, researchers working in the same regions and government representatives.

Indigenous Knowledge Integration

The project has relied on local and Indigenous knowledge communicated through the community consultations completed in 2014-2018 to guide the project's return of results and knowledge translation. Local perspectives provided presented by residents of the Dehcho and Sahtú Regions during consultations have helped ensure that the mission and design of this research addresses priorities and concerns of participating communities. Previously, the project incorporated the knowledge of local experts in the development of the dietary surveys. This local knowledge has been crucial in ensuring that the dietary survey uses the names for foods that are recognized by members of the participating communities. Finally, terminology workshops were held to translate express key terms from the project into Sahtúot'įnę Yatį́

(North Slavey) with help from local Elders. In these workshops, Elders shared their knowledge with us to refine the communication plan for the project. The terminology workshops helped to build important understanding and common language for relevant terms such as "contaminant" and "risk" and facilitate more meaningful language use and communication. Building off a terminology workshop held in February 2017 (Deline), follow-up workshops were held in December 2017 (Tulita), and February 2018 (Deline). This approach ensured these issues were discussed for both of the dialects spoken across the Sahtú Region.

Results

Participation rates in communities have ranged between 12 and 37%. Between January 2016 and March 2018, a total of 443 hair samples, 276 blood samples, and 198 spot urine samples were collected. The CRAs established with each participating communities preclude the research team from publishing: 1) community-specific biomonitoring results and 2) any results that have not yet been returned to participating communities. As such, no biomarker results from Year 3 can be included within this synopsis report. Instead, the results described herein include those from the six communities that took part from 2016-2017.

Among participants in Year 1 and 2, moose meat was consumed by the largest number of participants (91%) followed by lake whitefish (88%). Canada goose meat (53%) was the most commonly eaten game bird. Of the most commonly consumed traditional foods from land mammals, 10 of 14 were harvested from moose. Rabbit (54%), lake trout (57%), wild raspberries (50%), were reported also frequently consumed by respondents. Additionally, results from the 24-hr recall showed that, on the day prior to sample/data collection (November to February), 5.7% of Calories were from wild-harvested traditional foods and 31% of participants reported consuming traditional food in the previous 24 hours. The average number of Calories consumed in the previous 24 hours by project participants was 1906 kcal.

From the biological samples within Years 1-2, 144 blood, 127 urine, and 279 hair samples were collected. Several metals, including some toxic metals (e.g. cadmium, lead) and some metal nutrients (e.g. zinc, selenium), persistent organic pollutants, and fatty acids were quantified in urine, whole blood, and/or blood plasma. Levels of POPs and their metabolites were measured in the blood plasma of participants. These analyses included: Arochlor 1260, PCB Congeners (PCB138, PCB146, PCB153, PCB156, PCB163, PCB170, PCB180, PCB187, PCB194, PCB201, PCB203, AND PCB206), PBDEs biomarkers (#15, #17, #25, #28, #33, #47, #99, #100, and #153), and biomarkers for chlordane (cis-nonachlor, trans-nonachlor, gamma-chlordane, alpha-chlordane, and oxy-chlordane), hexachlorocyclohexane (gamma-HCH and beta-HCH), DDT (DDE and DDT), Toxaphene (Parlar no. 26 and 50), Hexachlorobenzene, and Mirex. Furthermore, mercury was measured in hair samples. For the vast majority of participants, mercury, cadmium, and lead exposures fell below the health-based guidance values available for these metals. Generally, these biomarkers appeared within the range of those seen in other Canadian biomonitoring studies, such as the Canadian Health Measures Survey (CHMS) and First Nations Biomonitoring Initiative (FNBI). Levels of some metal nutrients (e.g., manganese, selenium) in urine appeared higher than observed in nationally-representative biomonitoring studies (Table 1). Further, when results were pooled across communities and regions, the 95th percentile for particular biomarkers (e.g., blood lead, blood mercury, urine uranium) appeared higher than those seen in the CHMS. Future work will focus on whether differences are present after accounting for demographic variables (e.g., age, sex).

Table 1. Geometric mean (GM) and 95th Percentile (P95) of metals quantified in whole blood (µg/L) and urine (µg/L) in Year 1 and 2 Samples.

BLOOD	Mackenzie Valley project				CHMS[1]			
	Blood		Urine		Blood		Urine	
	GM	P95	GM	P95	GM	P95	GM	P95
Aluminium	NR	36	13	39		NA		NA
Arsenic	NR	0.59	5.2	32		4.1[d]	9.2	77
Barium	NR	1.5	1.4	8.3		NA		NA
Beryllium	0.021	0.30	0.011	0.11		NA		NA
Cadmium	0.58	3.4	0.32	1.3	0.31	2.6	0.40	1.9
Cesium	NR	3.7	4.2	7.1		NA	4.9	NA
Chromium*	NR	1.6	0.83	5.5		NA		NA
Cobalt*	NR	0.30	0.34	1.4	0.23	0.40	0.23	0.97
Copper*	970	1300	8.9	29	900	1200	11	28
Gallium	NR	0.0068	0.080	0.40		NA		NA
Iron	NA	NA	11	36	NA	NA		NA
Lead	12	48	0.6	3.2	13	32	0.52	1.9
Lithium	NR	3.3	18	57		NA		NA
Manganese*	10	18	0.26	0.76	9.8	15		0.36
Mercury	0.17	7.4	0.45	1.8	0.72	5.6		NA
Nickel*	NR	0.46	1.3	4.6	0.48	1.1	1.3	4.8
Rubidium	1900	2600	1500	2800		NA		NA
Selenium*	180	230	55	180	190	240	51	130
Strontium	18	30	98	390		NA		NA
Thallium	NA	NA	0.10	0.33		NA	0.23	0.62
Uranium	NR	0.0030	0.0049	0.022		<LOD		0.020
Vanadium	NA	NA	0.18	0.6		NA		0.13
Zinc*	5500	7300	340	1200	6000	7300	320	1200

[1] CHMS cycle 2.
NR. Results not reported for metals with detection rate under 30%.
ND. Not detected. Below the limit of detection of the method.
NA. Not available. These metals were not measured in this type of sample.|
*Essential element

In co-located environmental monitoring research, fish composition analysis (e.g. total mercury (HgT) and omega-3 polyunsaturated fatty acids or N-3 PUFA, including EPA+DHA) 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 8.6-fold higher than observed in benthivorous and planktivorous fish species (Laird et al., 2018). Additionally, there were substantial differences in the fatty acid profiles among fish species (Table 2). However, these mercury and EPA+DHA results also differed among lakes. For example, total PUFAs in lake trout from Trout Lake were 3.9-fold higher than from fish harvested in Mustard Lake (Laird et al., 2018). In contrast, mercury content of northern pike and walleye from Mustard Lake were significantly lower than those from Sanguez and McGill Lake.

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 ($\rho = -0.951$, $p<0.001$) and Mustard Lake ($\rho = -0.513$, $p<0.05$). Also, when pooled across lakes, particularly strong correlations were observed between HgT and EPA+DHA content for burbot, northern pike, and walleye. No clear, systematic patterns in the correlation between EPA+DHA and Hg have been reported in the literature. To date, the precise mechanisms (whether they be biological, ecological, or geographic), that drive these relationships remain unclear. In partnership with Dr. Heidi Swanson (University of Waterloo) and George Low (Dehcho AAROM), a detailed investigation of these mechanisms is currently underway.

Results from a Crystal Ball (Oracle™) model (based upon fish Hg data as well as the dietary survey results from the biomonitoring study) was compared against Health Canada's pTWI for methylmercury of 3.29 µg/kg/week. This work also incorporated the EPA+DHA data (Table 2) and the correlations between mercury and N-3 PUFA content. These analyses suggested that, among the fish species incorporated into the model, Northern Pike and Walleye were the two primary contributors to weekly intake of MeHg. In contrast, lake whitefish and lake trout were the two main contributors to N-3 PUFA intake (Laird 2018).

Table 2. Total mercury and EPA+DHA concentrations in wild-harvested freshwater fish caught in the Dehcho Region, Northwest Territories, Canada (2013-2015).

Fish Species	Lake	n	EPA+DHA (mg/100g)	Total Mercury (µg/g)
			Mean ± SD	Mean ± SD
Burbot	Mustard	5	109 ± 13	0.112 ± 0.019
	Trout	9	86 ± 16	0.317 ± 0.101
	Total	14	94 ± 19	0.244 ± 0.130
Cisco	Ekali	5	192 ± 51	0.116 ± 0.061
	Gargan	1	316	0.080
	Kakisa	8	242 ± 64	0.043 ± 0.004
	Sanguez	1	215	0.127
	Trout	6	252 ± 60	0.038 ± 0.003
	Total	21	235 ± 61	0.064 ± 0.045
Lake Trout	Mustard	39	278 ± 91	0.187 ± 0.081
	Trout	12	898 ± 694	0.341 ± 0.155
	Total	51	424 ± 428	0.223 ± 0.121
Lake Whitefish	Ekali	11	279 ± 102	0.084 ± 0.025
	Gargan	16	278 ± 52	0.128 ± 0.059
	Kakisa	10	321 ± 89	0.044 ± 0.023
	McGill	9	240 ± 56	0.168 ± 0.077
	Sanguez	3	628 ± 395	0.129 ± 0.036
	Tathlina	9	268 ± 30	0.083 ± 0.027
	Trout	10	240 ± 49	0.037 ± 0.009
	Total	68	288 ± 122	0.095 ± 0.061

Fish Species	Lake	n	EPA+DHA (mg/100g)	Total Mercury (µg/g)
			Mean ± SD	Mean ± SD
Northern Pike	Ekali	17	176 ± 109	0.433 ± 0.286
	Gargan	15	175 ± 86	0.412 ± 0.319
	Kakisa	10	187 ± 23	0.295 ± 0.266
	McGill	8	174 ± 38	0.485 ± 0.422
	Mustard	5	217 ± 17	0.156 ± 0.071
	Sanguez	10	192 ± 182	1.343 ± 0.824
	Tathlina	10	145 ± 26	0.374 ± 0.313
	Trout	10	205 ± 40	0.153 ± 0.085
	Total	85	181 ± 88	0.469 ± 0.503
Walleye	Ekali	17	231 ± 182	0.278 ± 0.099
	Kakisa	8	169 ± 17	0.282 ± 0.198
	McGill	7	160 ± 30	0.877 ± 0.246
	Sanguez	7	206 ± 181	0.724 ± 0.355
	Tathlina	9	162 ± 31	0.623 ± 0.240
	Trout	11	196 ± 32	0.293 ± 0.310
	Total	59	194 ± 117	0.458 ± 0.323
Sucker[1]	Kakisa	14	245 ± 46	0.090 ± 0.040
	McGill	8	198 ± 47	0.210 ± 0.10
	Mustard	1	348	0.150
	Tathlina	6	373 ± 132	0.210 ± 0.060
	Trout	6	263 ± 69	0.100 ± 0.010
	Total	35	262 ± 89	0.140 ± 0.08

[1] Pooling results from Longnose Sucker and White Sucker.

Discussion and Conclusions

This 2017-2018 NCP research focused on the implementation of the biomonitoring project in 3 communities of the Dehcho and Sahtú Regions of the Northwest Territories, and the return of the results in 6 communities. Additionally, the research team is collaborating with those conducting environmental monitoring in these regions in order to better answer the question of how people get exposed to these contaminants. Through this co-located environmental monitoring work, we have provided updated contaminant and nutrient results for species and lakes identified by the regions' Indigenous fishers to be of significant priority. Further, to the knowledge of the authors, this work has provided the largest composite dataset of paired Hg and N-3 PUFA profiles in fish harvested from lakes of the Canadian subarctic. The observations from this research, as described above, underscore the importance of: i) incorporating lake-based differences into site-specific exposure and risk characterisation; and ii) the collection of lake trout from additional lakes in order to obtain a clearer picture of the most typical fatty acid profile(s) for this species. Altogether, this research is helping to guide risk communication strategies and promote the development of messages that aim to maximize traditional food use and minimize contaminant exposure in First Nations communities of the Northwest Territories.

The human biomonitoring results have showed contaminant exposures for participants to be largely within the usual ranges observed in such biomonitoring studies. Further, given that contaminant exposures fell below each of the available health-based guidance values, current traditional food consumption patterns appear to pose negligible health risks in terms of these contaminants. As such, even though particular traditional foods in these regions occasionally show elevated levels of contaminants such as mercury and cadmium, most peoples' exposures to these contaminants appears to have remained low. The analysis of Year 3 samples will be important to determining the generalizability of the results reported herein. Efforts in 2018-2019 will focus of completing the project through the return of results in the three communities that took part between November 2017 and March 2018. Furthermore, the biomonitoring research will provide the information needed to create a screening tool to help identify those who are at most risk of contaminant exposure. This screening tool, which has been labeled as a critical outcome by policy leaders with whom we have partnered, will enable contaminant risk messaging and follow-up interventions at the individual and population level to be targeted to those most at risk.

Expected Project Completion Date

March 31, 2019

Project Website

Facebook: BiomonitoringNT
Twitter: @NTBiomonitoring

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Community Based Monitoring and Research

Surveillance et recherche communautaires

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

Project Leader/Chef de projet

Dr. Heidi Swanson, Assistant Professor, Dept. of Biology, 200 University Ave. University of Waterloo, Waterloo, Ontario, Canada N2L 3G1.
Tel: (519) 888-4567 Ext. 37387; Fax: (519) 746-0614; Email: heidi.swanson@uwaterloo.ca

George Low, Dehcho First Nations, 13 Riverview Drive, Hay River, NT X0E 0R7.
Tel: 867 876 0441; Email: geobarbgeo@hotmail.com

Project Team/Équipe de projet

Priscilla Canadien Deh Gah Gotie FN; Chief Gladys Norwegian, Jean Marie River FN; Mike Low, Dehcho AAROM, Hay River, NT; Dr. Brian Branfireun, Western University, London, Ontario; Dr. Leanne Baker, University of Waterloo, Waterloo, Ontario

Project Location/Emplacement(s) du projet

- Ekali Lake, NT
- Big Island Lake, NT
- Sanugez Lake, NT
- Willow Lake, NT

Abstract

This project began in 2016, and aims to determine why mercury levels in fish vary between lakes and species in the Dehcho region, NT. In August 2017, fish, benthic invertebrate, zooplankton, sediment, and water samples were collected from Ekali Lake and Big Island Lake. The lakes were chosen to represent two different regions – the Horn Plateau (Willow, Big Island) and the Mackenzie Lowlands (Ekali, Sanguez). Laboratory analyses are ongoing. Results reveal that size-standardized mercury levels in northern pike and lake whitefish are higher in the two Mackenzie Lowland lakes

Résumé

Ce projet amorcé en 2016 tente de déterminer pour quelle raison la concentration de mercure dans le poisson varie entre les lacs et les espèces dans la région du Dehcho (T.N.-O.). En août 2017, des échantillons de poissons, d'invertébrés benthiques, de zooplancton, de sédiments et d'eau ont été prélevés dans les lacs Ekali et Big Island. Ces lacs ont été choisis parce qu'ils représentent deux régions différentes – le plateau Horn (Willow, Big Island) et les basses terres du Mackenzie (Ekali et Sanguez). De plus, les analyses en laboratoire sont en cours. Les résultats révèlent que les concentrations

than in the Horn Plateau lakes. Methylmercury (MeHg) in invertebrates varied among taxa, and was higher in the Mackenzie Lowlands lakes than in the Horn Plateau lakes. Levels of total and MeHg in water, and total mercury in sediment are also higher in the Mackenzie Lowlands lakes than in the Horn Plateau lakes, although MeHg in sediments did not follow this pattern. Characteristics of the land that surrounds the lakes differ substantially between the two geographic regions. Higher percent MeHg in water than sediment in the Mackenzie Lowlands lakes suggests a strong catchment source of MeHg, whereas only slightly higher %MeHg in water than sediments in the Horn Plateau lakes suggests importance of both in-lake and catchment supply of MeHg. 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 to anthropogenic stressors, such as climate change and resource development.

normalisées de mercure dans le grand brochet et le grand corégone sont plus élevées dans les deux lacs des basses terres du Mackenzie que dans les lacs du plateau Horn. La concentration de méthylmercure chez les invertébrés variait entre les taxons et était plus élevée dans les lacs des basses terres du Mackenzie que dans les lacs du plateau Horn. Les concentrations de mercure total et de méthylmercure dans l'eau et de mercure total dans les sédiments sont également plus élevées dans les lacs des basses terres du Mackenzie que dans les lacs du plateau Horn, bien que cette différence ne s'observe pas dans la concentration du méthylmercure dans les sédiments. Les caractéristiques des terres qui entourent les lacs sont considérablement différentes entre les deux régions géographiques. La concentration de méthylmercure plus élevée dans l'eau que dans les sédiments dans les lacs des basses terres du Mackenzie dénote une importante source de méthylmercure dans le bassin versant, tandis que la concentration de MeHg légèrement plus élevée dans l'eau que dans les sédiments dans les lacs du plateau Horn révèle l'importance des sources de MeHg dans le lac et dans le bassin versant. 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 liées aux facteurs de stress anthropiques chez les poissons, comme les changements climatiques et l'exploitation des ressources.

Key Messages

- In lake sediments, the Horn Plateau lakes (Willow and Big Island) has lower total mercury, but higher MeHg than the Lowland lakes (Ekali and Sanguez).
- Mercury concentrations in water are lower in the Horn Plateau lakes (Big Island and Willow) than the two lowland lakes (Sanguez and Ekali), both for total mercury and MeHg (dissolved and unfiltered).

Messages clés

- Dans les sédiments lacustres, les lacs du plateau Horn (Willow et Big Island) contenaient moins de mercure total, mais plus de méthylmercure que les lacs des basses terres (Ekali et Sanguez).
- Les concentrations de mercure dans l'eau sont 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).

- Northern pike and lake whitefish have significantly higher size-standardized concentrations of total mercury in the Mackenzie Lowlands lakes (Ekali, Sanguez) than in the Horn Plateau lakes (Big Island, Willow).
- MeHg concentrations in invertebrates are higher in the Mackenzie Lowlands lakes (Ekali, Sanguez) than in the Horn Plateau lakes (Big Island, Willow).
- Catchment characteristics differ between the Mackenzie lowlands lakes (Sanguez and Ekali) and the Horne Plateau lakes (Big Island and Willow).

- Les concentrations de mercure total normalisées en fonction de la taille sont considérablement plus élevées chez le grand brochet et le grand corégone dans les lacs des basses terres du Mackenzie (Ekali, Sanguez) que dans les lacs du plateau Horn (Big Island, Willow).
- Les concentrations de MeHg chez les invertébrés sont supérieures dans les lacs des basses terres du Mackenzie (Ekali et Sanguez) que dans les lacs du plateau Horn (Big Island et 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 et Willow).

Objectives

This project aims to:

Long Term

- to develop a mechanistic understanding of the factors that explains 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; and
- 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 fish such as northern pike 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 8 lakes (funded by CIMP, 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. These variables include 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; Mackenzie Valley Lowlands (near Jean Marie River) in the Dehcho region of the NT. Results will allow us to 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 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, % area of wetlands in catchment, quantity and quality of dissolved organic carbon)?

Activities in 2017-2018

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 2017. Fish, invertebrates, and sediment were sampled in Big Island Lake and Willow Lake.

Laboratory Activities

Benthic invertebrates from each of the study lakes have been sorted into functional feeding groups, and analyzed for methyl mercury levels. Fish were analyzed for total mercury concentration (Western University, Biotron Laboratory), and stable isotope ratios (University of Waterloo). 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 concentrations of total and methyl mercury (Western University, Biotron Laboratory).

Community Engagement

The Dehcho First Nations (DFN) is the umbrella organization for the various First Nations and Métis organizations in the Dehcho Territory and is the administrator of the AAROM program. DFN and AAROM work with the community leaderships and First Nation and Dene Band administrations on a regular basis. This project has been and will continue to be explained at community meetings, annual workshops (e.g., the Annual Dehcho AAROM Results workshop which has replaced the very successful Country Foods workshop). In 2017, Swanson and Low presented results of the project to leaders and harvesters from the three involved communities. The research team tailors the work to the issues and concerns of communities, and through existing relationships, and works on a first-hand basis with each community during the study.

Capacity Building

Project leaders and team worked closely with fish harvesters and community members from Deh Gah Gotie First Nation and Jean Marie River First Nation during sampling camps at Ekali and Big Island lakes. A community monitor was recruited from Deh Gah Gotie First Nation, who became comfortable with measuring, weighing, and dissecting fish for muscle tissues, otoliths, opercles (walleye) and cleithra (northern pike).

Communications

Interim results on this project, along with results of the previously-funded portion of the project, were presented at the NCP results meeting in September 2017. In addition, Low has met with leadership of all partner First Nations over the winter of 2018 to disseminate interim results in meetings.

Posters have been prepared and are currently under review by GNWT Health and Social Services (some information from the posters includes data from previously-funded CIMP project 00154). Once approved, they will be sent to all communities.

Indigenous 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 of harvest pressure have resulted in a 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 (mid-August), water temperature in Big Island Lake ranged from 17°C (surface) to 13°C (26 m), and waters were well-oxygenated to bottom (stratification was relatively weak). At the time of sampling (late August), water temperature in Ekali Lake ranged from 18°C (surface) to 17°C (9 m), and waters were well-oxygenated to bottom; no stratification was evident.

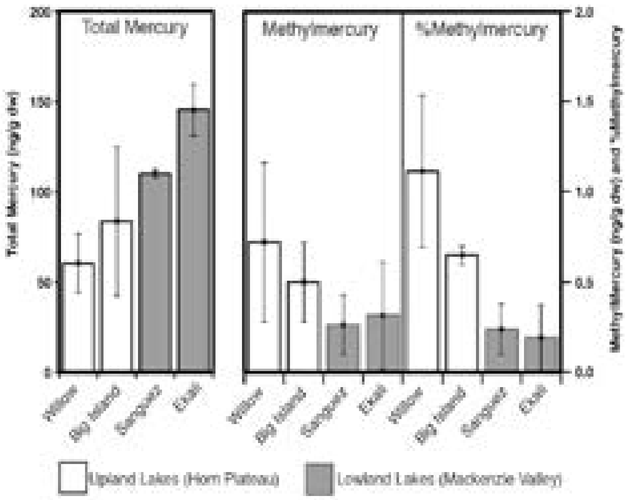
Invertebrates

Invertebrate community composition was more similar within lake pairs than between lake pairs. The concentration of total Hg and methyl Hg were significantly influenced by feeding strategy. Total Hg concentrations were highest in predatory invertebrates, followed by grazer-filterers in Dehcho lakes, and lowest in collector-gatherers. Concentrations of MeHg were also highest in predatory invertebrates. Primary consumer groups of benthic invertebrates contained on average 67-77% less MeHg than predatory invertebrates. Accounting for effects of functional feeding strategy and lake, concentrations of MeHg were higher in the lowland lakes (Ekali, Sanguez) than in the Horn Plateau lakes (Willow, Big Island).

Lake Sediment Total Mercury and Methylmercury (Figure 1)

Analysis of lake sediment mercury concentrations showed differences between the Horn Plateau lakes (Willow and Big Island), and the two lowland lakes (Ekali, Sanguez). Total Mercury in sediment was higher in the lowland lakes (Ekali, Sanguez), than in the Horn Plateau lakes (Willow, Big Island), but methylmercury was both higher in concentration, and as a percent of Total mercury, in the Horn Plateau lakes.

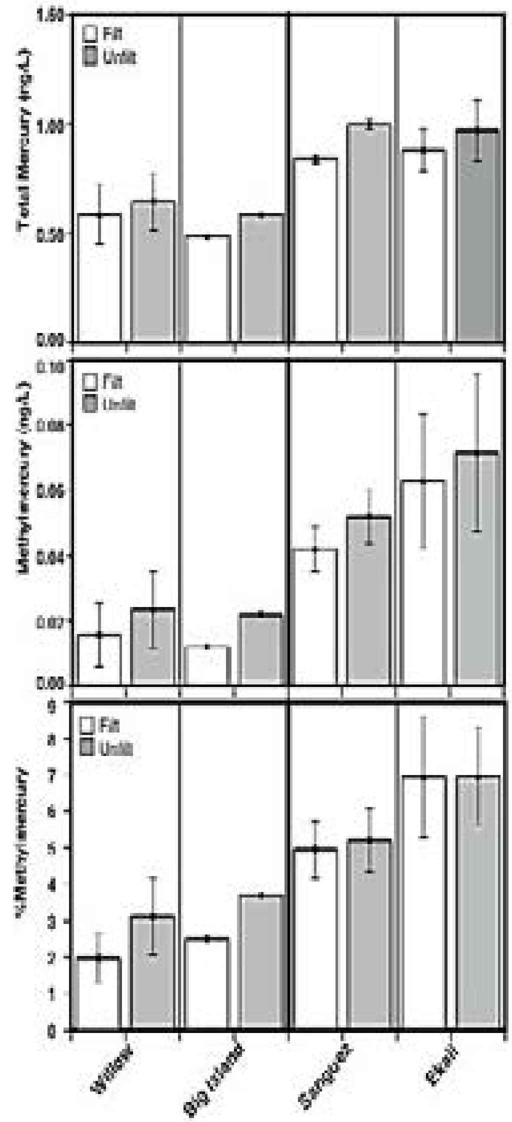
Figure 1. Mean Total mercury concentrations (left), Methylmercury concentrations (middle) and %Methylmercury (right) in sediments from Willow, Sanguez and Ekali Lakes. All data are expressed in dry weight concentration (ng/g). Error bars indicate standard error.



Lake Water Total Mercury and Methylmercury (Figure 2)

Unfiltered Total mercury in water was the same for the two lowland lakes (mean = 0.99 ng/L), while water from the two Horn Plateau lakes was lower (mean = 0.62 ng/L). 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. The percent Total mercury and percent Methylmercury in the dissolved form was similar for all lakes (85-90%). The percent Methylmercury was very different between the two geographic regions. Willow and Big Island lakes were lowest (~2.0% as filtered, and ~3% as unfiltered), while Sanguez and Ekali Lakes had percent Methylmercury 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 Willow and Big Island lakes included lake whitefish, northern pike, and lake trout. Food fishes captured in Sanguez and Ekali lakes included lake whitefish, northern pike, and walleye. All lake whitefish captured had mercury concentrations below the commercial sale guideline. All northern pike from Big Island Lake had mercury concentrations below the commercial sale guideline. In Sanguez Lake, northern pike exceeded the commercial sale guideline for mercury at a fork length of approximately 535 mm. In Willow Lake, northern pike exceeded the commercial sale guideline for mercury at a fork length of approximately 660 mm. In Ekali Lake, northern pike exceeded the commercial sale guideline for mercury at a fork length of approximately 600 mm. In Sanguez Lake, walleye exceeded the commercial guideline for mercury at a fork length of approximately 475 mm. In Big Island Lake, lake trout exceeded the commercial guideline for mercury at a fork length of approximately 635 mm. In Willow Lake, lake trout exceeded the commercial guideline for mercury at a fork length of approximately 615 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.

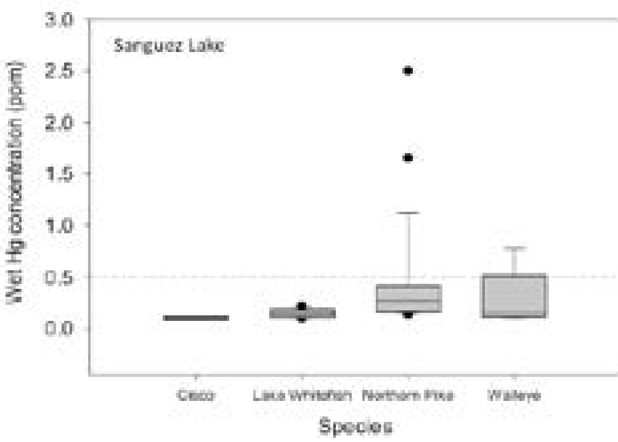


Figure 4: Boxplot of fish mercury concentrations (ppm wet weight) for fish captured from Willow Lake. The dotted blue line represents the commercial sale guideline.

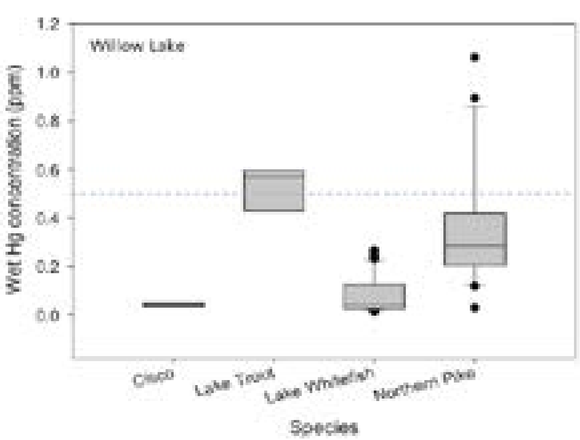


Figure 5: Boxplot of fish mercury concentrations (ppm wet weight) for fish captured from Big Island Lake. The dotted blue line represents the commercial sale guideline.

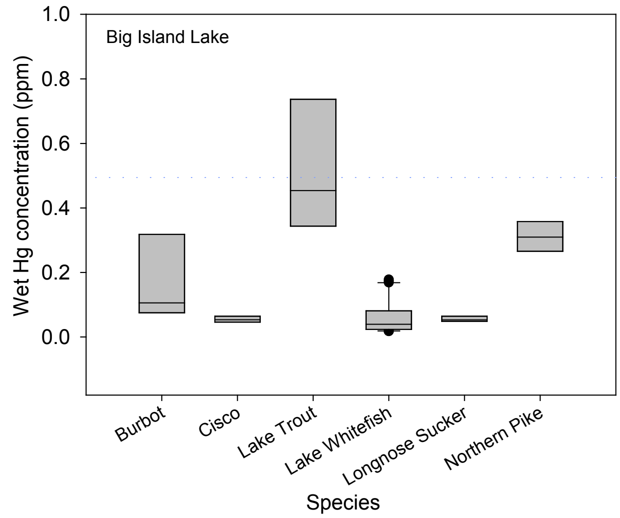


Figure 6: Boxplot of fish mercury concentrations (ppm wet weight) for fish captured from Ekali Lake. The dotted blue line represents the commercial sale guideline.

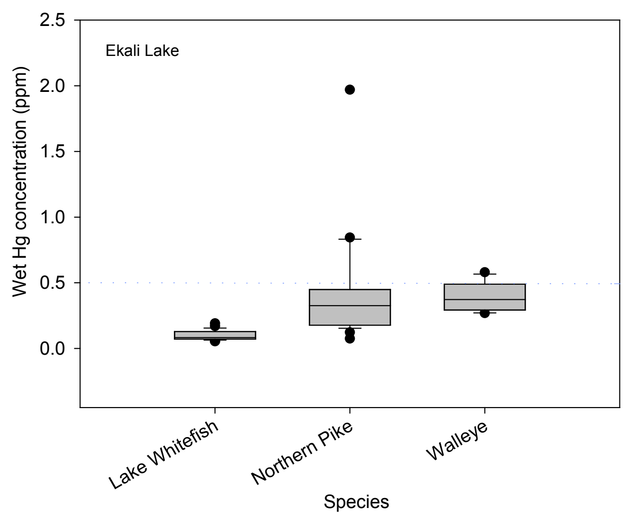
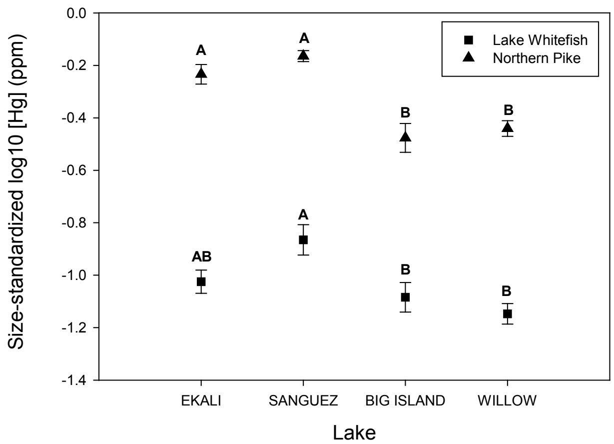


Figure 7. Size-standardized log10 wet mercury concentrations in northern pike (standardized to 650 mm fork length) and lake whitefish (standardized to 450 mm fork length) in each study lake. Northern pike and lake whitefish are the two food fish species common to all lakes. Letters indicate significant differences (p<0.05, Tukey's test) within species and between lakes.



Preliminary Catchment Delineation

Table 1. Lake Area, Catchment Area, and Catchment/Lake Area

Lake	Lake Area (km2)	Catchment Area (km2)	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 2 of 2, and continues on a previous 3-year project aimed at investigating causes of among-lake variation in food fish mercury concentrations in the Dehcho region, NT. Future work will include a three-year initiative that will expand the analyses to include 3 more lake pairs (McGill-Deep, Tathlina-Kakisa, Fish-Greasy). Interim analyses reveal that concentrations of methylmercury in water and benthic invertebrates are higher in lowland lakes than in lakes on the Horn Plateau, and that size-standardized concentrations of total mercury in lake whitefish and northern pike are also higher in lowland lakes. Future analyses will include fish age, trophic position, and carbon source as covariates.

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 percent methylmercury in water than sediment than water in the lowland lakes suggests a strong catchment source of methylmercury. The catchment to lake area ratios, as well as metrics such as percent 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.

Interim analyses of methylmercury levels in invertebrates reveal differences in functional feeding groups, and between the lowland and Horn Plateau regions. Future analyses that link these differences to effects of catchment and water chemistry will further elucidate mechanisms behind spatial variability in fish Hg in Dehcho lakes.

The combined catchment-food web approach taken in this study will lead to the ability 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 the next 3-year phase will continue 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 : développement des capacités et acquisition des connaissances

Project Leader/Chef de projet
Rodd Laing, Nunatsiavut Government, P.O Box 70, Nain, NL A0P 1L0 Tel: (709) 922-2567;
Email: rodd.laing@nunatsiavut.com

Project Team/Équipe de projet
Liz Pijogge, Northern Contaminants Researcher, Nunatsiavut Government; Paul McCarney, Research Manager, Nunatsiavut Government; Carla Pamak, Inuit Research Advisor, Nunatsiavut Government; Joey Angnatok, Mentor, Harvester, Nunatsiavut Government; Jane Kirk, Environment and Climate Change Canada

Project Location/Emplacement(s) du projet
- Nain, Nunatsiavut
- Saglek Fjord, Nunatsiavut

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

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

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

du Programme de lutte contre les contaminants dans le Nord (PLCN). Il comportait par ailleurs un volet de renforcement des capacités et un site d'échantillonnage supplémentaire sur lequel des prélèvements sont effectués depuis deux ans. 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 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 a result of collaboration of harvesters, community members, youth, Conservation Officers, Parks Canada, Environment 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/pêcheurs, des membres de la collectivité, des jeunes, des agents de conservation, Parcs Canada, Environnement et Changement climatique Canada et le personnel du Centre de recherches de Nain.
- 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'il soit propre à la consommation.

Objectives

This project aims to:

- 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; and,
- build capacity in youth, Nain Research Centre staff and harvesters.

Introduction

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

Char are an essential part to the diet of Labrador Inuit. Torngat Fish Producers Cooperative operate a char processing plant seasonally in Nain, and in partnership with the Nunatsiavut Government, have established a Social Fishing Enterprise where since 2013, 67,000 pounds of arctic char has been distributed to the 5 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 in the environment. As the diet of Labrador Inuit continues to shift towards the consumption of substantially more arctic char, as per the recommendations of the Inuit Health Survey, it is absolutely essential that the condition of these fish are understood. The region has a responsibility to monitor the arctic char to ensure that these recommendations are improving Inuit health and wellbeing and the region needs to be able to respond to community members concerns about the impacts of consuming more arctic char.

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

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

Activities in 2017-2018

Arctic Char Sampling

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

Analyses

Fish were weighed, length and gender determined, and had aging structures (otoliths) removed. Stomach fullness was assessed and the contents determined at a coarse level, i.e., invertebrates and/or fish. The presence of parasites, skinniness, discolored liver, and any other abnormality was noted. At least 100 g of skin on the 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. Analyses are underway.

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.

Indigenous Knowledge Integration

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

Results

The research team is still analyzing results that will be published in the next synopsis report.

Expected Project Completion Date

Ongoing.

Project Website

www.nunatsiavutresearchcentre.com
www.facebook.com/nainresearchcentre/

Acknowledgements

The project leaders acknowledge the hard work of the community members, youth, and harvesters that have contributed to this project. This project is based completely on samples collected from community members while also providing contributions to the community freezer.

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IHS, 2008

Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP)

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

Project Leader/Chef de projet

Jody Pellissey, Executive Director of Wek'èezhìı Renewable Resources Board, 102A 4504 49th Ave, Yellowknife, NT, X1A 1A7. Tel: 867-873-5740; Fax: 867-873-5743; jpellissey@wrrb.ca

Project Team/Équipe de projet

Susan Beaumont, Wek'èezhìı Renewable Resources Board (WRRB), Yellowknife, NT; Nicole Dion, Environment and Natural Resources, Government of Northwest Territories (ENR GNWT), Yellowknife, NT; Gloria Ekendia-Gon, Tłı̨chǫ Government (TG), Gamètì, NT; Dr. Sarah Elsasser, Wek'èezhìı Land and Water Board (WLWB), Yellowknife, NT; Dr. Marlene Evans, Environment and Climate Change Canada (ECCC), Saskatoon, SK; Ryan Fequet, WLWB, Yellowknife, NT; Dr. Jennifer Fresque-Baxter, ENR GNWT, Yellowknife, NT; Ryan Gregory, Water Resources Division, ENR GNWT, Yellowknife, NT; Anneli Jokela, WLWB, Yellowknife, NT; Roberta Judas, WLWB Wekweètì, NT; Priscilla Lamouelle, Department of Culture and Lands Protection, TG Behchokǫ̀, NT; Ellen Lea, Department of Fisheries and Oceans Canada (DFO), Inuvik, NT; Linna O'Hara, Department of Health and Social Services, Government of the Northwest Territories (HSS GNWT), Yellowknife, NT; Sean Richardson, Department of Culture & Lands Protection, TG, Behchokǫ̀, NT; Boyan Tracz, WRRB, Yellowknife, NT; Francois Laroche, Golder Associates Ltd., Yellowknife, NT; Jessica Hum, Department of Culture and Lands Protection, TG, Behchokǫ̀, NT

Project Location/Emplacement(s) du projet

- Gamètì (Rae Lakes), NT
- 64.1122° N, 117.3540° W

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. As a successful community-driven program, it 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?"

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. Un programme communautaire réussi fait véritablement participer les membres de la collectivité à la recherche sur les contaminants, notamment au prélèvement d'échantillons selon des méthodes scientifiques et aux observations en utilisant les connaissances du peuple tłı̨cho et les connaissances scientifiques pour répondre

In September 2017, a 5-day on-the-land monitoring camp returned to Rae Lakes, near the community of Gamètì, with the camp situated at the same site as the 2013 TAEMP camp was located. The 2017 participants returned to locations on Rae Lakes where sediment and water sampling occurred in 2013 to allow for comparative sampling, with the removal of one location and the addition of two 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. As well, youth participated in cultural activities, including making dry fish and dry meat, which were demonstrated by Gamètì elders. A results meeting was scheduled in Gamètì for June 2018; unfortunately, many participants were unexpectedly out of town and, therefore, no one attended.

Fish tissue analysis indicated mercury levels were low in Łıh (lake whitefish); while in Łıwezǫ̀ǫ̀ (lake trout), the mercury levels were close to or slightly exceeded Canadian Food Inspection Agency guidelines. Both łıh and łıwezǫ̀ǫ̀ did not show levels of mercury that were considered abnormal for northern lakes. Comparison of 2017 results to 2013 results showed no appreciable change in mercury concentration for łıh and fewer łıwezǫ̀ǫ̀ exceeding the guidelines. Water and sediment results supported the expectation that water and sediment quality is “good” (i.e. not abnormal) in Rae Lakes.

à la question : « Les poissons et l’eau sont-ils propres à la consommation? »

En septembre 2017, les participants d’un camp de surveillance terrestre de cinq jours sont retournés au lac Rae, près de la collectivité de Gamètì, le camp étant situé au même endroit où se trouvait le camp du PSEAT en 2013. Les participants de 2017 sont retournés à des endroits du lac Rae où des échantillons de sédiments et d’eau ont été prélevés en 2013 pour permettre un échantillonnage comparatif; à la demande des membres de la collectivité, un emplacement a été abandonné, et deux nouveaux emplacements ont été ajoutés. 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 jeunes ont également pu prendre part à des activités culturelles comme le séchage de poisson et de viande, dont les aînés de Gamètì ont fait des démonstrations. Une réunion de communication des résultats a été organisée à Gamètì en juin 2018; malheureusement, de nombreux participants étaient à l’extérieur, et par conséquent, personne ne s’est présenté à la réunion.

L’analyse des tissus de poisson a révélé que les concentrations de mercure étaient faibles chez le Łıh (grand corégone); tandis que chez le Łıwezǫ̀ǫ̀ (touladi), les concentrations de mercure étaient presque égales ou légèrement supérieures aux lignes directrices de l’Agence canadienne d’inspection des aliments. Le łıh et le łıwezǫ̀ǫ̀ ne présentaient pas de concentrations de mercure considérées comme anormales pour des lacs du Nord. La comparaison des résultats de 2017 avec ceux de 2013 n’a révélé aucun changement notable dans la concentration de mercure chez le łıh et a révélé une diminution du nombre de łıwezǫ̀ǫ̀ qui présentaient des concentrations supérieures aux lignes directrices. 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 Rae est « bonne » (c.-à.-d. non anormale).

Key Messages

- The fish tissue analyses of fish species typically consumed by residents of Gamètì showed that mercury levels were low in łıh while łıwezǫ̀ǫ̀ were close to or slightly exceeded the guidelines. 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 Rae Lakes. No water or sediment contaminant levels were considered to be abnormal;
- Gamètì community members were pleased with the implementation of the program, citing the importance of continued monitoring near their community; and,
- Non-statistical comparison of the 2017 to 2013 results suggests that there are no major changes in the quality of fish, water or sediment; a return to Gamètì in 2021 will allow for further tracking of potential changes.

Messages clés

- L'analyse des tissus d'espèces de poisson habituellement consommées par les habitants de Gamètì a montré que les concentrations de mercure étaient dans le łıh tandis que la concentration dans le łıwezǫ̀ǫ̀ était presque égale ou légèrement supérieure aux lignes directrices. 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 les lacs Rae. Aucune des concentrations de contaminants mesurées dans l'eau et les sédiments n'est considérée comme anormale.
- Les membres de la collectivité de Gamètì se sont dits satisfaits de la mise en œuvre du programme, soulignant l'importance d'une surveillance continue près de leur collectivité.
- La comparaison non statistique des résultats de 2013 à 2017 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 Gamètì en 2021 permettra d'assurer le suivi des changements potentiels.

Objectives

This project aims to:

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

Introduction

The purpose of the 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, 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 2017, community members in Gamètì were informed of the TAEMP through face-to-face community meetings, where support staff and community members discussed the TAEMP camp near Gamètì in 2013, and re-visited concepts related to Tłı̨chǫ and scientific knowledge relevant to water, sediment and fish, and concerns regarding potential contaminants. A key outcome of the workshops was advance planning of a 5-day on-the-land monitoring camp on Rae Lakes at a location selected by community members from Gamètì in 2013, Louie and Therese Zoe's camp. At the planning meetings, and at the on-the land camp, elders and community members had opportunities to describe fish health near Gamètì, as well as their concerns about aquatic ecosystem health and the need for adequate monitoring near the community. At the on-the-land camp in September 2017, biologists and community members collected fish tissue samples for analysis of a variety of metals, including mercury. Elders and community members ensured safe camp operations and transport by boats and provided direction on where fish nets were set and where water samples were collected. After discussion amongst the elders, six sites sampled in 2013 were revisited, with one site relocated near a recent burn. Two new sites were added; one site where the water levels in 2013 prevented sampling, and one site that was opportunistically sampled. Water and sediment samples were analyzed for metals, as well as chemical and physical properties. Cultural activities, led by Gamètì elders, included making dry fish and dry meat, and visiting gravesites. Youth were provided basic hands-on training in both science-based sampling methods and cultural-based observations and activities. Results meeting open to the public will be held in Gamètì in June 2018, and a presentation providing a comparison of the 2013 to 2017 results for fish, water and sediment will be given.

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 2017 fish camp near Gamètì 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 2017-2018

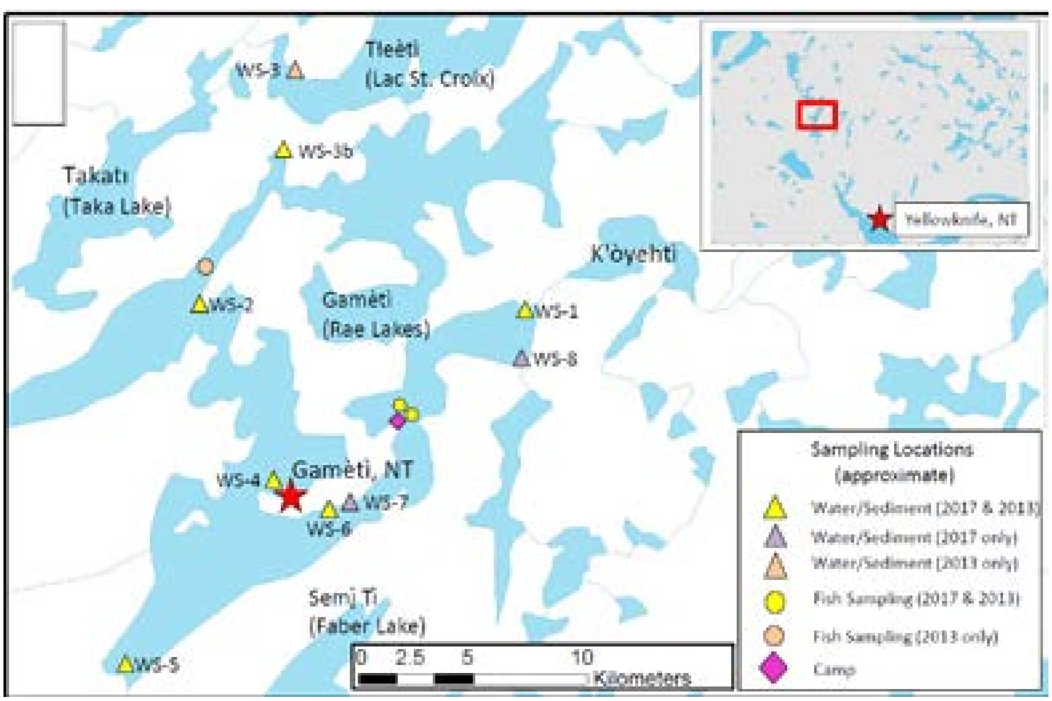
Introductory / Planning Workshops

Workshops were held in early August and September of 2017 to discuss the TAEMP with community members in Gamètì. The meetings provided a means to reacquaint community members with objectives/ approach of the TAEMP (i.e. the TAEMP had last occurred near Gamètì in 2013), and to 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 and availability of community participants. Selection of participants was discussed, and preliminary selection was determined based on relevant expertise/need/availability.

Monitoring Camp (i.e., “fish camp”)

A five-day on-the-land camp was held September 2017 to conduct fish, water and sediment sampling. It was decided that the camp location should remain at Louie and Therese Zoe’s camp, as decided in 2013. Water and sediment sampling locations were located as close as possible to six of the 2013 sampling locations, with one changed location and two new locations added at the request of community members (Figure 1). To further elaborate on the specifics of the TAEMP sampling methodology: Fish tissue samples were collected from łıwezǫǫ̀ and łıh, the fish species regularly consumed by Gamètì residents under the guidelines established by Environment and Climate Change Canada and the Golder Associates Ltd. technical protocols. All fish captured were identified to species, measured, and weighed. Additional data collected included: gender, stage of maturity, gonad weight, and general descriptions of the stomach contents and the presence/location

Figure 1. Location of the on-the-land camp, and locations where samples of fish, water, and sediment were collected on Rae Lakes during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near the community of Gamètì, September 2013 and 2017.



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.

The 5-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.

Results Meeting

A results meeting open was scheduled in Gamètì for June 19, 2018; unfortunately, many elders and participants were unexpectedly out of town and, therefore, no one attended. Materials with TAEMP fish, water and sediment results were left at the Community Government offices, along with Traditional Food Fact sheets that provide additional information on healthy traditional food choices (GNWT HSS 2017).

Community Engagement

The TAEMP has been developed and modified through a collaborative relationship among communities and agencies based in the NWT, which by design is based on consultation and engagement with communities near which sampling occurs. Partners include community members (harvesters, elders and youth), the TG, the WRRB, the WLWB, ENR-GNWT, ECCC, DFO, and HSS-GNWT. As in previous years of the Program, a collaborative approach was applied when engaging with community members in Gamètì, with in-person meetings and regular communications used to ensure understanding of expectations and responsibilities among participants. Overall, feedback from community members has been positive regarding the implementation of the TAEMP. Specific examples of positive feedback from community members and support staff can be found in the videos of the TAEMP on-the-land camp activities conducted from 2011-2014. The videos can be found at: https://wrrb.ca/news/taemp-fish-camp-videos. Also, Program partners, including funders, have provided positive commentary on the TAEMP, notably with regards to community engagement and the current approaches to management of the Program.

Capacity Building

Elders and youth were exposed to, and participated in, scientific sampling methods typically used to monitor aquatic ecosystems, including sediment and water quality sampling as well as fish tissue sampling for contaminant analysis. Demonstrations and activities built on knowledge transferred in 2013, and increased understanding of standard methods and the interpretation of results allows community members to have increased knowledge with regards to activities near Tłı̨chǫ communities. Scientists and youth were exposed to Tłı̨chǫ knowledge of the area, which promoted greater understanding of the local aquatic environment to participants, as well as a historical and cultural context to the area around the camp and sampling locations. 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 most of the youth who participated in 2017 were not the same youth who were present in 2013, the possibility that youth may continue with more specific training is strengthened by the availability of training initiatives via the TG. In this case, one of the youth from 2013 was hired as a bear monitor for the 2017 camp. Also, community members were hired in support of the camp, and their direct involvement benefits future initiatives in Gamètì by having community members available and experienced with assisting the operations of a monitoring camp. The TAEMP also involves staff from organizations inherently linked to Tłı̨chǫ communities, including the WLWB and the TG. Long-term capacity building occurs in these organizations through continued support by their trained staff, some of whom are also Tłı̨chǫ citizens living in Tłı̨chǫ communities. TG staff were key in the successful implementation of the TAEMP and cooperated with WRRB staff on a regular basis.

Communications

Communications with the community of Gamètì occurred primarily through the face-to-face interactions at the planning workshop and at the on-the-land camp, as well as at the upcoming results meeting. Collaboration with GNWT HSS, along with other TAEMP partners aided the 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, 2016, 2017). This appropriate messaging also informed all WRRB communications regarding 2017 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 2017 Northern Contaminants Program (NCP) Results Workshop on September 27, 2017 in Yellowknife. WRRB staff also participated at the Marian Watershed results workshop March 13, 2018. The overview of the TAEMP was well received by Tłı̨chǫ community members.

The *Common Fish of the Tłı̨chǫ Region*, a basic field guide to fish found in Wek'èezhìı, is available on the WRRB website. The 2017 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.

Indigenous Knowledge Integration

Elders and other community members guided all aspects of the project, with Tłı̨chǫ knowledge (i.e. Indigenous knowledge, or IK) incorporated throughout by design. The application of Tłı̨chǫ knowledge included: selection of participants, selection of the camp location, establishment of the on-the-land camp, direction on where samples were collected (*note*: with sampling locations initially decided upon in 2013, though one location was changed and two new locations were added in 2017 at the community members request), 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 Indigenous knowledge holders in a culturally appropriate on-the-land context. This form of engagement allows for building of mutual respect and trust through exchange of TK and science-based information while completing the sampling required and the various tasks which are needed for the operation of a traditional camp. Lastly, by bringing results back to communities, findings are discussed, which builds a shared appreciation of the perspectives provided by both Tłı̨chǫ knowledge and science.

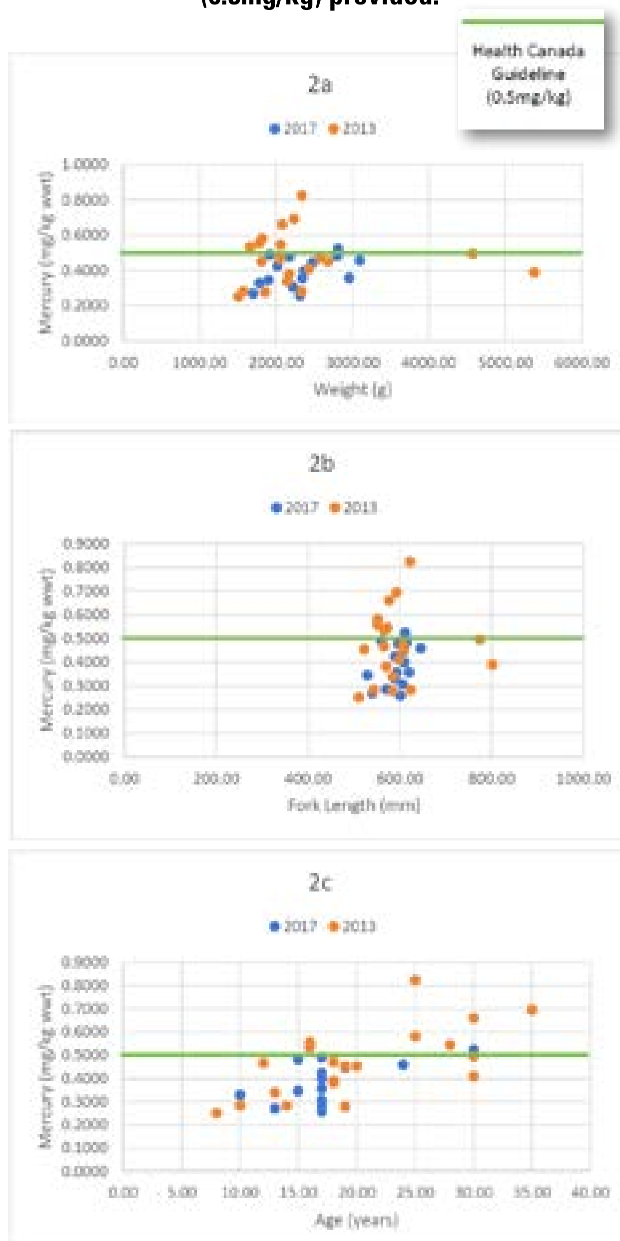
Results

Fish

The two fish species which had tissues collected for contaminant analyses were łıwezǫ̀ǫ̀ and łıh. These two species are regularly used for consumption in Gamètì and were the same species for which analyses occurred in 2013.

Łıwezǫ̀ǫ̀ from which tissues were sampled for analyses in 2017 (n=16) were on average 592.8mm in length (fork length; 95% CI+/-13.12) ranging from 530 to 645mm. They weighed on average 2325g (total weight; 95% CI+/-206.04) ranging from 1700 to 3100g, and were on average 17 years old (via otolith aging; 95% CI+/-2.31) ranging from 10 to 30 years (n=15; 1 of the 16 fish could not be aged due to damaged otolith). Lab analyses indicated that mercury concentrations in tissues were on average 0.388mg·kg^{-1} wwt (wet weight; 95% CI+/-0.042) ranging from 0.258 to 0.523mg·kg^{-1} wwt, with one of the sixteen fish sampled over the guideline for mercury of 0.5mg·kg^{-1}, (wet weight, wwt; Health Canada, 2017). Figure 2a, 2b, and 2c show the relationship of mercury concentrations in muscle tissue in relation to weight, fork length and age, with a strong positive relationship suggested with regards to age.

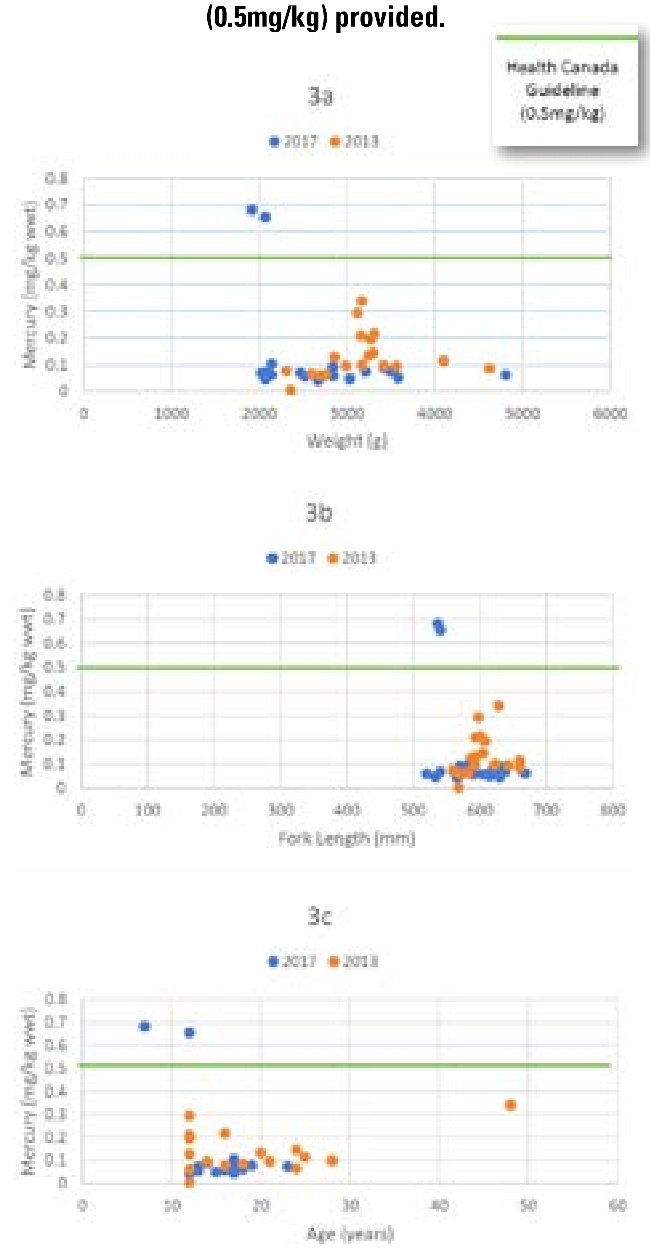
Figure 2. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and body weight (g) (2a), fork length (mm) (2b), and age (years; estimated via otolith aging) (2c) of Łıwezǫ̀ǫ̀ (Lake Trout) collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Health Canada Maximum Level for mercury concentration in commercial fish (0.5mg/kg) provided.



By comparison, łıwezǫǫ̀ sampled in 2013 (n=20) were on average 596.3mm in length (fork length; 95% CI+/-31.62) ranging from 511 to 802mm. They weighed on average 2354g (total weight; 95% CI+/-421.04) ranging from 1510 to 5380g and were on average 20 years old (via otolith aging; 95% CI+/-3.30) ranging from 8 to 35 years. Lab analyses indicated that mercury concentrations in tissues were on average 0.468$mg \cdot kg^{-1}$ wwt (wet weight; 95% CI+/-0.066) ranging from 0.251 to 0.825$mg \cdot kg^{-1}$ wwt.

Łıh sampled in 2017 (n=21) were on average 589.3mm in length (fork length; 95% CI+/-17.8) ranging from 520 to 668mm. They weighed on average 2746.7g (total weight; 95% CI+/-313.6) ranging from 1920 to 4810g and were on average 15 years old (via otolith aging; 95% CI+/-1.45) ranging from 7 to 23 years. Lab analyses indicated that mercury concentrations in tissues were on average 0.12$mg \cdot kg^{-1}$ wwt (wet weight; 95% CI+/-0.078) ranging from 0.042 to 0.682$mg \cdot kg^{-1}$ wwt, and none of the fish sampled were over the guideline for mercury of 0.5$mg \cdot kg^{-1}$, (wet weight, wwt; Health Canada, 2017). Figure 3a, 3b, and 3c show the relationship of mercury concentrations in muscle tissue in relation to weight, fork length and age, with a positive relationship suggested with regards to age.

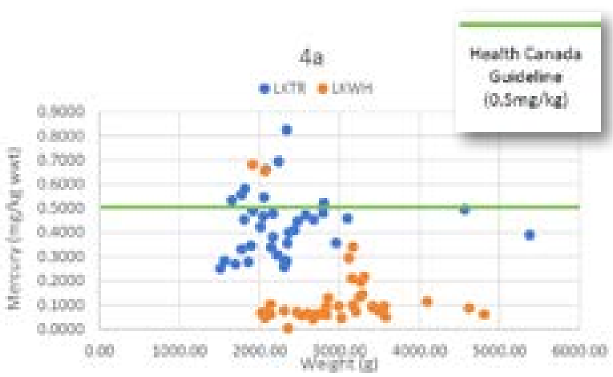
Figure 3. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and body weight (g) (3a), fork length (mm) (3b), and age (years; estimated via otolith aging) (3c) of Łıh (Lake Whitefish) collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Health Canada Maximum Level for mercury concentration in commercial fish (0.5mg/kg) provided.

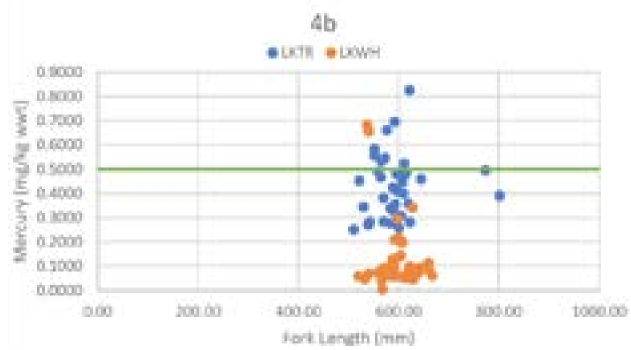


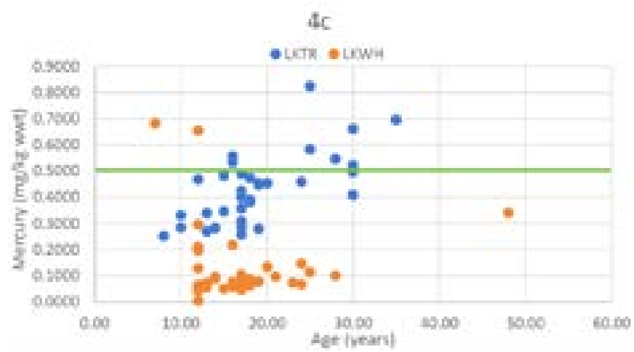
By comparison, łıh sampled in 2013 (n=19) were on average 604mm in length (fork length; 95% CI+/-13.08) ranging from 560 to 660mm. They weighed on average 3158.4g (total weight; 95% CI+/-248.1) ranging from 2310 to 4620g and were on average 19 years old (via otolith aging; 95% CI+/-4.19) ranging from 12 to 48 years. Lab analyses indicated that mercury concentrations in tissues were on average 0.133mg·kg^{-1} wwt (wet weight; 95% CI+/-0.038) ranging from 0.004 to 0.341mg·kg^{-1} wwt. All of the łıh sampled fell below the guideline for mercury.

Comparison of the cumulative data sets (2017 and 2013) for łıwezǫ̀ǫ̀ and łıh suggest positive relationships between mercury concentration in tissue and weight, length, and age (Figures 4a, 4b and 4c). Łıh consistently show lower concentration in their tissues than łıwezǫ̀ǫ̀, with the clearest differentiation visible with regards to weight (4a).

Figure 4. Comparison of the relationships between mercury concentration in tissues (mg/kg; wet weight) and body weight (g) (4a), fork length (mm) (4b), and age (years; estimated via otolith aging) (4c) for Łıwezǫ̀ǫ̀ (Lake Trout) and Łıh (Lake Whitefish) using cumulative data for each species collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Health Canada Maximum Level for mercury concentration in commercial fish 0.5mg/kg) provided.







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

Water

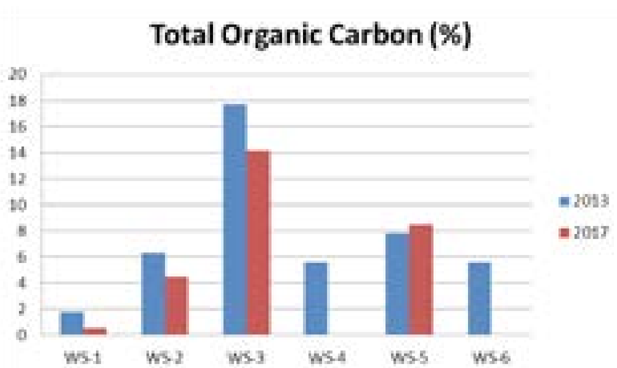
Analysis of water samples indicated no noticeable difference between 2017 and 2013 with regards to nutrient and physical parameters measured at all sample sites; all nutrients and physical parameters were found to be similar at all sites. For example, water samples in 2017 indicated pH ranged from 7.43 to 8.28, 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) guidelines (6.5-9.0) (CCME 2014). By comparison, pH ranged from 7.43 to 8.23 in 2013 (n=5). Most metal concentrations in Rae Lakes were very low with many measuring below method detection limits (MDL). The 2017 water samples were all better than FAL guidelines, while 2013 water samples had a few metal concentrations greater than FAL guidelines (e.g. aluminum, mercury, and silver).

In 2017, bacteria (*Escherichia coli* (*E. coli*), Enterococci, and Fecal Coliforms) were not detected at WS-7, or by WS-4. In 2013, bacteria were not detected at WS-6; in 2017, the bacteria counts were very low. Total coliform counts were similar at all three sites sampled in 2017, suggesting that WS-6 has not significantly affected Rae Lakes.

Sediment

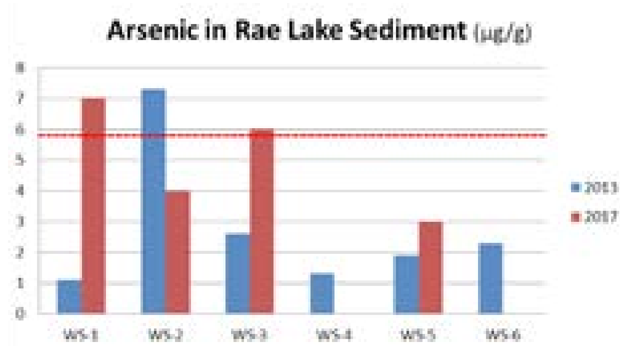
Sediment samples collected in 2013 and 2017 from WS-3 had the highest percentage of organic carbon (Figure 5). This was expected as these sites were chosen near recent burn areas.

Figure 5. Comparison of the Total Organic Carbon in sediment samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017.



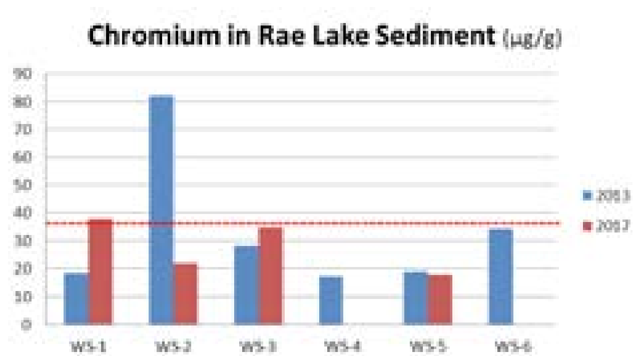
In 2017, sediment samples from WS-1 and WS-3 had arsenic concentrations of 7.0$\mu g \cdot L^{-1}$ and 6.0$\mu g \cdot L^{-1}$, respectively, and, in 2013, WS-2 was 7.3$\mu g \cdot L^{-1}$ (Figure 6); these are above the CCME Sediment Quality Guidelines for the Protection of Aquatic Life interim Sediment quality guidelines (ISQG) of 5.9$\mu g \cdot L^{-1}$ (CCME 2014). No locations sampled in 2013 or 2017 exceeded the CCME Probable Effects Levels (PEL) guidelines of 17$\mu g \cdot L^{-1}$ (CCME 2014).

Figure 6. Comparison of the total concentrations of Arsenic for sediment samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life interim sediment quality guidelines (ISQG) for Arsenic (5.9 µg/L).



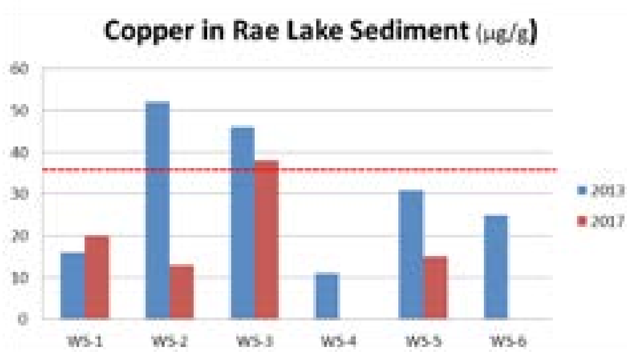
Chromium concentrations exceeded the ISQG guideline of 37$\mu g \cdot L^{-1}$, but not the PEL guideline of 90$\mu g \cdot L^{-1}$, at WS-1 (38$\mu g \cdot L^{-1}$) and WS-2 (82.2$\mu g \cdot L^{-1}$) in 2017 (Figure 7); concentrations at the remaining sampling locations ranged from 18.5 to 34.5$\mu g \cdot L^{-1}$. No locations sampled in 2013 exceeded the ISQG or the PEL guidelines.

Figure 7. Comparison of the total concentrations of Chromium for sediment samples collected during the on-the-land component of the Tłı̨chǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life Interim Sediment quality guidelines (ISQG) for Chromium (37µg/L) provided.



Copper concentrations exceeded the ISQG guideline of 36μg·L^{-1} at WS-2 (52μg·L^{-1}) and WS-3 (46μg·L^{-1}) in 2013, and in 2017 at WS-3 only (38μg·L^{-1}; Figure 8). No locations sampled in 2013 or 2017 exceeded the PEL guideline of 197μg·L^{-1} (CCME 2014).

Figure 8. Comparison of the total concentrations of Copper for sediment samples collected during the on-the-land component of the Tłįchǫ Aquatic Ecosystem Monitoring Program (TAEMP) near Gamètì, September 2013 and 2017. Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life Interim Sediment quality guidelines (ISQG) for Chromium (36μg/L) provided.



Mercury concentrations exceeded the ISQG guideline of 0.17μg·L^{-1}, but not the PEL guideline of 0.49μg·L^{-1}, at WS-1 (0.2μg·L^{-1}) in 2017; all other 2017 locations were below guidelines. By comparison, all locations sampled in 2013 were below both ISQG and PEL guidelines.

Discussion and Conclusion

The main objective of the 2017 fish, water and sediment quality monitoring program was to repeat the sampling that was done in 2013 to see if any changes had occurred; this objective was achieved.

Fish tissue analysis indicated mercury levels were low in łıh, with all tissue samples showing mercury concentrations below the Health Canada guideline. Łıwezǫǫ̀ 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, while łıh primarily feed on small fish and arthropods and typically show lower levels of contaminants (GNWT 2017a, b, Health Canada 2011, Cabana et al. 1994). On average, the concentration of mercury in łıwezǫǫ̀ 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 2017 to 2013, no appreciable differences were noticed between years for either łıwezǫǫ̀ or łıh. No statistical analyses of mercury concentrations in muscle tissue in relation to weight, fork length, and age were conducted, given that a visual examination of the scatter plots suggests positive relationships. Statistical analyses are expected through collaboration with Environment and Climate Change Canada, examining data in the context of the TAEMP, as well as comparing TAEMP 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 Environment and Natural Resources Water Resources Division and other water partners continue regarding use of TAEMP data in supporting implementation of the Water Strategy and related initiatives such as the Mackenzie DataStream, which was officially launched in November 2017 (Mackenzie DataStream 2017). Recently, interest was expressed regarding the use of TAEMP fish data as a "pilot" to test the capacity of DataStream. Use of TAEMP data in an open source format may help to address some of the data gaps in Wek'èezhìı, for as mentioned in the WWF Freshwater Health Assessments for Watersheds in Canada (WWF 2015, 2017), 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 Rae Lakes. Overall, the sampling results indicate there was no appreciable change in the water quality and sediment quality between 2013 and 2017, with the understanding that some variation of parameters is to be expected with varying natural conditions and low frequency sampling. In short, Rae Lakes water is typical of water originating on the Precambrian Shield and Rae Lakes would be classified as an oligotrophic lake. 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, 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 2013 or 2017, 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 łıwezǫ̀ǫ̀ 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 awaiting final decision from the GNWT's Minister of Lands (MVEIRB 2017) 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 NWT is highlighted in the WWF Freshwater Health Assessments for Watersheds in Canada (WWF 2015, 2017); 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; CIRNAC) State of Knowledge Report (AANDC 2013).

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 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 GNWT HSS and the Northern Contaminants Program. TAEMP will also complement the TG'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

The Gamètì portion of TAEMP was completed June 19, 2018 (Results Workshop). The TAEMP aims to continue as a long-term community-based program in coming years.

Project Website

See: http://www.wrrb.ca/ for TAEMP updates (e.g. https://wrrb.ca/news/gameti-fish-camp-2017).

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Imalirijiit: Environmental community-based monitoring of the George River Watershed, Nunavik

Imalirijiit : Surveillance environnementale communautaire du bassin hydrographique de la rivière George, Nunavik

Project Leader/Chef de projet

Marc Amyot, Professor, Département des sciences biologiques & Centre d'études nordiques (www.cen.ulaval.ca) 90 Vincent d'Indy, Montreal, CP 6128, Succ. Centre-Ville Pavillon Marie-Victorin Montréal (QC) H3C 3J7 Tel.: 514-343-7496; Email: m.amyot@umontreal.ca

Hilda Snowball, Mayor, Northern Village of Kangiqsualujjuaq, P.O. Box 120, Kangiqsualujjuaq, QC J0M-1N0 Tel: 819-337-5271 ext: 23; Fax: 819-337-5200; Email: hsnowball@nvkangiqsualujjuaq.ca

Project Team/Équipe de projet

Esther Lévesque, Département des sciences de l'environnement & Centre d'études nordiques; José Gérin-Lajoie, Département des sciences de l'environnement & Centre d'études nordiques; Gwyneth MacMillan, Ph.D. Candidate Département des sciences biologiques & Centre d'études nordiques; Eliane Grant, Département des sciences biologiques; Thora M. Herrmann, Département de géographie & Centre d'études nordiques; Jan Franssen, Département de géographie & Centre d'études nordiques; Jean-Pierre Dedieu, University of Grenoble-Alpes (UGA), Grenoble, France

Project Location/Emplacement(s) du projet

Kangiqsualujjuaq, QC

Abstract

In Canada's North, there is a growing interest in community-based environmental monitoring (CBEM), as resource exploitation and climate change increasingly impacts Indigenous territories. This one-year study followed up on a successful pilot Science Land Camp, involving youth conducted in 2016 in Kangiqsualujjuaq, that was co-initiated by Elders, local experts and researchers from Université du Québec à Trois-Rivières. This community-based program aims to establish baseline environmental conditions and country food quality before the start of a rare earth elements (REEs) mining project in the George River upper watershed. Youth

Résumé

Dans le Nord canadien, on observe un intérêt croissant à l'égard de la surveillance environnementale communautaire étant donné que l'exploitation des ressources et les changements climatiques font de plus en plus sentir leurs effets sur les territoires autochtones. Cette étude d'un an a été menée à la suite du déroulement réussi à Kangiqsualujjuaq en 2016 d'un camp expérimental de surveillance scientifique terrestre mobilisant des jeunes qui a été mis sur pied conjointement par des aînés, des spécialistes locaux et des chercheurs de l'Université du Québec à Trois-Rivières. Ce programme communautaire a pour objet

training workshops were successfully organized, as well as sampling at ten stations along the river involving in situ measurements, collection of water samples for laboratory analyses (35 metals including REEs, nutrients, chlorophyll-a) as well as macroinvertebrates and vertebrates (fish, seal) sampling. Lichens from nearby terrestrial sites were also collected, as potential bioindicators of atmospheric deposition of REEs.

Community engagement in sample collection for the CBEM project was very strong and led to high quality results, as shown by reliable data on REEs and other metals (including mercury, Hg) in water, lichens, invertebrates, fish and seal livers and muscles. The results obtained were very consistent with a recently published article on REEs from another site in Nunavik. Levels of REEs in fish and seal muscles were very low, whereas those in aquatic invertebrates were 1000 times higher. REE levels in lichens were about half those in invertebrates. With respect to mercury (Hg), levels in edible vertebrate tissues were below the Canadian consumption guideline of 0.5 ppm, except for some muscle tissues samples from sculpin. Land-based activities, hands-on workshops, real data collection and sharing between different generations and cultures through the Imalirijiit project, has helped make science practical and meaningful for local Inuit youth and other participants in the science camp. This project has also fostered local capacity in environmental monitoring in the community.

d'établir les conditions environnementales de référence et la qualité des aliments prélevés dans la nature avant le début d'un projet d'exploitation des éléments de terres rares dans le bassin de la rivière George. Des ateliers de formation à l'intention des jeunes ont été organisés et se sont bien déroulés. Par la suite, des échantillons ont été prélevés dans dix sites le long de la rivière, notamment par la prise de mesures sur place, le prélèvement d'échantillons d'eau à des fins d'analyse en laboratoire (35 métaux y compris des éléments de terres rares, des nutriments et de la chlorophylle-a) et l'échantillonnage de macroinvertébrés et de vertébrés (poisson, phoque). Des lichens ont été prélevés de sites terrestres situés à proximité puisqu'ils peuvent servir de bioindicateurs du dépôt atmosphérique de terres rares.

La grande participation de la collectivité au prélèvement d'échantillons dans le cadre du projet de surveillance environnementale communautaire a permis d'obtenir des résultats de qualité, comme le montrent les données fiables sur les terres rares et d'autres métaux (y compris le mercure ou Hg) dans l'eau, les lichens, les invertébrés, le poisson et le foie et les muscles de phoques. Les résultats obtenus étaient très similaires aux résultats figurant dans un article publié récemment sur les terres rares provenant d'un autre lieu du Nunavik. Les concentrations d'éléments de terres rares dans le poisson et les muscles des phoques étaient très faibles, mais ces concentrations étaient 1 000 fois plus élevées dans les invertébrés aquatiques. Les concentrations d'éléments de terres rares dans les lichens étaient environ deux fois moins élevées que dans les invertébrés. Les concentrations de mercure (Hg) dans les tissus de vertébrés comestibles étaient inférieures aux lignes directrices canadiennes sur la consommation de 0,5 ppm, sauf dans quelques échantillons de tissus musculaires de chabots. Les activités terrestres, les ateliers pratiques, la collecte de données en temps réel et l'échange entre les générations et les cultures dans le cadre du projet d'Imalirijiit confèrent un caractère utile et enrichissant à ces connaissances scientifiques pour les jeunes Inuits de la localité et les autres participants au camp scientifique. Ce projet favorise également le développement des capacités locales en matière de surveillance environnementale.

Key Messages

- A community-based environmental monitoring (CBEM) program was successfully implemented near the proposed site of a rare earth mining project.
- An environmental science land camp on issues relevant to youth was successfully held.
- Background pre-mining levels of rare earth elements (REEs) in water, aquatic invertebrates, fish, lichens and seal were obtained.
- REE levels were higher in organisms at the base of the food web than in fish and seal.
- REE levels were higher in fish and seal livers than in muscles.
- Levels of mercury in wildlife were generally lower than consumption guidelines.

Messages clés

- Un programme de surveillance environnementale communautaire a été mis en place avec succès près de l'emplacement proposé d'un projet d'exploitation minière de terres rares.
- Un camp expérimental de surveillance environnementale terrestre sur des questions qui touchent les jeunes a été une réussite.
- Des données de référence ont été obtenues sur l'eau, les invertébrés aquatiques, le poisson, les lichens et les phoques avant le début de l'exploitation des éléments de terres rares.
- Les concentrations d'éléments de terres rares étaient plus élevées dans les organismes qui se trouvent à la base du réseau trophique que dans le poisson et le phoque.
- Les concentrations d'éléments de terres rares étaient plus élevées dans le foie que dans les muscles du poisson et des phoques.
- Les concentrations de mercure dans les échantillons prélevés dans la faune étaient généralement inférieures aux lignes directrices de consommation.

Objectives

This project aims to:

- establish baseline environmental conditions through a pilot community-based environmental monitoring program of the George River watershed;
- measure contaminants in key species of country food collected in the George River watershed (marine, freshwater and terrestrial);
- develop an interactive map of the George River watershed integrating land uses, harvest sites, local knowledge, place names, and measurement data;
- foster local capacity in environmental monitoring (including biomonitoring), data management and interactive mapping; and,
- create interest in the environmental sciences among the youth while addressing local environmental issues.

Introduction

Adjusting to global climate and socio-environmental change has become a major issue for northern communities and for researchers. The Arctic is one of the most rapidly changing regions on the planet, and as a result, Inuit communities are facing many challenges (Arctic Human Development Report, 2015). Scientists and northern residents are witnessing accelerated warming in this region (Pearce et al., 2009). In addition, there is significant pressure to exploit northern natural resources at the same time as there are calls for sustainable development by governments and local populations. Arctic communities are concerned about their future and wish to better understand the social, environmental and economic changes related to ongoing industrial development and climate change (Rodon, et al., 2014). They are concerned about the effects of climate change, mining and non-traditional lifestyles on their health, well-being and quality of life (Pearce et al, 2015). They also worry about the future and the education of youth, the widening generation gap, the preservation of traditional hunting, fishing and gathering techniques, as well as threats to Inuit culture and language (Laugrand and Oosten, 2009).

Following a successful experience in 2013 of jointly organizing a land-based plant workshop with the Cree in Whapmagoostui, researchers from Université du Québec à Trois-Rivières launched a project call to the Nunavik Inuit communities in summer 2015. Kangiqsualujjuamiut manifested their desire to participate in such a project especially in the context of a rare earth elements (REEs) mining project which plans to start operating in the coming years in the George River upper watershed. The municipal council asked the researchers to propose several scenarios to a joint committee. All suggestions were summarized in three scenarios: 1) Monitoring the George River water quality; 2) Studying vegetation and landscape evolution in the Koroc River area; and 3) Inventorying edible marine resources in a location to be determined. The first scenario was unanimously chosen because of concerns about the Strange Lake Rare Earth mining project and its potential impacts on the George River watershed and the traditional activities of fishing, hunting and gathering.

The community wanted to develop their own independent environmental monitoring capacity and a strong youth training component. The Youth Committee was designated by the municipal council to act as local coordinators. The expertise of the team was expanded to match the need of the project identified by the community. This was done by including expertise in environmental biogeochemistry of metals (University of Montreal, Nunavik Research Center), remote sensing (University of Montreal, Université de Grenoble), geographical information systems (University of Montreal) and environmental water monitoring (Environment and Climate Change Canada).

A pilot study was conducted in 2016-2017 (Gérin-Lajoie et al., in press). Funding from the Northern Contaminant Program for 2017-2018 provided an opportunity to expand this initiative, by conducting a Summer Camp focused on contaminants, by increasing the environmental monitoring of the George River ecosystem, and by initiating a biomonitoring program of levels of metals in country food.

Activities in 2017-2018

Community Engagement

A local youth coordinator was chosen by the community and an educational program coordinator was chosen from within the group of researchers. Together, they organized pre- camp activities for three days before the youth's departure, including visiting a geologist camp near the community. The local Youth Committee was involved in all logistical aspects of the Science Land Camp, working in collaboration with the researchers. They also organized fundraising activities to contribute financially to the camp.

Working together, the team has learned how to successfully write grant co-applications with inputs from both researchers and the

Kangiqsualujjuaq Northern village. To date, five grants have been successful. The team's complementary expertise allowed them to apply both to scientific grants and to community-based monitoring grants. In December 2017, the mayor Hilda Snowball gave a joint oral presentation with J. Gérin-Lajoie at the Arctic Change Conference in Quebec City. The structure of the presentation was different from the usual scientific presentations. It was designed as a conversation between an Inuk stakeholder and a researcher, mutually asking questions such as: "How you expect researchers to work with your community?" "Does it make a difference for you as researchers to work on a project proposed by the community?" "How do you see the future of Imaliriit program?" The formula was very well-received by the audience.

This collaborative, multicultural and multidisciplinary initiative contributes to the scientific, educational and community objectives, for the benefit of researchers, local community and regional organizations.

Capacity Building and Training

Hilda Snowball, mayor of Kangiqsualujjuaq, stated the following: "Imalirijiit project has involved many Inuit youth and Elders. It has stimulated interest in science and on the land programs amongst Inuit youth. Also, it has provided educational hands-on learning experiences that made youth eager to learn more and expanded their interest to become involved in scientific projects."

In both 2016 and 2017, the team observed a strong interest from some guides in the scientific activities, data collection and scientific protocols. The team learned that hiring local coordinators from the community for both the science land camp and the country food collection by hunters was very effective.

An Interactive Mapping Workshop was organized at the University of Montreal (Geography department). The northern-based trainees learned how to build an interactive map using the uMap platform. The 3-day training included learning about map features, integrating pictures, GPS coordinates, audios and videos, organizing data and layers on the maps, discussing ownership of data and map sharing, and completing exercises to create new maps. The trainees plan to teach other community members to use uMap. Interactive mapping will contribute to display the collective body of knowledge around the George River watershed in a creative and evolving way.

Communications and Outreach

Researchers have learned how to better share information with the community and to be transparent. They understand the importance of frequently returning to the community to discuss plans, funding, and to share research results in relevant and understandable ways (for example, the comic strip on REEs; see appendix A.

Indigenous Knowledge

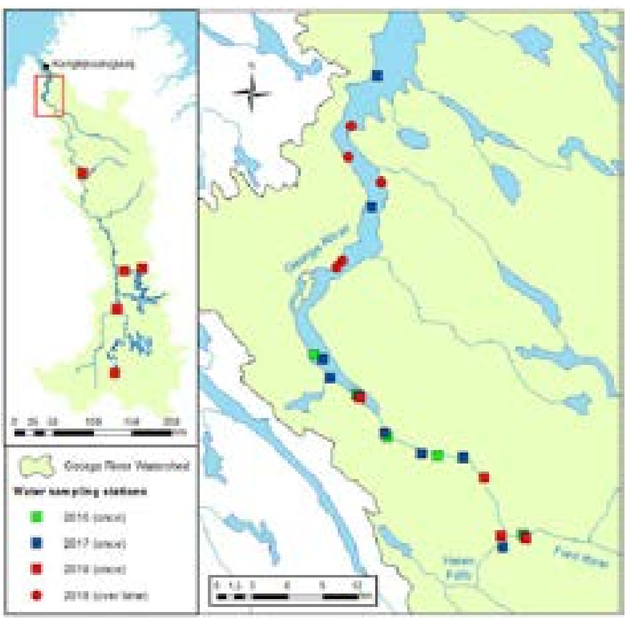
Inuit Knowledge (IK) was used in this study to identify the study area, the sampling sites and the target species for the country food monitoring. Local knowledge was very important for the interpretation and validation of remote sensing data at the watershed scale (e.g. for sedimentation and hydrological processes). Interviews, discussions and activities gathering youth, elders and guides took place several times during the science land camp to encourage intergenerational knowledge transfer, such as Inuit ecological knowledge, the river's movements and processes as well as the observed changes (vegetation growth, landslides, etc.) in the George River watershed, and navigational skills.

The IMALIRIJIIT program uses a hands-on and land-based approach that allows the community and researchers to merge Inuit ways and scientific procedures. These methods help us highlight similarities between the scientific method and the Inuit hunting and gathering culture such as curiosity, observation, analysis and problem solving which are required in both knowledge systems. Therefore, IK helped to fill gaps in the scientific knowledge of the George River watershed.

Contaminant Sampling

Five stations were sampled between Helen's Falls and Qikirtaaluit Islands (2016, 2017), along with an additional five sampling stations in 2017: one in the same stretch of the river, two in tributary creeks, one between two sets of rapids, and one in the estuary of the George River (Fig. 1). Each station was sampled only once. Surface water physico-chemical parameters were measured *in situ* using an electronic probe for precise data collection (*YSI Pro Plus*) and manual kits for educational purposes (*G3E/EWAG* protocols) (Fig. 2). Surface water samples were collected for laboratory analyses of water quality, including nutrients, alkalinity, dissolved carbon, major ions, and chlorophyll-*a*.

Figure 1. Sampling sites in relation to the REE site and Kangiqsualujjuaq.



Total and dissolved trace metal and rare earth element triplicate samples were filtered using acid- washed polypropylene/polyethylene syringes (without rubber gaskets) and filters with a polyethersulfone membrane (0.45µm, *Whatman GD/XP*). Samples were stored in polypropylene centrifuge tubes (metal-free *VWR*), preserved with 2% ultra-trace HNO_3 (*Omnitrace Ultra, VWR*) within 24 hours of sampling, and stored at 4°C in double bags prior to analysis. Milli-Q water blanks were collected, filtered and acidified *in situ*. Samples were collected using the clean hands, dirty hands sampling protocol for trace metals (St-Louis et al. 1994).

Different biological tissues were obtained with the help of the community, namely: stoneflies (pooled) at 4 stations, lichens at 15 stations, four seals, and 35 fish (2 cods, 7 skulpins and 26 whitefish). Analyses of total Hg was performed by atomic absorption spectroscopy (Direct Mercury Analyzer). MethylHg (MeHG) analyses were done by cold vapor atomic fluorescence spectroscopy (Tekran 2700) and the rare earth elements were measured by ICP-MS/MS (Agilent). A total of 564 analyses were performed for contaminants.

Results

In the following, we focus on the scientific results regarding contaminants measured in different environmental matrices. The interactions with the community are presented in the discussion section.

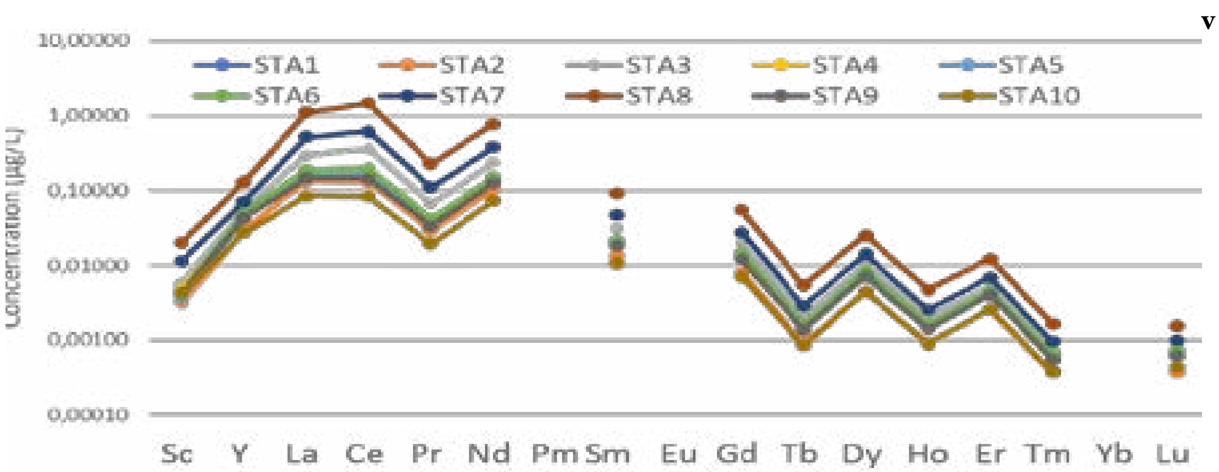
Baseline levels of REEs in the George River system

REEs in surface water

With a length of 475 km, George River is a major aquatic system in Northern Nunavik (Hydro-Québec, 2008). It originates from Lake Jannière and ends its course in the Ungava Bay. The village of Kangiqsualujjuaq is located near the mouth of the river. A rare earth mining project is in development near Lake Brisson in the George River watershed, approximately 300 km upstream from the village.

We sampled water at 10 stations located along the river, between the site of the mining project and the mouth of the river. Some of these stations were located in tributaries and one was in the estuary. When considering only the lanthanides (i.e. excluding Sc and Y; elements between La and Lu in Fig. 2), levels of unfiltered REEs followed a saw-tooth pattern as predicted by the Oddo-Harkins rule which states that the cosmic abundance of elements with an even atomic number is greater than that of adjacent elements with odd atomic

Figure 2. Levels of REES in the water of 10 stations along the George River.



number. The lighter REEs (left side of Fig. 2) were generally more concentrated than heavier ones (right side of Fig. 2; see also Table 1). Lanthanum (La), cerium (Ce) and neodymium (Nd) were the most common elements, with average concentrations ranging from 0.23 and 0.35 ug/L. The largest gradient of concentrations for an element was for cerium, with 18 times more Ce found at the most concentrated site compared to the least concentrated one.

Table 1. Average water concentrations, standard deviation and gradients (maximum value/ minimum value) of rare earth elements in 10 stations along the George River.

Element	Mean (ug/L)	Standard Deviation	Max:min
Sc	0.007	0.005	6.4
Y	0.055	0.028	4.8
La	0.300	0.296	13.3
Ce	0.352	0.402	17.9
Pr	0.064	0.059	11.8
Nd	0.227	0.199	10.6
Sm	0.030	0.023	8.6
Gd	0.019	0.013	7.6
Tb	0.002	0.001	6.5
Dy	0.010	0.006	5.7
Ho	0.002	0.001	5.4
Er	0.005	0.003	4.8
Tm *	0.001	0.000	4.5
Lu *	0.001	0.000	4.2

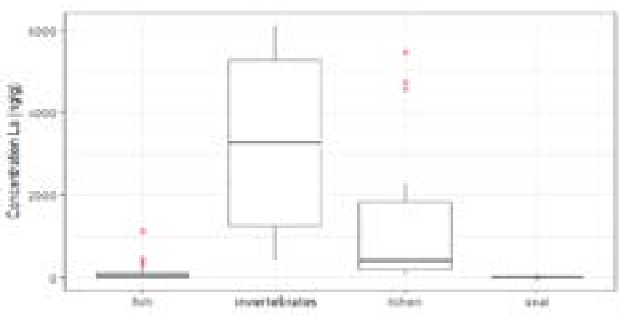
*Some data were below detection limits for Tm and Lu

REEs in potential biomonitors

There is no published data on REEs in animals and plants from the George River watershed. In order to establish a baseline before the start of a mining project and to identify promising biomonitors of REE contamination, biological samples associated with different vectors of pollution were chosen. Namely, we sampled fish (whitefish, sculpin, cod) to monitor REE changes in the water column, aquatic invertebrates to represent the benthic/sediment environment, ringed seal to represent the estuarine system, and lichen to track changes in atmospheric deposition of REEs.

Taking lanthanum (La) as a representative REE, we observed that fish and seal muscles had very low La levels, with averages of 9 ± 33 and 1.4 ± 1.4 ng/g wet weight (ww), respectively (Fig. 3). La levels in aquatic invertebrates were approximately 1000 times higher than in fish. La levels in lichen were approximately half those measured in the invertebrates.

Figure 3. Boxplots of La concentrations in fish (in west weight, ww), aquatic invertebrates (in dry weight, dw), lichens (in dw) and seals (in ww) collected in the George River watershed.



Mercury levels in fish muscles

Mercury (Hg), particularly in its methylated form MeHg is a leading source of consumption advisories in country food. Levels of Hg and MeHg were measured in livers, muscles and kidneys of three fish species commonly found in the river, namely the sculpin, the whitefish and the cod. Levels of Hg in all tissues were usually below the Canadian guideline for food consumption of 0.5 ppm, except for the muscles of some sculpins and for one whitefish (Fig. 4). MeHg represented around 95% of total Hg on average in sculpin and whitefish, but around 80% in cod. For a given species, %MeHg was on average higher in muscles than in other tissues (Fig. 5).

Figure 4. Boxplots of total mercury concentrations in livers, muscles and kidneys of three fish species collected in the George River.

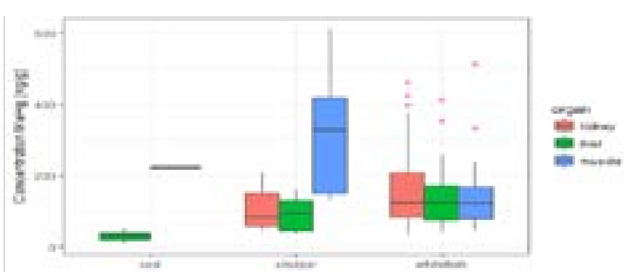
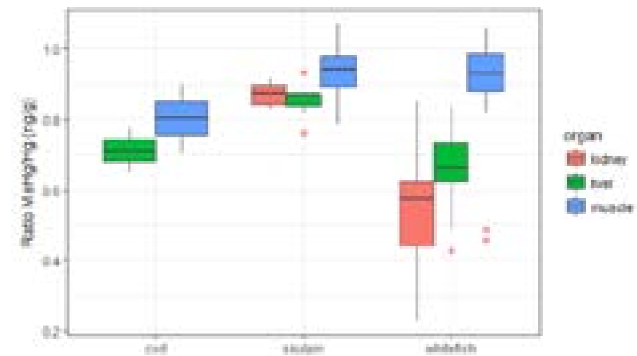


Figure 5. Percent of total mercury found as methylmercury in livers, muscles and kidneys of three fish species collected in the george River.



Discussion and Conclusions

Strong Community Interactions

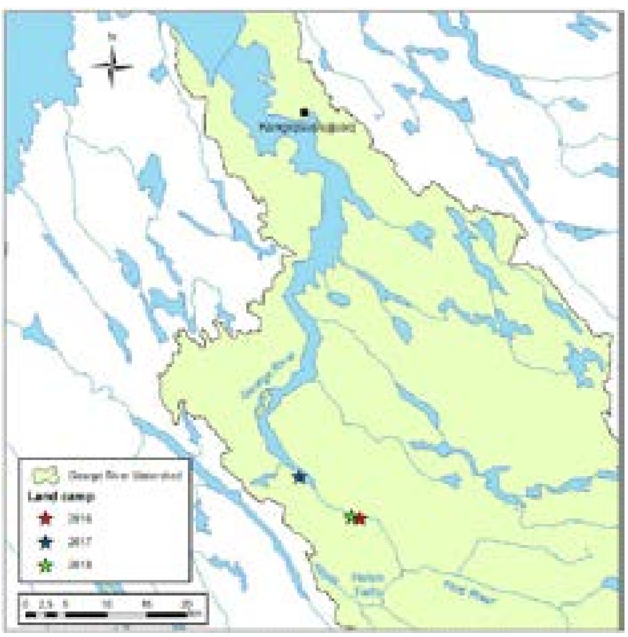
The main impetus for this project was to establish a functional community-based environmental monitoring program in a northern community. This objective was fulfilled because of the strong commitment of the community and its leaders, and their interest in developing knowledge linked to the possible establishment of a rare earth mine.

Using NCP funding as well as other sources, we conducted a science land camp with 13 youth members of the Kangiqsualujjuaq community, and involving 4 graduate students from University of Montreal and UQAT (Figure 6 a, b). School visits were also done, during which 30-40 young Inuit students were exposed to concepts related to geology. Three meetings were held with different stakeholders within the community (Youth committee, Mayor's office, Scientific Committee). A workshop to identify future research needs of the community was held with the Mayor of Kangiqsualujjuaq during the Arctic Change Conference, as well as in community with multiple stakeholders in early June. A workshop on interactive mapping training that was attended by 3 Northerners was also organized in Montreal during March 2018. In support to science land camp, 8 Northerners were hired as cooks, guides and assistants.

With respect to the collection of samples for environmental monitoring, some samples were collected by the students during the science camp. Further, 19 Northerners (including 16 hunters that were compensated) were involved in the collection of animals, using traditional methods.

Figure 6a. Participants of the 2017 Imalirijiit Science Land Camp

Figure 6b. Yearly land camp locations.



High quality of contaminant monitoring data collected by the community

The analyses of contaminants in environmental matrices represented one of the axes of the community-based environmental monitoring (other axes included hydrology, remote sensing, vegetation studies, and are not discussed here). Overall, our initial objective was to implement a high-quality monitoring program, with community sampling. The results of this first year are very promising in that respect. For instance, we successfully and reliably measured very low levels of REEs in water and vertebrate muscles. The general trends that we uncovered, namely the high REE levels in lichens and aquatic invertebrates compared to vertebrates, and the higher REE levels in vertebrate livers compared to muscles, are completely consistent with the only other published study on REEs in northern aquatic animals and plants in Canada (MacMillan et al., 2017). The concentrations of Hg found in country food were also consistent with past reports, with only some sculpins above regulatory guidelines regarding Hg levels in muscles.

In the future, we anticipate that this community-based environmental monitoring program will continue. On the basis of this initial study, the main recommendations are the following:

- Water samples for REE analyses should be taken every 2-3 years until a mine is operational, and then be taken at higher temporal resolution thereafter.
- For aquatic animals, the best choice of biomonitors appears to be the liver tissue of whitefish, since whitefish are common in the river and livers are more concentrated in REEs. They could also be collected every three years. Since invertebrates were difficult to sample and relatively rare in the rocky river-bottom, it not recommended at this time to included them in a routine monitoring program, even though they have higher levels of REEs. Additional sampling should be conducted at other times during the growing season to assess if invertebrates can be incorporated in the monitoring initiative.

- Lichens could be sampled over a wider geographical area every year, and REE concentrations could be mapped to establish the baseline atmospheric signature of REEs. They are promising biomonitors to follow the regional impact of a mine.
- Contaminant levels in country food could also be followed and organic contaminants could be incorporated in the analyses.

Expected Project Completion Date

March 2018

Project website (if applicable)

The construction of a web site and a Facebook page are planned for Fall 2019.

Acknowledgments

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Appendix A

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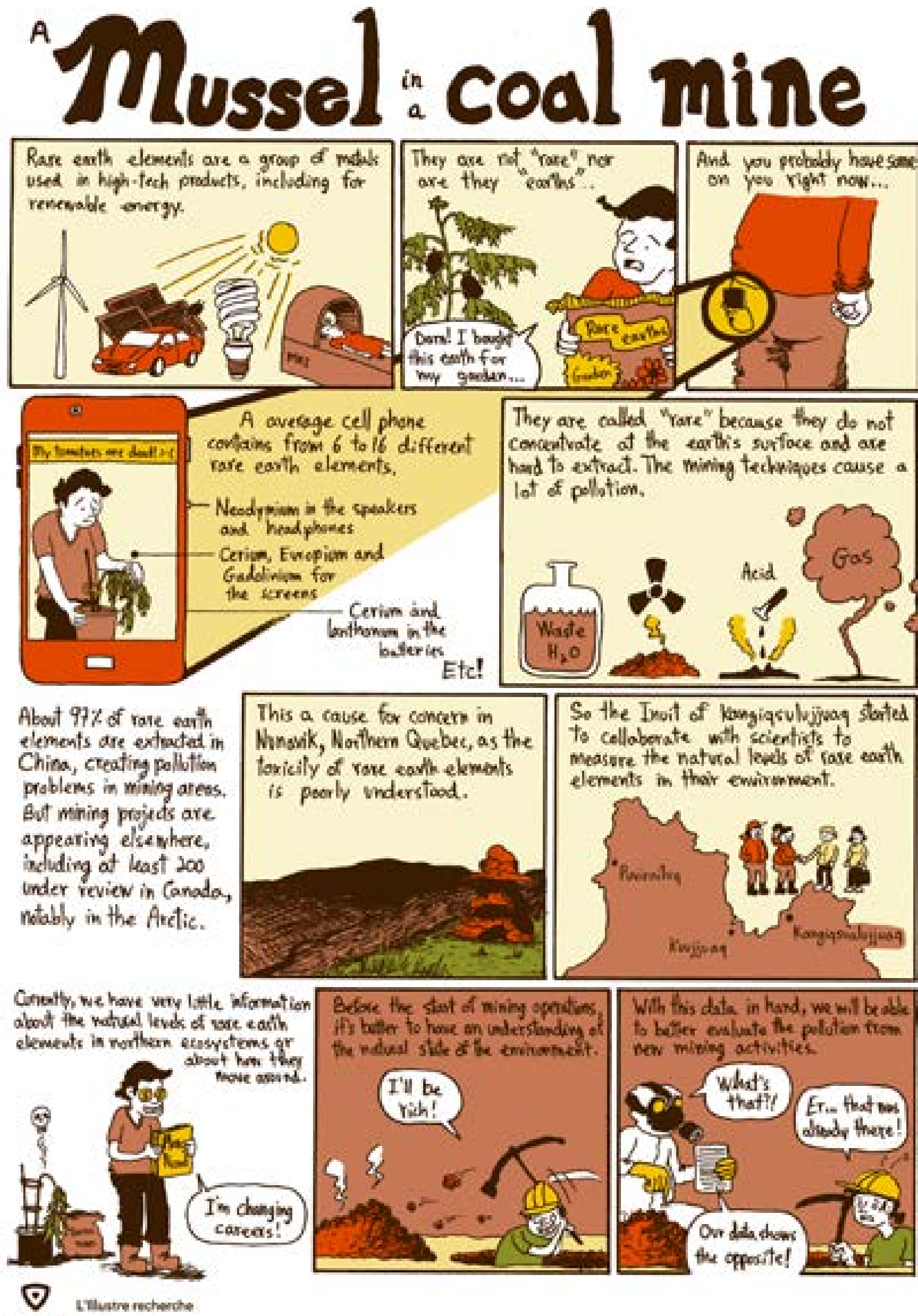
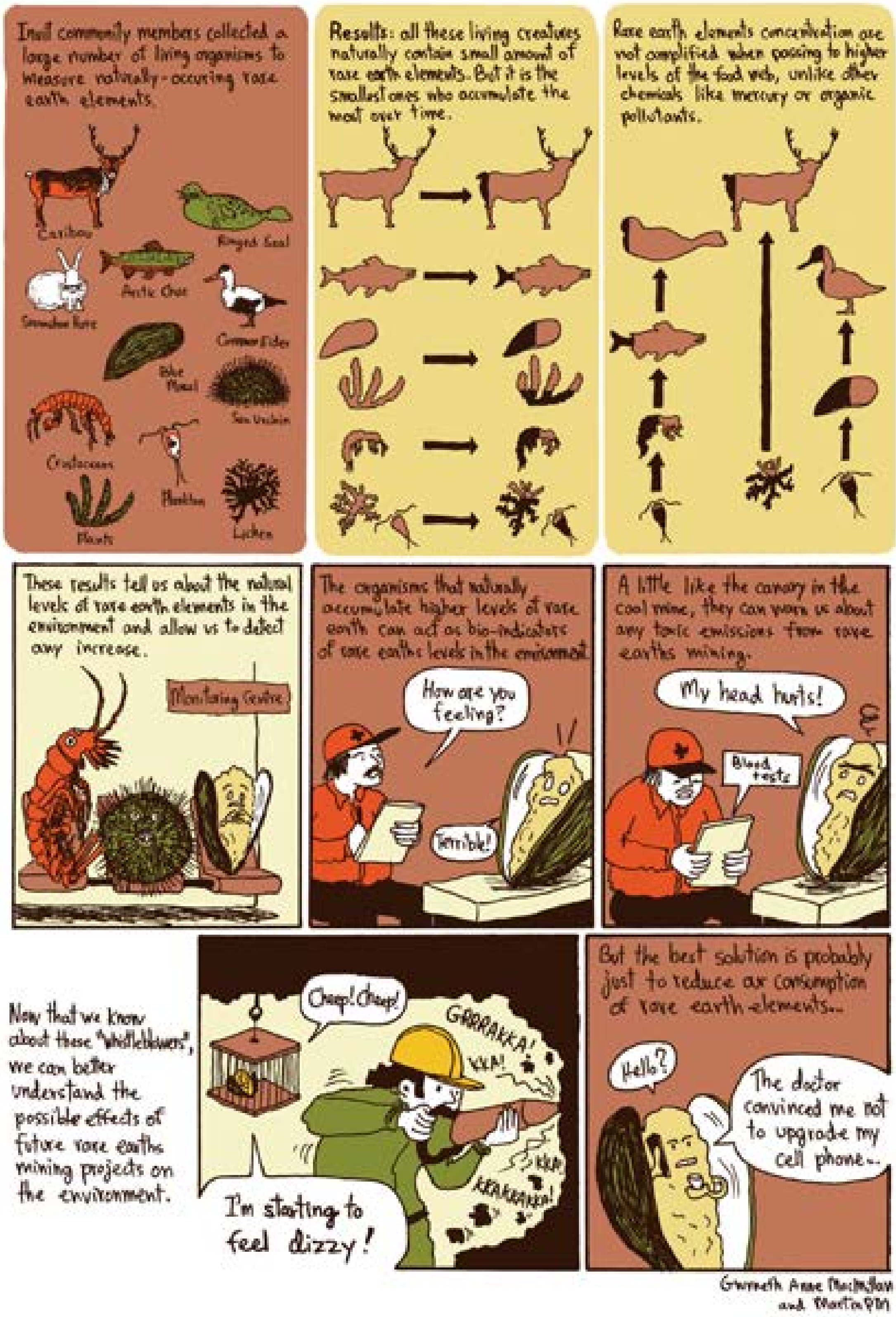



Inuit community members collected a large number of living organisms to measure naturally-occuring rare earth elements.
Caribou
Ringed Seal
Arctic Char
Snowshoe Hare
Common Eider
Blue Mussel
Sea Urchin
Crustaceans
Plankton
Plants
Lichen
Results: all these living creatures naturally contain small amount of rare earth elements. But it is the smallest ones who accumulate the most over time.
Rare earth elements concentration are not amplified when passing to higher levels of the food web, unlike other chemicals like mercury or organic pollutants.
These results tell us about the natural levels of rare earth elements in the environment and allow us to detect any increase.
Monitoring Centre
The organisms that naturally accumulate higher levels of rare earth can act as bio-indicators of rare earths levels in the environment.
How are you feeling?
Terrible!
A little like the canary in the coal mine, they can warn us about any toxic emissions from rare earths mining.
My head hurts!
Blood tests
Now that we know about these "whistleblowers", we can better understand the possible effects of future rare earths mining projects on the environment.
Cheep! Cheep!
GRRRAKKA!
KKA!
I'm starting to feel dizzy!
But the best solution is probably just to reduce our consumption of rare earth elements...
Hello?
The doctor convinced me not to upgrade my cell phone...
Gwyneth Anne MacMillan and MartinPM

Contaminants concentrations in traditional country food from the Eclipse Sound and dietary exposure in Pond Inlet, Nunavut: Science and local knowledge assessing a local baseline of the risks to human health

Concentrations de contaminants dans les aliments traditionnels du détroit d'Éclipse et exposition alimentaire à Pond Inlet, au Nunavut : utilisation des connaissances scientifiques et locales pour évaluer des données de référence locales à court terme sur les risques pour la santé humaine

Project Leader/Chef de projet

James Simonee, Community-based researcher, Pond Inlet, NU X0A 0S0, PO Box 23
Tel: 867-899-6060; Email: james@arcticonnexion.ca

Project Team/Équipe de projet

Vincent L'Hérault, ARCTIConnexion- Quebec City, and University of Winnipeg; Derek Muir, Environment Canada, Water Science and Technology Directorate, Burlington, Ontario; Xiaowa Wang, Environment Canada, Water Science and Technology Directorate, Burlington, Ontario; Chris Furgal, Indigenous Environmental Studies Program, Trent University, Peterborough, Ontario; Heidi Swanson, Department of Biology, University of Waterloo, Waterloo, Ontario; Pierre-Yves Daoust, Atlantic Veterinarian College, University of Prince Edward Island, Charlottetown

Project Location/Emplacement(s) du projet

- Pond Inlet, NU
- Emerson Island, NU
- Bylot Island, NU

Abstract

Traditional country food is vital to Inuit culture, as it has provided high-quality resources for millennia. With industrial development, natural contaminant concentrations (*e.g.* mercury) have, at times, increased in the atmosphere and oceans, accumulating in ecosystems and living organisms in the most remote Arctic regions with many adverse effects being identified on animal and human health. Balancing

Résumé

Les aliments traditionnels sont essentiels à la culture inuite et constituent une ressource de grande qualité depuis des millénaires. En raison de l'industrialisation, la concentration de contaminants naturels (*p. ex.* mercure) augmente parfois dans l'atmosphère et les océans, et ces contaminants s'accumulent dans les écosystèmes et les organismes vivants, même dans les régions les plus éloignées de l'Arctique, ce qui entraîne de

the benefits that country food represents to Arctic residents (body health, mental health, and culture) with the risks associated with the utilization of country food that contains contaminants is not an easy task.

In this Northern Contaminants Program (NCP) project, we monitored contaminants; mercury, trace metals and Persistent Organic Pollutants in different tissues of ringed seal, and documented local observations and knowledge in order to better understand this species as well as the community's exposure to contaminants. One of the most unique aspects of this project was that it was community-based under the lead of a local researcher and hunter, James Simonee, who received guidance from researchers from multiple university and research centres for training and guidance.

We (James Simonee, assistant, and research mentor Vincent L'Hérault) harvested and sampled 30 ringed seal from 3 different areas in the spring and fall of 2017. Contaminants and stable isotopes results are not yet available as they are still pending. We interviewed a total of 9 local participants; active hunters, elders and women on ringed seal about traditional uses, biology and ecology, population trends, and environmental changes. Interview results indicate a global decline in the ringed seal population of the Eclipse Sound region along with some observations of changes in blubber and pelt quality. Several causes to a declining seal population were discussed and included the rise of predators, shipping disturbance and contaminants. Based on the success of this baseline study and local capacity developed, we intend to pursue the expansion this project to other marine wildlife in the years to come.

nombreux effets néfastes sur la santé des animaux et des humains. Il n'est pas facile de concilier les avantages que représentent les aliments traditionnels pour les résidants de l'Arctique (santé corporelle, santé mentale et culture) et les risques rattachés à l'utilisation des aliments traditionnels qui contiennent des contaminants.

Dans le cadre de ce Programme de lutte contre les contaminants dans le Nord (PLCN), nous avons surveillé des contaminants comme le mercure, les métaux traces et les polluants organiques persistants dans différents tissus du phoque annelé et avons consigné des observations et des connaissances locales afin de mieux comprendre ces espèces ainsi que l'exposition de cette collectivité aux contaminants. Ce projet est tout à fait particulier puisqu'il s'agit d'un projet communautaire sous la direction d'un chercheur et d'un chasseur local, James Simonee, qui a été encadré et formé par des chercheurs de plusieurs centres universitaires et centres de recherche.

Nous (James Simonee, adjoint, et Vincent L'Hérault, mentor en recherche) avons récolté 30 phoques annelés et avons prélevé des échantillons de ces phoques provenant de trois secteurs différents au printemps et à l'automne 2017. Nous sommes toujours en attente des résultats sur les contaminants et les isotopes stables. Nous avons mené des entrevues avec neuf participants locaux; des chasseurs actifs, des aînés et des femmes sur les utilisations traditionnelles du phoque annelé, ses caractéristiques biologiques et écologiques, les tendances de sa population et les changements observés dans son environnement. Les résultats de ces entrevues révèlent un déclin général de la population de phoques annelés dans la région d'Eclipse Sound ainsi que certaines observations sur des changements dans la qualité du pannicule adipeux et de la peau. Plusieurs causes du déclin de la population de phoques ont été mentionnées, notamment la progression des prédateurs, les perturbations causées par le transport maritime et les contaminants. Compte tenu de la réussite de cette étude de référence et des capacités qui ont été acquises dans la collectivité, nous avons l'intention d'élargir ce projet pour qu'il englobe d'autres espèces marines au cours des prochaines années.

Key Messages

- This community-based project was led by a local researcher, with support from NCP researchers.
- This project harvested and sampled various tissues of 30 ringed seal for mercury, trace metals and Persistent Organic Pollutants. This allowed for among season comparison of contaminants in seal populations (lab results pending).
- Interview results suggest declining ringed-seal numbers in various traditional hunting areas.
- Interview results suggest potential linkages between declining seal and the rise of predators, shipping activity, and contaminants in the environment.

Messages clés

- Ce projet communautaire a été mené par un chercheur local, qui a été encadré par des chercheurs du PLCN.
- Dans le cadre de ce projet, des échantillons ont été prélevés sur différents tissus de 30 phoques annelés afin de mesurer les concentrations de mercure, de métaux traces et de polluants organiques persistants. Ces échantillons ont permis de procéder à la comparaison à l'intérieur d'une même saison des contaminants dans les populations de phoque (en attente des résultats de l'analyse en laboratoire).
- Les entrevues permettent de croire qu'il y a un déclin du nombre de phoques annelés dans différentes zones de chasse traditionnelles.
- Les personnes interrogées établissent des liens possibles entre le déclin du nombre de phoques et la progression des prédateurs, le transport maritime et la présence de contaminants dans l'environnement.

Objectives

This project aims to:

1. portray seasonal/spatial variation in mercury and trace metals concentration in ringed seal;
2. establish a baseline on POPs (legacy and newer concern POPs) for ringed seal; and,
3. document local observations and knowledge on the ecology of ringed seal, changes in populations, and environmental changes.

Introduction

Traditional country food is vital to Inuit culture as it has provided high-quality resources for millennia. The traditional practices associated with the hunt of wild animals and the use of derived products (e.g. skins for clothing) also contributes to community wellness as a whole. With industrial development in southern countries a century ago, natural contaminants concentration (e.g. mercury) have, at times, increased in the atmosphere and oceans, and have accumulated in ecosystems and living organisms in even the most remote Arctic regions. Persistent Organic Pollutants that are not naturally synthesized have also been released from industrial sources and now represent a great threat to the health of Arctic ecosystems, including marine food sources. Many adverse effects of contaminants on animal health and human health have been identified by experts, with infants being particularly vulnerable to contaminants. Balancing the benefits that country food represents to Arctic residents (body health, mental health, and culture) with the risks associated with the utilization of country food that contains contaminants is not an easy task.

In the early 2000s, mercury concentrations in ringed seal liver and kidney were well above Health Canada guidelines (0.5ug/g weight tissue) in Pond Inlet (Mittimatalik) as determined by other NCP scientists (Braune et al. 2015). However, no data has been collected since then in Pond inlet. Some POP (e.g. bromure derives utilized as flame retardants) concentrations have recently increased in marine mammal tissues and in human biomarkers in Arctic regions outside of Pond Inlet (Rotander et al. 2012, Hoguet et al. 2013). Beyond quantifying contaminant levels in wild animals, determining the mechanisms that causes the levels to vary is crucial for the community to better adapt and mitigate the risk.

In this 2017-18 NCP project, we (James Simonee, assistant, and research mentor Vincent L'Hérault) quantified the concentration of various contaminants in ringed seal for different organs and attempted to better understand the exposure levels of the community of Mittimatalik to contaminants by documenting local observations and knowledge.

Local research capacity in the field of contaminants science is still very limited in Arctic communities including Pond Inlet, and much remains to be done to promote and support community-based contaminants monitoring. This NCP project stems out of the motivation and interest of a local young hunter, James Simonee, who organized and led every aspect of the research project. We involved a team of mentors including high-profile NCP researchers to provide year-long mentorship and training opportunity both in Pond Inlet and at research centres.

We believe that this project complements past and current NCP-funded endeavours and provides quality data contributing to the existing large body of knowledge on contaminants in the Arctic. We also believe that, because it is led by a local researcher, this project will bring new perspectives and knowledge on the important question of risk communication and management.

Activities in 2017-2018

Mercury and trace metals concentrations in ringed seal and POPs (Objectives 1 and 2)

To determine spatial and seasonal variation in the concentration levels of ringed seal, we (James Simonee, assistants and research mentor Pierre-Yves Daoust) harvested seals in three different areas (Emerson Island, Pond Inlet, and Bylot Island) in the spring (ice season) and fall (ice-free season) of 2017 (Figure 1). In spring, field work was conducted by ski-doo for 3 weeks. In the fall, field work was conducted by boat for two weeks. During sampling periods, our daily work consisted of necropsy work on-site, recording body measurements, and collection and storage of specific animal tissues (meat, liver, blubber, fur, blood) utilized for contaminants analysis, isotope analysis, and infectious disease analysis. Samples collected were shipped to the Environment and Climate Change Canada's Burlington lab and the University of New Brunswick Sinlab for processing. Blubber samples were stored for future analysis of POPs levels.

Local observations and knowledge of ringed seal (Objective 3)

To explore local knowledge on ringed seal, we (James Simonee, assistant, and research mentor Vincent L'Hérault) conduct a series of individual interviews in the winter of 2018 with the Hunter and Trapper's (HTO) chair, active hunters and elders, and a group of local women. We designed a list of questions to structure the interview process (available upon request), yet interviews were conducted in a very flexible and open-ended fashion. We also performed mapping exercises to document spatial information. We were fortunate enough to run one interview on the land with an elder participant, which allowed documenting on-site information in a relevant context. Written consent was provided by each participant.

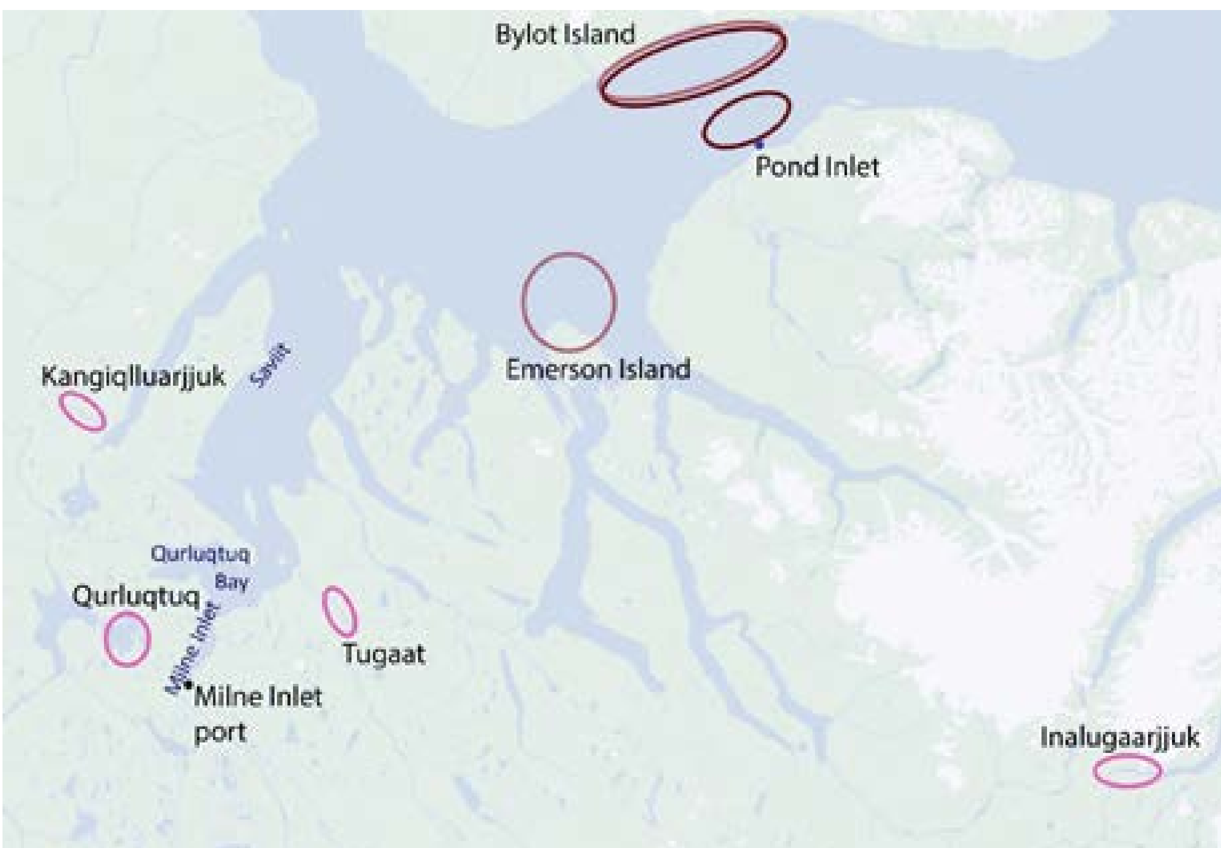
Community Engagement

Project leader, James Simonee, is a community-based researcher in Pond Inlet. James' research benefits from daily and continuous support from community members, fellow hunters, family, and the local Hunters and Trapper's Organization. 3 young assistants (Andrew Jaworenko, Jassie Simonee, and Ivan Koonoo) were trained during the project. They provided help during hunting trips, preparing sample bags, and sampling ringed seals. Through interviews of elders and hunters in town and out on the land, elders and hunters provided help and guidance during the project.

Capacity Building and Training

Veterinarian from the University of Prince Edward Island (PEI), Pierre-Yves Daoust, came to Pond Inlet in spring and fall of 2017 to provide field work training to James Simonee and assistants for the sampling and storage of specific animal tissue utilized for contaminants analysis. In September 2017 James travelled to PEI for 1 week to take part in advanced wildlife necropsy training with Pierre-Yves Daoust at the University of PEI. James travelled to Quebec City for 2 weeks in December 2017 for the Data Analysis and Communication workshops at ARCTIConnexion. Statistical analyses of Arctic char contaminants data (obtained in past research) were performed, while ringed seal samples (this project) were sorted and classified. Poster preparation was also part of the workshop. Research mentor Vincent L'Hérault travelled to Pond Inlet in the winter of 2018 to

Figure 1. Regional map of the study area. Pale and dark brown ellipses represent ringed seal harvest areas in spring and fall 2017, respectively. Pink ellipses represent harvest Arctic char harvest site in winter 2016 (for indicative purpose only).



provide a one-week interview research training to James Simonee and project assistants. Lastly, James Simonee travelled back to Québec City in the spring of 2018 for a one-week interview analysis and report writing training at ARCTIConnexion.

Communications and Outreach

Local

Project progress was shared along the way with members of the Mittimatalik Hunters & Trappers Organization during special board meetings, with a project poster delivered to the HTO as well. We also designed a Facebook page for the project for community outreach purposes for the community (see Project Website below). Presentation of the synopsis of a research report will be provided to HTO, with results highlights to be communicated and discussed on local radio.

National

Communications with a large public, academics and media were ensured through ARCTIConnexion's Facebook page (See Project Website below). Project progress and results were also presented in a poster presentation at ArcticNet conference in the fall of 2017 in Quebec City (Figure 2).

Indigenous Knowledge (see objective 3 in activities)

Indigenous knowledge was embedded in almost all aspects of this research project, since the project leader James Simonee (and his assistants) bears this knowledge. James conducted all interviews on his own, at times in Inuktitut, to gather information in the most culturally relevant way from other hunters, women, and elders. The scientific aspects of this project (sampling areas/sites and seasons) were designed using James' knowledge and hunting

Figure 2. James Simonee presenting his poster at the ArcticNet conference in the fall of 2017 in Quebec City.

experience, as well as knowledge contributed from local hunters. The main results obtained in interviews are described in the next section.

Results and Outputs/Deliverables

Results - Mercury and trace metals concentrations in ringed seal and POPs (Objective 1 and 2)

We harvested a total of 30 ringed seal during the project. 15 were harvested in the spring and 15 in the fall (Figure 2). The number of seal harvested varied among locations. In the spring, we harvested in Pond Inlet/Eclipse sound, Emerson island and Bylot island, whereas in the fall we were limited to Pond Inlet and Bylot areas due to weather conditions (strong winds). The number of male harvested in the spring was 4 times higher than the number of females harvested during that period, and no females were harvested during the fall (Figure 3). Unfortunately, this imbalance in the sex ratio could not be corrected for during the harvest as female and male are hard to distinguish at the distance where animals were shot. In the fall, the male-dominated sex ratio could be explained by the different habitat selection and migratory patterns among sex, where male were likely more available in the harvested areas (Pond Inlet and Bylot). At this moment, we do not have the age structure results available as the tooth-aging analyses are ongoing.

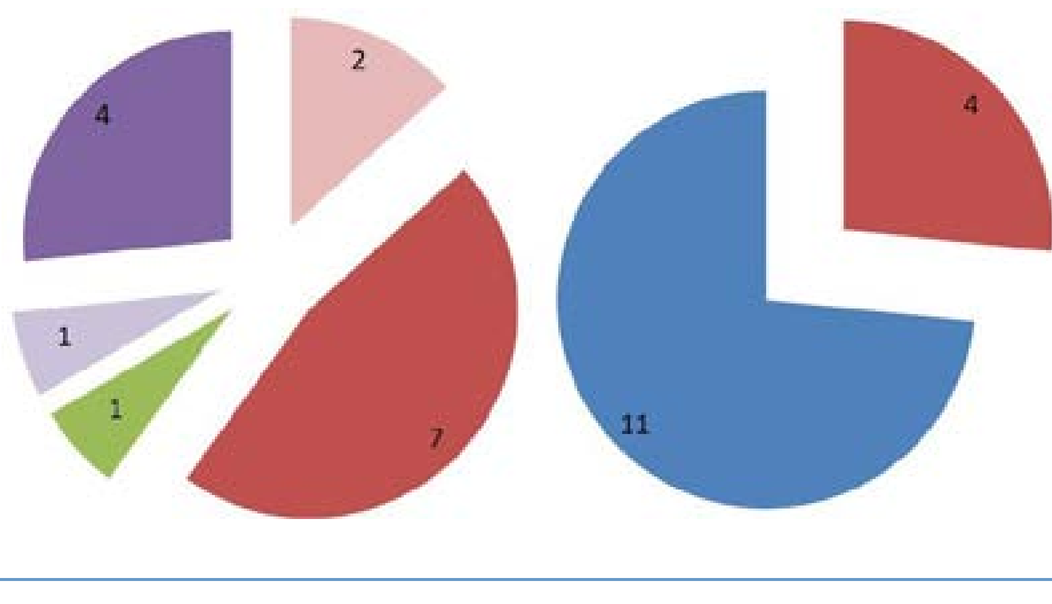
As for the contaminants results, we have not yet processed the mercury, methyl mercury and trace metals analysis on the samples collected in 2017. Stable isotope analyses and infectious disease analyses are also on the way. We will provide an update report of these results as soon as they are available (fall 2018). As planned for, these results will be shared with the Government of Nunavut's Health Department for whom we will seek advice before public release.

The deliverable for objectives 1 and 2 was a poster presentation at ArcticNet ASM 2017.

Local observations and knowledge of ringed seal (Objective 3)

We conducted individual interviews with 3 active hunters and 2 elders, as well as a group discussion with elder women. The key information documented is the following (full quotes are provided at the end of this report in the Appendix.

Figure 3. Summary of the ringed seal harvest in this study by season (left: spring, right: fall), area (Purple: Emerson Island, Green: Eclipse sound, Red: Bylot island, Blue: Pond Inlet), and gender (Female: pale colour, male: dark colour).



Uses of the seal

From the interview results, we learned that ringed seal formed the bulk of families' diets in the days prior to settlement. Seal were used with no waste; every part/organ had a use. Almost every organ but the bladder and gull bladder were used for food, blubber was used for heating, and skin/fur was prepared in different ways according to usage; boiling/shaving skin made it waterproof for kamiks, thicker skin in the spring was used for tent making. Women also reported that the wound of the seal would be plugged after the hunt so that even the blood could be used to feed dogs. Indeed, seal pelts were sold to the market which contributed to the local subsistence economy (**quote #1**).

As compared with the past, uses of seal are less diverse nowadays. Elders deplore the waste of the seal nowadays, even the meat, which contradicts with the traditional living principles and rules. Seal contributes less to food and clothing overall, even if some families hunt and use them extensively (**quote #2**).

Interestingly, seal pelts are not sold much in the market given their low value, but rather transformed into by-products such as mitts, kamiks, parkas, and pants, for which they can obtain a fair price locally and through social media selling platforms. However, according to women, such knowledge is being lost in the new generations and there is a need to bridge that gap (**quote #3**)

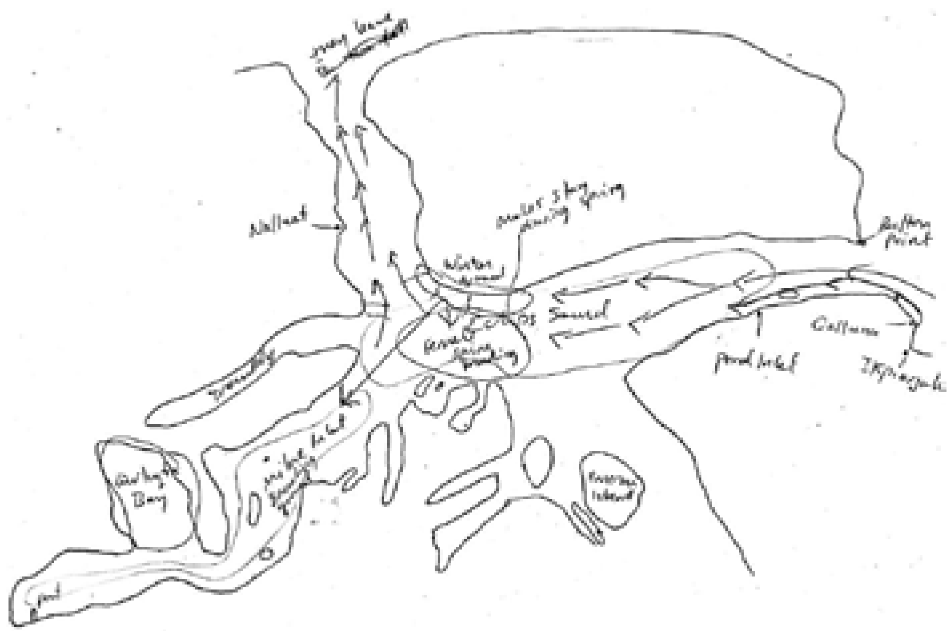
Biology/Ecology

From the interview results, we learned that seal has different morphology. Males have a bigger head than females, and seal can come in various sizes/length according to the areas they inhabit (**quote #4**).

Mating period happens in September when the seals gather in groups, and breeding happens in the late winter (**quote #5**).

A general migratory pattern is used by ringed seal inhabiting the Eclipse sound. In early winter when the floe-edge forms-up, ringed seal move in from the Baffin Bay to the west along the southern shore of Bylot Island (Figure 3). Most of them will overwinter in waters near the southwestern tip of Bylot Island, where there are a lot of open cracks in the sea ice. In the spring, males move closer to the shore and females migrate southward towards the middle of the

Figure 4. Hand-drawing of the regional map of the study area summarizing the main migratory patterns used by ringed seal near Pond Inlet. Information was provided by elder Moses Konark.



Eclipse sound (halfway to Emerson Island), and all along the Milne Inlet channel (Figure 4). Females will breed in these areas, and Inuit follow these patterns and set up hunting camps for seal pups (Figure 4). In the fall, seals gather and move up toward Nalluat and up to the Lancaster Sound.

Ringed seal mainly use cod, capelin, sculpin, staghorn, and amphipods as food sources. However, feeding habits may vary from one habitat to another.

Changes in condition (meat/blubber/fur quality)

From the interview results, we learned that the taste and quality of the meat has not seemed to change overtime, although the taste of seal from different areas isn't the same. Interestingly, it is more frequent to catch seal with thinner blubber of less quality marked with yellow spots (**quote #6**). Interestingly, the women had concerns about the quality of the fur that is considered thinner and softer nowadays (**quote #7**).

Population decline

From the interview results, we learned that most hunters/elders have observed important changes in the numbers of ringed seal in their respective traditional hunting area. That is, seals are harder to see than before in certain areas during the winter, whereas less breeding dens are found in others. Because our interviewees have experience from different areas, and because most of them also cover a large distance while hunting, we suppose that the declining trend in seal numbers is widespread in our study area (**quote #8-9**). The potential causes of the population decline are related to predatory pressure, mining related ship traffic, mining related dust pollution, and changes in ice conditions.

Predation pressure

From the interview results, we learned that the populations of predators of the seal, polar bear and killer whale, have increased in the area. The used to be a smaller number of polar bears but they are increasing nowadays and seem to be depleting the seal populations (**quote #10**). Killer whale are also more present and arrive earlier in the Eclipse Sound waters and can make seals flee away ashore (**quote #11**). Yet, whether or not killer whales contribute to decreasing seal numbers still remains to be seen as whales are the main prey of the killer whales.

Mining- shipping traffic

The increased shipping activity related to the export of iron ore from Baffin Land's Mary River project and Milnet Inlet port was a key concern for hunters and elders. Most of the hunters/elders interviewed have noticed important changes in the number of seals seen along the Milne Inlet channel (a key traditional breeding site, see Figure 4) and eastward from the community of Pond Inlet, i.e. where the shipping disturbance is the most intense (**quote #12-13**).

Mining-dust pollution

Hunters and elders were concerned about the iron dust being released in the environment, particularly near the Milne Inlet ports that connects to the marine ecosystem. The iron dust can be carried year-round by strong winds for several kilometers with potential for wildlife contamination during the summer when the sea ice melts. This contamination starts with the lowest trophic levels that can ingest the dust (**quote #14-15**).

Changes in ice condition

Several changes to the environment were reported by interviewees, but the most striking related to ice conditions. Most of the interviewees reported that the sea ice was thinner and melts earlier than in the past (**quote #16**). In the spring, the melting pattern is very different. Ice and snow used to melt on top of ice and form wide potholes filled with water and draining to seal holes. However, this phenomenon seems to be not frequent nowadays as the ice and snow seem to melt through the ice (**quote #16**). The implication of all of this on seal ecology is not well understood.

Expectations toward the future

From the interview results, we learned that most interviewees are very concerned by the changes in the seal population and the marine environment and most wish for decreased disturbance of the wildlife by the mining activities (**quote #17-18**). Changes have to occur through the younger generations who are the living force of adaptation (**quote #19**).

Discussion and Conclusions

Despite the fact that it is not possible to discuss the contaminants results due to our timeline for completion, we have learned that there are few aspects of our research sampling design that would require more attention in the future. First, future study design needs to take into account the unbalanced sex ratio of the seals sampled so far and, if necessary, to account for age classes. As shown in the interview results, it is also important to monitor seals from other areas of the Eclipse Sound, especially from the Milne Inlet channel that could be affected by additional contaminants sources (next to ocean-conveyed and atmosphere-conveyed contaminants sources). We also wish to increase our sample size in the areas already sampled, particularly for females.

Results from the interviews have provided a good baseline that allowed exploring different topics relating to ringed seal, its relationship to the environment and its importance for Inuit. We wish to use this body of knowledge as a guide to implement future research. As mentioned, documenting the Milne Inlet environment and wildlife, both through contaminants science and local knowledge, is a key to future research, particularly during the breeding months. Local knowledge on seal biology and migratory patterns can also be deepened in order to help protect and mitigate the impacts of shipping on ringed seal. An example of the possible application of this knowledge is through the determination of the most sensitive places and time of the year where shipping and or loading activities should be restricted. Local knowledge can also be used to avoid conflicts with local users. In general, interview results did not allow for the determination of food use patterns and exposure of the community to contaminants. More research, using a food survey, is needed to determine these two aspects.

Overall, this first year of research conducted on ringed seal allowed our team to get organized and build relationship between participants and mentors, involve the community of Pond Inlet; build capacity locally; start the collection of samples for contaminants analysis and others; meet with and collect baseline information from local hunters, elders and women; and outreach with researchers and other actors from outside the community. Our intention is to pursue the work started here as it relates to ring seal, and expand to other marine wildlife such as narwhal. We also wish to deepen some research questions based on previous work conducted on Arctic char contaminants.

Expected Project Completion Date

Fall 2018 (pending contaminants results, stable isotopes and infectious disease results)

Project Website

Facebook pages

https://www.facebook.com/Contaminants-monitoring-in-marine-country-food-in-Pond-Inlet- 1391819457614529/

https://www.facebook.com/ArctiConnexion-174923069277728/?ref=hl

Website

https://dev.immensite.ca/arctic
in development)

Acknowledgments

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Appendix - Interview Quotes

1. *"The seal meat is my food ever since I could remember and it was only our source of food, and I know that if there were no seal I won't be existing"*
   Jaykolassie Kiliktee

2. *"Winter is terribly cold up here and the hunters needed northern clothing. It is not nice to see people suffering cold due to no winter clothing."*
   Qamaniq Sangoya

3. "*I always wondered that as an elder today and after we're gone, the younger generations will be struggling to have no knowledge on sealskin preparing… I feel strongly that our young people need to learn the ways of Inuit knowledge*" **Regellie Ootook**

4. *"If we can look at those fiords, all of them have a bigger seal kind inhabiting there, and down the bay [eclipse sound] has smaller seals, then all the way down where the floe edge is there is even smaller seal inhabiting."* **Sam Oomik**

5. "*In February the seals start making dens for breeding shelters, and in March they make more dens everywhere… the breeding last 2 months starting March/April…Inuit look for soft snow den hunting pups.*" **Joanassie Mucpa**

6. *"I have seen some with that problem [with lesions], but not many, and when we cut open seal, it's noticeable that has yellow, or red spotted blubber. It's possible that this is caused by something."*
   Moses Konark

7. "*Have any one of you noticed as you worked on sealskin that some of the skin has soft parts? Also noticed that as I worked on the sealskin that its thickness has been longer than normal now, I've been wanted to ask this question, why is that? Maybe the water's getting warmer?*
   Qamaniq Sangoya

8. *"I haven't heard people caught any seals from that area [Milne Inlet] as they used to, as hunters usually talks about catching animals wherever they're hunting at, seems like the seals that used to be there do not around there anymore. We also used to go Qurluqtuq camp, that time there were many seals inhabited there. That was many years ago, now that the seals not there anymore, since the site is being built for loading and unloading place."*
   Moses Konark

9. *"The place that is Naggutiqaqpaktuq and Saattut camps all that used to be inhabited so many seals that where there is gone, anywhere there was ice cracks used to be full of seals no more now it is empty, all around the Igluluarjuit; qikiqtaarjuit, before that Tunnuujaqtalik as well as Qaiqsuarjuit all those ice cracks including Ivisaat, Igarjuaq that we used to wait stationery to hunt all that have nothing any more, it's been changed."*
   Sam Oomik

10. *"I could tell that when seal breeding time begins, the seal pups are being eaten more than ever by polar bears anywhere, even around near Pond Inlet here. It's hard to hunt for seal pups for us today, because the polar bears are taking over that hunting"* **Jaykolassie Kiliktee**

11. *"I remember that those sea mammals used to come around September, today they're arriving as soon as the ice melts they're here, maybe they're more increasing. I know for sure that they're more of them today, and that affecting seals too. I remember when there were more seals before the killer whales were too many around, now the seals would come near the shore, but they do not come around the shore when killer whales around. "* **Moses Konark**

12. *"I remember long before mining began in operations at Milne Inlet, there used to be lots of seals surfaced on a thin ice in the early winter. Then we went there after the mining began, and there were no seals on the thin ice where they're used to be surfaced on ice, not anymore that has been changed, I think the loading ship is getting in the way for the seal inhabitation in that area, and that the person is saying that the seals fled somewhere."* **Moses Konark**

13. *"I would want loading ships stop routing around there, we hunt sea mammals there, I got very angry when they're stopping around where we hunt, stopping waiting to get loaded. Last year where I was hunting narwhal around Qurluqtuq water, then not long after I harpooned whale I went hunting some farther up and there was a loading ship stopping where I want to hunt narwhal at Iqaluit, so I went up to the captain telling him aggressively and the next day that boat left."* **Sam Oomik**

14. *"Coming from here and ongoing up near Iluvilik, there's red powdery dust everywhere on the ice, but as coming closer over there more red dust is all over the ice, that type of dust melts the snow faster and some of it is real red colour."* **Abraham Kunuk**

15. *"That probably is impacting wild animals and fish that there, because of dust being blown away everywhere there, and that can cause fish impacted as well, when the ice melts there, that will become muddy with iron in the water and the water species that fish and seal eats can be effected on, that's my point of view."* **Moses Konark**

16. *"But we all noticed that the ice freezes thin every year today, but before, when the snow melts on top of the ice, the water used to flow into the seal holes, then the water that's top of the ice would be drained thru the seal holes only, then it was nice white smooth for travelling again, when the ice starts to melt the second time and finally melts all the way down thru the sea water, and before the snow melts completely that used to form deep potholes, which wasn't fun to travel on that ice back then, as it formed so bumpy. Especially the river's mouth gets fast melting today, and we all know that it has changed."* **Jaykolassie Kiliktee**

17. *"We do not want to seal be banned or vanished as well as other animals up here. We're used to the seal as our food, our body needs it and if we do not have the seal meat our body gets weak. Some of us do not use to the store groceries, doesn't seem to get satisfy our bodies with that food, but when we eat seal meat that's a different story, we then satisfy our tummies for a long time. So therefore, we Inuit still depend on wild animals as our food, so I want as an Inuk that our environment is safe, because we all know that if the environment were to be ruined, then the whole community would be ruined too, and in this map this area of Milne Inlet site was to be ruined with all kinds of toxic and chemicals, then the whole area there can be ruined as well."* **Jaykolassie Kiliktee**

18. *"For people who need a job, of course, they would be impacted by a closed mine, but for any other reasons that wouldn't be matter, because Inuit people aren't working at that mine, only few have a job there, though I know this community is helping that mining but that mining does not help this community. I know that for sure that we need to protect the wildlife environment, then gaining financially."* **Moses Konark**

19. *"I believe our younger generation will have more ideas to protect the environment, because they learned easily and faster, and they got lots of potential, they are our future with more power and educated."* **N/A**

Mobilizing Inuit Knowledge and land use observations to assess ecosystem trends and processes affecting contaminants

Mobiliser les connaissances Inuites et les observations sur l'utilisation des terres pour évaluer les tendances et les processus dans l'écosystème affectant les contaminants

- **Project Leader/Chef de projet**

  Dr. Joel Heath, Executive Director, The Arctic Eider Society, 52 Bonaventure Ave., St. John's, NL, A1C 3Z6 Tel: 613-416-9607 x 2; Fax: 613-701-0326; Email: info@arcticeider.com

  Mr. Lucassie Arragutainaq, Manager, Sanikiluaq Hunters & Trappers Association / Board of Directors, Arctic Eider Society, House 408B, Sanikiluaq NU, X0A 0W0 Tel: 867-266-8709; Email: sanihta@qiniq.com

- **Project Team/Équipe de projet**

  Dr. John Chételat, Environment and Climate Change Canada, Ottawa, ON; Dr. Steven Ferguson, Fisheries and Oceans Canada, Winnipeg, MB; Johnny Kudluarok, Arctic Eider Society, Sanikiluaq, NU; Dr. Robert Letcher, Environment and Climate Change Canada, National Wildlife Research Centre (NWRC), Carleton University, Ottawa, ON; Dr. Gita Ljubicic, Carleton University, Ottawa, ON; Dr. Scot Nickels, Inuit Tapiriit Kanatami, Ottawa, ON

- **Project Location/Emplacement(s) du projet**

  Sanikiluaq, NU

Abstract

The community of Sanikiluaq has been working to develop novel ways to systematically document Inuit knowledge and observations of ecosystem trends and processes. This project formed a key proof-of-concept for using the new SIKU.org platform and mobile app to document Inuit hunting stories of seals and polar bears. In doing so, this app and platform will provide context on animal ecology, diet, body condition and associated environmental conditions that could benefit contaminants research. In addition to ongoing consultation and co-development with Inuit, a workshop was held in Sanikiluaq in fall

Résumé

La collectivité de Sanikiluaq s'est efforcée de trouver de nouvelles méthodes pour documenter de façon systématique les connaissances inuites et les observations des tendances et des processus touchant l'écosystème. Ce projet a consisté à valider le bien-fondé de l'utilisation de la nouvelle plateforme SIKU.org et de l'application mobile pour consigner les témoignages d'Inuits sur la chasse au phoque et à l'ours blanc. Cette application et cette plateforme permettront ainsi de constituer un contexte sur les caractéristiques écologiques de ces animaux,

2017 to guide development of the mobile app and platform in the context of documenting seal and polar bear diets and body condition for Northern Contaminants Program (NCP) research. The community was highly supportive and workshop outcomes guided development of features, approaches to intellectual property and other details of the platform, mobile app and overall project.

Following development of the mobile app through fall 2017, field testing to document seal and polar bear diet and body condition began in winter 2018. Preliminary testing in January helped guide improvements and proof-of-concept for a fully functional mobile app and online platform was achieved in early March by Inuit hunters. The mobile app is now consistently allowing over a dozen hunters to document diet, body condition, associated sea ice and other conditions around seal and polar bear harvesting, as well as for other species, sea ice habitat features. The app works offline using a built in GPS and camera, and syncs up data and media to the online platform on return to wifi range.

With proof-of-concept for mobilizing raw data behind Inuit harvesting activities achieved, the next phase of the project is to deliver a 3 year pilot study that will a) provide an adequate database of Inuit observations for preliminary analysis, b) provide real-time trends and summaries of wildlife diet/condition for hunters and communities using SIKU, c) develop the back end for bulk transferring raw data (e.g. diet, body condition, etc.) to contaminants researchers in a framework that respects the intellectual property rights decisions of Inuit SIKU users d) directly incorporate these results into contaminants research and e) provide a full evaluation of the three year pilot program, including the ability to scale the tools developed for this project to more generally incorporating Inuit harvesting observations into contaminants research programs across the Arctic.

sur leur alimentation, l'état de leur corps et les conditions environnementales connexes qui pourraient faire progresser la recherche sur les contaminants. En plus de consultations continues et du développement concerté avec les Inuits, un atelier s'est tenu à Sanikiluaq à l'automne 2017 pour orienter l'élaboration de l'application mobile et de la plateforme dans le but de consigner des renseignements sur l'alimentation des phoques et des ours blancs pour la recherche du Programme de lutte contre les contaminants dans le Nord (PLCN). La collectivité a manifesté beaucoup d'intérêt pour l'atelier, dont les résultats ont orienté la conception de caractéristiques, les approches de la propriété intellectuelle et d'autres aspects de la plateforme, de l'application mobile et de l'ensemble du projet.

À la suite de l'élaboration de l'application mobile au cours de l'automne 2017, des essais sur le terrain ont été menés à l'hiver 2018 pour consigner le régime alimentaire et l'état corporel des phoques et des ours blancs. Les essais préliminaires menés en janvier ont contribué à orienter les améliorations, et la validation du concept d'une application mobile et d'une plateforme en ligne entièrement fonctionnelles a été réalisée au début de mars par des chasseurs inuits. L'application mobile permet maintenant à plus d'une douzaine de chasseurs de consigner systématiquement des données sur l'alimentation, l'état corporel, la glace de mer et d'autres conditions pertinentes pour la chasse au phoque et à l'ours blanc, ainsi que sur des caractéristiques de la glace de mer pour l'habitat d'autres espèces. L'application fonctionne hors-ligne au moyen d'un GPS et d'un appareil photo intégrés, et les données et les médias sont synchronisés avec la plateforme en ligne dès que l'appareil se trouve à portée d'un accès à Internet sans fil.

Maintenant que la validation du concept de la mobilisation des données brutes sur les activités de récolte des Inuits est effectuée, la phase suivante du projet consiste à réaliser une étude pilote de trois ans qui a) représentera une base adéquate de données d'observation des Inuits à des fins d'analyse préliminaire, b) présentera des tendances et des résumés en temps réel de l'alimentation et de l'état de la faune pour les chasseurs et les collectivités qui utilisent SIKU, c) élaborera l'interface d'arrière-plan pour le transfert en vrac des données brutes (par exemple, sur le régime alimentaire ou l'état corporel) aux chercheurs sur les contaminants dans un cadre qui respectera les décisions en matière de droits de propriété intellectuelle des utilisateurs inuits de SIKU, d) intégrera directement ces résultats à la recherche sur les contaminants et e) fournira une évaluation complète du projet pilote de trois ans, ce qui suppose notamment la capacité d'adapter les outils conçus pour ce projet de manière à intégrer de façon plus générale les observations sur la récolte par les Inuits aux programmes de recherche sur les contaminants de l'ensemble de l'Arctique.

Key Messages

- The community consultation and planning workshop in Sanikiluaq indicated strong support for the project and provided guidance on approach to developing the mobile and online tools to document wildlife diet, body condition, and environmental conditions as a part of harvesting activities, towards use of Inuit observations in contaminants research.
- Online platform (Figure 1) and mobile app (Figure 2) and features were developed in SIKU to support local hunters documenting, sharing and archiving observations from harvesting activities in support of contaminants research.
- A Proof-of-concept was achieved for the project by Inuit hunters in Winter 2018 with observations from hunters now showing on the SIKU.org platform
- The next phase of the project involves a three-year pilot program to continue to collect Inuit harvesting observations for seals and polar bears, develop real-time analysis and data synthesis tools in SIKU, use these data in research on contaminants pathways for seals and polar bears, and provide a full evaluation on the success of this approach

Messages clés

- L'atelier de consultation de la collectivité et de planification tenu à Sanikiluaq a permis de constater que le projet bénéficie d'un fort appui et d'orienter la conception des outils mobiles et en ligne qui permettent de consigner des renseignements sur le régime alimentaire, l'état corporel et les conditions environnementales dans le cadre des activités de récolte, dans le but que les observations des Inuits soient utilisées dans la recherche sur les contaminants.
- Les fonctions de la plateforme en ligne et de l'application mobile ont été conçues dans SIKU afin d'aider les chasseurs locaux à consigner, à communiquer et à archiver leurs observations découlant de leurs activités de récolte pour appuyer la recherche sur les contaminants.
- Les chasseurs inuits ont validé le concept du projet à l'hiver 2018 en formulant des observations qui figurent maintenant dans la plateforme SIKU.org.
- La phase suivante du projet consiste à mener un projet pilote de trois ans qui servira à continuer la collecte des observations sur la récolte des Inuits concernant les phoques et les ours blancs, à concevoir

towards meaningfully incorporating Inuit observations into contaminants science.

des outils d'analyse en temps réel et de synthèse des données dans SIKU, à utiliser ces données dans la recherche sur les chemins par lesquels les contaminants se rendent aux phoques et aux ours blancs et à procéder à une évaluation complète de la réussite de cette approche qui vise à réussir l'intégration des observations des Inuits aux connaissances scientifiques sur les contaminants.

Figure 1: Screenshot from SIKU news feed showing seal hunting stories documented by elder Peter Kattuk and youth Puasi Ippak. The "capelin" diet tag is visible in the news feed as well as in the detailed post view. The location shows on the map on the right, with recent sea ice satellite imagery from Sentinel 2 selected as a background demonstrating local ice conditions (radar, MODIS and other imagery are also available as well as historical weather/tide data from the time the post was created on the land).

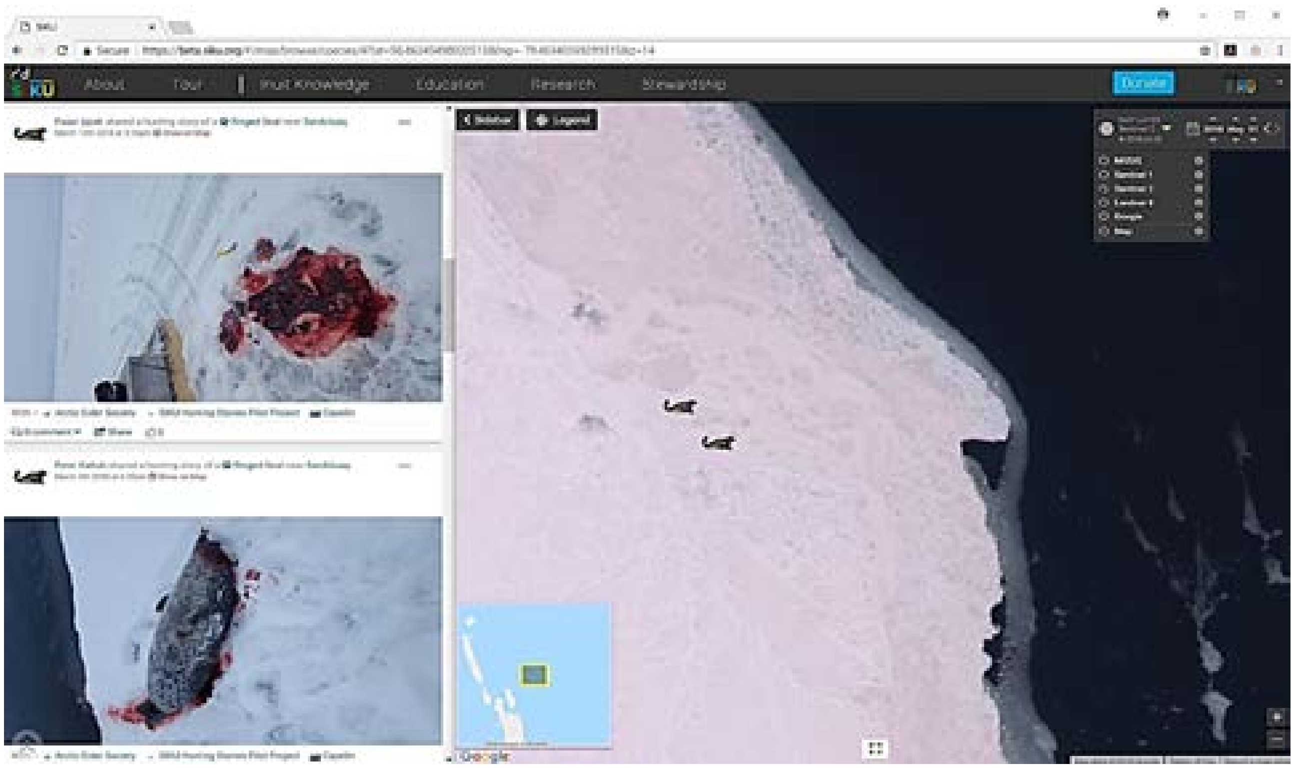
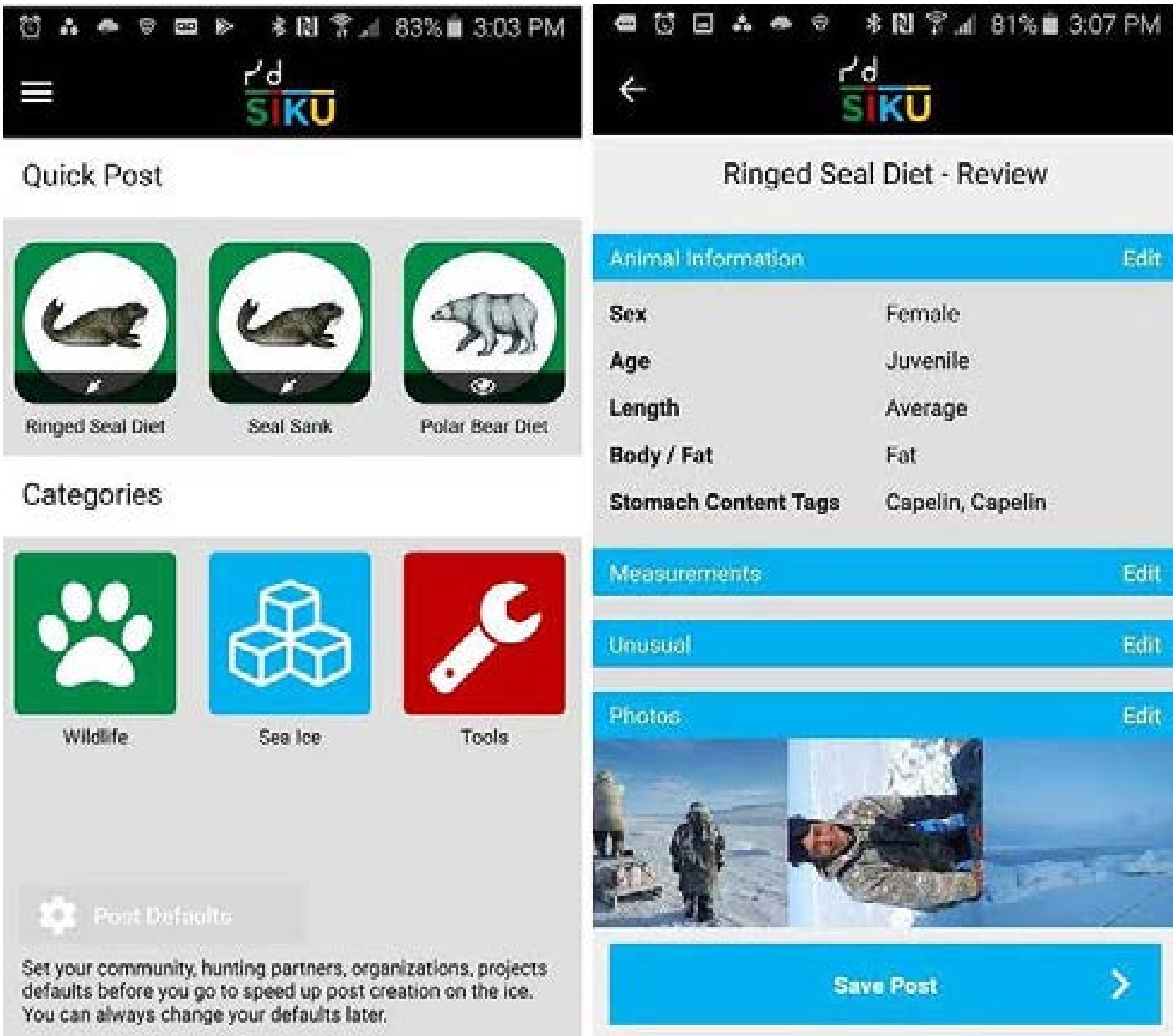


Figure 2: Screenshot from SIKU mobile app showing "quick posts" created specifically for the NCP program (left) along with a shot of a portion of the Review screen asking the hunter to confirm and submit the information provided during the post creation (previous screen, not shown). Body condition and diet information are shown along with photos. The mobile app works offline with the built in GPS, clock and camera and saves the posts so they can be uploaded when the hunter returns back to the community.



Objectives

This project aims to:

- build on existing capacity in Sanikiluaq for participatory research, and based on identified priorities and indicators, workshop the current project towards systematically documenting Inuit knowledge and observations, including approach, data management, intellectual property rights, and details of participatory approaches, priority indicators and how they are documented;
- build on capacity and ongoing community-driven research programs, training and employing local hunters to collect wildlife and sea ice observations during land-use activities (i.e., subsistence hunting and ongoing community-driven research programs), including the meaningful involvement of youth in research and monitoring efforts;
- lead the systematic collection by hunters of observations on the body condition and diet of important food species (with a focus on ringed seal and polar bear) through participatory methods and photos of harvested animals (Figure 3), their organs and stomach contents;
- build linkages with the Arctic Eider Society's existing community-driven research programs and SIKU.org Inuit Knowledge Wiki and Social Mapping Platform towards making project results accessible to community members in near-real time, providing a forum for ongoing feedback and updates on results/observations, ensuring the project is truly community-driven and contributes to regional environmental stewardship efforts through ongoing consultation, workshops and meaningful engagement in all components of the project; and,

Figure 3: Four photos submitted by Sanikiluaq hunters using the SIKU mobile app showing a number of key indicators relevant to understanding contaminants levels. From left to right: Diet (shrimp); Body Condition (fat); Pregnant (foetus shown); Injured (lesion on skin of flipper). The latter two were not originally parameters measured in SIKU; however, the flexibility of the app and approach allowed hunters to begin documenting these additional parameters right away. They are now formally incorporated into SIKU.

- evaluate proof-of-concept for the above objectives, and if successful, plan next steps for providing synthesis of Inuit knowledge indicators to contaminants researchers and develop 3-year pilot program towards a full evaluation of the project approach to incorporating Inuit knowledge and observations into contaminants science including the ability to scale to other communities, species and benefit contaminants research more generally across the Arctic.

Introduction

Ecosystem changes across the Arctic are increasingly evident, and could influence contaminant uptake and accumulation in the food web. To make more effective mechanistic connections between emissions and the accumulation, fate and trends in contaminant levels in tissues of high trophic level marine species such as ringed seals and polar bears, further research on factors affecting trends is required. This research requires knowledge of ecosystem changes collected over the same time periods as contaminants research and monitoring. More detailed knowledge of e.g. ringed seal and polar bear dietary profiles will define, with higher resolution, the source of exposure of POP contaminants, and how such contaminants are influenced by factors such as changing body condition and ice conditions. From these perspectives, Inuit observations will directly impact interpretation of contaminant levels and trends in polar bears and their ringed seal prey. Northern community members have the greatest expertise in observing and documenting ecosystem changes, and identifying key indicators and priorities for monitoring trends that could affect processes including contaminants accumulation. This project seeks to provide culturally relevant tools for systematically documenting local observations and indicators, making them accessible to community members for ongoing feedback, and contributing to the assessment of changes over time in ecosystem components including those related to key NCP monitoring species.

Diet and local environmental conditions can be important contributors to the accumulation and movement of contaminants, including trace metals and legacy and emerging persistent organic pollutants (POPs); tracing these contaminants is a priority of NCP. Stomach contents can provide additional context about how trace metals bioaccumulate in food webs, and can help contribute to risk assessments of traditional foods. Climate change is shifting animal ranges and phenology, which could have impacts on Arctic food webs and metal accumulation.

The project builds on the extensive capacity for community-driven research and monitoring in Sanikiluaq through the Hunters and Trappers Association (HTA), the Arctic Eider Society, and long term relationships with our diverse project partners. It also expands on ongoing projects, training, and tools developed for monitoring oceanographic conditions, sea ice habitats, wildlife, and contaminants in the marine food web. This includes a network of experienced community researchers, youth engagement and communications/outreach tools, particularly the SIKU.org platform. This platform was developed to date through funding from the Google.org Impact Challenge in Canada award in 2017 which provided substantial added value and matching funds to this project. It also builds on:

- Long term monitoring programs (e.g., for ringed seals and polar bears by the NCP and DFO);
- A legacy of participatory Inuit Knowledge documentation (e.g. Voices from the Bay);
- New projects evaluating participatory tools and approaches for documenting and sharing Inuit knowledge of changing ecosystems components (e.g. a participatory mapping evaluation project and Inuit knowledge of cumulative environmental impacts study in Sanikiluaq), through collaborations with Dr. Ljubicic at Carleton.

The approach of this project allows simultaneously addressing community priorities and those of scientific researchers studying contaminants. For example, in addition to being concerned about contaminants in key prey species, Inuit hunters in Sanikiluaq have noticed changing diets of ringed seals (e.g. from arctic cod to shrimp; Piita Katuk, personal communication) and have indicated that documenting and understanding these changes in diet is a priority; additionally, NCP researchers are interested in how changes in diet and food web dynamics can affect contaminants accumulation for ringed seals and polar bears. While these priorities for studying seal diets were arrived at independently, the approach of the current proposal allows addressing them simultaneously and collaboratively, while developing capacity for similar synergies that are possible through systematically documenting and mobilizing Inuit knowledge for environmental stewardship.

This project leveraged extensive matching funds and support and successfully delivered all core objectives including consultation workshops and proof-of-concept of the mobile app and online platform for documenting subsistence activities with Inuit harvesters. It is now ready to expand on this success and momentum to deliver a comprehensive three year pilot program using the new tools to systematically document harvesting activities, to develop real time data synthesis and visualization on the SIKU.org platform, to develop a framework for sending Inuit observations to contaminants researchers, while respecting Inuit intellectual property rights decisions, and more generally assessing the utility of these tools and approaches for incorporating Inuit knowledge and observations into contaminants research activities, for application at scale across the Arctic.

Activities in 2017-2018

Community Engagement

Host initial planning and consultation workshop in Sanikiluaq

A three-day workshop was organized in Sanikiluaq bringing together contaminants researchers with hunters, youth and members of the Sanikiluaq Hunters and Trappers Association to begin the process of engaging the community in all aspects of the project design and implementation. The workshop outcomes indicated strong support for the project and identified approaches and tools for documenting Inuit observations through the SIKU.org mobile app and online platform, dealing with intellectual property rights and options, and developing culturally relevant features including Inuktitut terminology for sea ice and environmental conditions. The workshop was initially planned for spring 2017; however, the late timing of the funding announcement for this new project led to the workshop taking place in fall 2017.

Ongoing consultation/development with Community liaisons

The Arctic Eider Society works closely with our community liaisons and board members from Sanikiluaq on an ongoing basis to direct programs and activities. Johnny Kudluarok and Lucassie Arragutainaq provided invaluable feedback in consultation with local hunters and youth that shaped and directed the development and project activities on an ongoing basis.

Field training and testing of the mobile app and online platform in Winter 2018

In January 2018, hunters and youth were provided with mobile devices and training in how to use the SIKU mobile app towards documenting Inuit observations during subsistence activities.

Feedback from hunters and youth on app features and framework

Extensive field testing of the mobile app began in early winter 2018. Early feedback helped shape multiple upgrades to improve the application by making it more intuitive for Inuit hunters and youth, to improve robustness to Arctic winter conditions, and to deal with northern offline and low bandwidth network infrastructure. This was further tested and proof-of-concept for consistent, reliable use of the mobile app documenting Inuit hunting stories was achieved in early March with hunters and youth continuing to use the app on an ongoing basis.

Capacity Building and Training

This project has helped build substantial capacity for community-driven research in Sanikiluaq including involvement of youth, transfer of Inuit knowledge and language (particularly sea ice terminology) from elders to youth during workshops and land use activities. It is more generally building capacity for Inuit self-determination in research and monitoring and working to improve how Inuit knowledge is incorporated into scientific research including contaminants research.

Communications and Outreach

The project involved extensive communications and outreach, including a plenary presentation at the Arctic Change 2017 conference in Quebec City, and broad media coverage through high profile TV, Radio, Newspaper and online coverage from all major media outlets as a part of our Google.org impact challenge campaign, which leveraged substantial matching funds for the project. Additional press coverage was received at the Arctic Change conference in Quebec City including CBC morning shows and an article in Le Soliel. Detailed press coverage is available at www.arcticeider.com/en/news and on the SIKU platform directly.

Indigenous Knowledge

This project's focus is explicitly on documenting and mobilizing Inuit knowledge and evaluating the ability of new tools to help incorporate Inuit knowledge and observations into contaminants research.

Results and Outputs/Deliverables

The project successfully achieved all of the project objectives including successful consultation and planning, proof-of-concept for developing the mobile app and online platform tools through SIKU.org and testing these in the field to document Inuit observations towards incorporating them into contaminants research. The primary deliverable is a generic mobile app and online infrastructure which can now be used to document and mobilize Inuit knowledge and observations more generally into contaminants and other research and will provide long-term benefits to Inuit self-determination in research.

Discussion and Conclusions

With proof-of-concept now achieved through successful consultation and implementation of the SIKU.org tools and mobile app by Inuit hunters, the project is ready to transition to being a more extensive three-year pilot study to broadly document seal and polar bear diet, body condition during subsistence activities, and to expand this to monitor other wildlife species. This next phase of the project will continue to work closely with community liaisons, hunters and youth to guide project activities including the development of real-time synthesis and analysis of the diet and body conditions results for Inuit hunters and communities, deliver these raw data to contaminants researchers while respecting intellectual property rights decisions of users, and complete a formal evaluation of how this approach can be more generally used for meaningfully incorporating Inuit knowledge and observations into contaminants research. It is quite clear that more information on wildlife diets is a key component of improving contaminants research, thus this project will formally evaluate how more information can be gathered and used through Inuit community-driven approaches, and how this can be scaled to other communities, regions and types of projects across the Arctic.

Expected Project Completion Date

This preliminary, one-year proof-of-concept project was successfully completed in March 2018. The second phase of this project is a three-year pilot program and full evaluation of the newly developed tools and approach that is slated for completion in March 2021.

Project Websites

- www.arcticeider.com
- siku.org (live project results available at https://beta.siku.org/)
- www.facebook.com/arcticeider/
- www.twitter.com/arcticeider/

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This project would not have been possible without extensive support and participation from the community of Sanikiluaq. Piita Kattuk, Puasi Ippak, Johnassie Ippak, Johnassie Inuktaluk, Jack Iqaluq, Lucassie Ippak, Josie Amitook, Charlie Novalinga, and Johnny Kudluarok in particular played key roles in testing the mobile app and providing ongoing feedback. Elders Jimmy Iqaluq and Johnny Kavik as well as the Sanikiluaq Hunters and Trappers Association Board and Council of the Municipality of Sanikiluaq provided key feedback during project development and consultation. Matching funds for this project were provided through the Google.org Impact Challenge in Canada. Substantial discounts for airfare were provided by Air Inuit. Extensive in kind support was provided through the Nunavut General Monitoring Plan, ArcticNet, Nunavik Marine Region Wildlife Board, Cree Nation of Chisasibi, Tides Canada, Polar Knowledge Canada, Fisheries and Oceans, Environment and Climate Change Canada, the University of Manitoba and Carleton University. Finally, we would like to acknowledge the funding and support of the NCP.

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

Project Leader/Chef de projet

Joel Heath, Executive Director, The Arctic Eider Society, 52 Bonaventure Ave. St. John's, NL A1C 3Z6
Tel: 1-613-366-2717; Email: heath.joel@gmail.com

John Chételat, Environment and Climate Change Canada, National Wildlife Research Centre, 1125 Colonel By Drive, Carleton University, Ottawa, ON K1A 0H3
Tel: (613) 991-9835; Fax: (613) 998-0458; E-mail: john.chetelat@canada.ca

Project Team/Équipe de projet

Raymond Mickpegak (Sakkuq Landholding Corp., Kuujjuaraapik); Lucassie Arragutainaq (Hunters and Trappers Association, Sanikiluaq); Allie Nalukturuk (Niqautik Hunters Association of Inukjuak); Annie Kasudluak (Amiturvik Landholding Corp., Umiujaq); John Lameboy (Cree Nation of Chisasibi)

Project Location/Emplacement(s) du projet

- Sanikiluaq, NU
- Inukjuak, QC
- Umiujaq, QC
- Kuujjuaraapik, QC
- Chisasibi, QC

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,

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 (RRC) de la Société des Eiders de l'Arctique a été établi pour mesurer et pour mieux comprendre les effets environnementaux cumulatifs à grande

Inukjuak, Umiujaq, Chisasibi), this NCP project is generating new information on contaminants (specifically metals) that provide a regionally integrated perspective on metal exposure in the East Hudson Bay and James Bay marine environment. The five communities sampled coastal bioindicator species (blue mussel, common eider, sea urchins) between 2015 and 2017. Offshore bioindicators (ringed seal, herring gull, plankton, marine sculpin, arctic cod) were additionally collected from Kuujjuaraapik, Inukjuak and/or 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.

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 (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 ont prélevé des échantillons d'espèces bioindicatrices côtières (moule bleue, eider à duvet, oursins) de 2015 à 2017. Des échantillons sont en outre prélevés sur des espèces bioindicatrices en mer (phoque annelé, goéland argenté, plancton, chabots vivant en milieu marin, morues polaires) par les collectivités de Kuujjuarapik, d'Inukjuak et de 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 des changements environnementaux.

Key Messages

- Blue mussels, sea urchin, common eider, Arctic cod, marine sculpin, and ringed seal were collected by community team members in East Hudson Bay and James 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 SIKU (https://www.beta.siku.org - previously called Interactive Knowledge Mapping Platform; IK-MAP).

Messages clés

- Les membres de l'équipe communautaire dans l'est de la baie d'Hudson et la baie James ont recueilli des moules bleues, des oursins, des eiders à duvet, des morues polaires, des chabots vivant en milieu marin et des phoques annelés.
- 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 SIKU (https://www.beta.siku.org, auparavant appelée carte interactive des connaissances).

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

This project is supporting 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 2017-2018

A list of the indicator species, tissue types and sample sizes collected over the 3 years of the project (2015 to 2017) are provided in Table 1.

In 2017, collections by community participants resulted in 88 animal samples, specifically blue mussel, sea urchin, common eider, Arctic cod, marine sculpin, plankton (amphipods, shrimp), and small prey fish (in gut contents of cod and sculpin). Animal tissues collected in 2017 are currently being processed at the National Wildlife Research Centre for chemical analyses. A new chemical analysis was conducted this year, sulphur stable isotopes, at the GG Hatch Stable Isotope Laboratory (University of Ottawa). Carbon and nitrogen stable isotopes were measured on all samples from the project, and the addition of sulphur isotope measurements on a subset of 160 samples will allow for a more detailed diet analysis and characterization of the trophic transfer of metals in the marine food web.

Over the three-year project, we have made excellent progress in collecting several bioindicators of metal bioaccumulation in the study area (Table 1). A total of 261 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.

Community Engagement, Capacity Building and Communications

In December 2015, the Arctic Eider Society released its Interactive Knowledge Mapping Platform (IK-MAP) for community-driven research and in 2017 this received a major upgrade with support from Google and was rebranded as SIKU. This online tool and mobile app provide near real-time results to communities in a user-friendly social media framework, with data and metadata 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 to 2017 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.

A workshop was held in Sanikiluaq during the week of October 9-13, 2017 to further guide development of SIKU: The Inuit Knowledge Wiki and Social Mapping Platform, for NCP and other research programs with community members and the Hunters and Trappers Association. The workshop provided an opportunity to present information on the contaminants project through a talk that was given on October 11 by John Chételat. On the same trip, John met on October 13 with the Sakkuq Landholding Corp. of Kuujjuaraapik (Raymond Mickpegak, Willie Novalinga) to discuss progress on the project.

Table 1. Tissue types, sample sizes, and locations of indicator species collected in 2015 to 2017 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)
2017	Blue mussel (*Mytilus edulis*)	Whole (no shell)	19	Sanikiluaq (10 pools) Inukjuak (6 pools) Chisasibi (3 pools)
2017	Sea urchin	Gonads	14	Sanikiluaq (10 pools) Inukjuak (4 pools)
2017	Common eider (*Somateria mollissima*)	Liver, muscle	3	Chisasibi (3)
2017	Arctic cod (*Boreogadus saida*)	Liver, muscle	27	Inukjuak (27)
2017	Sculpin (*Myoxocephalus* spp.)	Liver, muscle	11	Inukjuak (11)
2017	Small prey fish (gut contents)	Whole	2	Inukjuak (2 pools)
2017	Amphipods, shrimp, cumacean	Whole	4	Chisasibi (1 pool) Inukjuak (3 pools)
2017	Ringed seal (*Pusa hispida*)	Liver, muscle	8	Sanikiluaq (8)

This project has played an important role in connecting research among remote communities in Nunavut, Nunavik and the Eeyou Marine Region. These connections were further built upon as a part of larger scale efforts of the Arctic Eider Society through the Hudson Bay Consortium and a Hudson Bay Summit (February 27 to March 1 2018), which brought together Inuit and Cree from 27 communities around the Bays as well as Indigenous, provincial/territorial and federal agencies to discuss stewardship of the region. In particular, a workshop on coordinating research and identifying priorities provided a means to bring together the communities involved in this project and consider larger scale coordination of research priorities across the region, including contaminants research. A full report from the Hudson Bay Summit is forthcoming and there will be opportunities to further coordinate contaminants research through working groups and meetings of the Hudson Bay Consortium.

A scientific poster on this project was presented by John Chételat at the International Conference on Mercury as a Global Pollutant in July 2017 (Providence, Rhode Island, USA) and at a Science Café for senior leaders of Environment and Climate Change held in Ottawa in January 2018.

Indigenous Knowledge

A strong background of Indigenous Knowledge and consultation has guided the development of the East Hudson Bay Network, which was formalized initially in Voices from the Bay (McDonald et al. 1997) and further developed in meetings and workshops conducted by the Nunavut Hudson Bay Inter-Agency Working Group (NTK). This innovative approach has combined Indigenous Knowledge from each community to identify knowledge gaps and priorities for the region, which include contaminants monitoring as a part of assessing cumulative impacts of environmental change and hydroelectric developments. Field programs for this project were run by local hunters and Indigenous knowledge was used to identify field sampling sites and timing of sampling activities during the program to ensure minimal environmental impact and to maximize the effectiveness of the research. Partnering youth with more experienced hunters as a part of the field programs provided opportunities for Indigenous Knowledge transfer related to wildlife distribution, hunting skills and other environmental knowledge and skills, training the next generation of community driven researchers and helping preserve this essential local knowledge base.

Results and Discussion

Mercury, lead and cadmium concentrations in animals of East Hudson Bay and James Bay are presented in Table 2.

Concentrations of mercury ranged three orders of magnitude, with more mercury in animals that feed at a higher trophic 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 (Braune et al. 2015).

Total mercury concentrations in blue mussels were compared among communities to examine spatial variation in bioaccumulation within the study area. The average total mercury concentration of blue mussels was highest north of Chisasibi in James Bay (Holms $p<0.01$) and lowest in blue mussels around Sanikiluaq (Figure 1). The higher mercury concentrations near Chisasibi suggest that freshwater inputs from the La Grande Reservoir to James Bay may be impacting mercury bioaccumulation near the base of the food chain. Although statistically significant differences were found among communities, overall, average levels of total mercury in blue mussels were relatively low, ranging from 0.138-0.281 µg/g dry weight (Figure 1).

Figure 1. Total mercury concentrations in blue mussels collected in 2015 to 2017 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 = 54). Bars with different letters were statistically different (Holm's p-value <0.05).

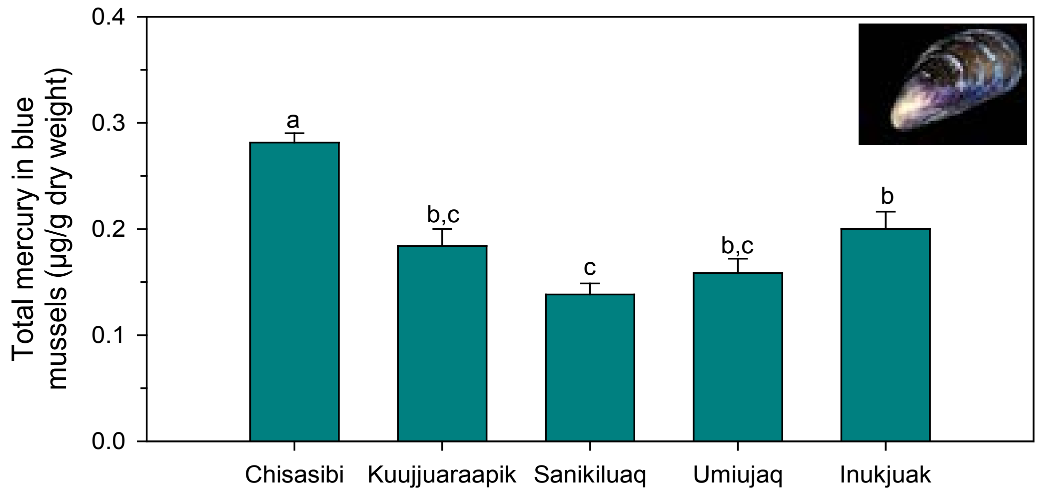

Table 2. Total mercury, lead and cadmium concentrations in animals collected in East Hudson Bay and James Bay in 2015 to 2017. Concentrations are presented on a dry weight basis. Average concentrations were not reported (---) if most of the values were below analytical detection. Note that some data are not reported here due to on-going laboratory analyses. n.d. = not determined

		Total Mercury (µg/g)		Lead (µg/g)		Cadmium (µg/g)	
Animal (Tissue)	Sample Size	Average	Range	Average	Range	Average	Range
Blue mussel (whole)	54	0.182	0.078-0.359	0.81	0.16-3.53	5.55	2.21-14.1
Sea urchin (gonad)	14	0.072	0.31-1.14	0.09	0.03-1.94	1.23	0.51-2.21
Arctic cod (liver)	57	0.061	0.010-0.316	---	<0.01-0.16	0.95	0.08-9.37
Arctic cod (muscle)	16	0.505	0.148-1.29	---	<0.01-0.04	---	<0.01-0.02
Sculpin (liver)	31	0.168	0.054-0.413	---	<0.01-0.09	2.19	0.20-12.9
Sculpin (muscle)	15	0.563	0.162-1.21	---	<0.01-0.03	---	<0.01-0.03
Common eider (liver)	55	1.67	0.116-11.5	0.04	<0.01-0.14	15.80	0.08-123
Common eider (muscle)	27	0.399	0.084-1.64		n.d.		n.d.
Herring gull (egg)	10	1.47	0.661-2.60	---	<0.05	---	<0.01
Ringed seal (liver)	24	16.1	0.783-146	0.05	<0.01-0.35	20.1	1.13-63.3
Ringed seal (muscle)	15	0.750	0.156-2.21	---	<0.01-1.38	0.16	0.06-0.32

Lead concentrations were typically very low (often below analytical detection) in most animals, with the exception of slightly higher levels in blue mussel and sea urchin. Lead does not biomagnify through marine food webs and concentrations are higher in animals near the base of the food chain (Dietz et al. 1996). Cadmium concentrations were higher in blue mussel, higher in liver than muscle of marine fish, and highest in liver of common eider and ringed seal. Similar cadmium concentrations have been reported in other Arctic marine regions (Dietz et al. 1996, Brown et al. 2016).

Conclusions

The final year of the project was completed successfully, with animal collections that focused on filling data gaps including the sampling of a new indicator species (sea urchin). The science generated from this NCP project will provide valuable information on: (1) metal levels in locally harvested marine animals, (2) spatial variation in metal bioaccumulation within the study area, and (3) 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.

Expected Project Completion Date

The field collections were completed in 2017 and the project funding ended in March 2018. Data analysis and reporting is on-going.

Project website (if applicable)

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

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

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

Project Leader/Chef de projet

Mary Gamberg, Gamberg Consulting, 708 Jarvis St. Whitehorse, YT Y1A 2J2
Email: mary.gamberg@gmail.com

Project Team/Équipe de projet

Lars Qaqqaq, Baker Lake, NU; Emma Kreuger and Keenan Lindell, Arviat NU

Project Location/Emplacement(s) du projet

- Baker Lake, NU
- Arviat, NU
- Chesterfield Inlet, NU
- Rankin Inlet, NU
- Whale Cove, NU

Abstract

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, it was hypothesized that the caribou may be getting additional mercury from this source. Interviews with elders and hunters in four Kivalliq communities indicated that Qamanirjuaq caribou forage for lichens on the tundra and hilltops in the winter and for lichens and other vegetation (including seaweed) on lakes, rivers and the seashore in the summer. Mercury concentrations were significantly and consistently lower in seaweed than in mushrooms and lichens in four Kivalliq communities, suggesting that seaweed is not a major source of mercury for the Qamanirjuaq caribou. Results of this project were presented to five Kivalliq communities in the fall of 2017.

Résumé

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, une hypothèse veut que le caribou ingère des quantités additionnelles de mercure à partir de cette source. Au cours d'entrevues, des aînés et des chasseurs de quatre collectivités de la région de Kivalliq ont indiqué que le caribou de Qamanirjuaq cherche des lichens dans la toundra et le sommet des collines en hiver et des lichens et d'autres plantes (y compris des algues) dans les lacs, les rivières et la rive pendant l'été. Les concentrations de mercure étaient toujours largement inférieures dans les algues par rapport aux champignons et aux

lichens dans quatre collectivités de Kivalliq, ce qui permet de croire que les algues ne sont pas une source importante de mercure pour le caribou de Qamanirjuaq. Les résultats de ce projet ont été présentés à cinq collectivités de la région de Kivalliq à l'automne 2017.

Key Messages

- Qamanirjuaq caribou forage for lichens on the tundra and hilltops in the winter and for lichens and other vegetation (including seaweed) on lakes, rivers and the seashore in the summer.
- Seaweed in the Kivalliq region is very low in mercury.
- Seaweed is not a major source of mercury to the Qamanirjuaq caribou.

Messages clés

- Le caribou de Qamanirjuaq cherche des lichens dans la toundra et le sommet des collines en hiver et des lichens et d'autres plantes (y compris des algues) dans les lacs, les rivières et la rive pendant l'été.
- Les algues dans la région de Kivalliq contiennent très peu de mercure.
- Les algues ne sont pas une source importante de mercure pour le caribou de Qamanirjuaq.

Objectives

This project aims to:

- determine if seaweed is a major contributor of mercury to the Qamanirjuaq caribou;
- gather Indigenous knowledge about caribou foraging habits in the Kivalliq region;
- measure mercury concentrations in caribou forage from the Kivalliq region: lichen, seaweed and mushrooms; and,
- 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 Indigenous 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 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 mercury 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. These extra samples could be accommodated since no samples were collected from Whale Cove (due to poor weather during the collection period) and no seaweed samples were collected from Baker Lake (since they do not exist there).

An important aspect of this project is the building of capacity in the North. Interviews with hunters and elders, sample collections and communications activities were conducted by three recent students of the Environmental Technology Program (ETP) at Arctic College in Iqaluit. In addition, with help from the Dept. 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 (Baker Lake and Arviat, NU).

Activities in 2017-18

Interviews were transcribed from Inuktitut to English (Bobby Suluk, Arviat) and comments were coded by Mary Gamberg and Lars Qaqqaq. Results were analyzed for frequency of occurrence.

Vegetation samples were analyzed for total mercury, and a subset for methylmercury. Results were analyzed comparing vegetation type, community and distance from the ocean (lichens and mushrooms only).

Results of the project were presented in person to five Kivalliq communities in the fall of 2017 by Mary Gamberg and Lars Qaqqaq.

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 the project researchers, giving them invaluable experience in conducting interviews, and doing research (collecting samples). Vegetation samples were collected in each of four communities 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 trained in vegetation and data collection as well as GPS use. Lars Qaqqaq assisted in those collections in Baker Lake and then participated in the communication of results of the study in five communities in the Kivalliq region as well as at the NCP Results Workshop in Yellowknife in September 2017.

Communications

Lars Qaqqaq and Mary Gamberg presented results of this project to Hunters and Trappers Organizations (HTOs) in Baker Lake, Chesterfield Inlet, Rankin Inlet, Whale Cove and Arviat in September 2017. Results were also presented in poster format and a presentation by Lars Qaqqaq at the NCP Results Conference in Yellowknife in September 2017. A manuscript for publication is currently being prepared by Lars Qaqqaq and Mary Gamberg.

Indigenous Knowledge Integrations

This project hinges on the exploration of Indigenous 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

Interviews

Most interviewees agreed that caribou eat mosses/lichens and seaweed. Mushrooms and shrubs/branches were mentioned by two and berries and bones/antlers by one elder. Seaweed was thought to be more commonly consumed in summer and mosses/lichens more in winter. There was less clarity on whether bulls and cows had a similar diet; one elder described bulls eating less during the rut and digging up plants from the clay at that time. Caribou were observed more in winter on tundra, lakes and hilltops and more in summer on lakes, rivers and the seashore. They were also observed in marshy areas.

Total mercury concentrations did not differ between lichen species (*Flavocetraria cuculatta* and *Cladonia mitis*), between seaweed species (*Laminaria digitate* and *Fucus distichus*) or between mushroom genera (*Boletus* and *Agaricus*). They also did not differ significantly among communities (Arviat, Rankin Inlet, Chesterfield Inlet and Baker Lake). Highest and most variable concentrations were found in mushrooms, and levels in seaweed were significantly lower than those in mushrooms and lichens (Figure 1). Methylmercury averaged 3% of total mercury (ranged from 1-7%); this proportion did not differ among lichen, mushrooms and seaweed.

Figure 1. Total mercury concentrations in vegetation from the Kivalliq region, NU.

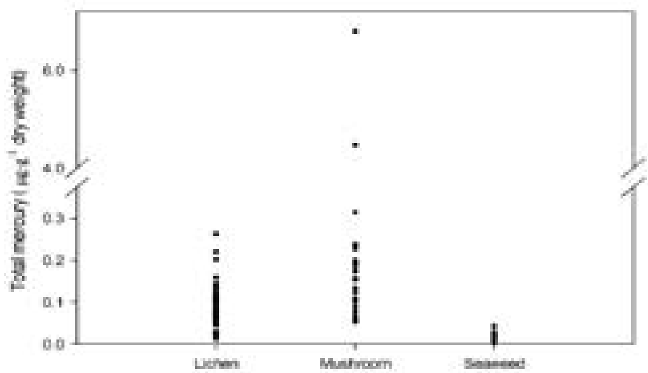
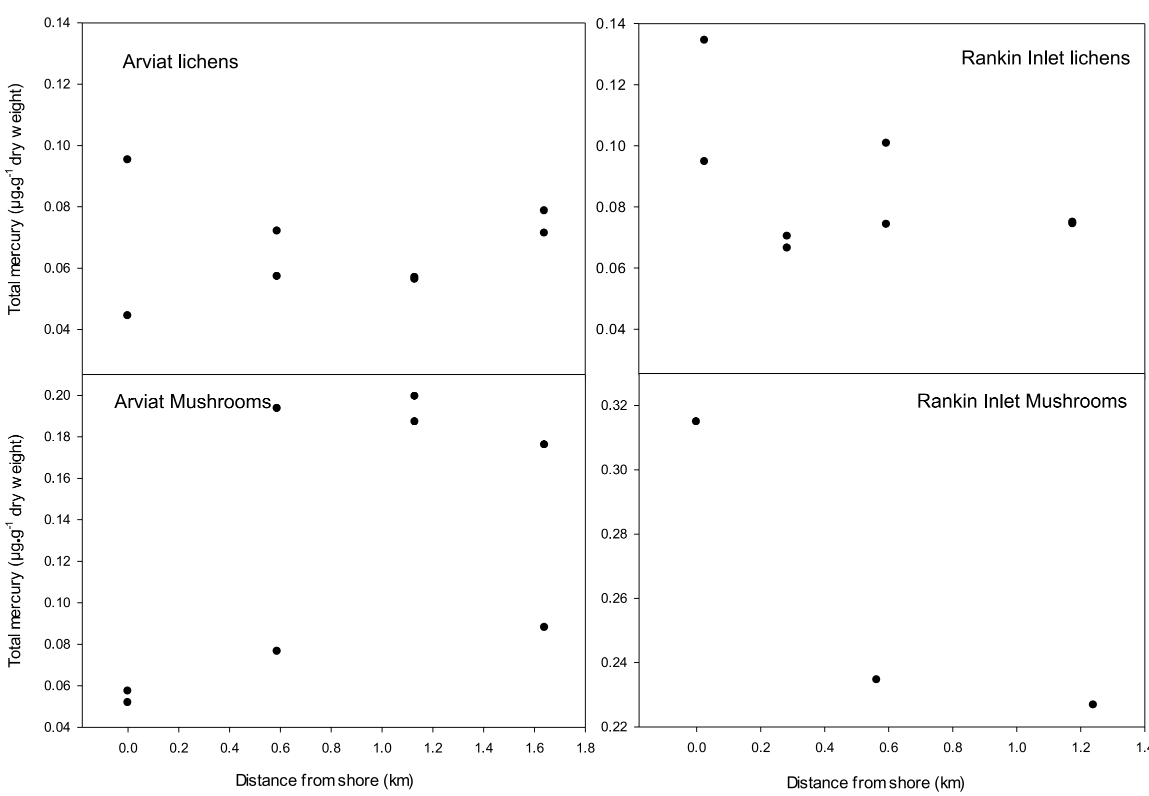


Figure 2. Total mercury concentrations in mushrooms and lichens from Arviat and Rankin Inlet relative to distance from shore.



In Arviat and Rankin Inlet, lichens and mushrooms were collected at four locations, starting at the seashore and then moving progressively inland. Mercury concentrations showed a general downward trend with distance from the shore in both mushrooms and lichens in Rankin Inlet. However, the relationship was not statistically significant for lichens and a statistical test was impossible for mushrooms since there were only three samples. Neither lichens nor mushrooms showed any trend with distance from the shore in Arviat. (Figure 2).

Discussion and Conclusions

Interviews with elders and hunters indicated that caribou eat mosses/lichens in the winter from the tundra and hilltops where they are more likely to be exposed. In the summer they eat other vegetation, including seaweed, in addition to the mosses/lichens, and are more likely to be found by lakes, rivers or the seashore. Some suggestions were made that caribou eat seaweed to get salt, and one elder described multiple caribou on Coats Island dying as a result of eating too much seaweed. It could be that the seaweed itself was the cause of death (perhaps by altering the balance of electrolytes), and it is also possible that those caribou had no other forage available and starved since seaweed consumption may represent a last attempt to avoid starvation under particularly severe foraging conditions (Hansen and Aanes 2012).

Total mercury concentrations in lichens and mushrooms did not decrease with distance from the seashore as was demonstrated by St. Pierre et al. (2015). It should be noted that in this study, only four locations with a maximum distance of 1.7 km from the ocean may not have been sufficient to show a possible trend.

Mercury concentrations were significantly and consistently lower in seaweed than in mushrooms and lichens. This suggests that even if similar quantities of these plant groups were consumed, seaweed would not be a major source of mercury for caribou. Indigenous Knowledge indicates that seaweed is consumed incidentally by caribou in the Kivalliq region, and mushrooms are available seasonally and are dependent on wet weather. Therefore, we can conclude that seaweed is not a significant source of mercury for the Qamanirjuaq caribou and that lichens remain the most likely primary source of mercury for these caribou.

Expected Project Completion Date

This project was completed as of March 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 to Bobby Suluk who transcribed the interviews from Inuktitut to English. Additional thanks to Lars Qaqqaq who contributed significantly to the communication of the project results to the communities and the NCP. Thanks also to Heidi Swanson (University of Waterloo) and Brian Branfireun (University of Western Ontario) for contributing the methyl mercury 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 dans l'environnement

Northern contaminants air monitoring: Organic pollutant measurements

Surveillance des contaminants atmosphériques dans le Nord : mesures des polluants organiques

Project Leader/Chef de projet

Hayley Hung, Air Quality Processes Research Section, Environment and Climate Change Canada (ECCC), 4905 Dufferin St., Toronto, ON M3H 5T4.
Tel (416) 739-5944; Fax (416) 739-4281; Email: hayley.hung@canada.ca

Project Team/Équipe de projet

Pat Falletta and Enzo Barresi, National Laboratory for Environmental Testing (NLET) Analytical Team, Derek Muir, Camilla Teixeira, Environment and Climate Change Canada, Burlington, Ontario; Artur Pajda, Alexandra Steffen, Nick Alexandrou, Helena Dryfhout-Clark, Organics Analysis Laboratory (OAL) Analytical Team, Toronto, Ontario; Liisa Jantunen, Environment and Climate Change Canada, Egbert, Ontario; Alert GAW Laboratory Staff, Environment and Climate Change Canada, Alert, Nunavut; Phil Fellin, Henrik Li, and Charles Geen, AirZOne, Missisauga, Ontario; Ellen Sedlack, Crown-Indigenous and Northern Affairs Canada, Whitehorse, Yukon; James MacDonald, Council of Yukon First Nations (CYFN), Whitehorse, Yukon; Derek Cooke, Ta'än Kwach'än Council, Whitehorse, Yukon; Jamie Thomas, IK student, Whitehorse, Yukon; Laberge Environmental Services, Whitehorse, Yukon

Project Location/Emplacement(s) du projet

- Alert, NU (82°30′ N, 62°20′ W)
- Little Fox Lake, YK (61°21′ N, 135°38′ W)

Abstract

The atmosphere is the most rapid pathway for organic pollutants to reach the remote Arctic. Since 1992, this continuous monitoring program has measured how much organic pollutants are present in Arctic air. Knowing how levels of organic pollutants change over time helps researchers identify if 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 project are used to negotiate and evaluate international control agreements on organic pollutants and

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

to test atmospheric models that explain how contaminants move from sources in the South to the Arctic.

Starting in 2006, we 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) and 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. We updated the time trends for PFASs in which the data now covers 2006 to 2017. 8:2 fluorotelomer alcohol (FTOH), 10:2 FTOH, and perfluorooctanesulfonic acid (PFOS) showed declining trends since 2012-2013. New emerging PFASs were screened in air samples collected from October 2015 to March 2017. Trace level of perfluorobutane sulfonamide (FBSA) was found but polyfluoroalkyl phosphate diesters (diPAPs) were below method detection limit. A passive flowthrough sampler (FTS) specifically designed for use in cold environments has been deployed at Little Fox Lake, Yukon, since August 2011. Sampling at this site is continuous and ongoing.

incidence sur le déplacement des contaminants vers l'Arctique. Les résultats de ce projet en cours servent à négocier et à évaluer l'efficacité des accords internationaux de lutte contre les contaminants, et à faire l'essai de modèles atmosphériques qui expliquent le déplacement des contaminants à partir de points d'origine situés au sud de l'Arctique. 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 at Alert, Nunavut, and Little Fox Lake, Yukon, and measurements are ongoing.
- Air concentrations of flame retardants (FRs) 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 low and

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.

background contamination of air samples in some years prevented the determination of time trends.

- Source region analysis suggested that perfluorooctanesulfonic acid (PFOS) levels at Alert were influenced by air masses transported from land while perfluorooctanoic acid (PFOA) levels were influenced by oceanic air masses.

- Des produits ignifuges sans BDE sont fréquemment détectés dans l'atmosphère à Alert, mais dans des concentrations 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

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

- continuing to measure the occurrence of selected organochlorines and polycyclic aromatic hydrocarbons in the Arctic atmosphere at Alert (measurements started in 1992);
- continuing to measure the occurrence of selected organochlorines and flame retardants in the air at Little Fox Lake to assess long-range transport from the Pacific Rim;
- analyzing and reporting data from Alert and Little Fox Lake to provide insight into pollutant trends and sources; and
- continuing to include new chemicals of concern to the target chemical list to assess their long-range transport potential to the Arctic via the atmosphere.

B. 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:

- having contributed to the assessments on POPs as part of the Arctic Monitoring and Assessment Program [AMAP] Work Plan;
- 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; and
- advising Canadian negotiators in preparing reasonable and practical strategies of control (consistent with the way contaminants move through the north).

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, levels and time trends of PFASs measured in air at Alert are updated up to 2017.

Activities in 2017-2018

Regular ground level atmospheric measurements of organochlorines (OCs) [polychlorinated biphenyls (PCBs), chlordane, dichlorodiphenyltrichloroethanes (DDTs), chlorobenzenes and selected herbicides], flame retardants (FRs) [14 polybrominated biphenyl ethers (PBDEs), 13 other brominated FRs and 2 highly chlorinated FRs] and polycyclic aromatic hydrocarbons (PAHs) (20 priority ones) are being made at Alert, Nunavut, using a custom-made super-high-volume air sampler (super-HiVol). Measurements involve routine weekly sample collection, extraction, analysis as well as archiving.

A separate high volume air sampler (PS-1 sampler), sampling with 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. Levels and time trends of PFASs in air at Alert up to 2017 are reported here.

Scientific Communications

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 published (Wong et al., 2018). 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.

Our project leader Hayley Hung gave a presentation with Professor Matthew MacLeod (Stockholm University) at the Thirteenth Meeting of the Persistent Organic Pollutant Review Committee (POPRC13) - Stockholm Convention on POPs at the “Arctic Monitoring and Assessment Programme (AMAP) side event on Chemicals of Emerging Arctic Concern (CEAC)” in Rome, Italy (17-20 October, 2017). This presentation highlighted the new AMAP CEAC Assessment which was published in 2017. NCP monitoring and research results of CEAC in abiotic and biotic media represented a significant portion of this assessment. Time trends of CUPs, PFASs, emerging FRs, PCA, PAHs and other new chemicals measured at Alert and Little Fox Lake are included in this report. The presentation was well-received and triggered discussions among the international delegates on how potentially these CEAC may become candidate POPs to be reviewed under the Stockholm Convention.

In addition, Hayley co-authored “Chapter 3.2 Environmental Drivers” of the AMAP Adaptation Actions for a Changing Arctic Report with Frank Rigét (Aarhus University) and Jason Stow (NCP Secretariat), which is currently in press. Atmospheric trends of POPs in Arctic air including those measured in this project are discussed in this chapter.

Hayley also 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 Global report has been released. Long-term trend results from Alert contributed to this report. The report can be downloaded from this website: http://chm.pops.int/Implementation/GlobalMonitoringPlan/MonitoringReports/tabid/525/Default.aspx

An oral presentation titled "Emerging Contaminants in Canadian Arctic Air" including time trends of emerging FRs, PFASs and SCCPs has been presented at the International Conference on Arctic Science: Bringing Knowledge to Action (April 24-27, 2017 Reston, Virginia, USA).

An oral presentation titled "POPs and Chemicals of Emerging Concern in Canadian Arctic Air" was presented at the 37th International Symposium of Halogenated Persistent Organic Pollutants (DIOXIN 2017) (August 20-25, 2017 Vancouver, Canada).

A poster titled "Persistent Organic Pollutants (POPs) and Emerging chemicals in Canadian Arctic Air" and an oral presentation titled "An Overview of the Stockholm Convention on Persistent Organic Pollutants (POPs)" were presented at the NCP Results Workshop (September 26-28, 2017 Yellowknife, Canada).

Communications, Community Engagement 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 following projects: "M-02 Air Measurement of Mercury at Alert and Little Fox Lake" (Project leader Alexandra [Sandy] Steffen) and "M-03 Passive Air Sampling Network for Organic Pollutants and Mercury" (Project leaders Hayley Hung and Sandy Steffen).

The following is a description of the activities that occurred in 2017-2018:

1. Iqaluit February 2017

On February 21, 2017, 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. We also had a fruitful meeting with the Nunavut Environmental Contaminants Committee (NECC) on February 20 to update our project plans and the needs of the community with respect to those plans. Sandy and Hayley also met and consulted with Mr. Matthew Hamp (Director of Public Works and Engineering, City of Iqaluit) regarding the passive air sampling campaign ongoing in Iqaluit under Project M03 "Passive Air Sampling Network for Organic Pollutants and Mercury". Travel funding will be requested in next year's budget to continue this teaching effort and in person meeting.

2. Whitehorse March 2017

The Yukon Contaminants Committee (YCC) hosted a Yukon event in Whitehorse where local community members and scientist gathered to meet, discuss contaminant issues, and garner ideas for working together in the future. Hayley and Sandy gave presentations on the work that we have done through the NCP. They participated in the discussions with the scientists and community members and started to develop the idea of a community based mercury monitoring program involving the mercury passive samplers.

3. Yellowknife September 2017

At the annual NCP symposium, Hayley, Geoff and Liisa made hands-on displays and demonstrations at the booth at the annual results workshop. While Sandy could not attend the meeting, she did prepare a video to wish the NCP a Happy 25th Anniversary. On September 28, 2017, while at the NCP Results Workshop, Hayley conducted a radio interview with CBC North's Melinda Trochu to talk about air monitoring of contaminants in the Arctic under NCP.

4. Inuvik October 2017

Sandy, Hayley and Liisa visited Inuvik from October 3-5, 2017. We met with Erika Hille and Annika Trimble at the Aurora College. We had a full discussion on what we are doing, why it's relevant and what we would like to do in the future. We met the location technicians who work with Hayley on the POPs passive sampling project. We met with Janet Boxwell, the Renewable Resources Manager of the Gwich'in Renewable Resources Board, and had a very good discussion about our work in the Arctic. We tried to meet with Shannon O'Hara who wanted to organize a community discussion but the timing did not work out while we were in Inuvik. We gave a presentation entitled "Contaminants in Arctic Air and Oceans" at the Aurora College in the evening of October 3rd that was open to community members at the College location. The seminar has been recorded and the college will share it with interested parties who could not attend in person. Hayley, Liisa and Sandy gave a seminar and hands on presentation to college students in the Environmental and Natural Resource Technology Program and East Three Secondary School Grade 10 students. Along with the college students, Hayley, Liisa, and Sandy conducted a site visit to the passive air sampling station which is currently placed in-town at the National Air Pollution Surveillance Program (NAPS) station. We spent some time scouting out a different location for the POPs and, eventually, the mercury passive samplers as the current site is not the best for our measurements. We sent out several invitations to meet with local radio and newspaper but the timing for interviews did not work out.

5. Whitehorse November 2017

On November 3, 2017 Sandy and Hayley called into the YCC meeting to discuss project plans for the upcoming fiscal year at Little Fox Lake. November 7, Sandy and Geoff travelled to Whitehorse for a technical and communications visit. November 8, they met with Derek Cook and Jamie Thomas to discuss the draft version of the Indigenous Knowledge (IK) report (see below). November 9, Sandy met with some members of the YCC (Ellen Sedlack, Shane Kilpatrick, Mary Gamberg, Derek Cooke) and updated them on the mercury science at Little Fox Lake, provided an update on Minamata COP1 meeting, discussed a potential community program for passive Hg sampling, discussed the future of the passive Hg sampling project (M03) and ideas for eventually building that into a community monitoring program. Sandy provided slides on the mercury measurements in the Yukon to both Mary Gamberg and Derek Cooke and they have used these slides for their communication programs and discussions with interested colleagues. We offered YCC members the chance to go on a site visit but no one was available. Geoff and Sandy also met up with our Laberge project partners (Bonnie Burns, Ken Nordin and Dylan Nordin) and discussed the site operations, the data and results, and future planning for work at the site.

6. Whitehorse February 2018

Hayley visited Whitehorse from February 5 to 7, 2018. She met with the YCC at the Ta'än Kwach'än Council (TKC) on February 5 to discuss about her project proposals. On February 6, Hayley gave a presentation at the CIRNAC office in Whitehorse during the Environment Directorate staff meeting about air monitoring of POPs and mercury at the Little Fox Lake station. She then gave two seminars at the Yukon College to students in courses of "Yukon Source Water Protection & Watershed Stewardship" and "Environmental Change and Community Health". After the seminars, she met with Derek Cook and Jamie Thomas to discuss about finalizing the IK report. On February 7, Hayley met with team members of Laberge Environmental Services to discuss about electrical power issues at the Little Fox Lake station.

7. Iqaluit January 2018

In January 23-25 2018, Sandy and Hayley visited 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. This year's hands-on session included the demonstration of using the Direct Mercury Analyzer which the college has recently acquired. They visited the POPs passive sampling site on January 24 and assisted operator Chris Spencer in changing one of the air samples. They also met with the NECC to discuss their communication, capacity building and IK plans.

Indigenous Knowledge (IK) Integration

In November 2016, Jamie Thomas was hired by CYFN, in consultation with Derek Cooke (TKC), to undertake an IK subproject under Passive the Air Sampling Network of Organic Contaminants and Mercury project to improve 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. March 11, 2017, Jamie hosted an event for local elders at the Yukon Horse Packing retreat facility which is located between Whitehorse and Little Fox Lake, on Fox Lake. This event was 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. Unfortunately, not many people were in attendance at the event, even though the event was advertised on the local radio station and advertised through the TKC website inviting elders and people of all ages to attend. Over the summer of 2017, with the help of the coordinators of First Nations elder of the Yukon College and TKC’s Derek Cooke, Jamie interviewed four elders and asked questions related to 5 themes: i) General knowledge of contaminants in the north; (ii) knowledge of weather patterns; (iii) forest fires; (iv) mining; and (v) environmental change. Jamie prepared a draft report summarizing the discussions.

When in Whitehorse, Sandy and Geoff discussed with Derek and Jamie about the IK report. The initial draft report was good but needed some modification to consolidate the information to undertake full analysis. The interviews with the elders provided some excellent information for the project. Jamie then revised the report and Sandy and Hayley are now going through the report and will work with Derek Cook to complete a full analysis. The report will then be sent to the elders for their feedback and approval before we continue finalizing the report. After approval from the elders, we will provide the report to the YCC and then make it more available from there. We want to be mindful of the elders and ensure that their knowledge is being conveyed in a manner in which they are comfortable. Sandy is hopeful that she will be able to incorporate some of this information into a scientific paper she is planning to publish on the mercury trends at Little Fox Lake in the upcoming Fiscal Year.

Results

Per and Polyfluoroalkyl Substances (PFASs) in Air at Alert

Data collected from February 2015 to March 2017 were analyzed for neutral and ionic PFASs. The time trends of 8:2 FTOH, 10:2 FTOH, PFOS, PFOA, PFBA and PFBS in Alert air from 2006 to2017 were derived using the digital filtration method. Details of the analytical method, time trends analysis and data treatment are given in Wong et al. (2018). Results are presented in Figures 1 and 2.

Atmospheric levels of 8:2 FTOH showed an overall increasing trend from 2006 to 2017, with a very long doubling time (t_2) of 24 years (y). 10:2 FTOH exhibited a decreasing trend with half-life ($t_{1/2}$) of 19 years. Visual inspection of the trends shown in Figure 1 indicated that 8:2 and 10:2 FTOH levels peaked in 2012, and both compounds have been decreasing since then. Half-lives derived from the 2012-2017 data for 8:2 FTOH $t_{1/2}$ = 3.5 years; 10:2 FTOH, $t_{1/2}$= 2.0 years.

Atmospheric levels of PFOS showed an overall increasing trend from 2006 to 2017 with t_2 = 4.9 years. Similar to the FTOHs, PFOS appeared to have peaked in 2013 (Figure 2). The half-life derived from the 2013-2017 data for PFOS was 2.0 years.

Figure 1. Time trends of 8:2 FTOH and 10:2 FTOH in air in Alert from 2006 to 2017. The natural log of air concentrations (ln C) is plotted against time. IDL indicated instrumental detection limit; MDL indicated method detection limit.

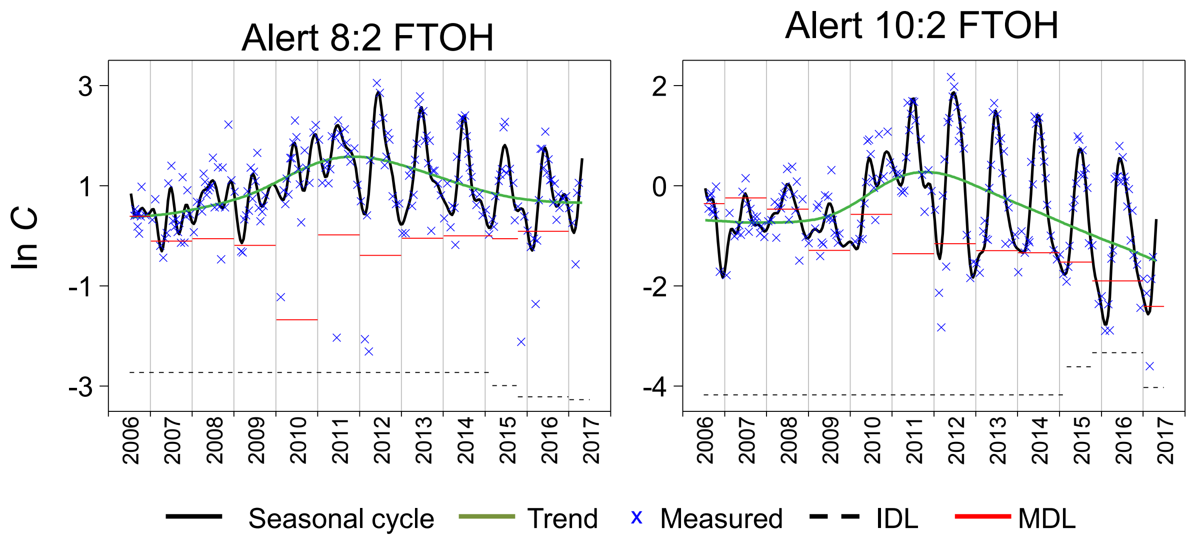
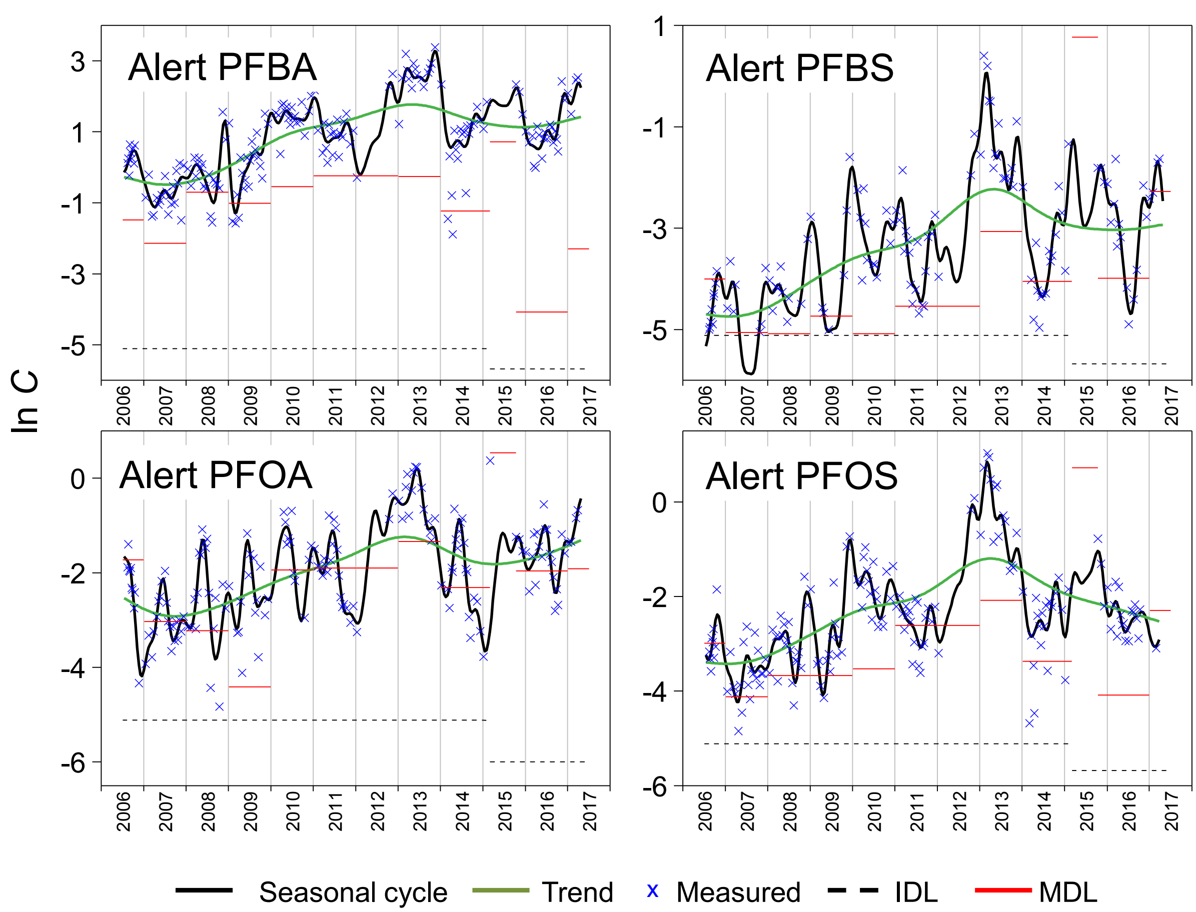


Figure 2. Time trends of PFBA, PFBS, PFOA and PFOS in air in Alert from 2006 to 2017. IDL indicated instrumental detection limit; MDL indicated method detection limit.



PFOA, PFBA and PFBS levels in air exhibited increasing trends from 2006 to2017. The doubling times were: PFOA = 4.8 years, PFBA = 3.6 years; PFBS = 3.4 years.

Extracts from samples that were collected from October 2015 to March 2017 ($n = 29$) were screened for perfluorobutane sulfonamide (FBSA), sodium bis-[2-(N-ethylperfluorooctane-1-sulfonamido)ethyl] phosphate (diSAmPAP), and polyfluoroalkyl phosphate diesters (diPAPs). diPAPs measured included 6:2 diPAP, 8:2 diPAP, 6:2/8:2 diPAP. These chemicals were analyzed using the same instrumental method as the ionic PFAS (Wong et al. 2018). The target/qualifying multiple reactions monitoring (MRM) monitored were: 6:2 diPAP (788.8->442.9/788.8->97), 8:2 diPAP (988.8->543/988.8->96.8), 6:2/8:2 diPAP (888.8->442.9/888.8->542.9), diSAmPAP (1202.8->525.9/1202.8->219), FBSA (298->77.93/298->118.96).

Levels of 6:2 diPAP, 8:2 diPAP, 6:2/8:2 diPAP and diSAmPAP in the air samples were not significantly different from the blank values, and hence below method detection limit (i.e. mean blank + 3´standard deviation). They were considered non-detected in the samples. FBSA was found in the air samples, with mean and standard deviation of 0.025 ± 0.027 g/m^3. Trace levels of FBSA were found in the blanks, with mean and standard deviation of 0.0031 ± 0.0036 pg/m^3. It was mostly found in PUF-XAD but not in the filters.

Discussions and Conclusions

Results suggested that 8:2 and 10:2 FTOHs in air in Alert have peaked in 2012. The declining trends of FTOHs since 2012 were consistent to those reported in the global air, in which Gawor et al. (2014) reported that 8:2 and 10:2 FTOH showed a decreasing trend in XAD based passive air sampler (XAD-PAS) samples collected from the Global Atmospheric Passive Sampling (GAPS) Network from 2006 to 2011. Our data is also in line with the findings of Wang et al. (2014a) that global emission of FTOHs from all sources peaked around 2010-2015.

However, Bossi et al. (2016) reported that there were no time trends observed for FTOHs in air at Greenland collected from 2008 to 2013. Stable concentrations of FTOHs were observed in sorbent impregnated passive air samplers (SIP-PAS) from GAPS sites deployed in Western Europe and Other Group (WEOG) region from 2009-2015 (Rauert et al. 2018). The WEOP includes the European countries of Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland and Ireland. The non-European countries part of the WEOP include Australia, Canada, Israel and New Zealand.

Air concentration of PFOS in Alert peaked in 2013. This may be due to the global phase-out of PFOS and related substances. In Andøya, Norway, atmospheric level of PFOS showed declining trend from 2009- 2014, while in Zeppelin, Svalbard (operated by Norway), non-changing trend was observed from 2006-2014 (Wong et al. 2018). However, increasing concentrations were observed for PFOS at both Alert and Ny-Ålesund (Svalbard, operated by Norway) in SIP-PAS collected from 2009 to 2015 (Rauert et al. 2018).

The declining trend of PFOS in Alert since 2013 is consistent with those reported in biota, though PFOS peaked earlier in the latter. For example, PFOS in ringed seals and polar bear from Greenland peaked in 2006 (Rigét et al. 2013); in ringed seals from the eastern Canadian Arctic peaked in 1998 and 2000 (Butt et al. 2007); in otters from the North Sea peaked in 2001 (Hart et al. 2009); and in human serums from United States of America population peaked in 1999-2000 (Kato et al. 2011).

PFOA, PFBS and PFBA were continuingly increasing over the study period, though PFOA levels seem to be levelling off after 2013. This agrees with Rauert et al. (2018) observations of increasing concentrations of the PFCAs at the polar sites in the SIP-PAS GAPS Network from 2009 to 2015. PFOA in air in Zeppelin (2006-2014) and Andøya (2009-2014) showed declining trends (Wong et al. 2018). Furthermore, the stable concentrations of PFOA in Alert air from 2013 to 2017 seems to agree with Wang et al. (2014b), in which the global emission of PFCAs is modelled to decline from 2012, and become consistent starting 2015 under the high emission scenario in which the emission scenario in 2015 was assumed to remain constant until 2030 (i.e. production did not cease according to global control measures).

As previously reported, concentrations of PFBA in Alert air were the highest perfluoroalkyl acids (PFAAs) being monitored (Wong et al. 2018). This is consistent with PFBA in a snow pit collected at the Devon Ice Cap in Nunavut in 2008 (MacInnis et al. 2017). The authors suggested that the elevated concentration of PFBA was due to atmospheric transformation of stratospheric ozone-depleting chlorofluorocarbons and hydrochlorofluorocarbon.

Trace level of FBSA is found in Alert air. FBSA is a major metabolite of new fluorinated surfactant replacements found in post-2002 products (Chu et al. 2014). Chu et al. (2016) were the first to report FBSA's presence in freshwater fish from different regions of Canada. Recently this compound was found in drinking water from Canada and other countries (Kaboré et al. 2018). We caution that this data is considered semi-quantitative as it was quantified using $^{13}C_8$-FOSA as internal standard instead of the isotope-labelled FBSA standard.

Expected Project Completion Date

Ongoing

Acknowledgments

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Mercury measurements at Alert and Little Fox Lake

Mesures du mercure à Alert et au lac Little Fox

Project Leader/Chef de projet

Alexandra (Sandy) Steffen, Environment and Climate Change Canada (ECCC), Science and Technology Branch (STB), Atmospheric Science and Technology Directorate (ASTD), 4905 Dufferin St, Toronto, Ontario, M3H 5T4. Tel: (416) 739-4116; Email:Alexandra.Steffen@Canada.ca

Project Team/Équipe de projet

Geoff Stupple, and Hayley Hung, Environment and Climate Change Canada, Toronto, ON; Greg Lawson and Jane Kirk, Environment and Climate Change Canada, Burlington, ON); Derek Cooke, Ta'än Kwach'än Council, YT; Laberge Environmental Services, Whitehorse, YT; Greg Skelton, Skelton Technical, Toronto, ON; Bridget Bergquist, University of Toronto, ON

Project Location/Emplacement(s) du projet

- Little Fox Lake, YK
- Alert, NU

Abstract

Mercury (Hg) is a priority pollutant of concern in Canada, especially Arctic regions. The Arctic primarily receives Hg via long range transport from regions that are mainly from outside of Canada. Our results from atmospheric Hg concentration measurements at Alert, Nunavut show a median decreasing trend of -0.9 ± 0.3 % per year for the past 23 years from 1995-2017. In contrast, Hg concentrations at Little Fox Lake, Yukon show an increasing median trend (+1.3% ± 1.2% per year for 10 years from 2007-2016). At Alert, Hg continues to show a distinct seasonal decrease in gaseous elemental Hg (GEM) in the spring. Concurrently, there are also seasonal patterns in shorter-lived Hg species including reactive gaseous mercury (RGM), and particle-bound mercury (PHg). There is a peak in PHg during early spring and a peak in RGM in late spring; both show enhanced deposition of mercury to the snow at the same time. Recent trend analysis shows that trends in the springtime concentration levels of PHg

Résumé

Le mercure (Hg) est un polluant prioritaire qui demeure préoccupant au Canada, en particulier dans les régions arctiques. L'Arctique reçoit des dépôts de mercure principalement par le transport à grande distance en provenance de régions 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 de 0,9 ± 0,3 % par année depuis 23 ans, de 1995 à 2017. En revanche, les concentrations de mercure mesurées au lac Little Fox, au Yukon, suivent une tendance médiane à la hausse (+1,3 % ± 1,2 % par année, sur une période de dix ans de 2007 à 2016). À Alert, le mercure élémentaire gazeux (MEG) continue de connaître une chute saisonnière caractéristique au printemps. En parallèle, on observe des profils saisonniers des espèces de mercure à plus courte durée de vie (mercure gazeux réactif, ou MGR, et mercure lié aux

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

particules, ou PHg). On observe un pic de PHg au début du printemps et un pic de MGR à la fin du printemps; ces deux espèces montrent un dépôt plus important dans la neige à la même période. Une analyse récente des tendances révèle un changement des concentrations de PHg et de MGR au printemps à Alert. 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.
- The timing, magnitude and composition of speciated mercury observations during springtime atmospheric mercury depletion events (AMDE) at Alert are changing. Speciated mercury describes the various types of mercury found in the air that have a shorter lifetime than GEM and include reactive gas phase mercury and mercury on particles.
- 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 des changements dans l'importance et la composition des observations de mercure différencié et le moment de ces observations pendant les phénomènes printaniers d'appauvrissement du mercure atmosphérique à Alert. Le mercure différencié désigne les différents types de mercure qui se trouvent dans l'air qui ont une durée de vie plus courte que celle du MEG et qui comprennent le mercure en phase gazeuse réactive et le mercure sur les particules.
- Les données scientifiques recueillies dans le cadre de ce programme serviront à l'élaboration des politiques et des stratégies nationales. De plus, elles serviront à évaluer l'efficacité des stratégies nationales et internationales de réduction des émissions de mercure.

Objectives

This project aims to:

- establish long-term concentrations, patterns, and trends of Hg in the Canadian high Arctic air at the Alert site;
- 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 to the arctic environment;
- assess how Hg cycling and emissions from areas in the Pacific Rim and western Canada impact mercury levels Canadian western Arctic using measurements at the Little Fox Lake site; and,
- engage with and train Northern students and community members on the transport and deposition of atmospheric mercury and its impact in the ecosystem.

Introduction

The Canadian Mercury Science Assessment concluded that mercury (Hg) remains a risk to Canadian ecosystems and human health (Steffen, 2016). Mercury is considered a pollutant of concern by the Arctic Council and a contaminant of mutual concern for the Great Lakes Water Quality agreement. The Minamata Convention on Mercury was ratified in 2017 and Canada, as part of this convention, will contribute data about mercury levels in Arctic regions to evaluate how well the convention, as currently employed, is able to reduce mercury levels. This project's data on the long-term concentrations, patterns, and trends of Hg in the Canadian high Arctic air has been and will continue to be crucial to the development of Canadian strategies for national and international pollution control objectives such as those outlined in the Minamata Convention on Mercury. Additionally, 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 and source attribution of Hg in the air, and assesses how the unique behaviour of Hg in the Arctic atmosphere may impact the pristine Arctic environment.

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) (Steffen et al., 2016) with Alert being on the lowest end of this trend. Interestingly, global emissions of anthropogenic Hg are not following the same pattern of decline and are increasing in some locations. This is important because 95% of the anthropogenic Hg deposited in Canada comes from sources outside of the country (Steffen et al., 2016). In addition, with climate change occurring at a rapid pace in Arctic regions, changes in atmospheric dynamics and chemistry are currently being seen. These changes will likely have an impact on how pollutants such as Hg are transported through the atmosphere and deposited to the Arctic. 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 (Pacyna et al., 2016). 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 data collected by this NCP project serves to monitor long term and seasonal trends of Hg in the high- and sub-Arctic. It provides important information to understand 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 2017-2018

Research activities

Ground-based continuous atmospheric measurements of total gaseous mercury (TGM)[1], gaseous elemental mercury (GEM), reactive gaseous mercury (RGM), and particulate mercury (PHg) continued at Alert. Site visits for maintenance and calibration of all Hg instruments at Alert were made in May 2017 and November 2017 on top of regular weekly checks by the onsite operator and student. Continuous measurements of TGM/GEM[2] at Little Fox Lake were also carried on through 2017-2018; a technical site visit was made in November 2017 on top of regular weekly checks by Laberge Environmental Services to check the instrument, download the data and perform minor repairs to the instrument on site.

In February 2017, the Alert operator and Geoff installed a temporary second Hg speciation system at Alert to run some experiments in the springtime. In April, Geoff and Sandy performed some experiments on this second speciation system to improve our understanding of the measurements and improve operation of the instrumentation.

Data from both sites for 2017 are reviewed monthly and have been quality controlled. The final data are submitted to the Environment Canada Data Catalogue (ECDC) at the links below. Currently, the data up to 2015 has been transferred into this location and the data from 2016 and 2017 are in the queue for publishing. Metadata from this program have also been updated in the Polar Data Catalogue (PDC).

Snow samples continued to be collected at Alert both weekly (from the ground) and on a per event basis (from a Teflon table). In addition, snow samples from over the sea ice to inland were also collected. Almost all the snow samples collected up to the end of 2017 have been analyzed at the Water Science and Technology Branch in Burlington, Ontario.

Filter samples were collected for Hg and lead (Pb) stable isotopic analysis in collaboration with the University of Toronto. The data from 2016 and 2017 has not yet been analyzed.

Communications, Community Engagement and Capacity Building

Outreach and communication under this project "Mercury Measurements at Alert and Little Fox Lake" is conducted in conjunction with that of the following projects: Northern Contaminants Air Monitoring: Organic Pollutant Measurements (Hayley Hung), and Passive Air Sampling Network for Organic Pollutants and Mercury (Project leaders Hayley and Sandy Steffen). These projects have joined forces for communication and capacity building activities because they are closely related in terms of goals, facilities and technical support.

We have accomplished quite a lot 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 Inuvik, NWT as well as various locations across the Arctic.

Iqaluit January 2018

January 23-25, 2018, Sandy and Hayley visited Iqaluit 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. This year's hands-on session included demonstrating how to use the Direct Mercury Analyzer which the

1 TGM at Alert is considered to be almost entirely GEM at Alert

2 For this report we will use the term GEM for Alert and Little Fox Lake

college recently acquired. They visited the POPs passive sampling site on January 24 and assisted operator Chris Spencer in changing of one of the air samples. They also met with the Nunavut Environmental Contaminants Committee (NECC) to discuss their communication, capacity building, and Indigenous Knowledge plans.

Yellowknife September 2017

At the annual NCP symposium, Hayley, Geoff and Liisa did hands-on displays and demonstrations at the booth at the annual results workshop. This trip to Yellowknife for Geoff offered an opportunity for him to meet various members of the NCP family, see the research that is being done, and get a chance to see the overview of the whole NCP program. On September 28, 2017, while at the NCP Results Workshop, Hayley conducted a radio interview with CBC North's Melinda Trochu to talk about air monitoring of contaminants in the Arctic under NCP.

Inuvik October 2017

Sandy, Hayley and Liisa visited Inuvik from October 3 to 5, 2017. They met with Erika Hille and Annika Trimble at the Aurora College. They had a full discussion on the work, why it's relevant, and plans for the future. They met the local technicians who work with Hayley on the POPs passive sampling project. They met with Janet Boxwell, the Renewable Resources Manager of the Gwich'in Renewable Resources Board, and had a very good discussion about the work in the Arctic. They tried to meet with Shannon O'Hara who wanted to organize a community discussion but the timing did not work out while in Inuvik. They gave a presentation entitled "Contaminants in Arctic Air and Oceans" at the Aurora College in the evening of October 3 that was open to community members at the College location. The seminar has been recorded and the college will share it with interested parties who could not attend in person. Hayley, Liisa and Sandy gave a seminar and hands on presentation to college students in the Environmental and Natural Resource Technology Program and East Three Secondary School Grade 10 students. Along with the college students, Hayley, Liisa and Sandy conducted a site visit to the passive air sampling station which is currently placed in-town at the National Air Pollution Surveillance Program (NAPS) station. They spent some time scouting out a different location for the POPs and, eventually, the Hg passive samplers as the current site is not the best for the measurements. They sent out several invitations to meet with local radio and newspaper but the timing for interviews did not work out.

Whitehorse November 2017

On November 3, 2017 Sandy and Hayley called into the Yukon Contaminants Committee (YCC) meeting to discuss project plans for the upcoming FY at Little Fox Lake. November 7, Sandy and Geoff travelled to Whitehorse for a technical and communications visit. November 8, they met with Derek Cooke and Jamie Thomas to discuss the draft version of the Indigenous Knowledge (IK) report. The initial draft report was good but further modification was needed to consolidate the information. The interviews with the elders provided some excellent information for the project, which we will share once we receive feedback and approval from the elders. Once that is done, the report will be provided to the YCC and some of this report's information may possibly be incorporated into a scientific paper Sandy is planning to publish on the Hg trends at Little Fox Lake. November 9, Sandy met with some members of the YCC (Ellen Sedlack, Shane Kilpatrick, Mary Gamberg, Derek Cooke) and updated them on the Hg science at Little Fox Lake, updated them on the Minamata Conference of the Parties (COP1) meeting, discussed a potential community program for passive Hg sampling and discussed the future of the passive Hg sampling project (M03) including ideas for eventually building that into a community monitoring program. Sandy provided slides on the Hg measurements in the Yukon to both Mary Gamberg and Derek Cooke who have used the slides for their communication programs and discussions with interested colleagues. A site visit to Little Fox Lake was offered to YCC members but no one was available to attend. Geoff and Sandy also met up with our Laberge project partners (Bonnie Burns, Ken Nordin and Dylan Nordin) and discussed the site operations, the data and results and future planning for work at the site.

Geneva September 2017

Sandy was part of the Canadian delegation for the first Conference of the Parties (COP1) of the Minamata Convention on Mercury. She was part of the negotiating team to forward the requirements of Article 22: Effectiveness Evaluation (EE). She worked with Jamie Knill of the Maritime Aboriginal Peoples Council and the Canadian delegation to ensure the inclusion of Indigenous people in the EE process of the treaty by specifically noting that Indigenous communities are invited as part of the *ad hoc* Group of Experts. Further, Canada successfully integrated in the recommended qualifications that members of the *ad hoc* Group of Experts include expertise such as Indigenous Knowledge. At the March 2018 *ad hoc* Group of Experts meeting, Eva Krummel from ICC actively participated as an observer and contributed to the report including recommendations on a global monitoring plan and an effectiveness evaluation strategy has been sent for review to the global community. This report will be presented at the second Conference of the Parties meeting in November 2018 for decision.

Indigenous Knowledge Integration

In collaboration with Derek Cooke (Ta'än Kwach'än Council), Bob Van Dijken (Council of Yukon First Nations (CYFN), retired) and Pat Roach (INAC, 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 Hg. 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 be engaged in a discussion on 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 about Indigenous Knowledge about five general themes: (i) General knowledge of contaminants in the north; (ii) knowledge of weather patterns; (iii) forest fires; (iv) mining; and (v) environmental change. Jamie prepared a draft report summarizing the discussions Hayley, Sandy and Derek are in the process of reviewing this report and preparing to present it to the participating elders for their consultation and approval to move forward with sharing the report.

Results

Figure 1a shows the gaseous elemental mercury (GEM) six hour averages for Alert from 1995 to 2017 and Figure 1b for Little Fox Lake from 2007 to 2017. We have 23 years of this quality controlled data from Alert and 11 years of data from Little Fox Lake. Figure 2a shows the annual mercury mean concentration levels for the speciation data from Alert including GEM, reactive gaseous mercury (RGM) and particulate mercury (PHg) from Alert from 2002 to 2017. Figure 2b shows the trends of RGM and PHg at Alert over 3 different time periods. Figure 3 shows a map of mercury concentration levels in the snow pack from transect samples from 2013-2016.

Figure 1a. Time series of total gaseous mercury (TGM) from Alert, Nunavut up to the end of 2017. Data is presented in six hour averages.

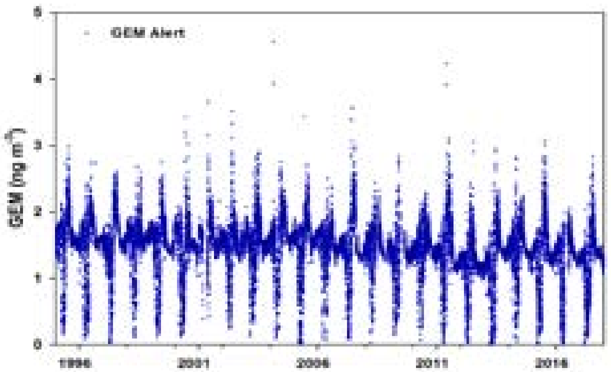


Figure 1b. Time series of total gaseous mercury (TGM) from Little Fox Lake, Yukon up to the end of 2017. Data is presented in six hour averages.

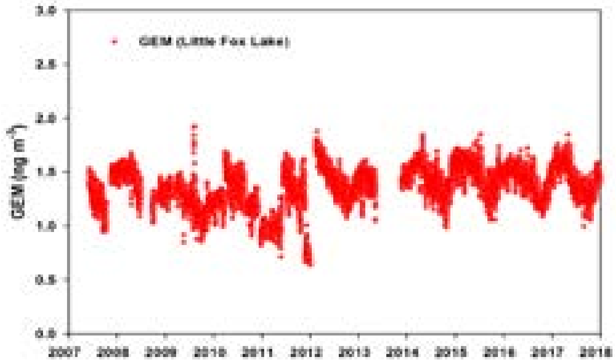


Figure 2a. Annual mean concentration data for atmospheric mercury speciation data from Alert, Nunavut up to the end of 2017. Blue circles represent mean gaseous elemental mercury (GEM) concentration levels in ng/m³, pink triangles represent the mean reactive gaseous mercury (RGM) concentration levels in pg/m³ and green squares represent particulate mercury (PHg) mean concentration levels in pg/m³. The crosses above and below the mean represent the range of the annual data set which is reported as six hour averages for that year.

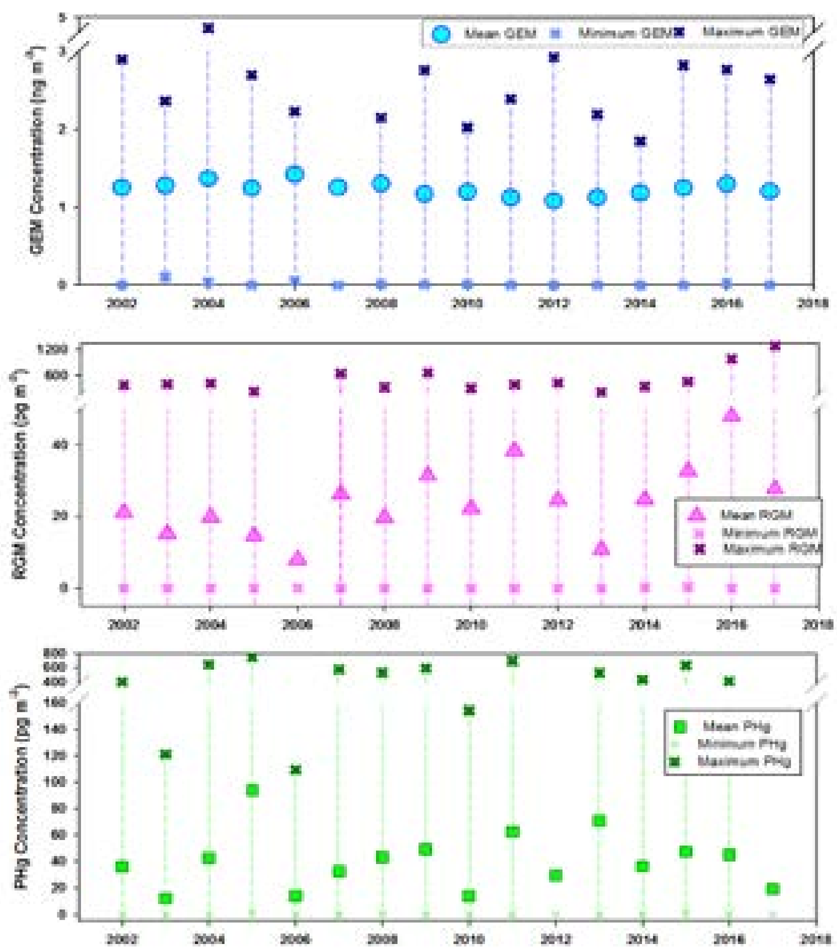


Figure 2b. Mann-Kendall Seasonal trend analysis for atmospheric mercury at Alert for three periods. Top panels are monthly trends (in pg m^{-3}) of reactive gaseous mercury (RGM) 2002-2008 (left); 2009-2017 (middle) and 2002-2017 (right). Bottom panels are monthly trends (in pg m^{-3}) of particulate gaseous mercury (PHg) 2002-2008 (left); 2009-2017 (middle) and 2002-2017 (right). Bars above the zero line indicate an increasing trend and bars below the zero line indicate a decreasing trend.

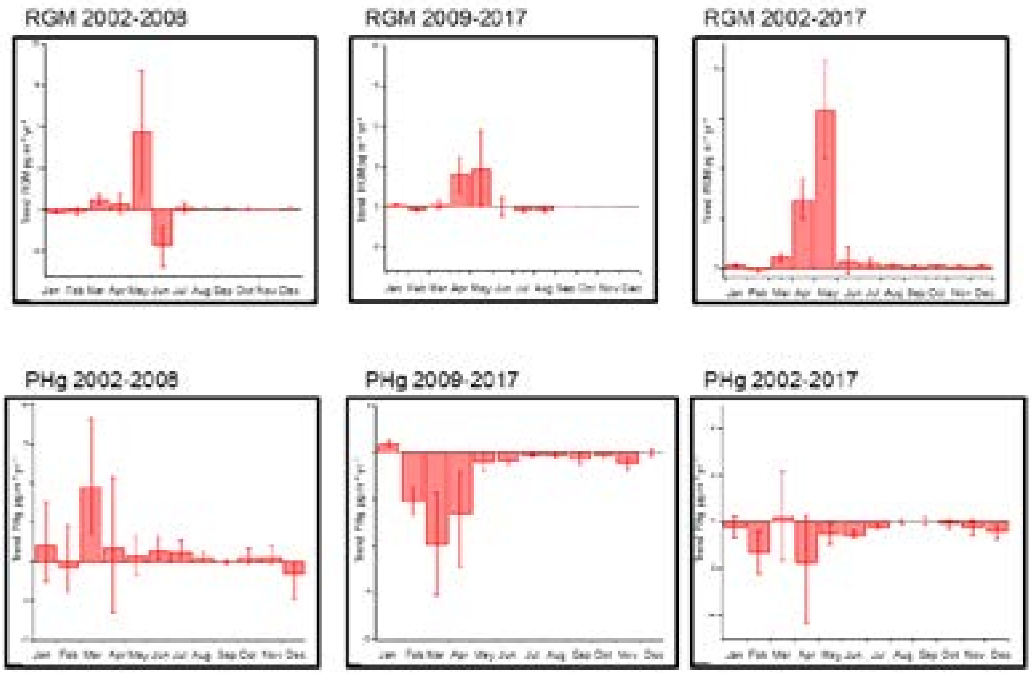
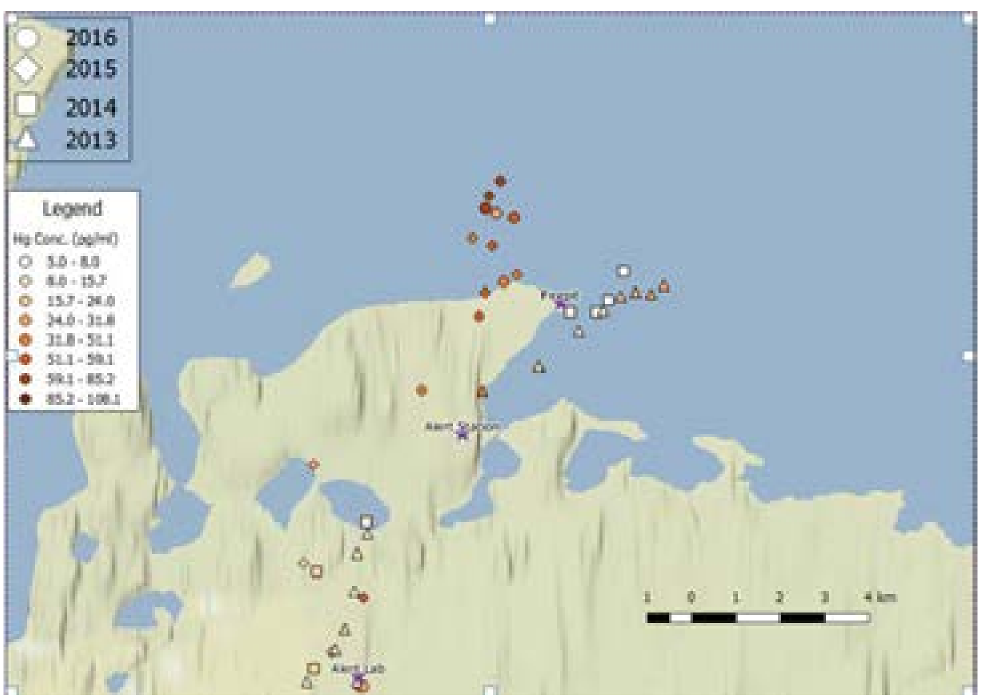


Figure 3. Map of mercury concentration levels in surface snow both over the local sea ice and inland from the shore around Alert. Mercury concentrations are in pg/mL. Triangles represent 2013 data; squares represent 2014 data, diamonds represent 2015 data and circles represent 2016 data.



Discussion and Conclusions

GEM measurements

Continuation of data collection was the primary focus again for this year. Figure 1a shows the quality controlled data at Alert from 1995-2017. 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. A trend analysis of this data from 1995-2017 yielded a decline of -0.9 ± 0.3 % per year for the past 23 years which is in keeping with previously reported trends. Figure 1b shows the GEM concentration data from 2007 to 2017 at Little Fox Lake. There is a seasonal signal from this site as well but is less pronounced and not driven by the same processes. In contrast to Alert, Little Fox Lake shows an increasing median trend (+1.3% ± 1.2% per year) 2007-2016. An analysis of this increasing concentration trend was done and showed that the increase is most likely due to the combination of inter-annual variability in the meteorology in that region and increased Hg emissions coming from Asia (Dastoor and Ryjkov, 2017; Wen, 2017). The impact of forest fires was also investigated for the increase in Hg concentration levels but it was shown that regional fires had little impact on this change (Darlington, 2017; Dastoor and Ryjkov, 2017).

Speciation measurements

Speciated atmospheric Hg data continued to be collected at Alert and the mean concentration and ranges of GEM, RGM and PHg from 2002-2017 are shown in Figure 2a. The top plot shows GEM mean concentrations (blue dot) and the maximum and minimum concentration levels for each year (blue crosses). The middle and bottom plots show the RGM and PHg mean concentrations (pink triangle and green square, respectively) and the maximum and minimum concentration levels for each year (pink and green crosses). Figure 2b shows the monthly time trend analysis for the 2002-2017, 2002-2008 and 2009-2017 periods for both RGM (top) and PHg (bottom) employing the seasonal Kendall test. This figure shows that from the 2002-2008 and 2009-2017 time periods there has been a shift in the springtime (March-June) trends for RGM and PHg and that these shifts impact the overall trends from 2002-2017. For RGM, increasing trends in March and May are shown (April was not significant) while a decreasing trend in June from 2002-2008 was shown. From 2009-2017, the trends shift to April showing an increasing trend and June to not showing a change (March was not significant). For the whole time period of 2002-2017, the results show that RGM is increasing in the March – May months. For PHg, a different shift is shown where from 2002-2008 there are not significant trends other than an increasing trend in March but in the 2009-2017 period, we see a decreasing trend in all four months. The overall (2002-2017) trend shows only a decreasing trend in May and June. These data indicate that the trends for the springtime Hg speciation concentrations are changing over time. It is known that these concentration levels are driven by atmospheric chemistry relating to sea ice dynamics (Moore et al., 2014), sea salt availability (Simpson et al., 2007) and the availability of aerosols; and that the deposition of Hg in the springtime is dependent on the composition of the atmosphere (Steffen et al., 2013; Steffen et al., 2014). Thus, these shifts indicate that there may be changes in the deposition of Hg at Alert in the springtime. Further investigation and analysis is warranted to understand if the deposition of mercury in snow pack is being affected by the shift in the atmospheric concentration levels of mercury.

The predictably of low GEM and high RGM/PHg values in the springtime at Alert allow for a unique opportunity to experiment with new methods and equipment and use this environment as a real life laboratory that will help move atmospheric Hg research forward. As such, a second speciation system was operated for several months during the springtime events, so that we can make modifications to the instruments without interrupting the primary monitoring systems and also allows for a direct comparison with the known standard method. Ozone was added to the inlet at varying concentrations to observe if there was an effect on the performance of the KCl coated denuder.

We did not observe a discernable change in the concentration between measurements, which provides us with additional confidence in our methods and demonstrates that we are not underestimating RGM concentrations, as some studies have suggested (Gustin et al., 2015). Again, making use of the unique atmospheric conditions at Alert, we collaborated with the instrument supplier, Tekran, and the National Oceanic and Atmospheric Administration (NOAA) to test out improvements to the instrumentation. Tekran supplied us with a new heated boot design that was used to test the role of different inlet temperatures and it was concluded that there was no conversion of Hg within the inlet between RGM/PHg. NOAA developed a standard addition unit for the speciation system that adds GEM to the inlet of the system and will enable better quality control for the data. This unit was installed in Nov 2017 and operated through the spring time to ensure accurate measurements of GEM. These investigations serve to help and improve our measurement methods and add value to our understanding of Hg processes in the atmosphere.

Snow measurements

Mercury is deposited from the air to the snow in the springtime. While some of that deposited Hg is re-emitted to the air, there are conditions in which that re-emission process is suppressed (in the presence of chlorine) and Hg is more readily retained in the snow pack (Lalonde et al., 2002; Mann et al., 2018). To assess if the snow pack around Alert can demonstrate these processes, a snow transect study was undertaken between 2013 and 2018 where snow was collected in a "low chlorine" influenced area (i.e. inland) and in a higher chlorine area (over the sea ice). Figure 3 shows the results from this sampling project from 2013-2016 (data from 2017 and 2018 are not yet fully analyzed). This figure shows a distinct difference between the Hg concentration levels in the snow over the sea ice and of those inland for the years 2015 and 2016 and less strongly for the years 2013 and 2014. Using the student t-test, the data overall show a statistically significant difference between the concentration levels of Hg over the sea ice snow than the snow collected inland. For the 2014 data – the difference between inland and over the sea ice was not found to be statistically significant.

It has been shown that when higher levels of chlorine are found in the snow sample there are concurrently higher levels of Hg as well (Steffen et al., 2013). Additional snow samples collected over this study will be analyzed for chlorine content in 2018-2019. Our results for Hg in snow indicate that there is a difference in the amount of Hg depending on whether it is on the sea ice or inland. Interestingly, the data from 2013-2014 show lower differences than the 2015-2016 data. This could be due to the where the samples were collected on the sea ice. As seen in Figure 3, the 2013-2014 samples were taken to the east of the "fire pit", which is the northernmost point from Alert, and the others were more to the north-west of this area. The more north westerly sites may be subjected to more open or new sea ice than the easterly ones and thus may have less chlorine. We will wait for the total ion concentration analysis of the snow to further investigate this data in order to draw more meaningful conclusions.

For several years we have collected lead and Hg isotopes on particles in the springtime at Alert in order to assess whether isotopes could aid in identifying different metal sources to the Arctic and help to further understand the impact of photochemical transformation processes of Hg on deposition. Results from the lead samples show that, in the winter/spring, lead particles are coming from Russian and Asian sources (summer/fall samples from other sites show that North America is the dominant source region). Further, the magnitude of lead loading to the Arctic continues to decrease over time. Both gas (as GEM) and particulate Hg isotopes were studied at Alert. The results show that the gas phase Hg at Alert is from a "mixed-pool" of background and urban/industrial emission sources which demonstrates that GEM at Alert is directly a result of long–range transport. Conversely, the Hg isotopic measurements on particles indicate that this pool of Hg is dominated by Hg that has been collected on the particles after conversion of GEM to RGM (through the springtime chemistry). This result shows that the Hg attached to particles found in the air at Alert is predominantly resulting from the local chemistry and not long range transport. This information helps to predict what will happen to Hg deposition in the high Arctic should anthropogenic particle emissions or the springtime photochemistry change.

Expected Project Completion Date

Ongoing

Project Data

This project's data is available on 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/

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Passive air sampling network for organic pollutants and mercury

Réseau d’échantillonnage atmosphérique passif pour mesurer les polluants organiques et le mercure

Project Leader/Chef de projet

Hayley Hung, Science and Technology Branch, Air Quality Processes Research Section, Environment and Climate Change Canada (ECCC), Toronto, ON M3H 5T4
Tel: (416) 739-5944; Email: Hayley.Hung@canada.ca

Alexandra Steffen, Science and Technology Branch, Air Quality Processes Research Section, Environment and Climate Change Canada (ECCC), Toronto, ON M3H 5T4
Tel: (416) 739-4116; Fax: (416) 739-4318; Email: Alexandra.Steffen@canada.ca

Project Team/Équipe de projet

Hayley Hung, Alexandra Steffen, Liisa Jantunen, Fiona Wong, Tom Harner, Geoff Stupple, and Organics Analysis Lab (OAL), Environment and Climate Change Canada; Derek Cooke, Ta’än Kwach’än Council; Jamie Thomas, Aurora Consulting, YK; Carl Mitchell, and Frank Wania, University of Toronto; Michael Barrett, Véronique Gilbert, Monica Nashak, Kativik Regional Government Administration; Donald S. McLennan, Angulalik Pedersen, Dwayne Beattie, Johann Wagner, Polar Knowledge Canada; David Oberg, and Chris Spencer, Nunavut Government Department of Environment; Erika Hille, Annika Trimble, Edwin Amos, Andrew Gordon, and Jolie Gareis, Aurora Research Institute, Aurora College; Diane Giroux, Annie Boucher, Akaitcho Territory Government; Rosie Bjornson, Kathleen Fordy, and Patrick Simon, Deninu Kue First Nation (DKFN), Fort Resolution; Arthur Beck and Shawn Mckay, Fort Resolution Métis Council; Tausia Lal, Hamlet of Fort Resolution; Rodd Laing, Liz Pijogge, Nunatsiavut Government; Tim Heron, Northwest Territory Métis Nation

Project Location/Emplacement(s) du projet

- Inuvik/Mackenzie Delta, NT
- Fort Resolution, NT
- Cambridge Bay, NU
- Kuujjuaq, QC
- Iqaluit, NU
- Nain, NL
- Northwest River, NL

Abstract

This project measures contaminants, namely persistent organic pollutants (POPs) and mercury, in the air at seven locations across Canada's North. Before the start of the project in 2014, these contaminants in the air in Canada were only measured at Alert and Little Fox Lake under the Northern Contaminants Program (NCP); and Alert, Little Fox Lake and Coral Harbour as part of the Global Atmospheric Sampling (GAPS) Network. The current project adds seven sites, including Inuvik/Mackenzie Delta, Fort Resolution, Cambridge Bay, Kuujjuaq, Iqaluit, Nain, and Northwest River. These additional sampling locations provide data to create a more comprehensive picture of the levels of contaminants over various environments, how they are carried through the air from more southerly regions and arrive in the Arctic and how contaminant levels are changing over time.

Under this project, POPs measurements continued at seven passive air sampling stations across the Arctic from April 2017 to March 2018. While passive sampling takes much longer than traditional sampling methods, the passive samplers are a low-cost, low-maintenance way to monitor contaminants in air because they do not require power for pumps or housing for the instruments that are usually used for contaminant sampling. Passive sampling is straightforward and can easily involve students or other interested persons in the sample collection. This can enhance communication between the project team and local communities as well as creates training opportunities for Northern students. This year, field tests for developing a passive mercury air sampler have been completed and the mercury passive samplers at the Arctic stations will soon be used at the 7 passive sampling sites and at Alert and Little Fox Lake. A northern student, Jamie Thomas, was engaged to research on Indigenous Knowledge (IK) in the Yukon region which may be used in the air monitoring projects for POPs and mercury. Jamie has interviewed four elders and has drafted a report which we are currently reviewing to better understand the IK information.

Résumé

Ce projet vise à mesurer les contaminants atmosphériques, dont les polluants organiques persistants (POP) et le mercure, à sept endroits du Nord canadien. Au Canada avant le début du projet en 2014, ces contaminants atmosphériques étaient mesurés uniquement à Alert et au lac Little Fox dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN) ainsi qu'à Alert, au lac Little Fox et à Coral Harbour dans le cadre du Réseau mondial d'échantillonnage atmosphérique passif. Le projet actuel englobe sept endroits supplémentaires dont Inuvik et le delta du Mackenzie, Fort Resolution, Cambridge Bay, Kuujjuaq, Iqaluit, Nain et Northwest River. Ces lieux d'échantillonnage supplémentaires fournissent des données qui permettent de produire un portrait plus complet des concentrations de contaminants dans différents environnements, de savoir de quelle façon ils sont transportés dans l'air à partir des régions méridionales jusqu'à l'Arctique et sur l'évolution des concentrations de contaminants.

Dans le cadre de ce projet, les mesures de POP se sont poursuivies à sept stations d'échantillonnage atmosphérique passif dans l'ensemble de l'Arctique d'avril 2017 à mars 2018. Bien que l'échantillonnage passif nécessite beaucoup plus de temps que les méthodes traditionnelles d'échantillonnage, les échantillonneurs passifs constituent un moyen économique et nécessitant peu d'entretien pour surveiller les contaminants atmosphériques parce qu'ils ne comportent pas de pompe; ils ne nécessitent donc pas d'électricité ni de boîtier de protection, contrairement aux instruments qui sont habituellement utilisés pour l'échantillonnage de contaminants. L'échantillonnage passif est simple et peut être effectué facilement par des étudiants ou d'autres personnes qui souhaitent participer au prélèvement d'échantillons.
Ce type d'échantillonnage peut améliorer la communication entre l'équipe de projet et les populations locales et créer des occasions de formation pour les étudiants du Nord. Cette année, des essais sur le terrain afin de mettre au point un échantillonneur passif pour détecter

les concentrations atmosphériques de mercure ont été menés, et les échantillonneurs passifs de mercure des stations de l'Arctique seront bientôt utilisés dans les sept emplacements d'échantillonnage passif ainsi qu'à Alert et au lac Little Fox. Un étudiant du Nord, Jamie Thomas, 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. Jamie a interrogé quatre aînés et a rédigé un rapport que nous examinons actuellement pour mieux comprendre les connaissances autochtones.

Key Messages

- Passive air sampling equipment for POPs has been sent to seven arctic sites and most stations were in operation since October 2014.
- Project leaders visited Iqaluit (Nunavut), Whitehorse (Yukon) and Inuvik (NWT) to discuss with the respective Regional Contaminants Committees and community leaders about the science activities and communication/outreach plans under this project. Project leaders also engaged communities through a variety of communication/capacity building activities, including giving lectures at the Nunavut Arctic College, Yukon College, the Aurora College and East Three Secondary School.
- Polychlorinated biphenyls (PCBs) were found in air samples collected at five arctic sites at concentrations similar to other Arctic locations. The highest concentrations were found in Nain, Nunatsiavut with levels close to those found at an urban site in Toronto. These high concentrations at Nain suggest potential local sources of PCBs in Nain.

Messages clés

- On a envoyé de l'équipement d'échantillonnage atmosphérique passif des POP à sept sites différents dans l'Arctique, et la plupart des stations étaient opérationnelles en octobre 2014.
- Les chefs de projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Inuvik (T.N.-O.) 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. Les chefs de projet se sont également adressés aux collectivités au moyen de différentes activités de communication et de renforcement des capacités, notamment en prononçant des conférences au Collège de l'Arctique du Nunavut, au Collège du Yukon, au Collège Aurora et à l'école secondaire East Three.
- Des biphényles polychlorés (BPC) ont été détectés dans les échantillons d'air prélevés à cinq lieux arctiques à des concentrations similaires à ce qui est enregistré ailleurs dans l'Arctique. Les concentrations les plus élevées ont été enregistrées à Nain, au Nunatsiavut, où les concentrations étaient presque égales aux concentrations constatées en milieu urbain à Toronto. Ces concentrations élevées à Nain permettent de croire qu'il y aurait des sources locales de BCP à Nain.

Objectives

Short-term objectives of this project are to:

- expand the geographic coverage of the air monitoring program by operating passive air sampling devices at seven locations across all Arctic regions. Separate devices will be deployed for POPs and mercury;
- work with the northern communities through the colleges and develop a community-based mercury monitoring program through mercury passive sampling;
- 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; and
- 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 to:

- provide key data to evaluate the overall effectiveness of the provisions outlined in the Stockholm Convention, the Convention on Long-range Transboundary Air Pollution (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; and,
- 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 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 is valuable for further constraining atmospheric models of pollutant transport, chemistry and deposition, since current validation data is 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.

This project is designed to build upon the two Northern Contaminants Program (NCP) core air monitoring projects for POPs and mercury in air, namely “Northern Contaminants Air Monitoring: Organic Pollutant Measurements” and “Mercury Measurements at Alert and Little Fox Lake”, 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 expand coverage and develop an Arctic network of passive air samplers (PAS). 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 resin-based (one-year integrated sampling) and

PUF-disk-based (3-month integrated sampling) PAS at seven 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 and is ideal for sampling in locations with relatively low air concentrations of organic contaminants, such as the Arctic.

Sampling at most of the seven sites started in winter 2014/15. However, in 2016/2017 some sites encountered problems and samples were not taken or lost, mostly due to changes in personnel. During 2017-2018, all seven sites were up and running. Some delays were encountered at some stations due to staff changeover, poor weather conditions and/or damage to the samplers (e.g. someone shot at the samplers at Fort Resolution), but sampling is currently ongoing.

The team initiated and successfully developed a mercury PAS composed of a small cylindrical container for activated carbon inserted into a diffusion tube of the commercial Radiello type PAS. Field tests for developing a passive mercury air sampler have been completed and we are planning to start using the mercury passive samplers at the arctic stations in FY 2018-19.

Activities in 2017-2018

Activities at Passive Air Sampling Sites

Sampling at most of the seven sites started in winter 2014-2015. However, in 2016-2017 some sites encountered problems and samples were not taken or lost, mostly due to changes in personnel. In 2017-2018 all sites became operational. With the help of Polar Knowledge Canada (Dwayne Beattie, Angulalik Pedersen and Gavin Greenley), a new sampling site has been set up North of Grenier Lake (+/- 13 km NE of the Hamlet, upwind of the town). We look forward to receiving samples from Cambridge Bay in the coming year. Additionally, with the help of Liz Pijogge and Rodd Laing, a station has been set up at Northwest River this year.

For the other stations, some delays were encountered due to staff changeover, poor weather conditions and/or damage to the samplers (e.g. 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 continued to be available online.

Passive sampler analysis

The XAD-PAS collected in 2015 were analyzed for polychlorinated biphenyls (PCBs). Preliminary results are presented here (see below).

Mercury Passive Sampler

The newly developed mercury passive air sampler has been tested around the world alongside active sampling instruments, including those at Alert and Little Fox Lake. It has been found that the Hg-PAS can produce accurate and precise concentration measurements similar to those of the active sampling devices and is capable in doing so at background concentrations under a wide range of environmental conditions, including the Arctic. A paper has been published documenting the field measurement results "McLagan et al., Global evaluation and calibration of a passive air sampler for gaseous mercury" (McLagan et al., 2018).

Communications, Community Engagement and Capacity Building

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

The following is a description of the activities that occurred in 2017-2018:

1. Iqaluit February 2017

On February 21, 2017, 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. We also had a fruitful meeting with the Nunavut Environmental Contaminants Committee (NECC) on February 20 to update our project plans and understand the needs of the community with respect to those plans. Sandy and Hayley also met and consulted with Mr. Matthew Hamp (Director of Public Works and Engineering, City of Iqaluit) regarding the passive air sampling campaign ongoing in Iqaluit under Project M03 "Passive Air Sampling Network for Organic Pollutants and Mercury". Travel funding will be requested in next year's budget to continue this teaching effort and in person meeting.

2. Whitehorse March 2017

The Yukon Contaminants Committee (YCC) hosted a Yukon event in Whitehorse where local community members and scientist gathered to meet, discuss contaminant issues, and garner ideas for working together in the future. Hayley and Sandy gave presentations on the work that we have done through the NCP. They participated in the discussions with the scientists and community members and started to develop the idea of a community based mercury monitoring program involving the mercury passive samplers.

3. Yellowknife September 2017

At the annual NCP symposium, Hayley, Geoff and Liisa made hands-on displays and demonstrations at the booth at the annual results workshop. While Sandy could not attend the meeting, she did prepare a video to wish the NCP a Happy 25th Anniversary. On September 28, 2017, while at the NCP Results Workshop, Hayley conducted a radio interview with CBC North's Melinda Trochu to talk about air monitoring of contaminants in the Arctic under NCP.

4. Inuvik October 2017

Sandy, Hayley and Liisa visited Inuvik from October 3 to 5, 2017. We met with Erika Hille and Annika Trimble at the Aurora College. We had a full discussion on what we are doing, why it's relevant and what we would like to do in the future. We met the location technicians who work with Hayley on the POPs passive sampling project. We met with Janet Boxwell, the Renewable Resources Manager of the Gwich'in Renewable Resources Board, and had a very good discussion about our work in the Arctic. We tried to meet with Shannon O'Hara who wanted to organize a community discussion but the timing did not work out while we were in Inuvik. We gave a presentation entitled "Contaminants in Arctic Air and Oceans" at the Aurora College in the evening of October 3 that was open to community members at the College location. The seminar has been recorded and the college will share it with interested parties who could not attend in person. Hayley, Liisa and Sandy gave a seminar and hands on presentation to college students in the Environmental and Natural Resource Technology Program and East Three Secondary School Grade 10 students. Along with the college students, Hayley, Liisa and Sandy conducted a site visit to the passive air sampling station which is currently placed in-town at the National Air Pollution Surveillance Program (NAPS) station. We spent some time scouting out a different location for the POPs and, eventually, the mercury passive samplers as the current site is not the best for our measurements. We sent out several invitations to meet with local radio and newspaper but the timing for interviews did not work out.

5. Whitehorse November 2017

On November 3, 2017 Sandy and Hayley called into the YCC meeting to discuss project plans for the upcoming fiscal year at Little Fox Lake. November 7, Sandy and Geoff travelled to Whitehorse for a technical and communications visit. November 8, they met with Derek Cook and Jamie Thomas to discuss the draft version of the IK report (see below). November 9, Sandy met with some members of the YCC (Ellen Sedlack, Shane Kilpatrick, Mary Gamberg, Derek Cooke) and updated them on the mercury science at Little Fox Lake, provided an update on Minamata COP1 meeting, discussed a potential community program for passive Hg sampling, discussed the future of the passive Hg sampling project (M03) and ideas for eventually building that into a community monitoring program. Sandy provided slides on the mercury measurements in the Yukon to both Mary Gamberg and Derek Cooke have used for their communication programs and discussions with interested colleagues. We offered site visit to YCC member but no one was available to take us up on it, next time! Geoff and Sandy also met up with our Laberge project partners (Bonnie Burns, Ken Nordin and Dylan Nordin) and discussed the site operations, the data and results and future planning for work at the site.

6. Whitehorse February 2018

Hayley visited Whitehorse from February 5-7, 2018. She met with the YCC at the Ta'än Kwach'än Council (TKC) on February 5 to discuss about her project proposals. On February 6, Hayley gave a presentation at the Crown Indigenous and Northern Affairs Canada (CIRNAC) office in Whitehorse during the Environment Directorate staff meeting about air monitoring of POPs and mercury at the Little Fox Lake station. She then gave two seminars at the Yukon College to students attending the courses: "Yukon Source Water Protection & Watershed Stewardship" and "Environmental Change and Community Health". After the seminars, she met with Derek Cooke and Jamie Thomas to discuss about finalizing the IK report. On February 7, Hayley met with team members of Laberge Environmental Services to discuss about electrical power issues at the Little Fox Lake station.

7. Iqaluit January 2018

In January 23-25, 2018, Sandy and Hayley visited 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. This year's hands-on session included the demonstration of using the Direct Mercury Analyzer which the college has recently acquired. They visited the POPs passive sampling site on January 24 and assisted operator Chris Spencer in changing one of the air samples. Sandy and Hayley also met with the NECC to discuss their communication, capacity building and IK plans.

Indigenous Knowledge (IK) Integration

In November 2016, Jamie Thomas was hired by CYFN, in consultation with Derek Cooke (TKC), to undertake an IK subproject under the Passive Air Sampling Network for Organic Pollutants and Mercury project to improve 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. March 11, 2017, Jamie hosted an event for local elders at the Yukon Horse Packing retreat facility which is located between Whitehorse and Little Fox Lake, on Fox Lake. This event was 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. Unfortunately, not many people were in attendance at the event, even though the event was advertised on the local radio station and advertised through the TKC website inviting elders and people of all ages to attend. Over the summer of 2017, with the help of the coordinators of First Nations elder of the Yukon College and TKC's Derek Cooke, Jamie interviewed four elders and asked questions related to 5 themes: i) General knowledge of contaminants in the north; (ii) knowledge of weather patterns; (iii) forest fires; (iv) mining;

and (v) environmental change Jamie prepared a draft report summarizing the discussions.

When in Whitehorse, Sandy and Geoff discussed with Derek and Jamie about the IK report. The initial draft report was good but needed some modification to consolidate the information to undertake full analysis. The interviews with the elders provided some excellent information for the project. Jamie then revised the report and Sandy and Hayley are now going through the report and will work with Derek Cook to complete a full analysis. The report will then be sent to the elders for their feedback and approval before we continue finalizing the report. After approval from the elders, we will provide the report to the YCC and then make it more available from there. We want to be mindful of the elders and ensure that their knowledge is being conveyed in a manner in which they are comfortable.

Results

PCBs in XAD-based Passive Samples (PAS) in 2015

We have analysed the XAS-PAS collected in 2015 for 27 PCB congeners. The target PCB congeners were: 11, 18, 28+31, 44, 52, 70, 77, 100, 101, 105, 110, 114, 118, 119, 126, 131, 138+163, 153, 156, 170, 171, 172, 180, 199, and 202. We present the results in units of pg/m^3 by assuming linear uptake of chemicals by the XAD-PAS. Sampling rate for XAS-PAS was 0.59 m^3/day for the Arctic sites and 1.85 m^3/day for the urban site (Hayward et al., 2010). XAD-PAS was a one-year integrated sample and designed to capture gas-phase compounds only (Wania et al., 2013). There was one field blank analyzed for each site. Trace levels of PCBs were found in the field blanks. Data presented here were blank corrected according to the field blank obtained at each sampling site.

The names of the Arctic sites and abbreviations used in the following discussion were: Fort Resolution (FR), Inuvik (IN), Iqaluit (IQ), Kuujjuaq (KU), and Nain (NA). Downsview (DV) is the urban site.

In general, the sum of 27 PCBs for all sites, from highest to lowest concentrations were: DV (8.6 pg/m^3) > NA (7.1 pg/m^3) > IN (2.2 pg/m^3) > FR (1.4 pg/m^3) > KU (0.0014 pg/m^3) > IQ (0.0008 pg/m^3).

Discussions and Conclusions

PCBs collected by XAS-PAS in 2015

PCB concentrations in air in the urban site, DV, were higher than in the Arctic sites. This is expected as consumption and storage of PCBs happens mostly in urban/industrial areas. Previous studies have reported higher atmospheric PCB levels were associated with urban sites (Pozo et al., 2009; Silva-Barni et al., 2018). However, it is interesting to observe that levels of PCBs in air from NA were only slightly lower than those in DV. This may suggest local point sources (such as waste burning, PCB-containing transformers) of PCBs at NA near the sampling site.

PCB levels were within the same range as those reported in air in Alert and other Arctic sites. The mean sum of eight PCBs (i.e. 28+31, 52, 101, 105, 118, 153, and 180) in the five Arctic sites was 1.1 pg/m^3, ranging from non-detect to 3.7 pg/m^3. The sum of seven PCBs (i.e. 28, 52, 101, 105, 118, 153, and 180) in Alert was 1.7 pg/m^3 in 2012 (data available at ebas.nilu.no). In air in Finland during 2011, the sum of seven PCBs in Råo was 12.5 ± 7.5 pg/m^3 and in Pallas was 4.1 ± 3.4 pg/m^3 (Anttila et al., 2016). In air in Norway, the sum of seven PCBs in 2015 ranged from 1.8-2.8 pg/m^3 for the three sites: Andøya, Zepplein, and Birkenes (NEA 2016).

In conclusion, our initial results indicate that PCBs were found in our Arctic passive air sampling sites. Our measurements were consistent with previous reports. We will further investigate the sources and transport of these chemicals to the Arctic and performance of the XAD-PAS as part of ongoing research.

Expected Project Completion Date

Ongoing

Acknowledgments

The team would like to acknowledge NCP for funding the passive air sampling network. The continued support of the five Regional Contaminants Committees, 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 the NCP in fiscal year 2013-2014. 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, Chris Spencer, Nunavut Government); Nain and Northwest River – two sites (Rodd Laing and Liz Pijogge, Nunatsiavut Government); Inuvik (Erika Hille, Annika Trimble, Edwin Amos, Andrew Gordon, Jolie Gareis, Aurora College); Cambridge Bay (Donald S. McLennan, Angulalik Pedersen, Dwayne Beattie, Johann Wagner, POLAR) and Kuujjuaq (Michael Barrett, Véronique Gilbert, 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

Project Leader/Chef de projet

Magali Houde, Environment and Climate Change Canada, Aquatic Contaminants Research Division, Montreal, QC. Tel: (514) 496-6774; Email: magali.houde@canada.ca

Derek Muir, Environment and Climate Change Canada, Aquatic Contaminants Research Division, Burlington, ON Tel: (905) 319-6921; Email: derek.muir@canada.ca

Steve Ferguson, Fisheries and Oceans, Arctic Aquatic Research Division, Winnipeg, MB Tel: (204) 983-5057; Email: steve.ferguson@dfo-mpo.gc.ca

Project Team/Équipe de projet

Qausuittuq (Resolute Bay) Hunters and Trappers Association, NU; Sachs Harbour Hunters and Trappers Committee, NWT; Arviat Hunters and Trappers Organization, NU; Jeff Kuptana, Sachs Harbour, NWT; Frank Nutarasungnik, Arviat, NU; Liz Pijogge and Rodd Laing, Environment Division, Nunatsiavut Government, NL; Brent Young, Fisheries and Oceans Canada, Winnipeg, MB; Aaron Fisk and Dave Yurkowski, University of Windsor, Windsor, ON; Bert Francoeur and Jacques Carrier, NLET inorganics, Environment and Climate Change Canada, Burlington, ON; Mary Williamson, Amy Sett, and Xiaowa Wang, Aquatic Contaminants Research Division, Environment and Climate Change Canada, Burlington, ON; Serge Moore, QLET organics, Environment and Climate Change Canada, Montreal, QC

Project Location/Emplacement(s) du projet

- Sachs Harbour, NT
- Resolute Bay, NU
- Arviat, NU
- Nain, NL

Abstract

The major questions that this project is addressing are: (i) how are concentrations of legacy contaminants and other persistent organic pollutants (POPs) as well as mercury changing over time in ringed seals? and (ii) are trends similar across the Inuit Nunangat? The presence and trends of new and emerging contaminants are also investigated. This project involves annual sampling completed by local harvesters and coordinated by Hunters and Trappers Associations/Committees in Sachs

Résumé

Ce projet porte principalement sur les questions suivantes : i) de quelle façon les concentrations de contaminants hérités du passé et d'autres POP ainsi que le mercure évoluent-elles au fil du temps chez le phoque annelé; ii) les tendances sont-elles semblables partout dans l'Inuit Nunangat? La présence et les tendances des nouveaux contaminants sont aussi étudiées. Ce projet comporte le prélèvement annuel d'échantillons par des chasseurs locaux, coordonné par les associations et les comités de

Harbour, Resolute Bay, Arviat, and Nain. The annual measurements of contaminants in Arctic ringed seals have demonstrated that seals are very good indicators of changing uses and production of chemicals widely incorporated in consumer and industrial products.

Since 2016, outreach activities to the communities and integration of Inuit knowledge have been added to this long-term monitoring project. This year, a one-day educational workshop on ringed seal health was successfully organized at the Inualthuya school in Sachs Harbour, NWT. This complementary project "*Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Sachs Harbour, Northwest Territories*" funded as part of the Northern Contaminants Program's (NCP) Communications, Capacity Building, and Outreach subprogram, allowed NCP research scientists working on contaminants in ringed seals to share information about their work and provided opportunities for Inuvialuit elders to share their knowledge with students and researchers in seal ecology and traditional methods of captures and skinning.

chasseurs et de trappeurs de Sachs Harbour, de Resolute Bay, d'Arviat et de Nain. Les mesures annuelles des contaminants chez le phoque annelé de l'Arctique ont montré que le phoque 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.

Depuis 2016, des activités de sensibilisation des collectivités et d'intégration des connaissances inuites ont été ajoutées à ce projet de surveillance à long terme. Cette année, l'école Inualthuya de Sachs Harbour, dans les Territoires du Nord-Ouest, a organisé avec succès un atelier éducatif d'une journée sur le phoque annelé. Ce projet complémentaire « d'apprentissage sur la santé du phoque annelé à partir de la science des contaminants et des connaissances inuites : atelier éducatif à Sachs Harbour (Territoires du Nord-Ouest) », financé en tant que volet du sous-programme de communications, de renforcement des capacités et de sensibilisation du Programme de lutte contre les contaminants dans le Nord, a permis aux chercheurs du PLCN qui s'occupent des contaminants chez le phoque annelé de communiquer de l'information sur leur travail et a permis aux aînés des Inuvialuits de faire part de leurs connaissances aux étudiants sur l'écologie du phoque et les méthodes traditionnelles de capture et d'écorchage.

Key Messages

- Legacy compounds such as PCBs, DDT, Chlordane, and HCH continue to decline in blubber of ringed seals.
- Mercury concentrations in liver and muscle vary from year to year but overall are not increasing in ringed seals.
- Trends were updated up to 2016 for flame retardants and results indicated very slow decrease of PBDEs and HBCD in blubber of seals for Sachs Harbour, Arviat, and Resolute.

Messages clés

- Les concentrations de composés hérités du passé comme les BPC, le dichlorodiphényltrichloroéthane (DDT), les chlordanes et l'hexachlorure de benzène (HCH) continuent de diminuer 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 tendances ont été mises à jour jusqu'à 2016 pour les produits ignifuges, et les résultats indiquent une très lente diminution des concentrations de PBDE et de HBCD

- In recent years, increases of perfluoroalkyl substances have been observed in liver of seals at some locations.
- The annual measurements of contaminants in Arctic ringed seals have indicated that seals are very good indicators of changing uses and production of chemicals widely incorporated in consumer and industrial products.
- Collaborations between this Environmental Monitoring and Research project and the Communications, Capacity Building and Outreach project "*Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Sachs Harbour, Northwest Territories*" provide opportunities to enhance local capacity building, communications and the use of traditional ecological knowledge in contaminants research on ringed seals.

dans le pannicule adipeux des phoques de Sachs Harbour, d'Arviat et de Resolute.

- Au cours des dernières années, des augmentations des concentrations de substances perfluoroalkyliques ont été observées dans le foie des phoques de certains endroits.
- Les mesures annuelles des contaminants chez le phoque annelé de l'Arctique indiquent que le phoque 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.
- Les collaborations entre le projet de surveillance de l'environnement et de recherche dont il est question ici et le projet « d'apprentissage sur la santé du phoque annelé à partir de la science des contaminants et des connaissances inuites : atelier éducatif à Sachs Harbour (Territoires du Nord-Ouest) » du programme de communications, de renforcement des capacités et de sensibilisation permettent d'améliorer le renforcement des capacités locales, les communications et l'utilisation des connaissances écologiques traditionnelles dans la recherche sur les contaminants dans les phoques annelés.

Objectives

The aim of this project is to:

- 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; and,
- collaborate in a health in ringed seal workshop in Sachs Harbour, NWT to help engage youth, elders and scientific researchers in learning about ringed seal health from both Inuit knowledge and scientific perspectives.

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. Currently this project focuses on updating trends of legacy compounds, organochlorine pesticides, flame retardants, perfluoroalkyl substances and mercury in ringed seal tissues.

Because ringed seals are an important species harvested by hunters each year in 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.

This report updates trends of legacy compounds, flame retardants, perfluoroalkyl substances and mercury in ringed seal tissues. Outreach to the Sachs Harbour community and integration of Inuit knowledge to this long-term monitoring project are also discussed.

Activities in 2017-2018

In 2017, ringed seal samples were successfully collected by hunters in the communities of Arviat (n=25), Sachs Harbour (n=15), Resolute (n=16), and Nain (n=17). 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 2017-2018, new and emerging POPs were determined in ringed seals samples (i.e, organophosphorus and selected brominated flame retardants, current use pesticides, and polychlorinated naphthalenes). Multi-element analyses were conducted on liver samples which provided concentrations of a range of metals and essential elements. In addition to mercury, knowledge of the concentrations two elements, selenium and cadmium, is particularly of interest. Methyl mercury can be very toxic to organisms and selenium has a protective role in reducing its effects. Information on cadmium is also important because of its toxicity and relatively high levels in seal liver.

Chemical analyses

Analyses of organic chemicals in the 2017 samples were done by the Quebec Laboratory for Environmental Testing (QLET; Environment and Climate Change Canada Montreal). Results for analyses should be received by June 2018. Chemical extraction and cleanup procedures for tissue samples followed the same general procedure as in previous years. Blubber samples (1 g) were extracted and lipid removed using USEPA Method 1699 (USEPA 2007). The lab determined selected organochlorine candidate POPs and polychlorinated naphthalenes by high resolution mass spectrometry. Brominated flame retardants were analyzed by gas chromatography mass spectrometry.

Total mercury in muscle was determined by Direct Mercury Analyser using EPA method 7473 (US Environmental Protection Agency 2007). Thirty-four 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 by using cold vapor atomic absorption spectrometry.

Quality assurance (QA) and statistical analyses

The National Laboratory for Environmental Testing (NLET, Environment and Climate Change Canada, Burlington, ON) lab is certified by certified by Canadian Standards Association and are participating annually in the NCP Interlab comparisons. QLET works using the same procedures and will participate for the first time to the Interlab comparisons study in 2018-2019. The Muir lab at Environment and Climate Change Canada (ECCC) in Burlington participated in the NCP Interlab 2017-2018 comparisons for PFASs and for mercury. QA steps included the analysis of reference materials for heavy metals and POPs and reagent blanks with each batch of samples. All results were blank subtracted.

Basic statistics, correlations and frequency distributions were determined using Systat Version 12 (Systat Software Inc., Chicago IL). Organohalogen concentrations in ringed seals were normalized to 100% lipid. For temporal trend comparisons results were first tested for normality using the Shapiro-Wilk test. All contaminants data were log_{10} transformed to give coefficients of skewness and kurtosis < 2 and geometric means (back transformed log data) were calculated. 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 of Arviat, Resolute, Sachs Harbour, and the Environment Division of the Nunatsiavut Government involved with the project. The main communications with the Hunters and Trappers were done by phone and email. Progress reports on the project in English and Inuktitut (for Nunavut) were sent in March 2018 to each participating communities after review by the Nunavut Environmental Contaminants Committee and the NWT Regional Contaminants Committee. Co-leaders of the project visited Resolute in August 2017 and Sachs Harbour in January 2018 and met with the Hunters and Trappers Committee, the local school children and professionals as well as elders. Results of this project were also presented at national and international meetings (e.g., NCP Results Workshop, Arctic Change, Society of Environmental Toxicology and Chemistry).

Inuit Knowledge

Effective communication and engagement between researchers and northern community members is central to Inuit Nunangat. The Nunavut Environmental Contaminants Committee (NECC) has recently suggested increasing community engagement as part of this ongoing work. Indigenous knowledge and community outreach components were therefore added to this project in 2016 in collaboration with Dominique Henri, an Indigenous knowledge expert at ECCC. 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. To this date, health in ringed seal workshops were held in Resolute Bay (2016) and Sachs Harbour (2018) to engage youth, elders and scientific researchers in learning about ringed seals from both Inuit knowledge and scientific perspectives. Interactions and discussions were very much appreciated by everyone. It is hoped to reiterate this experience every year in one of the four communities implicated in this core monitoring project.

Capacity Building

In January 2018, Magali Houde, a research assistant from Environment and Climate Change Canada; a student from the Environmental Training Program (Nunavut Arctic College); and a graduate student from the University of Winnipeg participated in the health in ringed seal workshop held in Sachs Harbour, NWT. Houde also participated to the Wildlife Contaminants Workshop at the Nunavut Arctic College in September 2017 in Iqaluit as part of training and capacity building. She provided background on contaminants pathways and sources and, with help of a local hunter, co-led a ringed seal dissection with students and discussions about wildlife sampling. Moreover, Derek Muir visited Resolute in August 2017 and met with the community members and the Hunters and Trappers Association.

Community Engagement

From September 2017 to January 2018, workshop program and content were co-developed by scientific researchers, Inualthuya school personnel and representatives from the Sachs Harbour Hunters and Trappers Committee. A main goal of this one-day workshop held at the Inualthuya School in was to engage youth, Elders and scientific researchers in learning about ringed seals from both Inuit knowledge and scientific perspectives. Presentations were done by scientists and discussions with Elders about ringed seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested were held. Games were also played with kids and interactive laboratory activities conducted in classes.

Results

Sample collection and hunter observations

In 2017 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 results for DNA analysis. 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 2017 (except for Nain, results pending) and results are shown in Figure 1. Results are for adults only (> four years of age) which show little variation of concentrations with age. Average mercury concentrations in muscle were generally lower in the period 2010-2016 compared to the late

Table 1. Change per year (%) of legacy contaminant concentrations in blubber of ringed seals (1990s-2016).

	Regions		
Chemicals	**Arctic Archipelago[1]**	**Beaufort Sea[2]**	**Hudson Bay[3]**
α-HCH	-7.0%	-4.7%	-9.2%
Dieldrin	-2.2%	-2.6%	-5.1%
HCB	-1.3%	-1.9%	-2.7%
Lindane	-5.9%	-4.4%	-8.2%
p,p-DDE	-2.6%	-0.7%	-6.4%
Sum Chlordane	-3.2%	-1.9%	-7.3%
Sum HCH	-4.7%	-2.9%	-8.3%
Sum DDT	-3.6%	-1.8%	-7.0%
Sum PCB	-2.2%	-1.5%	-4.8%

[1] Locations included in the analyses: Resolute, Arctic Bay, Grise Fjord, Pangnirtung

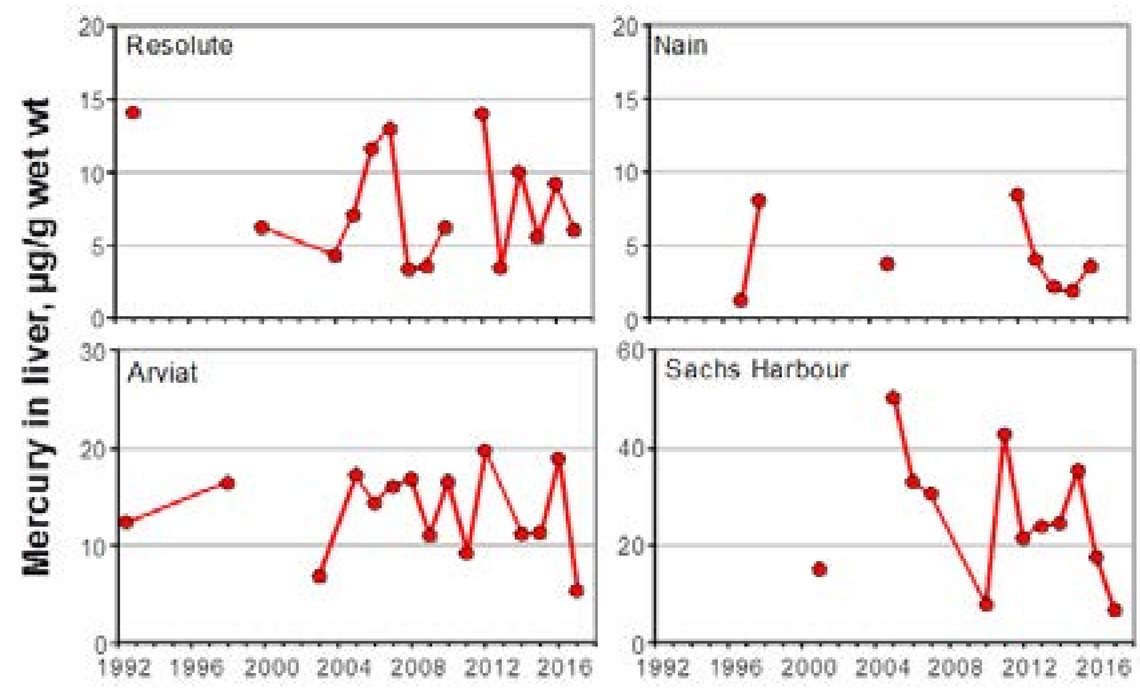
[2] Sachs Harbour, Ulukhaktok

[3] Arviat, Inukjuak

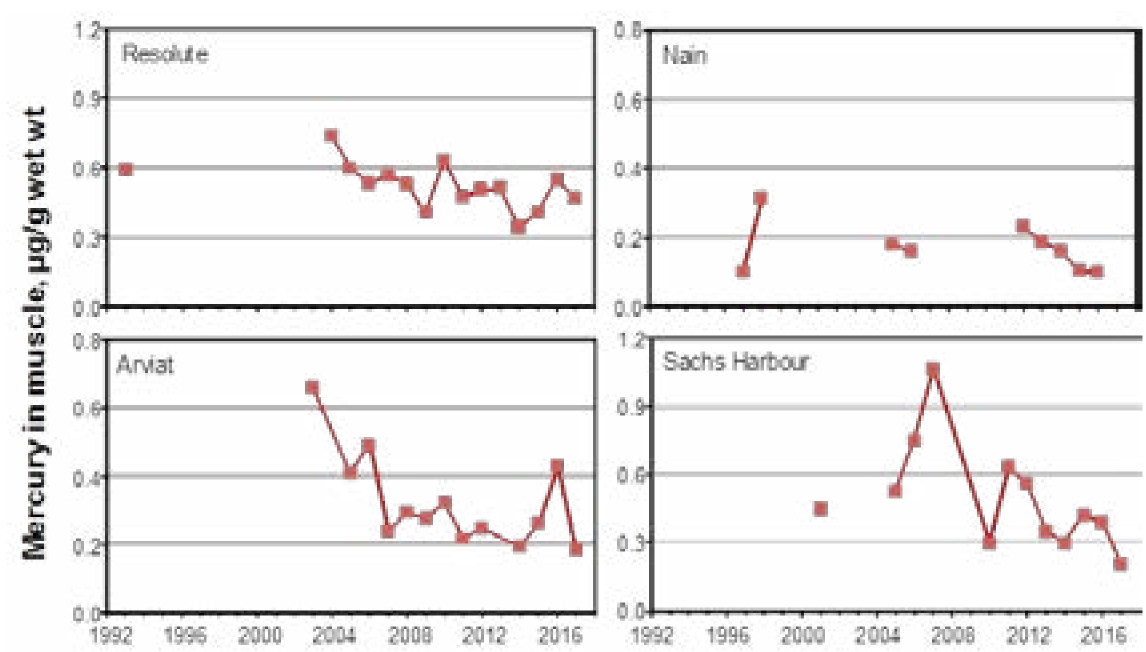
HCH: Hexachlorocyclohexane, HCB: Hexachlorobenzene, *p,p*-DDE: Dichlorodiphenyldichloroethylene, DDT: dichlorodiphenyltrichloroethane, PCB: polychlorinated biphenyls

Figure 1. Trends of mercury in A) liver and B) muscle of adult ringed seals (≥ 4 years old) from 1990s to 2017. Geometric mean concentrations are presented.

A. Liver



B. Muscle



1990s and early 2000s; however, differences were not statistically significant. Concentrations of mercury in liver were more variable than in muscle but no overall trends were observed through time. Continued annual sampling and comparison with climate and food web related variables may help determine reasons for this variation.

Legacy compounds

During 2017, temporal trends of PCBs and organochlorine pesticides in blubber of ringed seals were updated with 2016 data and percentages of annual decrease from 1990s to 2016 are indicated in Table 1. Data collected from nearby communities were integrated into regions to get an overview of the trends of these legacy compounds in seals. Concentrations of all chemical groups have been slowly declining at all sites, including Nain (results not shown), with low percentages of annual decrease measured. A manuscript is presently under preparation to present the spatial and temporal distribution of legacy POPs in ringed seals.

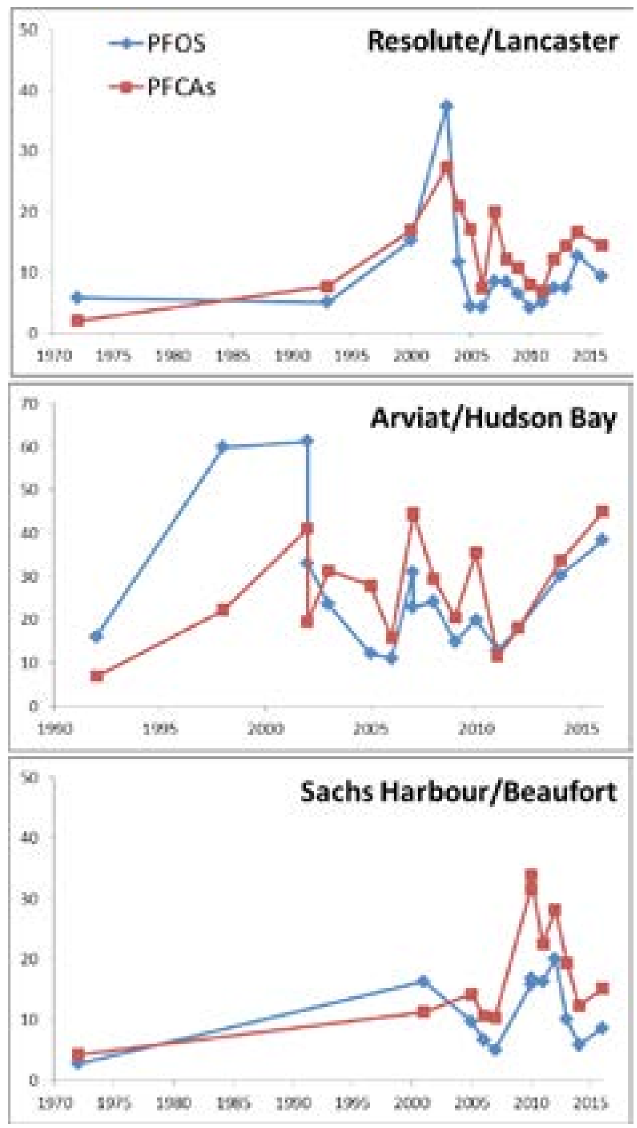
Flame retardants

The trends of polybrominated diphenyl ethers (PBDEs) and other emerging flame retardants (1990s-2014) were published in 2017 in a peer-review journal (Houde et al. 2017). Trends were updated up to 2016 this year and results indicated very slow decrease of PBDEs and HBCD in blubber of seals for Sachs Harbour, Arviat, and Resolute. Additional collection in Nain is needed in order to establish temporal trends.

Perfluoroalkyl substances

Trends for polyfluoroalkyl substances (PFAS) indicated that concentrations of perfluorooctane sulfonate (PFOS) and perfluorocarboxylic acids (PFCAs) in liver of ringed seals from Lancaster Sound and Hudson Bay declined over the period of the mid-2000s to 2011 but have increased in recent years (2011-2016) (Figure 2). Levels in animals from the southern Beaufort Sea (Sachs Harbour) increased from 2006 to 2011 then rapidly declined until 2014. Concentrations measured in 2016 were however higher than 2014. New PFAS (e.g., F53B, PFONS, PFOUdS, DONA) have also been detected at low concentrations (<1 ng/g wet weight) in ringed seals. These substances are replacements for PFASs that have been banned such as PFOS or phased out e.g., PFOA and other PFCAs with 8 or more perfluorinated carbon chains.

Figure 2. Temporal trends (1970s/1990s-2016) of perfluorooctane sulfonate (PFOS) and the sum of perfluorocarboxylic acids (PFCA) in liver of ringed seals from three different regions of Inuit Nunangat (ng/g wet wt).



Discussion and Conclusions

Results of this core monitoring project indicated that concentrations of legacy chemicals, such as PCBs, DDT, Chlordane, and HCH continued to decline slowly in blubber of ringed seals across the Inuit Nunangat. Trends were updated up to 2016 for flame retardants and results indicated very slow decrease of PBDEs and HBCD in blubber of seals for Sachs Harbour, Arviat, and Resolute. Additional collection in Nain is needed in order to establish temporal trends. Trends for polyfluoroalkyl substances (PFAS) indicated that concentrations of PFOS and perfluoroalkyl carboxylic acids (PFCAs) in liver of ringed seals have declined over the period of the mid-2000s to 2011 but increases were observed in recent years at some locations.

To increase communication with communities, a workshop entitled: "*Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Sachs Harbour, Northwest Territories*" was organized at the Inualthuya School in Sachs Harbour in collaboration with Dominique Henri. Students, elders, school personnel, and community members worked together with scientific researchers to increase understanding of contaminants in ringed seals and learn from Inuvialuit knowledge about seal ecology and traditional methods for capturing and skinning seals. Collaborations between this Environmental Monitoring and Research project and the Communications, Capacity Building and Outreach provide opportunities to enhance local capacity building, outreach and communications in communities involved in the core monitoring project. The long term vision is to hold a similar workshop in the two other communities that contribute to the NCP core ringed seal monitoring project starting with Arviat in 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 of Resolute, Sachs Harbour, and Arviat as well as the Nunavut Environmental Contaminants Committee, the NWT Regional Contaminants Committee, the NCP and the Environment Division, Nunatsiavut Government in Nain, for their support throughout the years. We finally acknowledge the staff of the NLET inorganics and QLET organics for conducting contaminant analyses 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

Project Leader/Chef de projet

Robert Letcher, Environment and Climate Change Canada, Ecotoxicology and Wildlife Health Division, Wildlife Toxicology Research Section, National Wildlife Research Centre, Carleton University, Ottawa, ON, L1A 0H3, Tel: 613-998-6696, Fax: 613-998-0458, E-mail: robert.letcher@canada.ca

Project Team/Équipe de projet

Markus Dyck, Nunavut Department of Environment (NDE), Government of Nunavut, Igloolik, NU; Abde Idrissi, Environment and Climate Change Canada, Ottawa, ON; Aaron Fisk, Great Lakes Institute for Environmental Research (GLIER), University of Windsor, Windsor, ON; Adam Morris, Environment and Climate Change Canada & Carleton University, Ottawa, ON; Eva Kruemmel (ScienTissiME), Independent consultant for Inuit Circumpolar Council (ICC), Ottawa, ON; Joel Heath, The Arctic Eider Society, Sanikiluaq, NU

Project Location/Emplacement(s) du projet

- Western Hudson Bay (Keewatin Region): Arviat, Rankin Inlet and Whale Cove
- Southern Hudson Bay (Qikiqtaaluk Region): Sanikiluaq
- Baffin Bay (Qikiqtaaluk Region): Clyde River and Pond Inlet

Abstract

The polar bear (*Ursus maritimus*) is the top predator of the Arctic marine ecosystem and food web. Starting in 2007 and ongoing through the 2017-2018 fiscal year, on a biennial or annual basis, this project assesses long-term time trends and changes in Northern Contaminants Program (NCP) priority persistent organic pollutants (POPs), both legacy and new, in polar bears. This project also measures elemental pollutants in polar bears in similar fashion. The focus of this project is on western and southern polar bear subpopulations in

Résumé

L'ours blanc (Ursus maritimus) est le superprédateur de l'écosystème et du réseau alimentaire marins de l'Arctique. Le projet, qui a débuté en 2007 et qui s'est poursuivi en 2017-2018, évalue sur une base annuelle ou bisannuelle les tendances et les variations temporelles à long terme qui caractérisent les polluants organiques persistants (POP) prioritaires (anciens et nouveaux) du Plan de lutte contre les contaminants dans le Nord (PLCN) dans les tissus des ours blancs. Ce projet sert également à mesurer les polluants

the climate change impacted Hudson Bay (Nunavut) region. Some newer POPs are currently banned or regulated (e.g. under the treaty of the Stockholm Convention on POPs). For example, tetra- to octa-brominated diphenyl ether (PBDE) flame retardant contaminants, in fat samples from bears from both subpopulations, continue to show gradual decreases since 2009. An even newer flame retardant, hexabromocyclododecane was put on the Stockholm Convention list in 2013, and has not been detectable in Hudson Bay bear fat samples since that same year. Since 2007 and every year until 2017, and despite increasing regulation, Arctic contaminants known as PFOS (perfluorooctane sulfonate) and the sum of perfluorinated carboxylic acids (ΣPFCA) have remained consistently at high concentrations in bear liver samples over this 10 year period (and higher in the livers of southern Hudson Bay bears). Other new contaminants like polychlorinated naphthalenes (PCNs) had ΣPCN concentrations in 2017-collected bears fat are comparable to legacy POPs such as the pesticide Mirex and ΣPBDEs. Total mercury levels in 2017-collected bear liver samples generally remained in the same range as historical levels going back to 2007. POP and mercury data in samples from bears from these subpopulations are used locally, regionally, nationally, and internationally to assess changes over time of POP and metal exposure to the bears and thus a sentinel of contamination of the Arctic marine ecosystem and the possible health impacts. To understand contaminant changes over time, important factors such as age, sex, body condition, time of collection, lipid content, and diet and food web structure are also being determined, as well as important observational information from Indigenous knowledge holders in the participating communities.

élémentaires chez l'ours blanc de la même façon. Ce projet porte sur les sous-populations d'ours blancs du sud et de l'ouest de la baie d'Hudson, dans la région de la baie d'Hudson (Nunavut), qui est touchée par les changements climatiques. Certains nouveaux POP sont actuellement interdits ou réglementés (p. ex. en vertu du traité de la Convention de Stockholm sur les polluants organiques persistants). Mentionnons par exemple les contaminants ignifuges tétrabromodiphényléthers ou octabromodiphényléthers (PBDE) trouvés dans les échantillons de graisse des ours des deux sous-populations, qui sont en diminution progressive depuis 2009. Un produit ignifuge encore plus récent, l'hexabromocyclododécane, a été inscrit sur la liste de la Convention de Stockholm en 2013 et n'est pas détectable dans les échantillons de graisse d'ours de la baie d'Hudson depuis cette année. Depuis 2007 et chaque année jusqu'en 2017, et malgré l'accroissement de la réglementation, les contaminants de l'Arctique appelés SPFO (sulfonate de perfluorooctane) et la somme des acides perfluorocarboxyliques (SAPFC) sont demeurés constamment élevés dans les échantillons de foie d'ours au cours de la période de 10 ans (les concentrations étaient plus élevées dans le foie des ours du sud de la baie d'Hudson). D'autres nouveaux contaminants comme les naphtalènes polychlorés (NPC) étaient présents dans les échantillons de graisse d'ours prélevés en 2017 à des concentrations comparables à celles des POP anciens, du pesticide Mirex et des SPBDE. Les concentrations de mercure total dans les échantillons de foie d'ours prélevés en 2017 sont demeurées généralement dans la même gamme de valeurs que les concentrations enregistrées depuis 2007. Les données sur les POP et le mercure dans les échantillons prélevés d'ours faisant partie de ces sous-populations sont utilisées aux échelles locale, régionale, nationale et internationale pour suivre l'évolution de l'exposition des ours aux POP et aux métaux et représentent ainsi une sentinelle de la contamination de l'écosystème marin de l'Arctique et des effets possibles sur la santé. Pour comprendre l'évolution des contaminants dans le temps, les principaux facteurs utilisés sont l'âge, le sexe, l'état corporel, le moment de la collecte et la teneur en lipides; l'alimentation et la structure du réseau trophique sont également définies ainsi que des observations importantes formulées par des dépositaires du savoir autochtone dans les collectivités participantes.

Key Messages

- For 2013-2014 collected tissue samples from southern and western Hudson Bay, chemical screening was recently completed for a large and complex suite of 295 legacy and new halogenated POPs. A total of 210 POPs were detected and/or quantifiable with some frequency in all fat or liver samples, and thus illustrating the increasingly "complex cocktail" of contaminants the bears are exposed to.
- Time trends for the sum (Σ) of PBDE concentrations (in fat) showed an increase from 1991 to 2010 and reaching about 80 ng/g (lipid weight) for western Hudson Bay bears, but have since decreased gradually; the most recently levels are in the 50 ng/g (lipid weight (lw)) range. The time trend assessment for southern Hudson Bay bears has been over a shorter period (starting in 2007-2008), where in 2010 the ΣPBDE concentrations were in the 120 ng/g lw range, but most recently concentrations are around 50 ng/g lw.
- HBCDD was consistently at very low levels, and close to the detection level for this contaminant, 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 in the most recent samples.
- During 2007-2018, for Hudson Bay bears, among the 22 per/poly-fluoroalkyl substances (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 liver samples from 2010 and up to 2017, PFOS concentrations were in the >1000

Messages clés

- Les échantillons de tissus prélevés en 2013-2014 dans le sud et l'ouest de la baie d'Hudson ont été soumis à des évaluations des substances chimiques qui ont été effectuées récemment pour une vaste gamme complexe de 295 POP halogénés hérités du passé ou nouveaux. En tout, 210 POP ont été détectés ou étaient quantifiables assez fréquemment dans tous les échantillons de graisse ou de foie, ce qui illustre la complexité grandissante du mélange de contaminants auxquels les ours sont exposés.
- Les tendances temporelles de la somme (Σ) des concentrations de PBDE (dans la graisse) montrent une augmentation de 1991 à 2010 des concentrations, qui atteignent environ 80 ng/g (poids lipidique) chez les ours de l'ouest de la baie d'Hudson, mais qui montrent depuis une diminution progressive; les concentrations les plus récentes sont de 50 ng/g (poids lipidique). L'évaluation des tendances temporelles pour les ours du sud de la baie d'Hudson a été menée sur une plus courte période (à compter de 2007-2008); en 2010, les concentrations de PBDE étaient de 120 ng/g (poids lipidique), mais plus récemment, les concentrations se situaient à environ 50 ng/g (poids lipidique).
- L'hexabromocyclododécane (HBCDD) se retrouvait invariablement à de très faibles concentrations et près du seuil de détection de ce contaminant 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 et 2016. Les concentrations de brominobiphényle-153 (BB-153) étaient assez élevées par rapport aux concentrations de S4PBDE pour la

ng/g (wet weight (ww)) range for southern Hudson Bay bears, and western bears were in the <1000 ng/g ww range. ΣPFCA concentrations were also higher in the southern bears and generally between 500 to 1000 ng/g ww for all bears. There continues to be no obvious increasing or decreasing trends for ΣPFCAs and PFOS for both subpopulations of bears during 2007-2017.

- From 2002 to 2017, total mercury (THg) concentrations in liver samples continued to range from 5 to 25 mg/g ww. Concentrations were slightly greater in bears from western Hudson Bay versus southern Hudson Bay, but remain generally unchanged for that period for both bear populations.

plupart des années, y compris dans les échantillons les plus récents.

- De 2007 à 2018, chez les ours de la baie d'Hudson, parmi les 22 composés perfluoroalkyliques et polyfluoroalkyliques (PFAS) analysés (dans le foie), les concentrations étaient toujours supérieures pour le SPFO et les SAPFC (faibles niveaux d'APFO, mais principalement des APFC en C9, en C10 et en C11).

- Dans les échantillons de foie prélevés de 2010 à 2017, les concentrations de SPFO étaient inférieures à >1000 ng/g (poids humide) pour les ours du sud de la baie d'Hudson, tandis que les concentrations pour les ours de l'ouest étaient de moins de 1000 ng/g (poids humide). Les concentrations d'APFC étaient également supérieures chez les ours du sud et se trouvaient généralement de 500 à 1 000 ng/g (poids humide) chez tous les ours. Aucune tendance apparente à la hausse ou à la baisse des SPFO et d'autres SAPFC n'a été observée pour les deux sous-populations d'ours de 2007 à 2017.

- De 2002 à 2017, les concentrations de mercure total (THg) dans les échantillons de foie sont demeurées entre 5 et 25 mg/g (poids humide). Les concentrations étaient légèrement supérieures chez les ours de l'ouest de la baie d'Hudson comparativement aux ours du sud de la baie d'Hudson, mais sont demeurées relativement stables pendant la période pour les deux populations d'ours.

Objectives

The aim of this project is:

- for polar bears from the two management zones in Hudson Bay, to continue to monitor the temporal trends and changes in the levels of legacy and emerging POP and element contaminants that are NCP priorities. These contaminant chemicals include those currently under review for regulatory action (e.g. Stockholm Convention on POPs);
- to use carbon and nitrogen stable isotopes and fatty acid profiles as ecological tracers, 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; and,
- 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 (AMAP 2017; AMAP 2016). These bioaccumulative POPs (and/or their precursors and degradation products) and mercury (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, such as 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 (AMAP 2018, AMAP 2016, AMAP 2011; Morris et al. 2016). POP and Hg levels are generally very high in polar bears despite of their relatively high ability to biotransform compounds via enzymes in the liver and thus excrete these compounds (AMAP 2017; Letcher et al. 2010).

Polar bears are distributed throughout the circumpolar region, are important to Arctic Indigenous Peoples, such as Inuit both culturally and economically, and thus are species for monitoring legacy and emerging POPs and Hg. The levels of POPs are generally the highest in the polar bear compared to other Arctic wildlife (AMAP 2017; AMAP 2016; Letcher et al. 2010; Rigét et al. 2016, 2018). 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 up to the year 2000 but have since remained relatively unchanged up to 2016 (Letcher et al. 2017). In the same bears, a number of new POPs, such as short-chain chlorinated paraffins (SCCPs), polychlorinated naphthalenes (PCNs), polybrominated diphenyl ethers (PBDEs), other non-PBDE flame retardants, and perfluoroalkyl substances (PFASs; in particular, the highly bioaccumulative perfluorooctane sulfonate (PFOS)) were reported, in some cases for the first time, in the liver and fat of polar bears (AMAP 2017; Boisvert et al., 2018; Letcher et al. 2017, 2018a, 2018b).

For 2017-2018, polar bears samples were analyzed for emerging POPs on a continued annual basis. Annual analyses of chemicals, that are priorities to national and international regulatory programmes or agreements, are important to determine whether they are present in the Arctic environment and in this case in polar bears. For example, negotiations on Hg that were initiated in 2009 under the United Nations Environment Programme (UNEP) produced a global, legally binding treaty on Hg named the Minamata Convention. The Minamata Convention was officially adopted and opened for signatures in October 2013, and entered into force on 16 August 2017 (http://www.mercuryconvention.org/Convention/Text/tabid/3426/language/en-US/Default.aspx). The present project also supports current agreements including the Stockholm Convention on POPs, the Basel Convention, 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. Several high priority POPs were recently added recommended for addition to the Stockholm Convention on POPs (http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/). Recently added POPs are DecaBDE (BDE-209; Annex A as of 2018), SCCPs (Annex A as of 2018), PCNs (Annex A and C as of 2015), hexchlorobutadiene (HCBD; Annex A as of 2015), and pentachlorophenol (PCP) and its salts and esters (Annex A as of 2015). POPs recommended for listing are dicofol isomers and perfluorooctanoic acid (PFOA and its salts and related compounds, while perfluorohexane sulfonic acids (PFHxS) and its salts and related compounds is under review.

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 time period that changes in sea-ice in western Hudson Bay were linked to shifts in the diet of polar bears, which showed that dietary shifts have varying influence on (mostly legacy) POP temporal trends; particularly PCBs, PBDEs and the more bioaccumulative legacy and new POPs established to be present in Arctic wildlife (McKinney et al. 2010, 2011a, 2011b).

Arctic ecosystems face multiple challenges at local and regional scales. Challenges include stress of changes in climate to arctic ecosystems, and exposure to anthropogenic POPs (AMAP 2017; Dietz et al. 2016; Ferguson et al. 2015; Letcher et al. 2010; McKinney et al., 2015). More recently the warming of the Arctic has been signaled by loss of multi-year sea ice and thawing of permafrost and accelerated coastal erosion. 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 such as the introduction of new species and loss of existing species. More recent research has shown that Arctic warming and changes in sea-ice means change in exposure to POPs and Hg to Arctic biota, particularly in polar bear (i.e. Canadian Hudson Bay and East Greenland subpopulations) (McKinney et al. 2015). With complementary NCP funding for the NSERC Visiting Fellow-Post-Doctoral Fellow, Dr. Adam Morris, and in the context of the present project, he is leading investigations into changes in important climate change variables over time and in relation to temporal trends of highly bioaccumulative POPs. The objective here is to determine the relationships between year, target contaminant concentrations and climate variables using multivariate statistical modeling.

Activities in 2017-2018

Field Sampling

Validated 2016 and 2017 Nunavut Wildlife Research Permits (NWRPs) were in place for polar bear sample collections during the harvests that occurred in late 2016 and early 2017 (the 2017-2018 monitoring year) and carried out by communities in Hudson Bay and Baffin Bay. In September 2017, we also successfully applied for and received a 2018 NWRP. The NWRPs were prepared and evaluated in collaboration with communities via the NDE (Wildlife Research Section: Markus Dyck and J. Ware). 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 2017-2018.

Field Sampling Leads

- Western Hudson Bay (Keewatin Region): *Rob Harmer* (Regional NDE manager)
- Arviat: *Joe Saviqataaq Jr.* (CO), *Alex Ishalook* (HTO Chairperson), *Hilda Panigoniak* (HTO Manager)
- Rankin Inlet: *Johanne Coutu-Autut* (CO) and *Daniel Kaludjak* (CO), *Joe Kaludjak* (HTO Chairperson), *Nigel Kubiluitok* (HTO Manager)
- Whale Cove: Vacant (CO) (*Rob Harmer* and *Johanne Coutu-Autut* temporary COs), *Solomon Voisey* (HTO Chairperson), *Lisa-Grace Jones* (HTO Manager)
- Southern Hudson Bay (Qikiqtaaluk Region): N/A
- Sanikiluaq: *Daniel Qavvik* (CO), *Lazarus Epoo-Kattuk* (HTO Chairperson), *Lucassie Arragutainaq* (HTO Manager)
- Baffin Bay (Qikiqtaaluk Region): N/A
- Clyde River: *Bruce Jerry Hainnu* (CO), *Jacobie Iqalukjuak* (HTO Chairperson), *Niore Iqalukjuak* (HTO Manager)
- Pond Inlet: *George Koonoo* (CO), *Jimmy Pitseolak* (HTO Chairperson), *Daisy Koonoo* and *Natasha Simonee* (HTO Co-Managers)

Community hunters and COs collected a grand total of 56 (adult and sub-adult) polar bear fat, liver and/or muscle sample sets during harvests in winter 2016-2017. Samples were from n=9 western Hudson Bay polar bears (Arviat (n=3; 1 male and 2 females) and Rankin Inlet (n=6; n=4 males and n=2 females)). From southern Hudson Bay (Sanikiluaq) a total of n=17 (n=12 males and n=5 females) Hudson Bay bears samples were collected. Also, opportunistically collected tissue samples of fat, liver and/or muscle sample sets from a total of n=30 bears from northern Baffin Island/Bay. That is, Clyde River (n=11; n=8 males and n=3 females), Pond Inlet (n=12; n=9 males and n=3 females) and Qikiqtarjuaq (Broughton Island; n=7; n=6 males and n=1 female). All of these samples were collected by local hunters in participating communities via interaction with local HTOs and Conservation officers (COs). All samples were sent from these communities to NDE offices in Igloolik where they were documented and processed.

In previous years, polar bear sub-samples were shipped to National Wildlife Research Centre (NWRC) in Ottawa in the October/November time frame. However, the wildlife technician (M. Harte) position was vacant, and as a result the biologists (Markus Dyck and Dr. J. Ware) could send the 2017-collected samples only after their fall field program concluded. As a consequence, the 2017-collected samples were shipped from NDE in Igloolik to the PI (Robert Letcher) at NWRC only in December 2017. All polar bear samples received by NWRC were further processed, and for the Hudson Bay bear samples portions were taken for POP (fat, liver), element/metal (liver), FA (fat) and SI (muscle) analysis. Remaining samples were archived and are currently stored in Environment and Climate Change Canada's National Wildlife Specimen Bank (ECCC-NWSB) at the NWRC in Ottawa for future considerations (e.g. future retrospective monitoring of new/emerging POPs).

Sample Analysis

In January 2018 the research team started on the contaminant and other analyses. By March 2018, we completed all the new POP analyses except for PBDEs and other non-PBDE flame retardants, which were carried out by the NWRC-OCRL or ALS Environmental (PCN analyses). Age determinations (via bear teeth) for all harvested bears in 2015 and 2016 were carried out and completed by Matson's Laboratories (Matson's Laboratory LLC, 8140 Flagler Road Missoula MT 59802, U.S.A.; http://www.matsonslab/com). The tooth-age analysis of 2017-collected bear samples will be completed over the course of 2018. All 2017-collected fat samples were analyzed by NWRC-Lab Services for a suite of Fatty acids (FAs; i.e., a suite of

37 saturated and polyunsaturated, C_6-C_{24} fatty acids). Analysis of stable isotopes (SIs) of nitrogen and carbon (i.e., ^{12}C, ^{13}C, ^{14}N and ^{15}N) in 2015, 2016 and 2017 collected muscle samples are being done by the lab of Dr. Aaron Fisk (Great Lakes Institute for Environmental Research (GLIER), University of Windsor). Muscle sub-samples from the 2017-2018 monitoring year were sent to the GLIER in early April 2018 and the SI determinations are on-track to be completed by the end of June 2018.

Capacity Building and Training

Dr. Robert Letcher (and ECCC) has had a long running cooperative relationship with the Nunavut Department of Environment (NDE) with respect to polar bear contaminants research and monitoring. In the 2017-2018 fiscal year, this project cooperated in building capacity and expertise in scientific sampling during the winter 2017 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. In cooperation with Markus Dyck and J. Ware (and M. Harte) in the NDE, and as necessary, with Dr. Robert Letcher, a supplementary number of sampling kits were arranged and sent directly to NDE. The number of sampling kits coincided with the number of bears required for these management zones and was within the allowable hunting quota for the communities involved (Hudson Bay and Baffin Bay). Each sampling kit contained a simple and easy to read sampling instructions manual for hunters in both English and Inuktitut. Electronic copies of the sampling instructions have been previously sent to the Nunavut Environmental Contaminants Committee (NECC; Co-Chairs Jean Allen (CIRNAC) and Andrew Dunford (Nunavut Tunngavik Incorporated (NTI))). As we noted in the 2017-2018 fiscal year, mid-year status report in September 2017, which was then circulated to and reviewed by the NECC, all polar bear harvests completed in 2017 were carried out by local hunters in the participating Nunavut communities (i.e., Arviat, Whale Cove, Rankin Inlet, Sanikiluaq, Pond Inlet and Clyde River). The participating project team members in the NDE continued to provide training to members of the HTOs that were involved. Hunters were compensated for the sampling. In other capacity building, a graduate student, Ms. Adelle Strobel (MSc student, Carleton University, Ottawa) successfully completed and defended her thesis in December 2017, on the bioaccumulation and fate of organophosphate ester (OPE) contaminants in polar bears and ringed seals. Dr. Adam Morris completed the compilation and analysis of a large metabolomics data set for Hudson Bay polar bears, which resulted in a recent publication (Morris et al. 2018a). A second paper has been submitted for publication (Morris et al. 2018b) examining the statistical relationship between the dominant metabolomics signature and concentrations of various POP and THg in polar bear liver and muscle tissue.

In a complimentary NCP funded project (see 2017-2018 NCP Synopsis Report for project N-01) led by Dr. Adam Morris, we examined climate change over time in relation to temporal trends of highly bioaccumulative POPs. He has compiled large amounts of climate-related temporal data, including air temperature, ocean temperature air pressure, wind speeds, precipitation, sea-ice related metrics, estimates of oceanic primary production, and information provided by the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) indices over several decades in the Arctic (Hudson Bay). Dr. Adam Morris has also compiled concentrations of priority contaminants (CB-153, BDE-47, PFOS, *p,p'*-DDE, a-HCH and THg) in target tissues of key NCP bioindicator species including caribou (kidney; Qamanirjuaq herd, 2006-2015), polar bears (fat or liver; Hudson Bay subpopulation, 1991-2015), thick-billed murre (eggs; (Coats Island, 1993-2015)) and fish (land-locked Arctic Char) from the Hudson Bay region. The objective is to determine the relationships between year, target contaminant concentrations and climate variables using multivariate statistical modeling.

Community Engagement and Communications and Outreach

In early October 2017, Robert Letcher travelled to Sanikiluaq to exchanged knowledge with local COs and HTO members. In consultation with the NECC, in 2017 and in collaboration with Markus Dyck at NDE, Robert Letcher again prepared a "*polar bear - contaminant fact sheet and mini-report*". The final, NECC-approved version of this fact sheet was circulated in September 2017 to COs and HTO members in participating communities in both English and Inuktitut. The fact sheet was written in plain language for easy understanding, as per the recommendation of the NECC. As part of the NDE requirements for harvesting polar bear, a hunter kill return sheet was submitted for harvest. On the kill sheets, the hunters have the opportunity to provide general observational comments. In the 2017-2018 fiscal year we were provided with the available kill sheets for polar bears harvested in 2017. This served to optimize information exchange, communication, and consequently assist with capacity building and the utilization of Inuit knowledge (which is discussed in greater detail in the next section).

The NCP selects its chemical monitoring priorities in conjunction with international processes and outcomes such as the listing of chemicals in annexes of the Stockholm Convention on POPs. In 2017 this project contributed information on POPs in Hudson Bay polar bears via ECCC to the Stockholm Convention's Persistent Organic Pollutants Review Committee (POPRC), which is reviewing and assessing chemicals for addition to the POP convention annexes. Among these POPs are Deca-BDE (BDE-209) and SCCPs (listed in Annex A as of 2017). Dicofol and PFOA have been recommended for listing and PFHxS is currently under review. The PI (Robert Letcher) continued to communicate and discuss POPRC data needs for these priority chemicals within ECCC-POPRC, CIRNAC and with team member Dr. Eva Kruemmel (as she attends/ participates in the POPRC meetings). New POP data and temporal trends for southern and western Hudson Bay polar bears were provided to the AMAP POPs Experts Group (led by Mr. Simon Wilson), as part of ongoing AMAP POP temporal trend assessments, and with the most recent one completed and published in 2016 (AMAP 2016; Rigét et al. 2018).

The co-PI, Robert Letcher, as well as VF-PDF, Adam Morris, were coauthors in several chapters of the recently released AMAP report on Chemicals of Emerging Arctic Concern (AMAP 2017). The PI, Robert Letcher, is also co-lead on another AMAP report, "*An Assessment of the Biological Effects of Organohalogen and Mercury Exposure in Arctic Wildlife and Fish*", which is currently in the production phase and will be released in 2018 (AMAP 2018). As detailed in the Project Statistics and Information table, there were numerous journal publication and reviews, reports, and oral and poster presentations at conferences or workshops. Presentations were made by Robert Letcher and Adam Morris and a polar bear expo booth was set-up at the 2017 NCP Results Workshop in Yellowknife, NT (September 2017). A presentation was made in Sanikiluaq to the participating CO and HTO members in that community (October 2017). Presentations were also made at Nanjing University of Science and Technology in China (May 2017), the SETAC-NA 2017 conference in Minneapolis, MN, U.S.A. in November 2017, ECCC Centre St. Laurent in Montreal (Feb. 2018), and the 3rd Annual Norwegian Environmental Toxicology Symposium (NETS) in Longyearbyen, Svalbard, Norway (March 2018). In 2017, NCP-supported polar bear contaminant research and monitoring was also the subject of numerous Canadian and U.S. media articles. (Electronic copies continued to be provided to NDE project partners that also fulfill the reporting obligations of the 2017 NWRP, and also to the NECC for edification and further distribution as deemed necessary. Whenever it was necessary, in 2017 the PI, Robert Letcher, responded to any inquires or concerns of the participating communities and the NECC, e.g. questions after the social-cultural review of the initial 2017-2018 proposal.

Indigenous Knowledge

Utilization of Indigenous Knowledge (IK) on an annual basis into this ongoing contaminants monitoring program for polar bears is occurring but can be improved by facilitating better communication with the hunters and communities. As in past sampling for this core monitoring project, the 2017 collection of samples was carried out exclusively by hunters in the participating Hudson Bay and Baffin Bay communities in coordination with the PI and involved agencies in Nunavut. This project worked within the guidelines of the allowable hunting quotas for each of the HTOs and communities. This project continued to seek any IK from Inuit knowledge holders that could be provided in the information provided by the hunters such as ecological information on behavior (e.g. observations of unusual dietary events other than ringed seal predation), body condition and population numbers as provided to wildlife COs and biologists.

As mentioned, in early October 2017 Robert Letcher travelled to Sanikiluaq to exchanged knowledge with local COs and HTO members. This visit was in partnership with the NCP funded project "*Mobilizing Inuit knowledge and land use observations to assess ecosystems trends and processes affecting contaminants*" (see the 2017-2018 Synopsis Report for this project) led by Dr. Joel Heath of the Arctic Eider Society. This project is building on existing community-driven research programs and an Interactive Knowledge Mapping Platform (smartphone app) known as SIKU. Building on existing capacity in Sanikiluaq, and using the developed smartphone app, SIKU is training and employing local hunters to collect wildlife and sea ice observations during land-use activities, including the meaningful involvement of youth in (POP/contaminant) research and monitoring efforts. In 2017-2018 this SIKU project demonstrated proof-of-concept of the application of the SIKU smartphone platform that included extensive consultation, app/online development, training and initial data collection. The hunters are keen on using the SIKU app and will continue to collect data in the spring and summer of 2018. The SIKU initiative is working towards the systematic collection of data on the body condition and diet of important food species (including for ringed seal and polar bear) by hunter observations, participatory methods and photos of harvested animals, and their organs and stomach contents. Diet and local environmental conditions can be important contributors to accumulation and movement of POPs and trace elements, and is also important in metabolomics signatures in relation to POP and Hg exposure. In 2018-2019, the SIKU collected data from seals and polar bears will start being synthesized and this observational information will be transferred and incorporated into future analysis of POP and metal trends in the present polar bear monitoring program.

Results and Outputs/Deliverables

Based on 2013-2014 collected tissue samples from southern Hudson Bay (SHB) and western Hudson Bay (WHB) bears, we reported on the analysis of a large and complex suite of 295 legacy and new halogenated POPs (Letcher et al. 2018a). A total of 210 POPs were detected and/or quantifiable with some frequency in all fat or liver samples. POP profile and concentration differences were investigated both within (e.g. age and sex) and between the two subpopulations. ΣPCBs remained the most concentrated group of POP contaminants in polar bear fat (Letcher et al. 2010). The geometric mean ΣPCB concentration was two to three fold greater than either the ΣCHL (chlordanes) or ΣPFAS (largely PFOS) [ΣPCB (SHB = 4335 ng/g lw, WHB = 4295 ng/g lw); ΣCHL (SHB = 1549 ng/g lw, WHB = 1618 ng/g lw); and ΣPFASs (SHB = 1991 ng/g ww, WHB = 1343 ng/g ww). The ΣPCB and ΣPFAS were greater than all other concentrations in both the SHB and WHB bears; with the ΣCHL concentration being greater relative to all other OCPs. ΣHCHs (hexchlorocyclohexanes) and ΣCBzs (chlorobenzenes) were greater in the WHB bears than those from SHB. ΣOPE (organophosphate esters), Σdicofol and ΣPCP (pentachlorophenol and pentachloroanisole) concentrations could not be calculated because of these low frequencies or complete lack of detection. POPs with intermediate concentrations (ΣDDT, ΣHCH, ΣCBz, ΣPBDE, ΣSCCP (short-chain chlorinated paraffins), ΣPCN (pentachloronaphthalenes), ΣMirex) were not different from each other within the two subpopulations, and when their 95% confidence intervals are considered (SHB range = 26.6–204 ng/g lw, and WHB = 20.2–298 ng/g lw).

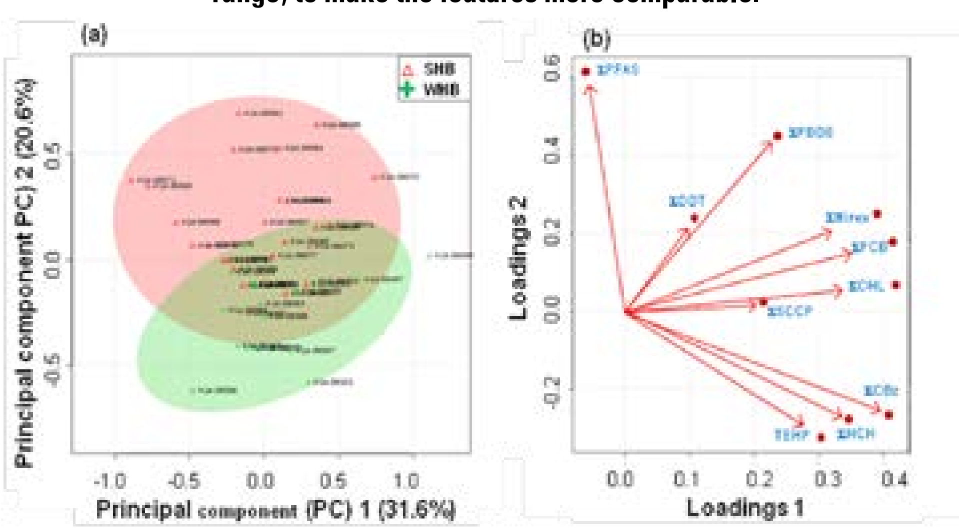
The subpopulation groupings in the principal components analysis (PCA) score plot (Figure 1a) were reasonably well resolved and did separate, demonstrating both similarity and differences among the POP patterns in bears from the same subpopulations, though there was a relatively large overlap of their 95% confidence regions (Letcher et al. 2018b).

The scores of the WHB versus SHB bears were significantly different across principle component (PC) 2 (2-tailed *t*-test, t =6.51, p = 0.001), but did not differ significantly across PC 1 (2-tailed *t*-test, t = −0.939, p = 0.354). The PCA loadings plot (Figure 1b) shows that despite having the largest concentrations (with the exception of PFASs), the loadings of ΣPCB and ΣCHL had little influence on the differentiation and clustering of the subpopulation scores (Figure 1a). Indeed, these concentrations were very similar between the SHB and WHB when the bears were not separated by age or sex. The ΣMirex and ΣSCCPs also had minimal impact on the separation of the scores of the bears. The primary drivers of the separation of the subpopulations across PC 2 were the loadings of ΣPFAS, ΣPBDE and ΣDDT concentrations, which were greater in SHB bears over WHB bears, as well as ΣCBz and ΣHCH, concentrations which were greater in WHB bears.

In Letcher et al. (2018b), 2013-2014 fat samples were analyzed for seventeen OPEs. Concentrations of tris(2-ethylhexyl) phosphate (TEHP), the only consistently detected OPE (detection frequency = 71–82%), were the lowest observed among all of the major contaminant groups. Mean TEHP concentrations were 0.163 ng/g lw and 0.308 ng/g lw in SHB and WHB bears, respectively. TEHP concentrations were spatially variable, however, application of a general linear model (GLM) did not detect significant influences of subpopulation or any other covariate on this compound (Figure 1). Trace (detectable) amounts of triphenyl phosphate (TPHP), tris(2-chloroisopropyl) phosphate (TCIPP), tris (2-butyoxyethyl) phosphate (TBOEP) and tri (n-butyl) phosphate (TNBP) were also found in the fat of the present bears but with <50% frequency of detection.

High concentrations of OPEs have been reported in arctic air while very little is known for wildlife where OPE tissue residues levels appear to be strongly influenced by biotransformation. In a recent study, we reported on the hepatic *in vitro* metabolism of six environmentally relevant OPEs (triesters) and corresponding OP diester formation in East Greenland polar bears and ringed seals (Strobel et al. 2018a). The *in vitro* metabolism assay results were compared

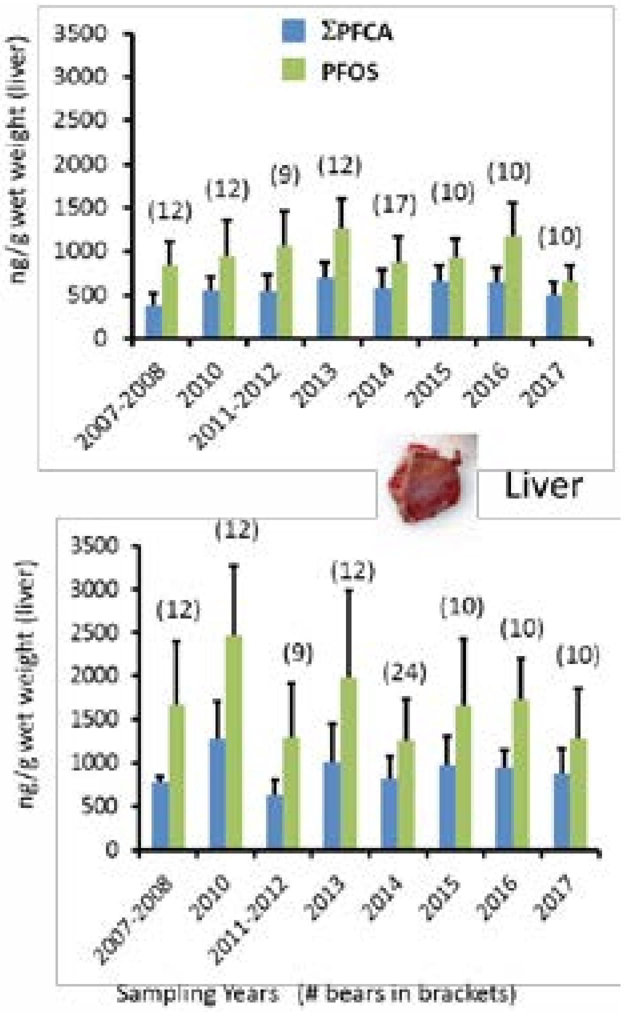
Figure 1. Score plot (a) and factor loadings (b) from principle components analyses (PCA) of the sum (Σ) or individual concentrations (ng/g lw; ΣPFASs ng/g ww) of major classes of organohalogen contaminants in polar bears from the SHB and WHB. 52.2 % was explained by the first 2 principal components (PC). The PCA data were log-transformed to improve the left-skewing and range scaled (each variable is divided by its range) to make the features more comparable.



to adipose levels in field samples from the same individuals. OP triester metabolism was generally rapid and structure-dependent, where polar bears metabolized OPEs more rapidly than ringed seals. Exceptions were the lack of triethyl phosphate (TEP) metabolism and slow metabolism of TEHP in both species. OP diester metabolites were also formed, with the exception of TEP which was not metabolized at all. Tris(1,3-dichloro-2-propyl) phosphate (TDCIPP) was completely converted to its corresponding diester. However, the mass balances showed that OP diester formation corresponding to TEHP, TNBP, and TBOEP did not account for 100 % of the OP triester depletion, which indicated alternate pathways of OP triester metabolism. TPHP was completely converted to its OP diester metabolite in polar bears but not in ringed seals suggesting species-specific differences. In a complimentary *in vitro* study, the metabolism of several alkyl-substituted TPHP OPEs was examined (Strobel et al. 2018b). It was found that alkyl-substitution substantially hindered TPHP metabolism, especially for polar bears which, generally metabolized OPEs more rapidly than ringed seals.

We have yet to complete the PBDE and non-PBDE FR analysis on the 2017-collected polar bear fat samples, which will be done in the summer of 2018. The delay is because we received the samples so late in 2017. As we reported last year, in the 2016-collected samples, the major 4 congeners (BDE-47, -99, -100 and -153) consistently accounted for > 90 % of the ΣPBDE 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 Σ_4PBDE concentrations up until 2010, followed by a gradual decline progressing to 2014 in WHB bears. The same gradual downward trend occurred between 2007 and 2016 in SHB bears. However, between 2014 and 2016, mean ΣPBDE concentrations appeared to have leveled off for bears from the WHB subpopulation.

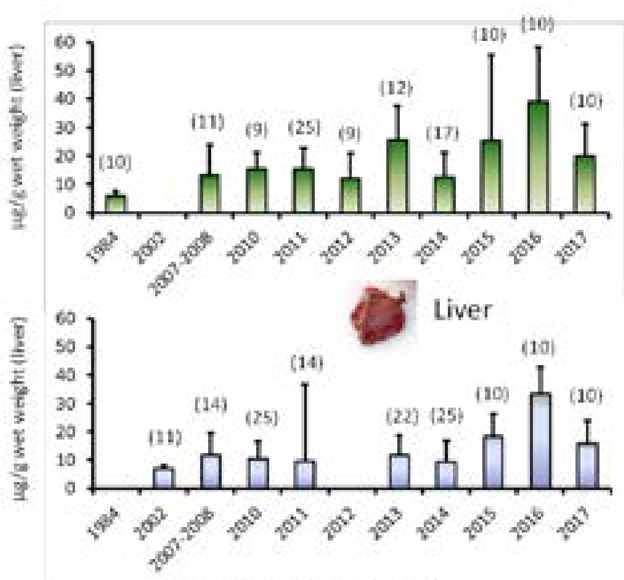
Figure 2. Temporal trends of the geometric mean concentrations (ww) of ΣPFCA and PFOS in the liver of WHB bears (2007-2017, top panel, R. Letcher, unpublished) and SHB bears (2007 – 2017, lower panel, R. Letcher, unpublished). Error bars are SDs. Data was not corrected for sex, age or diet.



We were able to complete the analysis of the 2017-collected liver samples for PFASs. When uncorrected for e.g. age, sex and diet for Hudson Bay bears, over the period of 2007-2017, 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 and in samples from 2010 and including up to 2017, PFOS concentrations were consistently greater than for ΣPFCAs among all bears in 2017-2018, and thus there were no obvious increasing or decreasing trends for ΣPFCAs and PFOS for both subpopulations of bears over the 2007-2017 period (Figure 2).

THg concentrations in the liver collected in 2017 from bears from WHB and SHB were retrospectively comparable to concentrations in samples from years going back before 2000 (i.e. 5 to 25 mg/g ww) (Figure 3). Similar to previous years, in 2017 liver samples THg concentrations in WHB bears were slightly greater than for the SHB bears. However, the THg concentrations were variable from year to year, so there is a need to continue annual monitoring of THg in Hudson Bay bears.

Figure 3. Temporal comparisons of the geometric mean concentrations (ww) of total mercury (THg) in liver tissue of polar bears from western (top panel) and southern (lower panel) Hudson Bay and collected in 1984 and 2002 (Rush et al. 2008), 2007-2008 (Routti et al. 2011), and 2011 to 2017 (R. Letcher, unpublished). The 2007-2017 data is not corrected for sex, age or diet.



Discussion and Conclusions

Based on 2013-2014 collected tissue samples from southern and western Hudson Bay, chemical screening was carried out for a large and complex suite of 295 legacy and new halogenated POPs (Letcher et al. 2018a). A total of 210 POPs were detected and/or quantifiable with some frequency in all fat or liver samples, and thus illustrating the increasingly "complex cocktail" of contaminants the bears are exposed to. 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, ΣPCNs, ΣPBDEs 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, SDDT and SClBz) (Figure 1). 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). This is good news since HCBD, PCP and PCA were all added in 2015 to Annex A, and dicofol is under consideration for listing, regarding the Stockholm Convention on POPs (http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/).

With respect to BFR temporal trends, and although uncorrected for e.g. age, sex and diet, from 1991 to 2016 the most concentrated BFRs, PBDEs, showed increasing Σ_4PBDE concentrations up until 2010, followed by a gradual decline progressing to 2014 in WHB bears. The same gradual downward trend occurred between 2007 and 2016 in SHB bears. However, between 2014 and 2016, mean ΣPBDE concentrations appeared to have leveled off for bears from the WHB subpopulation. These results are consistent with downward time trends after 2009 of ΣPBDE concentrations in the blubber of ringed seal from locations such as Arviat (Houde et al. 2017, and in the eggs for thick-billed murres from Prince Leopold Is. (Braune et al. 2015).

Liver *in vitro* assay studies demonstrated for the first time in any Arctic species that OP triester bioaccumulation and fate in polar bears versus their ringed seal prey is substantially influenced by biotransformation and is OPE structure dependent (Strobel et al. 2018a, 2018b). Also, *in vitro* metabolism results were consistent with low and mostly non-detectable levels of OPEs in fat field samples from the same East Greenland polar bears (Strobel et al. 2018a) as well as in Hudson Bay polar bears (Letcher et al. 2018a). These field studies are the first known reports of OPEs in Arctic biota (AMAP 2017).

To our knowledge, the (low ppb concentration) detection of C_4 perfluorobutane sulfonamide (FBSA) in liver of 2013-2014 collected Hudson Bay polar bears (Letcher et al. 2018a) is a first for any Arctic wildlife sample (AMAP 2017), although no corresponding perfluorobutane sulfonic acid (PFBS) was detectable in any liver sample. We reported similar findings for these PFASs in East Greenland bears (Boisvert et al. 2018; Letcher et al. 2018b). Perfluorobutane carboxylic acid (PFBA) was measureable at low ppb levels with almost 100 % frequency in all western and southern Hudson Bay bear livers. The cyclic analogue of PFOS, PFEtCHxS was quantifiable in all Hudson Bay bear liver samples. PFEtCHxS, FBSA and PFBA are representative of new and replacement PFASs currently being produced and used and continued monitoring in polar bears is warranted.

PFOS and ΣPFCA levels appeared to be neither increasing nor decreasing as there was no clear trend for the period of 2007-2017 (Figure 2). This lack of observable decreases in concentrations is despite C8 chemistry phase-out around 2002 by the major worldwide producer at the time, the 3M Company, and the addition of PFOS and its C8 chemistry to Annex B of the Stockholm Convention in 2009. However, since PFOS is listed in Annex B, this means there are many allowed uses. Also, not all of the countries that are Parties to the Stockholm Convention have ratified the listing of PFOS. Thus, it should not be all that surprising that there is very little evidence of temporal decreases in PFOS levels in Hudson Bay polar bears. The lack of decreasing ΣPFCA temporal trends in polar bears (Figure 2) are consistent with total global emissions reported by Wang et al. (2014), which were estimated to be between 50 and 600 tonnes/year between 2002 and 2015. PFOA and its salts and related compounds are recommended for listing, and PFHxS and its salts and related compounds are currently under review in regards to the Stockholm Convention. (http://chm.pops.int/TheConvention/ThePOPs/TheNewPOPs/). This stresses the importance of continuing sources of PFCAs, PFSAs, other PFASs and their precursors, 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 2017 were essentially unchanged and ranged between 5 and 25 mg/g ww, and slightly greater in bears from WHB versus SHB (Figure 3). 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 ww. Thus, over the longer time frame from 1984, 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 entered into force on 16 August 2017 (http://www.mercuryconvention.org/Convention/Text/tabid/3426/language/en-US/Default.aspx), and thus THg annual monitoring is warranted for Hudson Bay polar bears to assess the effectiveness of the enforced convention.

POP and Hg exposure for Hudson Bay polar bears is becoming increasingly complex. 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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(NCP Project (former) team members in bold; student or PDF indicated)

(These references are in addition to those listed in the NCP Project Metrics and Information Table)

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Temporal trends of mercury and halogenated organic compounds in Hendrickson Island, Sanikiluaq and Pangnirtung beluga

Tendances temporelles des concentrations de métaux lourds et de composés organiques halogénés chez les bélugas de l'île Hendrickson, de Sanikiluaq et de Pangnirtung

Project Leader/Chef de projet

Gary Stern, Centre for Earth Observation Science (CEOS), Department of Environment and Geography, University of Manitoba, 586-125 Dysart Rd. (Wallace Building), Winnipeg, MB, Canada, R3T 2N2. Email: Gary.stern@umanitoba.ca

Lisa Loseto, Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6. Email: Lisa.loseto@dfo-mpo.gc.ca

Steve Ferguson, Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6. Email: Steve.Ferguson@dfo-mpo.gc.ca

Cortney Watt, Fisheries and Oceans Canada, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada, R3T 2N6. Email: Cortney.Watt@dfo-mpo.gc.ca

Project Team/Équipe de projet

Sonja Ostertag, Bruno Rosenberg, and Thor Halldorson, DFO, FWI, Winnipeg, MB; Alexis Burt Ashley Gaden and Ainsleigh Loria, University of Manitoba, Winnipeg, MB; Fisheries Joint Management Committee, Inuvialuit Settlement Regioni, NT; Liisa Jantunen, and Tom Harner, Environment and Climate Change Canada, Toronto, ON

Project Location/Emplacement(s) du projet

- Hendrickson Island, NT
- Sanikiluaq, NU
- Pangnirtung, NU

Abstract

The overarching objectives of this project are to monitor contaminant levels in three beluga populations to assess spatial and temporal trends in mercury, organic halogenated compounds (including legacy and new compounds) along with supporting biological and dietary metrics (e.g. stable isotopes, size, age). Samples of liver, muscle and muktuk of beluga whales collected in 2017 were analyzed for total

Résumé

Les objectifs globaux de ce projet consistent à surveiller les niveaux de contaminants de trois populations de bélugas pour évaluer les tendances spatiales et temporelles du mercure et de composés halogénés organiques (hérités du passé et nouveaux) ainsi que les mesures biologiques et alimentaires à l'appui (p. ex. isotopes stables, taille, âge). On a analysé les concentrations de mercure total dans des

mercury. Levels of mercury remained similar to ranges found in previous years. Of the organs analyzed in this study, liver typically had the highest concentrations of mercury, followed by muscle and muktuk. 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 500 Hendrickson Island beluga from 22 collections, taken every year since 1993, with the exception of a gap between 1996 and 2001.

Mercury content varies among individual animals, and among organs defined by different processes associated with different mercury species. This variation makes rigorous detection of differences among animals, places, and times statistically difficult with low sample sizes. Knowing the age of the individuals is required for interpretation of liver concentrations and the beluga size and diet preferences is required for interpretation of muscle and muktuk mercury concentrations. Age data for this year is lacking due to the disruption of analytical instruments (LC/MS used to measure aspartic acid in eye lenses for age determination). The additional samples obtained each year improve the statistical analysis and ability to account for the confounding factors of size, age and gender and reduce the chances of reporting apparent differences if they are not real.

échantillons de foie, de muscles et de muktuk du béluga prélevés en 2017. Les concentrations de mercure sont semblables aux plages observées au cours des dernières années. Parmi les organes analysés dans le cadre de cette étude, le foie est celui qui, en général, présente les plus fortes concentrations de mercure, suivi des muscles et du muktuk. Les données provenant de ces échantillons ont été ajoutées à la base de données sans cesse grandissante sur la concentration de ces éléments dans les organes et les tissus des mammifères marins de l'Arctique. La base de données contient maintenant de l'information sur plus de 500 bélugas de l'île Hendrickson provenant de 22 prélèvements effectués chaque année depuis 1993, sauf de 1996 à 2001.

La teneur en mercure varie entre les individus et entre les organes, selon différents processus associés à différentes espèces de mercure. Vu cette variation, la détection rigoureuse de différences entre les animaux, les lieux et les périodes est difficile sur le plan statistique dans les échantillons de petite taille. Il faut connaître l'âge des individus pour interpréter les concentrations dans le foie et la taille du béluga et ses préférences alimentaires pour interpréter les concentrations de mercure dans ses muscles et son muktuk. Nous n'avons pas de données sur l'âge cette année en raison d'un problème concernant les instruments d'analyse (analyse par LC/MS utilisée pour mesurer l'acide aspartique dans le cristallin pour déterminer l'âge). Les échantillons supplémentaires obtenus chaque année améliorent l'analyse statistique et nous aident à tenir compte des facteurs de confusion comme la taille, l'âge et le sexe, ce qui réduit les risques de faire état de différences apparentes qui ne seront pas avérées.

Key Messages

- The mean level of mercury in 2017 liver samples from the Hendrickson Island beluga was 16.54 ± 12.54 µg/g. Mercury in muscle was lower than that in liver with a mean concentration of 0.96 ± 0.59 µg/g.
- In spite of the lower mercury values in muscles tissues from Hendrickson Island beluga, all

Messages clés

- La concentration moyenne de mercure dans les échantillons de foie prélevés en 2017 chez des bélugas de l'île Hendrickson était de 16,54 ± 12,54 µg/g. Les concentrations de mercure étaient plus faibles dans les muscles que celles dans le foie, la moyenne de ces concentrations étant de 0,96 ± 0,59 µg/g.

but one specimen still exceeded 0.5 µg/g, the concentration used to regulate the consumption of commercial fish in Canada.

- Of the three organs analyzed in the Hendrickson Island animals, muktuk contained the lowest levels of total mercury with a mean 0.42 ± 0.18 µg/g. Thirty percent of the samples (9 of 30) exceeded 0.5 µg/g.
- Unlike liver, total mercury in muscle and muktuk is equivalent to methylmercury (MeHg) (i.e. THg = MeHg). MeHg is the form of mercury that bioaccumulates and is toxic.

- Même si les valeurs de mercure étaient plus faibles dans les tissus des muscles des bélugas de l'île Hendrickson, toutes les concentrations, sauf chez un béluga, demeuraient supérieures à 0,5 µg/g, soit la concentration de référence utilisée pour réglementer la vente d'espèces commerciales de poissons au Canada.
- Parmi les trois organes et tissus analysés chez les animaux de l'île Hendrickson, c'est le muktuk qui renfermait les plus faibles concentrations de mercure total, soit en moyenne 0,42 ± 0,18 µg. Trente pour cent (30 %) des échantillons (9 des 30) dépassaient 0,5 µg/g.
- 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.

Objectives

The aims of this project are to:

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

Introduction

Monitoring contaminant concentrations in marine mammals is necessary to regulate consumption guidelines for the safety, health, and well-being of northern communities which practice subsistence hunts. This is especially important for western Arctic beluga as they have relatively high concentrations of mercury compared to other Canadian beluga populations (Lockhart et al. 2005). Each year, thanks to the partnerships with Inuvialuit hunters, new beluga samples are collected and analyzed for contaminants, and over time the accumulated data offer increasingly powerful means to detect changes (e.g. temporal trends) and relate them to environmental variables. Such monitoring efforts are especially important in light of the accelerated warming in the Arctic and sub-Arctic and what influence this may have on contaminant exposure to marine organisms.

Loseto et al. (2015) reviewed over three decades of data on Hg in beluga to evaluate trend drivers. Neither the diet nor trends in Hg emissions explained beluga Hg trends. Rather a strong fit with the Pacific Decadal Oscillation (lagged by 8yrs) provided the best fit with beluga Hg. These findings suggest that beluga Hg trends may reflect distant drivers of climate variability that likely altered dietary exposure in their large home range. With respect to organic contaminants, Nöel et al. (2018) determined that beluga diet accounted for the variation in some compound concentrations (∑PCBs, ∑Chlordanes, mirex, and dieldrin). However, despite regulatory bans on chlorinated contaminants, Nöel et al. (2018) reported no significant changes in concentrations between 1989 and 2015. Therefore, annual monitoring of contaminant concentrations in western Arctic beluga whales remains an important undertaking.

Activities in 2017-2018

Field and Laboratory

As part of their annual subsistence hunt, Inuvialuit hunters secured, measured, sexed and sub-sampled 32 beluga whales from Hendrickson Island, NWT in July and August 2017 (25 males, 5 females, 1 unknown). Tissues were frozen and shipped back to the Freshwater Institute, Winnipeg, MB. Aging the beluga is ongoing as of June 2018.

Total Hg (THg) in muscle, liver and muktuk was analysed at the Centre for Earth Observation Science (CEOS) at the University of Manitoba. THg was measured by Combustion Atomic Absorption Spectroscopy (C-AAS) on a Teledyne Leeman HYDRA IIc. Detection limits are 0.04 ng Hg (absolute; most beluga tissues have several thousand ng of Hg per 0.01 g of sample). Quality assurance and quality control was 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).

At Liisa Jantunen's and Tom Harner's labs at Environment and Climate Change Canada in Toronto, Cassandra Rauert, Sarah Bernstein, and Liisa processed and analyzed Hendrickson Island and Sanikiluaq beluga samples from 2016 for fluorinated organic compounds (FOCs), hexabromocyclododecanes (HBCDs) and polybrominated diphenyl ethers (PBDEs). Although these samples had been previously extracted at the Freshwater Institute (DFO), Winnipeg in 2017, the extracts needed further clean-up at Environment and Climate Change Canada (ECCC) prior to analysis.

ALS (Burlington) has been contacted to conduct analysis of legacy persistent organic pollutants (chlordanes, polychlorinated biphenyl compounds (PCBs)).

Communications and Outreach

Western Arctic/Hendrickson Island: youth and monitors continue to be hired at multiple sampling locations as part of the partnered Fisheries Joint Management Committee beluga harvest monitoring. Findings from long term monitoring of contaminants were published in a Special Issue in the Journal Arctic Science and plain language summaries were made available and distributed to local Hunters and Trappers Committees throughout the Inuvialuit Settlement Region (ISR).

Outreach efforts were made to re-connect the program with the community of Pangnirtung, meetings were held to discuss the value of sample collections.

In spring 2017, team members from University of Manitoba presented updated of the findings to the Hunters and Trappers Organization and community of Sanikiluaq.

Capacity Building and Training

Beluga whales were collected at Hendrickson Island in collaboration with Inuvialuit hunters. Samples of body organs were collected by trained collectors present at the hunt.

Inuvialuit hunters provided observations about the health, condition and movements of the beluga whales. The local indicators identified from the Northern Contaminants Program (NCP) funded program resulted in an updated monitoring form that includes questions for hunters and additional observations about the beluga health.

Results

Collections from Hendrickson Island are one of the most extensive with >500 samples from 22 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 2017 was 16.54 ± 12.54 µg/g (all concentrations reported in wet weight unless stated otherwise). The average mercury concentration in muscle was 17 times lower than that of liver (0.96 ± 0.59 µg/g), but most samples still exceeded 0.5 µg/g (range of 0.5-3.16 µg/g), the concentration used to regulate the consumption of commercial fish in Canada (Health Canada 2004; Canadian Food Inspection Agency 2014). Of the three organs analyzed, muktuk, contained the lowest levels of total mercury with a mean of 0.42 ± 0.18 µg/g. Thirty percent of the samples (9 of 30) exceeded 0.5 µg/g. Unlike liver, total mercury in muscle and muktuk is equivalent to methylmercury (MeHg), 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).

With respect to emerging persistent organic pollutants (POPs), average ∑HBCD concentrations were very similar between beluga samples taken in 2016 at Sanikiluaq, NU, and Hendrickson Island, NWT. Average ∑FOC concentrations, however, were about four times larger in Sanikiluaq beluga liver tissue compared to those from Hendrickson Island.

The analysis of legacy POPs, FOCs and PBDEs from 2017 Hendrickson Island beluga samples is ongoing, as is the analysis of PBDEs in 2016 Hendrickson Island and Sanikiluaq samples.

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.

Total fluorinated organic compounds (FOC) concentrations were much higher in Sanikiluaq beluga than in Hendrickson Island beluga. High PFOS concentrations have similarly been observed for other beluga and ringed seals in the Hudson Bay region compared to the western Canadian Arctic (Muir et al. 2013). The higher concentrations of FOCs in the sub-Arctic (Hudson Bay) are likely attributed to the closer proximity to southern (industrial) regions which produce/emit these chemicals.

Since some contaminants (e.g. mercury, PCBs) tend to accumulate in certain tissues (e.g. liver, blubber) in older animals, age is an important covariate in the statistical analysis of such datasets. Once beluga ages have been determined for 2017 samples, a thorough temporal trend analysis can be completed.

Table 1. Emerging POPs concentrations (mean ± SD) in 2016 male beluga whales

Location	∑HBCD*, blubber (ng/g lipid)	∑FOC^, liver (ng/g)
Hendrickson Island	2.40 ± 0.72 (n=10)	111 ± 56 (n=9)
Sanikiluaq	2.44 ± 0.96 (n=9)	460 ± 109 (n=10)

*equal to the sum of **α**-, **β**-, and **γ**-HBCD

^ equal to the sum of 18 congeners

Expected Project Completion Date

Temporal trend studies are long-term propositions, and thus annual sampling is projected into the foreseeable future.

Project website

There is a Facebook page (closed group) about the Beaufort Sea beluga and ongoing projects, administered by the Joint Secretariat – Inuvialuit Settlement Region with contributed material by DFO scientists. The page is searchable on Facebook "Beaufort Sea Beluga" or use the following link to the website: https://www.facebook.com/groups/189381521709387/ .

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Temporal trends of contaminants in Arctic seabird eggs

Tendances temporelles des contaminants dans les œufs des oiseaux de mer en Arctique

Project Leader/Chef de projet

Birgit Braune, Environment and Climate Change Canada, National Wildlife Research Centre, Carleton University (Raven Road), Ottawa, ON, K1A 0H3.
Tel: (613) 998-6694; Fax: (613) 9980458; E-mail: birgit.braune@canada.ca.

Mark Mallory, Biology Department, Acadia University, Wolfville, NS, B4P 2R6.
Tel: (902) 585-1798; Fax: (902) 585-1059; E-mail: mark.mallory@acadiau.ca.

Kyle Elliot, Department of Natural Resource Sciences, McGill University, Ste-Anne-de-Bellevue, QC, MS3-042.
Tel: (514) 398-7907; Fax: (613) 398 7990; E-mail: kyle.elliott@mcgill.ca.

Project Team/Équipe de projet

Abde Idrissi, Guy Savard, Robert Letcher, Amie Black, Paul Smith, Grant Gilchrist, Environment and Climate Change Canada, Ottawa, ON

Project Location/Emplacement(s) du projet

- Prince Leopold Island, NU
- Coats Island, NU

Abstract

This project monitors contaminants 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. Concentrations of total mercury (Hg) continue to increase in fulmar eggs but at a much slower rate, whereas Hg concentrations in murre eggs have plateaued and may only be starting to decrease recently. Concentrations of PCBs and DDT continue to plateau after dramatic declines in the 1970s and 1980s, whereas polychlorinated naphthalenes continue to decline. Climate change is affecting concentrations of organochlorines and total mercury in seabird eggs from Prince Leopold Island.

Résumé

Ce projet consiste à surveiller les contaminants dans les œufs d'oiseaux de mer de l'Arctique, car ils constituent un indice de la contamination des écosystèmes marins de l'Arctique. Des œufs de guillemots de Brünnich et de fulmars boréaux sont recueillis sur l'île Prince Leopold, dans l'Extrême-Arctique canadien, depuis 1975. Les concentrations de mercure total (Hg) continuent d'augmenter dans les œufs de fulmars, mais à un rythme considérablement moins élevé, tandis que les concentrations de Hg dans les œufs de guillemots ont stagné et pourraient avoir commencé à diminuer récemment seulement. Les concentrations de BPC et de DDT continuent de stagner après avoir diminué de façon marquée au cours des années 1970 et 1980, tandis que les concentrations de naphtalènes polychlorés continuent de diminuer. Les changements

climatiques ont une incidence sur les concentrations d'organochlorés et de mercure total dans les œufs d'oiseaux de mer de l'île Prince Leopold.

Key Messages

- Concentrations of total Hg continue to increase in fulmar eggs from Prince Leopold Island but at a much slower rate, whereas Hg concentrations in the murre eggs have plateaued and may be starting to decrease.
- Concentrations of PCBs and DDT declined dramatically in the 1970s and 1980s and are now plateauing in eggs of thick-billed murres and northern fulmars from Prince Leopold Island.
- Concentrations of polychlorinated naphthalenes continue to decline in eggs of thick-billed murres from Prince Leopold Island.
- Increased concentrations of total mercury as well as some organochlorines in seabird eggs from Prince Leopold Island are correlated with increasingly positive North Atlantic Oscillation conditions and increasing rainfall/precipitation in this region.

Messages clés

- Les concentrations de mercure total continuent d'augmenter dans les œufs de fulmars de l'île Prince Leopold, mais à un rythme considérablement moins élevé, tandis que les concentrations de mercure dans les œufs de guillemots ont stagné et pourraient avoir commencé à diminuer.
- Les concentrations de BPC et de DDT ont diminué de façon marquée au cours des années 1970 et 1980 et stagnent maintenant dans les œufs de guillemots de Brünnich et de fulmars boréaux de l'île Prince Leopold.
- Les concentrations de naphtalènes polychlorés (NPC) continuent de diminuer dans les œufs des guillemots de Brünnich de l'île Prince Leopold.
- L'augmentation des concentrations de mercure total et de certains organochlorés dans les œufs d'oiseaux de mer de l'île Prince Leopold est associée à des conditions d'oscillation nord-atlantique de plus en plus positives et à l'augmentation des pluies et des précipitations dans cette région.

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 (POP) (biennially as of 2014), total mercury (Hg) (annually), and the murre and fulmar eggs from Prince Leopold Island are also analyzed annually for polybrominated diphenyl ethers (PBDEs) and perfluoroalkyl substances (PFASs), and biennially for polychlorinated dibenzo-*p*-dioxins (PCDDs) and furans (PCDFs) as well as coplanar PCBs. All eggs are analyzed for stable isotopes of nitrogen as indicators of trophic position.

Since 1975, most of the legacy POPs (e.g. PCBs, DDT) in the murre and fulmar eggs have been declining (Braune et al. 2015a) as have the PCDDs, PCDFs and non-*ortho* PCBs (Braune and Mallory 2017) and the polychlorinated naphthalenes (PCNs) (Braune and Muir 2017), 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 2017-2018

Sample Collection/Analysis

Eggs of northern fulmars (n=15) and thick-billed murres (n=15) were successfully collected from Prince Leopold Island (74°02'N, 90°05'W), and thick-billed murre eggs (n=15) were also collected from Coats Island (62°30'N, 83°00'W) in northern Hudson Bay.

Although legacy POPs are now analyzed on a biennial basis in even years for this project, in 2017/2018 eggs were nonetheless analyzed for 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). Murre and fulmar eggs from Prince Leopold Island were analyzed for PFASs and the murre eggs from Prince Leopold Island were also analyzed for PCNs. 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. PCNs were analyzed by ALS Environmental (Burlington, ON). 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-a-HBCD was carried out using GC/MSD run in negative chemical ionization (NCI) mode according to NWRC Method No. MET-CHEM-OC-06D. Analyses of PFASs (10 PFCAs and 4 PFSAs) were carried out by the Organic Contaminants Research Laboratory (OCRL) (Letcher Lab) at NWRC using ultra high performance liquid chromatography-tandem mass spectrometry (UHPLC/MS/MS) in negative electrospray mode (ESI^-) according to NWRC Method No. MET-OCRL-EWHD-PFC-04. PCNs (75 congeners) were analyzed using the GC/HRMS isotope dilution method. 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 also participates in the NCP's QA/QC Program. Stable isotope (C, N) analyses were carried out at the G.G. Hatch Stable Isotope Laboratory, University of Ottawa in Ottawa, Ontario. All samples are archived in the National Wildlife Specimen Bank at the NWRC in Ottawa.

Capacity Building

Josiah Nakoolak from Coral Harbour was hired to help with the field work at Coats Island, and Uluriak Amarualik from Resolute Bay was hired to help the field team collect seabird eggs from Prince Leopold Island. We also arranged for Uluriak Amarualik to attend the NCP Results Workshop in Yellowknife in September 2017, so that she could interact with other scientists and community members involved in arctic research, learn about other NCP projects, and see how the results from the monitoring of arctic seabird eggs were used in a larger context.

Communications

Presentations on the work that Environment and Climate Change Canada (ECCC) is doing on arctic birds are given regularly in the communities of Resolute Bay and Coral Harbour, which are the closest communities to Prince Leopold Island and Coats Island, respectively. 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 (HTO), 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 during January 10 -11, 2017, where she presented a general overview of the work at Prince Leopold Island, a plain language field report for 2016 (English-Inuktitut), and plans for the 2017 field season. 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. Amie returned again to Resolute Bay in April 2018.

Paul Smith (ECCC, Ottawa), who also has a field camp on Coats Island, was to meet with the Aiviit HTO and the Irniurviit ACMC in Coral Harbour during the week of March 6th, 2017, to present results from last year's work and plans for the 2017 field season at Coats Island. However, poor weather prevented the plane from landing in Coral Harbour. Consultation was, therefore, limited to phone and e-mail. Paul returned to Coral Harbour in April 2018.

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 and presented at conferences/workshops. Three journal articles were published in Environmental Science and Technology, Journal of Environmental Sciences and Science of the Total Environment. In 2017-2018, platform presentations and/or posters were presented at the International Conference on Arctic Science: Bringing Knowledge to Action, 13th International Conference on Mercury as a Global Pollutant, SETAC North America 38th Annual Meeting, and Arctic Change conference. Other communications activities include presentations at the 2017-2018 Northern Contaminants Program results workshop, contributing data to a chapter in the AMAP Assessment 2016: Chemicals of Emerging Arctic Concern, and media articles.

Indigenous Knowledge Integration

We continue to meet with the Sulukvait ACMC to understand and address their concerns about the field work on Prince Leopold Island. We are also taking note of their observations on changing numbers of birds seen in the area as well as changing local weather patterns which may help us in our data interpretation.

Results

Annual mean concentrations for selected contaminants found in eggs of northern fulmars and thick-billed murres from Prince Leopold Island and murres from Coats Island in 2017 are presented in Table 1. Concentrations of total Hg appear to be still increasing in fulmar eggs from Prince Leopold Island but at a much slower rate, whereas Hg concentrations in the murre eggs have plateaued and may be starting to decrease (Figure 1). Concentrations of Σ_{35}PCB and SDDT have dramatically decreased since 1975 and are now plateauing (Figure 2), whereas concentrations of Σ_{67}PCN continue to decrease (Figure 3).

Figure 1. Mean annual concentrations of total mercury (Hg) (μg g^{-1} dry wt ± standard error) in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, Nunavut, 1975-2017.

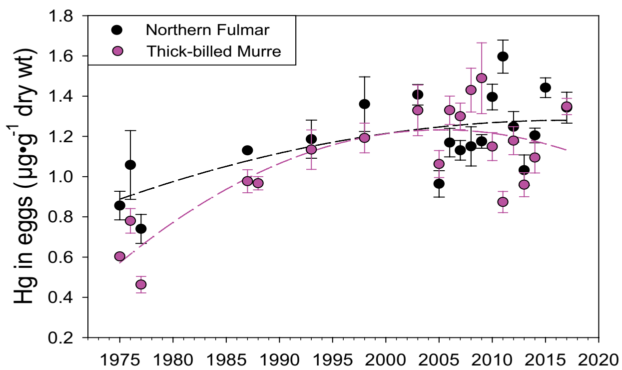


Table 1. Mean concentrations (± standard deviation) of % lipid, δ^{15}N (‰), total Hg (μg g^{-1} dry weight), and organochlorines (Σ_{35}PCB, *p,p'*-DDE, hexachlorobenzene (HCB), oxychlordane, heptachlor epoxide (HE), dieldrin, mirex), polybrominated diphenyl ethers (BDE-47, BDE-99, BDE-100), HBCD, ΣPFCA (C_6-C_{14}) and PFOS (ng g^{-1} wet weight) in eggs (n=15) of thick-billed murres and northern fulmars collected from Prince Leopold Island and thick-billed murres collected from Coats Island in 2017.

	Prince Leopold I.		Coats I.
	Fulmar	Murre	Murre
	Mean ± sd	Mean ± sd	Mean ± sd
% lipid	9.9 ± 0.92	11.6 ± 0.82	10.8 ± 0.93
δ^{15}N	13.5 ± 0.31	16.2 ± 0.68	13.9 ± 0.80
Hg	1.34 ± 0.172	1.35 ± 0.090	0.56 ± 0.101
Σ_{35}PCB	141 ± 24.8	54.4 ± 9.45	77.6 ± 14.2
p,p'- DDE	104 ± 19.0	78.9 ± 13.9	115 ± 27.8
HCB	30.7 ± 2.20	60.5 ± 8.73	72.2 ± 10.4
Oxychlordane	36.1 ± 6.48	7.16 ± 0.744	8.26 ± 1.62
HE	4.44 ± 0.462	4.58 ± 1.81	3.52 ± 0.944
Dieldrin	12.1 ± 0.80	12.7 ± 3.47	8.80 ± 2.11
Mirex	5.58 ± 0.719	1.22 ± 0.217	2.00 ± 0.495
BDE-47	<0.077	0.59 ± 0.309	0.68 ± 0.200
BDE-99	<0.024	0.10 ± 0.118	0.16 ± 0.093
BDE-100	<0.050	0.15 ± 0.127	0.17 ± 0.080
HBCD	1.29 ± 0.55	0.38 ± 0.157	0.43 ± 0.117
PFOS	11.2 ± 1.04	14.9 ± 1.17	---
ΣPFCA	20.2 ± 2.36	17.3 ± 1.20	---

Figure 2. Mean annual concentrations of Σ_{35}PCB and ΣDDT (μg g^{-1} lipid wt ± standard error) in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, Nunavut, 1975-2017.

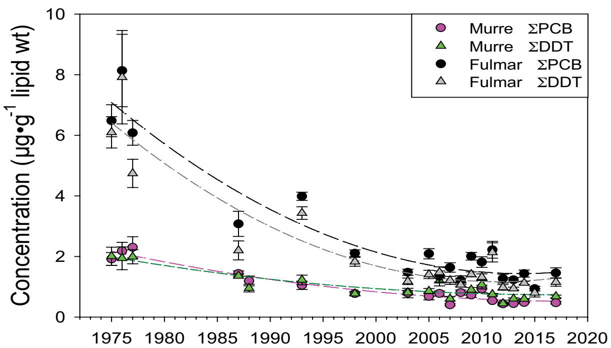
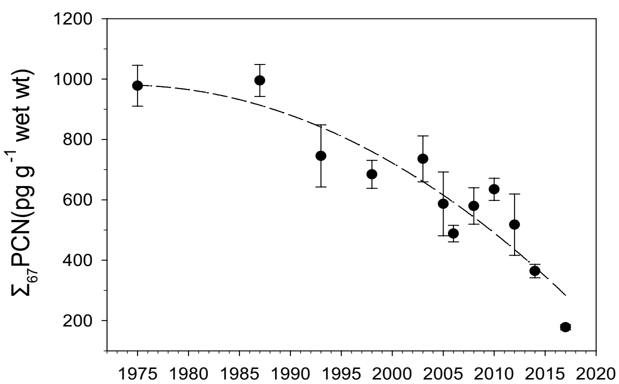


Figure 3. Mean annual concentrations of Σ_{67}PCN (pg g^{-1} wet wt ± standard error) in eggs of thick-billed murres from Prince Leopold Island, Nunavut, 1975-2017.



Discussion and Conclusions

The temporal trends for total Hg in eggs of northern fulmars and thick-billed murres from Prince Leopold Island from 1975 to 2017 have not changed much from the trends for 1975 to 2014 previously published by Braune et al. (2016). A study comparing total Hg trends in liver and egg tissues of thick-billed murres and northern fulmars from Prince Leopold Island between 1976 and 2013 showed that hepatic Hg was consistently higher than egg Hg (Mallory and Braune, 2018). Both species had similar egg Hg concentrations, but fulmars had higher hepatic Hg than murres. Mercury concentrations in murres showed more relative variation through time than fulmars. Mallory and Braune (2018) suggested that egg Hg better reflects exposure of birds to Hg in local Arctic prey, whereas liver Hg may incorporate longer term, year-round Hg exposure.

The trends for Σ_{35}PCB and ΣDDT continue to plateau after the dramatic declines during the 1970s and 1980s which resulted from the implementation of global and regional conventions which regulated or banned the use of most of the legacy POPs (AMAP 2016). Concentrations of Σ_{67} PCN, on the other hand, continue to decline. However, despite the fact that the manufacture of PCNs has been discontinued (Bidleman et al. 2010; Falandysz et al., 2008; Kilanowicz et al., 2011), there is evidence that emissions to the environment continue from combustion sources (Falandysz, 1998).

In recent years, a number of studies have started to examine the potential influence of environmental parameters or climate change on contaminant patterns and trends (e.g. Braune et al., 2014, 2015a; Dorresteijn et al., 2012; Loseto et al. 2015; McKinney et al., 2012; Riget et al., 2012, 2013). The single largest barrier to time-series studies of weather and climate influence is limited availability of consistent, long-term monitoring data for pollutants (Macdonald et al., 2005). The time series data for total Hg and organochlorine concentrations in eggs of northern fulmars and thick-billed murres from Prince Leopold Island from 1975 to 2014 were examined in the context of a number of weather/climate variables to determine whether or not climate change was having any discernible effect on the temporal trends observed. Not surprisingly, the majority of variability in the data was related to changing emission patterns. However, correlations were found suggesting that, under increasingly positive conditions of the North Atlantic Oscillation (NAO+) and the resultant increasing rainfall/precipitation, concentrations of total Hg and certain organochlorines will increase. These findings underscore the need for continued monitoring of environmental contaminants, regardless of their current trends.

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. In particular, we thank Josiah Nakoolak from Coral Harbour, who has been a valued member of the field team at Coats Island for so many years, and Uluriak Amarualik from Resolute Bay, who assisted with the 2017 collections at Prince Leopold Island and has shown a continued interest in the work there. Sample preparation and chemical analyses were carried out by Laboratory Services at the National Wildlife Research Centre in Ottawa and ALS Environmental in Burlington. Stable-nitrogen isotopes were analyzed by the G.G. Hatch Stable Isotope Laboratory at the University of Ottawa, Ottawa. Funding over the years has been provided by Environment and Climate Change Canada and the Northern Contaminants Program of Indigenous and Northern Affairs Canada. Logistical support out of Resolute Bay is provided by the Polar Continental Shelf Program at Natural Resources Canada.

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Temporal trends and spatial variations of 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

Project Leader/Chef de projet

Marlene S. Evans, Environment and Climate Change Canada, 11 Innovation Boulevard, Saskatoon, SK S7N 3H5. Tel: 306-975-5310; Fax: 306-975-5143; Email: marlene.evans@canada.ca

Derek Muir, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON L7S 1A1. Tel: 905-319-6921; Fax: 905-336-6430; Email: derek.muir@canada.ca.

Project Team/Équipe de projet

Beverley Maksagek, Ekaluktutiak (Cambridge Bay) Hunters and Trappers Organization, Cambridge Bay, NU; Milla Rautio, Univeristé du Québec à Chicoutimi, QC; Michael Power, University of Waterloo, ON; Donald S. McLennan, Canadian High Arctic Research Station, Hull, QC; Jane Kirk, Amila De Silva, and Xiaowa Wang, Environment and Climate Change Canada, Burlington, ON; Magali Houde, Environment and Climate Change Canada, Montreal, QC; Geoff Koehler, and Jonathan Keating, Environment and Climate Change Canada, Saskatoon, SK; Les Harris, Fisheries and Oceans Canada, Winnipeg, MB

Project Location/Emplacement(s) du projet

Ekaluktutiak (Cambridge Bay), NU

Abstract

This core biomonitoring study investigates trends in mercury concentrations in sea-run (anadromous) Arctic char from the domestic fishery at Ekaluktutiak (Cambridge Bay). Of particular scientific interest is investigating whether year-to year changes in mercury concentrations are similar to year-to-year changes in climate and mercury releases to the air from urban and industrial areas. Local fishermen harvested the Arctic char from the sea that was used for our mercury analyses. As part of other collaborative studies, fishermen working with the Hunters and Trappers Organization (HTO) and university researchers working with the HTO harvested lake trout, lake

Résumé

Cette étude de biosurveillance de base permet d'analyser les tendances des concentrations de mercure chez l'omble chevalier anadrome provenant de la pêche locale à Ekaluktutiak (Cambridge Bay). L'intérêt scientifique particulier de l'étude consiste à déterminer si les variations annuelles des concentrations de mercure sont similaires aux variations annuelles du climat et des émissions atmosphériques de mercure des zones urbaines et industrielles. Les pêcheurs locaux ont récolté les ombles chevaliers dans les eaux qui ont servi à nos analyses des concentrations de mercure. Dans le cadre d'autres études menées en collaboration, les pêcheurs de l'Organisation des chasseurs et

whitefish, least cisco, and char from Grenier Lake where the sea-run char return after feeding in the sea. A community fisherman also provided char from Keyhole Lake, a landlocked lake. Mercury concentrations were very low in the char that fed in the sea (sea-run char) and in char that were from Grenier Lake. Mercury concentrations were higher in landlocked char from Keyhole Lake. Posters were developed that more easily show our study findings with respect to mercury in fish.

des trappeurs et des chercheurs universitaires qui collaborent avec l'Organisation ont récolté le touladi, le grand corégone, le cisco sardinelle et l'omble chevalier dans le lac Grenier, où l'omble chevalier anadrome retourne après s'être nourri dans la mer. Un pêcheur de la collectivité a également fourni des ombles chevaliers récoltés dans le lac Keyhole, un lac fermé. Les concentrations de mercure étaient très faibles dans les ombles chevaliers qui se nourrissent en mer (ombles chevaliers anadromes) et dans les ombles chevaliers qui se trouvaient dans le lac Grenier. Les concentrations de mercure étaient supérieures chez l'omble chevalier dulcicole du lac Keyhole. Des affiches illustrent clairement les constatations de notre étude sur le mercure dans le poisson.

Key Messages

- Mercury concentrations remain very low in sea-run char from the Cambridge Bay domestic fishery.
- While air temperatures are warming in the Cambridge Bay area, mercury concentrations do not appear to be increasing in sea-run char.
- Thinner sea-run char tend to have slightly higher mercury concentrations than heavier sea-run char.
- Mercury concentrations are slightly higher in char living in Grenier Lake than char feeding in the sea.
- Mercury concentrations are higher in lake trout from Grenier Lake, possibly because they are older on average and have different feeding habits compared to fish in other lakes.

Messages clés

- Les concentrations de mercure demeurent très faibles chez l'omble chevalier anadrome provenant de la pêche locale à Cambridge Bay.
- Malgré la hausse de la température de l'air dans la région de Cambridge Bay, les concentrations de mercure ne semblent pas augmenter chez l'omble chevalier anadrome.
- Les ombles chevaliers anadromes de petite taille présentent des concentrations de mercure légèrement plus élevées que les individus de plus grande taille.
- Les concentrations de mercure sont légèrement plus élevées chez l'omble chevalier qui vit dans le lac Grenier que chez l'omble chevalier qui s'alimente dans la mer.
- Les concentrations de mercure sont plus élevées chez le touladi du lac Grenier, probablement parce que ces poissons sont plus vieux en moyenne que les poissons des autres lacs et ont des habitudes alimentaires différentes de ces poissons.

Objectives

This project aims to:

- continue mercury trend monitoring of sea-run (anadromous) Arctic char from the domestic fishery at Ekaluktutiak with a focus on investigating the role of climatic variability in affecting trends;
- continue to collaborate with Milla Rautio (Univeristé du Québec à Chicoutimi) and Michael Power (University of Waterloo) in their Polar Knowledge ecosystem studies of Grenier Lake and other lakes in the watershed. The focus on this freshwater study is on food webs and essential fatty acids;
- continue our mercury investigations of Arctic char and lake trout in Grenier Lake in collaboration with the Ekaluktutiak Hunters & Trappers Organization (HTO) and university researchers;
- visit Ekaluktutiak to discuss the findings of the sea-run Arctic char project; and,
- continue to contribute to the Arctic Monitoring and Assessment Program (AMAP) assessments on mercury trends.

Introduction

This sea-run Arctic char study is part of The Northern Contaminants Program's (NCP) 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, including persistent organic pollutants (POPs) and metals (Evans 2011, Evans and Muir 2014; Evans et al. 2015). Since 2014, the sea-run Arctic char biomonitoring program has been reduced to a single location, Cambridge Bay, and then only for mercury and other metal analyses. The primary reasons for continuing this core biomonitoring at Cambridge Bay are threefold. First, sea-run char are highly important in the Inuit diet, second only to caribou in daily intake (Laird et al. 2013; Hu et al. 2017). In addition to serving as a significant calorific source, char provide essential fatty acids to the Inuit diet, which offer some protection against the adverse impacts of high mercury intake from marine mammals. Second, Cambridge Bay is the site of a long-term commercial fishery for sea-run Arctic char (Day and Harris 2013) with an extensive record of mercury concentrations in fish populations 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). These earlier records allow us to investigate trends in mercury concentration in sea-run char prior to the inception of NCP. Third, the Canadian High Arctic Research Station (CHARS) was established at Cambridge Bay and is rapidly becoming a hub for the investigation of many aspects of the freshwater and marine environment including responses to climate change, for example, a study by Moore et al. (2016) and baseline studies as in Anonymous (2015). This new research station will complement the research station located in Resolute, whose programs began in the late 1960s (Schindler et al. 1974), and where landlocked char have been monitored for mercury and persistent organic contaminant trends since the 1990s (Muir et al. 2014; Chételat et al. 2015; Barst et al. 2016). Cambridge Bay presents additional research opportunities that, for example, allow for comparisons of responses to climate variability of landlocked, resident and sea-run char populations in marine and freshwater environments. These comparisons will help evaluate the hypothesis that freshwater environments are more responsive to climate change than marine systems. It also presents opportunities to investigate contaminant trends in lake trout, seals, caribou and muskox at a single location, i.e., an ecosystem-based study of contaminant trends in the environment and their response to climate and other sources of variability. Additionally, atmospheric monitoring station and a POPs and mercury seawater monitoring program have begun in Cambridge Bay.

The Arctic char being investigated under the NCP are from the domestic fishery at Cambridge Bay and migrate to and from Grenier Lake to the sea. Lake trout, lake whitefish and least cisco also live in Grenier Lake in addition to glacial relicts such as the predaceous *Mysis relicta*. Grenier Lake is regularly fished by the community and has become the focal site of various limnological studies as part of the expanding CHARS program (Anonymous 2015; Rautio et al. 2015); in anticipation of this expanding research opportunity, we arranged for the collection of lake trout and Arctic char beginning in 2014 and since then, have been analyzing them for mercury and stable isotopes. These data are adding to the past research conducted on sea-run and landlocked Arctic char populations in northern Canada, as well as lake trout in the broader Cambridge Bay area, including differences in mercury bioaccumulation as a function of species and migratory behavior (Gantner et al. 2010b; Swanson et al. 2010; Swanson et al. 2011; van der Velden et al. 2013a; van der Velden et al. 2013b). Moreover, it has allowed us to develop a successful collaboration with Milla Rautio in her Polar Knowledge funded study "Ecosystem Health of Arctic Freshwaters". Polar Knowledge gives significant consideration with NCP partnerships, particularly those involving topics of community interest. While 2017 was the first field season with Polar Knowledge funding, CHARS supported previous baseline studies of the biodiversity and productivity of Grenier and nearby lakes (Rautio et al. 2015) with additional collections made in 2015 and 2016. These studies investigated water chemistry, benthos, phytoplankton and zooplankton communities including their lipid content and fatty acid composition.

Activities in 2017-2018

Fish Collections

In August 2017, sea-run Arctic char were harvested from the sea by community fishermen for our NCP-funded study. Resident char, lake trout, lake whitefish, and least cisco were collected by Michael Power from Grenier Lake and some smaller lakes as part of Rautio et al.'s studies. In October, lake trout and lake whitefish were collected from Grenier Lake by a community fisherman; char could not be caught at this time despite significant effort. Indigenous knowledge suggests that char do not overwinter in Grenier Lake but migrate further inland to smaller lake ecosystems. Landlocked char were obtained from Keyhole Lake for mercury and other analyses. Keyhole Lake has been the subject of several past studies, including studies investigating mercury in these fish (Hunter 1968; Hunter 1969; Vanriel 1989; Gantner et al. 2010b).

Other Collections and Sample Sharing

Plankton, various benthic invertebrates, forage fish, in addition to plant and algal material were collected at Grenier Lake and the Experimental Lake watershed in August 2017 to investigate trophic pathways and fatty acids. These samples were shared with Environment and Climate Change Canada (ECCC) for stable isotope and mercury analyses. Local community members participated in these collections. Milla Rautio analyzed past food web collections, including our lake trout and char samples from Grenier Lake, for fatty acids. These collections are building a data base for trophic pathways within Grenier and other lakes, thereby contributing to the larger watershed ecology program.

Community Engagement

Community engagement has largely been through Beverley Maksagek with the Ekaluktutiak (Cambridge Bay) Hunters and Trappers Organization. This has involved telephone conversations and emails about this NCP-funded study including the proposal, consultation, and sea-run char and other fish collections. She has been instrumental in engaging local fishermen in participating in these studies. Additional conversations have been held around the Polar Knowledge study led by Milla Rautio and those field campaigns. In early 2018, Marlene and Beverly discussed the design of a plain language poster of the mercury results suitable for distribution in the community. Marlene visited Beverly in March to discuss study results and obtain more detailed comment on poster design. In order to make the results clearer, three posters were developed: sea-run char, Grenier Lake, and Keyhole Lake. Milla provided copies of the updated Grenier Lake poster to the community during her April 2018 visit. These posters were photocopied and made broadly available within the community.

Capacity Building and Training

Training was provided by Milla Rautio under her Polar Knowledge project, including Jimmy Haniliak who participated in the fish sampling on Grenier Lake (summer and fall) and Jasmin Tiktalek who assisted in the laboratory. In August, Milla Rautio, Michael Power and others took part in the Cambridge Bay Science Bioblitz, which involved community participation and training. Tommy Ekpakohak caught the fish from Keyhole Lake in early winter 2017.

Indigenous Knowledge

Indigenous Knowledge was shared, including the locations in Grenier Lake where lake whitefish could be caught in summer and discussion of the absence of char in fishing nets set in Grenier Lake during winter ice cover (confirmed by October catches). Richard Ekpakohak shared the locations of landlocked lakes which the community fishes for char, including Keyhole Lake.

Results and Discussion

Overall features of sea-run char and Grenier Lake fish populations

An overall picture is emerging of the sea-run harvested Arctic char population, in addition to Arctic char and lake trout harvested from Grenier Lake (Table 1). Sea-run char tend to be larger and older than summer caught char from Grenier Lake, but with lower mercury concentrations. Most Grenier Lake char had

Table 1. Biological features and mercury concentrations of Arctic char caught in Cambridge Bay (sea-run) and Grenier Lake over 2014-2017. Also shown are lake trout data for fish caught from Grenier Lake over 2014-2017 and lake whitefish and least cisco in 2017.

Species/location	Year	N	Fork Length (cm)	Condition Factor	Age (yr.)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Hg (µg/g)
Arctic char								
Sea-run	2014	10	658 ± 90	1.3 ± 0.2	12.8 ± 3.4	-24.0 ± 0.4	14.4 ± 0.8	0.05 ± 0.02
Grenier Lake	2014	15	519 ± 53	1.1 ± 0.1	8.1 ± 3.2	-24.8 ± 1.3	12.7 ± 1.7	0.07 ± 0.04
Grenier Lake	2015	12	610 ± 62	1.2 ± 0.1	10.4 ± 1.5	-24.5 ± 0.7	14.6 ± 0.3	0.05 ± 0.01
Sea-run	2016	20	707 ± 83	1.1 ± 0.2	13.6 ± 3.2	-23.7 ± 0.7	14.9 ± 0.4	0.07 ± 0.02
Grenier Lake	2016	15	510 ± 158	1.1 ± 0.1	9.2 ± 2.6	-24.9 ± 1.6	11.4 ± 2.2	0.08 ± 0.04
Sea-run	2017	15	652 ± 88	1.3 ± 0.1	15.3 ± 4.1	-	-	0.07 ± 0.02
Grenier Lake	2017	18	405 ± 162	1.1 ± 0.1	-	-	-	0.10 ± 0.04
Keyhole Lake	2017	11	646 ± 54	1.3 ± 0.1	8.6 ± 1.4	-	-	0.23 ± 0.13
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 ± 8.4	-25.7 ± 1.1	11.3 ± 1.1	0.49 ± 0.43
Grenier Lake	2017	15	578 ± 29	1.3 ± 0.1	25.6 ± 9.5	-	-	0.50 ± 0.19
Lake whitefish								
Grenier Lake	2017	16	403 ± 39	1.3 ± 0.2	-	-	-	0.25 ± 0.13
Least cisco								
Grenier Lake	2017	28	223 ± 40	1.0 ± 0.1	-	-	-	0.10 ± 0.02

food in their stomachs, indicative of a resident population. Overall, mercury concentrations were slightly higher in resident than sea-run char, this was also observed by Swanson et al. (2011). Mercury concentrations were higher in char from Keyhole Lake (0.23 ± 0.13 μg/g) than Grenier Lake (0.10 ± 0.04μg/g). Gantner et al. (2010a) reported that Keyhole Lake char had an average mercury concentrations of 0.09 μg/g; their char were smaller (401 ± 100 mm) but older (9 ± 6 yrs.) than our Keyhole Lake char (646 ± 54 mm; 8 ± 1 yrs.).

Mercury trends in anadromous char

Mercury concentrations remained low in sea-run char over 2004-2017 (Figure 1); air temperatures showed a general trend of increase over this period. Variations in mercury concentration were related to fork length (FL) and condition factor (CF); homogenized air temperature data for 2015 and 2016 are unavailable (Equation 1).

Equation 1 (2004-2014)

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)

Additional mercury data are available for 1977-1993, from the commercial fishery, to extend the trend analyses. However, fish caught in 1977 and 1978 were substantially smaller than fish caught in later years and so trend analyses were limited to 1993-2016. Variations in mercury concentrations were best explained by a negative relationship with condition factor and a positive relationship with fork length (Equation 2). Condition factor is a measure of how heavy a fish is for a given length. A fish with a condition factor of 0.8 is considered “skinny” whereas a fish with a condition factor of 1.9 would be considered “fat”.

Equation 2 (1996-2014)

Log Hg = -1.233 + 0.000*FL -0.265*CF (n=134, R^2=0.19, F=15.484, p<0.001)

Polar Knowledge Studies (Rautio, Power, Evans)

The Grenier Lake food web has been characterized based on carbon and nitrogen isotopes. Littoral zone carbon sources appear particularly important for char and lake trout while cisco and lake whitefish feed more on pelagic carbon sources and this may account for their somewhat higher mercury concentrations. Fatty acid concentration and composition also have been characterized. Fatty acid concentrations were higher in lake trout than char fillet (41.6 ± 38.6 versus 11.6 ± 5.7 μg/mg dry weight) while the converse was observed for liver (24.9 ± 7 versus 47.6 ± 17.3 μg/mg dry weight.

Poster design

The redesigned posters have more simple messaging, but the main improvement has been in the graphics where data are presented as color coded fish (green < 0.2 μg/g mercury; orange > 0.2 and < 0.5 μg/g mercury; and red > 0.5 μg/g mercury) and three size categories (Figure 2 and 3). Seeing data as fish schools has been much easier to understand than abstract symbols. X- and Y- axes are easily understood or quickly explained. Consultations have been held with the Nunavut Environmental Contaminants Committee and the Nunavut Department of Health on the messaging and its communication.

Conclusions

This study is a low-cost investigation of mercury in char, lake trout, lake whitefish and least cisco and their food webs. Mercury concentrations continue to be low in sea-run char with no evidence of a temporal increase despite warming trends. Mercury concentrations are somewhat lower in fish with lower condition factors. Continued monitoring will elucidate these relationships. Stable isotope data and other metrics will allow for a fuller investigation of the effects of climate warming on sea-run char biology. The data from this project is being used to build a data base that may be suitable for long-term trend monitoring, i.e., marine versus freshwater feeding fish and lake trout versus char that will build on the success of the long-term char and other studies at Resolute.

Figure 1. Left panel: Temporal variations in mercury concentrations (fillet, wet weight) of Arctic char collected from the Cambridge Bay area over 1975-2017 and mean air temperatures. Right panel: Relationship between condition factor and mercury concentration.

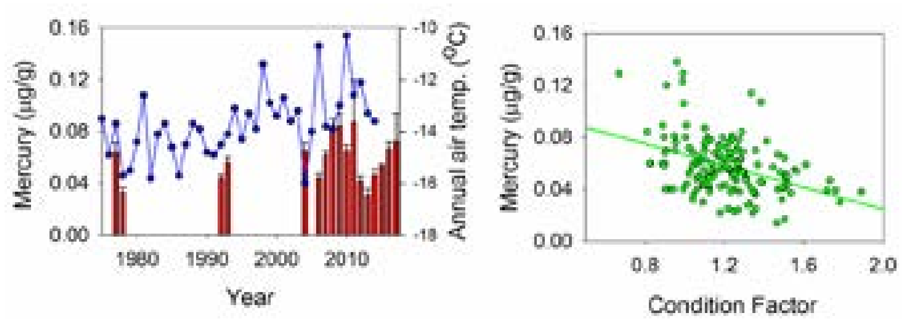


Figure 2. Mercury concentrations in char caught from Cambridge Bay and Grenier Lake in summer 2016 and 2017. Fish shown are shown as fish schools with three different size ranges and color coded as to mercury concentration, i.e., low (green: <0.2 µg/g) and medium (orange: >0.2 and <0.5 µg/g) concentrations. See text for additional explanation.

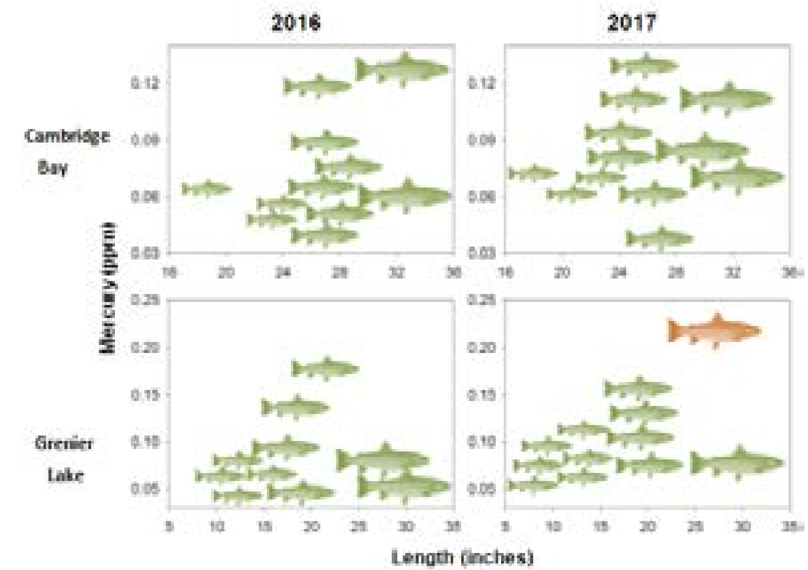
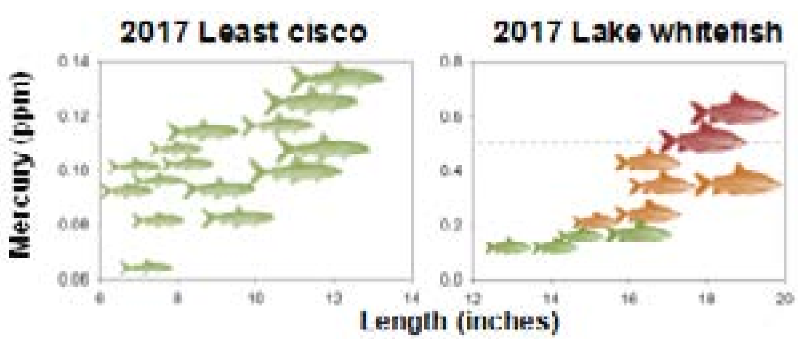


Figure 3. Mercury concentrations in least cisco and lake whitefish caught from Cambridge Bay and Grenier Lake in summer 2017. Fish shown are shown as fish schools with three different size ranges and color coded as to mercury concentration, i.e., low (green: <0.2 µg/g), medium (orange: >0.2 and <0.5 µg/g) and high (red: >0.5 µg/g) concentrations. See text for additional explanation.



Expected completion date

This is an ongoing biomonitoring study.

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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 confiné aux eaux intérieures dans les lacs de l'Extrême-Arctique

Project Leader/Chef de projet

Derek Muir, Aquatic Contaminants Research Division, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON L7S 1A1, Tel: (905) 319-6921; Email: derek.muir@canada.ca

Günter Köck, Institute for Interdisciplinary Mountain Research (ÖAW-IGF), A-6020 Innsbruck, Austria. Tel: +43 1 51581 2771; Email: guenter.koeck@oeaw.ac.at

Jane Kirk, Aquatic Contaminants Research Division, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON., Tel: (905) 336-4412, Email: jane.kirk@canada.ca

Project Team/Équipe de projet

Debbie Iqaluk, Resolute Bay NU; Xiaowa Wang, Mary Williamson, Amy Sett, Environment and Climate Change Canada, Burlington ON; Ben Barst, McGill University, Ste. Anne de Bellevue, QC; Ana Cabrerizo, Institute for Environmental Assessment and Water Research, IDAEA-CSIC. Barcelona, Spain; Karista Hudelson, University of Windsor, Windsor ON; Charlie Talbot, Environmental Science and Technology Laboratories, Environment and Climate Change Canada, Burlington ON; Enzo Barresi, Bert Francoeur and Jacques Carrier, National Laboratory for Environmental Testing, Burlington ON; Maryse Mathy, and Emma Hansen, Parks Canada, Nunavut Field Unit

Project Location/Emplacement(s) du projet

- Resolute, NU
- Quttinirpaaq National Park, NU

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. In 2017, we completed our annual sampling and collected char from lakes near the community of Resolute Bay on Cornwallis Island (Amituk, Char, North, Resolute, and Small) and in Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. Overall, results show that over the period of 2005-2017 concentrations of mercury in

Résumé

Cette étude à long terme porte sur les tendances temporelles relatives au mercure et à d'autres éléments traces, de même qu'à des polluants organiques persistants (POP), hérités et nouveaux, qui sont présents chez les ombles chevaliers dulcicoles. En 2017, nous avons achevé le prélèvement annuel de nos échantillons et avons recueilli des ombles dans des lacs situés à proximité de Resolute Bay, sur l'île Cornwallis (lacs Amituk, Char, North, Resolute et Small) et dans le lac Hazen, dans le

char declined in Hazen and Char Lakes but concentrations have levelled off or increased slightly in Resolute, North and Small lakes. Concentrations of POPs have generally declined since the early 2000s but the trends vary among lakes and specific chemicals. In Resolute Lake, toxaphene and PCBs have increased slightly since 2010 which may be due to old sources of contaminants being reintroduced into the lake with climate change.

parc national Quttinirpaaq, sur l'île d'Ellesmere. Dans l'ensemble, les résultats montrent que de 2005 à 2017, les concentrations de mercure chez l'omble chevalier ont diminué dans les lacs Hazen et Char, mais que les concentrations se sont stabilisées ou ont augmenté légèrement dans les lacs Resolute, North et Small. Les concentrations de POP diminuent généralement depuis le début des années 2000, mais les tendances varient selon les lacs et les types de produits chimiques. Dans le lac Resolute, le toxaphène et les BPC augmentent légèrement depuis 2010, ce qui pourrait être attribuable à la réintroduction d'anciennes sources de contaminants dans le lac en raison des changements climatiques.

Key Messages

- While concentrations of mercury in landlocked Arctic char still show overall declining trends since 2005, levels have recently levelled off or increased slightly.
- Concentrations of POPs have generally declined since 2000 but the trends vary among lakes and specific chemicals.
- The year to year variation in concentrations of both mercury 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 POP diminuent généralement depuis 2000, 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 POP hérités du passé chez l'omble chevalier pourrait être influencée par les changements climatiques.

Objectives

This project aims to:

- 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 lake watershed areas, water chemistry, diet and climate warming; and,
- determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information on a timely basis.

Introduction

Landlocked char are the only top predators in most Canadian high Arctic lakes (Köck et al. 2004, Power et al. 2012, 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. For example, using data from this study Lehnherr et al. (2018) recently showed that the condition factor (100*weight/length^3), a general measure of the well-being of a fish used to numerically compare individual fish and fish populations, declined in arctic char in Lake Hazen with the change particularly evident for 2007 to 2014. This change corresponded to a period of greater glacial melt inputs to the lake. 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 (Chételat et al. 2015, Muir et al. 2013) which complements studies on marine mammals and seabirds from the same regions. This temporal trend study has been supported by a series of food web studies on these lakes related to mercury and perfluorinated chemicals which have investigated the pathways and processes of bioaccumulation of mercury and perfluorinated substances (Gantner et al. 2010a, 2010b; Drevnick et al.2013; and Lescord et al.2015a, 2015b).

This study has previously reported on results of annual sampling and contaminant analysis of char at Resolute, Char and Amituk lakes on Cornwallis Island as well as from Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. It builds 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) and with previous data for Char Lake, Amituk Lake, and Lake Hazen, from pre- or early NCP studies (Fisk et al. 2003, Muir and Lockhart 1994) in the 1990s. North and Small lakes were sampled initially as part of food web studies on mercury (Gantner et al. 2010b) and we have continued sampling to follow temporal trends in a broader suite of lakes. Fishing has been more difficult in some lakes due to low numbers (Char), weather dependent access by helicopter (Amituk), and high cost of access (Lake Hazen). Annual sampling has been used to try to achieve the goal of detection of a 5% change over a 10-15 year period with a power of 80% and confidence level of 95% (INAC 2005). All six lakes have 13 or more years of sample collections. Collection numbers have typically ranged from 7 to 25 adult fish (>200 g) per lake except in Char Lake where the range has been 3 to 10 fish annually. Further details on past results from these study lakes are given in previous synopsis reports (Muir et al. 2015, 2016, 2017).

Activities in 2017-2018

Sample collection

Char were successfully collected in late-July and early August 2017 from Amituk, Char, Hazen, North, Small, and Resolute lakes. At Lake Hazen, Parks Canada staff at Quttinirpaaq National Park (QNP) were unable to capture fish through the ice in late June as they had done in the past (2011-2015). However, Parks Canada generously provided space for two team members (Koeck and Talbot) on flights into and out of QNP. The char in Hazen were caught by gill netting within a few hours. All fish were dissected within a few hours of collection and samples (skin-on fillets) were frozen in Resolute and a QNP Hazen camp, 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 2007b). 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 were homogenized under clean room conditions and submitted for analysis of legacy and emerging POPs as planned under the NCP Call for Proposals (2017-18). The analytical methodology followed US EPA Method 1699 (US EPA 2007a). In brief, samples were Soxhlet extracted with dichloromethane (DCM) and lipid removed by gel permeation chromatography by ALS Environmental (Burlington ON). Extracts were split into 4 subsamples for analysis for PCBs, organochlorine pesticides (OCPs), % lipid and halogenated flame retardants (HFRs). The sub-samples for PCBs and OCPs were cleaned up on silica column and analysed by GC-Low resolution MS (LRMS) and GC-high resolution mass spectrometry (GC-HRMS), respectively, by ALS Environmental. All data were recovery corrected for extraction and clean up losses relative to $^{13}C_{12}$ PCB-133 response. A third subsample was analysed by NLET for HFRs by GC-tandem mass (MS/MS) as well as for toxaphene and endosulfan by using GC-negative ion mass spectrometry (GC-NI-LRMS). Results of GC-MS/MS analysis of HFRs, toxaphene, and endosulfan in 2017 samples are pending.

PFASs including C4 to C15 perfluorocarboxylates (PFCAs) and C4 to C12 perfluoroalkane sulfonates were determined in fish muscle 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 the POPs, HFR, and PFAS analyses.

Stable Isotope Analyses

Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon ($d^{13}C$) and nitrogen ($d^{15}N$) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality Assurance (QA)

Reagent blanks were also run with each sample batch of 10 samples. Blanks for all analytes generally had non-detectable concentrations or levels <5% of measured values. No blank correction was used for PFASs, multi-elements, 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 non-detect.

The labs involved in this study participated in the NCP interlab (Phase 11) comparison for 2017-18 and in previous programs (Myers and Reiner2016, 2017).

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. Concentrations of major legacy POPs were lipid normalized (divided by fraction lipid) because wet weight concentrations were significantly correlated with % lipid (Cabrerizo-Pastor et al. 2018).

Capacity Building

The project depends on the help of local people in the Hamlet of Resolute. Debbie Iqaluk worked on the project in 2017. 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 2017 was sent to the Resolute Bay Hunters and Trappers Association (HTA) in late March 2017. Muir met with the Acting Manager of the HTA office during his trip to Resolute in early August 2017 as well as informally with members of the HTA. In September 2017, results were presented at the NCP Results workshop in Yellowknife, the ArcticNet (Arctic Change) Scientific Meeting, Quebec City, and at Society of Environmental Toxicology & Chemistry World Congress, in November in Orlando (FL).

Indigenous Knowledge Integration

Although Indigenous 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 concentrations (length adjusted) in char over time, updated with results from 2017 are shown graphically in Figure 1 for the 6 lakes that are consistently monitored in this study. The 2 year running average suggests declining concentrations in all lakes, except Small Lake, over the period 2005 to 2013. However, there has been a levelling off (Resolute and Amituk, 2015-2017) or significant increase (North, 2012-17; 4.1% per year). Char Lake was resampled for the first time since 2012 and concentrations were very similar to average levels from 2008 to 2012, also suggesting a levelling off compared to earlier declines (2000-2005). Small Lake was the only lake with a long running increase in concentrations (2007-2017, 7.9% per year.

POPs

Figure 2 presents the long term trends of geometric mean lipid weight concentrations for 6 major POPs, total hexachlorocyclohexanes (ΣHCH), total tetra, penta- and hexachlorobenzenes (ΣCBz), total chlordane related compounds (ΣCHL), total DDT-related compounds (ΣDDT), total toxaphene, and sum of 87 PCB congeners/co-eluters (ΣPCB). Results for legacy POPs are complete to 2017 except for toxaphene, for which results are pending. In addition, samples from Resolute and Amituk Lake for 2016 were analysed for toxaphene and endosulfan as well as for HFRs.

Figure 1. Trends of mercury (geometric means ± standard errors) in landlocked char from Resolute, Amituk, Hazen, Char, Hazen, Small and North lakes (early 90s-2017). All results are length adjusted using analysis of covariance. Red lines represent 2 year moving averages.

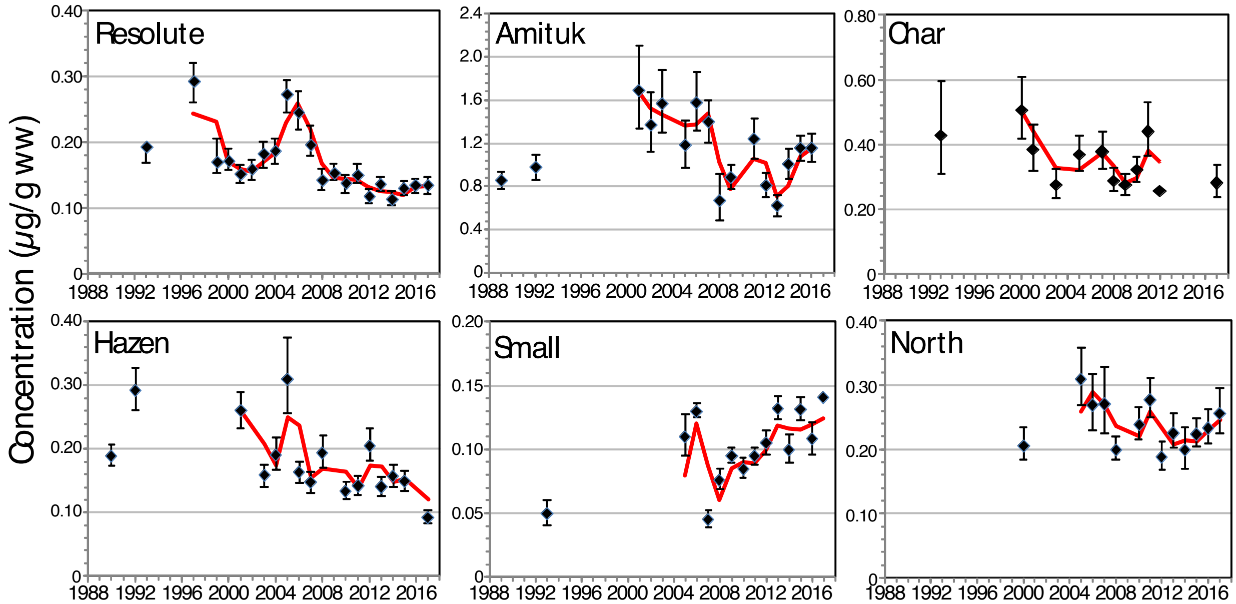
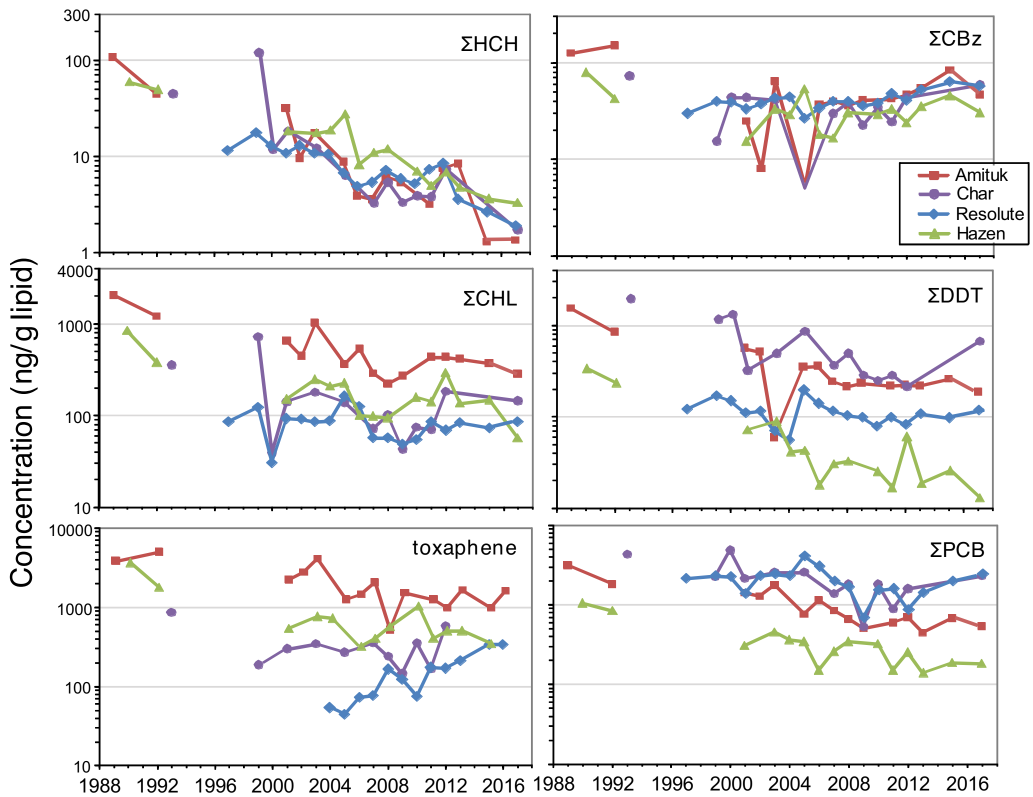


Figure 2. Trends of legacy POPs in landlocked char muscle from Amituk, Char, Resolute and Hazen lakes (early 00s – 2017). Symbols represent geometric means of lipid adjusted concentrations. Error bars are omitted for clarity.



Average concentrations of ΣHCH as well as ΣCBz are very similar in char from all four lakes (Figure 2). However, while ΣHCH continues to decline rapidly, ΣCBz concentrations are basically unchanged in all 4 lakes since the mid-2000s. ΣCHL shows distinctive differences in average concentrations among lakes with Amituk consistently having higher concentrations. While ΣCHL concentrations in char have declined significantly in Amituk and Hazen, they have remained relatively constant in Resolute and Char Lakes. Similarly, ΣDDT shows large differences in average concentrations among lakes with Hazen having 50-fold lower levels than Char Lake. ΣDDT concentrations have not declined significantly in Resolute or Char Lakes for the past 10 years.

The toxaphene concentrations in Figure 2 are based on a technical standard (Glassmeyer et al. 1999) rather than individual congeners, in order to compare with data from 1990 to early 2000s. However, congener data are also available and are reported in Cabrerizo et al (2018). Toxaphene has declined significantly in Amituk and Hazen Lakes but has actually increased in Resolute Lake since the mid-2000s. An increase also may have occurred in Char Lake since 2009, however, this needs to be confirmed with data for 2017.

ΣPCB concentrations also differ greatly among lakes with about 10-fold lower concentrations in Lake Hazen char compared with Resolute and Char Lakes (Figure 2). ΣPCB concentrations continue to decline in Hazen and Amituk Lakes but have been relatively constant in Resolute and Char lakes since the mid-2000s.

Discussion and Conclusions

The results for legacy POPs shown in Figure 2 are gradually bringing to light the influence of past local sources on trends of POPs. The influence of Resolute airport, which is within the catchment of Resolute Lake has been previously shown for PFOS which is 50-fold higher in Resolute char compared to Small or North Lake (Lescord et al. 2015a, Muir et al. 2017). However, unlike PFOS, concentrations of the ΣPCBs and OCPs are not especially elevated and actually, Amituk Lake char have consistently had some of the highest levels (ΣCHL, toxaphene) when comparing the four lakes. Nevertheless, mobilization of old sources appears to be occurring for toxaphene given the significant increase in concentrations in Resolute Lake char since 2004. In the case of ΣDDT, ΣCHL, ΣCBz and ΣPCBs, the results suggest continued sources which are maintaining concentrations in Resolute and Char Lake. DDT, chlordane and toxaphene could have been brought into the airbase for insect control in the 1950s and 1960s and subsequently deposited in the upper catchment from waste water or sewage sludge. Similarly, PCBs would have been used in electrical equipment at the airport until at least the late 1980s when the use of PCBs was phased out in Canada. While remobilization of older atmospherically deposited sources of these POPs from the catchments of all lakes could also occur, it would seem that this process is less important at the two very remote lakes, Amituk and Hazen lakes.

Unlike the trends for POPs, mercury concentrations are not elevated in char in Resolute Lake compared to the five other study lakes (Figure 1). Nevertheless, significant declines in mercury concentrations observed in Resolute Lake over the period 2005 to 2013 have now given way to no change. The extent of net methyl mercury production, may be particularly important, as illustrated by increasing concentrations in mercury in char in Small Lake which has higher dissolved organic carbon and methyl mercury in water than the other study lakes (Lescord et al. 2015b).

With continued monitoring, including studies encompassing water and soil sampling, we hope to be able to explain these trends of mercury and POPs in the arctic char.

Estimated Project Completion Date

Ongoing.

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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

Project Leader/Chef de projet

Marlene S. Evans, Environment and Climate Change Canada, 11 Innovation Boulevard, Saskatoon, SK S7N 3H5 Tel: 306-975-5310; Fax: 306-975-5143; E-mail: marlene.evans@canada.ca

Derek Muir, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON L7S 1A1 Tel: 905-319-6921; Fax: 905-336-6430; E-mail: derek.muir@canada.ca

Project Team/Équipe de projet

Rosy Bjornson, Kathleen Fordy and Diane Giroux, Akaitcho Territory Government, Fort Resolution, NT; Ray Griffith, Lutsel K'e Dene First Nation, Lutsel K'e, NT; George Low and Mike Low, Aboriginal Aquatic Resource and Oceans Management Program, Hay River, NT; Xinhua Zhu, Fisheries and Oceans Canada, Winnipeg, MB; Jane Kirk, Xiaowa Wang, and Sean Backus, Environment and Climate Change Canada, Burlington, ON; Jonathan Keating, Environment and Climate Change Canada, Saskatoon, SK

Project Location/Emplacement(s) du projet

- Lutsel K'e, NT
- Hay River, NT
- Fort Resolution, NT

Abstract

Our study measures trends in mercury, other metals, and persistent organic pollutants (POPs) 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 in these fish

Résumé

Notre étude mesure les tendances dans les concentrations de mercure et d'autres métaux et polluants organiques persistants (POP) 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 locale à Fort Resolution (bassin ouest). De plus, dans le cadre de nos autres études, nous poursuivrons

but with trends of continuing mercury increase in lake trout and burbot. We worked on a series of posters to present our mercury findings in a clear and understandable way; as part of this we met with several community organizations in March 2018 to discuss our study results and refine poster design. POPs concentrations are declining, particularly ΣDDT and ΣHCH. 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 (Buffalo Lake) and Great Bear Lake.

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, mais les concentrations de mercure continuent à augmenter chez le touladi et la lotte. Nous avons travaillé sur une série d'affiches visant à présenter nos résultats sur le mercure de manière claire et compréhensible. Dans le cadre de cette initiative, nous avons rencontré, durant mars 2018, plusieurs organismes communautaires afin de discuter de nos résultats d'études et d'améliorer la conception d'affiches. Les concentrations de POP diminuent, plus particulièrement celles du ΣDDT et du ΣHCH. 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 (lac Buffalo) et le Grand lac de l'Ours.

Key Messages

- Mercury concentrations remain relatively low (average <0.5 µg/g) in lake trout, burbot, and northern pike from Great Slave Lake.
- Mercury concentrations continue to show an increasing trend in lake trout and burbot but not northern pike.
- Persistent organic pollutant concentrations are declining, particularly in West Basin fish.

Messages clés

- Les concentrations de mercure demeurent relativement faibles (moyenne inférieure à 0,5 µg/g) chez le touladi, la lotte et le grand brochet du Grand lac des Esclaves.
- Les concentrations de mercure continuent d'augmenter chez les touladis et les lottes, mais pas chez les grands brochets.
- Les concentrations de polluants organiques persistants sont en déclin, en particulier chez les poissons du bassin de l'ouest.

Objectives

The aims of the project are to:

- determine mercury, metals and persistent organic contaminants (POPs) concentrations in lake trout harvested from two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot harvested from one location (West Basin at Fort Resolution) in 2017 to further extend our long-term POPs and mercury data bases;
- investigate mercury trends in Great Slave Lake fish and the factors that cause concentrations to differ from year to year;
- investigate trends in POPs and contribute information to AMAP expert work groups for trend monitoring for POPs;
- continue to work with Fort Resolution in their water quality monitoring of Resolution Bay waters; continue northern pike mercury monitoring;
- 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 and Heidi Swanson in their mercury in fish studies in lakes in the Dehcho, and Sean Backus in his mercury and flame-retardant study in Great Bear Lake fish;
- continue to provide support as requested to the Tłįchǫ Aquatic Ecosystem Monitoring Program (TAEMP); and,
- communicate results to communities and the commercial fisheries in a timely manner.

Introduction

This study is part of NCP's Blueprint for Environmental Monitoring and Research which is evaluating the success of the Stockholm Convention on Persistent Organic Pollutants and 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). The rate of decline has been reduced in recent years and many POPs are not showing the anticipated decline for reasons that are still not well understood. Mercury concentrations appear to be increasing 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 particular 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 is being conducted with a focus on perfluoroalkyl substances (PFASs), polybrominated diphenyl ethers (PBDEs) and novel brominated flame retardants (BFRs).

Under NCP, we have been investigating POPs and metals in Great Slave Lake food webs and sediments since the early 1990s (Evans et al. 1996, Evans and Muir 2016). Our focus has been on lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*). Fish are investigated from the low-productivity waters of the East Arm where direct atmospheric inputs are presumed to be the primary source of contaminants entering the environment. They also are being investigated from more productive waters of the West Basin which is under profound influence from the Slave River.

Lake trout are being monitored because of their importance in commercial (operating out of Hay River) and domestic fisheries of Great Slave Lake. As pelagic, cold-water stenotherms, they are limited to lakes which thermally stratify in the summer and maintain a well-oxygenated hypolimnion (Scott and Crossman 1998). Lake trout are being monitored from the commercial fishery operating out of Hay River (West Basin) and the domestic fishery at Lutsel K'e (East Arm). Lake trout from the East Arm are older and slower growing than West Basin fish but have slightly lower mercury concentrations (Evans and Muir 2013). Burbot are being monitored because their lipid-rich liver is a highly-prized food item and consumption advisories have been issued or considered for other locations including Lutsel K'e in the East Arm of Great Slave Lake. Burbot are sedentary predators and may be more responsive to conditions occurring at the sediment water interface (Rawson 1951, Scott and Crossman 1998) while lake trout may be more responsive to changes occurring in the pelagic region, including the thermocline. Burbot are being monitored at Resolution Bay (West Basin) by the community of Fort Resolution on the Slave River delta (Table 1). Monitoring at Lutsel K'e under NCP ended in 2004 but resumed in 2008 as part of Environment and Climate Change Canada studies under the Clean Air Regulatory Agenda (CARA) and now Climate Change and Atmospheric Contaminants (CCAP). Burbot provided by Lutsel K'e are smaller and younger than Resolution Bay fish. Burbot also are being monitored on the Mackenzie River near Fort Good Hope and showed pronounced trends of increase up to 2009 (Carrie et al. 2010).

We also have been monitoring northern pike at Fort Resolution. Northern pike are nearshore predators inhabiting warm waters and often residing in weedy areas. Mercury concentrations tend to be high in this species, most likely because of its habitat and proximity to sites of significant mercury methylation, such as wetlands and vegetated littoral zones (Evans et al. 2005, Lockhart et al. 2005, Chételat and Braune 2012).

As part of our collaborative studies with George and Mike Low, we have been contributing to the periodic assessments of mercury in pike (in addition to walleye, lake trout, burbot, and lake whitefish) in smaller lakes to the west of Great Slave Lake although these contributions have diminished in recent years. We also are part of the Tlicho Aquatic Ecosystem Monitoring Program monitoring project. To the north, we have been working with Deline since 2008 in the annual monitoring of lake trout and cisco for mercury, other metals, PBDEs, and PFAS as part of a CMP study led by Sean Backus. Overall, these data are contributing to a broader data base allowing us to investigate trends in warm-water lacustrine species including our studies in Alberta, Saskatchewan, Manitoba, and British Columbia.

Table 1. Fish collections made as part of the NCP and other contaminant studies on Great Slave Lake.

Species	West Basin	East Arm
Lake trout[1]	1993, 1999, 2000-2002, 2004-2017: Hay River	1993, 1995, 1999-2002, 2004-2017: Lutsel K'e
Burbot[2]	1993, 1995, 1996, 1999-2002, 2004-2017: Fort Resolution	1993, 1999-2002, 2004, 2008-2017: Lutsel K'e
Northern pike[3]	1999-2002, 2008-2017. Fort Resolution	1999-2002: Lutsel K'e

[1] Lake trout were not analyzed for POPs in 2014 and 2016.

[2] West Basin burbot were not analyzed for POPs in 2014 and 2016. East Arm burbot were last measured for POPs in 2013.

[3] Northern pike were monitored under NCP for mercury and POPs over 1999-2002. ECCC has continued mercury monitoring of northern pike in Resolution Bay because of their higher Hg concentrations and greater nearshore affinities. Pike were also analyzed in 1996.

Activities in 2017-2018

Fish Collections and Analyses

In autumn 2017, 20 lake trout were collected by Ernest Boucher from Lutsel K'e and by Sean Buckley with the commercial fishery operating out of Hay River; 20 burbot were collected by Gab Lafferty from Fort Resolution. As in past years, we continued burbot collections at Lutsel K'e and northern pike at Fort Resolution for mercury trend assessments. Length (total and fork), 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. Carbon and nitrogen stable isotope analyses were performed on all fish. Ten of the 20 lake trout (Lutsel K'e, Hay River) and burbot (Fort Resolution) were selected for mercury and other metals, legacy POPs and compounds of emerging concern, such as PBDEs and PFASs. With the exception of PBDEs and PFASs where analytical work is ongoing, analyses have been completed. Time trends in POPs from 1993-2017 were examined using PIA software (Bignert 2007) for lake trout fillet and burbot (lipid adjusted). Mercury trends were investigated using General Linear Model analyses. Analyses were conducted on fillet with the exception of POPs in burbot which were conducted on the liver. Walleye, northern pike and lake whitefish collected under the direction of Mike Low from Buffalo Lake in January 2017 also were analyzed for mercury.

Community Engagement

Community engagement has been in the form of discussions around this study, the results and their presentation in a form understandable and accessible to community members. At Fort Resolution, this engagement has included Rosy Bjornson (DKFN Resource Management Coordinator), Diane Giroux (AAROM coordinator) and Arthur Beck (Fort Resolution Metis Nation). At Lutsel K'e, primarily communications have been with Ray Griffith with the Wildlife Committee. At Hay River, communications have been with Peter Redvers with the Hay River/Katlodeeche Dene Band, Becky Cayen with the West Point First Nation, Trevor Beck (NWT Metis Nation) and George Low (Deh Cho AAROM coordinator). Discussions also have been held with Tim Heron (Fort Smith Metis) with a focus on results communications.

Capacity Building and Training

Each year capacity building is conducted through regular exchanges with communities through email and telephone communications where we discuss our studies and other subjects of interest, including possible funding opportunities to support enhanced studies. This has been most successful at Fort Resolution where Rosy Bjornson has accessed funds (primarily Aboriginal Aquatic Resources and Oceans Management program) to hire Kathleen Fordy as a trainee in environmental monitoring with an initial focus on water quality monitoring. Kathleen and Gab Lafferty visited Marlene's laboratory in January to learn more about fish processing and data management techniques with Kathleen selecting to focus her training on working with the angler survey data for the Buffalo River, located ca. 20 km from the community and very important in its domestic fishery.

Communications and Outreach

A poster presentation was given on mercury and other contaminant trend monitoring of Great Slave Lake at the 13th International Conference on Mercury as a Global Pollutant (ICMGP) held in Providence, Rhode Island July 16 – 21, 2017. A second poster on the major findings from the Great Slave studies was presented at the bi-annual NCP workshop in Yellowknife. A third presentation was given at the North and South Slave Regions Cumulative Impact Monitoring Program Workshop in Fort Resolution which focused on past studies under CIMP. This workshop was well attended by delegates from Fort Resolution, Yellowknife, Lutsel

K'e, Hay River, and Fort Smith. Marlene met with community representatives from various Metis, Akaitcho and Deh Cho organizations in late February and March to go over mercury results and how effectively this information was conveyed in her posters. At Fort Resolution, she met with Rosy Bjornson and Diane Giroux and others with the Deninu K'e First Nations and Arthur Beck and others with the Fort Resolution Metis. At Lutsel K'e, she met with Ray Griffith and Earnest Boucher with the Lutsel K'e Wildlife Committee. At Hay River, she met with Peter Redvers (with the K'atl'odeeche First Nation) and Becky Cayen (West Point First Nation) and their committee members. She also met with staff at the NWT Metis Nation and George Low, Deh Cho AAROM coordinator. Throughout the summer there were many more conversations about poster design and refinement.

Indigenous Knowledge

We rely on Indigenous knowledge for the collection of our fish samples with respect to timing and location. Fishermen providing fish for study are long-term residents of their communities, actively engaged in fisheries, and well versed in the biology of the fish being harvested from their area; we rely on them to keep us informed of any changes in the fish. We respond whenever contacted about issues dealing with fish health and have contributed to studies related to reported concerns in fish health, including Stark Lake and the relationship between burbot liver appearance and contaminant concentration (Evans and Landels 2015, Cott et al. 2018). Indigenous knowledge of fish harvesting practices was used in the assessment of the mercury data that we generated from our recent Buffalo Lake study.

Results and Discussion

The strongest declining trends in POP concentrations were observed for lake trout caught from the commercial fishery at Hay River with ΣHCH, dieldrin, ΣDDT, Σchlordane, ΣPCB and Σ toxaphene concentrations over 2010-2017 approximately one third less than concentrations observed over 1993-1994 (Figure 1; Table 2). Rates of decline ranged from 7.1-14.2% per year depending on the compound (Table 2). In contrast, only α-HCH, γ-HCH, ΣHCH, p,p'-DDE, and ΣDDT exhibited significant rates of decline in East Arm lake trout. Burbot caught from Fort Resolution also showed strong rates of POPs decline, although rates were lower than for lake trout from the commercial fishery. East Arm burbot showed similar rates of decline as lake trout. ΣCBz has shown no evidence of decline. Chlorobenzenes are produced by the chlorination of benzene with a wide variety of product uses, depending on the degree of chlorination.

PBDE concentrations were slightly higher in East Arm than West Basin lake trout fillet, with no evidence of decline. In contrast, ΣPBDE concentrations were substantially higher in East Arm than West Basin burbot liver with some evidence of decline since ca. 2011 (Figure 2). ΣPFCAs in East Arm lake trout were higher in the late 1990s and early 2000s than in more recent years. The West basin lake trout record is more detailed and shows increasing concentrations through the late 1990s to reach a peak in 2010 with a subsequent decline. The record for burbot liver is shorter but again shows higher concentrations in East Arm than West Basin fish.

Table 2. Time trends in legacy organic contaminants for lipid-adjusted burbot from Fort Resolution (1993-2017; n = 18 years) and Lutsel K'e (1993-2013, n = 11 years) and fork-length adjusted Lake Trout from the Hay River commercial fisheries (1999-2017, n = 15 years) and Lutsel K'e (1993-2017, n = 18 years). While the first collections were made in 1993, missing length or lipid data reduces the number of years that can be tested for adjusted data. Temporal trend is shown as the percent decline in contaminant concentration (log-linear) per year over the record; statistically significant ($p<=0.05$) slopes shown in bold with an asterisk. Also shown is YQR, the number of years required to detect an annual change of 5% with a power of 80% and a one-sided test (α = 5%).

	Lake Trout Hay River		Burbot Fort Resolution		Lake trout Lutsel K'e		Burbot Lutsel K'e	
Parameter	%/yr.	YQR	%/yr.	YQR	%/yr.	YQR	%/yr.	YQR
% lipid	2.9	17	2.1	17	2.4	23	-2.4	16
α-HCH	-6.3	26	-11.9*	21	-7.9*	17	-6.8*	23
β-HCH	-7.8*	41	1.0	41	0.1	49	-9.8*	30
γ-HCH	-14.2*	27	-6.8*	30	-6.6*	21	-4.9*	20
Σ-HCH	-8.8*	24	-11.9*	23	-8.0*	19	-6.4*	20
Dieldrin	-7.1*	23	-6.1*	27	-0.1	60	1.4	23
ΣCBz	4.0	22	-1.6	21	3.1	19	0.9	19
p,p'-DDE	-2.3	21	-2.6*	17	-1.4*	25	-1.2	14
Σ-DDT	-8.4*	21	-4.0*	18	-6.1*	20	-5.3*	18
Σ-CHL	-5.5*	26	-4.4*	22	0.2	18	-3.6	18
ΣPCB	-9.2*	29	-4.9*	17	-2.3	22	-2.5	15
Σ-10 PCB	-8.4*	26	-3.9*	19	-2.2	19	-1.8	18
Σ-Tox.	-8.3*	35	-3.9*	27	-3.2	33	-6.5	26
ΣPBDE	1.5	20	-6.4	21	9.5	25	-17.2	22
ΣPFCA	-7.8*	24	4.2	26	-3.2	33		

Figure 1. Average (± standard error) concentrations (ng/g wet weight) of persistent organic contaminants in West Basin (WB) and East Arm (EA) lake trout fillet and burbot liver by over three time intervals. Also shown is percent lipid composition for tissues analyzed.

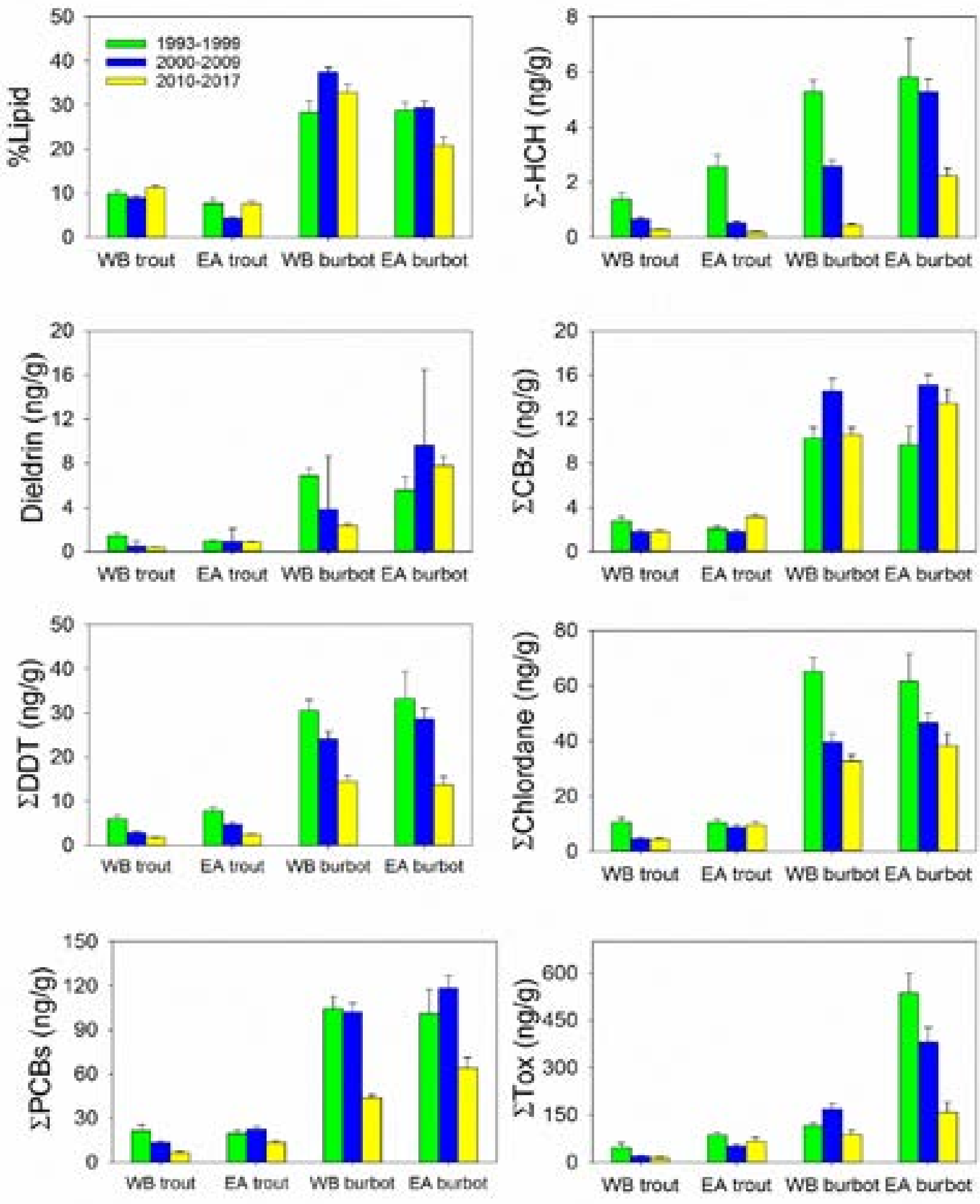
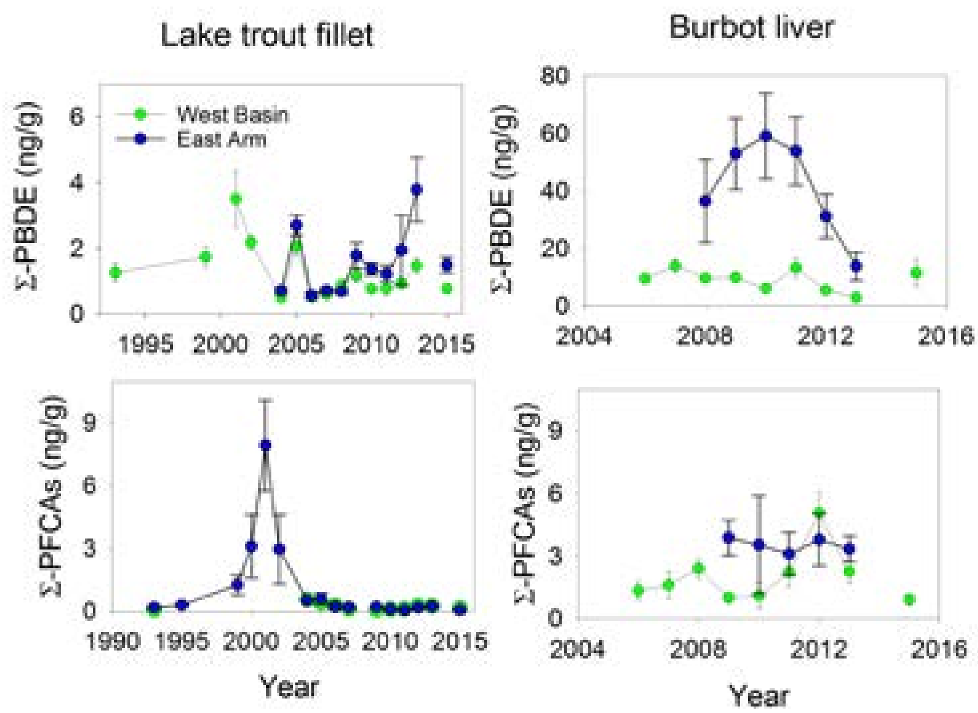


Figure 2. Trends in PBDEs and PFCAs in lake trout fillet and burbot liver. Data are shown as means (± 1 standard error) and are in ng/g wet weight.



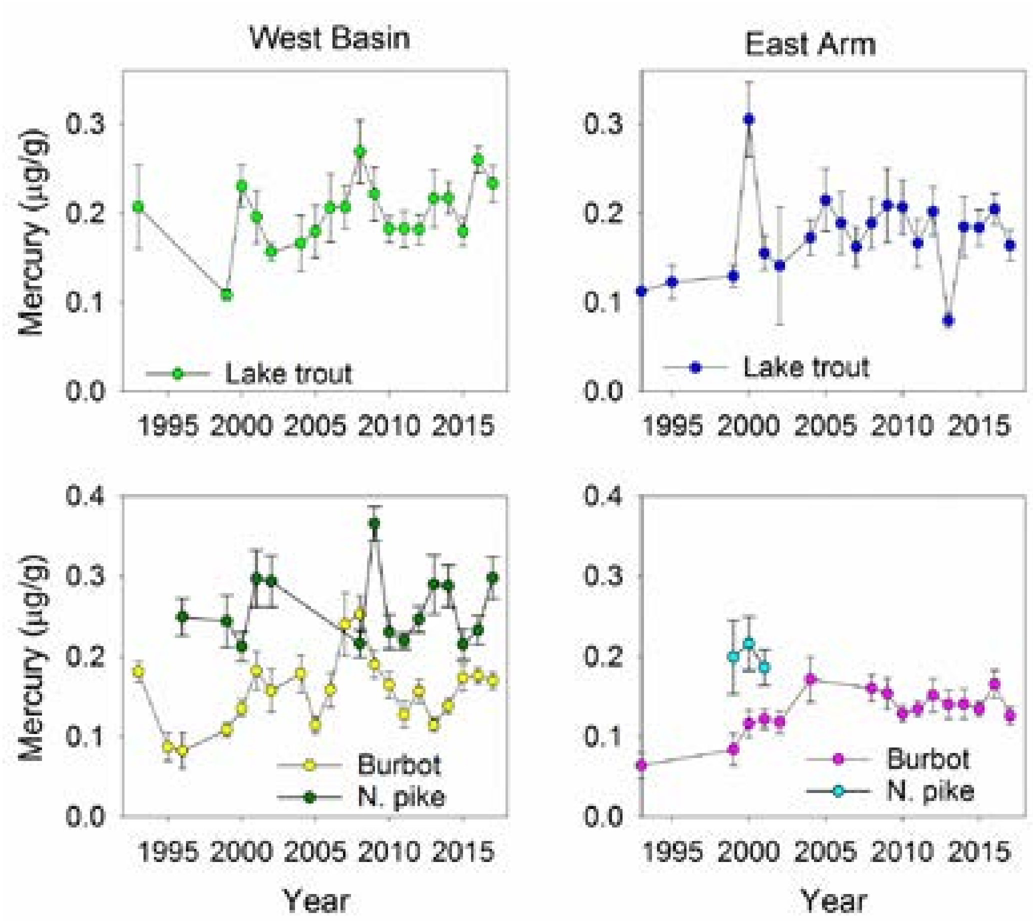
Mercury Trend Research Studies

Trend assessments in 2017 followed the general approach taken in Evans et al. (2013) although climate variables were not considered. Trend analyses of lake trout from the East Arm have been problematic with a significant year and fork length interaction. While this problem was previously resolved by dividing lake trout into small and large size categories, this was not a successful solution with the larger data set. However, excluding fish <550 mm (53 fish) and >800 mm (one fish) resolved this statistical problem. East Arm lake trout consist of a variety of morphs with different growth and hence mercury body burden characteristics (Chavarie et al. 2013; Chavarie et al. 2016). Lake trout and burbot from both study locations showed statistically significant trends of mercury increase over 1993-2017 (Table 3, Figure 3); there was no trend in mercury concentration in northern pike caught at Fort Resolution. Average mercury concentrations were <0.5 μg/g with the highest mercury concentrations in northern pike.

Table 3. 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, R^2 is the amount of variation explained by the model, and p is the significance level. See text for additional explanation. East Arm lake trout analyses are based on fish >550 mm and ≤ 800 fork length (FL).

Species/ Location	Period	Equation	n	F-ratio	R^2	p
Lake trout						
West Basin	1995-2017	Log Hg = -6.986 + 0.003*YR + 0.002*FL	201	102.88	0.51	0.000
East Arm	1993-2017	Log Hg = -10.622 + 0.004*YR + 0.001*FL	160	17.24	0.18	0.000
Burbot						
West Basin	1995-2017	Log Hg = -9.477 + 0.004*YR + 0.001*TL	219	31.856	0.23	0.000
East Arm	1999-2017	Log Hg = -9.861 + 0.004*YR + 0.001*TL	178	7.60	0.08	0.001
Northern pike						
West Basin	1996-2017	Log Hg = -1.306 +0.000*FL	258	57.19	0.18	0.000

Figure 3. Trends in mercury concentrations in lake trout, burbot and northern pike fillet. Data are shown as means (± 1 standard error) and are in ng/g wet weight. Data are not length (lake trout) nor lipid (burbot) adjusted.



Sediment Core Studies

In March 2014, a series of sediment cores were collected from two locations in the West Basin of Great Slave Lake, Kakisa Lake, and Stark Lake under ECCC's Clean Air Regulatory Program. The purpose of these collections was to investigate long-term trends in mercury deposition to these lakes and changing productivity with global warming; this data can in turn be related to mercury trend data for fish from those lakes; and POPs trend data for Great Slave Lake. Cores were analyzed for diatom remains by John Smol at Queen's University. For the core collected offshore of the Slave River, diatom assemblage composition and primary production have changed dramatically over the past ~170 years with the greatest changes starting in the 1990s and associated with recent warming trends (Figure 4a and 4b). The nature of the diatom assemblage shifts were similar to the response lakes throughout the world had from recent warming trends; the much later response to warming (~1990s) than what has been reported in other Subarctic lakes (~1850s to early 1900s) was related to the strong 'thermal inertia' of Great Slave Lake. The mercury profile was similar to that reported in Evans et al. (2013), as was the flux. Most metals showed only modest temporal variability over the past 90 years, with the exception of arsenic, which showed a pronounced peak over the mid-1960s to the early 1980 as we previously reported in our study related to the decommissioned Pine Point mine (Evans et al. 1998) and more recently by MacDonald et al. (2016).

Mercury Studies and Community Posters

Significant effort was directed towards developing posters, presenting the results of our mercury in fish findings for community distribution. In addition to our studies on Great Slave Lake, we worked with George Low over 2010-2014 measuring mercury in fish in 18 lakes and developed community-based posters on the basis of these studies. These posters were refined from previous versions to include the use of fish outlines rather than symbols to display data points, fish colored-coded as to mercury concentration and simplified language. Posters were made available at the bi-annual NCP workshop in Yellowknife and are being posted on the Arctic Institute of North America web site. In addition, we worked with George Low in a special study of mercury in lake whitefish, northern pike, and walleye caught from Buffalo Lake in 2017.

Water Intake Study

The water intake monitoring at Fort Resolution continues with Kathleen Fordy recording the routine parameters measured by the plant operator and filtering water for chlorophyll analyses (figure 5). Sampling frequency has become regular. Chlorophyll concentrations are low throughout most of the year, generally <2 µg/L, and in agreement with past studies (Fee et al. 1985; Evans and Muir 2016).

Conclusions

Contaminant concentrations remain in the Great Slave Lake fish investigated in this study. Mercury concentrations are increasing in lake trout and burbot, possibly in response to warming trends and enhanced lake productivity. Many persistent POPs are decreasing in concentration.

Expected completion date

Ongoing

Acknowledgements

We thank NCP for funding this project and Environment and Climate Change Canada for supporting the additional research conducted under this environmental monitoring and research envelope. The appreciation and support of the Deh Cho, Akaitcho, and Métis representatives is much appreciated. Special thanks go to Ernest Boucher (Lutsel K'e), Gab Lafferty (Fort Resolution) and Shawn Buckley (Hay River) for providing the fish analyzed in this study.

Figure 4a. Changes in diatom assemblages and chlorophyll concentrations in Great Slave Lake as recorded in a sediment core (#2) collected from 12 in the West Basin of Great Slave Lake.

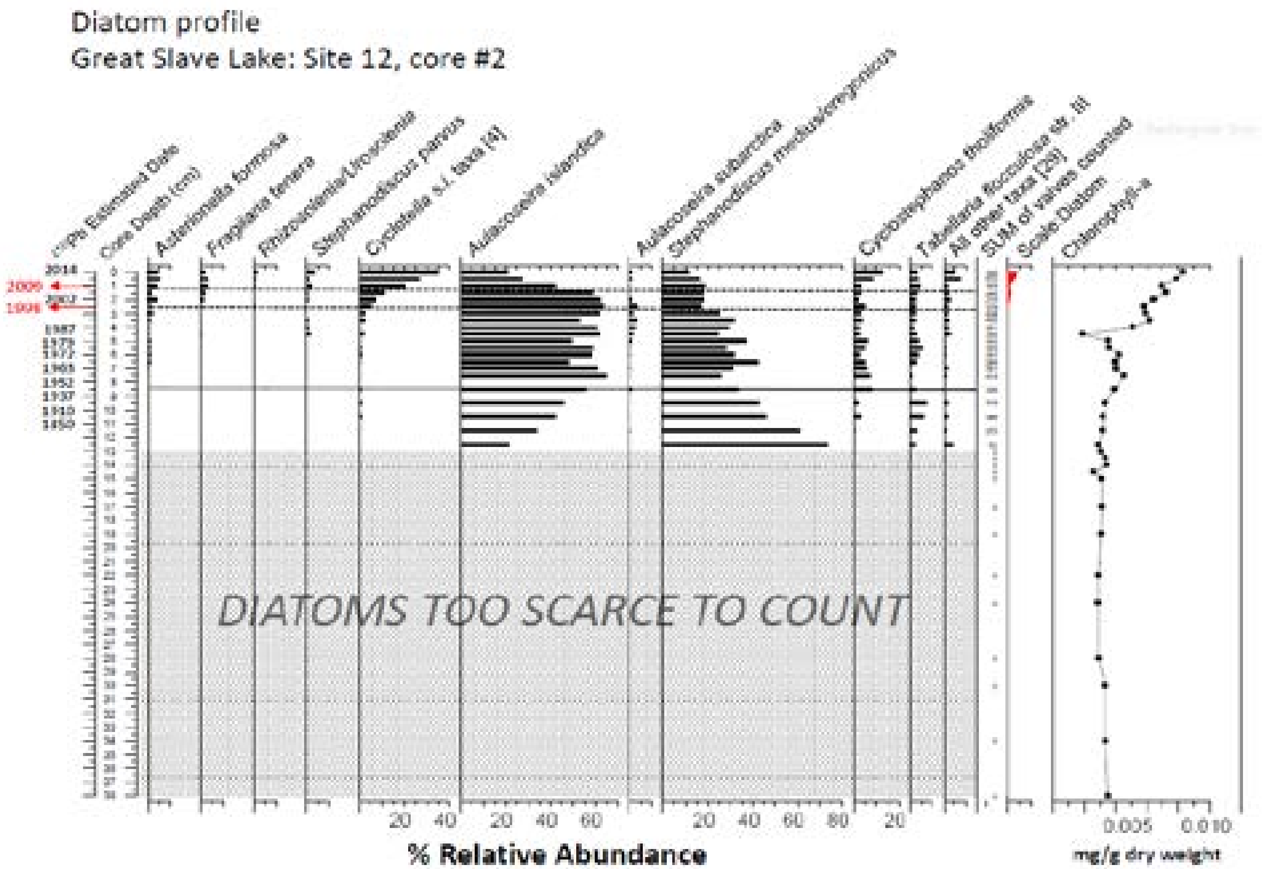


Figure 4b. Changes in mercury and arsenic concentrations in that sediment core collected from 12 core samples in the West Basin of Great Slave Lake.

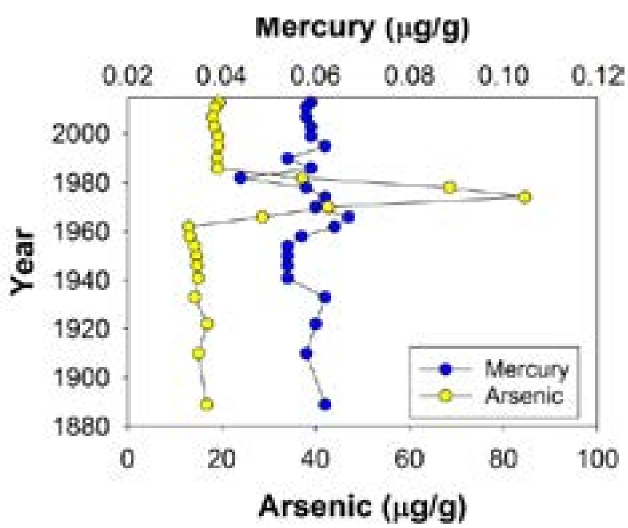
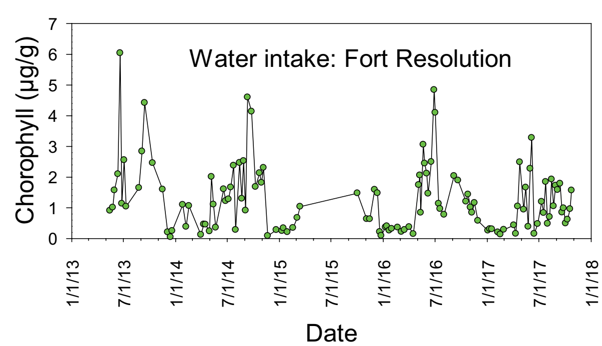


Figure 5. Long-term variability in chlorophyll concentrations in the water intake (untreated) for the drinking water supply at Fort Resolution. The intake is located a few hundred meters offshore of the community in Resolution Bay.



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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 des tendances temporelles des métaux traces et des contaminants organiques halogénés, y compris des composés persistants nouveaux et émergents, chez la lotte du fleuve Mackenzie à Fort Good Hope (Territoires du Nord-Ouest)

Project Leader/Chef de projet

Dr. Gary Stern, Centre for Earth Observation Science (CEOS), Department of Environment and Geography, University of Manitoba, 586-125 Dysart Road (Wallace Building), Winnipeg, MB R3T 2N2.
Tel: (204) 474-9084; Fax: (204) 474-8129; Gary.stern@umanitoba.ca

Ashley Gaden, Centre for Earth Observation Science (CEOS), Department of Environment and Geography, University of Manitoba, 546-125 Dysart Road (Wallace Building), Winnipeg, MB R3T 2N2.
Tel: (204) 272-1636; Fax: (204) 474-8129; Ashley.Gaden@umanitoba.ca

Project Team/Équipe de projet

Alexis Burt, and Ainsleigh Loria, Centre for Earth Observation Sciences, Winnipeg, MB; Liisa Jantunen and Tom Harner, Environment and Climate Change Canada, Toronto, ON; Fort Good Hope Renewable Resource Council, Fort Good Hope, NWT

Project Location/Emplacement(s) du projet

Fort Good Hope, NT

Abstract

Partnering with the Fort Good Hope Renewable Resources Council, we collected 40 burbot from the Mackenzie River (Rampart Rapids) in early 2018. Our goals for 2017-2018 were to analyze the concentrations of mercury and other contaminants (e.g. persistent organic pollutants), from this country food, analyze the data with historical time-series concentrations (spanning 32 years in total) and other attributes of the fish, and report information to relevant

Résumé

En partenariat avec le Conseil des ressources renouvelables et les membres de la collectivité de Fort Good Hope, nous avons recueilli 40 lottes du fleuve Mackenzie (rapides Rampart) au début de 2018. Nos objectifs pour 2017-2018 consistaient à analyser les concentrations de mercure et d’autres contaminants (par exemple, des polluants organiques persistants) dans cet aliment traditionnel, à analyser les données en fonction de séries chronologiques historiques

end users in the Sahtú region and the Northwest Territories. Knowledge on contaminants in burbot from this project is shared to key stakeholders (regional health authorities, the Fort Good Hope Renewable Resources Council, and the Sahtú Renewable Resources Board) to promote safe consumption guidelines and sustainable renewable resource management regimes by relevant administrations. Preliminary results indicate that average mercury concentrations in these fish (both liver and muscle tissue) remain below the recommended guideline for consumption. Length and age do not appear to influence mercury concentrations, although in some years females had higher concentrations in liver. Burbot with dark livers had higher concentrations of mercury in both liver and muscle compared to those with white livers. Dark livers are a sign of starvation (low lipid stores) and thus mercury is likely more concentrated in these dark livers. This seems to support local Indigenous Knowledge that dark livers are "unhealthy". Average annual mercury concentrations have increased over the last three decades, and thus there is a definite need to continue this environmental monitoring.

de concentrations (couvrant une période totale de 32 ans) et d'autres attributs du poisson et à communiquer l'information aux utilisateurs finaux concernés dans la région de Sahtú et les Territoires du Nord-Ouest. Les connaissances sur les contaminants de la lotte tirées de ce projet sont communiquées aux intervenants clés (autorités sanitaires régionales, le Conseil des ressources renouvelables et les membres de la collectivité de Fort Good Hope et l'Office des ressources renouvelables du Sahtú) afin de faire la promotion de l'adoption de lignes directrices sur la consommation sécuritaire et de régimes de gestion des ressources renouvelables par les administrations pertinentes. Selon les résultats préliminaires, les concentrations moyennes de mercure dans ces poissons (tissus du foie et tissus musculaires) demeurent inférieures à la ligne directrice recommandée pour la consommation. La taille et l'âge ne semblent pas avoir d'incidence sur les concentrations de mercure, bien que certaines années, les concentrations sont plus élevées dans le foie des femelles. Les lottes qui ont un foie foncé présentaient des concentrations de mercure plus élevées dans le foie et les muscles, comparativement aux lottes qui ont un foie blanc. Les foies de couleur foncée sont un signe de famine (ce qui se traduit par de faibles réserves lipidiques), ce qui explique la plus forte concentration de mercure dans ces foies. Selon les connaissances autochtones locales, les foies de couleur foncée ne sont pas « sains »; cette constatation semble le confirmer. Les concentrations annuelles moyennes de mercure augmentent depuis trente ans; il ne fait aucun doute que cette surveillance environnementale doit se poursuivre.

Key Messages

- Mean concentrations in muscle and liver over the entire data sets were 0.361 ± 0.144 (n = 742) and 0.100 ± 0.087 (n = 737) mg/g wet weight, respectively.
- Burbot with dark livers had statistically higher total mercury concentrations in liver ($t=3.819$, $p<0.001$) and muscle ($t=2.596$, $p=0.013$) compared to burbot with white livers. Dark livers are a sign of starvation and

Messages clés

- Les concentrations moyennes dans les muscles et le foie des ensembles complets de données étaient de 0,361 ± 0,144 (n=742) et de 0,100 ± 0,087 (n=737) mg/g (poids humide), respectivement.
- Les lottes qui avaient un foie foncé présentaient des concentrations de mercure total statistiquement supérieures dans le foie ($t=3{,}819$, $p<0{,}001$) et les muscles ($t=2{,}596$,

contaminants are likely bio-concentrating in these tissues.

- Length and age did not influence mercury concentrations. In some years, females contained higher concentrations of mercury in liver tissue compared to males.
- Average annual mercury concentrations have increased over the last three decades, and thus there is a definite need to continue this environmental monitoring.

p=0,013) comparativement aux lottes qui avaient des foies blancs. Les foies de couleur foncée sont un signe de sous-alimentation, et il est vraisemblable qu'il se produise une bioconcentration de ces contaminants dans les tissus du foie.

- La taille et l'âge n'ont pas d'incidence sur les concentrations de mercure. Certaines années, les tissus hépatiques des femelles présentaient des concentrations de mercure supérieures à celles des mâles.
- Les concentrations annuelles moyennes de mercure augmentent depuis trente ans; il ne fait aucun doute que cette surveillance environnementale doit se poursuivre.

Objectives

This project aims to:

- analyze burbot for mercury and other inorganic elements (e.g. Se, As);
- analyze burbot for legacy persistent organic pollutants (POPs), fluorinated organic contaminants (FOCs) and polybrominated diphenyl ethers (PBDEs);
- acquire additional biological data such as morphometric measurements (e.g. length, weight), age, and dietary indicators (i.e. stable isotope ratios of nitrogen and carbon);
- incorporate Indigenous Knowledge with scientific results; and,
- share results with northern end users.

Introduction

The Rampart Rapids burbot (loche, moria, *Lota lota*) community-based monitoring project is a collaboration between the Fort Good Hope Renewable Resources Council (FGH RRC), the University of Manitoba and the Northern Contaminants Program (CIRNAC). Beginning as early as 1985, burbot from this region have been monitored for contaminants such as mercury. This project provides information about the health of burbot to regional health authorities, the FGH RRC, and the Sahtú Renewable Resources Board (SRRB).

The purpose of this project is to monitor, in burbot, the concentrations, and trends of contaminants which bioaccumulate (i.e. chemicals and metals which increase in concentration over the life of an organism, such as mercury, arsenic, and POPs). This freshwater species was selected for monitoring because burbot is a country food, and as such, contaminants from these fish can be transferred, and expose a health risk, to the people that consume them. These types of long term datasets are pivotal towards observing and understanding possible changes in contaminants levels of northern freshwater species associated with climate change and variability, as well as natural resource extraction (e.g. within the Mackenzie River watershed).

In addition to temporal trend analyses of contaminants, we also seek to understand possible biological and ecological associations with the contaminants data (although previous results suggested no association (Carrie et al. 2010)), and to complement scientific findings with Indigenous Knowledge from Fort Good Hope's recreational fishers. Morphometric data (e.g. length, weight), ages, dietary indicators (e.g. stable isotope ratios of nitrogen and carbon), and observations provided by recreational fishers have been (or will be, for outstanding analyses) included with the 2017-2018 contaminants database. It is our aim to share all findings from this burbot monitoring project with our northern partners for the purposes of informing safe food choices and sustainable renewable resource management.

Activities in 2017-2018

Sample Collections and Lab Analyses

Whole fish were collected by Fort Good Hope recreational fishers between January 2 – February 6, 2018, stored frozen and shipped by FGH RRC, and received in Winnipeg on February 13, 2018. With the help of FGH RRC, recreational fishers completed Burbot Collection Sheets for each fish, including the date & location of capture, and the specimens' appearance, including condition of the liver.

Between March 6-14, 2018 at the Centre for Earth Observation Science (CEOS) at the University of Manitoba, burbot were measured (e.g. body length, weight, liver weight) and sexed by Ashley Gaden. Otoliths were removed for aging. Sub-samples of muscle and liver were taken for contaminant analyses. Remaining fish carcasses were incinerated on campus.

The analysis of total mercury was completed at CEOS by technician Ainsleigh Loria on sub-samples of liver and muscle on April 17, 2018. A student technician in Biological Sciences at the University of Manitoba was hired to determine the ages of the fish using the otoliths, and we anticipate this to be complete by July 2018.

At Liisa Jantunen's and Tom Harner's labs at Environment and Climate Change Canada in Toronto, Cassandra Rauert, Sarah Bernstein and Liisa processed and analyzed burbot samples from 2016 for FOCs and PBDEs. Although these samples had been previously extracted at the Freshwater Institute (DFO), Winnipeg, the extracts needed further clean-up at Environment and Climate Change Canada (ECCC) prior to analysis.

Remaining Lab Work for 2017-2018

Legacy POPs, FOCs and PBDEs: scheduled for summer (2018), to be analyzed by ALS.

- Inorganic elements in addition to mercury (e.g. selenium, arsenic): scheduled for fall (2018), to be analyzed by Queens University.
- Stable isotope ratios of nitrogen and carbon: scheduled for fall (2018), to be analyzed by Université Laval.

Community Engagement

Ashley Gaden attended the 2017 NCP Workshop in Yellowknife. While there, she met and participated in a helpful dialogue with Cindy Gilday (Sahtú Regional Contaminants Committee) and her assistant Dakota regarding concerns for improving engagement/ communications back to the community of Fort Good Hope. Since then, phone and email communication have been taking place between the Project Leads and the FGH RRC office. We have also requested to join a consortium (forum) of community members, local resource managers, industry people and researchers that work in the Sahtú region, organized through the Sahtú Renewable Resources Board (SRRB), to engage in activities and knowledge sharing in the region.

In our 2018-2019 NCP budget we allocated funds for an in-person visit to Fort Good Hope to engage the community on the project, including potential hands-on activities/presentations at the school. We are hoping to tie this face-to-face engagement with the community visit of another researcher, so as to maximize the time available for engagement with the community. We are also awaiting the FGH RRC to swear in a new president, vice-president, and other positions on the Council before making any travel arrangements (as of May 30, 2018).

Capacity Building and Training

Aurora College was contacted in December 2017 to inquire about environmental monitoring programs at Fort Good Hope, but the following month we were informed by Aurora College Community and Extensions Division, Sahtú Region, that there were none at that time.

One of the goals of our visit to Fort Good Hope is to discuss with the Council how best to build in northern capacity and training to meet both the Council's mandate/priorities and the project's objectives. We acknowledge this aspect of the project has been very limited to date; however, with the ongoing communications and successful coordination with the new FGH RRC office staff over the last few months, we believe the building of this rapport is essential toward our partnership and support of a visit.

Communications and Outreach

In addition to remote communication with the FGH RRC and SRRB, we provided a couple of documents to these organizations and a few others through the Aurora Research Institute (ARI). These included (1) a plain language description of the project, including benefits and risks to the community, in our NWT Research License application (January-March 2018), (2) a brief overview of the project and its history in the NCP Community Engagement form and in the Burbot Collection Sheets (February-March 2018), and (3) a three-page summary of mercury, selenium and arsenic results (up to 2016) which was requested for a hearing at SRRB (April 18, 2018). This latter document was reviewed by Emma Pike, Eric Leonard, and other members of the Northwest Territories Regional Contaminants Committee (NWT RCC) before submission to the FGH RRC and SRRB.

Indigenous Knowledge

In early conversations with Norman Pierrot, past FGH RRC President, he mentioned to watch for the colour of the burbot livers. White livers are considered healthy and, conversely, dark livers indicate an unhealthy condition. Therefore, in preparing our Burbot Collection Sheets, we specifically asked for comments relating to the conditions of the burbot. We were delighted to receive comments on all burbot regarding the status of their livers (which can be observed once fishing lures are removed from the burbot), and cross-referenced this with observations during dissections. Indeed, white livers tended to be quite large (up to 9% of the body weight), while dark livers were small (1-2% of body weight), smelly, and slimy (Figure 1). We furthermore explored statistical relationships between this data and the total mercury data.

Figure 1. Visual contrast between white "healthy" livers (left) and dark "unhealthy" livers (right) of burbot.

Results and Outputs/Deliverables

From the forty burbot collected, 25 were male, 10 were female and five were immature. A summary of measurements and total mercury (THg) from the latest collected burbot are presented in Table 1. Average concentrations of mercury are below the recommended guideline level of 0.50 mg/g for consumption (Health Canada 2004; Canadian Food Inspection Agency 2014).

Table 1. Length, weight, and total mercury (THg, wet weight) of Fort Good Hope burbot collected from January-February 2018 for the 2017-2018 NCP funding year. SD is short for standard deviation. n=40

Variable	Average (SD)	Minimum	Maximum
Length	717 (110) mm	490 mm	910 mm
Weight	2374 (1072) g	310 g	4900 g
Liver weight	101 (64.7) g	9.8 g	269 g
% liver weight of total weight	4 ± (2) %	1 %	9* %
THg in muscle	0.37 (0.1) mg/g	0.20 mg/g	0.94 mg/g
THg in liver	0.12 (0.1) mg/g	0.02 mg/g	0.56 mg/g

* The maximum value was actually 40%, but since this case was an outlier, we removed it from statistical analysis.

We found no correlation between mercury concentrations in either muscle or liver with length or weight, and there were no significant differences in mercury levels between males and females. Upon an examination of the liver condition, of which ten of the forty livers we received were small and dark, we did observe a weak association between "% liver weight of total body weight" and mercury concentrations in liver (Spearman rank $r = -0.66$) and muscle (Spearman rank $r = -0.54$) (Figure 2). Based on coloration alone, student t-tests revealed dark livers had statistically higher total mercury concentrations in liver ($t=3.819$, $p<0.001$), and muscle ($t=2.596$, $p=0.013$) compared to white livers (Figure 3).

Although it would appear burbot with proportionally very small, dark livers have relatively higher concentrations of mercury, it has been previously documented that contaminant loads do not predominantly influence liver condition. Instead, liver condition is statistically associated with fat content. In a report by Lockhart et al. (1989), authors described an experiment at the Freshwater Institute (DFO) in Winnipeg using burbot from Lake Winnipeg. One group of burbot was fed and another was starved. In the latter group, livers became increasingly smaller and darker from 56 to 112 days of starvation, illustrating that it is the lipid stores—not the contaminants—that are the primary driver for liver condition.

This phenomenon may help explain why mercury concentrations are higher in burbot with poor liver condition (i.e. starved). As energy stores (lipids) are used up, livers become smaller, but contaminants such as mercury remain, and thus they become more concentrated in a smaller space. This may also happen to a smaller extent in muscle tissues, which contain much less lipid content.

Figure 2. Relationship between the proportion of liver weight to body weight and total mercury in both muscle and liver tissue (n=39).

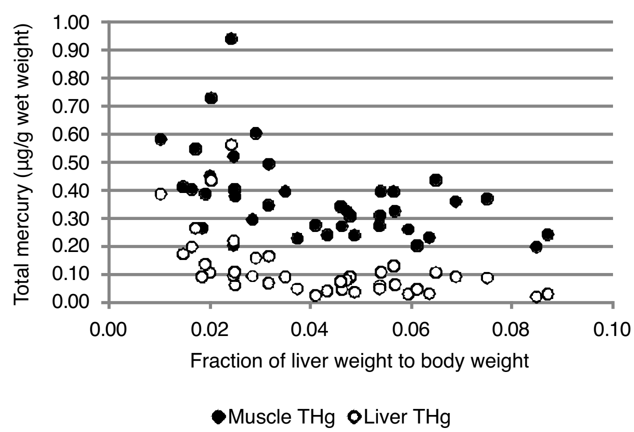


Figure 3. Contrast of total mercury concentrations in burbot tissues between dark and white livers.

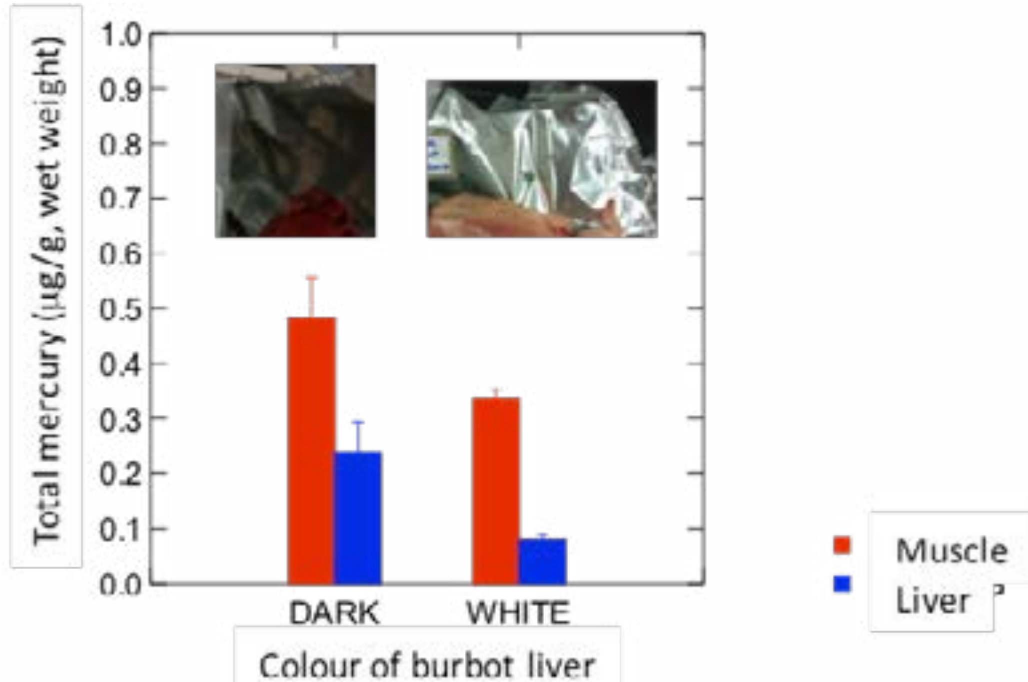
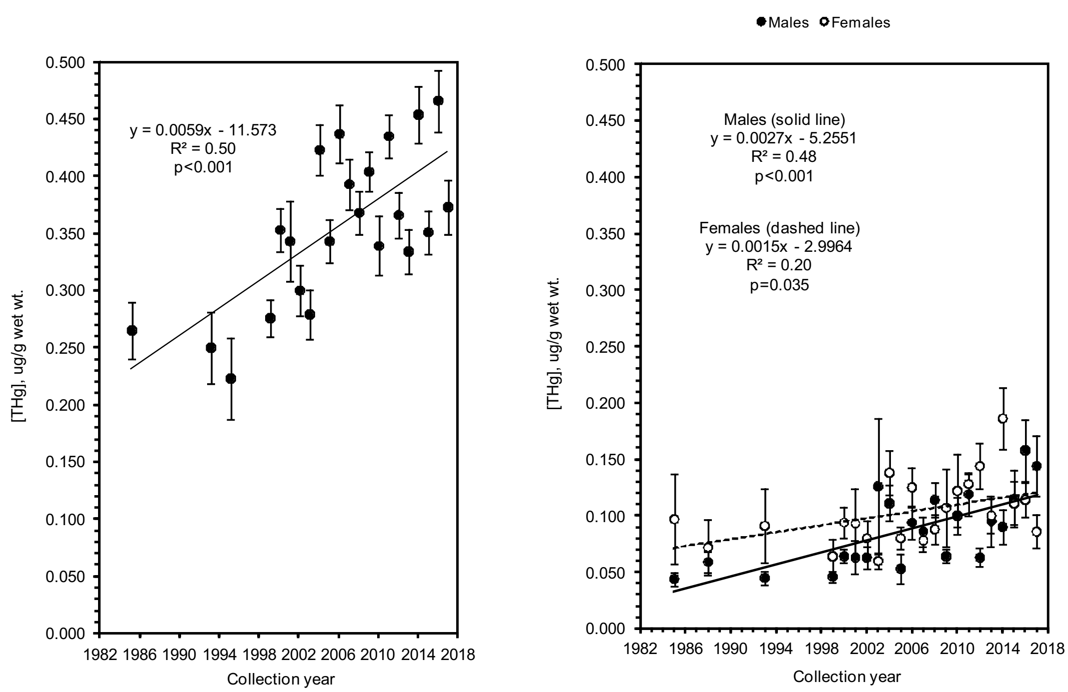


Figure 4. Average total mercury concentrations (with standard error bars) in muscle (left) and liver (right) from Fort Good Hope burbot, 1985-2017.



With respect to emerging POPs data in 2016 burbot, PBDE data analysis is ongoing. After blank-correcting the data, FOCs were only detected in three of nine burbot, and from these three specimens, average SFOC concentration was 1.85 ng/g (± 1.11 ng/g SD) in liver tissue.

Results from the entire time series

Time trend data from Fort Good Hope burbot tissues cover 32 years and 23 time points (1985, 1988, 1993, 1995, 1999-2017). Mean concentrations in muscle and liver over the entire data sets were 0.361 ± 0.144 (n = 742) and 0.100 ± 0.087 (n = 737) mg/g wet weight, respectively. No significant correlation between length (or age) and mercury concentration was observed with muscle or liver for either sex. Concentrations of THg in liver were higher in females (Kolmogorov-Smirnov two sample test = 0.139, p = 0.002), therefore the time series data for liver THg are plotted separately by sex (Figure 4). There were no significant sex differences in muscle THg data.

Discussion and Conclusions

This year marks a significant milestone in the project with respect to the inclusion of Indigenous Knowledge. We are also pleased to be increasing our network of researchers and end users in the Sahtú region in an effort to participate in knowledge mobilization activities.

Although average mercury levels in Fort Good Hope liver and muscle tissues are below the recommended guideline level of 0.50 mg/g for consumption (Health Canada 2004; Canadian Food Inspection Agency 2014), it is interesting to note that mean concentrations of mercury are higher than values reported for burbot collected at downstream sampling locations in the Mackenzie River watershed (Evans et al. 2016; Cott et al. 2016).

With respect to the time series, concentrations have increased approximately two- and three-fold in muscle and liver, respectively, since the mid-1980s (Figure 4). These increasing trends are gradual, exhibit inter-annual variability, but are significant nonetheless.

We aim to provide any remaining data on POPs, other metals, stable isotope ratios, etc. in our next report. Upon acquisition of this data and its statistical analysis, we plan to prepare an updated poster, summarizing all results, to partnering organizations in Fort Good Hope.

Expected Project Completion Date

Temporal trend studies are long-term projects, and thus annual sampling is projected into the foreseeable future.

Acknowledgments

Many thanks to NCP for funding this project, and to ArcticNet and the University of Manitoba for in-kind support.

We thank the community of Fort Good Hope, FGH RRC, SRRB and the Sahtú Land and Water Board (SLWB) for their interest in this project. We are particularly grateful to Diane Kochon, Benita King, Norman Pierrot, Joe Hanlon, Debbie Simmons, and Paul Dixon for their time coordinating and discussing the project. Thank you to Cindy Gilday, Emma Pike, Carmon Bessette and Eric Leonard (NWT RCC) for their role as advisors to the project.

Big thanks to Cassandra Rauert, Sarah Bernstein, Liisa Jantunen and Tom Harner for allocating extra resources to adequately prepare and analyze previous samples for POPs data. Thanks to Ainsleigh Loria for analyzing total mercury in the burbot tissues, and to Jake Ritchie and Pardis Karimi for their assistance with the fish dissections. We also wish to thank Kirsty Gurney, Mylène Ratelle, Marlene Evans and Heidi Swanson for helpful discussions.

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Temporal trends of contaminants in Yukon lake trout

Tendances temporelles des contaminants dans les touladis du Yukon

Project Leader/Chef de projet

Mary Gamberg, Gamberg Consulting, 708 Jarvis St. Whitehorse, YT Y1A 2J2
Email: mary.gamberg@gmail.com

Project Team/Équipe de projet

Derek Cooke, Ta'an Kwach'an Council, Whitehorse, YT; Monica Krieger, Champagne and Aishihik First Nations, Haines Junction YT; James Macdonald, Council of Yukon First Nations, Whitehorse, YT; Oliver Barker, Environment Yukon, Whitehorse YT; Darrell Otto, Yukon College, Whitehorse, YT; Ellen Sedlack, Yukon Contaminants Committee, Whitehorse, YT

Project Location/Emplacement(s) du projet

- Lake Laberge, YT
- Kusawa Lake, YT

Abstract

This project has been monitoring contaminants in lake trout from Lake Laberge and Kusawa Lake, in the Yukon, since 1993, and annually since 2001. In the fall of 2017 and early winter of 2018, seven lake trout were collected from Kusawa Lake and 12 from Lake Laberge. Otoliths were aged and liver and muscle samples from these fish are currently being analyzed. Previous data from this project are being gathered and curated prior to being analyzed and reported. Plain language summaries have been created for each lake and distributed widely. An outreach program (lecture and lab) was conducted with the Yukon Fisheries Field Assistant Program at Yukon College in May 2017 in Whitehorse, YT. Ta'an Kwach'an Council and Champagne and Aishihik First Nations are integrally involved in fish collections for this project and in the ongoing refinement of the communication of results. We have been developing our communication capacity, and

Résumé

Ce projet consiste à surveiller les contaminants chez les touladis de deux lacs du Yukon, soit les lacs Laberge et Kusawa, depuis 1993, et annuellement depuis 2001. À l'automne 2017 et au début de l'hiver 2018, sept touladis ont été recueillis dans le lac Kusawa, et 12 touladis ont été recueillis dans le lac Laberge. L'âge des otolites a été déterminé, et des échantillons de foie et de muscle de ces poissons sont en cours d'analyse. Les données antérieures recueillies dans le cadre de ce projet sont en voie d'être regroupées et organisées en vue de leur analyse et de leur communication. Des résumés en langage clair ont été créés pour chaque lac et distribués à toute la population. Un programme de sensibilisation (conférence et laboratoire) a été présenté en collaboration avec le programme d'agent des pêches adjoint sur le terrain au Yukon du Collège du Yukon en mai 2017 à Whitehorse (Yukon). Le conseil des Ta'an Kwach'an et les Premières Nations

are including Yukon Contaminants Committee, Yukon Environment (Fisheries) and Kwanlin Dun First Nation in discussions. As we move forward with this collaborative approach we anticipate many new opportunities for value-added consultation and communication activities.

de Champagne et d'Aishihik prennent part intégralement au prélèvement de poissons pour ce projet et à l'amélioration continue de la communication des résultats. Nous perfectionnons nos capacités de communication et faisons participer le Comité des contaminants du Yukon, le ministère de l'Environnement du Yukon (pêches) et la Première Nation de Kwanlin Dun aux discussions. Nous nous attendons à ce que de nombreuses nouvelles occasions d'activités de consultation et de communication à valeur ajoutée se présentent tout au long de cette démarche de collaboration.

Key Messages

- Lake trout samples were collected from Lake Laberge and Kusawa Lake in collaboration with Ta'an Kwach'an Council (TKC) and the Champagne and Aishihik First Nations (CAFN) and are currently being analyzed.
- Data from previous years from this project are currently being gathered and curated.
- Plain language summaries discussing lake trout from Lake Laberge and Kusawa Lake, were distributed widely and revised for inclusion in newsletters and websites (see Appendix A).

Messages clés

- Les échantillons de touladis ont été recueillis dans les lacs Laberge et Kusawa en collaboration avec le conseil des Ta'an Kwach'an et les Premières Nations de Champagne et d'Aishihik et sont en cours d'analyse.
- Les données des années précédentes provenant de ce projet sont en voie d'être rassemblées et organisées.
- Des résumés en langage clair sur les touladis des lacs Laberge et Kusawa ont été distribués à toute la population et sont en cours de révision pour être inclus dans des bulletins et des sites Web.

Objectives

This project aims to monitor contaminant levels in lake trout from two Yukon lakes (Kusawa and Laberge) in order to assess:

- temporal trends of contaminants in lake trout from these lakes;
- contaminant exposure to people consuming these lake trout; and,
- the health of the lake trout populations.

Introduction

This project has been monitoring contaminants in lake trout from Lake Laberge and Kusawa Lake, in the Yukon, since 1993, and annually since 2001. Mercury and selected elements have been measured since 1993, and starting in 2006, fish muscle has been measured for brominated flame retardants (PBDEs) and fluorinated organic compounds (e.g. PFOS) which have become contaminants of concern in the Canadian Arctic.
The decline in concentrations of many

organochlorines (polychlorinated biphenyl: PCBs, dichlorodiphenyltrichloroethane: DDT, toxaphene) in these fish has been an encouraging note and a testament to the effectiveness of international controls. In contrast, there has been no significant trend over time in mercury in Lake Laberge trout, and after a significant drop in mercury in Kusawa Lake trout in 2001, no significant trends have been observed. However, average mercury levels in the flesh of these fish remain just below the guideline of 0.05 mg/g for commercial sale, rendering it imperative to continue the monitoring of this important food resource for many Yukon residents.

Activities in 2017-2018

The engagement of new partners in fish sampling commenced with Ta'an Kwach'an Council (TKC) and Champagne and Aishihik First Nations (CAFN) setting nets in Lake Laberge and Kusawa Lake respectively, to collect fish for the project. Three trout were caught from Lake Laberge, but none from Kusawa Lake. Although a request was put out to the citizens of both First Nations, no additional fish were collected, so an angler was hired to provide the necessary samples. Seven trout were obtained from Kusawa Lake and five from Lake Laberge in October of 2017. An additional five trout were collected from Lake Laberge by TKC in January of 2018. These will be used to determine if seasonal differences exist in contaminant levels in these fish. Otoliths were aged, and liver and muscle samples are currently being analyzed. Fillets from processed fish were given to TKC or CAFN for distribution among their citizens.

In the past this project's samples were traditionally taken from the tail portion of the fish, rather than the more standard back portion above the midline and anterior to the dorsal fin. In 2017-2018 samples were taken from both locations in each fish collected in 2017 in order to determine whether the sampling location within the fish affects contaminant levels.

Community Engagement

Discussions were held with TKC and CAFN on developing a strategy for effective fish collections in the coming years, and plans were made to collect fish from fish camps on both lakes in the summer of 2018. Mary Gamberg met with the TKC Elders' Council in December 2017 to discuss the state of knowledge of contaminants in Lake Laberge fish. The Elders' Council decided to invite Mary Gamberg to the summer fish camp to collect samples for this project. Discussions were also held with the Fisheries section of Yukon Environment on how best to share resources and data. Initial discussions were held with the Kwanlin Dun First Nation, whose traditional territory includes a portion of Kusawa Lake. They are interested in becoming a more integral part of the project in the coming year.

Capacity Building and Training

Mary Gamberg spent one full day in May 2017 with the Yukon Fisheries Field Assistant Program at Yukon College in Whitehorse, YT. A lecture on contaminants in general and more specifically contaminants in fish was presented in the morning. The afternoon was spent in the lab, dissecting lake trout (donated by Yukon Environment) and teaching the students correct contaminant sampling techniques and record-keeping as well as techniques for taking morphometric measurements and the removal of otoliths (ear bones) for aging. Fish fillets from the dissections were taken home by the students or donated to a local musher for dog food.

Communications and Outreach

In addition to the Yukon College program, Mary Gamberg also presented the results of the project to two high school classes (Wood St. School) in October 2017. Mary Gamberg updated the fish contaminants section of the Yukon State of the Environment Report for Yukon Environment and since these updates were substantial, they were sent to and approved by the Yukon Contaminants Committee (YCC). Two separate plain language summaries were created for "*Contaminants in lake trout from Lake Laberge*" and "*Contaminants in lake trout from Kusawa Lake*". The summaries were revised and approved by Yukon Environment, YCC, NCP, TKC and CAFN. TKC was also provided with a background document on the plain language summary for publication in their quarterly newsletter and on their website. The plain language summaries were adapted for the Yukon Contaminants Website which is in development.

Indigenous Knowledge

Some of the fish collected for this project were caught using Indigenous Knowledge of fishing and fish habitat. A lengthy discussion with Mary Gamberg and the TKC Elders' Council resulted in a very valuable exchange of Indigenous Knowledge and western science regarding fish physiology, behaviour and habitat. This knowledge will continue to be used as we move forward with the project to collect fish and interpret data.

Results and Outputs/Deliverables

No new data was generated over this year. Previous data from this project are currently being gathered and curated prior to being analyzed and reported, and consultation with TKC and CAFN are continuing with regard to fish collections and the reporting of results.

Discussion and Conclusions

This year we have gained valuable experience regarding working with our new partners on collecting lake trout for this project and on the best way of communicating results. We have been developing our communication capacity, and are including YCC, Yukon Environment and Kwanlin Dun First Nation in decision-making processes. As we move forward with this collaborative approach we anticipate many new opportunities for value-added consultation and communication activities.

Expected Project Completion Date

This is an ongoing project.

Project website

In preparation.

Acknowledgments

We would like to acknowledge the support of the Ta'an Kwäch'än Council and the Champagne and Aishihik First Nations for the ability to conduct this study on their traditional lands and with their full support and assistance. In addition to the team members, we would like to acknowledge Deb Fulmer, Fish & Wildlife Program Coordinator TKC, who assisted with the logistics of fish collection and Glen Burdek and Daryn Vance who provided fish from Lake Laberge. Rod Malchow provided fish from both lakes for this project. We would also like to acknowledge Derek Muir and Xiaowa Wang (Environment Canada) who provided their analytical expertise. This project was funded by the Northern Contaminants Program, Crown-Indigenous Relations and Northern Affairs Canada.

Appendix A - Plain language Summaries

CONTAMINANT LEVELS IN LAKE TROUT FROM KUSAWA LAKE

Contaminants can stay in the environment for a long time and can affect the health of wildlife and people—especially those who eat a lot of traditional foods.

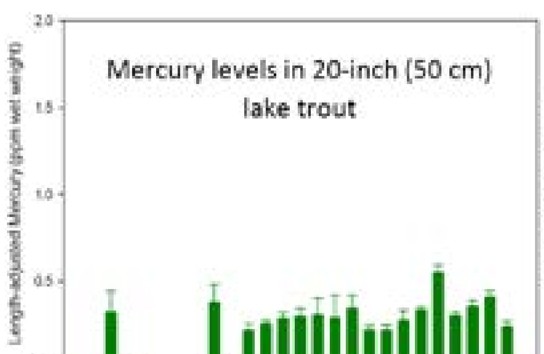
Mercury in fish is a concern in many places in the world, including the Arctic. Most mercury in Yukon lakes and rivers comes from natural sources such as volcanoes, erosion and forest fires. The Yukon also receives mercury and other contaminants from pollution from the south that gets blown to the Arctic by wind. Fish may absorb these contaminants and pass them on to the humans who eat them.

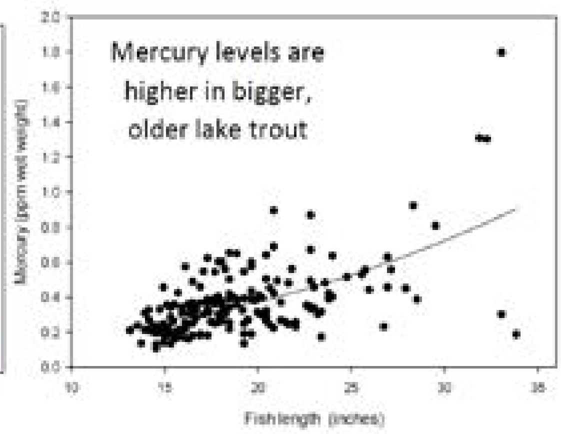
Lake trout from Kusawa Lake are studied every year by the Northern Contaminants Program for mercury and other contaminants. Older, longer fish have more mercury, which is why health advice is based on the length of the fish.

> **Advice on Fish Consumption**
>
> In general, Yukon adults do not need to limit consumption. However, eating lake trout or burbot that are less than 60 cm (24 inches) in length can help limit mercury intake.
>
> Women of childbearing age and children under 12 should limit their consumption of large Yukon lake trout and burbot according to the following guidelines:
>
> - Fish shorter than 40 cm (about 2 lbs): unlimited consumption.
> - Fish measuring between 40 and 60 cm (about 2 to 6 lbs): limit to three to four meals/week.
> - Fish longer than 60 cm (>6 lbs): limit to one or two meals/week.

Mercury

Mercury levels in lake trout flesh change from year to year, but overall are not going up or down. These changes may be caused by changes in temperature, rain and snow, as well as how much mercury pollution is put into the air in other parts of the world.

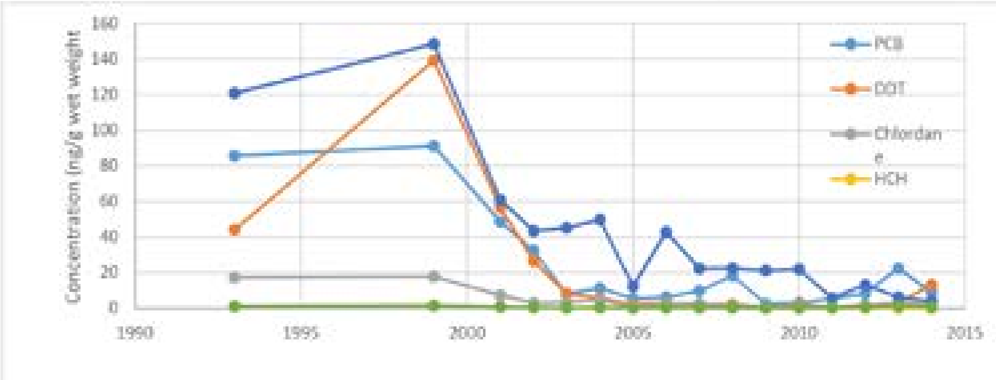




> **Predatory fish have higher levels of mercury than those lower on the food chain. To minimize your mercury consumption, eat lower on the food chain. Fish that are low in mercury include whitefish, salmon and grayling.**

Pesticides

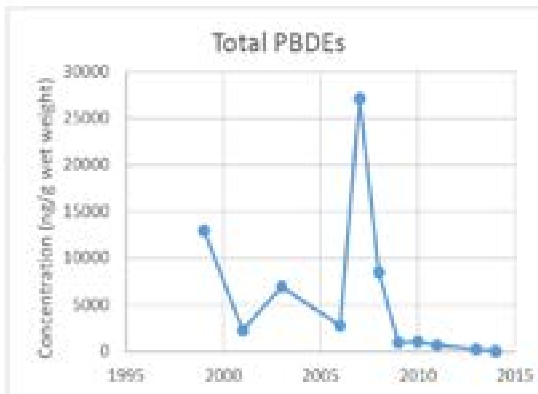
In general, levels of pesticides in lake trout from Kusawa Lake have gone down since we started measuring them in 1993. This is because many of these pesticides have been banned from widespread use.



Levels of pesticides and flame retardants in fish are below levels of concern.

Flame Retardants (PBDE)

These chemicals were widely used to reduce flammability in things like buildings, clothing and furnishings, but were banned in many countries by an international agreement (the Stockholm Convention) in 2009. Some countries stopped using them before that time. We are not sure why levels were particularly high in 2007, but in general, levels in lake trout from Kusawa Lake have gone down since we started measuring them in 1999.



What Can We Do About These Contaminants?

Our monitoring program provided evidence for national and international agreements to limit the amount of mercury being put into the environment. The Minimata Convention came into force on August 16, 2017 and will ensure that our fish are not exposed to increasing levels of mercury. This is a **big success** for us! Continued monitoring will ensure that contaminants are controlled in order to protect Arctic fish and wildlife.

For more information please contact the Champagne and Aishihik First Nations at 867-634-4200.

CONTAMINANT LEVELS IN LAKE TROUT FROM LAKE LABERGE

Contaminants can stay in the environment for a long time and can affect the health of wildlife and people—especially those who eat a lot of traditional foods.

Mercury in fish is a concern in many places in the world, including the Arctic. Most mercury in Yukon lakes and rivers comes from natural sources such as volcanoes, erosion and forest fires. The Yukon also receives mercury and other contaminants from pollution from the south that gets blown to the Arctic by wind. Fish may absorb these contaminants and pass them on to the humans who eat them.

Lake trout from Lake Laberge are studied every year by the Northern Contaminants Program for mercury and other contaminants. Older, longer fish have more mercury, which is why health advice is based on the length of the fish.

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In general, Yukon adults do not need to limit consumption. However, eating lake trout or burbot that are less than 60 cm (24 inches) in length can help limit mercury intake.

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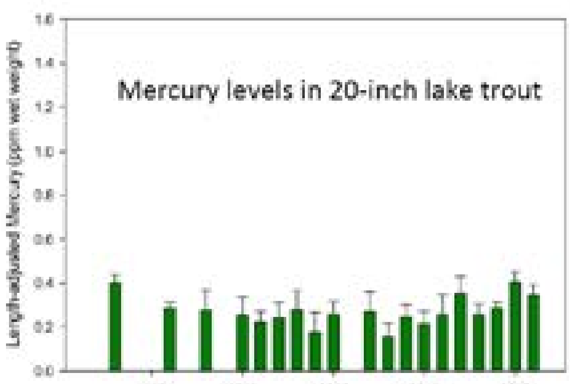
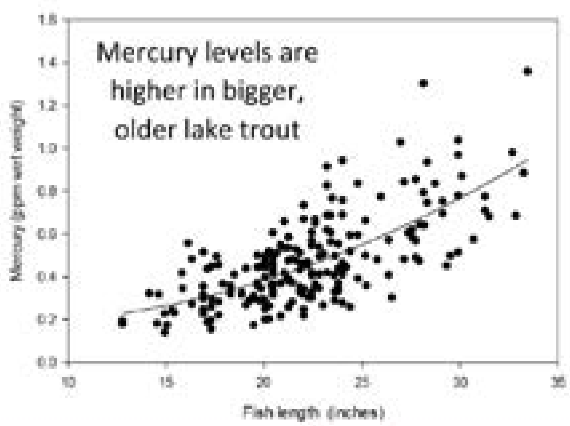
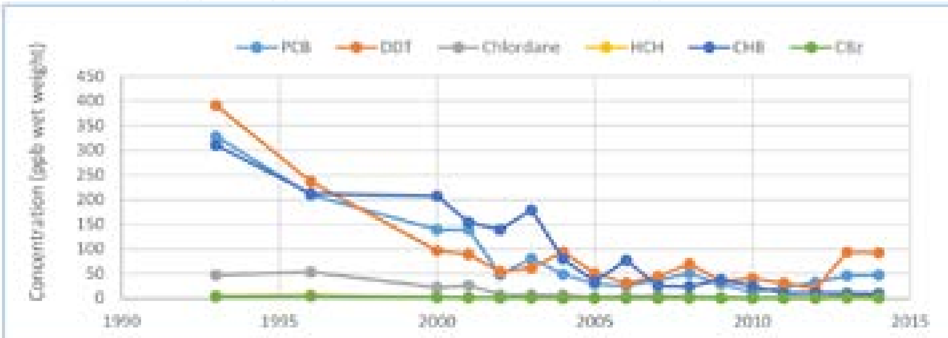




Predatory fish have higher levels of mercury than those lower on the food chain. To minimize your mercury consumption, eat lower on the food chain. Fish that are low in mercury include whitefish, salmon and grayling.

Pesticides

In general, levels of pesticides in lake trout from Lake Laberge have gone down since we started measuring them in 1993. This is because many of these pesticides have been banned from widespread use.



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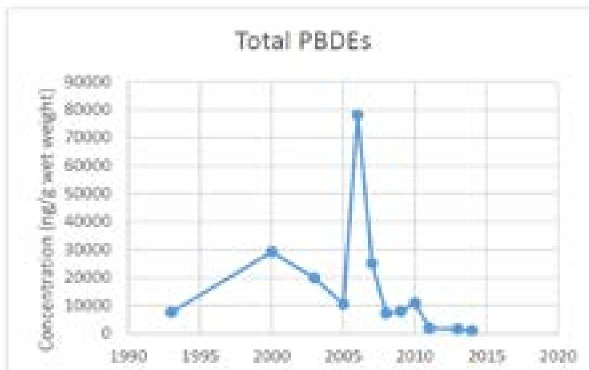

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For more information please contact Ta'an Kwach'an Council at 668-3613

Arctic caribou contaminant monitoring program

Programme de surveillance des contaminants chez le caribou de l'Arctique

Project Leader/Chef de projet

Mary Gamberg, Gamberg Consulting, 708 Jarvis St., Whitehorse, Yukon Y1A 2J2.
Tel: (867) 334-3360; Email mary.gamberg@gmail.com

Project Team/Équipe de projet

Mike Suitor, Martin Kienzler, Yukon Government; Mary Maje, Ross River Dena Council, YT; Nancy Amarualik, Resolute Bay Hunters and Trappers Association; Mitch Campbell, Government of Nunavut; Alex Ishalook, Arviat Hunters and Trappers Organization, NU; Xiaowa Wang and Derek Muir, Environment and Climate Change Canada.

Project Location/Emplacement(s) du projet

- North Yukon (Porcupine herd)
- Western Yukon (Forty-Mile herd)
- Kivalliq region, Nunavut (Qamanirjuaq herd)

Abstract

This project studies contaminant levels in caribou in the Canadian Arctic to determine if these populations remain healthy (in terms of contaminant loads); whether these important resources remain safe and healthy food choices for Northerners; and if contaminant levels are changing over time. In 2017-2018 samples were collected from nine Porcupine, 17 Qamanirjuaq and 13 Forty-Mile caribou. Sample analyses for these collections had not been completed at the time this report was prepared. Porcupine, Qamanirjuaq, Bluenose West, and Ahiak samples collected in the 2016-2017 year were analyzed, and results are presented in this report.

Renal lead declined over time in the Porcupine and Qamanirjuaq caribou and 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 (en ce qui concerne les niveaux de contaminants), si cette ressource alimentaire importante continue d'être une source de nourriture saine et sécuritaire pour les résidants du Nord, et si les concentrations de contaminants évoluent au fil du temps. En 2017-2018, des échantillons ont été prélevés sur neuf caribous de la harde de la Porcupine, 17 caribous de la harde de Qamanirjuaq et 13 caribous de la harde de Forty-Mile. Leur analyse n'était pas terminée au moment où le présent rapport a été rédigé. Les échantillons recueillis en 2016-2017 chez les caribous de la Porcupine, de Qamanirjuaq, de Bluenose Ouest et d'Ahiak ont été analysés, et les résultats obtenus figurent dans le présent rapport.

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 the higher energy needs for reproduction and nursing. Short-chain per- and polyfluoroalkyl substances (PFASs) are man-made chemicals that are used in things like Teflon and fire-fighting foams. Some types of PFASs are increasing over time in the Porcupine and Qamanirjuaq caribou (largely due to increases in pentafluorobenzoic acid (PFBA), a degradation product of a chemical used in automobile air conditioners). The longer-chain PFASs are, for the most part, no longer being manufactured for widespread use and are declining over time. Perfluoroalkyl sulfonic acids (PFSAs) are another group of man-made chemicals created for various industrial uses. They are also declining over time in caribou, largely due to the ban on use of perfluorooctanesulfonic acid (PFOS) which was used as a fabric protector. Polybrominated diphenyl ethers (PBDEs) were commonly used as flame retardants and are also found in caribou, although, like PFASs, concentrations were very low.

Levels of most contaminants 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. There have been no health advisories issued for caribou in NWT or Nunavut.

Les concentrations de plomb dans les reins des caribous de la Porcupine et de Qamanirjuaq caribou ont diminué, et 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 de leurs besoins énergétiques plus importants découlant de la reproduction et de l’allaitement. Les substances perfluoroalkyliques et polyfluoroalkyliques à chaîne courte (PFAS) sont des substances chimiques anthropiques utilisées dans la fabrication de produits comme le Teflon et les mousses extinctrices. Les concentrations de certains types de PFAS augmentent au fil du temps chez les caribous de la Porcupine et de Qamanirjuaq (en grande partie en raison d’augmentations des acides pentafluorobenzoïque [APFB], produit de dégradation d’un produit chimique utilisé dans les climatiseurs d’automobile). Les PFAS à longue chaîne ne sont essentiellement plus fabriqués pour une utilisation répandue, et leurs concentrations diminuent au fil du temps. L’acide perfluoroalkylsulfonique (PFSA) est un autre groupe de produits chimiques anthropiques destinés à différentes utilisations industrielles. Les concentrations de ce groupe de substances diminuent également chez le caribou, en grande partie en raison de l’interdiction de l’utilisation de l’acide perfluorooctane sulfonique (SPFO), qui servait à la protection des textiles. Les polybromodiphényléthers (PBDE) étaient couramment utilisés comme produits ignifuges et se trouvent également chez le caribou, bien que, comme dans le cas des PFAS, les concentrations soient très faibles.

La concentration de la plupart des contaminants mesurés dans les reins des caribous ne constituait pas une préoccupation sur le plan de la toxicologie, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d’organes consommée. Le ministère de la Santé du Yukon a conseillé aux citoyens de limiter la quantité de rognons et de foie provenant de caribous du Yukon qu'ils consomment; la quantité maximale recommandée varie selon la harde (p. ex. au maximum 25 rognons de caribous de la harde de la Porcupine par année). L'avis de santé publique confirme que les concentrations de métaux lourds sont très faibles dans la viande (les muscles) des caribous et que cette dernière demeure un aliment sain. Aucun avis de santé publique n'a été émis sur le caribou des Territoires du Nord-Ouest ou du Nunavut.

Key Messages

- Levels of most contaminants 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 are stable over the long term, although there is variation from year to year.
- Short-chain PFASs are increasing in the Porcupine and Qamanirjuaq caribou; this is likely coming from PFBA, a degradation product of a chemical used in automobile air conditioners.
- This program will continue to monitor the Porcupine and Qamanirjuaq caribou herds annually to maintain confidence in this traditional food and to better understand the dynamics of contaminants within this ecosystem (particularly mercury).

Messages clés

- La concentration de la plupart des contaminants mesurés dans les tissus de caribou n'est pas préoccupante, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. La viande (les muscles) des caribous n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.
- Les concentrations de mercure chez les caribous de la Porcupine et de Qamanirjuaq sont stables à long terme, malgré certaines variations d'une année à l'autre.
- Les concentrations de PFAS à chaîne courte augmentent au fil du temps chez les caribous de la Porcupine et de Qamanirjuaq, ce qui est probablement attribuable à l'APFB, produit de dégradation d'un produit chimique utilisé dans les climatiseurs d'automobile.
- 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

This project aims to:

- determine levels of and temporal trends in contaminants in Arctic caribou to:
- provide information to Northerners regarding contaminants in these traditional foods, so that they may be better able to make informed choices about food consumption;
- provide information for health assessments and/or advisories as required;
- provide information to wildlife managers so they can assess possible health effects of contaminants on Arctic caribou populations; and,
- further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

Introduction

Caribou are an important food resource for Northerners across the Arctic, and the Porcupine and Qamanirjuaq caribou herds were chosen by the Northern Contaminants Program for annual monitoring of mercury, inorganic elements, PBDEs (polybrominated diphenyl ethers) and PFASs (per- and polyfluoroalkyl substances). These herds were chosen because they are harvested on an annual basis, making annual sampling a realistic possibility, and because they can represent both the western (Porcupine) and eastern (Qamanirjuaq) Arctic. In addition, the blueprint for the Environmental Monitoring and Research subprogram specifies that one or two other herds will be monitored each year for the same list of contaminants.

Activities in 2017-2018

Samples were collected from nine Porcupine caribou in the fall of 2017 by hunters in Old Crow with the assistance of the North Yukon Renewable Resource Council. The target of 20 caribou was not reached this year, because the main herd migrated northwest into Alaska rather than south through Old Crow as in other years. Samples were collected from 17 Qamanirjuaq caribou herd in Arviat in the fall of 2017 in cooperation with the Arviat Hunters and Trappers Organization. Spring samples are currently being collected from the Finlayson caribou herd in Ross River, YT and from the Peary caribou in Resolute, NU. An additional 13 samples from the Forty-Mile caribou herd, a transboundary herd that ranges between western Yukon and Alaska were added to the project. These samples were collected opportunistically by Environment Yukon in the fall of 2017. A range map for the major barren-ground herds is provided for reference (Figure 1).

Figure 1. Home ranges of the major barren-ground caribou herds in Canada.

2017-2018 kidney samples are currently being analyzed for a suite of 34 elements using ICP-MS by NLET, Environment and Climate Change Canada, Burlington. Ten liver samples from each of the Porcupine and Qamanirjuaq herds are being analyzed for PBDEs (including deca-BDE) and PFASs by a private laboratory (ALS Global). 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.

Recent work done on contaminants in Greenland caribou, suggested that high levels of hepatic mercury may be negatively affecting the ability of caribou cows to become pregnant (Gamberg et al. 2016). In order to explore whether this may be true for caribou herds in Canada, and whether mercury could be potentially contributing to the decline of many of the large barren-ground herds in northern Canada, we collected fecal samples as well as the usual liver, kidney and teeth from 20 additional cows from the Qamanirjuaq caribou immediately after the rut (late November). It was important to collect samples at this time because the cows would be newly pregnant (if they were pregnant). As pregnancy progresses, cows will naturally lose some of their mercury to the growing fetus, so that the pregnant cows should always have less mercury than the non-pregnant cows. However, when they are newly pregnant, a difference in hepatic mercury between the two groups would be significant. Feces were analyzed for progesterone (Toronto Zoo) to determine pregnancy and the liver and kidneys were analyzed for total mercury.

Capacity Building

Mary Gamberg participated in the First Hunt Program in Arviat in September 2017, along with an Arctic College Environmental Technology Program graduate (Lars Qaqqaq). The main herd was not close to the community at that time, so high school students were unable to be involved in the hunt. However, the First Hunt Program coordinators and several community members participated in the hunt which provided an ideal opportunity for discussion about contaminants and caribou as well as demonstrations of sampling techniques. We harvested four caribou which were sampled for analysis. In November 2017, Mary Gamberg participated in a wildlife contaminants workshop presented to the students of the Environmental Technology Program (ETP) of Arctic College in Iqaluit, providing information on contaminants in the general environment and in caribou. This workshop will be offered again in September 2018.

Communications

Results of this project were communicated in the following ways:

- May 2017 – presented to the Porcupine Caribou Management Board and the community of Old Crow during ‘Big Caribou Days’ in Old Crow, YT;
- August 2017 – presented at DIOXIN in Vancouver and to the Hunters and Trappers Organization in Tuktoyaktuk NT;
- September 2017 – distributed a plain language summary to the hunters of the Qamanirjuaq caribou (English and Inuktitut) and presented to Hunters and Trappers Organizations in Whale Cove, Arviat, Chesterfield Inlet, Rankin Inlet and Baker Lake NU and at the NCP Results Workshop in Yellowknife NT;
- October 2017 – distributed a plain language summary to the hunters of the Porcupine caribou and presented at the Canadian Ecotoxicity Workshop in Guelph, ON and to a high school science class at Wood St. School in Whitehorse, YT;
- November 2017 – presented to the NECC and the Environmental Technology Program of Arctic College in Iqaluit as part of an NCP project: Wildlife Contaminants Workshop–linking wildlife and human health through a hands-on workshop;
- February 2018 – created a Facebook page to increase communication potential; during

the first two months 4168 people were reached; and,

- March 2018 – created caribou content for the Yukon Contaminants Website which should go live in early June 2018.

Indigenous Knowledge Integration

This program relies on Indigenous Knowledge when collecting samples from caribou for analysis. Local hunters use Indigenous Knowledge when hunting caribou and submitting samples as well as providing food for their families. Meetings between Mary Gamberg and local HTOs provide an opportunity for the exchange of Indigenous and western knowledge 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 Kivalliq region yielded the traditional Inuit knowledge that caribou commonly consume seaweed, which could be a significant source of mercury for Qamanirjuaq caribou. This information was incorporated into a companion project exploring mercury in seaweed, lichens, and mushrooms in the Kivalliq region.

Results and Discussion

Element Concentrations

Element concentrations are presented for samples collected in the spring of 2005 and 2014 (Bluenose West herd) and in the fall of 2016 (Porcupine, Qamanirjuaq and Ahiak herds). Although kidneys were analyzed for 34 elements, only results for the seven elements of concern were statistically analyzed in detail (arsenic [As], cadmium [Cd], copper [Cu], lead [Pb], mercury [Hg], selenium [Se] and zinc [Zn]). Porcupine and Qamanirjuaq results were analyzed for temporal trends.

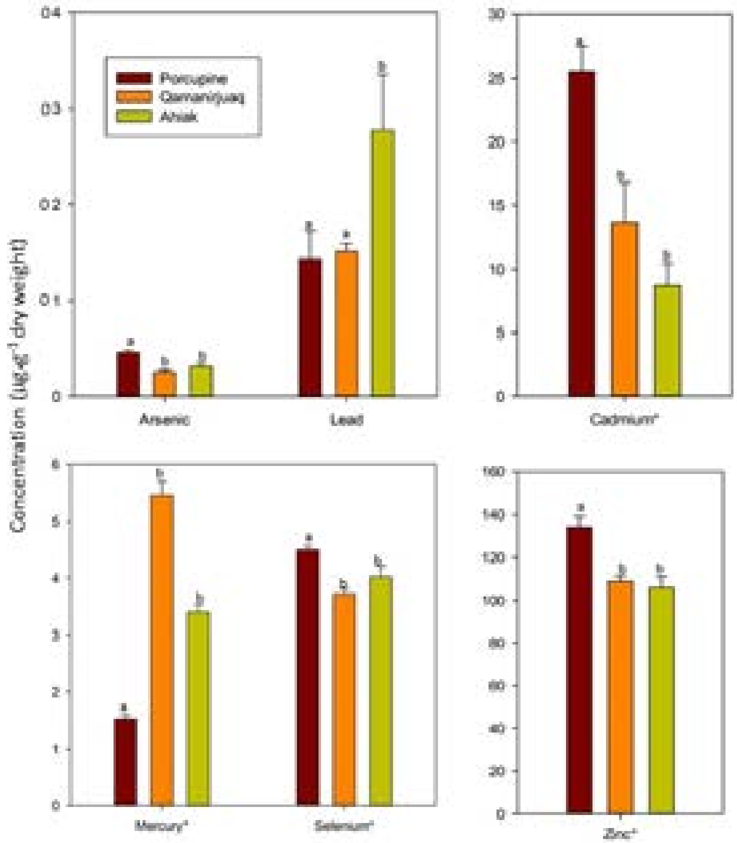
Age was positively correlated with renal Cd in the Porcupine, Qamanirjuaq and Bluenose West caribou and with Zn in the Porcupine and Bluenose West. Note that only 2005 data was included in this analysis for the Bluenose West herd because ages were not available for the 2014 data. Age was also positively correlated with Hg and Se in the Porcupine caribou, the largest data set (n=302 fall-collected males). These correlations were not apparent in the Ahiak 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).

The Qamanirjuaq and Ahiak herds were the only herds with large enough sample sizes of both male and female caribou to allow for a comparison between genders. Qamanirjuaq cows had higher As and Hg than bulls, while no differences were seen in the Ahiak herd (likely because of a low sample size). A tendency for cows to accumulate higher concentrations of toxic elements has been seen before (Gamberg et al. 2016) and is thought to be due to the higher forage intake by cows (relative to body weight) to furnish the additional energetic requirements of reproduction and nursing.

Element concentrations were compared among caribou collected in the fall of 2016 from the Porcupine, Qamanirjuaq and Ahiak herds (Figure 2). The Porcupine herd had lower renal Hg and higher renal As, Se and Zn than the other two herds while the Ahiak had higher renal lead levels than the other two herds. Renal cadmium was higher in Porcupine herd than the Qamanirjuaq, and higher in the Qamanirjuaq than the Ahiak. Copper did not differ significantly among the three herds.

The Bluenose West caribou spring collection in 2005 consisted solely of cows. Having no spring-collected samples from other herds in 2005 and considering that season was likely more important than the exact year, these data were compared with spring-collected Porcupine caribou cow data from 2003 (n=11). The Bluenose West herd had lower concentrations of As and Se than the Porcupine herd, and there were no differences in the other elements. The spring collection in 2014 consisted of nine bulls and one cow. For similar reasons, those data (with the one cow removed) were compared

Figure 2. Average renal element concentrations in three caribou herds. *Cadmium, mercury, selenium and zinc were corrected for age. Bars with the same letter are not significantly different.



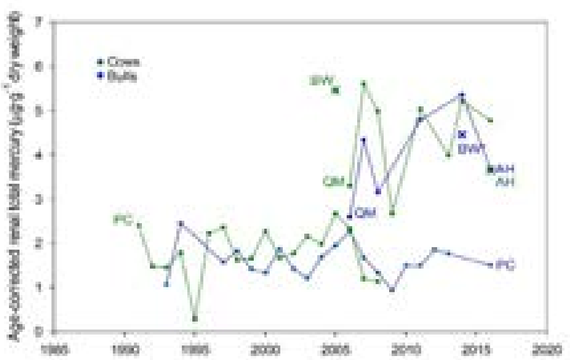
with spring-collected Qamanirjuaq bulls from 2012 (n=11). The Bluenose West caribou had higher levels of renal Cu but lower levels of Cd, Hg and Se.

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.

Of the 20 Qamanirjuaq cows collected immediately post-rut, only two were not pregnant and these were older animals (13 and 16 years old). The pregnant cows had an average hepatic liver concentration of 1.18 $mg \cdot g^{-1}$ dry weight, while the non-pregnant cows had an average of 1.35 $mg \cdot g^{-1}$ dry weight. This suggests that existing mercury levels are not precluding pregnancy in these caribou. However, in discussions with hunters in the Kivalliq region in the fall of 2017, many people described the caribou as being in the best condition they have seen over the last two years. They and attributed the excellent body condition to windy conditions in the summer that kept the insects away from the caribou reducing their stress and energy expenditures in avoiding the insects. It would be interesting to repeat this exercise in a year when conditions were not as beneficial to the caribou and they are in poor condition. It is possible that under those conditions, higher levels of mercury might add to the cumulative effects to the point where reproductive capacity is reduced.

An interesting aside from this work was that renal Hg levels in cows collected in November 2017 were significantly higher than levels in cows collected in August 2017 (8.37 mg·g^{-1} dry weight and 3.80 mg·g^{-1} dry weight respectively). This makes some sense since caribou start eating lichens that are higher in mercury in September, but we were unaware of the magnitude of the increase over such a short period of time. This high variability of contaminant concentrations over a short period of time, makes it more crucial to maintain a consistent month of sampling for the herds designated for temporal trend monitoring (at least as much as is possible in keeping with the sometimes unpredictable migration of the herds).

Figure 3. Age-corrected total mercury concentrations in caribou kidneys collected in spring (BW=Bluenose West) and fall (PC=Porcupine; QM=Qamanirjuaq; AH=Ahiak). *Data from BW 2014 bulls are not age corrected as no ages were available for this collection.



Temporal trends in elements were analyzed using only data from fall-collected bulls in the Porcupine herd and both genders collected in the fall from the Qamanirjuaq herd. Renal As and Pb have declined significantly over time in the Porcupine caribou herd, and Pb has also declined in the Qamanirjuaq herd. These trends 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. Age-corrected data were to test for temporal trends in Cd, Hg, Se and Zn. There is no statistically significant trend in renal Hg concentrations in either herd, although there is an upward trend in the Qamanirjuaq herd (Figure 3). High levels of interannual variation are likely caused by atmospheric patterns of deposition of Hg as well as local environmental conditions affecting Hg deposition.

Fluorinated compounds

PFASs are presented for the 2016 collections of the Ahiak, Porcupine and Qamanirjuaq herds, as well as the Dolphin & Union, Porcupine and Qamanirjuaq herds from 2015 and the Bluenose West from 2014. The Ahiak herd had higher levels of short-chain (C4-C7) PFCAs (polyfluorinated carboxylic acids) than the other herds, largely due to PFBA (perfluorobutyrate), which constituted 60% of the short chain PFCAs found (Figure 3). The longer-chain PFCAs (C8-C14) were higher in the Qamanirjuaq and Bluenose West caribou than the other herds. The Qamanirjuaq and Ahiak herds had higher concentrations of PFSAs (polyfluorinated sulfonic acids), particularly PFOS (perfluorooctanesulfonic acid) (Figure 4). We have just started measuring these compounds in caribou and the significance of differences in various compounds in certain herds has yet to be determined. Short-chain PFCAs are increasing over time in the Porcupine and Qamanirjuaq caribou (largely due to PFBA), while the longer-chain PFCAs and PFSAs are declining over time (the latter, largely due to PFOS) (Figure 5). However, there was a slight increase in 2016 in both herds. PFBA is a degradation product of the replacement compounds used after PFOS was phased out in Canada and the USA in the early 2000s. PFBA is also a degradation product of HCFCs (hydrochlorofluorocarbons) which are used in automobile air conditioners.

Figure 4. ΣPFCAs in liver from Arctic caribou collected 2014-2016.

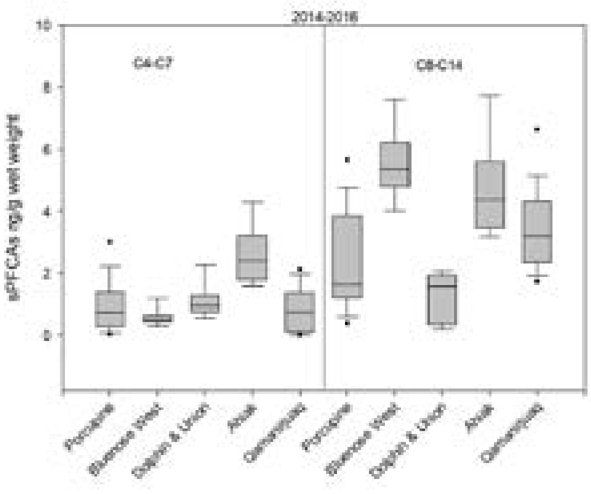
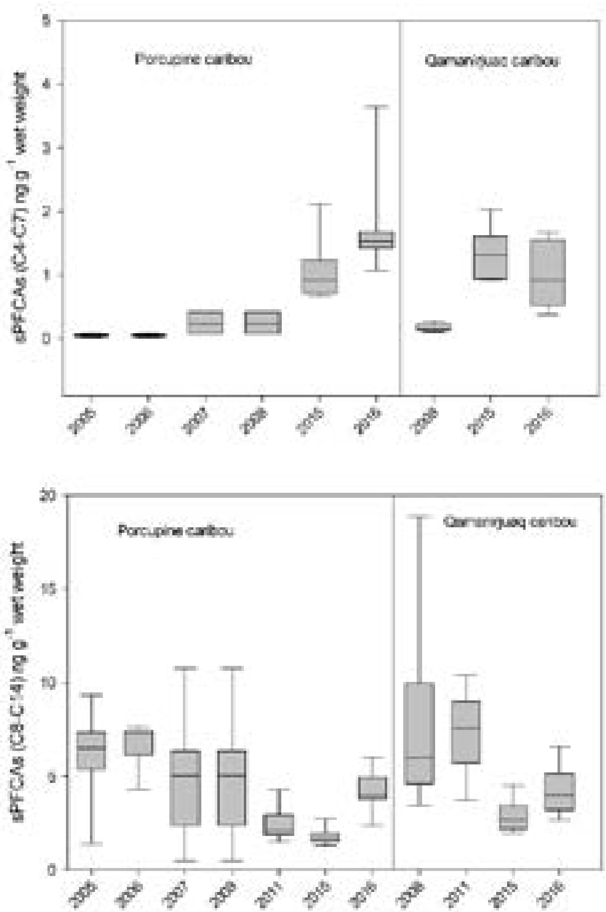


Figure 5. Short-chain (C4-C7; first panel) and long-chain (C8-C14; second panel) PFCAs in liver from Porcupine and Qamanirjuaq caribou over time.



PBDE concentrations

PBDE results are presented for the 2016 collections of the Ahiak, Porcupine and Qamanirjuaq herds, as well as the Dolphin & Union, Porcupine and Qamanirjuaq herds from 2015 and the Bluenose West from 2014. 43 congeners were measured and BDE-15, 99 and 183 accounted for 90% of ΣPBDEs. Neither age nor sex affected PBDE concentrations. The Bluenose West herd had significantly higher total PBDEs than the Qamanirjuaq, Ahiak and Porcupine herds and had similar levels to the Dolphin & Union herd. The congener profile was similar among the Bluenose West and Dolphin & Union caribou (Figure 6) and muskox from the range of the Dolphin & Union herd (not shown), all found in the highest Arctic locations, which may suggest a latitudinal effect of PBDE contamination in large ungulates.

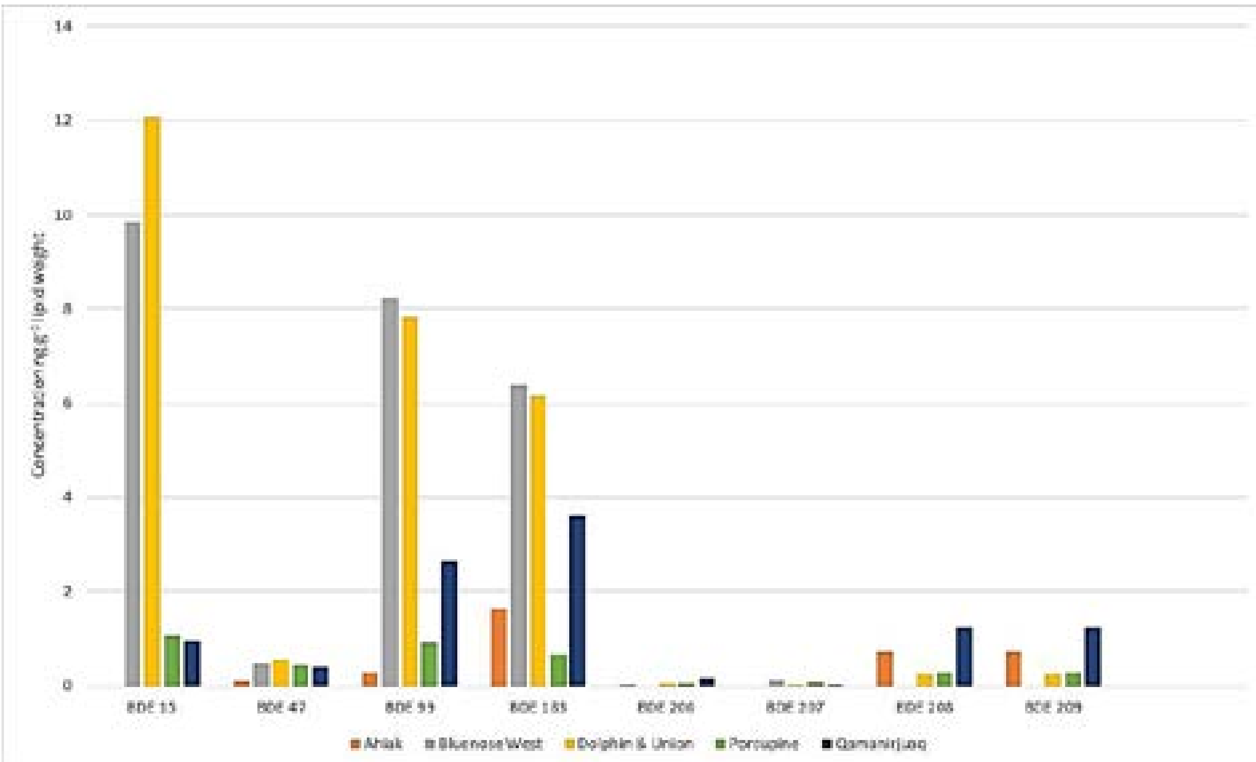
Conclusions

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.

Figure 6. PBDEs in liver from Arctic caribou collected 2014-2016.



Acknowledgements

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Appendix A - Plain Language Summaries

Report to the Hunters of the Porcupine Caribou – July, 2017

With the help of local hunters, we have been taking samples of the Porcupine caribou since 1991. We collect these samples to study changes in the amount of contaminants such as mercury and lead in kidneys of caribou. Since 2015, these samples are also being tested every year for 'new' contaminants (like stain repellents and flame retardants). One of the things we look for are contaminants carried to the Arctic by wind.

WHERE IS THIS STUDY BEING DONE?

Samples for this study are collected from Old Crow.

ACTIVITIES IN 2016-17

Samples from 23 caribou were collected from Old Crow in the fall of 2016.

- Kidneys were analyzed for a range of contaminants, as they are every year.
- Livers are being analyzed for emerging contaminants.
- We received results from the 2015 collection.

Photo credit: Peter Mather

WHAT WE HAVE LEARNED NEW THIS YEAR

- We have confirmed that lead has decreased slightly over time in Porcupine caribou. The decline in lead is likely because North America stopped using leaded gasoline in the early 1990s.
- We have confirmed that mercury is not increasing or decreasing over time; it appears to be cyclic.

Maximum Recommended Consumption of Porcupine Caribou for one adult for one year

	Kidneys	Livers	Muscle
Porcupine Caribou	24	12	All You Want

Tobacco contains much higher levels of cadmium than animal sources. Reducing or eliminating smoking is the most effective way of limiting cadmium intake.

WHAT WE HAVE LEARNED FROM THIS WHOLE PROJECT

- Porcupine caribou are largely free from contamination and are healthy to eat.
- Some caribou have high levels of mercury and cadmium in their organs. Some of the cadmium and mercury occurs naturally in the land, but some is brought here by wind from industry down south.

- Cadmium and mercury in caribou organs fluctuate over time but over the long term are remaining stable.
- The Porcupine caribou do not show high levels of radioactivity due to the nuclear accident at Fukushima, Japan in 2011.
- In the fall, mercury concentrations are higher in cows than in bulls, because cows are smaller and eat proportionally more food, therefore more mercury.
- In the spring, mercury may be lower in cows than in bulls, because some of the mercury is lost to the fetus and through milk production.
- Mercury is generally higher in the spring than the fall, because the caribou eat lichens through the winter which are higher in mercury than their summer foods of grasses and flowering plants.
- Mushrooms may provide a pulse of mercury in the fall, because mushrooms accumulate large amounts of mercury and are a preferred food when they are available.
- Mercury in the Porcupine caribou may be affected by rain, snow, wind, temperature, migration patterns, time of green-up and forage quality as well as mercury emissions coming from industry, forest fires and volcanoes.

We are continuing to monitor contaminants in the Porcupine Caribou to keep track of the amount of mercury in their organs, and to try to better understand how and why mercury accumulates in caribou the way it does.

HOW OUR RESEARCH IS HELPING THE WORLD

More than two decades of contaminant data from the Porcupine caribou were part of the evidence that led the United Nations Environmental Program to create the Minamata Convention. This is a global agreement that will limit mercury emissions to the environment and ultimately reduce the mercury in Arctic caribou. 69 countries have ratified the Convention and it will come into force on August 16, 2017.

We are making a difference!

For more information please contact Mary Gamberg Phone: 867-334-3360 mary.gamberg@gmail.com

REPORT TO THE HUNTERS OF THE KIVALLIQ REGION
CONTAMINANTS IN QAMANIRJUAQ CARIBOU – SEPTEMBER, 2017

- With the help of local hunters, we have been taking kidney, liver and muscle samples of Qamanirjuaq caribou since 2006.
- We collect these samples to study changes in the amount of contaminants such as mercury and lead in kidneys of caribou. These contaminants may be carried to the Arctic by wind.
- We use this information to
  - Provide information to Northerners so that they may be better able to make informed choices about food consumption and
  - Help guide policies that limit contamination of the environment.
- Starting in 2015, these samples will be tested every year for 'new' contaminants (like stain repellents and flame retardants).

WHERE IS THIS STUDY BEING DONE?

Samples for this study are collected from Arviat. Although we could sample the herd anywhere within its range, we can be most effective by working with hunters from one community so that the hunters become very familiar with the samples we need.

ACTIVITIES IN 2017-18

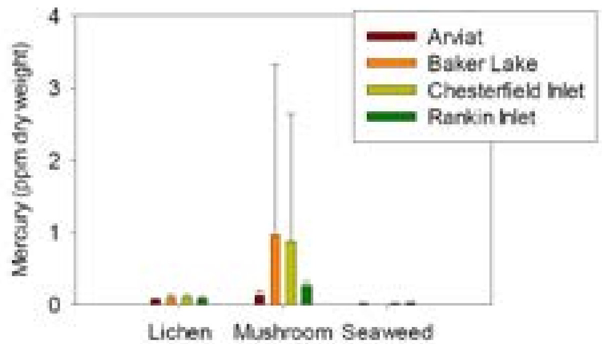
- Samples from 20 caribou (10 bulls; 10 cows) were collected from Arviat in the fall of 2016.
  - Kidneys were analyzed for a range of contaminants, as they are every year.
  - Livers are being analyzed for new contaminants.
  - We choose kidneys and livers for analysis because that is where the contaminants tend to accumulate.
- Samples were taken from an additional 20 cows immediately after the rut, to see if mercury could be stopping some cows from getting pregnant.
- Lichen, seaweed and mushrooms from Baker Lake, Chesterfield Inlet, Rankin Inlet and Arviat were analyzed for mercury to see if seaweed was an important source of mercury for caribou.

THIS PROJECT IS SUPPORTED BY THE NORTHERN CONTAMINANTS PROGRAM

For more information please contact Mary Gamberg, Gamberg Consulting
Phone: 867-334-3360 mary.gamberg@gmail.com

WHAT WE HAVE LEARNED NEW THIS YEAR

- Mercury levels are higher in 2016 than they were in 2015. We think that mercury increases and decreases in caribou as a natural cycle and this is just part of that cycle.
- Some of the chemicals now being used in car air conditioners may be increasing contaminants (PFBAs) in Arctic caribou. This requires further study.
- Only two of the cows that were sampled for mercury right after the rut were not pregnant and these were old cows (13 and 16 years old) who had similar levels of mercury as the pregnant cows. **Mercury is clearly not keeping the Qamanirjuaq caribou from becoming pregnant.**
- Mercury was higher in mushrooms than in lichen and lowest in seaweed. Concentrations did not differ among communities suggesting long-range transport as a source. **Seaweed is not a significant source of mercury for the Qamanirjuaq caribou.**



WHAT WE HAVE LEARNED FROM THIS WHOLE PROJECT

- Some caribou have mercury and cadmium in their organs. Some of the cadmium and mercury occurs naturally in the land, but some is brought here by wind from industry down south. Some mercury may also come from forest fires or volcanoes.
- We have not been studying the Qamanirjuaq caribou herd long enough to be able to say very much about whether mercury and cadmium are increasing or decreasing over the long term, but the Porcupine caribou from the western Arctic show us that although cadmium and mercury in caribou organs fluctuate over time in that herd, they do remain stable over the long term. It is good news that they are not increasing!
- **Caribou muscle (meat), marrow and brain have very low levels of contaminants.**

WHAT CAN WE DO?

Our monitoring program provided evidence for national and international agreements to limit the amount of mercury being deposited into the environment. The Minimata Convention came into force on August 16, 2017 and will ensure that Arctic caribou are not exposed to increasing levels of mercury. **This is a big success for us!** Continued monitoring will ensure that environmental controls of a variety of contaminants are adequate to protect Arctic wildlife and that they are implemented effectively.

WHAT CAN YOU DO?

Participate in monitoring and research projects, engage with HTAs, ask questions!

ᐅᓂᒃᑳᖅ ᐊᖑᓇᓱᒃᑎᓄᑦ ᑮᓇᐅᔭᖃᕐᕕᒥ
ᓯᓇᒥᐊᓄᑦ ᐊᒃᑐᒐᐅᓂᖏᑦ ᖃᒪᓂᕐᔪᐊᑦ ᑐᒃᑐᖏᑕ - ᓯᑉᑕᒻᐸ, 2017

- ᐊᖑᓇᓱᒃᑏᑦ ᐃᑲᔪᖅᑎᖃᑦᑐᑦ, ᑎᒍᓯᔪᓐᓇᖅᓯᓚᐅᖅᐳᑦ ᑎᖑᖏᓐᓂᒃ, ᑕᖅᑐᖏᓐᓂᒃ ᐊᒻᒪ ᓄᕆᖏᓐᓂᒃ ᖃᒪᓂᕐᔪᐊᑦ ᑐᒃᑐᖁᑎᖏᓐᓂᑦ ᐱᖏᐊᕐᓗᑕ 2006.
- ᑲᑎᖅᓯᐃᓚᐅᖅᐳᑦ ᖃᐅᔨᓴᖅᓯᓂᒃ ᓯᓇᒥᐊᓄᑦ ᐊᒃᑐᐃᒐᐅᓂᖏᓐᓄᑦ ᒧᒃᑭᓗᒋᑦ ᐊᒻᒪ ᓴᕕᖕᓄᒃ ᑐᒃᑐᑦ ᑕᖅᑐᖏᓐᓂ. ᑖᒃᑯᐊ ᐊᒃᑐᐃᔪᑕᐅᔪᑦ ᐅᑭᐅᖅᑕᖅᑐᒧᑦ ᑎᑭᑕᐅᕙᒃᑕ ᐊᓄᓂᒃᑯᑦ.
- ᖃᐅᔨᒪᔪᑕᐅᓂᐊᕐᒪᑕ
  - ᖃᐅᔨᒪᔪᑕᐅᓗᑎᒃ ᐅᑭᐅᖅᑕᖅᑐᒥᐅᓄᑦ ᑐᑭᓯᐅᒪᑎᐊᖅᑯᑎᒃ ᓂᕿᐊᖅᓯᐅᕐᓂᕐᒥᒃ ᓂᕆᓂᐊᖅᑕᕆᔭᓂᒃ ᐊᒻᒪ
  - ᐃᑲᔫᓗᑎᒃ ᒪᓕᒐᓕᐅᖅᑏᑦ ᖃᓄᐃᑐᕆᐊᑦ ᐊᕙᑎᒧᑦ ᓄᖃᖓᑎᒃᑯᑎᒃ.
- ᑕᐃᔅᓱᒪᓂ ᐱᖏᐊᕐᓗᓐᓂ 2015, ᖃᐅᔨᓴᖅᑏᑦ ᐅᑭᐅᑕᒫᑦ "ᓄᑕᕐᓂᒃ" ᓯᕿᓐᓇᖅᑐᓂᒃ (ᑭᒃᑯᓐᓂᐊᓂᒃ ᑐᖅᑯᓯᔭᑎᑦ, ᐃᑯᐊᓪᓚᖅᑕᐃᓕᔭᑎᒋᓗ).

ᓱᓇᒧᑦ ᑕᒪᓇ ᖃᐅᔨᓴᖅᓯᒃ ᐊᑐᕐᓂᖃᕐᓂᐊᖅᐸ?

ᖃᐅᔨᓴᖅᑏᑦ ᑲᑎᖅᓱᐃᓚᐅᖅᑕᑦ ᐊᕐᕕᐊᓂᑦ, ᑭᓯᐊᓂ ᐊᓯᖏᓐᓂᒃ ᖃᐅᔨᓴᕈᓐᓇᖅᑎᓪᓗᒋᑦ, ᑐᒃᑐᑦ ᐊᒥᖅᐃᑦ ᐊᕐᕕᐊᑦ ᓴᓂᐊᒍᑦ ᐱᓱᒃᑕᓚᐅᕐᒪᑕ ᐱᓕᕆᖃᑎᖃᕈᓐᓇᖅᓯᑦᑐᑕ ᐊᖑᓇᓱᒃᑎᓂᒃ ᓄᓇᓕᖕᒥ ᖃᐅᔨᒪᓕᕐᓗᑎᒡᓗ ᖃᐅᔨᓴᖅᑕᐅᓯᒪᔪᓂᒃ.

ᐱᓕᕆᐊᖑᒪᔪᖅ ᐃᓗᐊᓂ 2017-18

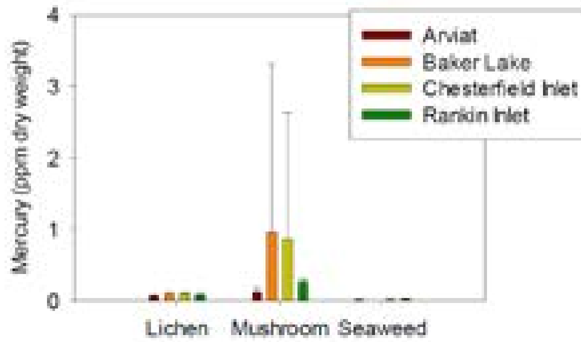
- ᖃᐅᔨᓴᐅᑉᓗᑎᒃ 20 ᑐᒃᑐᑦ (10 ᐸᖕᓂᑦ; 10 ᓄᕐᕋᑦ) ᑲᑎᑕᐅᓪᓗᑎᒃ ᐊᕐᕕᐊᒥᑦ ᐅᑭᐊᖑᓐᓂ 2016.
  - ᑕᒃᑐᖏᑦ ᖃᐅᔨᓴᐅᓪᓗᑎᒃ ᓯᕿᓐᓇᖅᑐᖃᕐᒪᖔᑕ, ᐅᑭᐅᑕᒫᑦ.
  - ᑎᒍᐃᑦ ᖃᐅᔨᓴᐅᓪᓗᑎᒃ ᓄᑕᕐᓂᒃ ᓯᕿᓐᓇᖅᑐᓂᒃ.
  - ᑎᖑᐃᑦ ᑕᒃᑐᖏᓪᓗ ᓂᕿᐊᓕᐅᖅᐸᕐᓂᖅ ᖃᐅᔨᓴᐅᓂᐊᕐᒪᑕ ᓯᕿᓐᓇᖅᑐᑦ ᐃᓂᒋᓇᔭᖅᑕᖏᑦ.
- ᖃᐅᔨᓴᖅᑏᑦ ᐱᔭᐅᑲᓂᓚᐅᖅᐳᑦ ᐃᓚᐅᑲᓂᖅᓗᑎᒃ 20 ᓄᕐᕋᖕᓂᑦ ᕿᐅᖅᓯᐅᓂᓕᕆᓂᖓᓂᑦ, ᒧᒃᑭ ᓄᑲᖅᑎᑕᐅᓂᖓ ᐃᓚᐅᓂᒃ ᐱᑕᖃᓐᓇᐃᓕᖅᑎᓯᒍᑎᒃ.
- ᑎᖕᒥᐅᔭᑦ, ᕿᕐᖁᐊᑦ, ᒪᔪᕐ ᑲᑎᑕᐅᓚᐅᖅᑐᑦ ᖃᒪᓂᑦᑐᐊᒥᑦ, ᐃᒡᓗᓕᒑᕐᒥᑦ, ᑲᖏᖅᖠᓂᕐᒥᑦ ᐊᕐᕕᐊᕐᒥᓗ ᒧᒃᑭᖅᓴᒪᓯᒪᓪᓚᑕ ᖃᐅᔨᓴᐅᓂᐊᕐᓗᑎᒃ ᑐᒃᑐᑦ ᓂᕆᒐᒪᑎᒃ.

ᑖᓐᓇ ᐱᓕᕆᐊᖅ ᐃᑲᔪᐅᑎᖅ ᐅᑭᐅᖅᑕᖅᑐᒥ ᓯᕿᓐᓇᖅᑐᓂᒃ ᐱᓕᕆᐊᖃᕐᓂᐅᓄᑦ

ᑐᑭᓯᑲᓂᕈᒪᒍᕕᑦ, ᑐᓴᖅᑎᓂᐊᖅᐸᑦ ᒥᐊᕆ ᒐᒻᐴ, ᒐᒻᐴ ᖃᐅᔨᒪᔪᑦᑎᒍᑦ
ᐅᖃᓗᑎᖓ: 867-334-3360 ᖃᕆᑕᐅᔭᒃᑯᑦ ᑐᑦᑕᕈᑎᖓ: mary.gamberg@gmail.com

ᓱᓇᓂᒃ ᓄᑖᓂᒃ ᐃᓕᑦᓯᒪᓕᖅᐱᑕ ᑕᕝᕙᓂ ᐊᕐᕌᒍᒥ

- ᒍᑯᓇᕐᑲᕐᓂᐅᔪᑦ ᐊᓯᖏᓂᙱᑦᑐᓕᖅᐳᑦ 2016 ᓯᕗᓂᖓᓂ ᐊᕐᕋᒍᒥᑦ 2015. ᐃᓱᒪᕗᒍᑦ ᒍᑯᓇ ᐱᕈᖅᐸᓕᐊᓂᖓ ᓄᐃᑉᐸᓕᐊᓂᖓᓗ ᐃᓄᓯᐅᑉ ᐃᓕᖁᓯᖓᓂᒃ ᒪᓕᒃᐳᖅ.
- ᐱᔪᓐᓇᖅᑐᑦ ᐃᓚᖏᑦ ᐊᑐᐊᑐᒐᐅᓯᖅᑐᑦ ᐊᒃᓱᐊᓕᑦ ᓂᕈᖅᑕᐅᑎᖏᓐᓄᑦ ᐊᖏᓕᕚᓕᐊᔪᑕᐅᔪᓐᓇᖅᐳᑦ (PFBAs) ᐅᑭᐅᖅᑕᖅᑐᒥ. ᑕᒪᓐᓇ ᖃᐅᔨᓴᐅᑲᓂᕆᐊᖃᖅᐳᖅ.
- ᓄᕐᓕᒃ ᒪᔾᔪ ᖃᐅᔨᒪᐅᓚᐅᕐᓂᒃ ᒍᑯᓇᕐᑲᕐᓂᖏᓐᓄᑦ ᕿᐅᖅᓱᓂᓕᑐᐊᖑᓂᒃ ᓄᕐᖃᖏᑎᑎᓐᓄᒥᒃ ᓯᓕ ᐊᒻᒪ ᐊᐅᑐᓂᙳᑦ ᓄᕐᖃᖅᑐᑦ (13 ᐊᒻᒪ 16 ᐅᑭᐅᖃᖅᑐᑦ) ᑎᐊᓐᓇᑐᑦ ᐊᔾᔨᒥᒃ ᒍᑯᓇᐊᖃᕐᓂᕐᒪᐅᓚᐅᖅᐳᑦ ᐃᑉᐸᐅᖃᖅᑐᓂᑦ. ᒍᑯᓇ ᑭᓯᐊᓂ ᐱᑕᖃᓗᐊᖏᑦᑐᖅ ᑲᒪᓂᖕᖠᐊᑦ ᑐᑦᑐᖁᑎᖏᑦ ᓄᕐᖅᑕᖅᑕᐃᓕᑎᑕᐅᓂᖏᑦ.
- ᒍᑯᓇ ᐊᓯᖏᓂᙱᑦᑐᓚᐅᖅᐳᖅ ᒪᕐᕉᓂᑦ ᐊᒪ ᒥᑭᓂᙱᑦᑐᑉᐸᓪᓗᓂ ᕿᑦᑯᐊᓂᑦ. ᓯᕗᓇᖅᑐᖃᕐᓂᖏᑦ ᓄᓇᓕᖓᓂ ᐊᔾᔨᒥᐊᓚᐅᓚᐳᑦ ᐅᑭᐅᒥ ᓯᕗᓂᖓᓂ ᐃᖏᕐᓂᖏᑦ ᐊᔾᔨᒥᐊᓚᐅᕐᒪᑕ. ᕿᑦᑯᐊᑦ ᒍᑯᓄᓂᒃ ᑎᒍᒥᐊᖏᒪᑕ ᖃᒪᓂᖕᖠᐊᑦ ᑐᑦᑐᖁᑎᖏᓐᓄᑦ.



ᓱᓇᓂᒃ ᐃᓕᑦᓯᒪᓕᖅᐱᑕ ᐱᓕᕆᐊᖑᔪᒥᑦ

- ᑐᑦᑐᑦ ᐃᓚᖏᑦ ᒍᑯᓇᕐᑲᕐᒪᑕ ᑲᑉᕕᐊᕐᑲᖅᓱᑎᒃᓱ ᐃᓄᑦᑎᖏᓐᓂ. ᑲᑉᕕᐊᑉ ᐊᒻᒪ ᒍᑯᓇ ᓄᓇᒧᑦ ᑎᑭᑉᐸᑦᑐᑦ ᐊᓄᕆᒃᑯᑦ ᖃᑦᑕᓇᑦ ᓄᓇᖓᓂᒃ. ᒍᑯᓇ ᐃᓚᖏᑦ ᓇᐸᖅᑐᓕᖓᓂᑦ ᓄᓇᓗ ᐅᓇᕐᓂᖓᒍᑦ ᓯᕐᑯᐸᖓᑦ ᐃᓚᖏᑦ ᓄᓇᖅᑎᖕᓄᑦ ᑎᑭᑉᐸᑦᑐᑎᑉ.
- ᖃᐅᔨᓴᖅᑐᐊᖏᑐᒍᑦ ᖃᒪᓂᖕᖠᐊᑦ ᑐᑦᑐᖁᑎᖏᓐᓂᒃ ᐅᖃᐅᓯᕆᓇᖏᓇᕐᑕ ᒍᑯᓇᕐᑲᖓᓚ ᑲᕐᓂᐊᖅᑲᖓᓚ ᐊᓯᓕᕚᓕᐊᒪᖓᓚ ᑐᑦᑐᓂ ᐅᑭᐅᒥ ᖃᖏᖅᑐᕐᓂ, ᑭᓯᐊᓂᓕ ᐳᐊᑭᐸᐃᑦ ᑐᑦᑐᖁᑎᖏᑦ ᐅᐊᓕᓂᖓ ᐱᑕᖃᕆᐊᖃᖏᑦᑐᖅ ᓯᕗᓇᖅᑐᑦ ᐅᑭᐅᓂᒃ ᐊᒥᓯᓂᒃ ᐊᒥᓯᓂᖏᑦ ᓰᓂᓗᐊᖅᓯᒪᖏᑎᑐᑦ. ᑕᒪᓐᓇ ᑐᓴᕐᒥᓇᕐᒪᑦ ᐱᔪᓐᓇᖅᑐᑦ ᐊᓯᖏᖅᐸᓕᐊᓗᐊᖏᓪᒪᑕ!
- ᑐᑦᑐᑦ ᓄᑭᖏᑦ (ᓂᕿᖓ), ᐸᑎᖓ, ᖃᓇᑕᖓᓗ ᐱᔪᓐᓇᖅᑐᖃᓗᐊᖏᑦᑐᑦ.

ᖃᓄᐃᓕᐅᕈᓐᓇᖅᐱᑕ?

ᖃᐅᔨᓴᕐᓂᐅᑉ ᐱᓕᕆᐊᖓ ᑲᓇᑕᒥ ᓯᓚᕐᔪᐊᕐᒥᓗ ᐊᖏᕈᑎ ᑎᑎᕋᖅᓯᒪᓕᖓᓕᑦ ᒍᑯᓇᐅᑉ ᐊᑐᖅᑕᐅᓂᖓ ᐊᑦᑎᒍᑦ ᑎᑭᑉᐸᓕᐊᔪᖅ. ᒥᓂᒪᑕ ᐊᖑᕈᑎᖓ ᐊᑐᓇᐊᓚᐅᕐᒪᑦ ᐊᐅᒍᖅ 16, 2017 ᐅᑭᐅᖅᑕᖅᑐᒥ ᑐᑦᑐᑦ ᒍᑯᓇᒧᑦ ᐊᑐᒐᐅᕐᑯᖏᓐᓄᑦ. ᑕᒪᓐᓇ ᐱᕚᓕᐊᕈᑎᒋᓚᐅᖅᐸᕙ? ᖃᐅᔨᓴᕐᓂᐅᑉ ᑲᔪᓯᓂᖓ ᐊᕙᑎᕗᑦ ᒥᐊᓂᕆᔭᐅᕐᑯᓗᒍ ᐅᑭᐅᖅᑕᖅᑐᒥ ᓂᕐᔪᑎᑦ ᐊᑐᒐᐅᑎᐊᕐᑯᓗᑎᒃ.

ᖃᓄᐃᓕᐅᕈᓐᓇᕐᓂᐊᖅᐱᕋ?

ᐃᓚᐅᓗᑎᑦ ᖃᐅᔨᓴᕐᓂᒥ ᐱᓕᕆᐊᕐᓂᖅ, ᒪᑲᐃᑎᑦ ᑲᑎᒪᔾᔪᑎᖏᓐᓂ ᐃᓚᐅᓗᑎᒃ, ᐊᐱᕆᖕᓗᑎᑦᓗ!

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

Project Leader/Chef de projet

Jane Kirk, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON, L7S 1A1. Tel: (905) 336-4712; Email: Jane.Kirk@canada.ca

Amila De Silva, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON, L7S 1A1. Tel: (905) 336-4407; Email: Amila.DeSilva@canada.ca

Derek Muir: Environment and Climate Change Canada, 867 Lakeshore Road, Burlington, ON, L7S 1A1. Tel: (905) 319-6921; Email: Derek.Muir@canada.ca

Rainer Lohmann: University of Rhode Island, Narragansett, South Ferry Road Narragansett, Rhode Island 02882. Tel: (401) 874-6612; Email: rlohmann@gso.uri.edu

Peter Amarualik Sr, Resolute, NU, XOA OVO

Project Team/Équipe de projet

Liz Pijogge, Rodd Laing, Nunatsiavut Government, Nain, Labrador; Stephen Insley, Wildlife Conservation Society Canada, Whitehorse, YK; Xiaowa Wang, Christine Spencer, Camila Teixeira, Amber Gleason, Amy Sett, ECCC, Burlington, ON; Liisa Jantunen, Air Quality Research Division, ECCC, Toronto, ON; Yuxin Ma, Dave Adelman, Carrie A. McDonough, University of Rhode Island, Narragansett, Rhode Island; Ana Cabrerizo, Institute for Environmental Assessment and Water Research, Instituto de Diagnóstico Ambiental y Estudios del Agua - Consejo Superior de Investigaciones Cientificas (IDAEA-CSIC). Barcelona, Spain; Jean-Sebastien Moore, Université Laval, Québec QC; Igor Lehnherr, University of Toronto Mississauga, Mississauga, ON; Brent Else, University of Calgary, Calgary, AB

Project Location/Emplacement(s) du projet

- Barrow Strait near Resolute Bay, NU (74.612, -95.026)
- Wellington Bay near Cambridge Bay, NU (69.2363, -106.4448)
- Beaufort Sea near Sachs Harbour, NT (71.9327, -125.3251)
- Anaktalak Fiord near Nain, NL (56.4481, -62.0045)

Abstract

This project examines levels and time trends of contaminants in Canadian Arctic marine waters. The project started in May 2014 and built on previous work in Barrow Strait near Resolute in 2011 and 2012. Seawater samples for a full suite of contaminants were successfully collected from Barrow Strait under ice covered conditions (May-June 2017) and from open water (August-September 2017) using (i) passive samplers (thin plastic films) deployed for four to six weeks (ii) large volume water samplers (200 L), and (iii) Niskin samplers to obtain 1 L samples at various depths. A full suite of collections was also 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 and in the Beaufort Sea near Sachs Harbour in open water in August 2017. Analyses of 2016 samples are complete and major findings to date are that while levels of numerous industrial surfactant compounds, used as stain repellants and firefighting foams (perfluoroalkyl substances, PFASs), have not changed over the sampling time, perfluorooctane sulfonate (PFOS) has declined to non-quantifiable levels since the mid-2000s in Barrow Strait. Since 2015, this project has also investigated the presence of organophosphate ester (OPE) flame retardants and plasticizers in seawater using active and passive sampling methods. Analysis indicated much higher levels of OPEs in water compared to historically used brominated flame retardants. Mercury concentrations in Barrow Strait (2014-2016) remain unchanged compared to 10 years earlier (2004-05). This project is continuing in 2018-2019 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.

Résumé

Ce projet vise à étudier les niveaux de contaminants et les tendances temporelles s'y rapportant dans les eaux marines de l'Arctique canadien. Le projet lancé en mai 2014 s'articule autour des travaux réalisés en 2011 et 2012 dans le détroit de Barrow près de Resolute. On a réussi à prélever des échantillons d'eau de mer afin d'y détecter une gamme complète de contaminants dans le détroit de Barrow, sous la couverture de glace (mai-juin 2017) et dans les eaux libres (août-septembre 2017) à l'aide i) d'échantillonneurs passifs (pellicule de plastique mince) déployés pendant des périodes de quatre 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 saison des eaux libres en juillet. Des échantillonneurs passifs ont été déployés avec succès dans la baie de Wellington, près de la baie Cambridge, et dans la mer de Beaufort près de Sachs Harbour dans les eaux libres, en août 2017. L'analyse d'échantillons prélevés en 2016 est achevée. À ce jour, il en ressort essentiellement que, bien que les concentrations de nombreux composés tensioactifs industriels, utilisés comme apprêts antitaches et mousses extinctrices (substances perfluoroalkyliques, PFAS) n'aient pas changé au cours de la période d'échantillonnage, le sulfonate de perfluorooctane (SPFO) a diminué à des concentrations non détectables depuis le milieu des années 2000 dans le détroit de Barrow. Depuis 2015, ce projet s'est aussi penché sur la présence de produits ignifuges à base d'esters d'organophosphates (EOP) et de plastifiants dans l'eau de mer en recourant à des méthodes d'échantillonnage actives et passives. L'analyse a indiqué des concentrations en EOP dans l'eau nettement plus élevées que les agents ignifuges bromés traditionnels. Les concentrations de mercure dans le détroit de Barrow (2014-2016) demeurent inchangées par rapport à il y a 10 ans (2004-2005). Ce projet, qui se poursuit en 2018-2019, 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.
- In Resolute Bay higher concentrations of 16 organophosphate ester flame retardants and plasticizers were found compared to brominated flame retardants.
- Levels of most of the perfluorinated alkyl substances (PFASs) analyzed show no temporal trend between 2005 and 2017; however, PFOS, which was used in aqueous film forming foams needed for firefighting, has decreased over this period possibly due to international restrictions on production and usage.
- Early May snow melt is a source of long chain PFASs such as PFOS and PFOA while June to August sea ice melt is a source of short chain PFASs such as PFBA based on timing of peak surface water PFAS concentrations compared to the rest of the water column.
- Mercury/methylmercury concentrations at Barrow Strait (2014-2016) remain unchanged compared to 10 years earlier (2004-05).
- Mercury/methylmercury concentrations in Clyde River and Anaktalak Bay were much lower than in Barrow Strait.
- Methylmercury concentrations in seawater build up during the ice-covered period but decrease during the ice-free conditions, likely due to photodemethylation.

Messages clés

- On a mesuré les concentrations de nombreux polluants organiques persistants (POP) hérités du passé, nouveaux ou émergents, ainsi que de mercure dans des échantillons d'eau de mer prélevés dans le détroit de Barrow près de Resolute Bay, au Nunavut et dans d'autres régions de l'Arctique.
- À Resolute Bay, les concentrations de 16 agents ignifuges à base d'EOP et plastifiants ont été déterminées comme quasi identiques aux concentrations en agents ignifuges bromés.
- Les concentrations de la plupart des substances perfluoroalkyliques (PFAS) analysées n'indiquent aucune tendance temporelle entre 2005 et 2017. Toutefois, les concentrations de SPFO, qui étaient utilisés dans les mousses de type AFFF pour la lutte contre les incendies, ont diminué au cours de cette période, possiblement en raison des restrictions internationales en matière de production et d'utilisation.
- La fonte des neiges du début mai est une source de PFAS à longue chaîne, comme les SPFO et les acides perfluorooctanoïques (APFO), tandis que la fonte des glaces de mer de juin à août est une source de PFAS à courte chaîne, comme les acides pentafluorobenzoïques, en fonction du moment de la mesure des pics de concentrations de PFAS dans les eaux de surface en comparaison du reste de la colonne d'eau.
- Les concentrations de mercure et de méthylmercure dans le détroit de Barrow (2014-2016) demeurent inchangées par rapport à il y a 10 ans (2004-2005).

- Les concentrations de mercure et de méthylmercure à Clyde River et dans la baie Anaktalak étaient nettement plus faibles que celles relevées dans le détroit de Barrow.
- Les concentrations en méthylmercure dans l'eau de mer s'amplifient sous la couverture de glace, mais diminuent durant les périodes sans glace, probablement en raison de la photodéméthylation.

Objectives

This project aims to:

- sample seawater in Barrow Strait /Lancaster Sound near Resolute Bay for legacy and new/emerging organic contaminants using passive sampling methods at two time points over the spring/summer season in 2017-18:
  - During early melt (May -June)
  - During open water (August)
- compare the results from passive samples with active samples collected during that period;
- continue passive sampling for hydrophobic organics in Anaktalak Fiord near Nain, in the Beaufort Sea near Sachs Harbour, and in Wellington Bay near Cambridge Bay;
- collect seawater profiles for perfluorinated alkyl substances (PFASs), organophosphate ester flame retardants and plasticizers (OPEs also known as OPFRs) and mercury/methyl mercury using Niskin samplers in 2017-18: (1) During early melt (May -June) (2) During open water (August) in Barrow Strait/ Lancaster Sound and in Anaktalak Fiord;
- combine data accumulated from previous studies for hydrophobic POPs (including passives from 2012 and actives from 2007, 2008, 2012), PFAS, OPEs, and mercury/ methyl mercury in order to establish temporal trends in high central Canadian Arctic seawater; and,
- further 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 examines 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/ methyl mercury 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 from 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 became a core monitoring project in 2016-2017 and is contributing to the long-term monitoring plan for marine ecosystems.

New data on emerging organic contaminants in Arctic seawater has recently been published.

Jantunen et al (2015) and Jantunen (2014) reported ng/L concentrations of six OPEs in samples collected during the same cruises and noted that concentration of OPEs in arctic waters were high compared to polybrominated diphenyl ethers (PBDEs), organochlorine pesticides (OCPs) and current use pesticides (CUPs). Li et al (2017) reported eight OPEs in air and water in the northeast Atlantic between Greenland and Svalbard by sampling on board the Polarstern in 2014, with three types of chlorinated OPEs comprising 87% of the total concentrations. Li et al. hypothesized that glacier and snow melt contributed to high concentrations (5 to 9 ng/L) of OPEs in seawater in Arctic regions. These results are consistent with our preliminary survey of seawater in Barrow Strait. In 2007-2010, Morris et al. (2016, 2018) determined detection and concentrations of CUPs and brominate flame retardants (BFRs) in seawater from Barrow Strait, Rae Strait near Gjoa Haven and Cumberland Sound, and investigated bioaccumulation in the marine food web. Results showed that CUPs including endosulfan, dacthal, chlorpyrifos, and pentachloronitrobenzene, as well as BFRs including PBDEs, 2,4,6-tribromophenyl allyl ether, 1,2,3,4,5-pentabromobenzene and pentabromotoluene were detectable in the marine food chain with highest levels in invertebrates and arctic cod. Yeung et al. (2017) recently reported vertical profiles of PFASs in various sites in the central Arctic Ocean, excluding the Canadian basin, from 2012 to a depth of 3000 m. In that study, total PFAS concentrations were on average 0.80 ng/L and congener analysis indicated significant atmospheric inputs.

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, Heimburger et al. (2015) found a MeHg concentration maxima in the pycnocline waters, but at much shallower depths (150–200 m) than in other open oceans of the world. Heimburger et al. (2015) also 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 ecodynamics will likely lead to higher marine MeHg production".

Activities in 2017-2018

Field Work

Seawater samples were successfully collected from four locations this year including:

1. Barrow Strait near Resolute Bay (74.612, -95.026)
2. Wellington Bay near Cambridge Bay (69.2363, -106.4448)
3. Beaufort Sea near Sachs Harbour (71.9327, -125.3251)
4. Anaktalak Fiord near Nain (56.4481, -62.0045).

Passive samplers for hydrophobic organic contaminants were deployed by Resolute Bay resident Peter Amarualik and his son Jeffrey in Barrow Strait in May-June 2017 for a five to six-week period as well as in November 2017 (these latter samplers will be recovered in May 2018 to obtain a seven-month long record). Similarly, in Wellington Bay, passive samplers deployed in 2016 were successfully retrieved in August 2017 and new passive samplers were deployed and will be recovered in July 2018. At the Beaufort Sea and Anaktalak Bay sites, passive samplers were deployed in summer 2017 for four to six weeks by Stephen Insley (Wildlife Conservation Society Canada) and local resident Jeff Kuptana, and Nain resident and Nunatsiavut Environment Division Northern contaminant specialist, Liz Pijogge, respectively. Collection of smaller (1 L) 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) and Anaktalak Bay (August).

To compare contaminant values obtained from large volume and passive sampling methods, large volume samples (200-300 L) were also collected directly with a filter/XAD column pumping system in May and in 19 L stainless steel cans in early August in Barrow Strait. In May, the large volume sampling was done by Peter Amarualik and in August by team member Amy Sett working with Peter Amarualik and a local high school student, Tim Idlout. Water in the stainless steel cans was then extracted by pumping water through XAD resin at the Polar Continental Shelf Program (PCSP) lab in Resolute. Preliminary results suggest that the samples from the cans provides similar data for polychlorinated biphenyl (PCBs) and hexachlorobenzene (HCB) as the under ice samples.

Chemical Analyses

Samples were distributed to various labs in October 2018 and are being analyzed for several contaminant groups. Results for organic contaminants from 2016 are available while 2017 results are pending.

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 July 2017 with Environment and Climate Change Canada team member, Amy Sett, who assisted with clean protocols. Peter also sub-contracted a field assistant to help with work so that there are two people on the ice together at all times. At Nain, the sampling was led by Nain resident and Northern Contaminant Specialist with the Nunatsiavut Environment Division Liz Pijogge, who was assisted by Environment and Climate Change Canada team member, Amber Gleason.

Communications

This year, a short information sheet on the project, including photos, methods, and results to date, was approved by the Nunavut Environmental Contaminants Committee (NECC) and distributed to the Hunters and Trappers Association (HTA) of Resolute. In addition, we were very successful in reaching out to the community of Nain using the Nain Research Centre's website and social media, including Twitter and Facebook. For example, during the seawater sampling at Nain, live tweets of the field season were posted on the twitter feed (@JaneKirkHg) as well as the Nain Research Centre's twitter feed (@NG_Research). Co-lead Derek Muir visited the HTA office in Resolute in July 2017. Results from this project were also presented at five conferences/ workshops in 2016-2017 including the NCP Results Workshop and SETAC North America, where this work was presented in the Arctic Contaminants session, which was led and co-chaired by Kirk and De Silva.

Indigenous Knowledge Integration

Due to the logistic difficulties in using passive, large volume and Niskin sampling at Resolute and Nain, the success of this project is heavily dependent on the community field team's knowledge of the ice and water conditions in the area. Team members took photos of the ice conditions and compared conditions with those from previous years at the same time.

Results and Discussion

Perfluoroalkyl Substances (PFASs)

Total PFAS (sum of the 16 PFAS congeners) concentrations are <5 ng/L in Arctic seawater from Barrow Strait/Lancaster Sound (Figure 1) and Anaktalak Bay (data not shown). With the addition of perfluorobutanoic acid (PFBA) analyses in 2011, we are able to show that PFBA comprises the majority (56-90%) of the PFASs in Barrow Strait/Lancaster Sound. In fact, in our most recent sampling in Resolute, total PFAS was 2.2 ± 0.5 ng/L, which is higher than those recently reported by Yeung et al., likely because Yeung et al. did not analyze PFBA.

Due to the availability of earlier data from Barrow Strait/Lancaster Sound, an initial temporal analysis is possible and demonstrates that while PFOA concentrations shows no trend between 2005-2017, PFOS has decreased significantly over this period (Figure 2) with an elimination half-life of 4.4 years. In fact, PFOS levels measured in May 2014-2016 corresponded to 0.0036, 0.0046, and 0.0034 ng/L which are just below the limit of quantitation (0.005 ng/L). However, the most recent 2017 data had higher levels of PFOS (0.018 ng/L). The decreasing PFOS concentrations could be a result of international restrictions on production and usage of it and its precursors.

Figure 1. Concentrations of the 16 PFAS congeners that are currently being quantified in Arctic seawater. Panel a) all PFAS concentrations in deep (50-100 m) samples collected in May from Barrow Strait/Lancaster Sound over time from 2005-2017. Panel b) Concentrations of PFBA since 2011 (no samples were available in 2006, 2009, and 2013). Acronyms refer to perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), perfluorododecanoic acid (PFDoDA, perfluorotridecanoic acid (PFTrDA), perfluorotetradecanoic acid (PFTeDA), perfluorooctane sulfonate (PFOS), perfluoroethylcylohexane sulfonate (PFECHS), perfluorohexane sulfonate (PFHxS), perfluorobutane sulfonate (PFBS), perlfuorooctanesulfonamide (PFOSA).

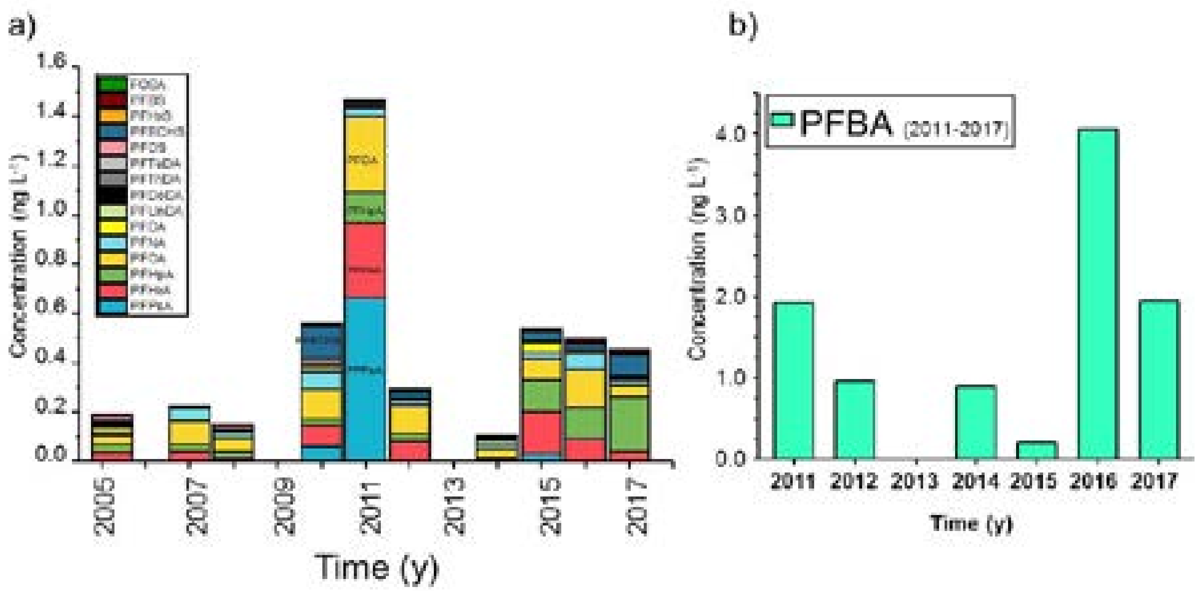


Figure 2. Temporal trends in PFOS and PFOA concentrations at Barrow Strait/Lancaster Sound near Resolute Bay, Nunavut 2005-2017 using natural logarithm of median values (ng/L). Error bars indicate standard deviation for concentration data in depths 10-100 m. Note: the temporal trend for PFOS does not include 2017 data.

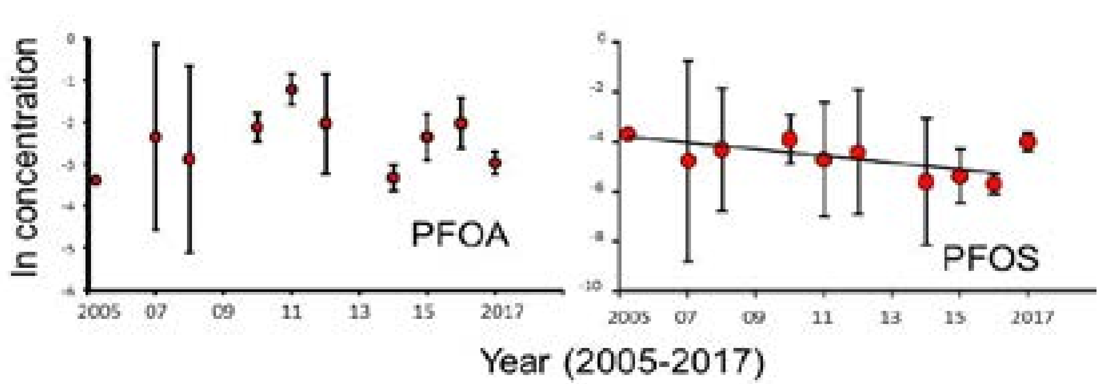


Figure 3. Water column profiles of select PFASs (PFBA, PFHxA, PFOA, and PFOS) during key time periods (ice melt, snow melt, snow and ice melt in May and June and open water conditions in August) at Barrow Strait/ Lancaster Sound.

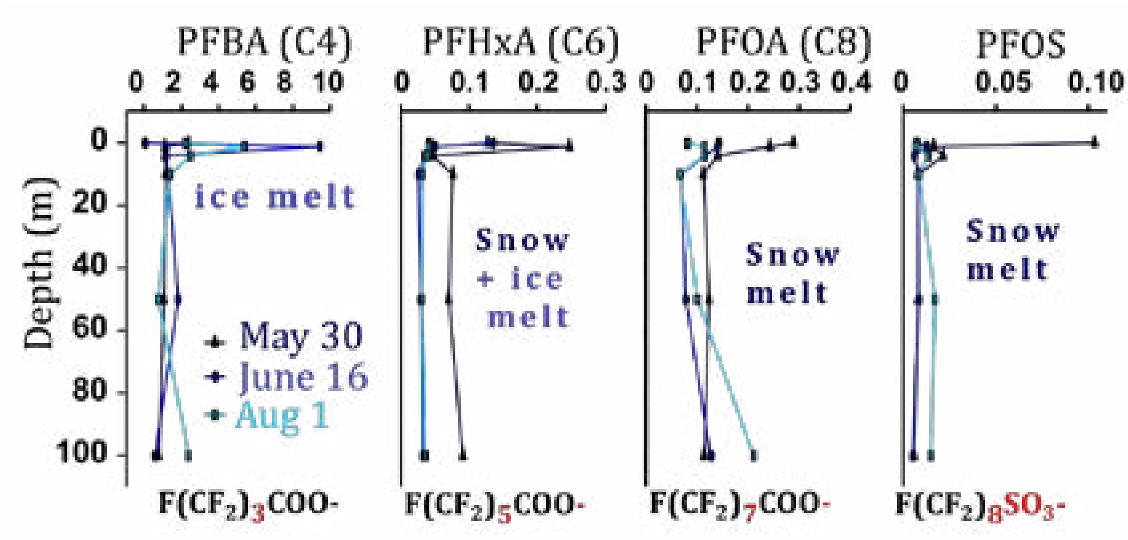
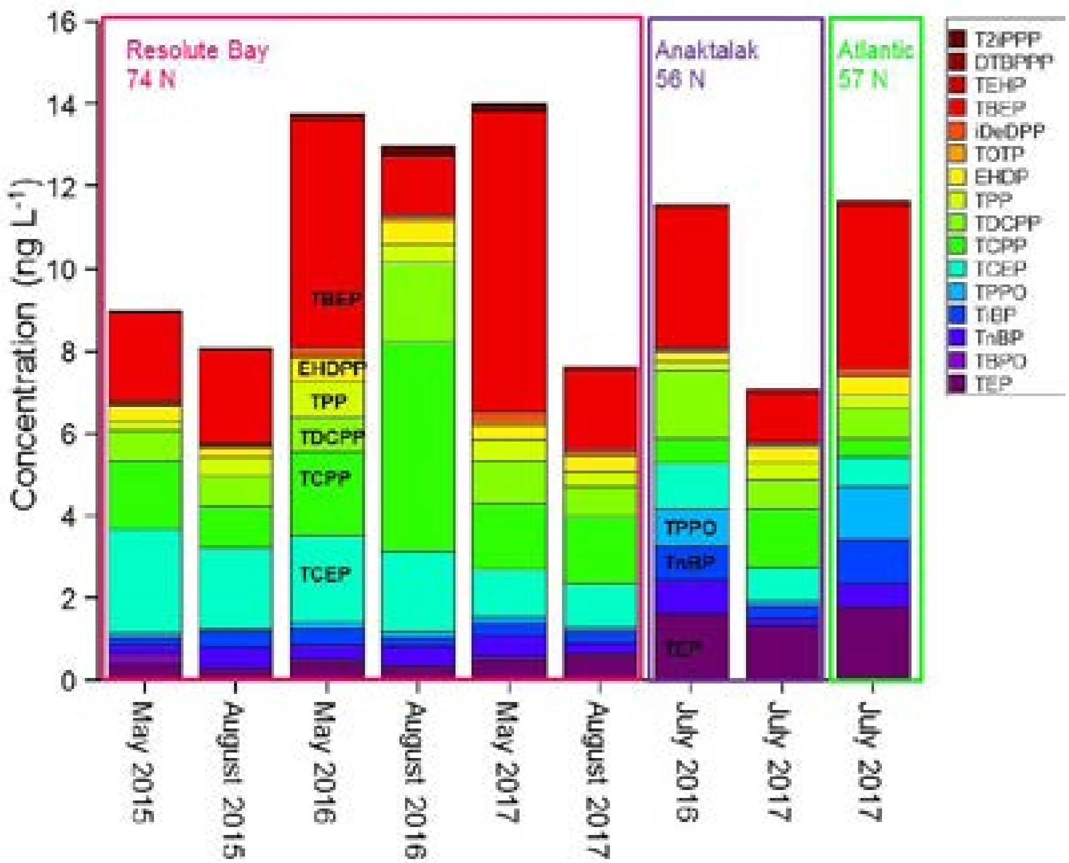


Figure 4. Concentration of organophosphate ester flame retardants and plasticizers in active water samples from Barrow Strait/Lancaster Sound near Resolute Bay, Nunavut 2015-2017, Anaktalak Bay in Labrador (56°26.99 N, 61°59.29 W) and a new 2017 reference site in the Atlantic Ocean (56°56.06 N, 61°17.00W).



Obtaining vertical profiles during different key spring/summer periods has also provided important information about the sources of different PFASs to Arctic seawater (Figure 3). In Barrow Strait/Lancaster Sound, elevated surface concentrations of long chain acids (such as PFOS and PFOA) during the early May spring melt suggest that snow melt is an important source of these congeners, while elevated surface concentrations of short chain acids (such as PFBA; C4) during the June-August melt periods suggest that sea ice melt is an important source of these congeners (Figure 3). For mid-length PFASs, such as PFHxA (C6), elevated surface concentrations during the early and late melt periods suggest a combination of snow and sea ice sources.

Organophosphate Ester Flame Retardants and Plasticizers (OPEs)

Analyses of 16 OPEs in Arctic seawater demonstrates a predominance of tributoxylethyl phosphate (TBEP) and triphenylphosphate (TPP) as well as the chlorine containing OPEs, tris(2-chloroisopropyl)phosphate (TCPP) and tris(2-chloroethyl)phosphate (TCEP) (Figure 4). These substances were also detected in ship-based air sampling in Resolute Bay (Sühring et al. 2016), suggesting long range transport potential of these substances. Concentrations of chlorine containing OPEs in Barrow Strait/Lancaster Sound and Sachs Harbour were also comparable to active sampling-derived OPE concentrations in seawater measured by Li et al. in the North Atlantic and Arctic Oceans (Table 1).

Comparison of 2015 and 2016 OPE data from active and passive sampling methods in Barrow Strait/Lancaster Sound and Sachs Harbour has been carried out (McDonough et al. 2018) and demonstrates that concentrations of TCEP and tris(1,3-dichloro-2-propyl)phosphate (TDCPP) were comparable among the two methods (Table 1). For example, mean passive sampling-derived TCEP concentrations were 1100 pg/L in Sachs Harbour and 1300 pg/L in Barrow Strait/Lancaster Sound, while active sampling-derived concentrations ranged from 818 – 2021 pg/L in Barrow Strait. The range of Tris(1,3-dichloro-2-propyl)phosphate (TDCIPP) concentrations from passive samplers were <DL (below detection limit) – 527 pg/L and <DL – 960 pg/L for active sampling. However, active-derived concentrations of TCIPP were greater (930 – 5667 pg/L) than passive-derived concentrations from active samplers (<DL – 600 pg/L), possibly due to differences in the fraction sampled among the sampling approaches or uncertainties in physicochemical properties used in calculating passive-derived concentrations. Both active and passive sampling efforts indicated higher concentrations of OPEs compared to brominated flame retardants. For example, in Barrow Strait total OPEs ranged from 7.6 to 15 ng/L whereas at the same site, total brominated diphenyl ether (BDE) concentrations were 0.003 to 0.015 ng/L. The difference in magnitude is similar to OPE and BDE concentrations measured in Arctic air (Sühring et al. 2016) and may be reflective of differences in physical properties or usage. Given the bioaccumulation and biomagnification of BDEs, Arctic biota such as seabirds, ringed seals and polar bears remain valuable sentinels for environmental exposure to BDEs. However, OPEs and short chain PFAS are more water soluble and in the case of OPEs, undergo metabolism. Therefore, this research project is highly pertinent for establishing environmental exposure for these contaminants and tracking temporal trends.

Mercury (Hg)

Depth profiles of total mercury (total Hg; all forms of Hg in a sample) and methylated Hg (includes both monomethylmercury (MeHg), the toxic and bioaccumulative form of methylated Hg and dimethylmercury (DMHg), the toxic, gaseous form of methylated Hg) from 2014-2016 compared to earlier data from 2004 and 2005 (St. Louis et al. 2007; Kirk et al. 2012) demonstrates that there is little variation in THg concentrations with time, depth, or among ice-covered and open water conditions (Figure 5). However, concentrations of methylated Hg are consistently lower at the surface in open water than under the ice, suggesting that methylated Hg species build up over the winter under the ice but are then photodemethylated in open waters after ice off (Figures 5 and 6). Concentrations of both THg and methylated Hg

Figure 5. Vertical profiles of total mercury (left) and methylated mercury (right) profiles in Barrow Strait (2014-16) and comparison with earlier measurements from St Louis et at. 2007 and Kirk et al. 2012.

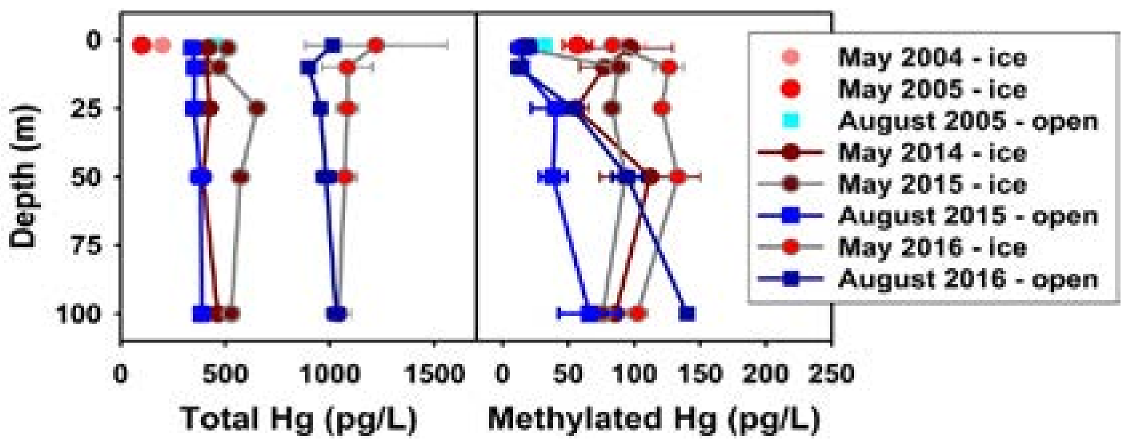


Figure 6. Concentrations of methylated Hg (includes both monomethyl Hg and dimethyl Hg) in surface waters under ice cover (left panel) and in open water (right panel) at Barrow Strait/Lancaster Sound 2004-2016.

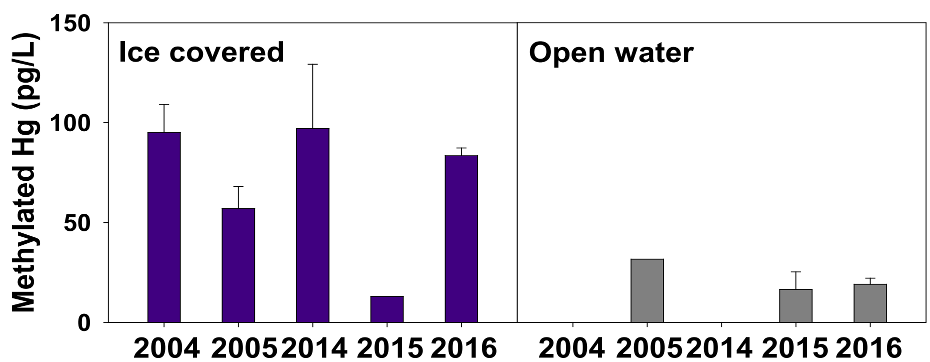
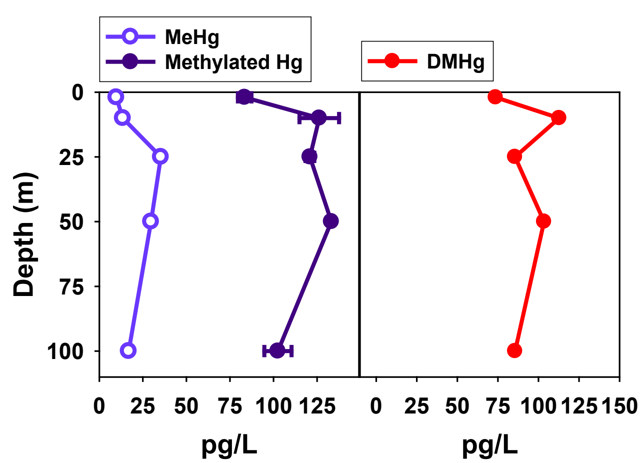


Figure 7. Vertical profiles of methylated Hg, monomethylmercury (MeHg) (left panel) and dimethyl Hg (DMHg; right panel, calculated by subtraction of MeHg from methylated Hg) at Barrow Strait/Lancaster Sound August 2016.



were much lower throughout the water column in open water conditions in both the Clyde River area in summer 2015 and Anaktalak Bay near Nain in summer 2016 than at our Barrow Strait location. This data is, thus, allowing us to begin to assess both temporal and spatial trends in seawater Hg concentrations in the Canadian Archipelago. 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 the majority of methylated Hg at this site is dimethyl Hg (Figure 7). This is important because volatile DMHg can be evaded to the atmosphere, where it is likely degraded to MeHg, representing a marine source of atmospheric MeHg (Baya et al 2014). This marine sourced atmospheric MeHg was recently shown to be an important MeHg source to lichen growing in Arctic coastal regions (St. Pierre et al. 2016).

Conclusions

This work is an ongoing project that is unique because of the general lack of reporting of contaminants in the water from marine areas, including the Arctic due to its logistic difficulty in sampling and requirement of advanced instrumentation to reach such low detection limits. By reporting the concentrations of legacy and emerging contaminants in three locations in the Arctic Archipelago and an additional site in Labrador, we are able to develop a comprehensive picture of Arctic marine contamination. By continuing to do this research each year, we will be able to quantify the change in contaminants in Arctic seawater in response to other perturbations (global production, climate, land development, increased traffic).

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 2017.

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Investigation of the toxic effects of mercury in landlocked Arctic char

Enquête sur les effets toxiques du mercure chez l'omble chevalier dulcicole

Project Leader/Chef de projet

Niladri (Nil) Basu, Associate Professor, Canada Research Chair (CRC) in Environmental Health Sciences, Center for Indigenous Peoples' Nutrition and Environment (CINE)
21,111 Lakeshore Road, McGill University, Ste. Anne de Bellevue, QC H9X 3V9. Tel: 514-398-8642; Email: niladri.basu@mcgill.ca

Benjamin Barst, Postdoctoral Fellow, Department of Natural Resource Sciences, 21,111 Lakeshore Road, McGill University, Ste. Anne de Bellevue, QC H9X 3V9.
Tel: 514-216-6019; Email: benjamin.barst@mcgill.ca

Project Team/Équipe de projet

Paul Drevnick, Alberta Environment and Parks, Environmental Monitoring and Science Division, Calgary, AB; Derek Muir, Aquatic Contaminants Research Division of Environment and Climate Change Canada, Burlington, ON; Debbie Iqaluk, Resolute Bay, NU; Günter Köck, Austrian Academy of Sciences and University of Innsbruck, Austria

Project Location/Emplacement(s) du projet

- Cornwallis Island, NU
- Small, North, Amituk lakes, Cornwallis Island, NU
- East and West lakes, Melville Island, NU

Abstract

In the Canadian Arctic, mercury (Hg) concentrations in the tissues of lake-dwelling Arctic char may exceed levels known to be toxic for fish. Starting in 2011, we began collecting tissues from landlocked Arctic char from Small, 9-mile, North, and Amituk lakes on Cornwallis Island in cooperation with the "core" monitoring project to determine whether wild Arctic char populations are experiencing Hg toxicity. To build upon our previous work, in 2017 we sampled Arctic char from three lakes representing a mercury contamination gradient on Cornwallis Island (Small, North, and Amituk), and Arctic char from twin lakes

Résumé

Dans l'Arctique canadien, les concentrations en mercure dans les tissus de l'omble chevalier lacustre peuvent dépasser les concentrations reconnues comme étant toxiques pour le poisson. En 2011, nous avons commencé à prélever des tissus de l'omble chevalier dulcicole des lacs Small, Nine Mile, North et Amituk de l'île Cornwallis en collaboration avec le projet de surveillance « de base » afin de déterminer si les populations sauvages étaient effectivement confrontées à la toxicité du mercure. En nous appuyant sur nos travaux réalisés en 2017, nous avons prélevé des échantillons d'omble chevalier de trois lacs représentant un gradient de

on Melville Island (East and West) that are undergoing climate-driven changes at different rates. Mercury, and other metals, are pro-oxidants, which can interfere with the anti-oxidant defense systems of fish leading to a state of oxidative stress. We have measured biomarkers of oxidative stress in the tissues of Arctic char to better understand the potential impacts of Hg contamination and climate change on fish health. In Arctic char collected in 2017, we noted inconsistent responses in antioxidant enzyme activities; glutathione peroxidase (GSH-Px) activity increased with total Hg in the livers of Arctic char, while catalase (CAT) activity decreased with increasing total Hg. TBARS, a measure of lipid damage, decreased significantly with liver total Hg across the study lakes. For East and West lakes, none of the oxidative stress biomarkers measured in livers differed significantly between the two populations. Conversely, GSH-Px activity was significantly higher in gills collected from West Lake Arctic char than those collected from East Lake. TBARS levels were higher in the gills of Arctic char collected from East Lake, though CAT activities were similar between the two populations. The results of our five-year study indicate that Arctic char do not effectively detoxify methylmercury in their tissues, which is correlated with changes in liver histology and the antioxidant defense system.

contamination au mercure sur l'île Cornwallis (Small, North, et Amituk), ainsi que des échantillons de la même espèce de lacs jumeaux sur l'île Merville (East et West) touchés par des modifications liées au changement climatique, mais à des niveaux différents. Le mercure (ainsi que d'autres métaux) est un pro-oxydant qui peut nuire aux systèmes de défense antioxydante des poissons et provoquer chez ces derniers un état de stress oxydatif. Nous avons mesuré les biomarqueurs du stress oxydatif dans les tissus de l'omble chevalier afin de mieux comprendre les conséquences possibles d'une contamination au mercure et du changement climatique sur la santé des poissons. En analysant les tissus de l'omble chevalier prélevés en 2017, nous avons constaté des incohérences au niveau de l'activité des enzymes antioxydants. Par exemple, l'activité du glutathion peroxydase (GPx) augmentait en fonction de la concentration totale de mercure dans le foie, alors que l'activité des catalases (CAT) diminuait plus la concentration en mercure était élevée. Le TBARS, une mesure des dommages lipidiques, a diminué de façon significative compte tenu de la concentration totale de mercure dans le foie dans les lacs à l'étude. Pour ce qui est des lacs East et West, aucun des biomarqueurs de stress oxydatif mesurés dans le foie des poissons ne différait de façon notable entre les deux populations. Réciproquement, l'activité du GPx était nettement plus élevée dans les ouïes de l'omble chevalier échantillonné dans le lac West comparativement aux ouïes de l'omble du lac East. Les niveaux TBARS étaient plus élevés dans les ouïes de l'omble chevalier échantillonné dans le lac East, bien que l'activité des CAT était analogue entre les deux populations. Les résultats de notre étude d'une durée de cinq ans indiquent que l'omble chevalier ne détoxifie pas le méthylmercure dans ses tissus, ce qui va dans le sens des changements observés dans l'histologie du foie et au niveau du système de défense antioxydant.

Key Messages

- Total Hg in Arctic char muscle varied among the five study populations.
- Oxidative stress biomarkers in livers varied among Arctic char populations.
- Oxidative stress biomarkers in liver varied with total Hg in liver.
- West Lake char had significantly higher total Hg concentrations in muscle, liver, brain, and gill tissues than Arctic char from nearby East Lake.

Messages clés

- La concentration totale en mercure dans le tissu musculaire de l'omble chevalier variait parmi les cinq populations étudiées.
- Les biomarqueurs de stress oxydatif mesurés dans le foie variaient parmi les populations d'omble chevalier.
- Les biomarqueurs de stress oxydatif mesurés dans le foie variaient en fonction de la concentration totale en mercure dans le foie.
- L'omble chevalier du lac West présentait des concentrations totales en mercure considérablement plus élevées dans ses muscles, son foie, son cerveau et ses ouïes, comparativement à l'omble chevalier du lac East, situé à proximité.

Objectives

This project aims to:

- finalize our study of Hg exposure, potential exposure-associated hepatotoxicity and neurotoxicity, and potential effects on general health and reproduction in landlocked Arctic char from "NCP focal ecosystem" lakes on Cornwallis Island;
- better understand the potential impacts of Hg in the context of climate change by studying two populations of Arctic char on Melville Island, which occupy lakes with watersheds undergoing climate-driven changes at different rates;
- better incorporate Indigenous Knowledge into our assessment of Arctic char health by surveying members of the Resolute Bay community;
- expand collaborations with the Nunavut Research Institute (NRI) by involving their students to participate in the proposed research in the field and at McGill University; and,
- 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 our team and others indicate that toxic effects are likely to occur at whole-body concentrations (wet weight) exceeding 0.2 μg/g (Beckvar et al. 2005), or 0.3 μg/g (Dillon et al. 2010; Sandheinrich and Wiener, 2011). Equivalent concentrations in edible muscle are 0.33 and 0.5 μg/g, respectively, or dietary concentrations of 0.2 μg/g (Depew et al. 2012). It is unclear how the 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 mercury 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, from 2015 and 2016 with funds from NCP we sampled Arctic char from Small, 9-mile, North, and Amituk lakes on Cornwallis Island to test a suite of hypotheses related to Hg hepatotoxicity and neurotoxicity.

Activities in 2017-2018

To investigate further the hepatoxic and neurotoxic effects of Hg on landlocked char, we first performed a subcellular partitioning procedure using the optic lobes from Arctic char collected in 2016 from Small, North, and Amituk Lakes. This procedure separates cells into metal-sensitive fractions (enzymes and organelles) and detoxified fractions (heat-stable proteins and metal-rich granules). We collected additional char (n=50 total) collected in 2017 from three lakes (Small, North, Amituk) near Resolute Bay, NU and two lakes (East and West) on Melville Island. East and West lakes are of importance because they have adjacent, geologically similar watersheds in the Cape Bounty Arctic Watershed Observatory (CBAWO), which are currently undergoing climate-driven changes at different rates. As in 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. For this project, samples of muscle from char from all lakes were analyzed for Hg_T with a direct mercury analyzer at Burlington's National Laboratory for Environmental Testing (NLET). Arctic char livers and brains from the five populations were collected for Hg determinations and for analyses of endpoints relating to oxidative stress (glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), catalase (CAT), and thiobarbituric acid reactive substances (TBARS) at McGill University. Due to the elevated levels of turbidity in West Lake, we hypothesized that West Lake char may accumulate significant levels of Hg (and potentially other metals) via gills. Therefore, gill tissues from East and West Lake char were also analyzed by direct mercury analyzer at McGill University. To date, all tissues have been analyzed for Hg_T and livers and gills (East and West) have been analyzed for TBARS, GSH-Px, and CAT. Liver SOD and the suite of oxidative stress biomarkers will be measured in brains collected in 2017 over the next few weeks.

Community Engagement

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. Members of the Resolute Bay community were surveyed on the health of Arctic char in the summer of 2017. The surveys were developed in collaboration with the Nunavut Environmental Contaminants Committee (NECC) and were carried out during Nunavut Coastal Resource Inventory surveys.

Capacity Building and Training

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 took 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 CIRNAC 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.

Communications and Outreach

Barst presented results at McGill's Northern Research Network Forum (Montreal, Canada), at the International Conference on Mercury as a Global Pollutant (Rhode Island, USA), and co-presented at the NCP Results Workshop (Yellowknife, NWT) with Muir. Both Barst and Muir took part in the Researcher EXPO at the 2017 NCP Workshop.

Indigenous Knowledge

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 six 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). Additionally, during the summer of 2017, members of the Government of Nunavut traveled to Resolute Bay to conduct interviews as part of the Nunavut Coastal Resource Inventory. During these interviews residents of Resolute Bay (n=9) were asked a series of questions about the health of Arctic char.

Results

Mercury in Char Tissues from the Five Study Lakes

Summary data for fish size and Hg_T concentrations in muscle, liver, brain, and gill (from East and West Lake char only) are provided in Appendix A. Total Hg in the muscle of all char collected from Small and East lakes were below the toxicity threshold for effects in fish reported by Beckvar et al. (2005; 0.33 µg/g wet wt. in muscle) and the threshold reported by Dillon et al. (2010; 0.5 µg/g wet wt. in muscle). Total Hg concentrations in individuals from West, North, and Amituk lakes exceeded both thresholds. Liver Hg_T concentrations were one to two times higher than muscle Hg_T concentrations – to a maximum of 3.4 µg/g wet wt. in an individual from Amituk Lake. Data produced in previous years, indicate that the majority of Hg_T in the liver is present as MeHg (mean = 101%).

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, and the other regions were used for Hg determinations. For char collected in 2017, brain Hg_T concentrations followed a similar trend as muscle and liver concentrations across the five lakes (East < Small < West < North < Amituk). Brain and liver Hg_T concentrations were significantly correlated ($r^2 = 0.87$, $p < 0.0001$) across lakes, and the ratio between the two approached unity with increasing liver Hg_T Similar to livers, the majority of Hg_T measured in the brains of Arctic char collected in 2016 was in the form of MeHg (mean ~100 %). The majority of the Hg_T present in the optic lobes of Arctic char collected in 2016 from Small, North, and Amituk lakes was associated with sensitive subcellular sites (Figure1). The mean Hg_T concentration in gill tissues collected from East Lake char was significantly lower than mean Hg_T in gill tissues collected from West Lake char ($p = 0.016$; Appendix A).

Oxidative Stress Biomarkers in Char Tissues from the Five Study Lakes

We measured the activities of GSH-Px and CAT, and measured TBARS in the livers of Arctic char from Small, North, Amituk, East, and West lakes collected in 2017. Mean GSH-Px activities in liver differed significantly among the char populations with the lowest levels in West Lake char and the highest in Amituk Lake char. Mean CAT activities differed significantly among the char populations. Arctic char from Amituk Lake had the lowest CAT activities followed by char from North, Small, West, and East lakes. Levels of TBARS in char liver differed significantly among the study populations with highest levels in Small, East and West Lake fish. Across lakes, GSH-Px activities were positively correlated with Hg_T in the livers of Arctic char ($r^2 = 0.13$, $p = 0.013$). Conversely, the activities of CAT were negatively correlated with liver Hg_T across the study lakes ($r^2 = 0.23$, $p = 0.0005$). Levels of TBARS decreased significantly with increasing HgT across the study lakes ($r^2 = 0.19$, $p = 0.0019$).

General Health Indicators in Char from the Five Study Lakes

For char collected in 2017, condition factor (weight X 100 / length^3), a measure of fish health, varied significantly among lakes; Arctic char from North Lake had the highest condition factor followed by char from East, Amituk, Small, and West lakes. Condition factor was not significantly correlated with Hg_T in muscle or liver. The gonadosomatic index ((gonad weight / total weight) X 100) for males and female char did not differ significantly among the 5 lakes studied. From all five study lakes, we captured 25 females, 19 males, and 6 immature fish. Half of the immature fish captured in 2017 were from West Lake.

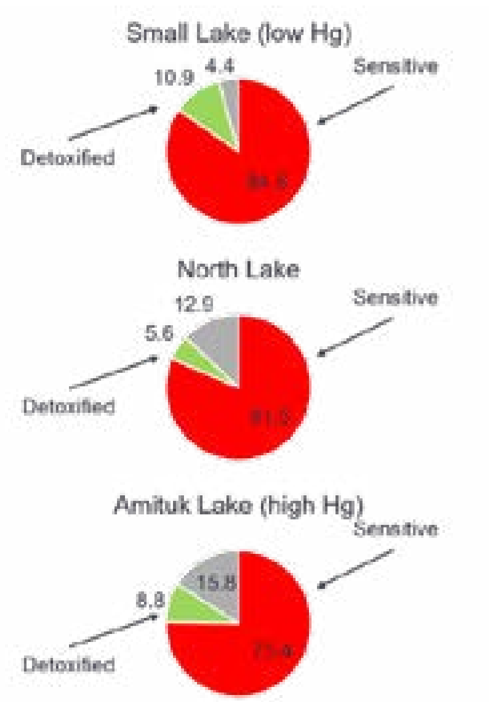
A Comparison of East Lake and West Lake Arctic Char

Mean Hg_T concentrations were significantly higher in muscle, liver, brain, and gill tissues of Arctic char from West Lake than those from nearby East Lake. None of the oxidative stress biomarkers measured in livers differed significantly between the two populations. Conversely, the activity of GSH-Px was significantly higher in gills collected from West Lake Arctic char than those collected from East Lake ($p = 0.021$). TBARS levels were higher in the gills of char collected from East Lake ($p = 0.017$), and CAT activities did not differ significantly between the two populations. The body condition factor of West Lake char was significantly lower than the condition factor of char collected from East Lake ($p = 0.003$).

Indigenous Knowledge

The list of questions and responses given by Resolute Bay community members regarding the health of Arctic char are provided in Appendix B. In general, the interviewees did not report unhealthy Arctic char populations on Cornwallis Island, Somerset Island, or Prince of Wales Island. Conversely, two interviewees noted larger sized char as well as larger populations. In lakes on Cornwallis Island, healthy landlocked Arctic char were noted in Resolute Lake and "skinny and small" landlocked char were noted in Twelve-Mile Lake. Fletcher Lake (Somerset Island) and Eleanor Lake (Cornwallis Island) Arctic char (sea-run) were chosen as the healthiest fish by 3 of the 9 respondents. Arctic char from the two lakes were also among the "tastiest", as were sea-run char from many of the lakes on the northeast portion of Cornwallis Island.

Figure 1. Subcellular distribution of total Hg in optic lobes of Arctic char (n=3 samples per lake) collected from Small, North, and Amituk lakes on Cornwallis Island in 2016. The red, green, and grey regions in each pie chart represent the percentages of total Hg associated with the sensitive fractions (enzymes and organelles), detoxified fractions (heat-stable proteins and metal-rich granules), and the debris fraction (primarily composed of unbroken cells), respectively.



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 five study lakes exceeded the 0.33 µg/g 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. We noted an increased incidence of liver fibrosis in Amituk Lake char collected in 2011 and 2012, which could be an effect of elevated Hg burdens. Despite these histological changes in Amituk Lake char, lipid peroxidation levels were higher in lower Hg fish from Small and West lakes. Our previous NCP-funded work indicated that Small Lake char had elevated concentrations of iron (Fe) in their livers (Barst et al. 2016), which like Hg can impact antioxidant defenses and result in lipid peroxidation. Higher levels of lipid peroxidation were associated with low body condition factors and low Hg burdens, highlighting the importance of considering other factors which may influence char health (such as Fe).

The apparent lack of a Hg detoxification mechanism in the liver may have implications for downstream organs such as the brain. Our results indicate that Arctic char accumulate Hg in the brain, which increases in concentration along the bioaccumulation gradient and is mainly in the more toxic form of MeHg. Additionally, Hg_T was primarily associated with sensitive sites within char brains. The presence of Hg_T in "inappropriate" sites such as mitochondria and enzymes may lead to deleterious effects. However, none of the biomarkers we measured in Arctic char collected in 2016 indicate that Hg results in neurotoxicity. In the coming weeks we will analyze oxidative stress biomarkers in the brains of char collected in 2017 to help increase statistical power, and to better understand if there is increased oxidative stress in brains of char as a result of their habitat undergoing rapid climate-driven changes (West Lake). Furthermore, we will analyze CAT activities in Arctic char brains for the first time. 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 ppm 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, CAT 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.

We included East and West Arctic char populations in our study to better understand the health of Arctic char in the context of climate change. Mercury and other metals have been measured in Arctic char from East and West lakes since 2008 by Derek Muir. Results show that several metals, including Hg, have increased in muscle tissues of West Lake char since monitoring began. Our work in 2017 demonstrates that Hg_T levels are significantly higher in West Lake char tissues than those of East Lake char. These higher Hg_T burdens, the lower condition factors, and differing oxidative stress biomarkers in gills indicate that char from West Lake are less healthy than their counterparts from East Lake.

Expected Project Completion Date

June 2018

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Appendix A

Table 1. Summary data for fork length, mass, and concentrations of total mercury (Hg_T) in muscle, liver, brain, and gill of landlocked Arctic char collected from lakes on Cornwallis Island (Small, North, Amituk) and Melville Island (East and West) in 2017.

				HgT (µg/g wet wt) muscle			HgT (µg/g wet wt) liver			HgT (µg/g wet wt) brain			HgT (µg/g wet wt) gill		
Lake	n	Fork length (cm)	Mass (g)	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Small	13	33.1	277.0	0.12	0.04	0.08 - 0.18	0.25	0.07	0.17 - 0.36	0.11	0.04	0.05 - 0.17	—	—	—
North	11	44.4	1019.5	0.44	0.17	0.11 - 0.62	0.69	0.40	0.25 - 1.51	0.30	0.16	0.05 - 0.68	—	—	—
Amituk	5	44.9	800.7	1.12	0.49	0.10 - 1.5	2.11	1.15	0.27 - 3.4	1.12	0.56	0.09 - 1.60	—	—	—
East	13	37.8	471.9	0.07	0.02	0.04 - 0.12	0.18	0.10	0.08 - 0.28	0.05	0.02	0.02 - 0.10	0.04	0.01	0.02 - 0.06
West	8	31.4	221.0	0.26	0.14	0.09 - 0.53	0.52	0.49	0.23 - 1.66	0.26	0.25	0.06 - 0.81	0.17	0.14	0.05 - 0.50

Appendix B

Table 2. The list of questions and responses given by Resolute Bay community members regarding the health of Arctic char.

Interview	Have you noticed any changes in the fish? Skinnier, change in colour, change in taste, look sickly?	Have you noticed any changes in the catch rates at these locations?	In which lakes do the fish appear to be the healthiest?	Which locations have the best tasting fish?	Which locations have fish with a large number of parasites?	Other comments
1	Odd fish comes out unhealthy - caught one once with a hump/hunch on its back (caught on westside of Somerset Island)	No noticeable changes	Resolute Lake (Cornwallis Island) - they're getting bigger	Eleanor Lake (Cornwallis Island) and Fletcher Lake (Somerset Island) (personal preference)	Worms are found in fish in Eleanor Lake (Cornwallis Island) - they're light in color	
2	No				No reports of any parasites	People usually go fishing from May-Sept/Oct due to the dark winter months
3	No	No	Fletcher Lake (Somerset Island) and Eleanor Lake (Cornwallis Island)		None - just some are found with scars from the seagulls	
4				Fletcher Lake (Somerset Island) Eleanor Lake (Cornwallis Island) and Laura Lakes (Cornwallis Island) (because they eat kinguk - Amphipods)		
5				A lake in northwest Cornwallis Island, Eleanor Lake (Cornwallis Island), Sophia Lake (Cornwallis Island), Lake near Depot Point (Cornwallis Island) are better tasting because they are sea-run		
6			Fletcher Lake (Somerset Island)			
7	Not really. Different diets of the fish will change its taste. Catching larger fish recently	No	The ones that eat amphipods are more desirable	Laura Lakes (Cornwallis Island), Eleanor Lake (Cornwallis Island), Crooked Lake (Prince of Wales Island), Fletcher Lake (Somerset Island)	Landlocked char have more parasites, not sure which lakes though	
8	Meretta Lake (Cornwallis Island) landlocked char are getting bigger and population is growing	The populations are growing and the fish are getting bigger	All healthy except for Twelve Mile Lake (Cornwallis Island), they're usually skinny and small	Creswell Bay, fatty fish there - Eleanor Lake (Cornwallis Island) ones are good, 'Back Bay' (Prince of Wales Island) has the best tasting fish	None - just some are found with scars from the seagulls	Resolute Lake (Cornwallis Island) usually has landlocked char but the sea-run char sometimes make an appearance
9	They get skinny and fat in their normal cycles		Fletcher Lake (Somerset Island) and Eleanor Lake (Cornwallis Island)	Fletcher Lake (Somerset Island)	Laura Lake (Cornwallis Island)	

Impact of climate change on the mobilization and bioaccumulation of persistent organic pollutants in arctic freshwater systems

Effets du changement climatique sur la mobilisation et la bioaccumulation des polluants organiques persistants dans les systèmes d'eau douce de l'Arctique

- **Project Leader/Chef de projet**
  Ana Cabrerizo, Amila De Silva, and Derek Muir, Water Science and Technology Directorate, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington ON L7S 1A1, Tel: 905-319-6921; Fax: 905-336-6430; anacabrerizopastor@hotmail.com; amila.desilva@canada.ca; derek.muir@canada.ca
- **Project Team/Équipe de projet**
  Jane Kirk, Xiaowa Wang, Chris Spencer, and Camila Teixeira, Environment and Climate Change Canada, Burlington, ON; Debbie Iqaluk, Resolute Bay, NU; Scott Lamoureux and Melissa Lafreniere, Queen's University, Kingston ON

- **Project Location/Emplacement(s) du projet**
  Cape Bounty, Melville Island, NU

Abstract

This long term study (2008-2016) examines trends over time in levels of legacy persistent organic pollutants (POPs) in landlocked Arctic char from West and East lakes in the Cape Bounty Arctic Watershed Observatory (CBAWO), on southern Melville Island. This study also helps assess the main terrestrial repositories of legacy POPs such as lake sediments, soils and vegetation. CBAWO is considered a remote and uninhabited location, 400 km from the nearest community of Resolute, Nunavut and represents an environment largely unimpacted by direct human activity. Due to its remoteness and absence of human activities, all organic pollutants found in freshwater and terrestrial compartments have been introduced through

Résumé

Cette étude à long terme (2008-2016) se penche sur les tendances temporelles des concentrations de polluants organiques persistants (POP) hérités du passé chez l'omble chevalier dulcicole des lacs East et West au Cape Bounty Arctic Watershed Observatory (CBAWO), situé au sud de l'île Melville. L'étude contribue également à l'évaluation des réserves terrestres principales de POP hérités du passé, comme les sédiments lacustres, les sols et la végétation. Situé à quelque 400 km de son plus proche voisin, la collectivité de Resolute, au Nunavut, le CBAWO est considéré comme un lieu éloigné et inhabité de même qu'un environnement en grande partie non perturbé par l'activité humaine directe. En raison de son éloignement et de l'absence d'activité humaine, tous les polluants

long range atmospheric transport. We've found that legacy POPs and OCPs in char declined in East Lake over the period 2008 to 2016 but have significantly increased (especially more hydrophobic chemicals such as polychlorinated biphenyls (PCBs) and DDTs) in West Lake. PCBs levels also showed an increasing trend in samples from the stomach content of the char (2008-2016) from West Lake. In West Lake higher levels of elevated particulate organic carbon (POC) and dissolve organic carbon (DOC) are probably associated with continued permafrost disturbances and subaqueous slumps in the West Lake and watershed. Increased levels of PCBs in char from West lake, together with increases in sedimentation rates, high turbidity, elevated POC and DOC, observed in West Lake, are altering the temporal trends of legacy POPs in Arctic char from West Lake.

organiques qui se retrouvent dans l'eau douce et les milieux environnementaux terrestres sont le résultat du transport atmosphérique sur de longues distances. Nous avons constaté que les concentrations de POP hérités du passé et en pesticides organochlorés (POC) chez l'omble chevalier du lac East ont diminué entre 2008 et 2016, mais qu'elles ont considérablement augmenté (en particulier pour ce qui est des produits chimiques hydrophobes, comme les biphényles polychlorés [BPC] et les DDT) dans le lac West. Les concentrations de BPC présentaient aussi une tendance à la hausse dans les échantillons prélevés du contenu de l'estomac de l'omble chevalier du lac West (2008-2016). Dans le lac West, les concentrations plus élevées en carbone organique particulaire (COP) et en carbone organique dissous (COD) sont probablement liées aux perturbations continues du pergélisol et aux effondrements subaquatiques dans le lac West et dans son bassin hydrographique. Les concentrations accrues en BPC chez l'omble chevalier du lac West, ainsi que les hausses des taux de sédimentation, la turbidité élevée et les concentrations élevées en COP et en COD dans le lac West influent sur les tendances temporelles des concentrations en POP chez l'omble chevalier du lac West.

Key Messages

- Legacy POPs such as PCBs and OCPs were measured for the first time in Arctic char, fish stomach content, lake sediments and vegetation samples collected in two lakes on Melville Island.
- Lipid content was observed to be a key factor controlling concentrations of PCBs and OCPs in Arctic terrestrial vegetation as well as the char.
- ΣPCBs, ΣHCH and ΣDDT levels in Arctic char from East Lake, which are not greatly impacted by permafrost disturbances, have declined significantly in the past 8 years.
- ΣPCBs and ΣDDTs in Arctic char from West Lake have significantly increased due to permafrost degradation which are greatly affecting this lake.

Messages clés

- Certains POP hérités du passé, comme le BPC et les POC, ont été mesurés pour la première fois chez l'omble chevalier ainsi que dans le contenu de l'estomac des poissons, dans les sédiments lacustres et dans des échantillons de végétaux prélevés dans les deux lacs de l'île Melville.
- Il a été observé que la concentration dans les lipides est un facteur déterminant du contrôle des concentrations de BPC et de POC dans la végétation terrestre ainsi que dans l'omble chevalier de l'Arctique.
- Les concentrations de ΣPCB, ΣHCH et ΣDDT chez l'omble chevalier du lac East, qui n'est pas fortement touché par les perturbations du pergélisol, ont considérablement diminué au cours des huit dernières années.

- Using data from sediment cores taken from each lake we found that fluxes of PCBs have leveled off in sediments from East Lake while significantly larger sedimentation rates and therefore of PCBs fluxes were observed in West Lake, especially after 2010.

- Les concentrations de ΣPCB et ΣDDT chez l'omble chevalier du lac West ont considérablement augmenté en raison de la dégradation du pergélisol qui touche particulièrement ce plan d'eau.

- À la lumière des données provenant des carottes de sédiments prélevées de chacun de ces lacs, nous avons constaté que les fluctuations des concentrations de BPC se sont stabilisées au niveau des sédiments du lac East, tandis que des taux considérablement plus élevés de sédimentation et, ainsi, de flux de BPC, ont été observés dans le lac West, particulièrement après 2010.

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 analysing:
  - water/snow, soil, vegetation, biota and in sediment cores, for legacy pollutants such as polychlorinated biphenyls (PCBs), recently regulated, such as brominated flame retardants (BFRs) and per/poly-fluorinated alkyl substances (PFASs); and
  - stable $\delta^{13}C$ signatures to assess changes in the sources of carbon delivered to these water bodies.

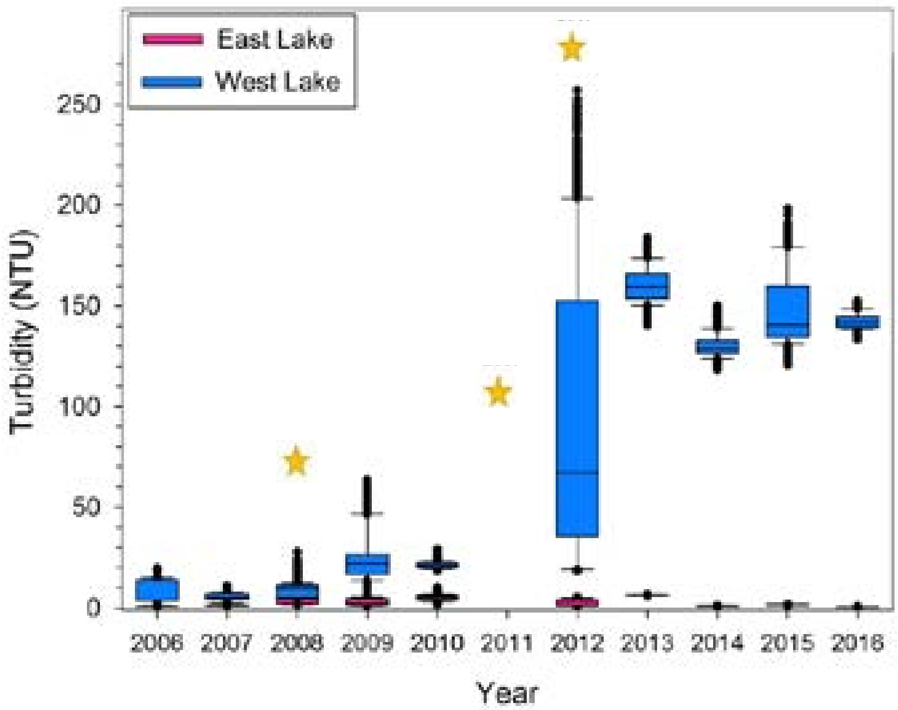
- examine temporal trends of PCBs, PBDEs and PFASs in archived landlocked arctic char samples from the selected area (2008-2016) in order to assess the effects over time of remobilization due to warming and compare with ongoing analyses of mercury and other elements; and,

- 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) located on Melville Island (74°55' N, 109°35' W) has revealed ongoing permafrost disturbances, which are of significant magnitude and importance on the West Lake watershed and lake, even though both catchments are broadly similar (Lamoureux & Lafrenière 2014; Lamoureux et al 2014). As illustrated in Figure 1 high turbidity combined with elevated particulate organic carbon (POC), dissolved organic carbon (DOC), and other water chemistry parameters, is associated with continued permafrost disturbances and subaqueous slumps in the West Lake watershed (Lamoureux & Lafrenière 2014; Roberts et al, 2018).

Figure 1. Turbidity (NTU) of East and West Lake (depths 10-20m) 2006-2016. Stars indicate dates of subaqueous slumps observed in West Lake: September 2008, December 2011, and February 2012. Note the large difference in turbidity between the two lakes



The water chemistry and discharge record at Cape Bounty is the longest of its kind in the North American Arctic (Favaro & 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). There are observations of rapidly rising DOC concentrations in aquatic ecosystems draining boreal aquatic systems (McGuire et al. 2008), peatlands (Parmentier et al. 2012) or permafrost thaw (Schuur et al. 2009). If destabilized, these C stores could dramatically increase organic pollutants as suggested recently for the sub-Antarctic environment (Cabrerizo et al. 2013). However, the coupling of these perturbations of the carbon (C), nutrient and hydrological cycles by climate change and the cycling of organic pollutants are still far from being well understood (Macdonald et al. 2005; Cabrerizo et al 2013). Therefore, there is a need to study the mobilization of organic pollutants (from legacy to emerging pollutants) due to climate disturbances from C-rich reservoirs into aquatic polar ecosystems and their impact into Arctic food webs.

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 2017-2018

The activities performed during 2017-2018 were mainly focused on the completion of sample analyses collected during 2016 and data analysis of legacy POPs and PFASs in temporal series of char from West and East Lakes, soil, vegetation, water and snow samples. Sediment cores, vegetation samples, zooplankton and fish stomach content samples from West and East Lakes were analysed for PCBs/OCPs/BFRs.

Analytical Methods

Samples from sediments, vegetation and zooplankton/fish stomach content for legacy POPs, were homogenized and shipped to ALS Global Laboratories (Burlington ON) for extraction and for lipid determination in the case of vegetation and zooplankton/stomach content samples. ALS Global Laboratories (Burlington ON) is accredited by the Canadian Association for Laboratory Accreditation and ISO 17025 certified. Briefly, a subsample of each type was spiked with a mix containing $^{13}C_{12}$-labelled PCBs and extracted with Soxhlet for 24 h in DCM. For sediment samples, ALS carried out the whole analytical procedure. For vegetation and zooplankton/fish stomach content samples, ¾ of the extracts were subjected to a gel permeation chromatography column (GPC) and shipped to Environment and Climate Change Canada (ECCC) in Burlington ON for further processing. The remaining ¼ of the extract was used for lipid determination. At ECCC a mix containing $^{13}C_{12}$-labelled PCBs (different to those used for extraction) was added to the extracts. Extracts were evaporated until 200 µl and cleaned on 5 g of activate silica (60-200 mesh silica gel). The fraction containing the PCBs and some OCPs was eluted with 60 ml of hexane. A second fraction containing the remaining OCPs was eluted with 90 ml DCM:hexane (1:1). Both fractions were concentrated on a TurboVap to 0.5 ml and reduced to 100µl under N_2 and underwent solvent exchange to isooctane. A mix containing PCB 30, 142 and $^{13}C_{12}$-labelled PCBs (CB-77, CB-81, CB-126, CB-169) was added and used as instrument performance standards. PCBs (70 congeners from mono to decachloro PCBs (Wellington Laboratories)) and OCPs (HCHs, including α-HCH, β-HCH and γ-HCH; DDTs including o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD o,p'-DDT, p,p'-DDT and HCB) were analyzed by gas chromatography (Agilent 7890B) coupled to tandem mass spectrometry (Agilent 7000C) (GC-MS/MS) operating in Multiple Reaction Monitoring (MRM) with a 60 m × 0.25 mm i.d. (RESTEK Rxi-5Sil MS) columns coated with 5% phenyl-95% methylpolysiloxane (film thickness 0.25 µm). After sample injection (splitless) onto the column (injection port temperature = 250°C), the GC temperature profile was as follows: (1) initial oven temperature was 90°C; held for two min (2) ramped at 15°C/min to 190°C, oven held 0.7 min (3) ramped at 3°C/min to 203°C, oven held five min (4) with the final ramp of 3°C/min to a maximum temperature of 300°C and the oven was held for five min. The MS transfer line, source and quadrupoles temperatures were 280 °C, 300°C, 180°C respectively. Both fractions were also run in a GC/MS operating in negative chemical ionization for the determination of BFRs.

Analyses of the legacy POPs and BFRs were conducted in clean laboratories of ALS Global Laboratories and at ECCC Burlington (Class 10000 equivalent lab with HEPA air filtration).

Quality Assurance (QA)

Reagent blanks were also run with each sample batch of 10 samples. Only few PCBs were detected in method blanks (CB 49, 52, 87, 95, 149), and its contribution were in the range from 3 to 7% of levels found in the samples. No blank correction was used.

Recoveries were routinely monitored in char, soil and vegetation using $^{13}C_{12}$-labelled PCBs and they ranged from 75 to 115 %. The labs involved in this study participated in the NCP interlab (Phase 11) comparison for 2017-2018.

Community Engagement

In spring of 2017, we informed NECC of the project and ask for their advice on any further consultations as well as on the information in the poster and suggestions for the Facebook page. As a result, we have highlighted and acknowledged the Inuit Community contribution to this project with a post dedicated about how the use of Indigenous knowledge was applied to our project. This was posted on the Facebook page on 17th Sept 2017,

Capacity Building

Indigenous knowledge from Inuit communities, especially from Debbie Iqaluk (Resolute Community) was used during fishing and other sample collections conducted for the completion of 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.

Communications

Results were presented at the NCP Results workshop in Yellowknife (September 2017), at the Dioxin Conference (Vancouver) in August 2017, at the Society of Environmental Toxicology & Chemistry conference in Minneapolis (November 2017), at the ArcticNet (Arctic Change) Scientific Meeting, Quebec City (December 2017), at the 38th International Symposium of Halogenated Persistent Organic Pollutants: Dioxin 2018 (Davos, Switzerland June, 2018) and at the Society of Environmental Toxicology & Chemistry conference in Helsinki (May 2019).

Indigenous Integration

Although Indigenous knowledge integration is not formally part of the project the success of the project depended heavily on the community field team's knowledge of the fish habitat in the lakes as well as ice and water conditions. Debbie Iqaluk is a co-author of scientific presentations and scientific papers on this study due to her key role.

Results

POPs in vegetation

Figure 2 presents the profile distribution of PCB homologs and selected OCP, HCB, in different vegetation types collected in catchment areas of West and East lakes. Σ_{70}PCB concentrations in vegetation (Figure 2) were in the range of 0.35-0.69 ng/g dry weight in lichen; 0.19-0.37 ng/g dw in mosses; 0.28-0.68 ng/g dw in grass, 0.35 ng/g dw in Arctic willow (*Salix Arctica*) and 0.42 ng/g dw in purple saxifrage (*Saxifraga oppositifolia*). Vegetation lipid content was very low in this study. Arctic mosses showed values <0.5%. Lipid content around 1% was detected in vascular plants (e.g. grass), Arctic willow and *Saxifraga oppositifolia*, while lichens showed slightly higher lipid content, in the range of 1.48 to 2.19 %. However, despite the low values, lipid content was observed to be a key factor controlling to levels of PCBs and OCPs in Arctic terrestrial vegetation since a significant dependence (p-level < 0.05) of individual PCBs ($r^2 = 0.52$-0.63) and OCPs ($r^2 = 0.47$-0.80) concentrations on lipid content were observed.

POPs in Arctic char

Figure 3 presents the long term trends of geometric mean lipid weight concentrations for four major POPs families, total hexachlorocyclohexanes (ΣHCH), total DDT-related compounds (ΣDDT), and sum of 70 PCB congeners/co-eluters (Σ_{70}PCB). Results for legacy POPs are complete to 2016.

Figure 2. Profile distribution of PCBs and HCB in different vegetation types collected in catchment areas of West and East lakes

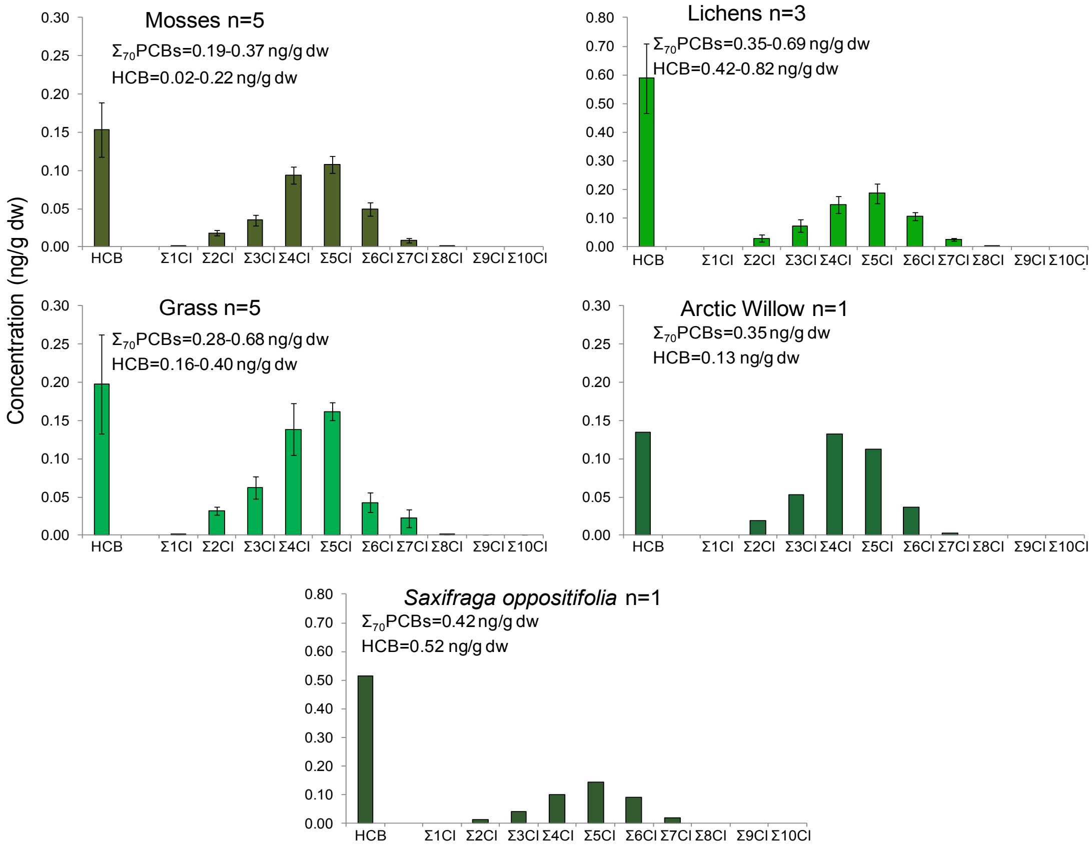


Figure 3. Trends of legacy PCBs and OCPs in landlocked char muscle from West and East lakes (2008 – 2016). Symbols represent geometric means of lipid adjusted concentrations. Error bars are also shown.

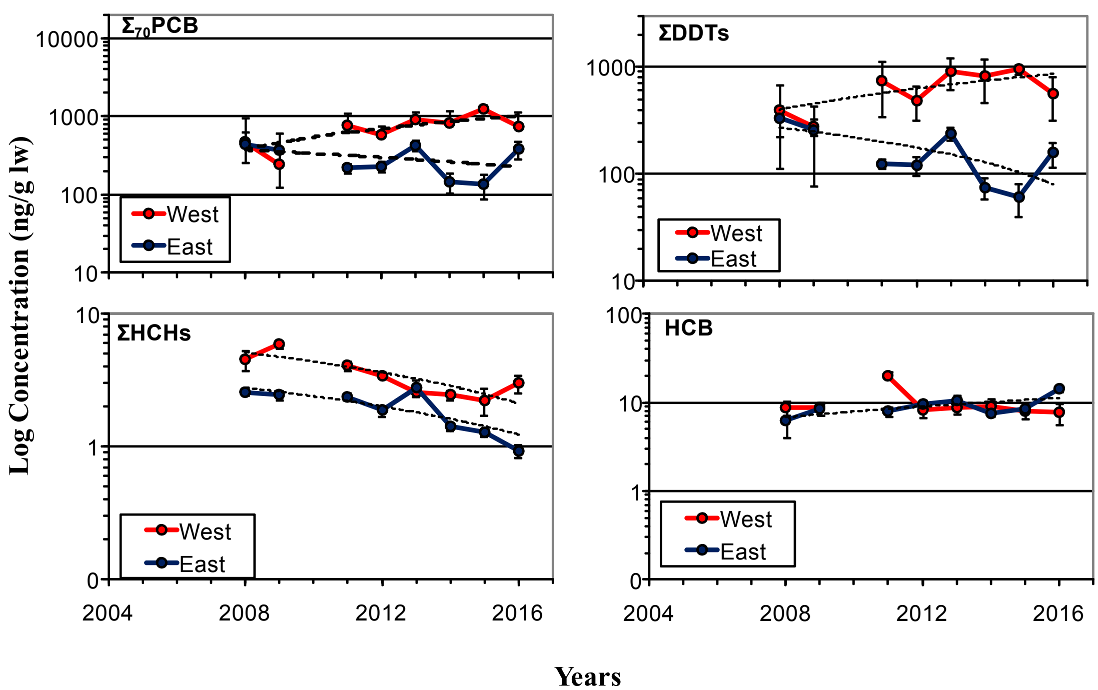


Figure 4. Trends of legacy PCBs and DDTs in the stomach content from West and East lakes (2008 – 2016).

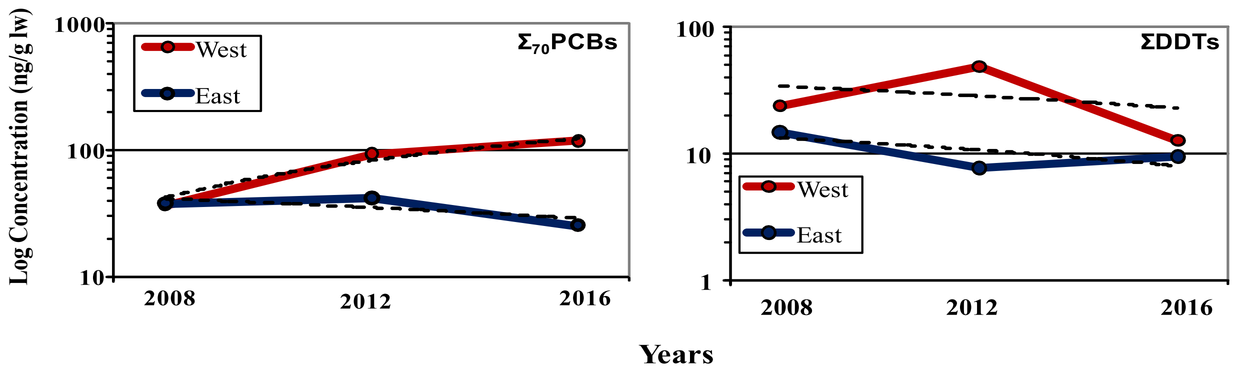
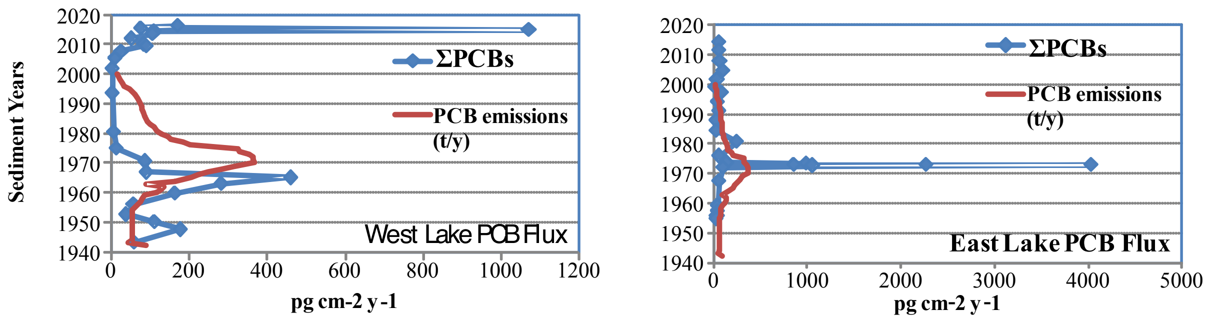


Figure 5. PCBs fluxes in sediment cores from West and East lakes and the estimated years. PCB emissions (in red) are based on estimates in Breivik et al. (2007)



Average concentrations of ΣPCBs, ΣHCH as well as ΣDDTs are higher in char from West Lake in comparison to char collected in East Lake (Figure 2), especially after the year 2009. No statistically significant differences were observed for HCB concentrations in both lakes. Observed declines in levels of ΣPCBs, ΣHCH and ΣDDT in char from East Lake over the past eight years, are consistent with the past national/ regional bans and restriction on uses/emissions of legacy PCBs and chlorinated pesticides in circumpolar and neighboring countries. More hydrophobic compounds such as Σ_{70}PCBs and DDTs in char from West Lake show a statistically significant increasing trend over the past eight years.

POPs in Fish Stomach Content from West and East lakes:

Figure 4 presents trends of lipid weight concentrations for Σ_{70}PCBs and ΣDDTs in the stomach content (e.g. midges) of char collected in West and East lakes at the initial, midpoint and end of the temporal series (2008, 2012 and 2016). Overall, concentration of Σ_{70}PCBs and ΣDDTs were higher in the stomach content of char collected in West Lake in comparison to char from East lake, especially after 2012. Additionally, statistically significant increase of Σ_{70}PCBs were observed in the stomach content of char from West Lake. These results suggest that available food in West Lake is more contaminated with legacy POPs than in East lake.

PCBs in Sediments from West and East lakes

The top 23 slices from the sediment cores, estimated to represent the past 90 years were analysed to assess the fluxes of PCBs in West and East lakes (Figure 5). Overall, the peak of PCBs emissions (tons/year) agrees well with the PCBs flux peak detected in both lakes in the 60s-70s. While the fluxes of PCBs have declined significantly in both lakes after the 1970s, consistent with the past national/regional bans and restriction on uses/emissions of legacy PCBs, increases on sediment accumulation rates from 2.69 g cm^{-2} yr^{-1} in 2010 up to 8.49 g cm^{-2} yr^{-1} in 2015 were observed in West Lake. Sedimentation rates in East Lake within the same period remained almost constant. The increases in sedimentation rates on West Lake since 2010 are likely due to sediment slumping and permafrost disturbances on West catchment as suggested by Roberts et al. (2018). This has resulted in significantly increasing fluxes of PCBs in sediments from West Lake.

Discussion and Conclusions

The results for legacy POPs shown in Figure 3, 4, and 5 are gradually bringing to light the influence of permafrost degradation and sediment slumping on temporal trends of POPs in Arctic char. The greater inputs of terrestrial carbon and higher turbidity occurred in West Lake especially after 2012 (Figure 1) are mobilizing old sources of PCBs attached to organic carbon, which are affecting the concentrations of PCBs and DDTs in the lower trophic levels (e.g. midges) and therefore exerting an important impact on temporal trends of PCBs and DDTs in Arctic char from West Lake. On the other hand, no significant disturbances are observed in East Lake, in which the declining trends of all pollutants have been observed. For those less hydrophobic compounds such as HCHs, HCB and PFASs (Cabrerizo et al. 2017) no significant differences in concentration on temporal trends in char were observed, likely due to the low sorption of these pollutants to the organic carbon. The analysis of pollutants in terrestrial compartments such as vegetation and soils collected in the catchments areas of West and East lakes show that both soils (Cabrerizo et al. 2017, 2018) and vegetation act as important repositories of hydrophobic PCBs and OCPs. Any alteration to Arctic soils or vegetation due to warming or other perturbations will likely provide large inputs of stored pollutants to the atmosphere and to adjacent rivers/lakes. These inputs could potentially affect water quality and arctic food webs, including those organisms such as caribou and reindeer that feed on arctic vegetation.

The findings of this study are very relevant not only for the international scientific community but also for local communities as freshwater environments such are lakes and rivers are major ecosystem features of the circumpolar Arctic and provide important sources of food (e.g. Arctic char) as well as drinking water for Inuit communities. Alteration of organic carbon sources (soil, sediments, etc.) due to accelerated warming as those observed in West Lake could decrease the quality of food and increase levels of legacy PCBs and DDTs.

Expected Project Completion Date

The funding for this project ended on March 31, 2018. Data analysis is complete and manuscript preparation is underway.

Project Website

A Facebook account was set up for the project that includes relevant information of the project. https://www.facebook.com/Biopollar.

Acknowledgments

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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

- **Project Leader/Chef de projet**
  Kyle Elliott, Department of Natural Resource Sciences, McGill University, Ste-Anne-de-Bellevue, QC. Tel: (514) 398-7907; Fax: (613) 3987990; E-mail: kyle.elliott@mcgill.ca

  Kim Fernie, Ecotoxicology & Wildlife Health, Science & Technology Branch, Environment & Climate Change Canada, Burlington, ON. Tel: (905)-336-4843; Email: kim.fernie@canada.ca
- **Project Team/Équipe de projet**
  Birgit Braune, and Robert Letcher, Environment and Climate Change Canada, Ottawa, ON; Jessica Head, Department of Natural Resource Sciences, McGill University, Montreal, QC

- **Project Location/Emplacement(s) du projet**
  Coats Island, Hudson Bay

Abstract

Pagophilic (ice-associated) Arctic species are facing multiple stressors from climate change and toxic contamination. We investigated whether contaminants magnified the impact of climate change on wildlife by limiting their ability to respond to changes in ice availability. In 2017-2018, 67 thick-billed murres were tracked via GPS-accelerometers, and concentrations of hormones, mercury and per-/polyfluoroalkyl substances (PFAS) were measured in the blood plasma of 47 of the 67 birds. We investigated concentrations of these contaminants in relation to circulating hormone levels to determine whether contaminants disrupted foraging activities. Levels of PFASs were low, and unrelated to hormones or behaviour. However, mercury levels were associated with pre-trip levels of circulating triiodothyronine (T3) hormones. In contrast to a medium-ice year (2016), in a

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 intensifiaient l'impact des changements climatiques sur les espèces sauvages en limitant leur capacité à réagir aux changements de disponibilité de la glace. En 2017-2018, on a suivi 67 guillemots de Brünnich au moyen d'accéléromètres GPS et on a mesuré les concentrations d'hormones, de mercure et de substances perfluoroalkyles et polyfluoroalkyles (PFAS) dans le plasma sanguin de 47 des 67 individus. Nous avons étudié les concentrations de ces contaminants par rapport aux niveaux d'hormones circulantes afin de déterminer si les contaminants perturbaient les activités d'alimentation. Les concentrations en PFAS étaient faibles et n'avaient aucun lien avec les hormones ou le comportement.

low-ice year (2017), the relationship between T3 and Hg was negative. The pre-trip levels of T3 were associated with foraging behaviour; in contrast to 2016, higher levels of T3 were associated with lower diving rates. We found no associations with corticosterone. GPS tracks demonstrated that birds foraged to the north of the colony during incubation (when ice was present) and moved to forage to the northwest as chick-rearing progressed (when ice was no longer present). Birds from each subcolony partitioned the space available. Thus, mercury was negatively associated with T3, which may relate to decreased diving rates away from ice concentrations. Based on our collective 2016-18 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 2018 with a larger sample size and different environmental conditions.

Toutefois, les niveaux de mercure étaient associés aux concentrations d'hormones circulantes de type triiodothyronine (T3) avant sorties. Contrairement à une année d'englacement moyen (2016), la relation entre T3 et le mercure était négative lors d'une année de faible englacement (2017). Les concentrations de T3 avant sorties étaient associées au comportement de recherche de nourriture; contrairement à 2016, des concentrations plus élevées de T3 étaient associées à un taux de plongée plus faible. Nous n'avons trouvé aucun lien avec la corticostérone. Les suivis GPS ont permis de démontrer que les oiseaux s'alimentaient au nord de la colonie durant l'incubation (en présence de glaces), puis se déplaçaient vers le nord-ouest pour s'y alimenter au fil de l'élevage des petits (lorsque les glaces avaient disparu). Des oiseaux de chaque sous-colonie occupaient l'espace disponible. Par conséquent, il existe une corrélation négative entre le mercure et le T3, ce qui pourrait avoir un lien avec la diminution du taux de plongée loin des concentrations de glace. En nous fondant sur nos données collectives recueillies de 2016 à 2018, 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 2018 à l'aide d'une gamme d'échantillons plus vaste et dans différentes conditions environnementales.

Key Messages

Reduced ice cover associated with climate change is altering how ice-obligate animals forage, sometimes leading to reduced reproductive success and survival. Contaminants may add additional stress to already-stressed populations. Levels of BFRs and PFAS were quite low. However, mercury may influence the ability of murres to adjust to variation in ice cover via associations with hormones. The underlying mechanism appears to vary among years of varying ice concentrations.

Messages clés

La diminution de la couverture de glace liée aux changements climatiques modifie les modes d'alimentation des animaux dépendants de la glace, ce qui entraîne parfois une diminution de la reproduction et de la survie de telles espèces. Les contaminants peuvent exacerber le stress des populations. Les concentrations d'agents ignifuges bromés 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 glace en raison de leur association avec les taux d'hormones. Les mécanismes sous-jacents semblent varier d'une année à l'autre selon les différentes concentrations mesurées dans la glace.

Objectives

This project aims to:

- obtain plasma samples from 60 incubating male murres before and after each GPS deployment (male murres will be focused on in 2017 to avoid sex as a confounding variable in analyses and because only males are present on the colony during daylight);
- analyze initial blood samples from all 60 male murres for mercury, and a sub-sample for NCP-priority brominated and perfluorinated compounds;
- measure biomarkers (free/total T3/T4; total corticosterone) on those same plasma samples from before and after each GPS deployment;
- monitor energy expenditure and gain of birds monitored for contaminants by attaching GPS-accelerometers to 60 incubating thick-billed murres at Coats Island; and,
- use a path analysis to link contamination with energy expenditure and intake with hormone levels.

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 sets 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, and leading seabirds to use unsustainable levels of energy to find food (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 our 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 2017-2018

Sample Collection/Analysis

Between July 20 and August 5, 2017, Kyle Elliott, along with students Allison Patterson, Scott Flemming, Esteban Gongora, Sarah Poole and Emile Brisson-Curadeau, and research assistant Josiah Nakoolak (Coral Harbour), collected blood samples from 46 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. In total, GPS data was collected from 66 individuals; however, we were unable to obtain second blood samples from 20 individuals (either because of difficulty retrapping birds meant that retrap date was beyond a biologically meaningful post-deployment date or because of difficulty in obtaining a 5 mL blood sample in the field). The Lab Services Unit at the National Wildlife Research Center (NWRC) analyzed total mercury in the red blood cells of all 46 birds. NWRC Lab Services will also use red blood cells to confirm the genetic sex of all birds for which genetic sex is not already known (Method MET-DNA-SEX-01C). Levels of PFASs were measured in 46 birds by the Letcher Organic Contaminants Research Laboratory (ORCL). Also, plasma from all 46 birds was analyzed for free and total forms of triiodothyronine and thyroxine (NWRC Lab Services) and corticosterone (J. Head). Behavioural analyses from GPS-accelerometers were undertaken by PhD student Allison Patterson and MSc student Emile Brisson-Curadeau.

We successfully achieved our objectives as described in our 2017-2018 NCP proposal, with the exception of being unable to obtain second blood samples from 14 birds due to the above constraints. Given the results from 2016-17, we focused on measuring PFAS and Hg in as many individuals as possible rather than measuring additional legacy POPs and BFRs on fewer individuals. However, we were able to obtain PFAS levels from more individuals than had originally been envisioned. All GPS-depth-accelerometer data are archived at MOVEBANK.

Analytical Methods

Analyses of total Hg were carried out by NWRC Lab Services in Ottawa, Ontario. 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). Both the Lab Services Unit and the OCRL at the NWRC also participated separately in the NCP's QA/QC Program. All samples are archived in the National Wildlife Specimen Bank at the NWRC in Ottawa.

Community Engagement

As in past years, all appropriate Canadian Wildlife Service (CWS) and Nunavut research and collection permits will be obtained, the process of which includes consultation with northern communities in the surrounding area. The HTO in the hamlet of Coral Harbour, which is the closest community to Coats Island, is contacted by a project team member by translated FAX prior to the field season, to update them on plans. Paul Smith (S&T, Ottawa) met with the Coral Harbour HTO in March 2016 to make a presentation on all marine bird research being conducted in the eastern Canadian Arctic, including Coats Island. A presentation by Paul Smith to the Coral Harbour HTO on all bird research being conducted in the eastern Canadian Arctic, including Coats Island, was attempted in March 2017. Due to poor weather, Dr. Smith was unable to make it to Coral, and so the consultation occurred remotely. An additional consultation occurred in Winter 2018 to update the community on progress and determine how to proceed.

Capacity Building

We built substantial capacity in 2017-2018 via the training of seven students: Sarah Poole, Ana Morales, Esteban Gongora, Scott Flemming, Emile Brisson-Curadeau, Ashley Hanas and Allison Patterson. Sarah, Scott Esteban, Allison and Emile conducted field research in the North. Ashley and Ana 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 2017, and spent time helping to select birds for blood sampling, capturing birds, and handling birds. We tried to recruit another individual from Coral Harbour to help with research, but were unable to find anyone willing to participate. Also, with NCP support, students in the NAC Environmental Technology Program attended a lecture that highlighted seabird contaminant monitoring work in Nunavut. Finally, Jupie Angootealuk, who will participate in the research expedition in 2018-2019, was flown to the Arctic Change meeting in Quebec City during December 2017 to participate in a science meeting.

Communications

We presented a platform talk entitled "Climate change, contaminants, ecotoxicology: interactions in Arctic seabirds at their southern range limits" at the DIOXIN meeting in Vancouver. We also presented a platform talk entitled "Does mercury interfere with thick-billed murres' ability to respond to ice disappearance at their southern range limits in the Canadian Arctic?" at Arctic Change in Quebec City.

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 April 2018 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 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.

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 1.37 ± 0.31 µg/g dry weight (0.46 ± 0.12 µg/g wet weight), ranging from 0.81 to 2.28 µg/g dry weight (0.20 to 0.78 µg/g wet weight). Levels of PFAS were uniformly quite low (Table 1). PFOS and PFUdA, followed by PFTrDA, were the PFASs present in the highest concentrations (Table 1).

Table 1. Levels of PFASs in thick-billed murre plasma (in ng/g wet weight).

	Average	SD	Minimum	Maximum
PFEtCHxS	0.032	0.026	0.010	0.078
PFBS	0.041	0.027	0.012	0.126
PFHxS	0.153	0.084	0.027	0.447
PFOS	3.317	1.340	1.108	6.481
PFDS	0.044	0.027	0.024	0.081
PFBA	0.218	0.105	0.192	0.639
PFPeA	0.024	0.045	0.015	0.276
PFHxA	0.070	0.048	0.013	0.281
PFHpA	0.055	0.057	0.013	0.245
PFOA	0.195	0.091	0.074	0.563
PFNA	0.736	0.338	0.008	1.509
PFDA	0.745	0.193	0.450	1.220
PFUdA	3.725	0.735	2.712	6.176
PFDoA	0.798	0.163	0.560	1.215
PFTrDA	2.125	0.524	1.322	3.373
PFTeDA	0.337	0.086	0.199	0.523
PFHxDA	0.092	0.115	0.027	0.450
PFODA	0.006	0.002	0.005	0.015

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 2). 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 $t_{23} = 2.17$, $P < 0.04$).

Table 2. Hormone levels in thick-billed murre plasma pre- and post- foraging trips.

Biomarker	Average	SD	Minimum	Maximum
Pre-trip Free T4 (pg/mL)	13.34	9.06	1.63	67.00
Pre-trip Free T3 (pg/mL)	3.25	1.87	0.62	9.62
Pre-trip Total T4 (ng/mL)	19.91	9.07	1.50	43.30
Pre-trip Total T3 (ng/mL)	0.88	0.48	0.18	2.86
Post-trip Free T4 (pg/mL)	10.25	5.26	3.50	28.60
Post-trip Free T3 (pg/mL)	2.38	1.86	0.08	6.70
Post-trip Total T4 (ng/mL)	13.12	9.54	1.50	42.20
Post-trip Total T3 (ng/mL)	0.67	0.46	0.10	2.78
Pre-trip Corticosterone (pg/mL)	112.23	210.84	0.26	755.38
Post-trip Corticosterone (pg/mL)	238.15	382.36	0.26	1499.53

Objective 3

Foraging parameters are reported in Table 3. Daily energy expenditure was measured from the accelerometers using dynamic body acceleration. Dynamic body acceleration averaged 0.35 ± 0.15 g, which translated into an estimate of daily energy expenditure of 1824 ± 631 kJ/d. The primary foraging area switched from the area north of the colony during incubation (when ice was present) to the area northwest of the colony during chick-rearing (when ice was not present), with several individuals spending significant time between the colony and Bencas Island (Fig. 1).

Figure 1. Utilization distributions (UDs) for thick-billed murres at three different stages based on GPS-accelerometers (bottom right) attached to birds. The percentage UD represents the percentage of points that are utilized by the particular distribution. For example, a 25% UD means that the area includes the core 25% of points.

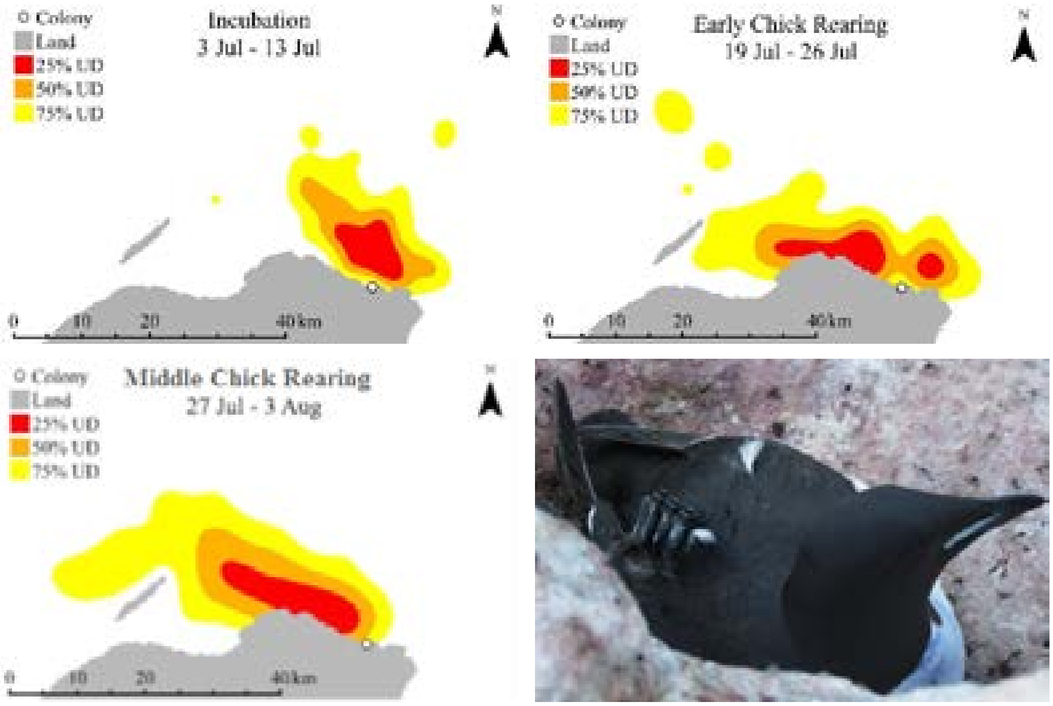


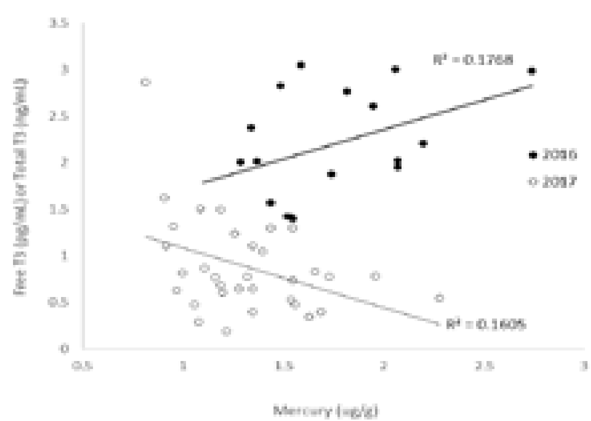
Table 3. Foraging parameters for thick-billed murres at Coast Island in 2017.

	Average	SD	Minimum	Maximum
Time spent diving per day (h)	2.63	1.55	0	6.7
Time spent flying per day (h)	1.88	1.22	0	4.7
Time spent swimming per day (h)	5.84	5.72	0.1	17
Dive depth (m)	48.64	31.54	0	134
Maximum distance from colony (km)	19.63	12.92	0.02	87
Stops per trip	3.97	2.59	1	16

Objective 4

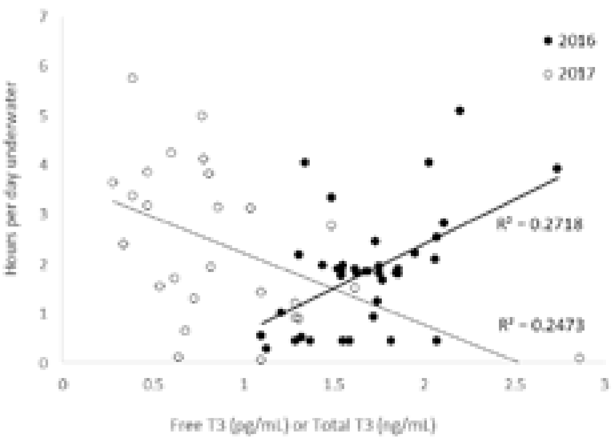
There was no relationship between the first or second principal component of any of the three organohalogen contaminant groups and any of the biomarkers (all $P > 0.05$). However, there was a significant, but weak, relationship between mercury levels and total T3 across individuals ($t_{14} = -2.03$, one-tailed $P = 0.02$; $R^2 = 0.16$; Fig. 2).

Figure 2. Pre-trip free T3 (2016) and total T3 (2017) levels as a function of mercury levels in thick-billed murres at Coats Island.



There was a significant, negative association between total T3 and hours per day underwater (t_{25} = 6.84, $P < 0.0001$; R^2 = 0.25; Fig. 2). There were no other associations between hormone levels and daily energy expenditure, time spent diving or time spent flying. As indicated by Fig. 1 and 2, and relationships therein, the overall path analysis indicated that mercury had a statistically-significant effect on total T3, which then affected time spent diving.

Figure 3. Pre-trip free T3 levels (2016) and total T3 levels (2017) relative to time spent diving for thick-billed murres at Coats Island.



Discussion and Conclusions

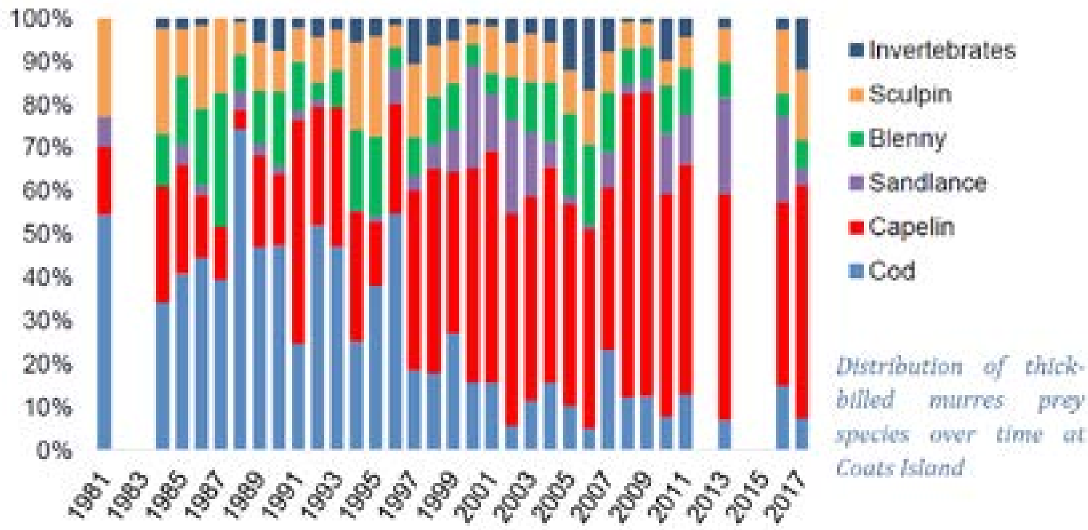
T3 is the biologically active thyroid hormone in vertebrates (McNabb 2007). High T3 is associated with high resting metabolic rate, which can aid in thermoregulation (McNabb 2007; Welcker et al. 2012; Elliott et al. 2013). In warm waters, high T3 may reduce dive duration by increasing oxygen consumption during dives (i.e. metabolic rate; Elliott et al. 2015). In cold waters, high T3 may increase dive duration by improving thermoregulation (McNabb 2007). Regardless, T3 may play a key role in diving metabolic homeostasis, and T3 may regulate diving rates to be maintained within a particular range.

High mercury levels were associated with low levels of T3. Low T3 was 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). Interestingly, in both 2016 and 2017, out of ~20 possible associations investigated between contaminants, hormones and behaviour, only associations between Hg, T3 and time spent diving were significant. However, in 2016, the associations were opposite, but with the net result that effect of Hg on diving was similar (that is, in 2016 Hg increased T3 and T3 decreased diving while in 2017 Hg decreased T3 and T3 increased diving; in both years, the indirect effect of high Hg via T3 was decreased time spent diving).

Arctic cod is the keystone species for Canadian Arctic marine ecosystems, including the northern Hudson Bay ecosystem (Welch et al. 1992). In particular, Arctic cod is the key forage fish for thick-billed murres, ringed seals, beluga and other predators (Welch et al. 1992). Arctic cod occurs primarily in cool waters (below 4 degrees Celsius), and is consequently associated with ice (Welch et al. 1992). Thick-billed murres spend less time underwater when hunting for cod, which occur in large schools and therefore require less underwater search times. Apparently, those individuals with higher levels of mercury, had lower levels of T3, which may have influenced their ability to dive to the depths needed to obtain cod.

Levels of 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).

Figure 4. Thick-billed murre chick diet at Coats Island between 1981 and 2017.



Ice conditions in Hudson Bay 2017 were anomalously low (median: 12% coverage in July compared to 1981-2017 average of 17% and 2016 median of 15%). Associated with the reduced ice cover, murres bred 1.5 days (median hatch date = 18 July) earlier than the previous record. Furthermore, the proportion of Arctic cod in the diet was among the lowest on record (Fig. 4). In 2016, when waters were cooler, high T3 levels may have led to increased diving rates while in 2017, when waters were warmer, high T3 levels may have led to reduced diving rates.

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Expected Project Completion Date

31 March 2019.

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Appendix

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 to Arctic seabird tissues and eggs

Les plastiques comme vecteur de contaminants chez les tissus et les œufs des oiseaux marins arctiques

Project Leader/Chef de projet

Dr. Mark Mallory, Canada Research Chair, Tier II Coastal Wetland Ecosystems, Biology Department, Acadia University, 33 Westwood Drive, Wolfville, Nova Scotia, B4P 2R6,
Tel: (902) 585-1798; Fax: (902) 585-1059; Email: mark.mallory@acadiau.ca

Dr. Jennifer Provencher, Weston Post-Doctoral Fellow in Northern Research, Biology Department, Acadia University, 33 Westwood Drive, Wolfville, Nova Scotia, B4P 2R6.
Email: Jennifer.provencher@canada.ca

Project Team/Équipe de projet

Amie Black, Birgit Braune and Robert Letcher, Environment and Climate Change Canada, Ottawa; Kim Fernie, Environment and Climate Change Canada, Burlington; Peter Ross, Vancouver Aquarium, Vancouver

Project Location/Emplacement(s) du projet

Prince Leopold Island, NU

Abstract

Plastic debris is commonly ingested by seabirds, even in high Arctic waters, but only recently has attention turned to what the impacts may be of this ingested pollution. Importantly, there is increasing evidence that once marine plastic pollution is in the gut of seabirds, contaminants adsorbed to plastics are released, which may have negative effects on exposed wildlife. We examine how chemical contaminants known to be associated with ingested plastics, may be transferred to two Arctic marine bird species (northern fulmars; *Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*). This project completes analyses of plastic debris and contaminants on bird samples that were already collected as part of an ongoing NCP monitoring project on seabirds from Prince

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. Plus important encore, de plus en plus de données probantes montrent qu'une fois que le plastique se retrouve dans le tube digestif des oiseaux de mer, les contaminants absorbés par le plastique sont rejetés, ce qui peut entraîner des effets nocifs sur les espèces sauvages exposées. Nous analysons comment les contaminants chimiques reconnus pour être associés aux plastiques ingérés peuvent être transférés à deux espèces d'oiseaux de mer arctiques, soit le fulmar boréal (Fulmarus glacialis) et la mouette tridactyle (Rissa tridactyla). Ce projet mettait la touche

Leopold Island. We assessed both adult liver tissue and eggs for phthalates, trace elements, organochlorines, PCBs and other contaminants. Patterns in contaminant concentrations will be examined between species with varying plastic ingestion levels, between the sexes within each species, and in the eggs. Results of these analyses are expected in late 2018 and early 2019. This work builds on past work in the region, and will further identify the potential risks marine plastics may pose to marine birds, and evaluate if eggs contain contaminants shown to be plastic-associated, such as phthalates.

finale aux analyses des débris de plastique et des contaminants sur des échantillons préalablement prélevés chez des oiseaux dans le cadre du projet de surveillance continu du PLCN des oiseaux de mer de l'île Prince Leopold. Nous avons analysé des tissus du foie et des œufs d'espèces adultes pour la présence de phtalates, d'éléments en trace, d'organochlorés, de BPC et d'autres contaminants. Les profils de concentration de contaminants seront examinés parmi les espèces présentant des niveaux différents d'ingestion de plastique, entre les sexes de chaque espèce, et dans les œufs de ces espèces. Les résultats de ces analyses sont attendus vers la fin 2018 et le début 2019. Ils prennent appui sur les travaux antérieurs réalisés dans cette région, et contribueront à préciser les risques que peuvent représenter les plastiques en milieu marin pour les oiseaux de mer, en plus de déterminer si les œufs contiennent des contaminants associés à des plastiques, par exemple les phtalates.

Key Messages

- Plastic ingestion varies with species and season in the seabirds that have been examined in the Canadian Arctic.
- Both environmental contaminants that are absorbed by plastics and plastic-associated contaminants should be investigated in species that ingest plastic debris.
- The potential for some species to metabolise certain plastics should be considered when examining the relationship between plastic ingestion and plastic-associated contaminants in wildlife.

Messages clés

- L'ingestion de plastique varie d'une espèce à l'autre et selon la saison chez les oiseaux de mer qui ont fait l'objet d'études dans l'Arctique canadien.
- Les deux contaminants environnementaux qui sont absorbés par les plastiques et les contaminants associés au plastique doivent faire l'objet d'études chez les espèces qui ingèrent des débris de plastique.
- La capacité des espèces à métaboliser certains types de plastique devrait être prise en compte au moment d'évaluer le lien entre l'ingestion de plastique et les effets des contaminants associés aux plastiques sur la faune.

Objectives

The aim of this project is to contribute to our growing understanding of the link between macro-contaminants (i.e. plastics) and micro-contaminants (i.e. chemicals), and to 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.

Overall, our current phase of work focuses on three main questions:

1. how do chemical contaminants that are associated with ingested plastic differ in species known to have significantly different plastic ingestion levels;
2. if the chemical contaminants are plastic-associated then are they transferred from adult females to egg; and,
3. do the potential plastic-associated contaminant concentrations show a sex bias distribution in seabird species which may have implications for monitoring these contaminants in wildlife.

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 can be 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 debris can also adsorb 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 that show plastics can act as a vector in the movement of toxic chemicals into food webs through animal ingestion (Avio et al., 2016; Bakir et al., 2014; Hamlin et al., 2015; Teuten et al., 2009; Van Cauwenberghe and Janssen, 2014)including resin pellets, fragments and microscopic plastic fragments, contain organic contaminants, including polychlorinated biphenyls (PCBs, with potential impacts for both wildlife and human health (Hamlin et al., 2015).

As this increased awareness is growing, NCP has included plastics as an emerging priority under the 2017-18 Blueprint for Environmental Monitoring and Research. As well, chemical compounds that are associated with marine plastic debris are included in NCP's list of new and/or emerging persistent organic pollutants (POPs) of concern including a growing suite of brominated flame retardants (BFRs; Rani et al., 2015; Tanaka et al., 2015), both α- and β- hexachlorocyclohexane (Zhang et al., 2015), PFOS (Wang et al., 2015) and α- and β-endosulfan (Zhang et al., 2015). Furthermore, legacy POPs such as PCBs, (Endo et al., 2005; Zhang et al., 2015), DDTs (e.g. p,p '-DDT), endrin, aldrin, heptachlor, chlordane (Zhang et al., 2015), and mercury (Hg; Graca et al., 2014) are also associated with marine plastics.

This project focuses on expanding our understanding of how chemical contaminants may be plastic-associated and how they accumulate and move through Arctic biota. The first objective of this project is to examine the concentrations of chemical contaminants known to be associated with marine plastic debris in two seabird species confirmed to have differing plastic ingestion levels (as outlined above). Understanding how these potential plastic-associated contaminants are taken up by seabirds commonly consumed by humans in the North will inform questions related to plastic effects on wildlife, and themes related to the safety and security of seabird country food items in the face of increasing plastics pollution in northern ecosystems. Marine birds are ideal for this study, but the results will be important for a number of country food species as other harvested wildlife such as fish, seals and whales have been shown to ingest plastics (Rebolledo et al. 2013, Kuhn et al. 2015).

The second objective of this project focuses on assessing what potentially plastic-associated contaminants are passed from female to the egg, and relating this to ingested plastics burden in the females. This work serves two functions. First, it further explores why females may have lower levels of some contaminants compared with males if they are offloading some contaminants during egg production. Second, this section of the project will explore which contaminants are offloaded to the eggs by the females, and thus what chemical contaminants may be affecting egg development and survival as several contaminants associated with plastics are known to be hormone disruptors.

The third objective is to examine whether there is a potential sex bias in plastic-associated contaminant concentrations in northern fulmars (a species with high plastic ingestion levels, and for which we have both male and female samples). While we have data from previous work on female concentrations of Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs), we currently have no information on these concentrations in males. Examining for differences in contaminants concentrations between the sexes is important as these can lead to contaminants having differential effects on groups within a species (Morrill et al., 2014; Provencher et al., 2016)males and females differ in their levels of contaminants and/or parasitic infections. Most contaminants and gastro-intestinal parasites are obtained through prey ingestion, and thus the causes of sex differences in the distribution of these factors might follow similar pathways. We studied the northern common eider duck (Somateria molissima borealis.

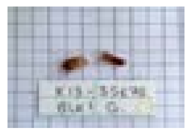
Importantly, recent studies show that plastic accumulation rates vary across Arctic seabird species, leading to potential differences in species-specific exposure, or within species demographic differential exposure to plastic-associated contaminants (Poon et al., 2017; Provencher et al., 2010, 2009). This project will help inform questions around the transfer of plastic-related contaminants in marine birds, and aims to inform larger global questions about how plastics affect marine wildlife. Since marine birds and other country food species such as marine mammals 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 provides the NCP with the opportunity 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)and showed concentrations ranging from < 28 to 2300 ng/g. This indicates that concentrations are highly variable between particles. Among several characters, discoloration (e.g., yellowing, 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).

Activities in 2017-2018

In this past year the focus of this project has been to complete the chemical analysis of different tissues for a variety of contaminants, both environmental contaminants and plastic-associated contaminants. This effort was focused on extending our knowledge of contaminants specifically related to plastics in species and samples from the National Specimen Bank located at the National Wildlife Research Centre (NWRC) in Ottawa. Our focus was specifically on analyzing liver and eggs from black-legged kittiwakes and northern fulmars for phthalates to address objectives 1, 2 and 3 (Fig 1a and b). Additionally, we analyzed environmental contaminants known to be associated with plastics in male northern fulmar livers to enable us to assess any sex differences in plastic related contaminants (Fig 1b). For comparison, northern fulmars' samples collected from Labrador Sea in 2015 can be found in Appendix A.

Figure 1a. 2013 Black-Legged Kittiwakes (BLKI) samples from Prince Leopold Island (PLI).

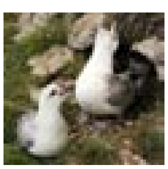
7 BLKI PLI in 2013
(6 ♀, 1 ♂) with
matched eggs



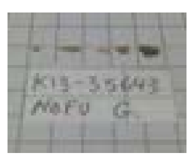
Frequency of occurrence (FO) = 9%
Avg # = 0.1
Avg mass = 0.002g

Tissue	Analysis	N	Funding	Analytical status
Liver (♀)	Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs)	6	ECCC (Fernie)	Letcher Lab - Complete
Liver (♀)	ICP	6	Acadia	RPC - Complete
Eggs	Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs)	6	ECCC (Fernie)	Letcher Lab - Complete
Blood	Hg	5	Acadia	Mallory - Complete
GIT	Accumulated plastics quantified	11 /2	ECCC/ Carleton	NWRC/ Carleton - Complete
Ingested plastics	Fourier transform infrared spectroscopy (FTIR)	11 /2	NCP 2016-17	Van Aq - FTIR Complete
Liver (♀)	Phthalates,	6	NCP 2017-18	Phthalates (ALS) - Complete
Eggs	Phthalates, ICP	6	NCP 2017-18	Phthalates (ALS) - Complete

Figure 1b. 2013 Northern Fulmars (NOFU) samples from Prince Leopold Island.



9 NOFU PLI in 2013
(5 ♀, 4 ♂) with
matched eggs



FO = 90%
Avg # = 3.4
Avg mass = 0.02g

Tissue	Analysis	N	Funding	Analytical Status
Liver (♀)	Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs)	5	ECCC (Fernie)	Letcher Lab - Complete

Liver (♀)	ICP	9	Acadia	Complete
Eggs	Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs)	5	ECCC (Fernie)	Letcher Lab - Complete
Blood	Hg	3	Acadia	Mallory - Complete
Muscle	OPEs, PBDEs, Hg	5	NCP 2016-17	Letcher Lab/Acadia - Complete
Brain	Hg	5	NCP 2016-17	Acadia - Complete
GIT	Accumulated plastics quantified	9 /31	ECCC/ Carleton	NWRC/ Carleton - Complete
Ingested plastics	FTIR	9 /31	NCP 2016-17	Van Aq – FTIR Complete
Liver (♂)	Hg, MeHg, C, N, S, OC/PCB/FR, PFASs (PFOS/PFCAs)	4	NCP 2017-18	Letcher Lab/Acadia - Complete
Liver (all)	Phthalates	9	NCP 2017-18	Phthalates (ALS) - Complete
Eggs	Phthalates, ICP	5	NCP 2017-18	Phthalates (ALS) - Complete

Community Engagement

Our team regularly meets with the Hunters and Trapper Association (HTA) in Resolute Bay, NU, the community closest to Prince Leopold Island. Each season the overall program is presented to the board, with all relevant updates included and current projects highlighted. In addition, the research team also consults with the Sulukvait Area Co-Management Committee for Prince Leopold Island who are responsible for managing the area. When applicable, Environment and Climate Change Canada works with local management groups to facilitate communication and finances between the research group and the community members.

In addition, all work for this project has been done under the appropriate permits. This includes Animal Care (through Environment and Climate Change Canada and Acadia University), the Canadian Wildlife Service, the Government of Nunavut (Wildlife Research Permit), the Nunavut Water Board, and the Nunavut Impact Review Board.

Capacity building and training

The field work component of this project at Prince Leopold Island, NU involved Enooyaq Sudlovenick, an Inuit Field Research Assistant (IFRA) as administered by the Canadian Wildlife Service Iqaluit office.

All birds to be used in this study were a part of the Wildlife Contaminants Workshop in 2014, both supported by the NCP. During the workshop the students in the Environmental Technology Program at the Nunavut Arctic College in Iqaluit were trained to dissect seabirds and collect tissues for contaminants analysis. This was led by Guy Savard (National Wildlife Specimen Bank, Environment and Climate Change Canada) and Jennifer Provencher, Robert Letcher and Birgit Braune have also been active contributors to the Workshop.

In the future, this project and the associated results will also be presented as part of the NCP supported northern marine bird work at the proposed Wildlife Contaminants Workshop (NCP application led by Jamal Shirley from the Nunavut Research Institute currently under review). Jennifer Provencher is a co-applicant of the Wildlife Contaminants Workshop and will incorporate the project results into the material presented on contaminants work in the marine birds component taught to the Environmental Technology Program students.

Communications

Our research group regularly meets in person with the HTA board in Resolute Bay, NU (usually in the winter and spring months). Results from this study will be incorporated into the overall presentation that is given to the community and board. All future plans, including this project, will be reviewed and presented to the HTAs and the Area Co-Management Committee for Prince Leopold Island Migratory Bird Sanctuary for comments and questions. Once the work is completed we will also report the results back to the communities in our annual update meetings.

A summary of the results will also be incorporated into a series of posters that we will distribute to communicate project results, as well as the Mallory Lab's annual, translated "Coastlines" science pamphlet, a laymen's highlight summary of work each year. We will ensure that these materials are made available in both English and Inuktitut, and we will consult with both regional committees to ensure that messaging is appropriate.

Indigenous Knowledge

Knowledge from the local community research team members is incorporated in setting up the research camp each year. A local ecological knowledge study on marine birds was conducted in the mid-2000s by Mark Mallory, and the data from that study is still used to interpret our research (e.g., ice-bird relationships, community value of different species). All field work is done in collaboration with the HTA board and the Sulukvait Area Co-Management Committee (ACMC) in Resolute Bay, NU and undertaken with their consultation.

During the Wildlife Contaminants Workshop in 2014, 2015 and 2016, Joshua Kanga from the local Hunters and Trappers Association in Iqaluit participated in a session that shared Indigenous knowledge on wildlife and contaminants. He spoke about how hunters know when meat is not good to consume, including seabirds.

In the 2017/18 Workshop (NCP proposal led by Jamal Shirley from the Nunavut Research Institute) discussions with students and local knowledge holders will include questions about plastics, and how hunters may come into contact with ingested plastics in different wildlife species.

Results

In total we have now analysed 1684 different tissue-contaminant combinations in relation to the work examining how plastics may act as a vector for contaminants in wildlife. This includes using visual sorting methodologies (Provencher et al., 2017; van Franeker et al., 2011), Fourier-transform infrared spectroscopy (FTIR) of ingested plastic pieces, inductively coupled plasma mass spectrometry (ICP-MS) analysis for trace elements, gravity column chromatography for PCBs among others.

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 because of the complexity of the analysis to determine significant relationships between the various contaminants. These results will be examined in the coming months, and ultimately submitted for peer-review. Two different publications are planned at this point. The first publication will examine the distribution of plastic-related and plastic-derive contaminants in the liver of the two species examined, and in relation to the accumulated plastics. The second publication will examine specifically the maternal transfer of the plastic-related and plastic-derived contaminants from females to eggs.

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., 2017; 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). As we move beyond identifying what species may be susceptible to ingesting plastics, the next series of questions around wildlife health is what the impacts of ingested plastics are.

The data that we have compiled as part of this NCP supported work is allowing us to better address what these plastic related impacts may be, including how contaminants from plastics are taken up by species, and what tissues plastic-related contaminants may concentrate in the most. The continued analysis of the contaminant related data in this project will help to address this globally relevant question as plastics are pervasive throughout aquatic environments (Jambeck et al., 2015; Worm et al., 2017).

Seabirds are the main focus of this research, but other groups of Arctic wildlife 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 (Miranda and de Carvalho-Souza, 2016). 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 2018 to early 2019.

Acknowledgments

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Appendix A

2015 Northern Fulmars samples from Labrador Sea.

31 NOFU
Labrador Sea in
2015 (20 ♀, 23 ♂)

FO = 97%
Avg # = 21.7
Avg mass = 0.22g

Tissue	Analysis	N	Funding	Analytical Status
Liver (♀)	PCB	10	MEOPAR	RPC - Complete
Liver (♀)	PFASs	6	NCP 2016-17	Letcher Lab - Complete
Preening gland oil	Phthalates	31	NCP 2016-17	Phthalates (ALS) - Complete
Muscle	OPEs, PBDEs, Hg	6	NCP 2016-17	Letcher Lab/Acadia - Complete
Brain	OPEs, PBDEs, Hg	10	NCP 2016-17	Letcher Lab/Acadia – Complete
Fat	OPEs, PBDEs, Hg	6	NCP 2016-17	Letcher Lab/Acadia – Complete
GITs	Accumulated plastics quantified	31/ 677	ECCC/Carleton	NWRC/Carleton - Complete
Excrement	Microplastics quantified	30	In collaboration with Jesse Vermaire	Carleton - Complete
Ingested plastics	FTIR	31/ 677	NCP 2016-17	Van Aq - FTIR Complete
Ingested plastics	PCB	50	MEOPAR	Complete

Assessing persistent organic pollutants (POPs) and microplastics (MPs) in Canadian Arctic air and water as an entry point into the Arctic food chain

Évaluer les polluants organiques persistants et les microplastiques dans l'air et l'eau de l'Arctique canadien en tant que points d'entrée dans la chaîne alimentaire dans l'Arctique

Project Leader/Chef de projet

Liisa M. Jantunen, Centre for Atmospheric Research Experiments, Environment and Climate Change Canada (ECCC), 6248 Eighth Line, Egbert, ON L0L 1N0.
Tel: 705-458-3318; Fax: 705-458-3301; Email: liisa.jantunen@canada.ca

Project Team/Équipe de projet

Hayley Hung, Fiona Wong, Chubashini Shunthirasingham and the Organic Analysis Laboratory, ECCC, Toronto, ON; Jane Kirk, Amila De Silva and Derek Muir, ECCC, Burlington, ON; Gary Stern and Monika Pucko, University of Manitoba, Winnipeg, MB; Nunavut Arctic College, Iqaluit NT; Jason Carpenter, Daniel Martin and Karen Nungaq, Pond Inlet; Chelsea Rochman and Clara Thaysen, University of Toronto, Toronto, ON

Project Location/Emplacement(s) du projet

- Central archipelago, Canada
- Eastern archipelago, Canada
- Beaufort Sea, Canada

Abstract

In collaboration with ArcticNet, we collected air, water and sediment samples to determine levels of persistent organic contaminants in the Canadian Archipelago in the summer of 2017 from on board the CCSG Amundsen and Sir Wilfrid Laurier. The contaminants we are focusing on are pesticides, flame retardants, fluorine containing compounds and fossil fuel related compounds. The major concern with persistent organic pollutants (POPs) is that they are taken up by arctic biota including fish, seals and whales so when traditional foods are eaten, Northerners are exposed.

Résumé

En collaboration avec ArcticNet, nous avons prélevé des échantillons d'air, d'eau et de sédiments pour déterminer les niveaux de contaminants organiques persistants dans l'archipel canadien à l'été 2017 à bord des NGCC Amundsen et Sir Wilfrid Laurier. Les contaminants sur lesquels les efforts sont axés sont les pesticides, les agents ignifuges, les composés contenant du fluor et les composés dérivés de combustibles fossiles. La principale préoccupation relative aux polluants organiques persistants (POP) est qu'ils sont absorbés par le biote de l'Arctique, y compris le poisson, le

Our group has been conducting research on pesticides in the Arctic since the early 1990s. Over the years, the types of compounds investigated has evolved as the lists of compounds of concern have expanded. This work is complemented by air sampling at Alert and an Arctic cod project targeting the same list of compounds. Recently we identified a new class of flame retardants and plasticizers (isopropylated diphenyl phosphates) in arctic snow and melt pond water, these compounds are classified as high priority compounds by the Canadian Chemicals Management Plan.

We have developed pesticide trends in air and water over time at different locations in the Canadian Archipelago, and the data collected in the summer of 2017 will add to these temporal and spatial trends. Generally, the trends show that chemicals that have been banned by national and international regulators such as the Stockholm Convention of Persistent Organic Pollutant, are declining in air and water where chemicals that are still being used are remaining constant or increasing. We were also able to provide training and capacity building to a Karen Nungaq, student attending Nunavut Arctic College from from Pond Inlet. She participated in the schools on board program where she learned about and participated in the multiple scientific programs while on board the Amundsen.

phoque et la baleine, de sorte que les habitants du Nord s'exposent à des contaminants lorsqu'ils consomment des aliments traditionnels.

Notre groupe effectue des recherches sur les pesticides dans l'Arctique depuis le début des années 1990. Au fil des ans, les types de composés étudiés ont évolué à mesure que les listes des composés préoccupants se sont allongées. Ces travaux sont menés à bien par l'échantillonnage de l'air à Alert, et un projet portant sur la morue polaire ciblant la même liste de composés. Nous avons récemment recensé une nouvelle catégorie de produits ignifuges et de plastifiants (phosphates de diphényle isopropylés) dans les neiges et les eaux des mares de fonte de l'Arctique. Ces composés sont classés prioritaires dans le Plan de gestion des produits chimiques du Canada.

Nous avons cerné les tendances dans les concentrations de pesticides dans l'air et dans l'eau au fil du temps en prélevant des échantillons à différents endroits de l'archipel canadien. Les données recueillies à l'été 2017 permettront de mieux cerner ces tendances temporelles et spatiales. En général, les tendances montrent que les substances chimiques qui ont été interdites par des organismes de réglementation nationaux et internationaux, comme la Convention de Stockholm sur les polluants organiques persistants, sont en baisse dans l'air et dans l'eau, tandis que les concentrations de substances chimiques encore utilisées sont soit constantes, soit en augmentation. Nous avons aussi pu offrir un service de formation et de renforcement des capacités à Karen Nungaq, étudiante au Collège de l'Arctique du Nunavut originaire de Pond Inlet. Elle a participé au programme « Écoles à bord », qui lui a permis de connaître les multiples programmes scientifiques menés à bord de l'Amundsen et d'y prendre part.

Key Messages

- All proposed samples were collected in the summer of 2017.
- A northern student from Nunavut Arctic College in Iqaluit participated in the field study on board the Amundsen.
- Passive water samplers from the Global passive water sampling network (AQUA-GAPS) were deployed in three regions of the Canadian Archipelago.
- A Canadian Chemical Management Plan high priority compound of concern, (isopropylated triphenyl phosphates) was identified in arctic snow, melt pond water and sediment.

Messages clés

- Tous les échantillons proposés ont été prélevés à l'été 2017.
- Un étudiant du Collège de l'Arctique du Nunavut originaire d'Iqaluit a participé à une étude sur le terrain à bord de l'Amundsen.
- Des échantillonneurs d'eau passifs du réseau AQUA-GAPS (réseau global d'échantillonnage d'eau passif) ont été déployés dans trois régions de l'archipel canadien.
- Un composé préoccupant déterminé comme prioritaire dans le Plan de gestion des produits chimiques du Canada (phosphates de diphényle isopropylés) a été recensé dans les neiges, les eaux des mares de fonte et les sédiments de l'Arctique.

Objectives

The objectives of this project are to:

- measure levels of persistent organic pollutants (POPs) in Canadian arctic air and water;
- deploy passive water samplers in multiple locations in the Canadian Arctic,
- assess levels of target compounds in sediment;
- screen for new and emerging compounds of concern in the Canadian Arctic; and,
- provide environmental sampling training to a northern student.

Introduction

Since 2007 we have been collecting air and water samples in the Canadian Archipelago in collaboration with ArcticNet. This relationship with ArcticNet has enabled us to collected yearly samples from similar places in the Canadian Arctic at a reasonable cost, as they provide discounted flights, scientific support and ship time at no cost. In 2013, we started collecting sediment (odd years) and zooplankton (even years) every other year. In 2014, we expanded the water sampling by deploying passive water samplers in the Beaufort Sea and in 2016 we added Cambridge Bay and Baffin Bay to give an east to west transect across the Canadian archipelago. In the summer of 2017, we collected air, water, and sediment samples for persistent organic contaminants in the Canadian Archipelago from on board the CCSG Amundsen in the central and eastern archipelago and air and water samples from on board the CCGS Sir Wilfrid Laurier in the Beaufort Sea.

Additionally, in 2017 passive water samplers for the Global Passive water sampling network (AQUA-GAPS) were added to three sites.

Our group has been conducting research on pesticides in the Arctic since the early 1990s. Over the years, the types of compounds investigated has evolved as the lists of compounds of concern have expanded. The contaminants we are currently focusing on are pesticides, flame retardants, fluorine containing compounds and fossil fuel related compounds. We also collaborated with Stockholm University in Sweden who analyzed archived sediment samples for volatile methyl siloxane compounds. This work is complemented by air sampling at Alert lead by Hayley Hung and an Arctic cod project lead by Gary Stern targeting the same list of compounds. The major concern with persistent organic pollutants (POPs) is that they are taken up by Arctic biota including fish, seals and whales so when traditional foods are eaten, Northerners are exposed.

We have developed pesticide trends in air and water over time at different locations in the Canadian Archipelago (Jantunen et al., 2015), the data collected in the summer of 2017 will add to those temporal and spatial trends. Generally, the trends show that chemicals that have been banned are declining in air and water where chemicals that are still being used are remaining constant or increasing.

This year for the first time, Liisa Jantunen visited Inuvik and presented her work at a public forum; and a lecture/hands-on demonstration a group of high school and college students. While in Iqaluit in February 2017, the Liisa Jantunen gave a lecture and hands on demonstrations to a group of college students from Nunavut Arctic College in Iqaluit. During this visit, Karen Nungaq from Pond Inlet, a student at the college that was recruited, participated in the schools on board program where she learned about and participated in the different scientific program on the Amundsen.

Many of the target compounds in this study are included in the Stockholm Convention and the Convention on Long Range Transboundary Air Transport (CLRTAP) lists of banned chemicals. Monitoring the levels of compounds in the environment is also a part of the Stockholm Convention Global Monitoring Plan. Additionally, many of the new and emerging target compounds are on Canada's Chemical Management Plan priority compound lists or emerging priority lists and/or have been identified by the Arctic Monitoring and Assessment Program (AMAP) as chemicals of concern.

Activities in 2017-2018

Community Engagement

Liisa Jantunen visited Inuvik, where a public forum was held, to talk about water sampling for contaminants in the Arctic.

Capacity Building and Training

Karen Nungaq from Nunavut Arctic College participated in the ArcticNet cruise as part of the schools on board program. She learned about and participated in all of the ongoing projects on board the Amundsen, including POP and microplastics sampling.

Liisa Jantunen gave a lecture and hands-on demonstration regarding this project's field to college students from Aurora College and high school students from the local school in Inuvik that was well received. She discussed air and water sampling from on board the Amundsen and gave the students a chance to assemble the sampling equipment.

Communications and Outreach

A poster and scientific exhibit were presented at the NCP Results workshop in Yellowknife in September 2017. This included air, water and sediment sampling techniques for contaminants. A pamphlet has also been developed. During 2017-2018 it was review and finalized by the NWT-RCC and NECC, and will be translated next year.

Indigenous Knowledge

Indigenous Knowledge (IK) is currently only indirectly related to this project. Given our sampling platform onboard the CCGS Amundsen and Laurier, and the lack contact with local community, applying IK to this project is an ongoing challenge. This year Karen Nungaq, a northern student, was on-board and participated our sampling program, it was hoped that she would give some insight into how to better incorporate IK into this project. We are awaiting more information on how the cruise went, how we could incorporate IK into the project. Karen has been offered supplies and/or content for a presentation in her community. Unfortunately, Karen did not follow-up.

The project leader has also been in contact with Eric Leonard to participate in the Northwest Territories Regional Contaminants Committee (NWTRCC) meeting to better incorporate IK into this project.

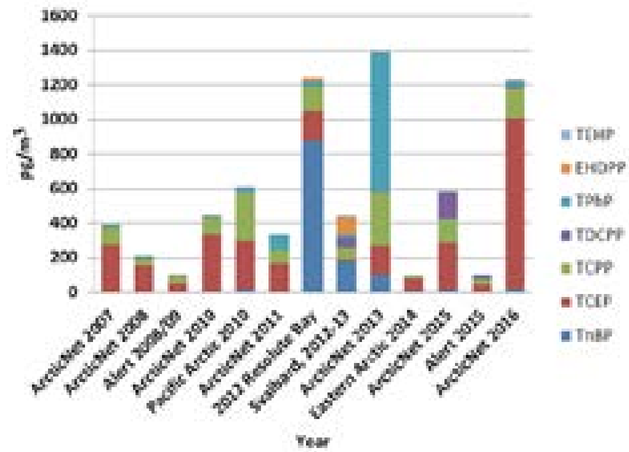
Results and Outputs/Deliverables

Air Samples

In the summer of 2017 air samples were collected in the central and eastern Canadian archipelago (Amundsen) and in the Beaufort Sea (Laurier). Sample extraction, processing and analysis is on-going.

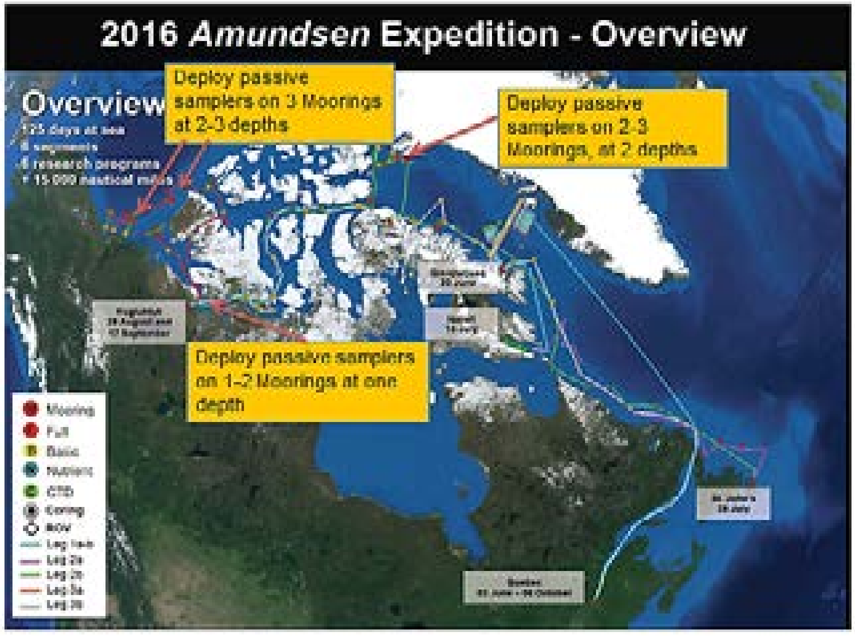
We have analysed the air samples taken as part of this study back to 2007 for a set of flame retardants and plasticisers. A summary of samples for organophosphate ester in the Arctic from this project and other studies can be found in Figure 1.

Figure 1. Concentrations of organophosphate ethers (OPEs) in air 2007 to 2016 from all sources including sampling onboard the Amundsen (ArcticNet), pacific Arctic, Resolute Bay, Svalbard, and Eastern Arctic. (ArcticNet, 2007-2013: Suhring et al., 2016; ArcticNet 2014-2016, 2012 Resolute Bay and Alert: Jantunen et al., unpublished data; Pacific Arctic 2010: Möller et al., 2012 and Eastern Arctic, 2014: Li et al., 2017).



Samples taken in Resolute Bay in 2012 show high levels of tri (n-butyl) phosphate (TnBP) that is probably from a local source, the airport. TnBP is the primary ingredient in airplane hydraulic fluid and high levels are also seen to a lesser degree in samples from Svalbard. In 2013 there was a spike in the triphenyl phosphate (TPhP) concentrations from onboard the Amundsen, the reason for this is unknown. Additionally, in 2016, there was a spike in concentrations in tris(2-carboxyethyl)phosphine (TCEP), reasons are also unknown. We will continue to investigate sources of OPEs to the Canadian Arctic including potential local sources.

Figure 2. Map of passive sampler deployment locations in 2017. Samples will be retrieved and redeployed in 2018.



Passive Water Samplers

This year, one mooring in the Beaufort Sea was lost and along with it, one set of passive samplers. We were able to retrieve and redeploy passive water samplers at all other sites in the northern Davis Straight, near Cambridge Bay and the Beaufort Sea (Figure 2). In five out of 10 of our passive sampling cages, AQUA-GAPS passive strips were also deployed (Lohmann et al., 2010; 2016). We have successfully developed a method to effectively cleanup the older style semi-permeable membrane device (SPMD) passive water samplers. This year only polyethylene (PE) and poly(dimethylsiloxane) (PDMS) passive samplers were deployed and no SPMD samplers were deployed. PE and PDMS samplers are much less expensive, require much less sample processing than SPMD samplers and thus there is less chance of losses of target compounds.

Grab Water Samples

Levels of total OPEs in surface water vary by location in the archipelago, with lower concentrations on the eastern region compared to the central and western region, Figure 3. This may be related to the loads of OPEs in Atlantic versus Pacific waters. Asia is a large producer and consumer of products that contain OPEs as flame retardants and plasticizers which could be a large source of the OPEs entering Pacific waters. Grab samples for OPEs were also taken at depth in the Beaufort Sea, concentrations decline rapidly with depth.

In the Canadian Arctic, OPEs are found at high levels compared to other contaminants including other brominated flame retardants and organochlorine pesticides. Concentrations of dissolved and particulate OPEs have similar proportions, see Figure 4. There are different proportions of OPEs in surface water in different regions of the Canadian Arctic; this implies different sources, different transport processes and/or degradation processes.

Figure 3. Summary of water sample collected in the Canadian Archipelago between 2013 and 2017, summarized by region. The yellow markers are where samples were collected. Levels of OPEs (marked by coloured bars) are slightly lower in the eastern side of the Archipelago than the western, although there is not a significant correlation with longitude.

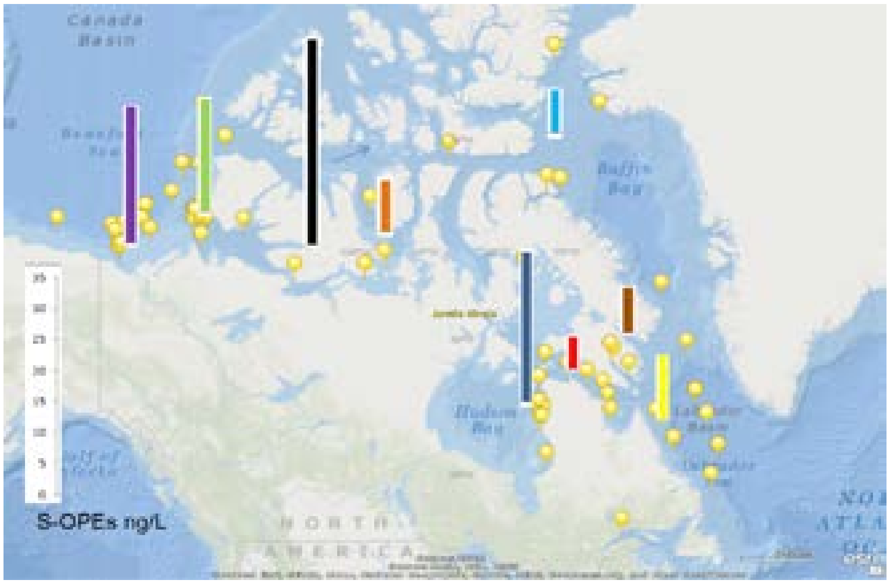
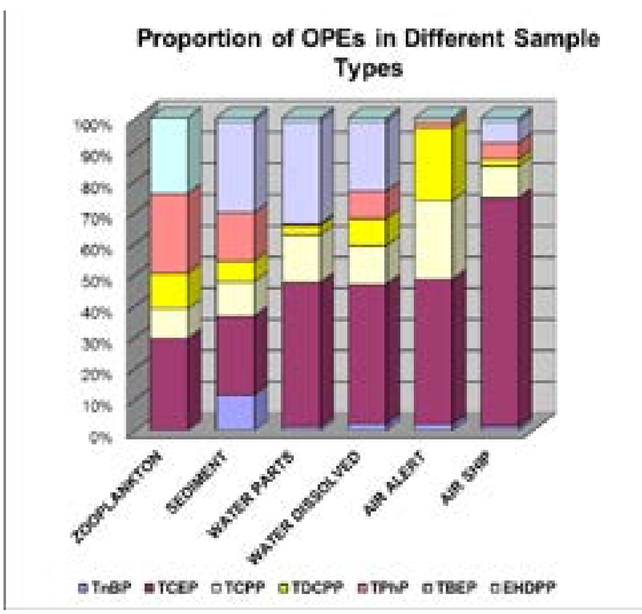


Figure 4. The relative proportions of the organophosphate esters (OPEs) in several arctic media. Different OPE compounds accumulate in different media, where more lipophilic compounds show higher proportion in zooplankton such as ethyl-hexyl dipropyl phosphate (EHDPP) and more volatile compounds are dominant in air.

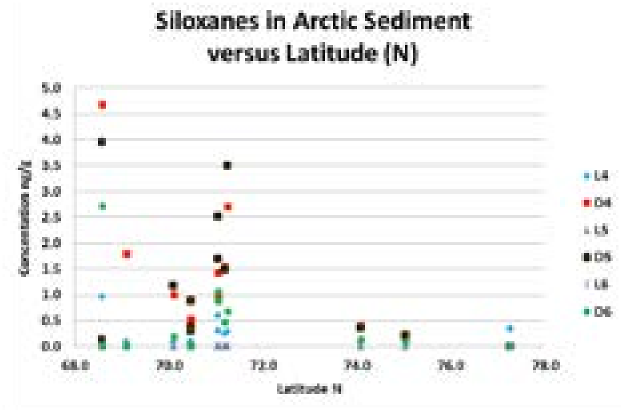


OPEs were analyzed in many different sample types including air, dissolved water, water particulate, sediment, and zooplankton. All media are dominated by the more volatile TCEP compound. This is a chlorinated compound and might be more stable then alkylated OPEs. The proportions of the individual OPEs vary depending on samples type. This may be the result of selective uptake or sorption by one media, degradation, and/or metabolism, Figure 4.

Sediment Samples

Archived sediment samples were analyzed for the cyclic and linear volatile methylsiloxanes. Compounds sought were: octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), dodecamethylcyclohexasiloxane (D6), decamethyltetrasiloxane (L4), dodecamethylpentasiloxane (L5) and tetradecamethylhexasiloxane (L6). L5 was below detection limits in all samples, whereas all other compounds were found in most samples. Levels of siloxanes declined with increased latitude but had no correlation with the organic carbon-water partition coefficient (K_{OC}) (Figure 5) (Panagopoulos et al., 2018).

Figure 5. Summary of siloxane levels by latitude (°N) in archived sediment samples. Levels decreased with latitude but showed no correlation with the organic carbon-water partition co-efficient (K_{OC}).



Discussion and Conclusions

We continue the spatial and temporal trends of POPs and new and emerging compounds of concern in the Canadian Arctic. As more analytical standard become available for compounds identified by Canada's Chemical Management Plan, our target compound list for screening will continue to grow. This year we identified eight alkylated triphenyl phosphates (specifically isopropylated diphenyl phosphates) in the arctic snow and melt pond water. We will also be screening a related set of compounds, tert-butylated triphenyl phosphates, in the coming year. Data from this project is regularly communicated to the Canadian Chemical Management Plan (CMP) which undertakes risk assessments and management of compounds identified by the Domestic Substance List (DSL) as potential hazardous compounds. Several OPE compounds are currently under assessment. Data generated from this project is also included in dossiers to nominated compounds to the Stockholm Convention.

Although the samples were not taken in the same area of the Canadian archipelago as other studies, similar ranges of OPEs were found in Canadian Archipelago waters, and Canadian Arctic surface waters were dominated by TCEP as found with this study (McDonaugh et al., 2018). Although, in the Barrow Strait, McDonaugh et al. (2018) found that TCiPP was the dominant compound in surface waters; this was also found in north Atlantic-Arctic surface waters (Li et al., 2017). Since Europe banned TCEP in favour of technical tris (chloroisopropyl) phosphate (TCPP), it is not surprising that tris (1-chloro-2-propyl) phosphate (TCiPP) is dominant OPE in the European Arctic. Li et al. (2017) also reported OPEs in air, and similar ranges of concentrations were found to this study. Li et al. (2017) also found that TCEP was the dominant compound in air.

ArcticNet renewal is currently under way. The Letter of Intent has been submitted, a theme headed by Gary Stern, of which Liisa is a network investigator, was submitted. If successful a full proposal will be prepared over the summer of 2018.

The collection of samples for microplastics analysis funded in 2017-2018 will continue. Samples were taken in 2017 in Hudson Bay and the central and eastern archipelago. These samples are being processed and analyzed by collaborators with in-kind support. Sampling for microplastics will continue in the future.

Collaborations and sharing archived samples with other groups continue to be fruitful. A set of samples taken for Mario Lebrato in 2011 in the Canadian Archipelago investigating Mg:Ca and Sr:Ca ratio in global oceans has been written up for publication and will be submitted to Nature Geosciences.

Expected Project Completion Date

Analysis of all samples that were collected in 2017 will be completed by December 2018. The next phase of sampling will begin in 2018-2019.

Acknowledgments

We thank Environment and Climate Change Canada for their ongoing support. We thank ArcticNet for ship time, funding for travel and a berth for the northern student during the schools on board program. This year we also thank Sarah Bernstein, Chelsea Rochman, Ainsleigh Loria and Clara Thaysen for help during sampling and Alexis Burt for ongoing support. We thank Dimitrios Panagopoulos for the sediment siloxane data and inclusion of the data in an upcoming publication. We thank Kim Juniper, Ryan Flagg and Paul Macaun at Ocean Networks Canada for deploying the passive water sampler at Cambridge Bay. We thank the ArcticNet mooring group, especially Shawn Meredyk for enabling us to deploy our passive water samplers on the moorings.

Over the many years this work has been supported by the Northern Contaminants Program, ArcticNet, Environment and Climate Change Canada, Circumpolar Flaw Lead Study, International Polar Year, NSERC Discovery Grant Program, Chemical Management Plan (CMP) and the University of Toronto.

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Microplastics in the Beaufort Sea beluga food web

Microplastiques dans le réseau trophique du béluga de la mer de Beaufort

Project Leader/Chef de projet

Peter S. Ross & Marie Noel, Ocean Pollution Research Program, Ocean Wise, 4160 Marine Drive, Vancouver, BC, V7V 1H2. Tel: (604) 239-6929, Email: peter.ross@ocean.org ; marie.noel@ocean.org

Project Team/Équipe de projet

Rhiannon Moore, Ocean Wise / Simon Fraser University, Vancouver, BC; Lisa Loseto, Fisheries, Oceans & the Canadian Coast Guard, Freshwater Institute, Winnipeg, MB

Project Location/Emplacement(s) du projet

- Tuktoyaktuk, NT
- Beaufort Sea, Canada

Abstract

Microplastics (particles < 5 mm) are increasingly seen as a threat to ocean life. They have been detected in industrialized coastal environments, as well as remote parts of the world. Our team previously reported on widespread distribution of microplastics in the NE Pacific Ocean, as well as ingestion by two keystone zooplankton species. This raises concerns about potential effects on biota. We proposed to carry out a focused study of microplastics in the Beaufort Sea beluga whale (*Delphinapterus leucas*) food web in collaboration with Fisheries, Oceans & the Canadian Coast Guard Canada (DFO) and the community of Tuktoyaktuk. Samples of water and sediment were collected with Inuvialuit youth citizen scientists. Several species of fish (Arctic Cisco (*Coregonus autumnalis*), Arctic Flounder (*Liopsetta glacialis*), Arctic Cod (*Boreogadus saida*), Saffron Cod (*Eleginus gracilis*) and Fourhorn Skulpin (*Myoxocephalus scorpioides*)) and beluga digestive tracts were collected between July and September, 2017. In the lab, we invested considerable time and effort

Résumé

Les microplastiques (particules de moins de 5 mm) sont de plus en plus perçus comme une menace à la vie océanique. Ils ont été détectés dans les environnements côtiers industrialisés de même que dans des régions éloignées du monde. Nous avions déjà signalé une distribution répandue des microplastiques dans le nord-est de l'océan Pacifique, de même que l'ingestion par deux espèces de zooplanctons clés. Cela soulève des préoccupations sur les effets éventuels sur le biote. Nous proposons d'effectuer une étude ciblée sur les microplastiques dans le réseau trophique du béluga (Delphinapterus leucas) de la mer de Beaufort en collaboration avec Pêches et Océans (MPO) et la Garde côtière canadienne, ainsi qu'avec la collectivité de Tuktoyaktuk. Des échantillons d'eau et de sédiments ont été prélevés avec l'aide de jeunes chercheurs bénévoles inuvialuits. Des échantillons de diverses espèces de poissons, dont le cisco arctique (Coregonus autumnalis), la plie arctique (Liopsetta glacialis), la morue polaire

in the development of high quality protocols for extraction and analysis of microplastics, so as to maximize the reliability and reproducibility of results in the emerging microplastics research field. After completion of the trials, 15 fish samples were dissected, digested and vacuum filtered. In addition, a specialized "wet lab" was retrofitted to accommodate the handling and extraction process for the larger beluga samples. Sample processing will continue in the summer and fall of 2018 with the final step consisting of Fourier Transform InfraRed spectrometry (FT-IR) analyses to determine individual microplastic particle polymer identity. These results will provide an assessment of microplastic abundance and type in the southern Beaufort Sea beluga food web, and evaluate the potential for transfer of microplastics from fish to beluga whale within a food web.

(Boreogadus saida), le navaga jaune (Eleginus gracilis) et le chaboisseau à quatre cornes (Myoxocephalus scorpioides), ainsi que dans l'appareil digestif du béluga, ont été prélevés entre juillet et septembre 2017. Au laboratoire, nous consacrons toujours beaucoup de temps et d'efforts à l'élaboration de protocoles de grande qualité pour l'extraction et l'analyse des microplastiques, afin de maximiser la fiabilité et la reproductibilité des résultats dans ce nouveau domaine d'étude que sont les microplastiques. Après l'achèvement des essais, 15 échantillons ont été disséqués, analysés et filtrés sous vide. De plus, un laboratoire expérimental spécialisé a été modernisé pour prendre en charge les processus d'extraction et de manipulation des plus gros échantillons de béluga. Le traitement des échantillons se poursuivra durant l'été et l'automne 2018. L'étape finale consistera à effectuer des analyses en spectrométrie infrarouge à transformée de Fourier (FTIR) pour déterminer l'identité de la particule de microplastique. Ces résultats fourniront une évaluation de l'abondance et des types de microplastiques dans le réseau trophique du béluga du sud de la mer de Beaufort et permettront d'évaluer le potentiel de transfert des poissons au béluga dans un réseau trophique.

Key Messages

- Extensive sampling was conducted in 2017: Arctic Cisco, Arctic Flounder, Fourhorn Skulpin, Saffron Cod, Arctic Cod and Beluga stomachs were collected through partnerships with Fisheries, Oceans & the Canadian Coast Guard Canada (DFO) and the community of Tuktoyaktuk.
- A specialized 'wet lab' has been retrofitted at the Ocean Wise laboratory to accommodate the handling and extraction process of beluga stomachs.
- Refined methods to extract microplastics from the digestive tracts of Beluga whales and each fish species have been developed.

Messages clés

- Des échantillonnages exhaustifs ont été effectués en 2017 : des échantillons ont été prélevés chez le cisco arctique, la plie arctique, le chaboisseau à quatre cornes, le navaga jaune et la morue polaire, ainsi que dans l'estomac de bélugas, en partenariat avec Pêches et Océan, la Garde côtière canadienne et la collectivité de Tuktoyaktuk.
- Un laboratoire expérimental spécialisé a été modernisé au laboratoire d'Ocean Wise pour prendre en charge les processus d'extraction et de manipulation des plus gros échantillons de béluga.
- Des méthodes perfectionnées d'extraction des microplastiques de l'appareil digestif du béluga et de chacune des espèces de poissons échantillonnées ont été élaborées.

Objectives

This project aims to:

- conduct an assessment of microplastics in the southern Beaufort Sea beluga whale food web by using newly-developed techniques to extract, enumerate and analyse microplastics from samples of beluga stomach and gut contents, as well as beluga prey stomach and gut contents; and
- provide an initial basis for tracking the source, transport, fate and effects of this emerging contaminant class in Canada's North.

Introduction

The threats posed to biota from microplastics (items < 5 mm) in the world's oceans are of increasing concern (Thompson et al. 2004; Ross & Morales 2015). While most research on microplastic pollution has largely focused on areas close to human activities, remote regions are far from immune. Studies have revealed that plastic litter is found in the Arctic (Lusher et al. 2015; Obbard et al. 2014; Trevail et al. 2015) as a form of marine litter, is found in varying quantities and sizes around the globe from surface waters to deep-sea sediments. Identifying patterns of microplastic distribution will benefit an understanding of the scale of their potential effect on the environment and organisms. As sea ice extent is reducing in the Arctic, heightened shipping and fishing activity may increase marine pollution in the area. Microplastics may enter the region following ocean transport and local input, although baseline contamination measurements are still required. Here we present the first study of microplastics in Arctic waters, south and southwest of Svalbard, Norway. Microplastics were found in surface (top 16 cm with macro-plastic ingestion by seabirds, cetaceans and Greenland shark (Trevail et al. 2015). The presence of microplastics in the Arctic has been reported in ice cores, with the authors noting the potential for large quantities to be released as a consequence of climate change associate sea ice melting (Obbard et al. 2014). A second report from Svalbard (Norway) found that a majority of microplastics in water consisted of fibers, with average concentrations of 0.34 (± 0.31) particles per m^3 in surface waters and 2.68 (± 2.95) particles per m^3 in subsurface water (~ 6 m) (Lusher et al. 2015) as a form of marine litter, is found in varying quantities and sizes around the globe from surface waters to deep-sea sediments. Identifying patterns of microplastic distribution will benefit an understanding of the scale of their potential effect on the environment and organisms. As sea ice extent is reducing in the Arctic, heightened shipping and fishing activity may increase marine pollution in the area. Microplastics may enter the region following ocean transport and local input, although baseline contamination measurements are still required. Here we present the first study of microplastics in Arctic waters, south and southwest of Svalbard, Norway. Microplastics were found in surface (top 16 cm. While microplastics have not been reported in detail in arctic biota, plastic fragments of varying sizes have been identified in stomachs, signalling an emerging concern about the breakdown of parent products into smaller and smaller pieces (Poon et al., 2016; Provencher et al., 2016).

Previous research from our laboratory revealed both the widespread distribution of microplastics in seawater in the Northeast Pacific Ocean (Desforges et al. 2014), and the ready ingestion of microplastic particles by two zooplankton species in the Northeast Pacific Ocean (*Neocalanus cristatus* and *Euphausia pacifica)* (Desforges et al. 2015). The authors estimated that individual adult salmon in coastal British Columbia could be consuming as much as 90 microplastic particles per day. Ingestion of microplastics by Arctic zooplankton, fish and potentially beluga whales raises a similar concern: are microplastics being ingested at the bottom of the Arctic food chain in a manner that delivers plastic to aquatic species, such as Arctic cod or beluga whales? Such questions are bound to have bearing on the health of indigenous marine foods that are valued by the Inuit.

The proposed project is to carry out a focused study of microplastics in the Beaufort Sea beluga whale (*Delphinapterus leucas*) food web in collaboration with the community of Tuktoyaktuk. This complements a current partnership with Fisheries, Oceans & the Canadian Coast Guard Canada (DFO) to track the Arctic-wide distribution of microplastics in seawater and zooplankton. As part of the NCP funding, this project expanded on the Beaufort Sea component of a DFO partnership, with individual prey-based isolation and microplastic determination within each stomach sample from beluga (as opposed to a single composite extracted from the beluga stomach). Additional biota samples were collected (Arctic Cod, Arctic Cisco, Flounder, Saffron Cod), with a similar effort being carried out to isolate individual prey from within the stomach contents of these biota for later analysis. Given the emergence of this topic of concern, and the limited data available for the Arctic, our findings and our partnership with the Inuvialuit community should provide a culturally relevant understanding of a potential human and ecological threat in the Arctic.

Activities in 2017-2018

2017 Field Work

Project team members carried out the citizen science component of this project between August 24, 2017 and September 11, 2017. They worked with Inuvialuit youth and community members to collect water, sediment and fish samples. Youth and elders reached sample locations by canoe and boat, respectively. Inuvialuit youth collected fish using a traditional shoreline gill net provided generously by their family. Youth put nets out evenings and brought them in the following day. All lake whitefish and salmon were kept by the youth and all other species were collected for this study. Additionally, youth collected sediment and water samples aboard the Polar Prince during leg 12 of the Canada C3 expedition (Appendix 1).

These collections expand on the existing partnership with Fisheries and Oceans. Additional fish were collected through the Canadian Beaufort Sea: Marine Ecosystem Assessment /Frosti program and the coastal monitoring program at Shingle Point. Twenty Saffron Cod (*Eleginus gracilis*) and 20 Arctic Cisco (*Coregonus autumnalis)* were collected at Shingle Point, and 20 Arctic Cod (*Boreogadus saida*) were collected in the Beaufort Sea aboard the Frosti.

Finally, the 2017 field season also included the collection of four beluga digestive tracts. Through the annual beluga hunt on Hendrickson Island, NT, the community of Tuktoyaktuk, provided the beluga digestive tracts. These collections were made possible through the Beluga Monitoring Program, a partnership between DFO, and the community of Tuktoyaktuk.

Microplastics Extraction

Laboratory methods to extract microplastics particles and fibres have been refined for each species and are detailed below.

All whole fish are removed from freezer to thaw, and the following day were dissected in a Biological Safety Cabinet (BSC). The whole fish were weighed prior to dissection. All equipment including dissection tools and sample beakers were carefully rinsed with filtered water to eliminate the risk of external microplastic contamination. Once the entire digestive tract was removed from the fish, it was placed in a rinsed glass jar and weighed. A digestive solution (3 times the volume of the digestive tract) of 10% Potassium Hydroxide (KOH) was added to the jar containing the sample. Samples were left sealed in jars for 2-3 weeks within a secure fume hood until fully digested into a homogenous liquid. The liquid was subsequently filtered through a 20 μm polycarbonate filter (PC, 47 mm diameter) under a vacuum inside the BSC. Resultant filters were then archived for the next step involving microscopy.

Effort was carried out to isolate individual prey from the stomach condense of all biota for later analysis (such as isopods and smaller benthic organisms). Prey species found in stomach samples (notably *Eleginus gracilis)* were individually isolated and went through the same extraction process as all other species. The main prey species found in larger fish are capelin (*Mallotus villosus)* (Figure 1).

Figure 1: Capelins and isopod found in the stomach of a saffron cod.

A specialized "wet lab" was retrofitted to accommodate the handling and extraction process for the larger beluga samples (Figure 2). Based on the experience of the Ocean Wise microplastics lab and literature review, a protocol was developed for the processing of beluga digestive tracts. Stomach contents were rinsed using filtered water (10 µm) and sieved through 4.75 mm and 63 µm sieves. Food remains as well as bigger particles collected on the 4.75 mm sieve will be collected for further identification. The 63 µm sieve was rinsed with filtered water. Individual prey items were separated into separate scintillation vials for separate cleanup, extraction and enumeration/analysis. Samples were then digested using 10% KOH for 2-3 weeks until biological material has dissolved. The digest was filtered through a polycarbonate filter (20 µm pore, 47 mm diameter, 11 µm thick) under a vacuum inside the Biological Safety Cabinet (BSC). The sample filter was transferred into a Petri dish until further analyses.

Figure 2: MSc student Rhiannon Moore extracting content from beluga stomach in a clean air enclosure.

Community Engagement

Project team members carried out the citizen science component of this project between August 24, 2017 and September 11, 2017. They worked with Inuvialuit youth and community members to collect water, sediment and fish samples. Youth and elders reached sample locations by canoe and boat, respectively.

Capacity Building and Training

The citizen science component of this project was carried out between August 24th, 2017 to September 11th, 2017. Staff worked extensively with Inuvialuit youth and community members to collect water, sediment and fish samples. Community members were trained to collect water and sediment for microplastic analysis.

Research was carried out by Rhiannon Moore, a MITACS intern at Ocean Wise and an MSc student at Simon Fraser University. Through her program and work at Ocean Wise she has acquired extensive knowledge on microplastics laboratory techniques for extraction and quantification as well as microplastics issues as it relates to conservation.

Communications and Outreach

Information on the microplastics in beluga food web project was presented at the various Hunter and Trapper Committees throughout the region (Inuvik, Tuktoyaktuk, Paulatuk and Ulukhaktok) as part of the presentation about the beluga monitoring program. Project updates and proposals were also presented to the two major wildlife boards in the ISR in winter and summer (Inuvialuit Game Council and Fisheries Joint Management Committee).

Rhiannon Moore delivered two presentations on microplastics at the Mangilaluk School in Tuktoyaktuk in September 2017. As part of her voyage on leg 12 of the Canada C3 expedition, she delivered a number of presentations (see project metrics table) as well as one public talk at the Vancouver Aquarium as part of the Ocean Matters Speaker Series (Beluga whales, microplastics and an Inuit community https://www.youtube.com/watch?v=fZJWun67DEM).

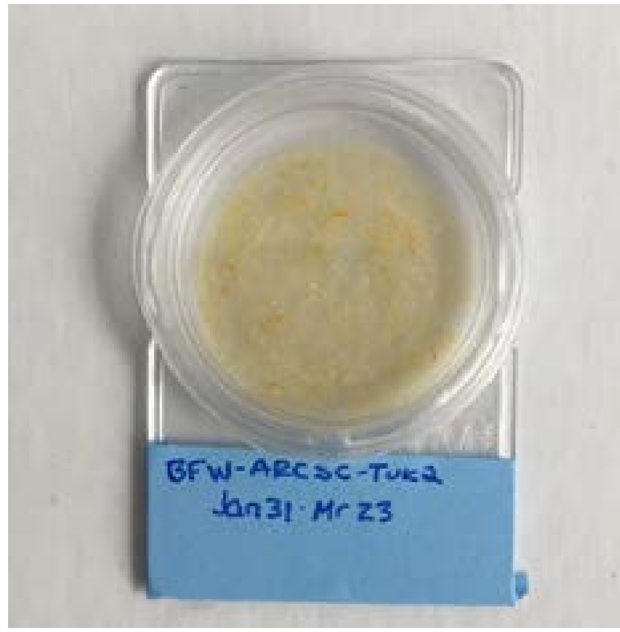
Indigenous Knowledge

We worked closely with Tuktoyaktuk community members to gather knowledge about fish in the area and how/where to collect them effectively. Youth and elders reached sample locations by canoe and boat, respectively.

Results

After collection of samples in the summer of 2017, we invested a considerable amount of time in the design and trials of high quality protocols to extract microplastics from the stomachs of various species of fish. After completion of the trials, 15 fish have been dissected, chemically digested and vacuum filtered as of April 2018. Resultant filter papers (Figure 3) will be analyzed under a microscope in order to count, characterize and measure microplastics.

Figure 3: Filter resulting from the digestion of an Arctic cisco stomach.



Discussion and Conclusion

Laboratory work in spring and summer 2018 involved continued dissection and digestion of all samples including beluga digestive tracts. All suspected microplastic particles and fibers were enumerated and characterized on each sample filter including procedural blanks (to inform of any external microplastic contamination) using light microscopy and image analysis. All suspect plastic particles were further analyzed using our Fourier Transform Infra-Red Spectrometer (FT-IR). This component necessitated a considerable technical effort, due to biofouling/weathering effects on FTIR signature of some microplastics encountered in the stomach samples. Microplastics, both fibers and fragments, were found in the digestive tracts of the Beluga whales. Complete assessment of microplastic in fish samples, expected for fall 2019, will shed light on the trophic transfer of these contaminants via Beluga prey.

Expected Project Completion Date

Preliminary results will be available in the fall 2019.

Acknowledgments

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APPENDIX

Appendix 1: Water, sediment and fish samples collected through citizen scientists.

Date	Sample ID	Latitude	Longitude	Sample volume (L)	Depth (m)
Water Samples					
8/26/2017	BW1	57.8000	77.07735	1	Subsurface
8/26/2017	SW1	57.8000	77.07735	60	Subsurface
8/26/2017	BW2	57.8343	77.09528	1	Subsurface
8/27/2017	SW2	57.8343	77.09528	60	Subsurface
8/28/2017	BW3	57.3686	77.00999	1	Subsurface
8/28/2017	SW3	57.3686	77.00999	60	Subsurface
8/28/2017	SW4	57.3437	77.00976	60	Subsurface
8/29/2017	SW5	57.7109	77.04573	60	Subsurface
9/1/2017	SW6	57.7053	77.05490	60	Subsurface
9/1/2017	SW7	57.6966	77.05367	60	Subsurface
9/1/2017	SW8	57.6966	77.05367	sediment salt experiment	Subsurface
9/2/2017	SW9	69.43863	133.03999	60	Subsurface
9/2/2017	SW10	69.43824	133.04122	60	Subsurface
9/3/2017	SW11	69.40931	133.03586	60	Subsurface
9/3/2017	SW12	69.40931	133.03586	60	Subsurface
9/3/2017	SW13	69.40931	133.03586	60	Subsurface
9/3/2017	SW14	69.40931	133.03586	60	Subsurface
9/3/2017	SW15	69.43856	132.99513	60	Subsurface
9/4/2017	SW16	69.44262	133.03816	60	Subsurface
9/4/2017	SW17	69.44188	133.04056	60	Subsurface
9/4/2017	SW18	69.44181	133.04617	60	Subsurface
9/4/2017	SW19	69.44342	133.04883	60	Subsurface
9/6/2017	SW20	69.44726	133.03447	60	Subsurface
9/6/2017	SW21	69.45075	133.03291	60	Subsurface
9/6/2017	SW22	69.44855	133.04181	60	Subsurface
9/6/2017	SW23	69.43046	133.06533	60	Subsurface
9/6/2017	SW24	69.42918	133.06766	60	Subsurface
9/6/2017	SW25	69.42633	133.07264	60	Subsurface
9/6/2017	SW26	69.42328	133.08198	60	Subsurface
9/6/2017	SW27	69.42328	133.08198	60	Subsurface
9/11/2017	SW28	69.56995	138.91359	60	Subsurface
9/11/2017	SW29	69.56768	138.91694	60	Subsurface
9/11/2017	BW4	69.53132	139.12503	1	Subsurface
Sediment samples					
8/25/2017	1	77.06172	57.7788		
8/25/2017	2	77.06193	57.8133		

Date	Sample ID	Latitude	Longitude	Sample volume (L)	Depth (m)
8/25/2017	3	77.06041	57.7849		
8/26/2017	4	77.06225	57.7731		
8/26/2017	5	77.04905	57.6603		
8/26/2017	6	n/a	n/a		
8/26/2017	7	77.09539	57.8344		
8/28/2017	8	77.01020	57.3859		
8/28/2017	9	77.00999	57.3686		
8/29/2017	10	77.04752	57.7169		
8/29/2017	11	77.00978	57.3434		
8/29/2017	12	77.04573	57.7109		
9/1/2017	13	77.05490	57.7053		
9/1/2017	14	77.05367	57.6966		
9/2/2017	15	69.43863	133.03999		
9/3/2017	16	69.43832	133.04126		
9/3/2017	17	69.43832	133.04126		
9/3/2017	18	69.43856	132.99513		
9/4/2017	19	69.44262	133.03816		
9/4/2017	20	69.44188	133.04056		
9/4/2017	21	69.44181	133.04617		
9/4/2017	22	69.44342	133.04883		
9/6/2017	23	69.45075	133.03291		
9/6/2017	24	69.43046	133.06533		
9/6/2017	25	69.42918	133.06766		
9/6/2017	26	69.42633	133.07264		
9/6/2017	27	69.42328	133.08198		
9/6/2017	28	69.42328	133.08198		
9/11/2017	29	69.56767	138.91696		
9/11/2017	30	69.56768	138.91694		
9/11/2017	31	69.53155	139.12583		
9/11/2017	33	69.53155	139.12583		
9/11/2017	34	69.53132	139.12503		
Fish samples				Species ID	
9/7/2017	BFW1	77.05367	57.6966	Arctic Flounder	
9/7/2017	BFW2	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW3	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW4	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW5	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW6	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW7	77.05367	57.6966	Arctic Flounder	
9/8/2017	BFW8	77.05367	57.6966	Starry Flounder	
9/8/2017	BFW9	77.05367	57.6966	Starry Flounder	

9/8/2017	BFW10	77.05367	57.6966	Bull head/sculpin
9/8/2017	BFW11	77.05367	57.6966	Bull head/sculpin
9/8/2017	BFW12	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW13	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW14	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW15	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW16	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW17	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW18	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW19	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW20	77.05367	57.6966	Arctic Cisco
9/8/2017	BFW21	77.05367	57.6966	Arctic Cisco

Interacting effects of contaminants and climate change on the health of western Arctic beluga whales: Applying an expanded gene expression toolbox to a time series

Interactions des effets des contaminants et des changements climatiques sur la santé du béluga de l'ouest de l'Arctique : application d'une boîte à outils élargie d'expression génétique à une série chronologique

- **Project Leader/Chef de projet**
  Marie Noel, Ocean Pollution Research Program, Ocean Wise, 4160 Marine Drive, West Vancouver, BC, V7V 1H2. Tel: (604) 239-6967, E-mail: marie.noel@ocean.org.
  Lisa Loseto, Fisheries, Oceans & the Canadian Coast Guard, Freshwater Institute, 501 University Crescent, Winnipeg, MB, R3T 2N6. Tel: (204) 983-5135, Email: Lisa.Loseto@dfo-mpo.gc.ca
- **Project Team/Équipe de projet**
  Peter S. Ross, Ocean Wise, Vancouver, BC; Ellika Crichton, Ocean Wise / University of British Columbia, Vancouver, BC; Bruno Rosenberg, Fisheries and Oceans Canada, Winnipeg, MB; Gary Stern, University of Manitoba, Winnipeg, MB; Gregg Tomy, University of Manitoba, Winnipeg, MB

- **Project Location/Emplacement(s) du projet**
  Beaufort Sea, Canada

Abstract

Beluga whales (*Delphinapteurus leucas*) in the Arctic may be vulnerable to the combined effects of contaminants and a changing climate. NCP supported our previous work on Hendrickson Island (2008-2010) that demonstrated the effect of PCBs on the health of Beaufort Sea beluga using a new genomics toolbox (17 genes). Our previous study suggested that genes involved in metabolism and condition were altered by inter-annual changes in feeding ecology by beluga (Noel et al., 2014), but a longer time series is needed to document the effects of climate

Résumé

Les bélugas (*Delphinapterus leucas*) de l'Arctique peuvent être vulnérables aux effets combinés des contaminants et des changements climatiques. Le PLCN a appuyé nos travaux antérieurs sur l'île Hendrickson (de 2008 à 2010) qui ont démontré les effets des BPC sur la santé du béluga de la mer de Beaufort en utilisant une nouvelle boîte d'outils génomiques (17 gènes). Notre étude antérieure suggérait que les gènes impliqués dans le métabolisme étaient altérés par les changements d'une année à l'autre dans

change on their health. The goal of the work for the 2017-2018 funds was to expand the genomics toolbox from 17 to 27 genes. Our rigorous quality assurance work demonstrated that out of the 10 candidate genes selected, six primer pairs passed and will provide us additional information on the nutritional status of the whales. In addition, we submitted 2017 samples for metabolomics analyses. The analyses of such molecules, together with gene expression information, will provide valuable information for an in-depth health assessment. As of April 2018, laboratory work is being finalized.

Key Messages

- Additional samples were collected in the summer of 2017 and the remainder of the year was spent processing samples for genomics analyses.
- We conducted extensive quality assurance/quality control on 10 new genes that can provide information on nutritional stress (for a total of 27 genes).
- We extracted RNA, made complementary DNA (cDNA) from up to 15 individuals from each of the following sampling years: 2012, 2013, 2014, 2015, 2016 and 2017.
- We are currently finishing the PCR runs for the 23 genes that pass quality assurance and quality control (QA/QC).
- 2017 blood samples for metabolomics analyses have been submitted.

les relations trophiques du béluga[1]. Cependant, une série chronologique plus longue est requise pour documenter les effets des changements climatiques sur leur santé. Les travaux financés en 2017-2018 visaient à élargir la boîte à outils génomiques, la faisant passer de 17 à 27 gènes. Nos travaux rigoureux d'assurance-qualité ont démontré que, parmi les 10 gènes candidats sélectionnés, six paires d'amorces ont passé le test et nous fourniront des renseignements additionnels sur l'état nutritionnel des baleines. En outre, nous avons soumis les échantillons de 2017 à des analyses métabolomiques. Les analyses de ces molécules, ainsi que les renseignements sur l'expression génétique, nous fourniront de précieux renseignements qui permettront d'effectuer une évaluation approfondie de l'état de santé de ces espèces. En avril 2018, les travaux en laboratoire étaient sur le point d'être achevés.

Messages clés

- D'autres échantillons ont été prélevés à l'été 2017. Le reste de l'année a été consacré au traitement des échantillons en vue des analyses génomiques.
- Nous avons soumis 10 nouveaux gènes susceptibles de fournir de l'information sur le stress nutritionnel à de rigoureux processus d'assurance et de contrôle de la qualité (soit un total de 27 gènes).
- Nous avons extrait de l'ARN et fabriqué de l'ADN complémentaire (ADNc) à partir de jusqu'à 15 individus pour chacune des années d'échantillonnage suivantes : 2012, 2013, 2014, 2015, 2016 et 2017.
- Nous avons presque terminé d'effectuer la réaction en chaîne de la polymérase pour les 23 gènes qui ont passé les processus d'assurance et de contrôle de la qualité.
- Des prélèvements sanguins de 2017 ont été soumis aux fins d'analyse métabolomique.

1 NOËL, M., L. L. Loseto, C. C. Helbing, N. Veldhoen, N. J. Dangerfield et P. S. Ross. « PCBs are associated with altered gene transcript profiles in Arctic beluga whales (Delphinapterus leucas) ». Environmental Science and Technology 48, 2014, p. 2942 à 2951.

Objectives

This project aims to:

- expand the beluga-specific genomics toolbox;
- assess the use of metabolomics to complement genomics results; and,
- evaluate whether climate change might have an impact on the health of beluga whales at the molecular level.

Introduction

Because of its sentinel role at the top of the food web, and its harvesting as a country food by Inuit, the beluga has been an important monitoring species for decades in the Arctic. While wildlife of the remote Arctic are generally exposed to moderate levels of contaminants compared to their southern counterparts, an increasing number of studies report contaminant-associated health effects in Arctic marine mammals (Desforges et al. 2013; Brown et al., 2014, Noel et al., 2014). A complicating factor for contaminant-induced impacts in the North is that climate change may add a layer of stress to beluga whales, by altering contaminant pathways, or by reducing the condition of beluga whales through food web changes (Macdonald 2005). Changes in Arctic sea ice cover, temperature profiles, food web productivity, and beluga distribution and feeding ecology may profoundly change the course of contaminant fate and transport in the Arctic environment, as well as the condition and health of beluga. Climate change has the potential to confound our understanding of mechanistic linkages between contaminant exposure and health effects, but may also have serious implications for the health of beluga whale populations.

Biological effects can be measured at different levels of biological organization, from the molecular level (gene expression) to the ecosystem level, with the former responding early and therefore providing an early warning signal of health effects. Through gene expression, the information contained within genes is transformed into useful products such as proteins which are required for the structure, function and regulation of the body's tissues and organs. Contaminants, as well as various environmental factors, can interfere with gene expression by increasing or decreasing the expression of certain genes, therefore impacting major vital biological systems in the organism.

Our 2008-2010 study revealed PCB-associated effects on important genes indicating a response to contaminants, but the altered expression of genes involved in growth, development and metabolism appeared to indicate potential health impacts related to differences in feeding ecology or body condition associated with a changing ice regime (Noel et al., 2014). However, additional temporal sampling is necessary to extend these observations and provide some insight to the troubling questions about the potential for interactive effects associated with persistent contaminants and a rapidly changing climate in beluga whales. Since then, additional information related to nutrition has become available, with new work being done at the new biotracers lab at Fisheries and Oceans Canada (DFO) (Winnipeg) which enhanced capacity for nutritional (e.g. compound specific stable isotopes and fatty acids) and stress assessments (e.g. measurements of cortisol and other hormones on LC/MS).

This study directly addresses one of the primary goals of the NCP that is to "assess the influence of the environmental change on exposure and effects of contaminants on Arctic ecosystems" (AMAP 2013). In addition, the AMAP 2013 recommends "the application of new genomics techniques as a powerful means of examining the relationship between physiological endpoints and persistent contaminants. These techniques should be applied to examine subtle effects on higher trophic level arctic animals".

Activities in 2017-2018

NCP funds allowed for the collection of additional samples in 2017, as well as sample processing and genomics analyses for newly collected samples as well as archived samples from 2008, 2009, 2010, 2012, 2013, 2014, 2015 and 2016.

2017 Field Work

The community of Tuktoyaktuk harvested a total of 32 beluga whales in the summer of 2017. Blubber and liver samples for genomics analyses were collected in RNA later for 15 adult males. After collection, samples were stored at 4°C for 24 hours and then transferred into a -20°C freezer until further analyses. In addition, blood samples were collected, plasma and serum subsequently separated and stored in a dry shipper in the field and then in -80°C back at the lab for metabolomics analyses.

Genomics analyses

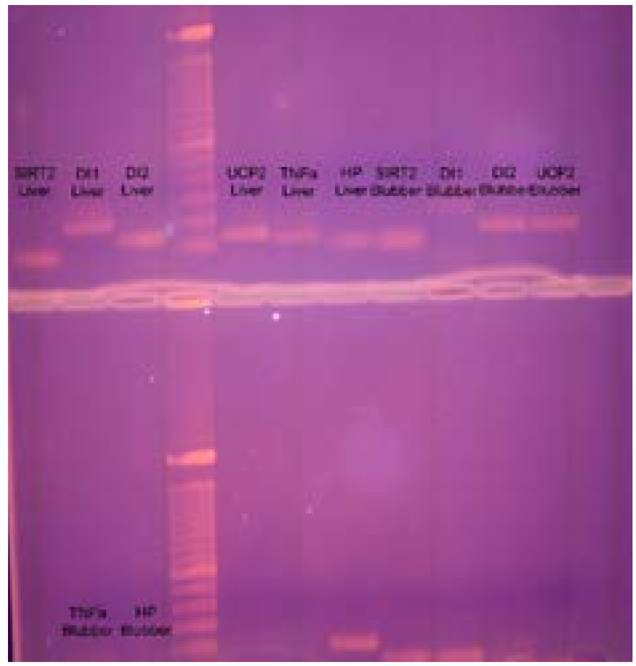
Quality Assurance / Quality Control (QA/QC) of 10 new Primer Pairs

Primer sets for the 10 additional genes considered in the proposed work have been developed for other marine mammal species (Martinez et al., 2013; Muller et al., 2013; Castelli et al., 2014; Spitz et al., 2015). However, given the limited genomic resources for marine mammals, gene-specific sequences from several mammalian species are usually used in order to identify parts of the sequence that are highly conserved across species and design specific primer pairs. For these reasons, primer sets developed for other marine mammal species are likely to be applicable to beluga whales but will require a rigorous QA/QC process for each tissue analyzed prior to running the samples.

Each new PCR primer pair considered was assessed in a three-tiered process:

- Tier 1: Gel electrophoresis was used to ensure that the amplified fragment had the correct predicted size (Figure 1).
- Tier 2: The amplified sequence was sent for sequencing to confirm that a gene-specific sequence was amplified (results pending from the University of British Columbia).
- Tier 3: To satisfy the requirements for application of the comparative Ct method (ΔCt), standard curve analysis was performed for each primer pair using serially diluted cDNA template. The slope of ΔCt (test gene minus normalizer gene) versus the log of cDNA template dilution will have to be <0.1 for the primer pair to be validated for the use with beluga whale samples.

Figure 1: Example of a gel that was run for the primers that were being tested.



RNA Isolation, cDNA Synthesis and PCR Assays

RNA isolation and cDNA synthesis were conducted following procedures described previously (Veldhoen et al., 2001; Buckman et al., 2011). Tissues were homogenized with TRIzol reagent and a 3 mm diameter tungsten-carbide bead using a mixer mill. For the blubber samples, glycogen was added to the samples after phase separation to facilitate RNA precipitation. Isolated total RNA was resuspended in diethyl pyrocarbonate-treated distilled deionized water (DEPC) and stored at -80°C. RNA concentrations were confirmed through spectrophotometry and 1 μg of each sample was used to produce cDNA with the High Capacity cDNA reverse transcription kit (Applied Biosystems).

Quadruplicate reactions were performed for each sample on an Applied Biosystems StepOne Plus real time PCR system. The amplification thermocycler program for most transcripts included an initial activation step at 95°C (9 min), followed by 40 cycles of 95°C denaturation (15s), 60°C annealing (30s), and 72°C elongation (45s). One last step at 95°C (30s) was performed to create the denaturation profile at the end of the reaction.

Table 1. RNA was extracted and cDNA synthesized for up to 15 individuals per year since 2008. (Note: no samples were collected in 2011).

	n	RNA extraction		cDNA synthesis	
		Blubber	Liver	Blubber	Liver
2008	15	√	X	√	X
2009	15	√	X	√	X
2010	10	√	X	√	X
2012	7	√	X	√	X
2013	11	√	X	√	X
2014	12	√	X	√	X
2015	9	√	X	√	X
2016	?	X	X	X	X
2017	14	√	√	√	√

Metabolomics Analyses

Plasma samples were sent to SGS-Axys Analytical Services for metabolomics analyses using high performance liquid chromatography tandem mass spectrometry.

Results

Genomics Analyses

Ten primer pairs that have been successfully used in other marine mammal species were tested for their applicability in beluga whales. To this extent, a three-tiered quality assurance/ quality control process was conducted to assess each of the primer pairs. Four primer pairs were deemed unacceptable for use in beluga whales after the first tier of the Quality Assurance/ Quality Control (QA/QC) protocol (Acox1, Acat2, CRP, PPARα). Six primer pairs (DI1, DI2, UCP2, TNFα, HP, SIRT2) passed the second tier of the QA/QC protocol and are now being examined at the third tier (Table 2).

Table 2. Results of the three tiered QA/QC for all 10 genes of interest

	Tier 1	Tier 2	Tier 3
Acox1	Fail	N/A	N/A
Acat2	Fail	N/A	N/A
CRP	Fail	N/A	N/A
PPARα	Fail	N/A	N/A
DI1	Pass	Pass	In progress
DI2	Pass	Pass	In progress
UCP2	Pass	Pass	In progress
TNFα	Pass	Pass	In progress
HP	Pass	Pass	In progress
SIRT2	Pass	Pass	In progress

Community Engagement

This project relies entirely on collaboration with the community of Tuktoyaktuk. As part of the beluga monitoring program, staff worked extensively with Inuvialuit youth and community members to collect various samples from harvested beluga whales on Hendrickson Island.

Capacity Building and Training

Field assistants were trained in the field to collect samples for genomics analyses. Training included how to subsample and preserve the samples correctly. These practices ensured that samples didn't degrade and allowed for extraction of RNA at a later date.

Ellika Crichton is an MSc student working on the project. She is enrolled at the University of British Columbia in Vancouver and throughout her program will acquire knowledge on molecular techniques for extraction of RNA and quantification of gene expression as well as on threats facing beluga whales such as contaminants and climate change and potential implications for Inuvialuit communities.

Information on the beluga health project was presented at the various Hunter and Trapper Committees throughout the region (Inuvik, Tuktoyaktuk, Paulatuk, and Ulukhaktok) as part of the presentation about the beluga monitoring program. Project updates and proposals were also presented to the two major wildlife boards in the ISR in winter and summer (Inuvialuit Game Council and Fisheries Joint Management Committee).

Ellika Crichton gave a presentation outlining the project at the 22nd Biennial Conference on the Biology of Marine Mammals in Halifax in October 2017. In addition, she presented her project as part of the biology department speaker series at Simon Fraser University.

Discussion and Conclusions

The expansion of our genomics tool box combined with preliminary metabolomics data will help us broaden our understanding of beluga health. Genes of interest were carefully selected to provide adequate information on contaminant exposure, general stress and nutritional stress. Taken together, these results will help evaluate beluga health as it relates to persistent organic pollutant exposure and direct or indirect climate change-related effects.

Expected Project Completion Date

Due to the extent of lab work involved in this project, as of June 2018, laboratory analyses are still being conducted. We are anticipating that laboratory work will be completed in the summer of 2018; data analyses will follow.

Acknowledgments

We are grateful to the Hunters and Trappers Committee of Inuvik and Tuktoyaktuk as well as the hunters from the communities for allowing us to sample from their landed belugas. We thank the beluga monitors at Hendrickson Island over the years that include Frank Pokiak, Verna Pokiak, Jonas Felix, Rex Noksana, Lionel Kikoak along with the DFO and FJMC sampling crew (C. Blakeston, J. Brewster, S. MacPhee, E. Way-Nee, D. Swainson, L. Murray, A. Gordon, K. Hansen-Craik). Funding for the beluga monitoring program was provided by the Fisheries Joint Management Committee and Fisheries and Oceans Canada.

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Snowpack mercury mass balance over the spring melt period, Iqaluit, NU

Bilan massique du mercure dans le manteau de neige à la fonte printanière, Iqaluit (Nunavut)

- **Project Leader/Chef de projet**
  Murray Richardson, Associate Professor, Department of Geography and Environmental Studies, Carleton University, Ottawa, K1S 5B6 Tel: (613) 520-2600 ext. 2574; Fax: (613) 520-4301;
  E-mail: murray.richardson@carleton.ca
- **Project Team/Équipe de projet**
  Chris Eckley, US Environmental Protection Agency; Jane Kirk, Amber Gleason, and Greg Lawson, Environment and Climate Change Canada; Jamal Shirley, Nunavut Research Institute; Keegan Smith, Carleton University

- **Project Location/Emplacement(s) du projet**
  Iqaluit, NU

Abstract

The purpose of this this two-year project is to improve understanding and predictive modelling of the fate of mercury in end-of-winter Arctic snowpack. This requires intensive monitoring of the surface to air exchanges of mercury prior to and throughout the spring melt period. The study is being conducted near the community of Iqaluit, NU, South Baffin Island. In Arctic coastal regions such as this, mercury cycling is strongly influenced by marine aerosols and the enhanced atmospheric deposition rates associated with springtime atmospheric mercury depletion events, which have yet to be reported on for Baffin Island. Field activities in 2017 began in mid-June after the onset of spring melt. Despite the late start to the field season, we collected a 25-day time series of snow-air and soil-air mercury fluxes. Fluxes from snow were initially high at the onset of the monitoring period because of a fresh snowfall, but subsequent fluxes from snow

Résumé

Ce projet d'une durée de deux ans vise à améliorer la compréhension et la modélisation prédictive du devenir du mercure dans le manteau de neige à la fin de l'hiver dans l'Arctique. Ceci passe par une surveillance intensive des échanges de mercure entre la surface et l'air, avant et pendant la période de fonte printanière. L'étude est menée à proximité de la collectivité d'Iqaluit, au Nunavut, au sud de l'île de Baffin. Dans ces régions côtières de l'Arctique, le cycle du mercure est fortement influencé par les aérosols marins et par les dépôts atmosphériques accrus liés aux phénomènes printaniers d'appauvrissement du mercure atmosphérique, qui n'ont pas encore été rapportés pour l'île de Baffin. Les activités sur le terrain menées en 2017 ont commencé à la mi-juin, après le début de la fonte printanière. Malgré des débuts tardifs, nous avons pu recueillir une série de flux de mercure neige-air et sol-air couvrant

and soil surfaces were low for the duration of the field season. A second field-season will be conducted in the spring of 2018, with the goal of an earlier start to capture the pre-melt surface-air exchanges of mercury and the potential contribution of atmospheric mercury depletion events to the net contribution of snowpack mercury to surface waters during the spring melt period.

une période de 25 jours. Les flux provenant de la neige étaient élevés au commencement de la période de surveillance en raison de la nouvelle tombée de neige. Cependant, les flux subséquents de la neige et des surfaces du sol étaient faibles pour toute la durée des travaux sur le terrain. Une seconde ronde de travaux sur le terrain aura lieu au printemps 2018 afin de commencer à analyser les échanges de mercure entre la surface et l'air avant la fonte des neiges et, ainsi, d'établir l'apport possible des phénomènes d'appauvrissement du mercure atmosphérique sur la contribution nette du mercure dans le manteau de neige au mercure mesuré dans les eaux de surface pendant la période de fonte printanière.

Key Messages

- Snowpack-air fluxes of gaseous elemental mercury were low during the late season melt period.
- A short-lived, high gaseous elemental mercury emission event occurred immediately following a fresh snowfall event. This event was followed by a return to lower flux rates within two days.
- Soil-air gaseous elemental mercury (GEM) fluxes were lower than snowpack-air GEM fluxes for the period immediately following snowpack disappearance.
- In year two of this study, field activities will start in early spring to capture data over the pre-melt period and to monitor for the occurrence of atmospheric mercury depletion events which play an important role in mercury cycling in Arctic coastal regions.

Messages clés

- Les flux de mercure élémentaire gazeux entre le manteau de neige et l'air étaient faibles vers la fin de la saison de la fonte des neiges.
- Un événement de courte durée d'émission d'une forte concentration de mercure élémentaire gazeux est survenu immédiatement après un événement de tombée de neige. Cet événement a été suivi d'un retour à des flux plus faibles après deux jours.
- Les flux de mercure élémentaire gazeux (MEG) entre le sol et l'air étaient plus faibles que les échanges de MEG entre le manteau de neige et l'air pour la période suivant immédiatement la fonte complète du manteau de neige.
- Pour la 2e année de cette étude, les activités sur le terrain commenceront au début du printemps afin de recueillir des données avant la fonte des neiges et surveiller la survenue de phénomènes d'appauvrissement du mercure atmosphérique, lesquels jouent un rôle important dans le cycle du mercure dans les régions côtières de l'Arctique.

Objectives

The long-term objective of this research project is to improve current understanding of Arctic snowpack Hg dynamics during the spring melt period and the physical mechanisms that govern partitioning of the spring snowpack Hg burden between emission *vs* meltwater output pathways. The key question posed in this study is: "How do short-term variations in weather conditions (e.g. over periods of days to weeks) during arctic spring affect the relative fractions of meltwater Hg outputs versus Hg re-emission to the atmosphere, from the end-of-winter snowpack." The specific, short-term objectives are to:

1. Produce a point-scale snowpack Hg mass balance estimate, resolved at a daily time step, for the entire spring snowmelt period, by monitoring surface-air Hg fluxes and meltwater Hg outputs over time;

2. Produce detailed, vertically resolved snowpack water and energy balance estimates using hydrometric and micrometeorological techniques; and,

3. Use results from objectives 1 and 2 to interpret daily patterns of snowpack Hg losses via surface-air emission and meltwater output pathways in relation to weather/climate variables, snowpack physical and chemical characteristics and snowmelt rates.

Introduction

Arctic freshwater and marine environments are sensitive to atmospheric mercury (Hg) pollution, as indicated by high concentrations of Hg in aquatic and marine food webs, including fish and marine mammals, consumed by many Northern and Indigenous people. Most anthropogenic releases of Hg are in an inorganic form; however, most of the Hg that bioaccumulates in fish is in an organic form (methylmercury—MeHg). Hg is unique among heavy metals in that it can exist in the pure gas phase as gaseous elemental mercury (Hg^0 or GEM). This allows for the long-range transport of Hg in the atmosphere (0.5 to 2 years atmospheric residence time) and contamination of remote ecosystems through atmospheric deposition. In the atmosphere, GEM can react with strong oxidants, such as halogen radicals, to form chemical species termed reactive gaseous Hg (RGM) and particulate Hg (PHg), both of which have relatively short atmospheric residence times and therefore are rapidly deposited to underlying surfaces, such as landscapes and water bodies (Steffen et al. 2008).

In Arctic landscapes, snow plays a dominant role in the accumulation and downstream export of atmospherically deposited Hg, but more research is required to understand the role of snow and snowmelt processes on the Hg cycling in these regions. Additionally, Hg deposition can be enhanced in Arctic coastal regions due to unique atmospheric chemistry causing atmospheric mercury depletion events (AMDEs; Steffen et al. 2008). Therefore, in Arctic coastal regions, Hg accumulates in the seasonal snowpack throughout the winter, with potentially large additional inputs just prior to the spring melt period from AMDEs. There are, however, large uncertainties surrounding the fate of the end of winter snowpack Hg burden during the spring melt period, and the possible effects of climate induced changes in temperature regimes, sea ice conditions, and snow accumulation and melt regimes. In particular, there are gaps in our current understanding of how the spring melt regime can control release of Hg out of the base of the melting snowpack to freshwater and marine environments, versus losses back to the atmosphere through volatilization.

The goal of this two-year study is to measure and model the snowpack Hg mass balance melt period to quantify the fate of atmospherically deposited Hg during annual spring melt period. The work is being conducted outside of the community of Iqaluit, NU at the location of ongoing research activities focussed on snow hydrology and water-balance monitoring. Knowledge acquired through the proposed study will help improve understanding of the likely impacts of climate change on arctic Hg cycling, and its effects on the movement of Hg between terrestrial, aquatic and marine environments during Arctic spring.

Activities in 2017-2018

Field Activities

Field activities were conducted between June 10th and July 5th 2017. A Tekran 2537 ambient air mercury analyzer was deployed over a late-lying snowpack spanning an area of approximately 250 m^2 and an average depth of approximately 50 cm at the start of the sampling period. Snow temperatures were isothermal with active melt happening during daytime periods. Snowpack relative density was consistently near 0.3 (i.e. 30% water equivalent). Prior to and throughout the measurement period, the snowpack was sampled for major ion chemistry and total mercury (THg).

During the first half of the sampling period, we measured surface-air GEM fluxes over snow. The chamber was moved several times to assess spatial variability of snow-air fluxes. After 13 days, more than half of initial snowpack area had ablated, and the chamber was moved to a freshly exposed soil location. Measurements were subsequently collected over soil for approximately 12 days until July 3rd. Over the course of the entire 25-day period, approximately 8 days of sampling were missed due to equipment malfunction or other logistical challenges.

Community Engagement

The Nunavut Regional Contaminants Committee co-chair, Jean Allen, was consulted on the proposal and provided verbal and written input and advice. Murray Richardson presented past and ongoing Northern Contaminants program (NCP) studies to the NECC committee and members of the Nunavut Water Management Strategy committee in October, 2017. In November 2017, Murray Richardson also ran a researcher booth on aquatic science with collaborator John Chételat at the NCP results in Yellowknife.

Capacity Building

As part of parallel research activities under a POLAR Knowledge Canada grant, Murray Richardson and team member Keegan Smith have provided training in snow hydrology to Nunavut Arctic College Environmental

Figure 1. Photos from the spring 2017 field season including the Teflon Dynamic Flux Chamber (DFC) place over the late-lying spring snowpack (left) and project team member Chris Eckley checking the data stream of the Tekran 2537 (right).

Technology Program (NAC ETP) students since 2015, in collaboration with ETP instructors Daniel Martin and Jason Carpenter. This has typically involved a small amount of classroom training combined with 2 days of field methods for second year students at ETP's annual spring field camp in April. Normally, several students show interest in participating in additional field activities during late April and early June after the term is ended. These individuals receive additional training as well as a daily stipend. These activities continued successfully during the 2017 field season. Murray Richardson also participated in the Sentinel International Arctic Field School ("A changing cryosphere: from sensors to decision making") in Iqaluit, NU, March 2nd -9th 2018, and contributed materials and teaching on snow hydrology. The participants in this program included second year NAC ETP students.

Indigenous Knowledge

Travelling through the rugged terrain near Iqaluit during spring snowmelt presents many logistical challenges. Land skills of field assistants and their knowledge of local terrain have contributed indispensably to the success of the project. During the Sentinel International field school, there were additional opportunities to link and compare Indigenous and Scientific Knowledge of snow properties through an igloo construction workshop (led by an experienced Inuk hunter) and parallel snow science activities including snow pit temperature and density profiling.

Results

Surface-air fluxes of GEM over the entire measurement period are shown in Figure 2. High GEM emissions exceeding 30 ng m^{-2} hr^{1} were recorded at the onset of the sampling effort. This emission peak corresponded to a fresh snowfall of approximately 2 cm that occurred on the evening of June 10th. The flux chamber was placed directly over the new snow at approximate 9:00 am the following morning and the observed peak occurred at 11 am, followed by a secondary peak of approximately 11.5 ng m^{-2} hr^{1} on the following day at approximately the same time.

Figure 2. Time series of GEM fluxes over snow and freshly exposed bare soil. In the bottom time series, the y-axis is reduced to better illustrate emission peaks throughout the monitoring period. Dashed vertical lines indicate timing of fresh snow fall and the transition from snow to soil, as indicated.

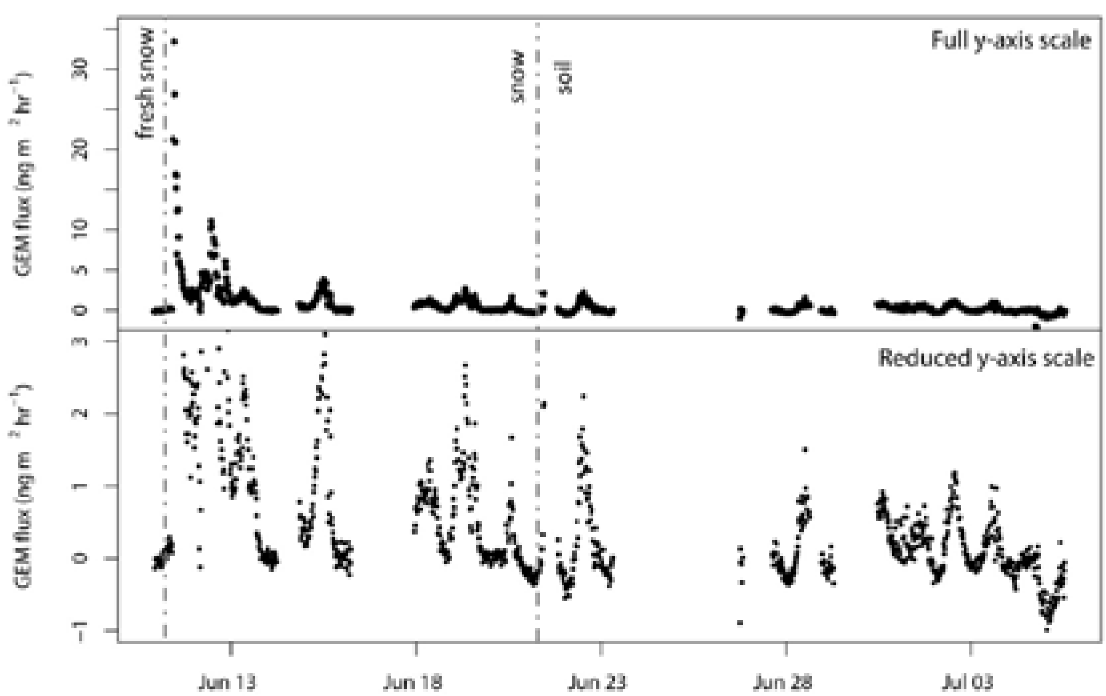


Table 1. Statistical summary of GEM fluxes from snow and soil surfaces over the study period.

	Mean (and median) GEM flux (ng m^{-2} hr^{-1})	Range GEM flux (ng m^{-2} hr^{-1})
Entire Study Period (snow and soil fluxes)	0.68 (0.1)	-2.13 to 37.19
Snow fluxes only	1.11 (0.21)	-0.63 to 37.19
Soil fluxes only	0.1 (0.01)	-2.13 to 2.24

We concurrently measured meteorological conditions including air temperature, net radiation and wind speed and used these to analyze diel fluctuations in GEM fluxes using a multiple linear regression and Regression Tree modelling. A shorter-term time series of these data used for statistical analysis is shown in Figure 3. This time series corresponds to the snow sampling period only and excludes the very high GEM fluxes associated with fresh snowfall. Here, the diurnal cycle of high GEM emissions is clearly visible, driven by solar radiation. Missing data associated with equipment malfunctions are also clearly seen here. A particular challenge was maintaining a proper seal around the chamber during peak snowpack ablation periods which caused the apparatus to constantly shift and re-settle.

Since continuous, error-free measurements using the DFC method can be challenging in this type of environment (poor access, very windy, and rapidly melting snowpack), methods for gap filling are required to produce a continuous record for the snowpack mass balance. We have made preliminary progress with statistical modelling of GEM for the measurement period shown in Figure 3. Multiple linear regression was tested but not effective due to complex interactions among driving variables. Instead, we used a Random Forest (Breiman 2001) regression tree approach which is non-parametric and more flexible for such datasets. Random Forest analysis demonstrated net radiation to be the most important of the meteorological variables tested and overall model fir for the fitted data was strong, explaining 71% of variation in observed variations in GEM. This method shows some promise for gap filling, which will be required to complete mass balance analyses of 2018 field season data.

An example times series showing the Random Forest gap-filled results provided in Figures 4 and 5. In Figure 5, the same data are shown along with a cross-validation test in which valid data from June 19th were removed from the dataset and the period was gap filled using the Random Forest model.

Discussion and Conclusions

Various studies have reported snow-air exchanges of GEM in Arctic regions and the magnitudes of these fluxes vary widely. These variations often result from differences in the specific measurement technique used (e.g. DFC-based methods versus micrometeorological-based approaches). However, fluxes of GEM from arctic snow packs measured using a DFC approach also vary widely, ranging from 0 to 70 ng m^2 hr^{-1} in the reported literature (Ferrari et al. 2005, Sommar et al. 2007, Mann et al. 2014). Even within individual studies, fluxes can vary over similarly large ranges, normally always peaking during mid-day periods, which reflects photo-chemically mediated production of GEM within the snowpack. High flux rates (e.g. >10 ng m^{-2} hr^{-1}) are most commonly associated with fresh snowfall or AMDEs episodes. The flux rates reported in Figure 2 and Table 1 are consistent with these findings. Over the course of 12 days we found flux rates from the snowpack to be relative low except for at the onset of the monitoring period when the chamber was placed over freshly fallen snow. Following the initial peak of 32 ng m^{-2} hr^{-1}, flux rates declined over the subsequent two days to more consistently low levels. This behaviour is consistent with the concept of an "easily" reducible Hg fraction associated with AMDEs (Kamp et al. 2018) or fresh snow (Sommar et al. 2007). Fresh snowfall can be high in total Hg due the scavenging of atmospheric Hg sources, and subsequent re-emission following this wet deposition can occur (Sommar et al. 2007).

The DFC method does not measure deposition of oxidized Hg species via dry AMDEs or wet deposition. Since high snowpack-air fluxes of GEM are typically associated with recently deposited Hg, it is problematic to assume that these fluxes represent a net loss of snowpack Hg over the study period. A snowpack Hg mass balance must, therefore, employ regular snow surface sampling to estimate inputs of Hg via these sources. Such sampling was not conducted in 2017 due to the late start in the season and the relatively short monitoring period.

Modelling of GEM flux time series is not commonly reported in the literature. We used empirical modelling as an approach to fill data-gaps in the time series, which can be used to satisfy data requirements for snowpack mass balance analysis provided adequate model performance. Although our empirical model appears to effectively capture the diel variations in GEM flux during the gap-fill periods, the peak was underestimated for the June 19th cross-validation period and the early to late-morning fluxes were largely underestimated. It is possible that these errors can be reduced by supplementing our net-radiometer with a four-component radiometer which will provide incoming short-wave radiation. Net radiation is affected by outgoing short- and long-wave radiation and hence surface albedo and emissivity. It is likely that short-wave radiation will be a stronger predictor of GEM fluxes from snow and soil, compared to net-radiation. Monitoring of snowpack temperature and melt rates will also be conducted in 2018 to improve understanding of the key factors driving GEM emissions during the snowmelt period. The 2018 season will also start earlier (in late April) to capture GEM fluxes during the pre-melt season and the potential occurrence and role of AMDEs in this Arctic coastal region.

Figure 3. Time series of Hg(0) (a), wind speed (b), air temperature (c) and net radiation (d) for selected modelling period (snowpack measurements only excluding the initial high fluxes associated with fresh snow). Gaps in Hg(0) record can be seen and are the result of equipment malfunctions or other logistical challenges.

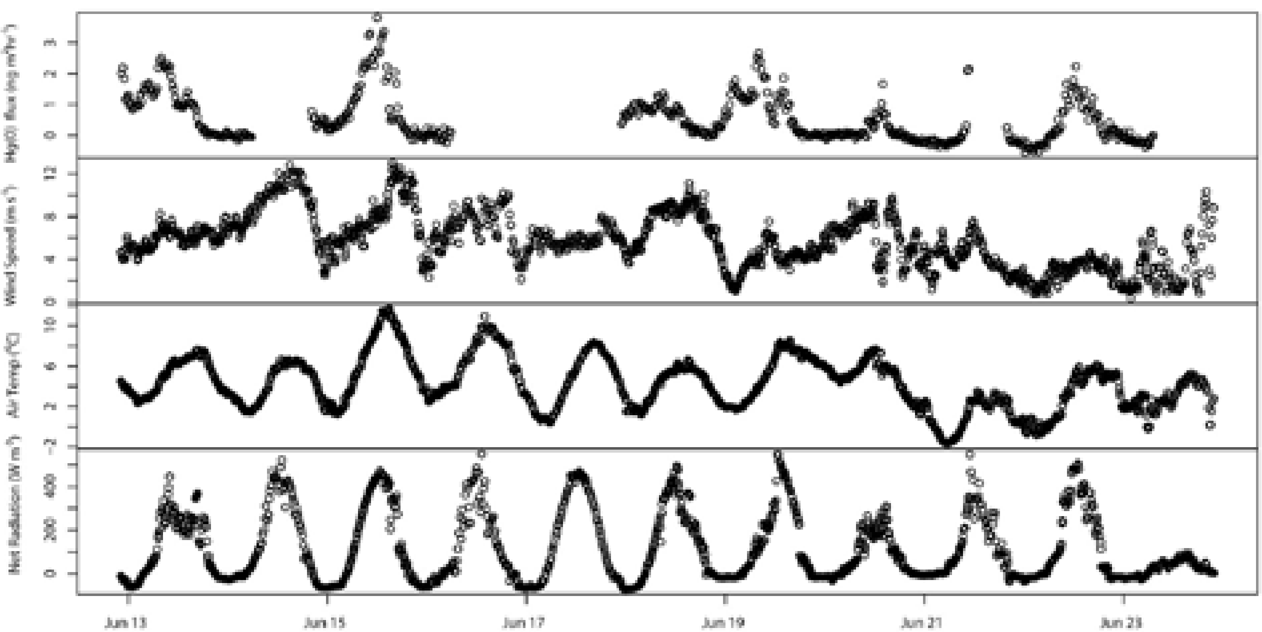


Figure 4. Time series of GEM emissions from snowpack over a 10-day period. Gap-filled periods using random forest regression are shown in red.

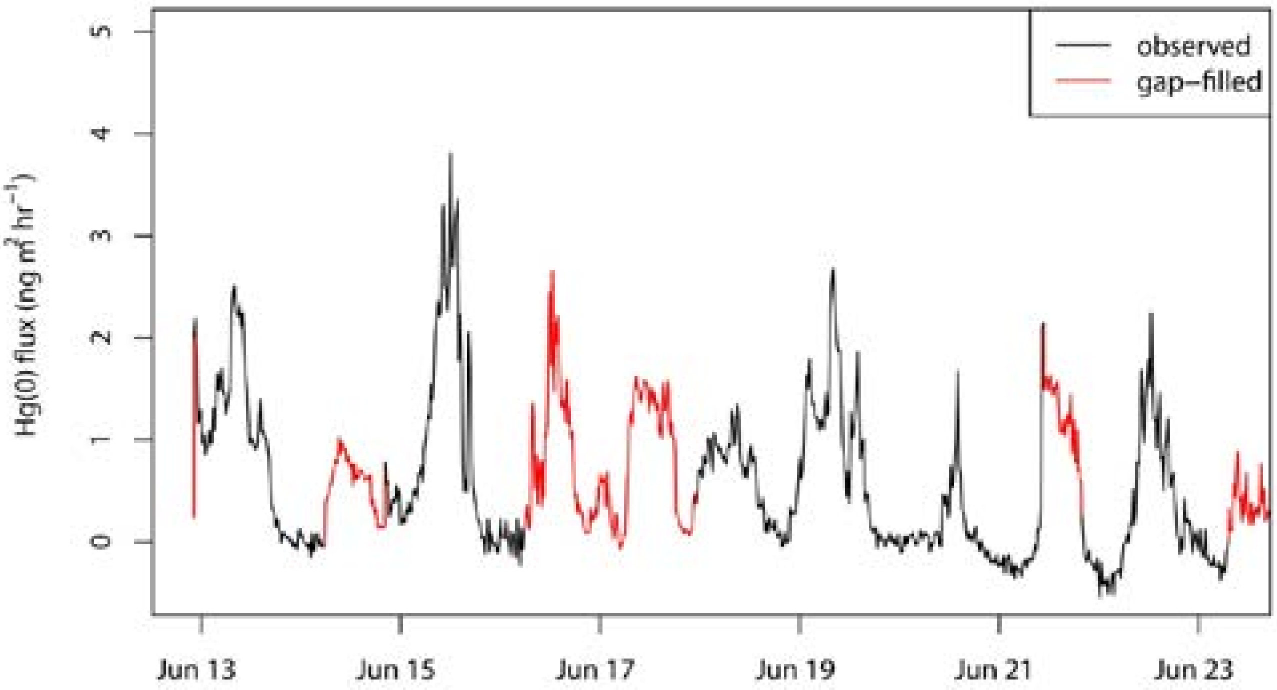
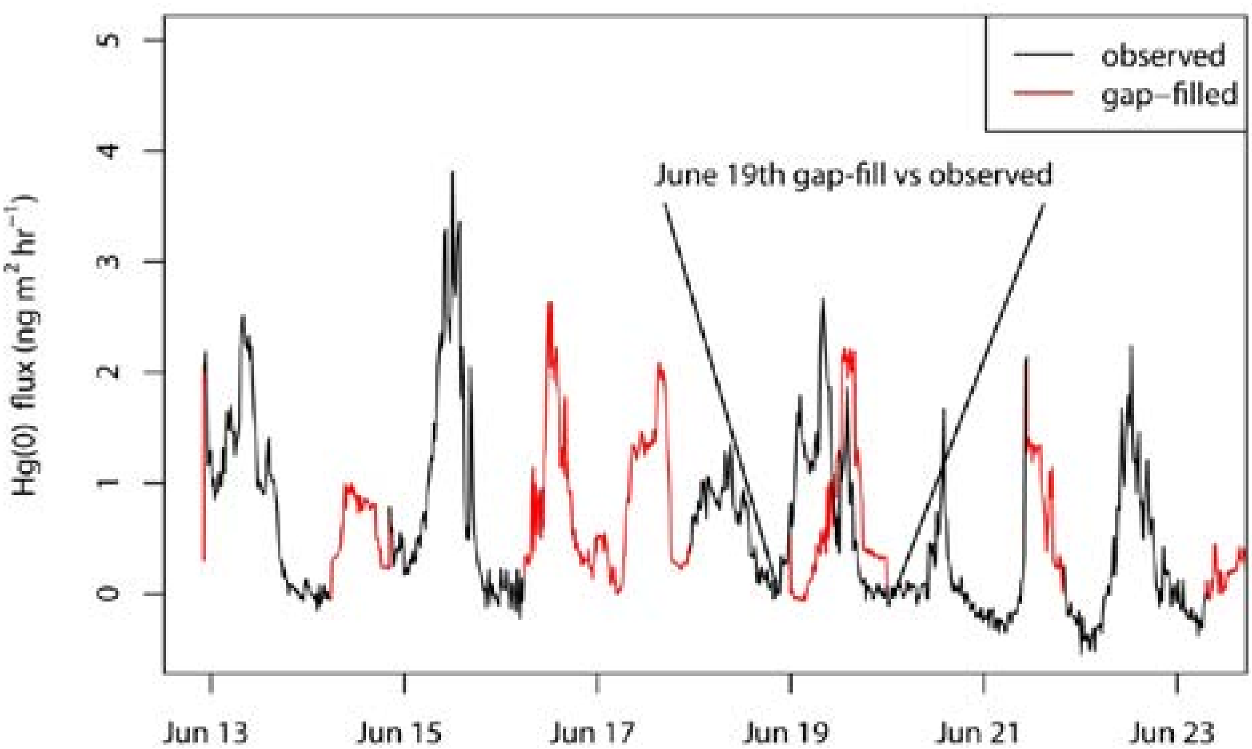


Figure 5. Time series of GEM emissions from snowpack over a 10-day period. Gap-filled periods using random forest regression are shown in red along with a test period during which a 24-hour period of data was removed and gap filled (June 19th). The original data are included during the test period, for comparison.



Expected Project Completion Date

A second field season was conducted in May and June of 2018. Results are pending further analysis. The project will be completed on schedule (March 2019).

Acknowledgments

We are grateful for the NCP funding that supported this work, as well as other granting agencies including NSERC, Polar Knowledge Canada and ArcticNet that helped to fund synergistic activities. We would like to thank all of the ETP students who helped with field activities and/or played other important supporting roles in 2017 including: Jeremy Fraser, Daniel Taukie, Dylan Qappik and the entire class of 2017. We also thank ETP instructors Jason Carpenter and Daniel Martin for supporting this work and staff at NRI: Jamal Shirley, Rick Armstrong and Mary-Ellen Thomas. Finally, parts of this report have been excerpted from the original application for funding to the Northern Contaminants Program, with text contributions from Chris. Eckley, Jane Kirk and Jamal Shirley.

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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

Project Leader/Chef de projet

Jane Kirk, Environment and Climate Change Canada (ECCC), Aquatic Contaminants Research Division (ACRD), Burlington, ON., Tel: 905-336-4712; Fax: 905-336-6430; Email: jane.kirk@canada.ca

Sarah Roberts, ECCC, ACRD, Burlington, ON., Tel: 905-336-4776; Email: sarah.roberts2@canada.ca

Liz Pijogge, Nunatsiavut Government, Environment Division, Nain, Labrador., Tel: 709-922-2942 Ext. 283; Email: Liz.Pijogge@nunatsiavut.com

Project Team/Équipe de projet

Rodd Laing, Carla Pamak, Nunatsiavut Government; Amila De Silva, ECCC, Burlington, ON; Elsie Sunderland, Harvard University, Boston, MA; Derek Muir, ECCC, Burlington, ON; Igor Lehnherr and Dingyi (Alvin) Xiong, University of Toronto Mississauga, Mississauga, ON; Magali Houde, ECCC, Montreal, QC; Tanya Brown, Memorial University of Newfoundland, St. John's, NL; Miling Li, University of British Columbia, Vancouver, BC; Amber Gleason, ECCC, Burlington ON; Christine Spencer, ECCC, Burlington ON; Mary Williamson, ECCC, Burlington ON; Jessica Ewald, Harvard University, Boston, MA; Christine Spencer, ECCC, Burlington ON; Mary Williamson, ECCC, Burlington ON; Miling Li, Harvard University, Boston, MA; Jessica Ewald, Harvard University, Boston, MA

Project Location/Emplacement(s) du projet

- Lake Melville, NL
- Rigolet, NL
- Northwest River, NL

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 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. This research is a community-based monitoring project, working with collaborators from the Nunatsiavut Government and community members from North West River and Rigolet, to investigate contaminant levels in Lake Melville's food web and to provide a benchmark for future studies by providing a baseline dataset.

81 seal samples were collected during harvests by local hunters between 2013-2017 and are being analyzed for mercury and methylmercury. A subset of these samples are being analyzed for mercury stable isotopes, PFASs and PCBs. Average methylmercury concentrations in the liver and muscle of Lake Melville seals collected between 2013-2017 were 202 ± 226 and 133 ± 129 ng/g wet weight (ww), respectively, with 24 of 81 liver samples and 19 of 81 muscle samples surpassing the Canadian frequent consumer guideline of 200 ng/g ww. Average mercury 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 mercury concentrations between 2007-2011 were 107-1070 ng/g) (Brown et al. 2016), likely because many of the seals sampled between 2013-2016 were pups. Results from mercury stable isotope

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 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 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. Il s'agit ici d'un projet de surveillance communautaire mené avec des collaborateurs du gouvernement du Nunatsiavut et des membres des collectivités de North West River et de Rigolet visant à étudier les niveaux de contaminants dans le réseau trophique du lac Melville et à fournir un point de référence (à savoir un ensemble des données de référence) qui servira à de futures études.

Quatre-vingt-un échantillons ont été prélevés chez le phoque par les chasseurs locaux de 2013 à 2017. Ces échantillons ont été analysés en vue d'y déceler la présence de mercure et de méthylmercure. Un sous-ensemble de ces échantillons fait l'objet d'analyses en vue de détecter des isotopes stables de mercure, des PFAS et des BPC. Les concentrations moyennes de méthylmercure dans le foie et le tissu musculaire des phoques du lac Melville échantillonnés entre 2013 et 2017 étaient de 202 ± 226 et 133 ± 129 ng/g-1 (poids humide), respectivement, dans 24 des 81 échantillons de

analyses demonstrate that Lake Melville seals obtain food from both inland and marine sources. Analyses of seals collected in 2017 for PFASs show that adult ringed seals in Lake Melville have 67 ± 12 ng/g ww total PFAS, which is comparable to ringed seals in other areas in Labrador, Hudson Bay and the Beaufort Sea but generally higher than ringed seals from the more northern areas, such as Resolute, Sachs Harbour and Pangnirtung. Higher PFAS were observed in pups compared to adults and were associated with higher trophic level and terrestrial feeding. We are continuing this project in 2018-2019 so that adult seals can be 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 for predicting the impacts of the 22 hydro-electric power developments planned across Canada.

foie et dans 19 des 81 échantillons de muscles, dépassant les directives canadiennes en matière de fréquence de consommation de 200 ng/g (poids humide). Les concentrations moyennes de mercure chez le phoque annelé du lac Melville sont au niveau inférieur de la fourchette signalée dans 14 collectivités à travers la région subarctique et l'Extrême-Arctique canadiens (les concentrations moyennes de mercure dans les muscles entre 2007 et 2011 étaient de 107 à 1070 ng/g)1, probablement parce qu'un bon nombre des phoques échantillonnés entre 2013 et 2016 étaient des nouveau-nés. 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. Des analyses d'échantillons prélevés en 2017 visant à détecter des PFAS indiquent que les phoques annelés adultes du lac Melville présentent une concentration totale de PFAS de 67 ± 12 ng/g (poids humide), ce qui est comparable aux phoques annelés d'autres régions du Labrador, de la baie d'Hudson et de la mer de Beaufort, mais aussi généralement plus élevé que les phoques annelés de régions plus au nord, notamment de Resolute, Sachs Harbour et Pangnirtung. Des concentrations plus élevées de PFAS ont été observées chez les nouveau-nés en comparaison des adultes et étaient associées à un niveau trophique plus élevé ainsi qu'à une alimentation terrestre. Ce projet se poursuivra en 2018-2019 dans le but d'analyser des échantillons prélevés sur des phoques adultes à la recherche d'une gamme complète de contaminants et pour mesurer les marqueurs de l'état de santé du phoque, 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, especially MeHg and predicted increases in MeHg resulting from hydroelectric power development on the Churchill River.
- This project is analyzing Hg, MeHg, carbon and nitrogen stable isotopes, PFASs, and PCBs in the Lake Melville food web, including ringed seals.
- Information from the project is allowing 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 to be determined.
- Average MeHg concentrations in the liver and muscle of Lake Melville seals collected between 2013-2017 were 202 ± 226 and 133 ± 129 ng/g ww and are comparable to those recently reported at other Labrador locations.
- 2017 data show that adult ringed seals in Lake Melville have 67 ± 12 ng/g ww total PFAS, which is comparable to ringed seals in other areas in Labrador, Hudson Bay and the Beaufort Sea: Nain: 45±6 ng/g, Arviat: 71±8 ng/g, Ulukhaktok 51 ±6 ng/g, but generally higher than ringed seals from the more northern areas such as Resolute, Sachs Harbour and Pangnirtung.
- Some types of PFASs, PFOS and long chain perfluorocarboxylates, were higher in Lake Melville ringed seals than other locations but correlation analysis suggests this is driven by the juvenile status of the seals.
- Higher PFAS were associated with higher trophic level and terrestrial feeding.
- 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.

Messages clés

- Les riverains du lac Melville se préoccupent des concentrations de contaminants dans les aliments qu'ils récoltent dans la nature (par exemple, le phoque annelé) en particulier du méthylmercure et des augmentations prévues de méthylmercure résultant des activités de développement hydroélectrique de Churchill River.
- Le présent projet vise à mener des analyses des isotopes stables du carbone et de l'azote, du mercure, du méthylmercure, des PFAS et des BPC dans le réseau trophique du lac Melville, y compris chez le phoque annelé.
- Les résultats du projet permettent de déterminer l'importance relative des sources de contaminants locales par rapport aux sources régionales, ainsi que 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 encore indéterminés.
- Les concentrations moyennes de méthylmercure dans le foie et les muscles des phoques du lac Melville échantillonnés entre 2013 et 2017 étaient de 202 ± 226 et 133 ± 129 ng/g (poids humide), respectivement, et sont comparables à celles récemment signalées chez des nouveau-nés à d'autres emplacements au Labrador.
- Des données obtenues en 2017 indiquent que les phoques annelés adultes du lac Melville présentent une concentration totale de PFAS de 67 ± 12 ng/g (poids humide), ce qui est comparable aux phoques annelés d'autres régions du Labrador, de la baie d'Hudson et de la mer de Beaufort (Nain – 45 ±6 ng/g; Arviat – 71 ±8 ng/g; Ulukhaktok – 51 ±6 ng/g), mais est généralement plus élevé que les phoques annelés de régions plus au nord, notamment de Resolute, Sachs Harbour et Pangnirtung.
- Certains types de PFAS, de SPFO et de perfluorocarboxylates à chaîne longue

Objectives

This project aims to:

- differentiate among global versus local and terrestrial versus marine sources of MeHg, PFASs and 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;

étaient présents en concentrations plus importantes chez le phoque annelé du lac Melville en comparaison à d'autres emplacements. Or, une analyse de corrélation donne à penser que ceci est attribuable au bas âge des phoques échantillonnés.

- Les concentrations plus élevées de PFAS étaient associées à un niveau trophique plus élevé et à une alimentation terrestre.
- 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.

- 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;
- determine the effects of contaminant exposure on ringed seal health by evaluating relationships between mercury, PFAS and PCB tissue levels and genomic and cellular responses; and,
- 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".

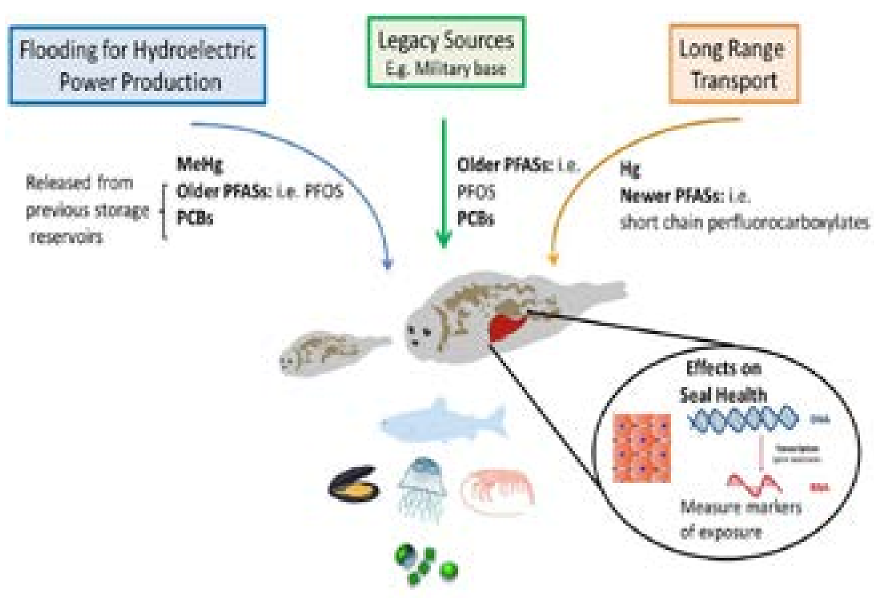
Introduction

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 harvested country foods, particularly MeHg, and the projected increases in MeHg originating from past and future hydroelectric power development on the Churchill River. In addition to Hg and MeHg, other contaminants of potential concern in the region include "new" synthetic chemicals such as PFASs and legacy contaminants, such as 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 and 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, etc.). We have recently secured funding for 2018-2020 to continue this project as a community-based monitoring 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. 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 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.

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 impacts of contaminant exposure on ringed seal health are 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.



Activities in 2017-2018

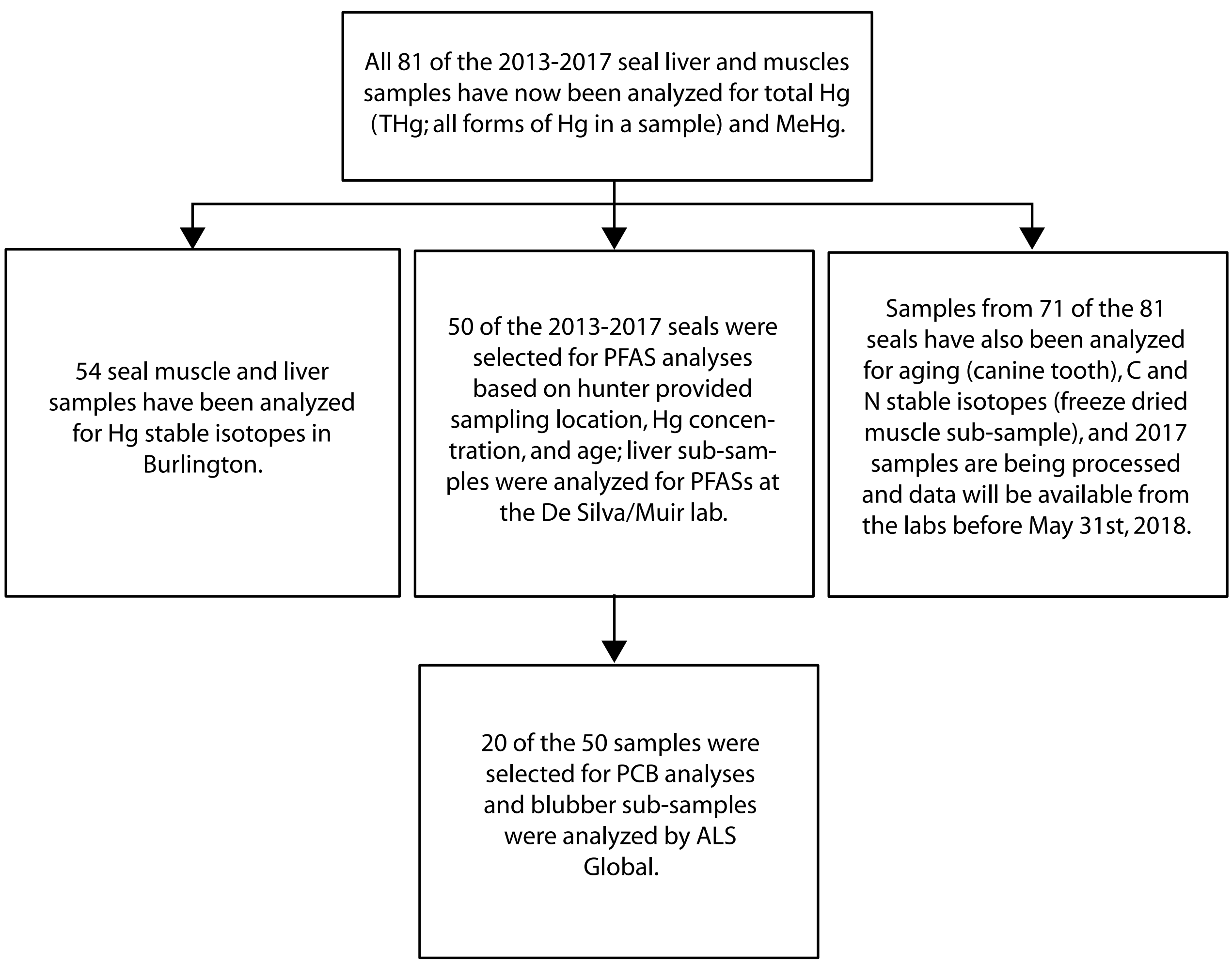
Sampling and Analyses

As part of this project and earlier work by collaborators, sampling of the Lake Melville ringed seal population was carried out during community harvests (nunalinni pinasuannik) with support from Nunatsiavut Government staff between 2013-2017. Muscle, liver, blubber, kidney, stomach, and jaws were sampled from 81 ringed seals (n=10-20 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”. Detail on the sample analysis is provided in the flowchart below (Figure 2).

In 2017, efforts were made to provide the training and supplies needed to sample seal liver tissues for biological effects work. Instructions, vials with RNALater solution, and a cryogenic dry shipper which utilizes liquid nitrogen to keep samples frozen during transportation were supplied. However, samples came back in poor condition (not immersed in the RNALater solution and warm); thus, biological effects work could not be carried out.

As part of 2013-2015 work led by Harvard and the Nunatsiavut Government 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) were also collected. A subset of these fish are now being analyzed for PFASs at the De Silva/Muir lab in Burlington.

Figure 2. Flowchart showing sampling analysis on the 2013-2017 seal samples.



In August 2016, we sampled the base of the food web (plankton) as well as lower food web organisms at 6 sites and analyzed them for THg and MeHg, Hg isotopes, PFASs, C isotopes and N isotopes (Figure 3). In June 2017, we repeated this sampling when productivity is generally higher than in august in Lake Melville so that different size fractions (80-153, 153-500, >500, μm) at additional sites spanning a freshwater-marine gradient could be sampled (Figure 3). Indigenous knowledge on productive zones of Lake Melville from field team members Liz Pijogge 2016-2017 Nain resident), Kevin Gear (2016-2017; Northwest River resident), Martin Shiwak (2016; Rigolet resident) and Carl Michelin (2017; Rigolet resident) was important for this sampling trip and allowed the collection of lower food web organisms, krill, scallops, urchin, and jellyfish at a subset of sites (Figure 3).

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 6-9 sites in both 2016 and 2017 (Figure 3). 2016 water PFAS analyses is complete, while 2017 sample analyses is underway. Water was also collected for basic water chemistry parameters to help interpretation of contaminant data.

Capacity Building

All seal collections for this project were coordinated by Northwest River resident Marina Biasutti-Brown and carried out by hunters from Upper Lake Melville and Rigolet during traditional harvesting seal hunts. Payment and training of all hunters 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 June 2017, Liz Pijogge (Nunatsiavut Government), Amber Gleason (ECCC), Kevin Gear (Northwest River resident) and Carl Michelin (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

Figure 3. Map of sites where plankton (for THg, MeHg, Hg, C and N stable isotopes and PFAS analyses) and water (for PFAS and water chemistry analyses) was collected in August 2016 and June 2017. Krill, jellyfish, scallops, and urchins were also collected at sites 16a and 32.

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. In 2017, we were very successful in reaching out to the communities about this project and about contaminants in Lake Melville by tweeting and posting updates and photos during the June 2017 field season on the Nain Research Centre (@NG_Research) and Jane Kirk's twitter feeds (@JaneKirkHg) as well as the Nain Research Centre's Facebook page (https://www.facebook.com/nainresearchcentre). We also completed four presentations at national and international conferences and workshops, including Arctic Change in Quebec City, the NCP Results Workshop in Yellowknife.

Indigenous Knowledge Integration

All seal collections are carried out during community harvests (nunalinni pinasuannik) and therefore completely rely on Indigenous Knowledge, including knowledge of when and where to collect samples and any potential changes in ringed seal populations and/or habitat. In 2017, the project also relied on Indigenous Knowledge to obtain both adult and juvenile seals so that bioaccumulation and biomagnification of contaminants through the complete food web could be explored. The success rate of the hunter-based collections at Lake Melville was high between 2013-2017 (n=81 samples collected) with excellent morphometric data, information on age, gender, and kill location recorded. This project also relies on Indigenous Knowledge of field team members (Liz Pijogge, Kevin Gear, and Carl Michelin) for collections of water, plankton, and lower food web organisms, including safe travel on Lake Melville and knowledge of productive zones for sampling plankton, krill, scallops, urchin, and jellyfish.

Results, Discussions, and Conclusions

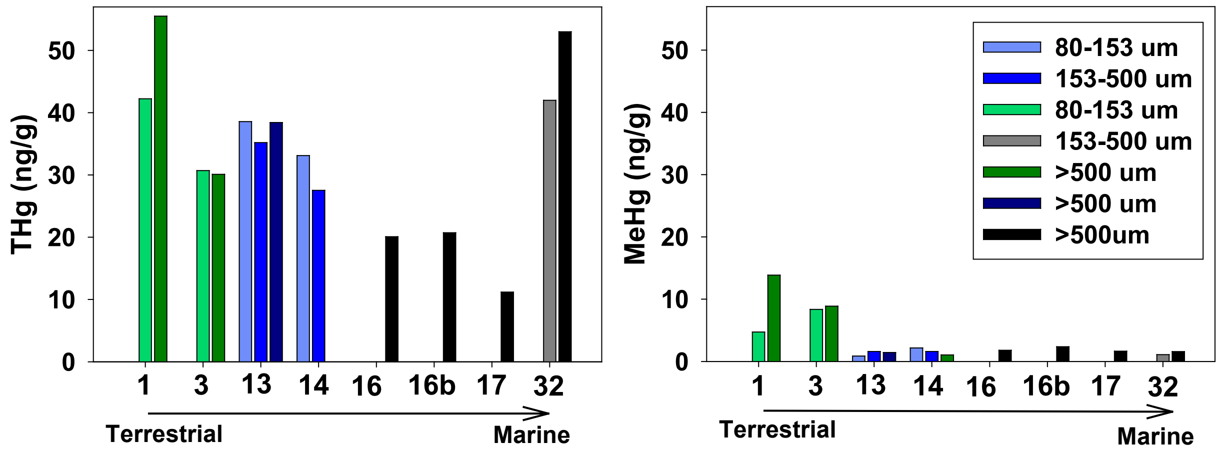
Mercury (Hg), Methylmercury (MeHg), and Hg Isotopes

Average MeHg concentrations in the liver and muscle of Lake Melville seals collected between 2013-2017 were 202 ± 226 and 133 ± 129 ng/g wet weight (ww), respectively, with 24 of 81 liver samples and 19 of 81 muscle samples surpassing the Canadian frequent consumer guideline of 200 ng/g ww. 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/g) (Brown et al. 2016). This is likely because many of the seals sampled between 2013-2016 were pups/young of the year. Although the aging from the 2017 collections is not yet complete, the hunter recorded observations, length and girth data, as well as the THg and MeHg analyses suggest that adult seals were primarily sampled in 2017. 2017 liver and muscle MeHg concentrations were 566 ± 203 and 298 ± 89 ng/g, which is much higher than average values from the 2013-2016 collections and higher than the Canadian frequent consumer guideline of 200 ng/g ww.

Average concentrations of THg and MeHg in plankton collected in 2016-2017 were 40.5 ± 21.4 and 9.2 ± 12.7 ng/g, respectively, and varied greatly along the Lake Melville freshwater-marine gradient. In our 2017 plankton samples, which were collected at maximum plankton productivity in late June, MeHg concentrations and %MeHg in all three size fractions (80-153, 153-500, >500, µm) were highest at sites influenced by freshwater/terrestrial inputs and then decreased with increasing marine influence (Figure 4). These concentrations and patterns are similar to those observed in 2013 by Schartup et al. (2015), who also collected plankton in late June.

As suggested by Li et al. (2016) for the Lake Melville fish food web, results of THg, MeHg, Hg, C isotopes, and N isotope analyses for the

Figure 4. THg (left) and MeHg (right) in various plankton (omajuit imâni) size fractions (80-153, 153-500, and >500 µm) collected across a freshwater/terrestrial and marine gradient in Lake Melville in June 2017.



more complete food web demonstrates two distinct feeding groups within Lake Melville (freshwater/terrestrial versus marine) and suggest that Lake Melville seals are feeding on predominantly marine organisms (Figure 5). However, most of the seals analyzed for Hg, C, and N isotopes are pups, which likely have different $\delta^{15}N‰$ signatures compared to adults. Although the 2017 seal samples have not been aged yet, the hunter recorded length information and elevated THg and MeHg values suggest that adults were collected and analyses will confirm which food web (marine, freshwater, or mixed) they belong to. Hg stable isotope analyses of the Lake Melville food web demonstrates that seals have higher δ^{202}Hg values (x axis; Figure 6) compared to their prey items (fishes and krill), indicating that seals have in vivo demethylation capability that preferentially retains heavier Hg isotopes within their body. A similar phenomenon is observed in some human studies. Plankton have much lower δ^{202}Hg and δ^{199}Hg values compared to the krill, jellyfish, and fishes; however, it is well established that Hg isotopes do not fractionate between lower food web organisms and fishes. Therefore, the lower δ^{202}Hg and δ^{199}Hg in plankton reflect their much lower %MeHg (30 ± 15%) relative to higher food web organisms (fishes, scallops, krill, jellyfish) and thus an isotope composition more similar to the water column, which has low δ^{202}Hg and δ^{199}Hg signatures. The Hg isotope signatures of the bivalves (mussels and scallops) represents a mixture of the sediment and the water column, indicating that they obtain their MeHg burden from both of these sources.

The above information on baseline MeHg concentrations, sources, and food web dynamics is fundamental for understanding how climate changes and flooding for hydroelectric power creation will alter MeHg levels in Lake Melville.

Figure 5. MeHg concentrations versus trophic position, as indicated by $\delta^{15}N$ (‰), in Lake Melville seals (natsiap) collected 2013-2015.

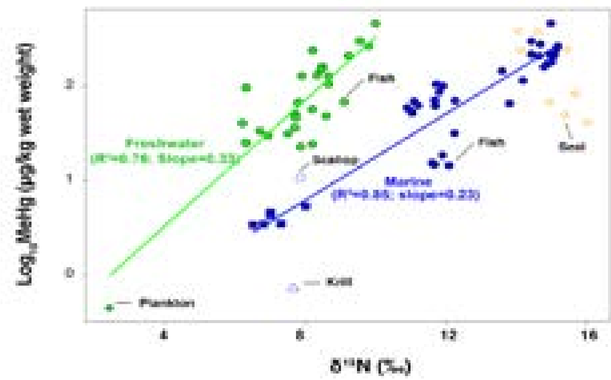
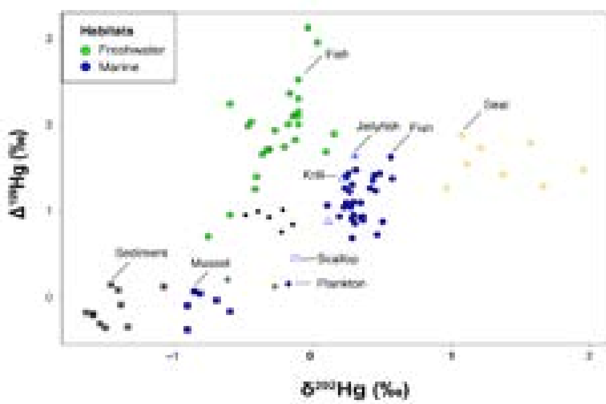


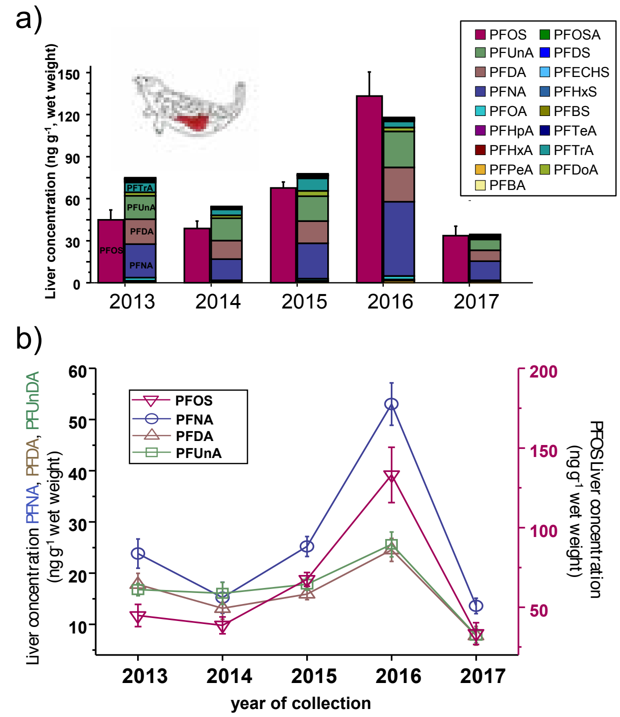
Figure 6. Stable Hg isotope composition of the Lake Melville food web, including sediment, plankton (omajuit imâni), mussels, scallops (matsojak), jellyfish, krill (kingupvaujâtuit), marine and freshwater fishes (minnigiak), and seals (natsiap).



Perfluoroalkyl substances (PFASs)

Since 2013, we have measured PFAS annually in ringed seals in Lake Melville using liver, which is the target organ for PFAS accumulation (Figure 7). As with other Arctic marine mammals, the predominant PFAS corresponded to perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), and perfluoroundecanoic acid (PFUnDA) corresponding to 43, 19, 12, and 14% of the total PFAS burden in liver, respectively.

Figure 7. a) Average PFOS concentration and distribution of other PFAS in ringed seal liver collected 2013-2017 and b) temporal variation using average and standard error PFOS, PFNA, PFDA, and PFUnDA without any adjustment for age, length or isotopes.



The levels of PFAS in ringed seals in Lake Melville are higher than other Arctic sites. Average annual concentrations in Lake Melville seals correspond to 14-53 ng/g PFNA, 8-25 ng/g PFDA, 8 -26 ng/g PFUnDA, 33-133 ng/g PFOS. In a review by Butt et al. (2010), ringed seals from Grise Fjord contained 3 to 5 ng/g of PFNA, PFDA, and PFUnDA, and 27 ng/g PFOS. In Gjoa Haven, ringed seals were elevated in perfluorocarboxylates, such as 48 ng/g PFNA, 16 ng/g PFDA, and 13 ng/g PFUnDA but PFOS levels (13 ng/g) were of the same order of magnitude to other locations. Riget et al. (2013) reported mean concentrations in East Greenland ringed seals corresponding to 8 ng/g PFNA, 8 ng/g PFDA, 20 ng/g PFUnDA, and 112 ng/g PFOS. These differences may be location-specific, related to dietary intake, or to the age of the seals. The Canadian government has proposed federal environmental quality guidelines (FEQG) for PFOS including 8300 ng g^{-1} fish tissue for fish health and for mammalian health, the FEQG is 4.6 ng g^{-1} PFOS in a prey item based on toxicity studies in mink and rats (Environment and Climate Change Canada 2017). Given the wide range in these proposed FEQG's and the lack of available toxicity studies in marine mammals, it is not known what the threshold PFAS level is in seals to cause adverse effect in the seals themselves and/or consumers of seals. However, the concentrations of PFAS measured in Lake Melville ringed seals are much lower than polar bears which have PFOS liver concentrations ranging from 490 to 1559 ng g^{-1} wet weight due to biomagnification (Letcher et al. 2010).

It is possible that the elevated PFAS in Lake Melville seals are related to the juvenile age status of these seals since PFASs undergo maternal transfer through cord blood and milk. With this hypothesis in mind, adult seals were targeted for sampling in our 2017 proposal. Though precise aging is still underway, the 2017 samples had lower concentrations of PFAS (Figure 7b) and lower concentrations were associated with larger (and likely older) animals (Figure 8). These results suggest that an age correction factor will be necessary to ascertain temporal trends. The most recent 2017 data in Lake Melville ringed seals is similar to ringed seals of similar size other areas in the Arctic (Table 1).

A positive correlation of PFOS and long chain perfluorocarboxylates such as PFNA, PFDA, PFUnDA, PFDoA, PFTrDA was observed with the N-15 stable isotope ratio in seals (Figure 8), suggesting that seals at higher trophic levels have greater accumulation of PFAS. Furthermore, C-13 stable isotope ratio was negatively correlated with higher concentrations of long chain perfluorocarboxylates and PFOS (Figure 8) suggesting that seals with a more terrestrial feeding strategy (i.e. more negative $d^{13}C$) have higher levels of PFAS.

In summary, in Lake Melville seals, determinants of PFAS were age (using length as a proxy), trophic status (using $d^{15}N$) and terrestrial feeding ($d^{13}C$). In a similar study on polar bears in Svalbard, Tartu et al. (2017) reported that higher PFAS concentrations were correlated to $d^{15}N$ diet; however, unlike our study, higher PFAS were noted in more marine-based feeding (higher $d^{13}C$). Another possible factor for higher PFAS concentrations in Lake Melville seals compared to those in other regions in the Arctic is the geophysical features of the area whereby the estuary concentrates PFAS due to seasonal and hydrological factors, including sediment load and flow. Routti et al. (2016) also observed higher concentrations of PFAS in ringed seals in a fjord area of Svalbard receiving high inflows from the Atlantic Ocean compared to other areas that receive inflows from the Arctic Ocean (i.e. 97 ±22 ng g^{-1} versus 19±5 ng g^{-1} PFOS).

Table 1. Total PFAS (ΣPFAS) concentration in ringed seal liver in Lake Melville (this study) and from other areas of the Arctic in relation to age and size.

Location	year	n	Body length (cm)	Total PFAS (ng g^{-1}, wet weight liver)	Age (years)
Lake Melville	2016	9	86 ±4	251 ±26	<1
Lake Melville	2017	10	129 ±3	68 ±12	Pending
Arviata	2014	14	109 ±3	71 ±8	7 ±2
Ulukhaktoka	2010	9	117 ±3	50 ±6	12 ±3
Naina	2016	10	119 ±2	45 ±6	4 ±2
Pangnirtunga	2011	14	117 ±3	28 ±6	2 ±0.4
Resolutea	2016	8	126 ±3	26 ±3	Pending
Sachs Harboura	2014	10	116 ±3	21 ±3	6 ±2

[a] Data provided by Magali Houde and Derek Muir

Figure 8. Relationship of PFAS concentration in liver with seal body length indicating higher concentrations in smaller seals.

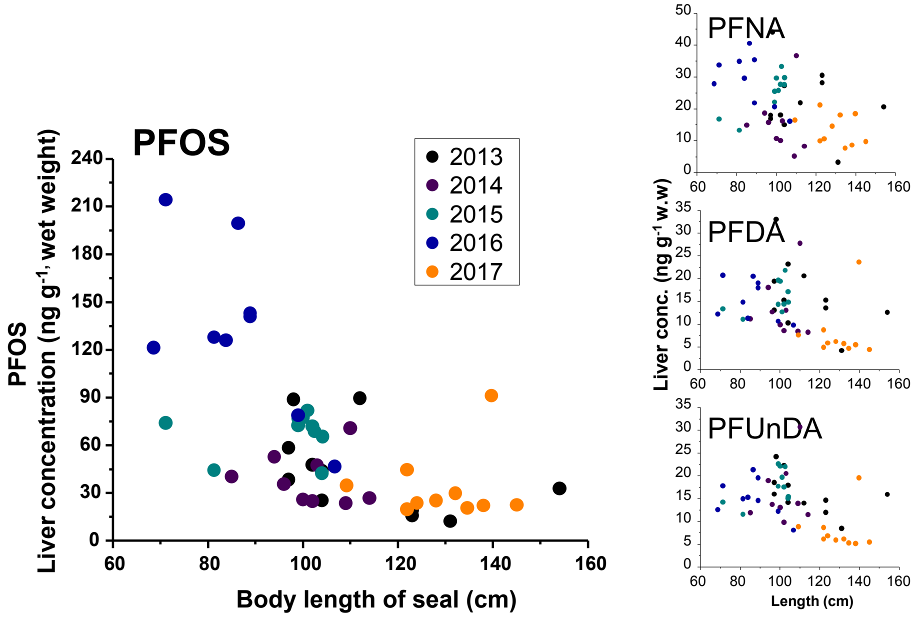
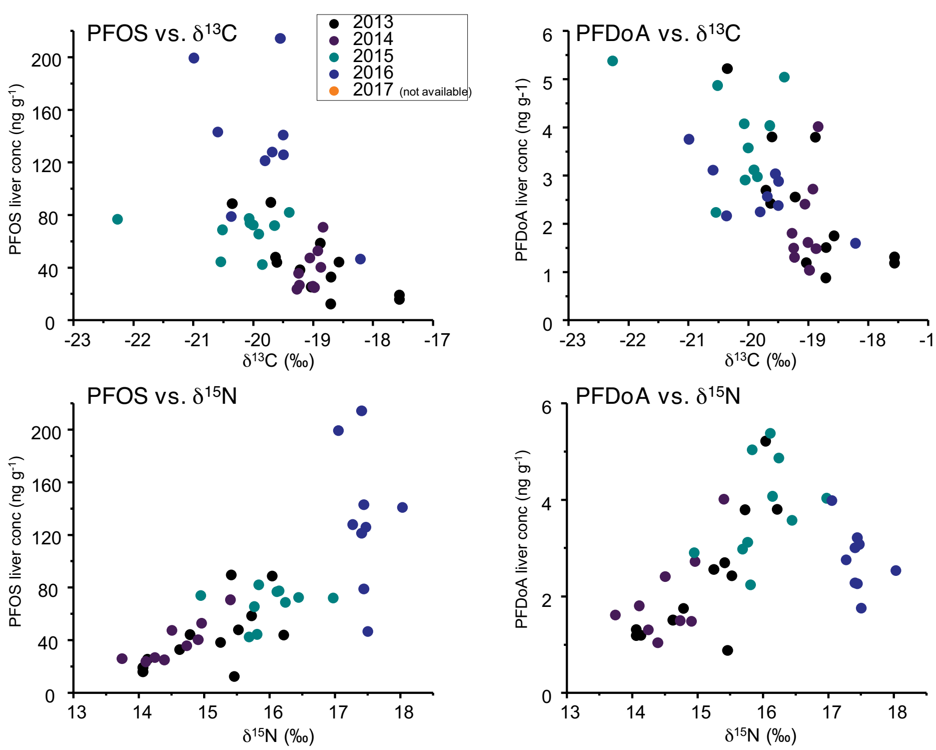


Figure 9. PFOS and PFDoA concentrations versus dietary strategy ($\delta^{13}C$) and trophic position ($\delta^{15}N$) in Lake Melville seal livers. Negative correlations with $\delta^{13}C$ suggest greater PFAS from terrestrially feeding seals and higher trophic level. PFNA, PFDA, PFUnDA, PFDoA, PFTrDA, PFTeDA, and PFOS were all negative correlated with $\delta^{13}C$ (Spearman correlation coefficient < -0.44, p<0.05). PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoA, PFTrDA, PFTeDA, PFHxS, PFOS, PFDS were positively correlated with $\delta^{15}N$ (Spearman correlation coefficient>0.32, p<0.05).



Expected Project Completion Date

Results from 2017-18 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 providing the necessary funding to produce the data within this report. We finally acknowledge Isabella Borea of Environment and Climate Change Canada/University of Waterloo for PFAS analyses and Ron MacLeod and Whitney Davis at ALS Global (Burlington) for conducting PCBs analysis and providing detailed data reports.

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Investigating the abundance, types and potential sources of microplastics in the Arctic

Étude des sources, de l'abondance et des types de microplastiques dans l'Arctique

Project Leader/Chef de projet

Chelsea Rochman, PhD Department of Ecology and Evolutionary Biology, University of Toronto, 25 Harbord St Toronto, ON M5S3G5, Tel: 416 978-6952; Email: chelsea.rochman@utoronto.ca

Liisa M. Jantunen, PhD Centre for Atmospheric Research Experiments, Environment and Climate Change Canada (ECCC), 6248 Eighth Line, Egbert, ON L0L 1N0
Tel: 705-458-3318; Fax: 705-458-3301; E-mail: liisa.jantunen@canada.ca

Patricia Corcoran, PhD Associate Professor and Undergraduate Chair, Earth Sciences; Director, Centre for Environment and Sustainability, University of Western Ontario, London, Ontario, Canada N6A 5B7
Tel: 1-519-661-2111 ext. 86836; Email: pcorcor@uwo.ca

Project Team/Équipe de projet

Gary Stern and Alexis Burt (University of Manitoba); Hayley Hung (Environment and Climate Change Canada); Miriam Diamond (University of Toronto); Jason Carpenter and Daniel Martin (Nunavut Arctic College); James Macdonald (Council of Yukon First Nations [CYFN]); Derek Cooke (Ta'än Kwach'än Council); Ellen Sedlack (Yukon INAC); Laberge Environmental Services

Project Location/Emplacement(s) du projet

- Eastern Canadian Archipelago
- Central Canadian Archipelago
- Alert, NU

Abstract

Microplastics pollution is found across the globe, but with limited information from Polar Regions. Although there is evidence of microplastics in the Arctic and Antarctic, little is understood about the sources, fate and extent of contamination. This project was funded to collect samples of water, sediment, and zooplankton in collaboration with ArcticNet from on board the CCGS Amundsen in central and eastern Canadian Archipelago. Additional snow samples were collected at Alert, NU. Samples have been archived or have been distributed to collaborators that are willing to provide analysis of these samples at no cost. Thus far, we are able to conclude that the Arctic

Résumé

La pollution par les microplastiques est présente partout sur la planète, mais l'information provenant des régions polaires est limitée. Même si on observe des traces de microplastique dans l'Arctique et l'Antarctique, on en connaît peu sur les sources, le devenir et l'étendue de la contamination. Ce projet a été financé en vue de prélever des échantillons d'eau, de sédiments et de zooplancton en collaboration avec ArcticNet à partir du NGCC Amundsen dans les régions est et centre de l'archipel canadien. Des échantillons de neige ont aussi été recueillis à Alert, au Nunavut. Les échantillons ont été soit archivés, soit distribués à des collaborateurs qui sont disposés à les soumettre à des analyses

is contaminated with anthropogenic particles, and that the vast majority of the type of particle found in zooplankton, surface water, and snow samples is microfibres.

gratuitement. À ce jour, nous avons pu conclure que l'Arctique est contaminé par des particules d'origine anthropique, et que la grande majorité des types de particules recensés dans les échantillons de zooplancton, d'eau de surface et de neige sont des microfibres.

Key Messages

- Samples were collected for microplastics in the Canadian Archipelago in the summer of 2017.
- Sample types included: surface water, surface sediment, zooplankton from vertical tows and snow from Alert.
- Samples have been archived or distributed to collaborators that are willing to do the analysis at no cost to NCP.

Messages clés

- Des échantillons ont été recueillis dans l'archipel arctique canadien à l'été 2017 pour voir s'ils contenaient des microplastiques.
- Les échantillons recueillis comprenaient : des eaux de surface, des sédiments de surface, des zooplanctons de traits verticaux et de la neige d'Alert.
- Les échantillons ont été soit archivés, soit distribués à des collaborateurs qui sont disposés à les analyser sans frais dans le cadre du PLCN.

Objectives

This project aims to:

- collect snow, water, sediment and zooplankton for Microplastics; and,
- archive samples for future analysis.

Introduction

Microplastics (MP) contaminate the oceans from the poles to the equators and from the sea surface to the deep sea (GESAMP 2016). In addition, MPs have been recorded in freshwater systems, including in lakes, rivers and streams globally (Eerkes-Medrano et al. 2015, Ballent et al. 2016). Hundreds of studies document concentrations of MPs in samples from across the globe, and therefore, for most regions, the presence of the contamination is less important than potential sources, transport pathways, fate, and impacts.

MP debris has been identified as a global pollutant of concern that is capable of long-range transport and can cause adverse effects in wildlife. Microplastic pollution is a field of intense interest globally, but limited information is available for Canadian regions. This is particularly true for Canadian Arctic regions. Consequently, the NCP has identified assessing the presence and distribution of MPs in Arctic marine ecosystems a priority. The Arctic Monitoring and Assessment Programme (AMAP) has also added Marine Plastics and MPs to their list of Chemicals of Emerging Arctic Concern.

We know from a handful of studies that MPs are found in water, ice and sea birds from Arctic regions (Obbard et al., 2014; Lusher et al., 2015; Amelineau et al., 2016). Arctic birds have been found to ingest plastics, with ~85% of the northern fulmars and ~10% of thick-billed murres containing plastics (Poon et al., 2017; Provencher et al., 2010, 2009) and northern fulmars also eliminate microplastics in their guano (van Franeker, 2011) which can lead to deposition of normally buoyant polymers onto the seafloor.

To date, information about the sources, fate and impacts, and temporal trends of MPs in the Arctic are extremely limited, although one study in the Greenland Sea found an increase in MPs in ocean water between 2005-2014 (Amelineau et al., 2016). More detailed assessments of MPs in the Arctic are important because the region is a remote and fragile ecosystem under threat from multiple anthropogenic stressors. Microplastics add yet another stress to Arctic ecosystems.

Activities in 2017-2018

Sampling

Water, zooplankton and sediment samples were collected from the *CCGS Amundsen* in the Summer of 2017 from the Hudson Bay and the Canadian Arctic Archipelago of Nunavut (Figure 1). Surface water samples were collected from 26 stations, and zooplankton and sediment samples were collected from 20. Samples were collected on Leg 2a: Kuujjuaraapik to Iqaluit and 2b: Iqaluit to Puvirnituq on the *Amundsen* Expedition.

Snow samples were collected from Alert, Nunavut by Environment and Climate Change Canada in the summer of 2017. These samples were collected from two different sample sites, one from inland and one from sea ice (Figure 2). Five samples were taken from the inland site, and five samples were taken from the sea ice site. A field blank was taken from the inland sampling site.

Analysis

Samples are being analyzed by Aimee Huntington in Chelsea Rochman's lab at the University of Toronto, Laura Hernandez in Nathalie Tufjenki's lab at McGill University and Patricia Corcoran at The University of Western Ontario. Water samples, zooplankton samples and sediment samples are all being extracted using published methods, microplastics are being picked under a microscope and analysed to material type via FTIR and Raman spectroscopy. Analysis is ongoing, but preliminary results are below.

Community Engagement

- Liisa visited Inuvik and gave a talk at a public forum where MPs were discussed in arctic water and sediment.
- Chelsea Rochman visited Iqaluit and gave a talk at the Arctic College and to the local community at an evening lecture with translation.

Capacity Building and Training

- M-22 (*Assessing Persistent Organic Pollutants (POPs) and Microplastics (MPs) in Canadian Arctic Air and Water as an Entry Point into the Arctic Food Chain*), a parallel project, enabled Karen Nungaq, a student from Nunavut Arctic College to participate in the schools on board program while on board the Amundsen. She participated in all of the sampling programs going on during her stay, this included sampling MPs.
- Liisa gave a lecture and hands on demonstration to college students from Aurora College and high school students from the local school that included a discussion on MPs.

Communications and Outreach

- Liisa presented a poster and scientific exhibit at the NCP workshop in Yellowknife in September 2017 presented water, zooplankton sediment sampling techniques for microplastics.

Indigenous Knowledge (IK)

- Liisa has contacted Karen Nungaq several times to inquire about how the cruise went, how we could incorporate IK into the project, and if she would like supplies and/or content for a presentation in her community. Unfortunately, she has not responded to my requests.

Results and Outputs/Deliverables

Completed samples were collected and have been archived for when funding becomes available for analysis. Collaborators were very generous and analyzed some samples for microplastics at no cost to this project.

Preliminary Results

Preliminary analyses have been conducted on the snow, surface water and zooplankton samples in the Rochman Lab. This includes counts of suspected microplastic particles in snow samples and some zooplankton and surface water samples.

Microplastics were found in snow samples, but below blank levels (Figure 2). In total, only one litre of snow was collected, and in the future we'd recommend sampling a greater volume. The vast majority of the particles found in snow samples were fibres (Figure 3-5). There is little difference between the sea ice and inland sites in regards to the number of particles found. The inland snow site had an average of 6.3 particles per sample, with a standard deviation of 5.5. The sea ice site had an average of 6.8 particles per sample, with a standard deviation of 10.2. The inland field blank indicates some contamination while collecting the snow. There were two fibres present in the field blank. Neither fibres present appear to match fibres found in samples. Raman spectroscopy will be conducted on these fibres, and if they are a match to other fibres in the snow samples they will be removed from the total count.

Ten zooplankton samples have been analyzed thus far (Figure 6). The average number of particles across these samples was 4.1 particles/gram, with a standard deviation of 2.5 particles. The main type of particle found in zooplankton samples was microfibres. The field blank indicated that contamination was present. Three fibres were found in the sample, two of which were blue and one was clear. Once Raman Spectroscopy is conducted, if the fibres from the field blank match the fibres from the samples, then they will be removed from the total count.

Eleven surface water samples have been analyzed thus far (Figure 6). The average number of particles across the eleven sites is 0.6 particles/L, with a standard deviation of 0.3 particles. The predominant particle type is also microfibres. In the field blank there was 0.5 particles found per litre. If Raman Spectroscopy confirms that the fibres from the field blank match those from samples they will be removed from the total count.

Figure 1. Map shows the sampling stations for zooplankton and surface water.

Figure 2. Map showing the sample sites of inland and sea ice snow sampling. The station marked A is the inland site and B is the sea ice location.

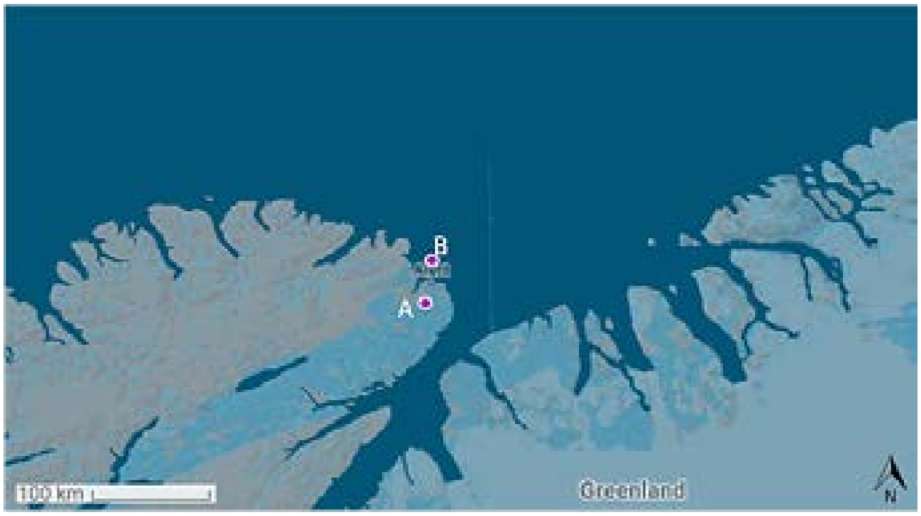


Figure 3. Bar plot showing the average number of particles in snow samples (error bars display std deviation) found across samples from each location (n=5).

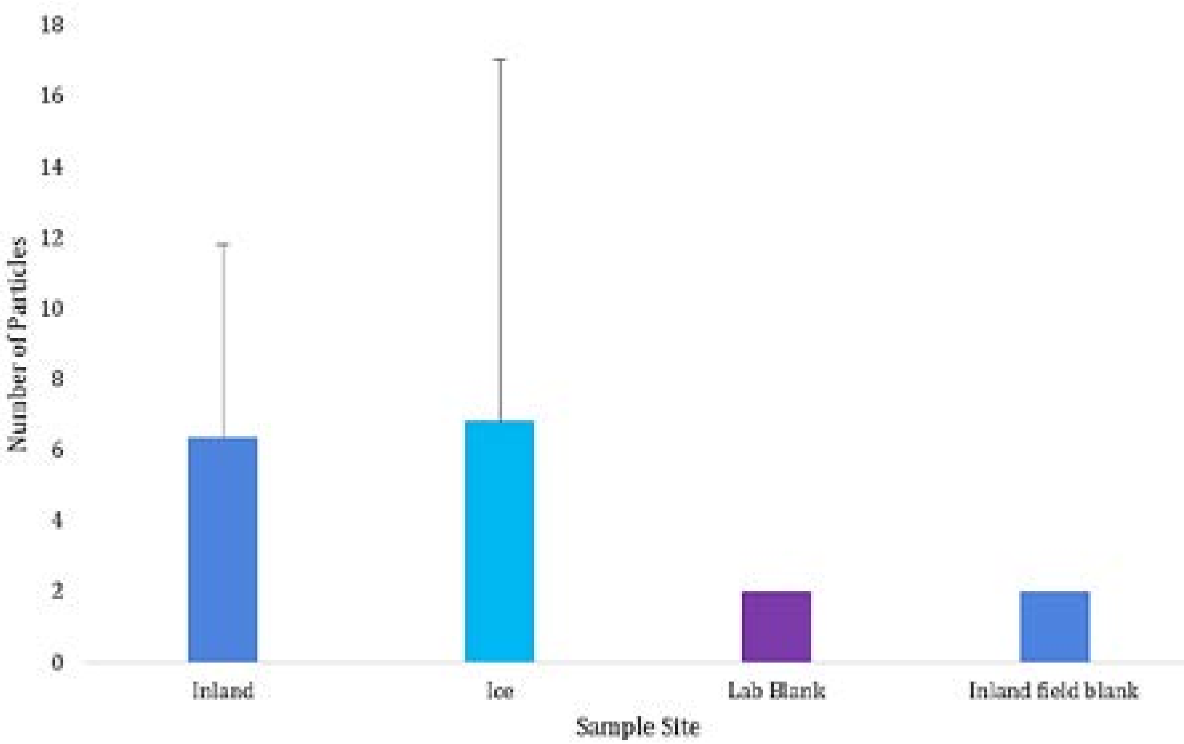


Figure 4. Bar plot showing the distribution of microplastics in snow for the inland sampling site according to category. Field and lab blanks are included.

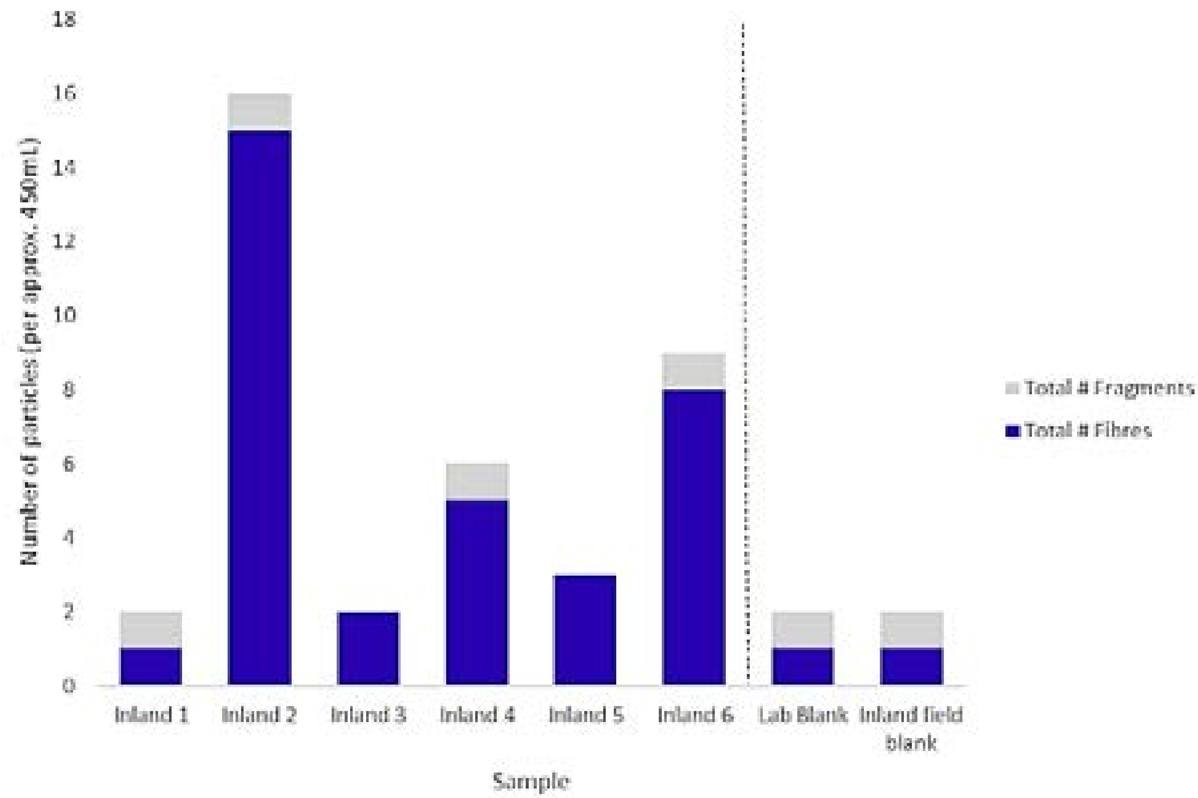


Figure 5. Bar plot showing the distribution of microplastics in snow for the sea ice sampling site according to category. Field and lab blanks are included.

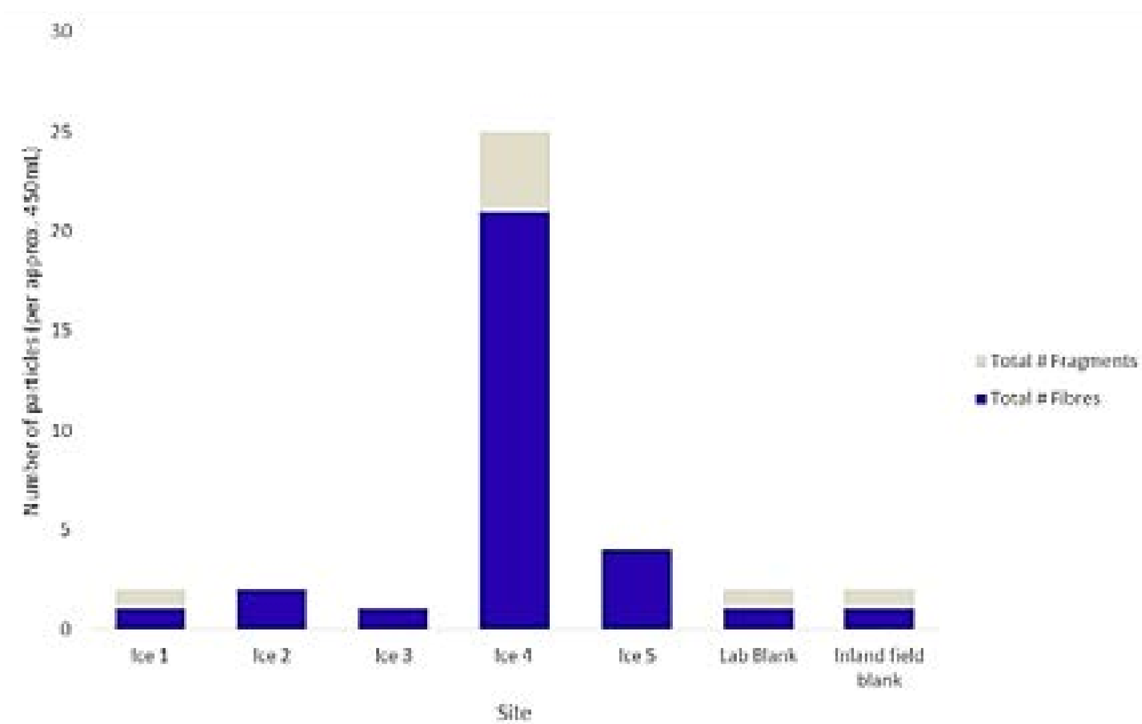
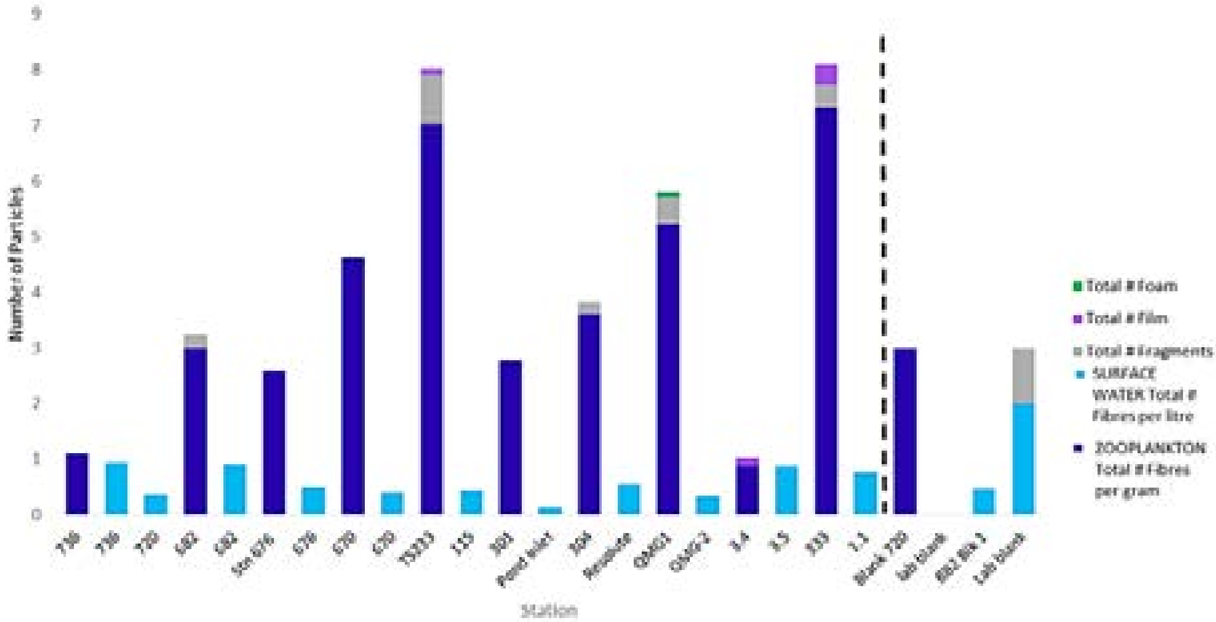


Figure 6. Bar plot showing the category and quantify of particles at each site for surface water and zooplankton samples. Field and lab blanks are included. Results presented are the number of particles per gram for zooplankton and per litre for water. Nearby or sites are side-by-side for comparison. The x axis follows the path that the CCGS Amundsen took where 736 was the first sample site and 1.1 was the last.

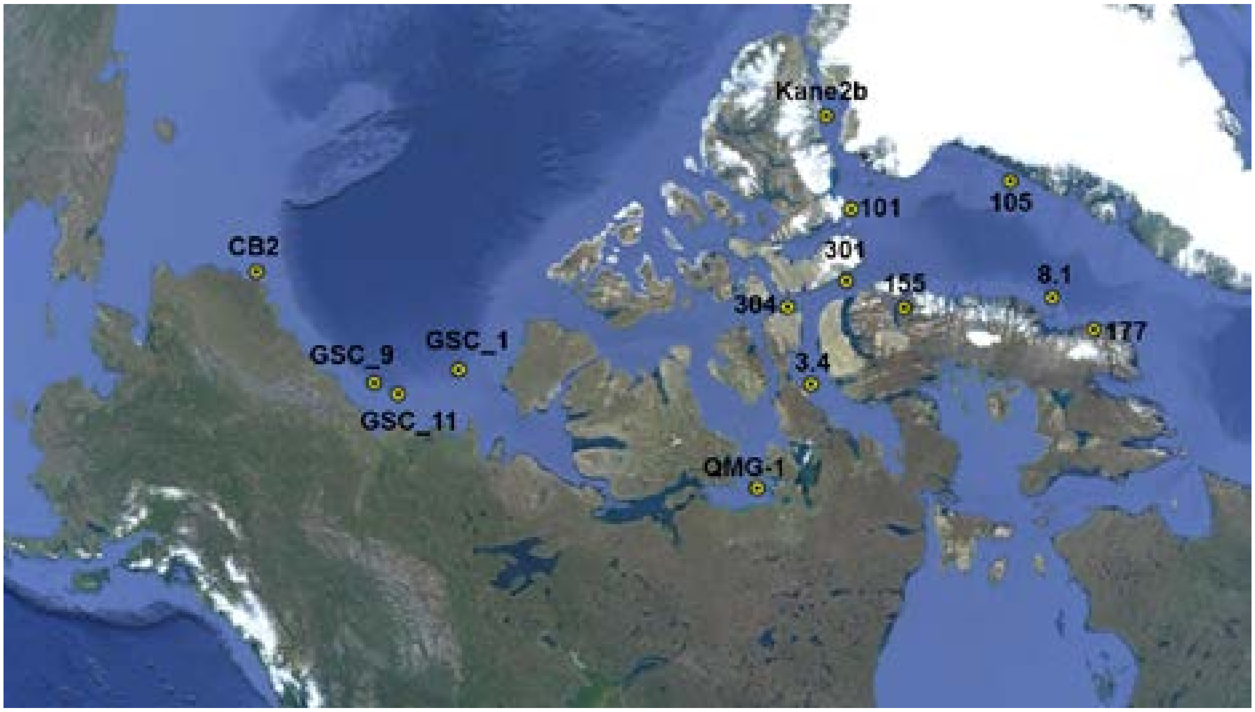


Preliminary results of microplastic abundance and particle types of microplastics present in Arctic Ocean sediments from the Canadian arctic are presented below. Please note that only the sample fraction >500 µm has been analyzed, through visual counting and sorting on a Zeiss stereoscope (8x). Sample fractions 20 – 500 µm remain uncounted to date. Raman identification of polymer type has not yet been conducted on these samples, so total abundances may be overestimated.

Sediment Samples

Fourteen surface sediment samples collected between 2014 and 2017 have been processed and analyzed for microplastic particles (Figure 7). Whole samples were oven dried and size fractioned into >500 µm, 355-500 µm, 125-355 µm, and 2-125 µm. Sieving followed by two rounds of density separation using $CaCl_2$ at 1.4 g/cm^3 was the method employed for sediment processing.

Figure 7. The 14 sediment sample sites across the Canadian Arctic Archipelago. The sites spanned ~3300 km across the Arctic Ocean.



QA/QC Protocols Followed During Lab Processing

Laboratory processing blanks were included in analysis for every 5 samples, totaling 3 laboratory blanks included with the arctic samples. Procedural blanks contained 2.67 ± 2.52 particles/sample. In addition, one oven blank has been run to date, which contained 3 particles/sample. All particle types found in blanks were fibers.

Abundance of Microplastic Particles > 500 µm in Sediments from the Canadian Arctic

Preliminary results indicate the presence of microplastic particles >500 µm in all 14 samples. However, abundance of particles varied across sites (Figure 8). Microplastic abundance ranged from 361 to 5,188 particles/kg dried sediment, with an average of 1,818 ± 1,453 particles/kg dried sediment. The highest abundance of microplastics was found in sample Stn CB2, the western-most sample located in the Beaufort Sea just offshore of Alaska. The lowest abundance was found in sample Stn 177, located in the eastern Canadian arctic, in the Davis Strait just offshore of Qikiqtarjuaq, Baffin Island.

Composition of microplastic particles >500 um from sediments of the Canadian arctic

Particle types were mostly fibers (86.9%), with fragments (11.6%) being the second most common type (Figure 9). Films and spheres/beads were present very rarely (0-9% and 0-5%, respectively). Films were found only at two sites, and spheres/beads were found at three sites only. Three sites did not contain any fragments, and these sites were the three deepest sites. Most fibres and fragments found were white, black, and blue.

Discussion and Conclusions

Samples have been distributed to collaborators Nathalie Tufenji at McGill University for the analysis of nano-plastics by pyro-GC/MS. Samples have also been distributed to Jennifer Adams and Chelsea Rochman at University of Toronto and Patricia Corcoran at the University of Western Ontario for water, zooplankton and sediment analysis.

Figure 8. Microplastic abundance from surface sediments at 14 sites across the Canadian Arctic Ocean.

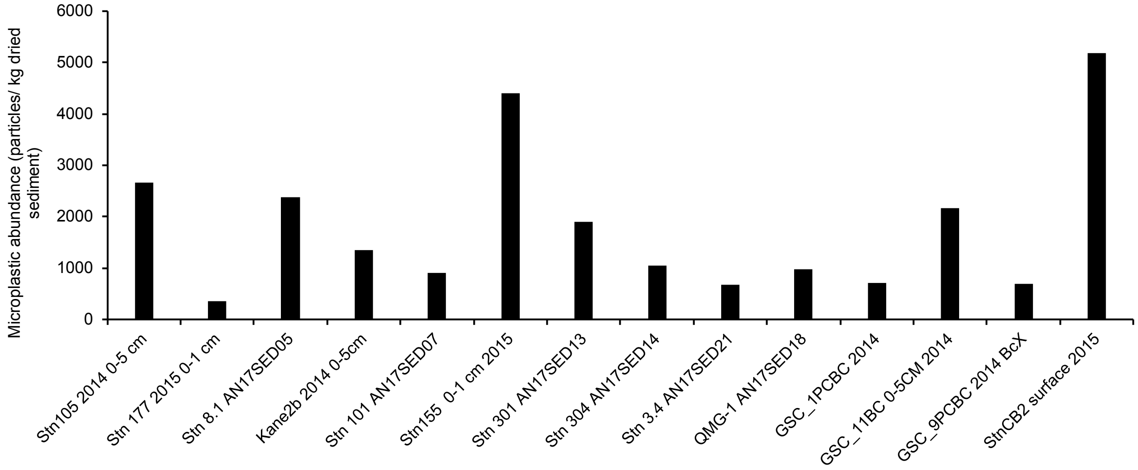
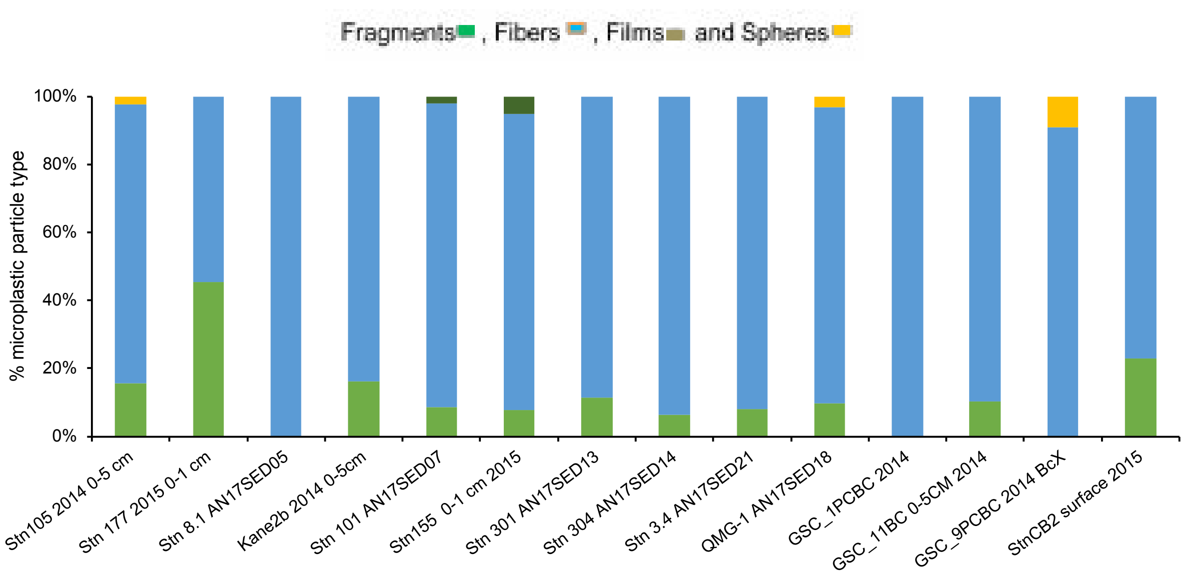


Figure 9. Microplastic particle type compositions for all 14 surface sediment samples across the Canadian arctic.



Thus far, we are able to conclude that the Arctic is contaminated with anthropogenic particles, and that the vast majority of the type of particle found in zooplankton, surface water, and snow samples is microfibres. Raman analysis and FTIR will soon confirm whether the particles are microplastics and allow us to subtract relevant contamination in our blanks from the samples to get a true observation of microplastic contamination in our samples.

Expected Project Completion Date

Completed, samples have been collected, archived and/or distributed to collaborators.

Project website

n/a

Acknowledgments

We thank ECCC for their continuing support and for sampling equipment. ArcticNet for funding and ship-time, the crew and fellow scientists of the CCGS Amundsen for help during sampling. Thanks to Sandy Steffen and Geoff Stupple for collection of the snow samples.

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Fine-scale temporal changes in mercury accumulation in Labrador ringed seals *(Pusa hispida)* using laser ablation technology on whiskers and claws: influence of a changing ice regime

Changements temporels à petite échelle de l'accumulation de mercure chez le phoque annelé *(Pusa hispida)* du Labrador à l'aide de la technologie d'ablation au laser appliquée aux moustaches et aux griffes : influence d'un régime des glaces en évolution

Project Leader/Chef de projet

Tanya M. Brown, Memorial University of Newfoundland, St. John's, NL, A1B 3X9.
Tel: (709) 864-7417, Fax: (709) 864-3119, Email: tanya.brown@mun.ca

Marie Nöel, Ocean Pollution Research Program, Ocean Wise, 4160 Marine Drive, West Vancouver, BC, V7V 1H2., Tel: (604) 239-6967, Email: marie.noel@ocean.org

Project Team/Équipe de projet

Aaron T. Fisk, Associate Professor, Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON; Peter S. Ross, Director, Ocean Pollution Research Program, Ocean Wise, Vancouver, BC; Ken J. Reimer, Professor Emeritus, Royal Military College of Canada, Kingston, ON; Jody Spence, Lab Manager, School of Earth and Ocean Science's ICP-MS and Laser Ablation Facility, Victoria, BC

Project Location/Emplacement(s) du projet

- Nachvak Fjord, Labrador
- Saglek Fjord, Labrador
- Okak Bay, Labrador
- Anaktalak Bay, Labrador

Abstract

The Labrador coast is experiencing changing sea ice conditions, with 2010 having a below normal extent of ice coverage and earlier spring breakup. Recent studies have reported a shift in ringed seal (*Pusa hispida*) foraging and/or feeding ecology in response to unfavourable ice conditions. The change in foraging and feeding habits, in turn, might change the amount of

Résumé

La côte du Labrador est soumise à diverses conditions de glace de mer. En 2010, la couverture de glace était inférieure à la normale, et la débâcle printanière est survenue plus tôt que de coutume. Des études menées récemment ont permis de relever un changement dans les activités de recherche de nourriture et/ou les relations trophiques du phoque annelé (Pusa

mercury seals are exposed to in their diet as well as their environment. This may, in turn, impact mercury (Hg) accumulation in seals. The present study measures Hg concentrations and stable isotopes along both ringed seal whiskers (n=20) and claws (n=20) and provides a history of diet and Hg exposure over varying climate conditions. This data will contribute meaningful information with respect to marine mammal toxicology which could be harnessed in wildlife management practices that employ non-lethal sampling methods.

hispida) en raison des conditions défavorables de la glace. Réciproquement, ces nouvelles habitudes de recherche de nourriture peuvent changer la quantité de mercure auxquels les phoques sont exposés dans leur régime alimentaire ainsi que dans leur environnement. Cela pourrait également avoir une incidence sur l'accumulation de mercure chez le phoque annelé. La présente étude vise à mesurer les concentrations de mercure et d'isotopes stables dans les moustaches (n=20) et les griffes (n=20) du phoque annelé, et établit l'historique du régime alimentaire et de l'exposition au mercure au fil des diverses conditions climatiques. Ces données fourniront des renseignements utiles concernant la toxicologie sur les mammifères marins, information qui pourrait être transposée en pratiques de gestion de la faune assorties de méthodes d'échantillonnage non mortelles.

Key Messages

- Hg concentrations and stable N and C isotope ratios along ringed seal whiskers (n=20) and claws (n=20) were measured using laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) and continuous flow ion ratio mass spectrometry (CFIR-MS), respectively.
- Hg was measured in ringed seal muscle (n=20) using a Direct Mercury Analyzer.
- Intra- and inter- annual variation in Hg levels and biological, ecological, and physical factors are being evaluated using whisker and fur samples from seals aged 3-21 years. These samples were collected from the northern Labrador coast between 2008 and 2011.

Messages clés

- Les concentrations de mercure et d'isotopes stables de l'azote et du carbone dans les moustaches (n=20) et les griffes (n=20) du phoque annelé ont été mesurées par spectrométrie de masse avec plasma à couplage inductif (ICP-MS) par ablation laser (LA-ICP-MS) et par spectrométrie de masse en flux continu (CF-IRMS), respectivement.
- Le taux de mercure a été mesuré dans les muscles du phoque annelé (n=20) au moyen d'un analyseur de mercure.
- Les variations intra- et interannuelles des concentrations de mercure et les facteurs biologiques, écologiques et physiques sont en cours d'évaluation en utilisant des échantillons de moustache et de griffe de phoques âgés de 3 à 21 ans. Ces échantillons ont été prélevés le long de la côte du nord du Labrador entre 2008 et 2011.

Objectives

This project aims to:

- measure Hg concentrations along ringed seal whiskers and claws using laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS). This fine-scale historical record of Hg measured along ringed seal whiskers and claws will be used to investigate the factors influencing intra- and inter- annual variation in Hg levels in ringed seals;
- compare Hg concentrations from claws and whiskers to muscle tissues; and,
- evaluate the associations between Hg concentrations in claws and whiskers and biological (age, weight, length, sex), ecological (carbon and nitrogen stable isotopes), and physical (timing of seal ice breakup and duration of the ice-free season) factors.

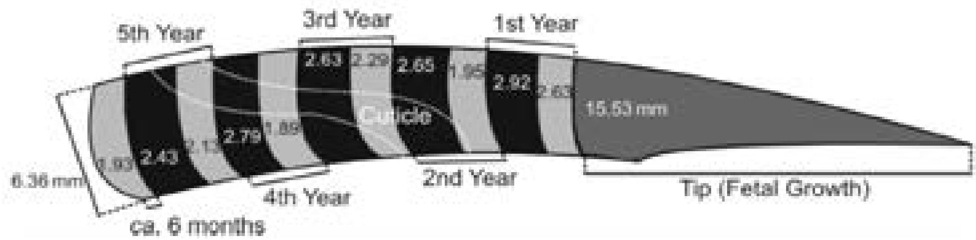
Introduction

Mercury (Hg), in the form of methylmercury (MeHg), can bioaccumulate up the food chain and reach high concentrations in high trophic level marine mammals, such as ringed seals (*Pusa hispida*). They can therefore be at risk of adverse health effects such as neurotoxicity or immunotoxicity (Basu et al. 2009; Frouin et al. 2012).

Ringed seals ingest mercury through their diet. Once assimilated, mercury accumulates in various tissues including hair, whiskers and claws that are resistant to degradation and have a stable composition. Mercury concentrations will, therefore, remain unchanged after deposition and these tissues can provide a record of mercury accumulation over time. Seal whiskers have been used in previous studies to investigate intra-annual variation in dietary signatures (i.e., stable isotopes) (Cherel et al., 2011; Newland et al., 2011) and, more recently, Hg concentrations (Nöel et al., 2015a). Ringed seal claws consist of alternating light and dark growth annuli (Figure 1) which can be used as intra- and inter- annual biomarkers of feeding and fasting cycles (Ferreira et al., 2011; Carroll et al., 2013). While the timing of deposition is not well understood, Ferreira et al. (2011) hypothesized that the growth of the light annulus may occur between May and October – December, during the period of maximum energy intake, and the growth of the dark annulus may occur between January and April during the reduced feeding and fasting period. Laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) allows a direct and continuous analysis of Hg along individual whiskers and claws. The resolution achieved by LA-ICP-MS along the length of growing whiskers or claws translates into a high-time resolution of Hg levels over short time intervals - in some cases shorter than a day (Pozebon et al., 2008; Steely et al., 2007).

The Labrador coast is experiencing changing sea ice conditions, with 2010 having a below normal extent of ice coverage and earlier spring breakup (Colbourne et al. 2010). Recent studies have reported a shift in ringed seal foraging and/or feeding ecology in response to unfavourable ice conditions (Brown et al., 2016) which may, in turn, impact Hg accumulation. The present study measures Hg concentrations and stable isotopes along both ringed seal whiskers and claws, and provides a history of diet and Hg exposure, over varying climate conditions. This data will contribute meaningful information with respect to marine mammal toxicology, which could be harnessed in wildlife management practices that employ non-lethal sampling methods.

Figure 1. Ringed seal claws consist of alternating light and dark annuli showing intra-annual growth (from Ferreira et al., 2011).



Activities in 2017-2018

Community Engagement

This study makes use of archived samples that were collected as part of previously funded NCP research programs in Nunatsiavut and as a result much of our community engagement for the program was incorporated during the sample collection years (2008-11). At the Tukisinnik Community Research Forum in Nain (June 2010), we presented background information, current research and results for the marine food web study and the ringed seal health study to the Nunatsiavut Government, community members, Parks Canada, Industry, and the Torngat Wildlife Plants and Fisheries Secretariat. We provided a plain-language review of our research (in English and Inuktitut) to the Nunatsiavut communities, Nunatsiavut Government, Parks Canada and the Torngat Wildlife, Plants and Fisheries Secretariat in the form of a report in 2011.

During our 2008-2011 field seasons, short presentations on our marine food web and ringed seal health study were presented to the Parks Canada/Nunatsiavut Government Base Camp. This gave us an opportunity for questions and exchange of ideas and concerns in an atmosphere which has a spirit of cooperation and is well-suited to partnership building. Over 60 Inuit from Nunatsiavut and Nunavik (including many elders) participated in base camp.

There have been ongoing discussions over the years regarding this study with the Inuit Research Advisor for Nunatsiavut (Carla Pamak), the Director of Environment for the Nunatsiavut Government (former Research Manager) (Rodd Laing), and with community members from Nunatsiavut communities.

Capacity Building and Training

Since the inception of our Nunatsiavut marine food web study and ringed seal health study which were awarded NCP and ArcticNet funds from 2008 to 2011, an overarching goal has been to enhance capacity building between Inuit and researchers and integrate a training component for Inuit students into our programs. From 2008 to 2011, Nasivvik, IPY, NCP and ArcticNet funds supported Inuit students who spent 5-weeks of the summer enrolled in our kANGIDLUASUk student intern program. The students were exposed to scientific fieldwork in a variety of fields and worked closely with scientists during both research programs. This unique program offered a cross-cultural exchange of knowledge among researchers and Inuit youth. Inuit students who have participated in the program have gained the experience, skills and confidence to subsequently work outside of the student program with university-based researchers, mining companies, and Inuit owned environmental consulting firms. During our final field work year, Dorothy Angnatok (a former kANGIDLUASUk student intern) was hired as a research assistant for our research programs. Dorothy progressed from a student intern position to a research assistant position, providing her the opportunity to take on a leadership role within many of our ongoing projects (including the ringed seal health study).

Communications and Outreach

We presented background information, current research and results for our ringed seal studies that were taking place in the region to the Nunatsiavut Government, community members, Parks Canada, Industry, and the Torngat Wildlife Plants and Fisheries Secretariat. We provided a plain-language review of our research (in English and Inuktitut) to the Nunatsiavut communities, Nunatsiavut Government, Parks Canada and the Torngat Wildlife, Plants and Fisheries Secretariat in the form of a report in 2011.

Results from these studies were also presented at our annual stakeholder meetings and at the Annual NCP results workshops. Representatives from the agencies outlined below who form our stakeholder group were present at our annual stakeholder meeting:

- Nunatsiavut Government
- Parks Canada
- Torngat Wildlife, Plants and Fisheries Secretariat
- Department of National Defence
- Director General Environment
- North Warning System Office
- Fisheries, Oceans & the Canadian Coast Guard
- Newfoundland and Labrador Government
- Sikumiut Environmental Management Ltd.
- Environment Canada

Discussions regarding this study has taken place over the past year with the Inuit Research Advisor for Nunatsiavut (Carla Pamak) and the Director of Environment for the Nunatsiavut Government (former Research Manager) (Rodd Laing) as well as community members from Nunatsiavut Communities. Discussions will continue to take place as our results are compiled and a plain-language overview of our research (in English and Inuktitut) will be presented to the Nunatsiavut communities, Nunatsiavut Government, Parks Canada and the Torngat Wildlife, Plants and Fisheries Secretariat in the form of a report.

Indigenous Knowledge

An overarching goal of all our ringed seal studies in Nunatsiavut have been to integrate Inuit and Inuit Knowledge into all aspects of our programs. Inuit and Inuit knowledge were incorporated through the consultation and collection of our samples from 2008 to 2011 and through an NCP funded ringed seal Indigenous Knowledge (IK) project entitled "Tukisimakatigennik (understanding together): Inuit Knowledge and scientific inquiry into contaminant trends in Nunatsiavut". TK on sea ice changes along the Labrador coast, in addition to measurements taken during our study period are being incorporated in the data analysis for this project.

Sample Selection and Preparation

We selected samples from 20 ringed seals that were between the ages of 3 and 21 years, and were harvested between 2008 and 2011. Out of those 20 seals, 13 had both whiskers and claws available for Hg and stable isotope analysis (Table 1). All seals had muscle available for Hg and stable isotope analysis (Table 1).

Table 1. 20 claws, whiskers and livers were selected for Hg and stable carbon and nitrogen analysis from ringed seals harvested between 2008 and 2011.

Seal ID	Location	Collection Year	Age	Sex	Whisker	Claw	Muscle
SRS-0804	Saglek	2008	3	n/a	X	√	√
SRS-0833	Saglek	2008	4	n/a	X	√	√
NRS-0809	Nachvak	2008	4	M	X	√	√
ORS-0810	Okak	2008	6	F	X	√	√
ORS-0812	Okak	2008	6	F	X	√	√
ORS-0813	Okak	2008	6	M	X	√	√
ORS-0816	Okak	2008	6	F	X	√	√
ARS- 0806	Anaktalak	2008	7	M	X	√	√
NRS-0805	Nachvak	2008	7	M	X	√	√
SRS-0817	Saglek	2008	8	M	X	√	√
ORS-0837	Okak	2008	8	n/a	X	√	√
SRS-0809	Saglek	2008	9	F	X	√	√
NRS-0816	Nachvak	2008	9	F	X	√	√
PH09-05	Nachvak	2009	17	F	√	X	√
PH09-08	Saglek	2009	14	F	√	X	√
PH09-11	Saglek	2009	3	M	√	√	√
PH09-23	Okak	2009	14	M	√	X	√
PH09-24	Okak	2009	3	F	√	√	√
PH10-26	Nachvak	2010	11	F	√	X	√
PH10-27	Nachvak	2010	11	F	√	X	√
PH10-29	Nachvak	2010	20	M	√	X	√
PH10-31	Saglek	2010	17	F	√	X	√
PH10-32	Saglek	2010	16	F	√	X	√
PH10-33	Saglek	2010	19	M	√	X	√
PH10-37	Saglek	2010	16	F	√	X	√
PH10-38	Saglek	2010	14	F	√	X	√
PH10-45	Okak	2010	17	M	√	X	√
PH10-47	Okak	2010	3	M	√	√	√
PH10-44	Okak	2010	6	M	X	√	√
PH11-001	Saglek	2011	11	M	√	√	√
PH11-002	Saglek	2011	3	M	√	√	√
PH11-003	Saglek	2011	6	F	√	√	√
PH11-004	Saglek	2011	4	F	√	√	√
PH11-005	Saglek	2011	21	M	√	X	√

Ringed seals use their claws, especially the ones on the outer edge, to maintain breathing holes, which results in wear at the tip of the claw (Smith and Stirling, 1975). Digit number I tends to be longer than others, therefore we opted to analyse this claw in order to have access to the longest possible diet and trace element history (Ferreira et al., 2011; Carroll et al., 2013). Digit I was dissected out using a scalpel and placed into a 5 mL scintillation vials with ultra-clean water. Samples were then incubated at 50°C in a water bath for 45 minutes. This allowed for loosening of soft tissues without compromising the mercury content of the claw. The ungula crest and remaining cuticle skin of the cornified claw sheath was then carefully shaved off with a scalpel blade. The longest whisker from each individual was selected for analyses and averaged 9.0 ± 1.0 cm.

To ensure the removal of external contamination, claws and whiskers will be rinsed successively with acetone, deionized water and acetone before being left to dry at room temperature. This technique was previously used to wash harbour seal whiskers and grizzly bear hair where it was proven not to impact trace element levels (Nöel et al., 2014; 2015a, b).

LA-ICP-MS analysis

LA-ICP-MS analysis is being conducted at the School of Earth and Ocean Sciences ICP-MS laboratory, University of Victoria, Canada, using a Thermo X-Series 2 Quadrupole ICP-MS coupled to a New Wave UP-213 laser ablation system. While Hg is the focus of the present study, a total of seven additional elements are being analyzed simultaneously (Cd, Pb, Cu, Ni, Co, Zn, Cr). We chose these seven additional elements because of their known toxicity to humans or other mammals and/or because of a known point source in the area (e.g. Vale Canada Limited, Voisey's Bay Mine). The consecutive line scan method used follows the method outlined in Sanborn and Telmer (2003) and successfully used in previous studies (Nöel et al., 2014; 2015a, b). Whiskers and claws were ablated using the same parameters as the ones used in a previous harbour seal study (spot size: 65µm, firing frequency: 20Hz and speed: 100µm/s; Nöel et al., 2015b). As there is currently no suitable claw/whisker standard for LA-ICP-MS analyses, DOLT-2 (National Research Council of Canada, ON), dogfish liver powder, and a NIST glass (National Institute of Standards and Technology) are being used as external standards.

As of April 30th, 2018, all 20 whiskers and eight claws have been analysed using LA-ICP-MS. To our knowledge there are no other studies using LA-ICP-MS on seal claws, therefore three claws were run three times using parallel lines to ensure that Hg trends along the claw are similar regardless of the position of the laser.

Results

Hg and stable C and N isotope measurements have been obtained in ringed seal muscle, whiskers and claws. We are currently waiting on the sulphur measurements for the claws and whiskers so that we can proceed with the standardization of our data and subsequently the intra- and inter-annual measurements between Hg concentrations and the biological, ecological and physical factors. Average concentrations of Hg in muscle tissue were higher (p=0.001) in 2010 than 2008 and 2009 (Figure 2). Concentrations of Hg are being analyzed in muscle tissue from 2011. Hg concentrations correlated (p=0.04, r^2=0.20) with $\delta^{15}N$ levels. No corrections (p>0.05) were found between Hg concentrations and $\delta^{13}C$ levels. Preliminary results suggest that increased Hg concentrations in 2010 ringed seals is consistent with a change in diet (altered fatty acid and $\delta^{15}N$ profiles) which was associated with changes in ice condition (Brown et al. 2015). We are currently completing the analysis and interpretation of the stable isotope and Hg concentrations in the individual claws and whiskers of these seals. This fine-scale approach will allow us to better understand the ecological (e.g., diet) and biological factors influencing intra- and inter-annual variation in Hg exposure of ringed seals in Labrador. Results from this study will provide additional insight into whether a changing sea ice regime or other shifting environmental variables along the Labrador coast are having a significant influence on feeding ecology and Hg accumulation in ringed seals.

Figure 2. Average concentrations of total Hg were higher (p=0.001) in 2010 ringed seals compared to the other sampling years (2008 and 2009).

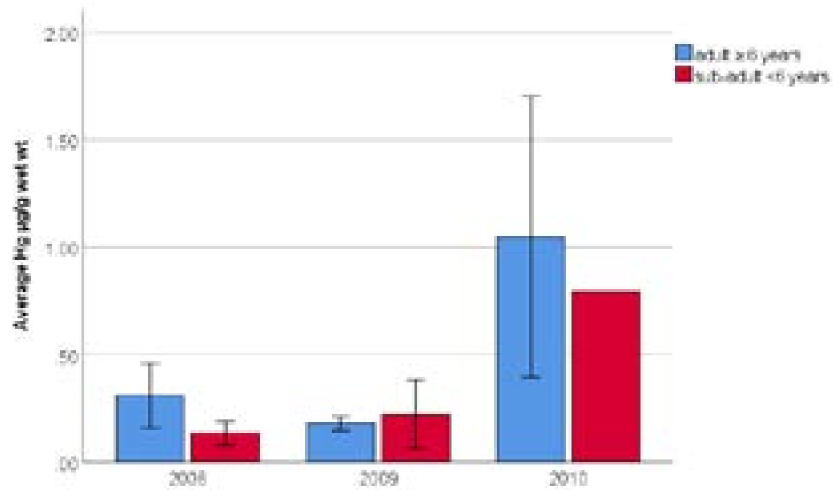
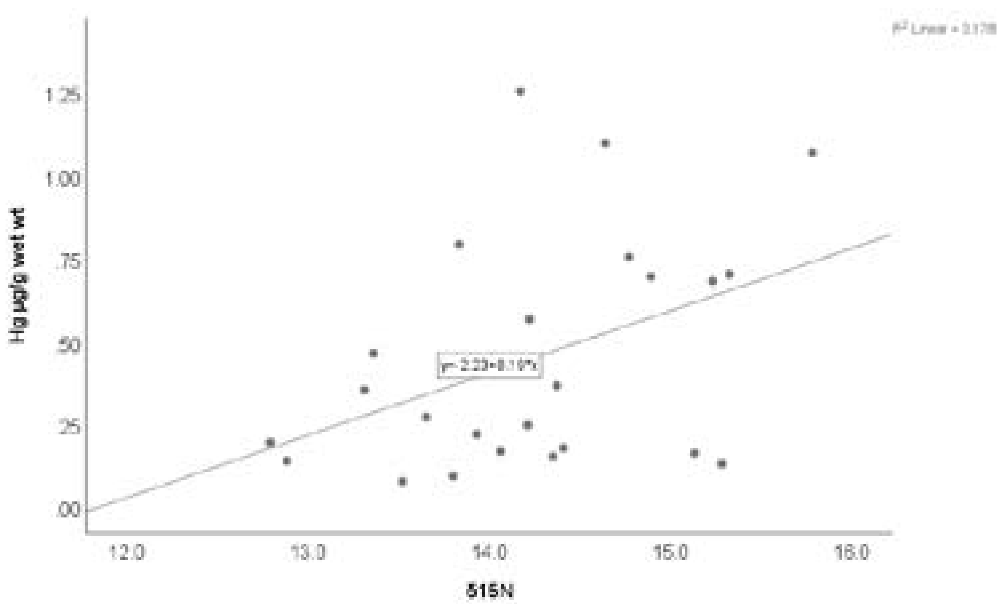


Figure 3. Total mercury in Hg correlated (p=0.001) with increasing δ15N.



Expected Project Completion Date

Fall of 2019, complete the evaluation of intra- and inter- annual variation in Hg levels and biological, ecological, and physical factors in whisker and claw samples and the comparison of Hg and stable isotope data across three tissue matrices (whisker, claw, and muscle). We are working on expanding the dataset to include samples collected from 2011 to 2020. This will allow for a more recent and longer (20 + years) temporal dataset. Submit manuscript for publication in 2021.

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Temporal trends of emerging pollutant and mercury deposition through ice and sediment core sampling

Tendances temporelles des dépôts de nouveaux polluants et de mercure mesurés par prélèvement de carottes de glace et de sédiments

Project Leader/Chef de projet

Cora Young, Department of Chemistry, York University, 4700 Keele St, Toronto, ON M3J 1P3. Tel: 416-736-2100 x22391; Email: youngcj@yorku.ca

Alison Criscitiello, Department of Earth and Atmospheric Sciences, University of Alberta, 1-26 Earth Sciences Building, Edmonton AB T6G 2E3. Tel: 781-307-1311; Email: glacierz@gmail.com

Amila De Silva, Water Science and Technology Directorate, Environment and Climate Change Canada, 867 Lakeshore Road, Burlington ON L7S 1A1. Tel: 905-36-4407; Fax: 905-336-4699; Email: amila.desilva@canada.ca

Igor Lehnherr, Department of Geography and Planning, University of Toronto, 3359 Mississauga Road N., Mississauga, ON L5L 1C6. Tel: 905-569-5769; Email: igor.lehnherr@utoronto.ca

Project Team/Équipe de projet

Jane Kirk, Environment and Climate Change Canada, Burlington, ON; Jocelyn Hirose, Parks Canada, Canmore, AB

Project Location/Emplacement(s) du projet

- Mount Oxford plateau, NU
- Lake Hazen, NU

Abstract

Contaminants produced and emitted in low-latitude regions can travel through the atmosphere and be deposited in high-latitude regions, such as the Arctic. Remote Arctic ice caps preserve and record concentrations of these chemicals and allow us to understand trends in atmospheric transport and deposition of contaminants. This project collects ice cores from the summit of a remote ice cap on Ellesmere Island in the Canadian High Arctic, as well as sediment cores from Lake Hazen located downstream of the ice cap. Ice and sediment cores are analyzed for priority contaminants, including mercury and emerging pollutants. By

Résumé

Les contaminants produits et émis dans les régions en basses latitudes peuvent voyager par l'atmosphère et se déposer dans les régions des hautes latitudes comme dans l'Arctique. Les calottes glaciaires des régions éloignées de l'Arctique préservent et emmagasinent les concentrations de ces produits chimiques et nous permettent de comprendre les tendances relatives au transport atmosphérique et au dépôt des contaminants. Le projet prévoit le prélèvement de carottes de glace du sommet d'une calotte glaciaire dans une région éloignée sur l'île d'Ellesmere dans l'Extrême-Arctique et de carottes de sédiments prélevées au lac

examining ice cores, we are able to determine how these chemicals are transported to the High Arctic and identify any changes in deposition over time. Data from sediment cores are used to understand how these contaminants make their way into downstream water bodies where they may bioaccumulate in aquatic organisms, such as Arctic char. Understanding the sources and pathways that lead to Arctic pollution, and how pollutant accumulation in the Arctic responds to changes in production and emission of these contaminants, will aid in our understanding and management of contaminant exposure for people and wildlife in the North. In this study, we collect samples with the ultimate goal of examining a suite of emerging pollutants including mercury from ice cores, allowing us to better understand spatial trends and sources of long-range transport to the Arctic. This information complements current air sampling programs in the Arctic.

Hazen situé en aval de la calotte glaciaire. Les carottes de glace et de sédiments sont analysées afin de détecter les contaminants prioritaires, dont le mercure et les nouveaux polluants. En examinant les carottes de glace, nous avons été en mesure de déterminer comment les polluants sont transportés vers l'Extrême-Arctique et de détecter les éventuelles tendances temporelles. Les données provenant des carottes de sédiments sont utilisées pour comprendre comment ces contaminants se retrouvent dans les plans d'eau en aval, où ils pourraient se bioaccumuler dans des organismes aquatiques comme l'omble chevalier. La connaissance des sources et des voies de cheminement qui entraînent la pollution de l'Arctique et la compréhension de la façon dont l'accumulation de polluants dans l'Arctique réagit aux variations de production et d'émission de ces contaminants nous aideront à mieux comprendre et gérer l'exposition aux contaminants des personnes et de la faune du Nord. La présente étude prévoit la collecte d'échantillons dans le but d'examiner une série de nouveaux polluants dans des carottes de glace, y compris du mercure, ce qui nous permettra de mieux comprendre les tendances spatiales et les sources de transport à grande distance des contaminants dans l'Arctique. Ces renseignements complètent les résultats des programmes d'échantillonnage atmosphérique en cours dans l'Arctique.

Key Messages

- Ice cores were collected from the Mount Oxford plateau in May 2017.
- Sediment cores were collected from Lake Hazen in May 2017.
- Age-depth relationships will be determined for ice and sediment cores.

Messages clés

- Des carottes de glace ont été prélevées sur le plateau du mont Oxford en mai 2017.
- Des carottes de sédiments ont été prélevées dans le lac Hazen en mai 2017.
- Les relations âge-profondeur ont été déterminées pour les carottes de glace et de sédiments.

Objectives

This project aims to:

- collect ice cores from the Mount Oxford plateau and sediment cores from Lake Hazen in May 2017;
- establish deposition age-depth relationships for ice and sediment cores using state-of-the-science techniques;
- understand how mercury and emerging contaminants are transported to the High Arctic and identify any changes in deposition over time; and,
- understand how mercury and emerging contaminants make their way from glaciers to downstream water bodies where they have the potential to bioaccumulate into aquatic organisms, such as Arctic char.

Introduction

There is a need for air data for mercury and emerging compounds to assess temporal trends and transport pathways. Trends into the future can be effectively captured by continued or new atmospheric monitoring. Past temporal trends will not be described by this monitoring program, but can be understood through precipitation and deposition records from remote ice caps (Garmash et al., 2013; Zhang et al., 2013)even though there are no direct sources and their long range atmospheric transport potential is generally lower than that of legacy pesticides. Data on the deposition of CUPs in the Arctic are required to assess the impact of their global usage and emission. In this study, selected CUPs were measured in the layers of a snow pit sampled on the Devon Ice Cap, Nunavut, Canada. The oldest sampled layers correspond to deposition from the early 1990s. Dacthal and endosulfan sulfate were most frequently detected, with peak deposition fluxes of 1.0 and 0.4 pg cm^{-2}. The trends captured in ice caps can be compared to known changes in production and emission of these contaminants to better understand long-range transport pathways. Lake sediments are also useful archives for examining past trends in contaminant deposition and delivery (Muir et al., 2009), however, lake sediments reflect both direct atmospheric deposition as well as catchment inputs, and reflect the total pollution received by the watershed. Analysis of these samples can inform our understanding of the presence of contaminants and their loadings to the Arctic terrestrial and aquatic environment. Furthermore, by utilizing ice and sediment cores in tandem, we will be able to examine the fate of these various contaminants during transport through the watershed, as the primary source of water and sediment to Lake Hazen is glacier meltwater. The sediment core data will also provide a valuable link between the ice core data and the Arctic char (*Salvelinus alpinus*) monitoring data collected at Lake Hazen, allowing for better interpretation of temporal trends in contaminant concentrations measured in fish.

Activities in 2017-2018

Sample Collection

Ice core samples were collected from the Mount Oxford plateau (Figure 1; 82°10.7403’N, 72°57.3283’W), Ellesmere Island, NU in May 2017 by project leaders Alison Criscitiello and Igor Lehnherr, along with Jocelyn Hirose. Three ice cores were collected, ranging in length from 13.8 to 17.7 m. Samples for contaminant analysis were shipped frozen to Environment and Climate Change Canada in Burlington, ON, while a single core for dating was shipped to Desert Research Institute, Reno, NV.

Duplicate sediment cores were collected from Lake Hazen (Figure 1) in May 2017 by project leader Igor Lehnherr, using a Uwitec gravity corer. Cores were collected from two different locations in Lake Hazen, each reflecting sediment inputs from different glacier-fed river inflows. One site is characterized by high sediment inputs from two large rivers, while the second site receives more moderate sediment input from a smaller riverine inflow. Both sites are located in the deep central trench of Lake Hazen, and sediment cores were collected from a depth of 260-265 m, corresponding to the maximum lake depth. The cores were sectioned in the Lake Hazen field lab at 0.5 cm intervals immediately after collection, and samples were stored frozen in pre-cleaned containers until analysis.

Core dating

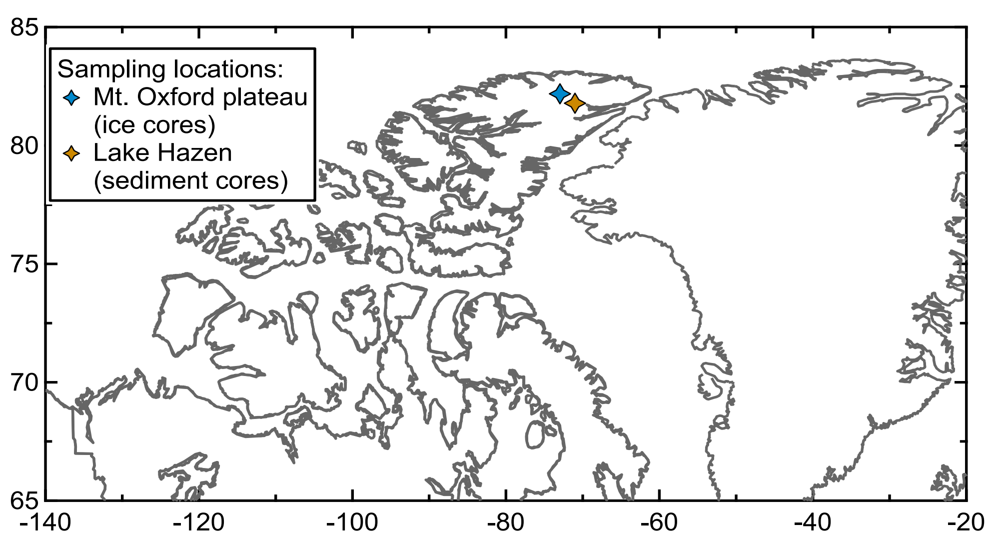
Ice cores were analyzed for marker species using inductively coupled plasma mass spectrometry (ICP-MS). Measured tracer species included sodium, magnesium, calcium, sulfur, chlorine, vanadium, chromium, manganese, cobalt, copper, zinc, bromine, iodine, cerium, lead, thallium, bismuth, hydrogen peroxide, nitrate, ammonium, black carbon, and isotopes of hydrogen and oxygen. These measurements will be used to determine the annual deposition to the Mount Oxford plateau coring site by project leader Alison Criscitiello, according to established protocols (Arienzo et al., 2016; Criscitiello et al., 2014; McConnell et al., 2002). The accuracy of this method is +/- 1 year.

Sample preparation and dating of sediment cores was conducted at Flett Research Ltd (Winnipeg, MB). Activities of ^{210}Pb and ^{226}Ra are being measured using alpha spectrometry, and sediments will be dated using the Constant Rate of Supply (CRS) age model (Sanchez-Cabeza and Ruiz-Fernandez, 2012). Additional cores collected at the same time and locations for a related project will also be analyzed using gamma-ray spectrometry at the Paleoecological Environmental Assessment and Research Laboratory (Queen's University) to provide additional sediment dating information.

Community Engagement

Co-PI Criscitiello led a field sampling team visit to Qarmartalik School in Resolute Bay at the end of the field season, talking with 3rd, 4th, and 5th graders about ice coring in Nunavut, and polar science in the North. The kids conducted scientist interviews, and then toured the team around the school. Criscitiello met with the school Principal as well as the science teacher, Kevin Xu, (as she has done the past 3 years) to help foster an ongoing relationship between the school in Resolute and scientists working in Nunavut. Co-PI Lehnherr also participated in the Qarmartalik School Science Fair as a judge (June 2, 2017).

Figure 1. Sampling locations for ice and sediment cores.



Capacity Building and Training

Because of the highly specific sampling process and remote location far from communities (~700 km from Grise Fiord), there is no on-site involvement of communities or hunting and trapping organizations in this proposed project.

Communications and Outreach

In the past, results of long-range transport from the Devon Ice Cap have been communicated to local communities by presentations, posters, and a video. We will prepare a poster for circulation in High Arctic communities describing the results of this study once they are available.

Indigenous Knowledge

Indigenous knowledge of prevailing winds and ocean/ice behaviour throughout the year will be used to understand the temporal trends of pollutants and mercury derived from the ice and sediment cores. This Indigenous knowledge will be derived primarily from the 2001 Elder's Conference on Climate Change summary document.

Results and Outputs/Deliverables

Ice Core

The Mount Oxford ice core has been dated at annual resolution (1920-2017), using several tie-points such as plutonium and lead (Figure 2), and subsequently annual-layer picking based on the oxygen isotope data ($\delta^{18}O$, δD) and anion/cation glaciochemistry (nssS, Cl, Na, Mg, H_2O_2).

Sediment core

A radioisotope activity depth profile in a Lake Hazen sediment core collected in May 2017 was used to build an age-depth model to reconstruct the accumulation of emerging pollutants and mercury in the lake through time (up to 300 years before present). The preliminary flux of total mercury to the sediments of Lake Hazen is shown in Figure 3, representing two hundred years of deposition to the area.

Figure 2. Age-depth model tie-point examples using (top) Pu^{239} from the Mount Oxford ice core compared with composite Pu^{239} measurements from the Arctic (Arienzo et al., 2016), and (bottom) Pb^{208} from the Mount Oxford ice core compared with Pb^{208} measurements from Summit, Greenland (McConnell and Arienzo, unpublished data).

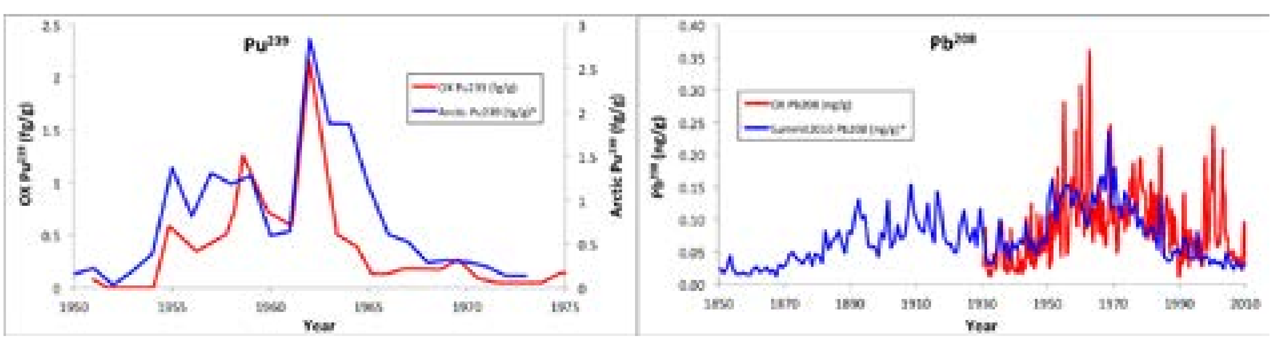
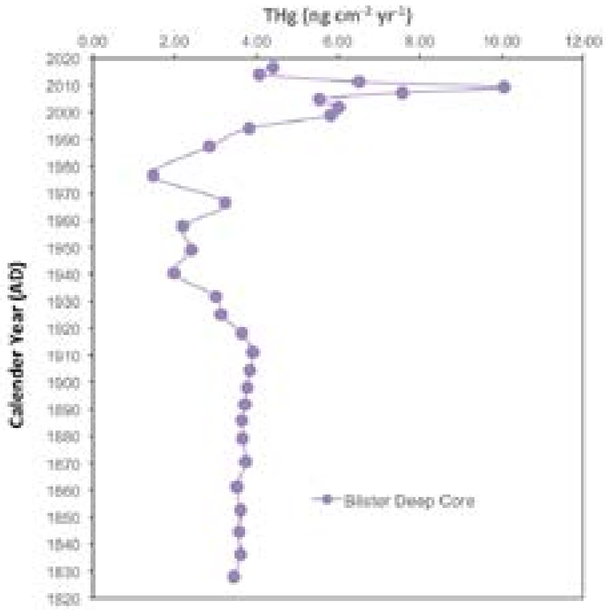


Figure 3. Preliminary total mercury flux depth profile in a Lake Hazen sediment core.



Discussion and Conclusions

Successful collection of ice and sediment cores, along with dating of both, will allow chemical analyses of emerging contaminants and mercury in the upcoming year.

Expected Project Completion Date

Project is continuing with 2018-2019 funding and should be completed in March 2019.

Acknowledgments

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Investigation into relatively high walleye mercury concentrations in Tathlina Lake

Étude des concentrations plutôt élevées de mercure chez le doré jaune du lac Tathlina

Project Leader/Chef de projet

Dr. Deborah MacLatchy, Professor & President, Biology Dept., 75 University Ave. W, Wilfrid Laurier University, Waterloo, Ontario, Canada, N2L 3C5.
Tel: (519) 884-0710 Ext. 2859 Fax: 519-746-2472, Email: dmaclatchy@wlu.ca

Dr. Heidi Swanson, Assistant Professor, Dept. of Biology, 200 University Ave. University of Waterloo, Waterloo, Ontario, Canada N2L 3G1. Tel: (519) 888-4567 Ext. 37387 Fax: (519) 746-0614,
Email: heidi.swanson@uwaterloo.ca

Project Team/Équipe de projet

George Low, Dehcho First Nations; Dr. Andrea Lister, Research Coordinator, Biology Depart., Wilfrid Laurier University, Waterloo, Ontario, Canada; Melaine Simba, Environmental Coordinator, Ka'a'gee Tu First Nation, Kakisa, NT

Project Location/Emplacement(s) du projet

Kakisa Lake, NT
Tathlina Lake, NT

Abstract

The objective of this project is to understand why mercury levels in walleye from Kakisa Lake are lower than in Tathlina Lake. This is in spite of the fact that these lakes are connected, have similar fish communities, and are both shallow, warm, and productive. In 2017, fish, water, bugs, and sediment were collected from Kakisa Lake. Tathlina Lake will be sampled in 2018. Once the second year of sampling is complete, fish ecology, benthic invertebrate communities, and levels of mercury in benthic invertebrates, water, sediment, and fish will be compared between the two lakes. This data will help elucidate the drivers of the differences in fish mercury contamination between the two fish populations. Data generated in 2017

Résumé

Ce projet avait pour objectif de comprendre pourquoi les niveaux de mercure chez le doré du lac Kakisa sont moins élevés que chez le doré du lac Tathlina, ceci en dépit du fait que ces lacs sont reliés, présentent des communautés de poissons semblables, qu'ils sont tous deux peu profonds, que leurs eaux sont chaudes, et qu'ils sont tous les deux productifs. En 2017, des échantillons de poisson, d'eau, d'insectes et de sédiments ont été prélevés du lac Kakisa. Le lac Tathlina sera échantillonné en 2018. Au terme de la seconde année d'échantillonnage, l'écologie piscicole, les communautés d'invertébrés benthiques et les niveaux de mercure chez les invertébrés benthiques ainsi que dans l'eau, les sédiments et les poissons

indicate that fish in Kakisa Lake generally have mercury levels that are below Health Canada's commercial sale guideline, which is important because Kakisa Lake supports an important commercial fishery. Future results will aid in understanding why walleye from Tathlina Lake are more likely to exceed this guideline, and how catchments, food web structure, and benthic invertebrate communities ultimately affect mercury levels in fish.

seront comparés entre les lacs. Ces données aideront à élucider les divers facteurs expliquant les différences de contamination des poissons par le mercure entre les deux populations de poissons. Les données produites en 2017 indiquent que, de manière générale, les poissons du lac Kakisa présentent des niveaux de mercure inférieurs à la ligne directrice pour la vente commerciale de Santé Canada, un facteur important, car le lac Kakisa soutient une pêche commerciale d'envergure. Des résultats plus poussés aideront à comprendre pourquoi le doré du lac Tathlina est plus susceptible de dépasser ce seuil et comment les bassins versants, la structure du réseau alimentaire et les communautés d'invertébrés benthiques influent sur les niveaux de mercure chez le poisson.

Key Messages

- No walleye from Kakisa Lake had mercury levels that exceeded the commercial sale guideline.
- Three northern pike from Kakisa Lake exceeded the commercial sale guideline; northern pike were more likely to exceed this guideline at sizes greater than 550 mm.
- Results from ultra-trace analyses of mercury in water indicate that most of the mercury entering the lake from Kakisa River is in the particulate form. Methyl mercury concentrations in water were 10 times higher in a small tributary than in either the Kakisa River or in the main basin of the lake; substantial methylation may thus be occurring either in the catchment or in small, shallow streams. Further research is necessary to determine the primary sites of mercury methylation in this lake system.

Messages clés

- Aucun doré du lac Kakisa ne présentait de niveau de mercure supérieur à la ligne directrice pour la vente commerciale.
- Trois grands brochets du lac Kakisa présentaient des niveaux de mercure supérieurs à la ligne directrice pour la vente commerciale. De plus, les brochets du nord de plus de 550 mm étaient plus susceptibles de dépasser ce seuil.
- Les résultats d'analyses d'ultratraces de mercure dans l'eau indiquent que la majeure partie du mercure déversé dans le lac depuis la rivière Kakisa se présente sous forme de particules. Les concentrations en méthylmercure dans l'eau étaient 10 fois plus élevées dans un petit tributaire que dans la rivière Kakisa ou dans le bassin principal du lac. Aussi, une méthylation substantielle peut se produire soit au niveau du bassin versant, soit dans de petits ruisseaux peu profonds. Des recherches plus poussées sont nécessaires pour établir les principaux sites de méthylation du mercure dans ce réseau lacustre.

Objectives

This project aims to:

Long Term

- gain an understanding of the drivers underlying relatively high (compared to Kakisa) concentrations of mercury in walleye in Tathlina Lake, Northwest Territories

Short Term

- sample and measure mercury and methyl mercury in walleye and northern pike in Tathlina and Kakisa lakes;
- characterize the distribution of mercury and methyl mercury in sediment, water, invertebrates and plankton in the lakes that this project studies to determine if lower food web characteristics are linked to variability in food fish mercury; and
- understand variability in mercury bioaccumulation between these two lakes that support commercially- and culturally-important fisheries.

Introduction

Mercury concentrations in food fish species vary widely among lakes in the Dehcho region. Research conducted by Swanson, Low, Simba, and Branfireun showed that size-standardized mercury levels in walleye muscle from Tathlina Lake were the second highest of the lakes studied (McGill (Swanson et al. 2017)). In contrast, walleye from neighbouring Kakisa Lake had the lowest size-standardized mercury levels. In Tathlina Lake, walleye greater than 18 inches in length were found to have mercury levels exceeding Health Canada's 0.5 ppm guideline. While the commercial fishery at Tathlina Lake has been scaled down in recent years, there is interest in rejuvenating this fishery and it is still a culturally and economically important fishery to the Ka'a'gee Tu First Nation (KTFN).

In contrast to results found for walleye, mercury levels in northern pike in 2014-2015 were similar between Tathlina and Kakisa lakes, and intermediate when compared with six other lakes. Size-standardized mercury levels (at 650 mm fork length) were below Health Canada's 0.5 ppm guideline. The incongruity of spatial patterns between walleye and northern pike in Tathlina and Kakisa lakes cannot be fully explained by current data.

To strengthen the predictive relationships of fish mercury concentrations in Tathlina and Kakisa lakes, we are examining mercury levels in larger sample sizes of fish (n=30) that represent a greater size and age range than what has been sampled before. We are also quantifying characteristics of the catchments of both Kakisa and Tathlina Lakes, and sampling lower trophic levels, including benthic invertebrates, and abiotic ecosystem components (water and sediment). When combined with data gathered from other intensively sampled lake pairs in the Dehcho region, we will be in a much better position to make predictions of the effects of climate change and resource development on fish mercury concentrations.

Activities in 2017-2018

Field Activities

The order of lake sampling was altered to reflect logistical constraints regarding Tathlina Lake (fly-in), and the preferences of the community (Ka'a' Gee Tu First Nation (KTFN)). Because KTFN was holding a youth camp on Kakisa Lake in summer 2017 which would allow increased outreach and capacity-building, they requested we reverse the sampling order. We thus sampled Kakisa Lake in summer 2017, both Kakisa and Tathlina lakes in March 2018, and Tathlina Lake in 2018. Fish, benthic invertebrates, sediments, and water were sampled during a week-long on-the-land camp held at Kakisa Lake in August 2017. Nine youth participated in the sampling, as well as a commercial fisher.

Laboratory Activities

Analyses of total mercury have been completed on all fishes captured at the Western University Biotron Analytical Laboratory using a Direct Mercury Analyzer, whereas analyses of mercury in water were completed using a Tekran 2600 at the same laboratory. Analyses of methyl mercury have been completed for invertebrates that were separated by functional feeding group using a Tekran 2700 at the Western University Biotron Analytical Laboratory, whereas analyses of methyl and total mercury in sediments are ongoing.

Community Engagement

Sampling occurred during a week-long community camp that was selected by KTFN. Outreach activities were completed with youth, and sampling was conducted in conjunction with community monitors and a commercial fisherman. At the end of the sampling camp, flesh from sampled fish (which had been prepared for consumption) were prepared and served at a community feast, which several elders and community members travelled to (access was via boat on Kakisa Lake).

Capacity Building and Training

Members of the community were hired to assist with the logistics of the field trips, collect biotic and abiotic samples, and participate in all aspects of the field research at both lakes. They worked directly with researchers from Wilfrid Laurier University and the University of Waterloo. New training on field sampling techniques for the characterization of food webs at the lakes was demonstrated, along with the opportunity for the community members to continue to sample fish according to the standardized sampling methods that have already been taught. Some of our community partners have received their Aurora Collage certification through the 5-week environmental training course, and their skill and knowledge was invaluable in completing the field research.

Communications and Outreach

As part of the communications and outreach portion of this study, the research team initiated communications with Melaine Simba – June and July 2017 to plan for community sampling camp. Activities over the one-week camp were led by Mike Low, Swanson and Branfireun and included fish dissection, invertebrate sampling, and water sampling, respectively.

Results from this research were communicated directly with the KTFN during field trips, emails, and conference calls, as well as at two face-to-face meetings and at the Northern Contaminants Program Results workshop.

All data were reported to Health Canada and GNWT, Health and Social Services for risk assessments and the release of consumption advisories as required.

Indigenous Knowledge

This project was developed in direct response to questions and concerns from the community in regards to the safety and security of their commercial and subsistence fisheries on Kakisa and Tathlina Lake; the research was community-driven. Indigenous and local knowledge was used to develop the project questions, choose the fishing locations, and guide sampling of water and sediment (in terms of priority locations). Community members highlighted areas of the land and lake that they thought were particularly susceptible to climate-induced change (e.g., recent changes in water colour or taste) and that were particularly important for winter and summer fisheries. Priority sampling was conducted in these locations. In addition, local fishers asked if we could investigate levels of mercury in fish that had been prepared in traditional ways, including smoked fish. These analyses have been added to our ongoing research plan.

Results and Outputs/Deliverables

Mercury in Water

Total mercury concentrations in unfiltered and filtered water samples were lowest in tributary waters and highest in Kakisa River. In contrast, methyl mercury concentrations in unfiltered and filtered water samples were lowest mid-lake, and highest in small tributary waters. Percent methyl mercury was substantially lower in waters from the Kakisa River and from the mid-lake than in tributary waters; percent methyl mercury in inflow waters was relatively high, at 25%.

Mercury in Fish

Total mercury concentrations in fish varied from a minimum of 0.02 ppm in a white sucker, and 0.80 in a northern pike. Mean mercury concentrations in all species were below the 0.5 ppm Health Canada guideline. All mercury concentrations in lake whitefish and white sucker were below the 0.5 ppm Health Canada guideline, and all walleye except one (fork length 445 mm) were below the guideline; this walleye had a mercury concentration of 0.5 ppm wet weight (at the guideline). Fork length explained 68% of variation in northern pike mercury concentrations. Age and stable isotope analyses are ongoing (Figure 2). Mercury concentrations were more likely to exceed the Health Canada guideline in Pike that were larger than ~ 550 mm.

Discussion and Conclusions

In 2018-2019, we will complete analyses of mercury in sediment and benthic invertebrates, stable isotope ratios in fish and invertebrates, and age in fish. Samples will be collected from Tathlina Lake, and analyses of these samples will lend insight into the differences in mercury levels in walleye and northern pike between the two lakes. These findings are of particular importance because of the commercial and subsistence fisheries present in the region. Methyl mercury in water was much lower in mid-lake samples than in tributary samples; this suggests that methylation rates in the catchment and/or in small tributary streams may be much higher than in the lake, and that catchment inputs of methyl mercury are more important than in-lake production of methyl mercury. In general, fish from Kakisa Lake have mercury concentrations that are below the Health Canada guideline of 0.5 ppm. No walleye exceeded the guideline, whereas 3 northern pike exceeded the guideline.

Expected Project Completion Date

March 31, 2020

Figure 1. Total mercury concentrations in lake whitefish (LKWH), northern pike (NRPK), walleye (WALL), and white sucker (WHSC) captured from Kakisa Lake in 2017.

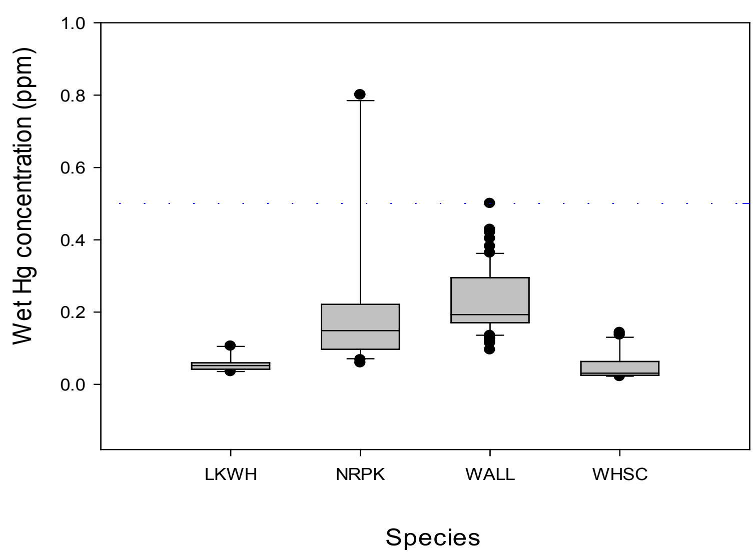


Figure 2. Linear regression between log10 wet mercury concentrations (ppm) and log 10 fork length (mm) in northern pike captured from Kakisa Lake in 2017.

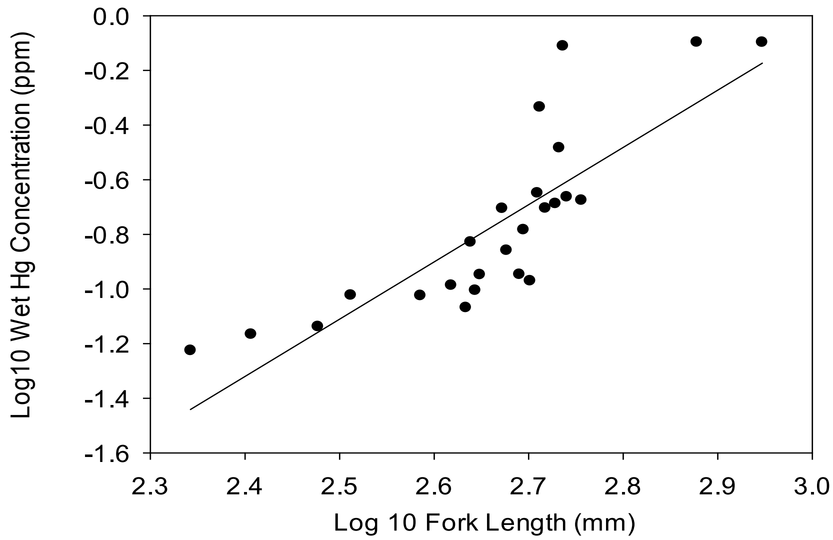


Table 1. Concentrations of total and methyl mercury in filtered and unfiltered water samples collected in August 2017

Site	Filtered or Unfiltered?	Total Hg (ng/L)	Methyl Hg (ng/L)	%MeHg of total	% Total Hg that is dissolved
Kakisa Lake – Tributary	Filtered	0.537	0.135	25	
Kakisa Lake - Tributary	Unfiltered	0.573	0.137	24	94
Kakisa River	Filtered	0.993	0.030	3	
Kakisa River	Unfiltered	3.396	0.035	1	29
Kakisa Lake – mid-lake	Filtered	0.716	0.007	1	
Kakisa Lake – mid-lake	Unfiltered	1.138	0.009	0.7	63

Acknowledgments

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

References

Swanson, H.K., Branfireun, B., and Low, G. 2017. An investigation of variable fish mercury concentrations in Dehcho Lakes. NWT Cumulative Impact Monitoring Program 2017/18 Annual Report. 12 pages.

Communications, Capacity and Outreach

Communications, capacités et sensibilisation

Yukon Contaminants Committee (YCC)

Comité des contaminants du Yukon (CCY)

- **Project Leader/Chef de projet**
  Chair: Ellen Sedlack, Crown Indigenous Relations and Northern Affairs Canada, Yukon Region, 415C-300 Main St., Whitehorse, Yukon Y1A 2B5. Email: Ellen.Sedlack@Canada.ca
- **Project Team/Équipe de projet**
  Yukon Contaminants Committee (YCC) including: James MacDonald, Council of Yukon First Nations (Co-Chair YCC), Dr. Mary Vanderkop, Dr. Aynslie Ogden, Dr. Brendan Hanley, Yukon Government; Mary Gamberg, independent consultant and researcher; Derek Cooke, Ta'an Kwäch'än Council

- **Project Location/Emplacement(s) du projet**
  Yukon, Canada

Abstract

The YCC has operated since 1991 and continues to keep residents of the Yukon informed of the Northern Contaminants Program's initiatives. In 2017-2018 the YCC continued to work with Yukon Health authorities on contaminants in traditional food sources. At various workshops throughout the Yukon and the Results Workshop in Yellowknife this past fiscal year, YCC members discussed NCP initiatives with participants, and described the application process for NCP funding. The YCC was successful at recruiting three Yukon communities (White River First Nation, the First Nation of Nacho Nyäk Dun and Taku River Tlingit First Nation) to submit proposals researching long-range contaminants in wildlife in their Traditional Territories These projects were approved for funding as part of the NCP's Community-based Monitoring Program in 2018-2019, and will span over a two-year period. The YCC was also

Résumé

Le CCY, qui existe depuis 1991, continue d'informer les résidants du Yukon sur les initiatives exécutées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). En 2017-2018, le CCY a poursuivi sa collaboration avec les autorités sanitaires du Yukon en lien avec les sources d'aliments traditionnels du territoire. Dans le cadre de divers ateliers tenus à travers le Yukon et de l'atelier sur les résultats qui a eu lieu à Yellowknife au cours du dernier exercice, les membres du CCY ont discuté des initiatives du PLCN avec les participants et décrit les processus de demande de financement dans le cadre du Programme de lutte. Le CCY est parvenu à recruter trois collectivités du Yukon (Première Nation de White River, Première Nation des Nacho Nyak Dun, et Première Nation des Tlingits de la rivière Taku) afin de leur présenter des propositions de recherche des contaminants transportés sur de longues distances dans la

successful in securing funding for the Yukon College to purchase a direct mercury analyzer.

faune de leurs territoires traditionnels. Le financement de ces projets a été approuvé dans le cadre du programme de surveillance communautaire régional du PLCN en 2018-2019, et ces projets s'échelonneront sur une période de deux ans. Le CCY a réussi à s'assurer du financement qui permettra au Collège du Yukon d'acquérir un analyseur de mercure.

Key Messages

- Our Traditional Country Foods are safe to eat.
- Levels of contaminants are generally low in the Yukon Territory.
- New contaminants are emerging globally due to climate change and monitoring and we must continue to ensure traditional food are safe to eat.
- 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 and contributing to this research.

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.
- De nouveaux contaminants apparaissent à l'échelle mondiale en raison des changements climatiques, et nous devons continuer de veiller à ce que les aliments traditionnels soient sans danger pour la consommation.
- Les travaux liés au PLCN sont toujours pertinents aux échelons 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 à cette recherche.

Objectives

This project aims to:

- enhance the confidence of Yukon residents in making informed decisions about Traditional Country Food consumption and other health related factors;
- ensure that the residents of the Yukon 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;
- ensure that the programs offered by – and the research done for – the NCP meets the needs of the residents of Yukon; and,
- ensure that the residents of the Yukon are aware of the funding envelopes and calls for proposals available under the NCP.

Introduction

The Northern Contaminants Program makes use of the Regional Contaminants Committees as conduits between the regions and the national program. In addition to their ongoing role as the contact between the residents of the Yukon and the NCP, the YCC is responsible for reviewing all regional proposals from a socio-cultural standpoint. 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. These activities require the fiscal support of the National Program.

The YCC has spent the past 25 years communicating results of the Northern Contaminants Program Yukon residents and contributing to national and international publications. The YCC is considered to be the point of contact for long-range contaminant issues in the Yukon.

Activities in 2017/18

Communications and Outreach

- In 2017-2018 the Yukon Contaminants Committee continued working on communications and outreach to Yukoners pertaining to potential long-range contaminants in traditional food sources. Communications include discussion with community members and through the Council of Yukon First Nations (CYFN) website.
- At various workshops throughout the Yukon and the Results Workshop in Yellowknife, YCC members discussed NCP initiatives with participants, and described how to apply for funding.
- The development of a data resource library for the region.
- YCC would also like to become more inclusive of NCP and YCC communication material for distribution in Yukon (YT) with translation services for the Southern Tutchone language this fiscal. Other language translation requirements will also be explored, as more extensive translation services may be needed in YT.

Community Engagement

- The YCC was successful at recruiting three Yukon communities (White River First Nation, the First Nation of Nacho Nyäk Dun and Taku River Tlingit First Nation) in submitting proposals to see long-range contaminants in wildlife in their Traditional Territories.

Capacity Building and Training

- The YCC was also successful in securing funding for the Yukon College to purchase a direct mercury analyser. Please see Appendix 1.

General

- The YCC met several times over the course of the year as well as with researchers, in which communication strategies on contaminants issues were discussed
- The YCC reviewed each project proposal submitted to the NCP related to or connected with the Yukon. The YCC made comments and assessed the value of these projects through recommendations to the NCP Secretariat and later to the NCP Management Committee.
- James MacDonald and Ellen Sedlack attended the CYFN General Assembly in Carcross, Yukon in June 2017 and were available to answer any questions about the NCP and the YCC. Moreover, information was provided to Yukon communities on the NCP program and funding opportunities. This was directly related to the contaminants workshop that was held in March 2017 in Whitehorse and has formed the basis for new interest and projects in the Yukon.

Results and Outputs/Deliverables

This year some members of the YCC attended NCP Management Committee meetings to recommend funding for potential NCP projects. The YCC reviewed Yukon Territory project proposals, and made comments in writing to the NCP in preparation for the April 2018 Management Committee meeting in Nain, Labrador. The YCC attended the NCP proposal review integration meeting and reviewed and commented on proposals. The YCC reviewed the northerncontaminants.ca website which is maintained and updated through CYFN. Some members of the YCC (James MacDonald and Mary Gamberg) attended the NCP Results Workshop in Yellowknife, Northwest Territories, in September 2017. The YCC also communicated information about contaminants and the NCP to residents of the Yukon. The YCC also met with researchers including Hayley Hung about the Little Fox Lake air monitoring site, and local researcher Mary Gamberg about her projects, as well as assisted with refining communication handouts/website information for Mary Gamberg's projects.

Discussion and Conclusion

The regional office will continue to coordinate contaminants projects in the Yukon, including the fiscal agreements where required, as well as assist National and International NCP initiatives. The regional office will work with the Yukon Contaminants Committee to review all proposals relevant to the Yukon for socio-cultural content. There has also been preliminary discussion to complete and approve an updated Terms of Reference for the YCC as well as partake in a second strategic planning session for the committee to understand roles/responsibilities and how to further NCP initiatives in the Territory. This planning session will build upon the first session held in 2016-2017.

Expected Project Completion Date

Ongoing

Acknowledgements

The Chair of YCC, Ellen Sedlack would like to acknowledge the in-kind and funding support received by the NCP and its Secretariat, along with the contributions of all the members of the YCC. In particular, special thanks goes out to James MacDonald for his contribution to assisting CIRNAC, Yukon region and the YCC with his involvement, collaboration and connection with the Yukon First Nation in the Territory.

Appendix 1

CBC North News Story about Yukon College's new Direct Mercury Analyzer

The Direct Mercury Analyzer will allow researchers at Yukon College to better understand how much of the toxic pollutant is in the Yukon environment. The machine will allow a Yukon researcher to create the territory's 1st data set of mercury in permafrost.

Reference:

McKay, J. (2018, May 10). New machine at Yukon College will open up mercury research in the territory. *CBC news*. Retrieved from https://www.cbc.ca/news/canada/north/new-mercury-machine-yukon-college-1.4656284 on June 27, 2019

Northwest Territories Regional Contaminants Committee (2017-2018)

Comité régional des contaminants des Territoires du Nord-Ouest (2017-2018)

Project Leader/Chef de projet

Emma Pike, Program Manager NCP, Contaminants and Remediation Division, Crown-Indigenous Relations and Northern Affairs Canada, P.O. Box 1500, Yellowknife, NT X1A 2R3. Tel: 867-669-2830; Fax: 867-669-2700; Email: emma.pike@canada.ca

Tim Heron, Northwest Territory Métis Nation (Chair), PO Box 720 Fort Smith, NT. X0E 0P0. Tel: 867-872-2770; Fax: 867-872-3586; Email: lands.resources@nwtmetis.ca

Tyanna Steinwand, Tłı̨cho Government (co-Vice-Chair), Bag Service #21 Behchokǫ, NT. X0E 0Y0. Tel: (867)-392-6381 ex. 1357; Fax: (867)-392-6381; Email: tyannasteinwand@tlicho.com

Shannon O'Hara, Inuvialuit Regional Corporation (co-Vice-Chair), Bag Service #21Inuvik, NT X0E 0T0. Tel: (867)-777-7026, Email: sohara@inuvialuit.com

Project Team/Équipe de projet

Dahti Tsetso/Robyn McLeod, Dehcho First Nations; Tas-Tsi Catholique, Gwich'in Tribal Council; Shin Shiga/Nicole Goodman, North Slave Métis Alliance; Diane Giroux, Akaitcho Territory Government; Cindy Gilday/Dakota Erutse, Sahtú Secretariat Inc.; Trevor Teed, Dene Nation; Eric Loring, Inuit Tapiriit Kanatami; Erika Hille, Aurora Research Institute; Kaitlyn Menard, GNWT Health and Social Services; Brett Elkin/Heather Fenton, GNWT Environment and Natural Resources; Meredith Seabrook, GNWT Cumulative Impact Monitoring Program (CIMP); Ellen Lea, Department of Fisheries and Oceans Canada; Ben Linaker, Health Canada; Simon Smith, NCP Secretariat, Crown-Indigenous Relations and Northern Affairs Canada; Carmon Bessette, Crown-Indigenous Relations and Northern Affairs Canada

Project Location/Emplacement(s) du projet

Northwest Territories, Canada

Abstract

In the 2017-2018 year, the Northwest Territories Regional Contaminants Committee (NWTRCC) continued to fulfill its mandate of communicating results of research to Northwest Territories (NWT) residents and providing input on proposed research projects from a social/cultural lens. The 2017 Northern Contaminant Program (NCP) Results Workshop was held in Yellowknife, and the Regional Contaminants Committee (RCC) Secretariat and Committee members played an important role in planning this meeting. In addition to this, the NWTRCC held a number of in person and teleconference meetings to meet its objectives. Members also worked independently, in the communities they represent, to share research and where possible identify community research priorities in regards to long-range contaminants.

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 continues to highlight the need to integrate Indigenous Knowledge in all stages of research projects, and to ensure research helps to address community concerns about whether the water is safe to drink and country foods are safe to eat.

Résumé

En 2017-2018, le Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO) a continué de remplir son mandat, soit de communiquer les résultats de recherche aux résidants des Territoires du Nord-Ouest (T.N.-O.) et de leur fournir des perspectives sur des projets de recherche d’un point de vue social et culturel. L’atelier sur les résultats de 2017 du Programme de lutte contre les contaminants dans le Nord (PLCN), le Secrétariat du Comité régional des contaminants (CRC) et les membres du Comité ont grandement contribué à la planification de cette réunion. En outre, le CRCTNO a organisé un certain nombre de réunions par conférence téléphonique en vue de respecter ses objectifs. Les membres ont aussi travaillé indépendamment dans les collectivités qu’ils représentent pour partager leurs recherches et, dans la mesure du possible, relever les priorités de recherche communautaires concernant les contaminants transportés sur de longues distances.

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 dans les Territoires du Nord-Ouest. Les résultats de ces études sont transmis aux collectivités.
- Le CRCTNO continue de mettre en évidence le besoin d’intégrer les connaissances autochtones à tous les stades des projets de recherche pour veiller à ce que ceux-ci aident à offrir une réponse aux préoccupations de la collectivité, à savoir si l’eau et les aliments locaux peuvent être consommés sans danger.

Objectives

The NWTRCC aims to:

- support and advance a communications network that ensures Northerners are informed about contaminants studies, results, and activities;
- identify priorities and information gaps related to environmental contaminants research in the NWT e.g. health risk assessment work for mercury in fish in the NWT;
- act as a central repository of environmental contaminants information in each region;
- provide advice to Indigenous governments on appropriate funding sources; review and advise researchers on NCP NWT proposals for social/cultural criteria;
- invite scientists to participate in conference calls and to travel to NWT communities to present their research findings/results, where possible; and,
- coordinate meetings with other Programs, such as Cumulative Impact Monitoring Program (CIMP) to avoid overlap and allow efficiencies where appropriate.

Introduction

The Northwest Territories Regional Contaminants Committee was created with the inception of the Northern Contaminants Program as part of its overall governance structure, and consists of representatives from federal, territorial and Indigenous governments. The NWTRCC advises on communication of information to residents of the Territory regarding long-range contaminants in the atmosphere, land, water, fish, wildlife and humans as part of the Northern Contaminants Program.

Many of the NWTRCC members sit on the CIMP committee, Protected Areas Strategy, Mackenzie River Basin Board and the Government of Northwest Territories (GNWT) Water Strategy, making them a well-informed network and resource for communities. This knowledge is also used during the Social/Cultural Review to eliminate duplication and facilitates integration of proposals with other programs. The NWTRCC also provides comments discussed during the social/cultural review to the Northern Contaminants Program (NCP) Management Committee.

Activities in 2017-18

The NWTRCC continued to communicate results of research to NWT residents as applicable and where possible engaged community members on this information. Through the Social-Cultural review, the NWTRCC provided constructive input and advice on proposed NCP projects across the Territory. The NWTRCC also held a number of teleconference and in person meetings in order to ensure effective communication among all members and determine priorities of the RCC for the year. The NWTRCC supported a successful NCP Results Workshop in Yellowknife in September 2017. The NWTRCC continued its engagement with NCP researchers working across the Territory to ensure they had the correct community contacts, engaged community members in a useful way, and endeavored to promote research that is relevant to community member. In order to ensure efficiency of government programming, the NWTRCC worked with other programs such as the GNWT Cumulative Impacts Monitoring Program to ensure there was not unnecessary overlap and research priorities in the Territory were being addressed in a way that fit together logically.

Community Engagement

Various members of the committee engaged with the communities they represent. The Dehcho representatives shared information on NCP on the organization's Facebook page and regional mercury studies were explained at a Youth Camp. The Sahtú Secretariat representatives communicated with the research team studying burbot in Fort Good Hope to ensure they were up to date on the research and could help facilitate results presentation to the community. The Sahtú representative also presented on NCP work at the Sahtú Secretariat Annual Assembly. The North Slave Métis Alliance (NSMA) representative held meetings with leadership and general membership twice during the year to update them on NCP initiatives. Issues related to long-range contaminants were communicated to members via the NSMA lands newsletter twice during the year. The Gwich'in Tribal Council representative shared relevant NCP reports with community representatives and engaged them on discussing applicable NCP funding proposals.

The Inuvialuit Regional Corporation representative engaged with researchers on a variety of projects across the Inuvialuit Settlement Region (ISR), and helped facilitate communication of research results to communities.

Capacity Building and Training

The NWT RCC secretariat facilitated participation of local high school students in the introductory session of the NCP Results Workshop held in Yellowknife in September 2017, helping to build knowledge of what a contaminant is, and the issues associated with long-range transport of contaminants.

The Sahtú Secretariat was represented by two individuals in order to ensure they could build capacity by having a Sahtú student take on part of the position and learn the functions of the NCP representative.

A number of new RCC members started working with the Committee this year, and this has helped, and continues to help, develop capacity in regards to communicating and disseminating information on NCP research across the Territory. The new RCC members also develop expertise in providing recommendations and suggestions to researchers in their work.

Communications and Outreach

The NCP Secretariat completed a social media campaign associated with the NCP Results Workshop, which the NWTRCC members shared with other local social media sites, which greatly increased participation in the workshop, from a broader audience than normally expected.

The Akaitcho Territory Government representative provided three updates to the Government executive over the course of the year on NCP work. Information on NCP was also shared on the Government website. The RCC communicates internally on a regular basis in order to ensure all members have the opportunity to provide their perspective both on various NCP projects but also the priorities and functioning of the RCC itself.

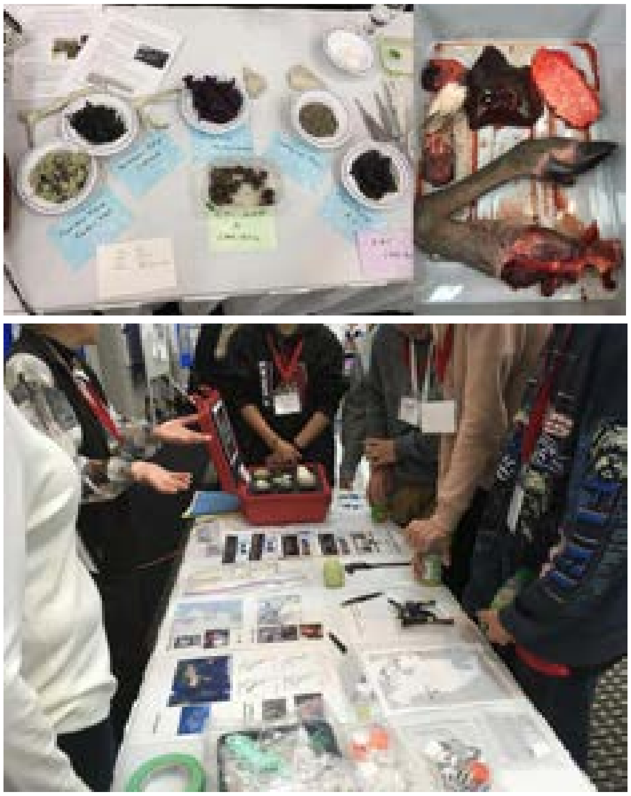
Indigenous Knowledge

RCC Members regularly incorporate or provide support for Indigenous knowledge in their engagement work, and when reviewing proposals from a socialcultural lens, ensure the incorporation of Indigenous knowledge into NCP projects is being done in a culturally sensitive, relevant and appropriate manner.

Discussion and Conclusions

The NCP results workshop held in Yellowknife this past year was a great success and feedback was very positive in support of having it in the North. This allowed more Northerners to attend and therefore receive contaminants messaging directly from a wide variety of researchers (Figure 1). It also facilitated a strong networking opportunity for researchers that were new to the program. The addition of the Contaminants 101 introduction session and having local schools participate also broadened the support and interest in NCP.

Figure 1. A selection of photos from the student interactive session with researchers at the NCP results workshop, September 2017.



Expected Project Completion Date

Ongoing Committee.

Acknowledgements

The Northwest Territories Regional Contaminants Committee recognizes the support of the Northern Contaminants Program to carry out its important work across the Territory.

Nunavut Environmental Contaminants Committee (NECC)

Comité des contaminants de l’environnement du Nunavut (CCEN)

Project Leader/Chef de projet

Jean Allen, Contaminants Specialist, Contaminated Sites Division, Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), NECC co-chair. P.O. Box 2200, Iqaluit, NU X0A 0H0.
Tel: (867)-975-4732; Fax: (867)-975-4560; Email: Jean.Allen@canada.gc.ca

Andrew Dunford, Environmental Policy Analyst, Department of Social and Cultural Development Nunavut Tunngavik Inc. (NTI), NECC co-chair, P.O. Box 638, Iqaluit, NU X0A 0H0.
Tel: (867)-975-4904; Fax: (867)-975-4949; Email: ADunford@tunngavik.com

Project Team/Équipe de projet

Simon Smith/Jason Stow, NCP Secretariat, CIRNAC, Ottawa, ON; David Abernethy, Nunavut General Monitoring Program, CIRNAC, Iqaluit, NU; Christopher Lewis/Zoya Martin, Department of Fisheries and Oceans (DFO), Iqaluit, NU; Michele LeBlanc-Havard and Amy Caughey, Government of Nunavut (GN), Department of Health (DOH), Iqaluit, NU; David Oberg, Sara Holzman, Angela Young/Teresa Tufts, and Caryn Smith, GN, Department of Environment (DOE), Iqaluit, NU; Eric Loring, Inuit Tapiriit Kanatami (ITK), Ottawa, ON; Jamal Shirley, Nunavut Research Institute (NRI), Iqaluit, NU; Erin Keenan/Sarah Spencer/Amber Giles, Nunavut Wildlife Management Board (NWMB), Iqaluit, NU; Nancy Amarualik, Resolute Bay Hunters and Trappers Association (HTA), Resolute Bay, NU

Project Location/Emplacement(s) du projet

Nunavut, Canada

Abstract

The NECC represents the Northern Contaminants Program (NCP) in Nunavut 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. The NECC attended the NCP Management Committee (NCPMC) meetings in Ottawa, ON in April and October 2017; hosted a productive social-culture review

Résumé

Le Comité des contaminants environnementaux du Nunavut (CCEN) représente le Programme de lutte contre les contaminants dans le Nord (PLCN) au Nunavut et s’assure que les intérêts des résidants du Nord et des Inuits sont pris en compte dans la recherche scientifique menée au Nunavut. Il se veut en outre une ressource pour les Nunavummiuts dans l’obtention des renseignements sur les contaminants transportés sur de grandes

of NCP proposals in Iqaluit, NU in February 2017; and hosted 2 other face-to-face meetings in Iqaluit in September and October 2017. The NECC participated in the NCP Results Workshop in Yellowknife, NT (September 2017); Wildlife Contaminants Workshop in Iqaluit, NU (November 2017); the Royal Tour in Iqaluit, NU (June 2017) and the Sentinel North International Field School in Iqaluit, NU (March 2018). The NECC provided feedback to NCP researchers on communications, met face-to-face with NCP-funded researchers to discuss their respective proposals/projects, and attended seminars/workshop held by NCP researchers.

Key Messages

- The NECC has spent the past 19 years communicating results of the NCP to Nunavummiut and contributed to national/international publications.
- 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.
- This year the NECC attended several internal and external meetings, participated in five capacity-building activities funded by NCP, and met or corresponded with numerous NCP-funded researchers to provide feedback on projects and communication materials.

distances que l'on trouve au Nunavut. Le CCEN a participé aux réunions du Comité de gestion du PLCN qui ont eu lieu à Ottawa (Ontario) en avril et en octobre 2017; dirigé un examen socioculturel productif des propositions du PLCN en février 2017 à Iqaluit (Nunavut); et tenu deux autres réunions en personne en septembre et octobre 2017, à Iqaluit. Le CCEN a participé à l'atelier sur les résultats à Yellowknife (Territoires du Nord-Ouest) en septembre 2017, à l'atelier sur les contaminants des espèces sauvages à Iqaluit (Nunavut) en novembre 2017, à la tournée royale d'Iqaluit en juin 2017 et à un stage international dans le cadre du programme Sentinelle nord à Iqaluit (Nunavut) en mars 2018. Le CCEN a présenté des commentaires aux chercheurs du PLCN au sujet des produits de communication destinés aux collectivités, a rencontré en personne des chercheurs financés dans le cadre du PLCN pour discuter de leurs propositions et projets respectifs, et a assisté à des séminaires et à un atelier organisés par des chercheurs du PLCN.

Messages clés

- Depuis 19 ans, le CCEN communique les résultats du PLCN aux Nunavummiuts et contribue à des publications nationales et internationales.
- 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.
- L'objectif du Comité est de fournir aux Nunavummiuts de l'information sur les contaminants transportés sur de longues distances que l'on trouve au Nunavut.
- Cette année, le CCEN a participé à plusieurs réunions internes et externes et à cinq activités de renforcement des capacités financées par le PLCN, et s'est entretenu ou a correspondu avec de nombreux chercheurs financés par le PLCN en vue de présenter des commentaires sur les projets et les documents de communication.

Objectives

The NECC aims to:

- through its social-cultural review of all Nunavut-based NCP proposals, the NECC ensures the interests of Nunavummiut are being addressed during research activities, including:
  - local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
  - Inuit Qaujimajatugangit (IQ) is incorporated into the study design and process;
  - research results are appropriately communicated back to participating or nearby communities; and,
  - meaningful community consultation is achieved.
- assist researchers with conversion of NCP-funded contaminant research results into plain language that is understood by Nunavummiut;
- assist and advise NCP-funded researchers on the relevant methods and distribution of communication materials to communities;
- by way of the Government of Nunavut Department of Environment (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 Government of Nunavut (GN), provide support to the CMOH who will work in collaboration with NTI on the development, implementation and follow up of nutrition recommendations, food policies, and public health messages resulting from NCP funded contaminants research; and,
- 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 started 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 Nunavut-based proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

Activities in 2017-2018

Meetings and Teleconferences

- Attended the NCP Management Committee meeting in Ottawa, ON in April 2017 (NTI, CIRNAC, GN-DOE, and 2 GN-DOH representatives).
- Hosted a face-to-face NECC meeting/teleconference in Iqaluit on September 8, 2017 to provide an update on the NCP MC meeting and funding decisions and to discuss the mid-year report and our participation in the NCP Results Workshop.

- Hosted a face-to-face NECC meeting/ teleconference in Iqaluit on October 11, 2017 to review mid-year reports, NCP Blueprints and Call for Proposals.

- Attended the NCP Management Committee meeting in Ottawa, ON in October 2017 (NTI, CIRNAC and GN-DOE).

- Hosted a face-to-face NECC social-cultural review meeting on February 21-23, 2018 in Iqaluit to review 33 Nunavut-based NCP proposals. A total of 13 members, 3 community members (Pitsiula Kilabuk from Pangnirtung; Shirley Tagalik from Arviat; and John Lyall Sr. from Cambridge Bay); and 11 Environmental Technology Program (ETP) students (on a rotational basis) participated in the proposal review. Co-chairs provided detailed feedback in a summary report to the NCP Secretariat in March 2018.

- Met with Pierre-Yves D'aoust, Contaminants concentrations in traditional country food from the Eclipse Sound and dietary exposure in Pond Inlet, Nunavut: Science and local knowledge assessing a local baseline of the risks to human health (CB-06) on May 29; Murray Richardson, Snowpack mercury mass balance over the spring melt period, Iqaluit, NU (M-26) on June 14; Tanner Liang, unfunded - The Efficacy of Terrestrial Mosses as Biomonitors of Atmospheric POPs and Hg Deposition in Nunavut (M-23) on August 23; Frank Wania, Quantifying the effect of transient and permanent dietary transitions in the north on human exposure to persistent organic pollutants and mercury (H-07) on September 28; Mary Gamberg, Arctic caribou contaminant monitoring program (M-14) on November 24; Hayley Hung and Alexandra Steffen, (Northern contaminants air monitoring: Organic pollutant measurements (M-01), Mercury measurements at Alert and Little Fox Lake (M-02), Passive air sampling network for organic pollutants and mercury (M-03)) on January 25; and Murray Richardson (M-26) again on March 8.

- Corresponded with a number of other NCP-funded researchers including Magali Houde, Melissa McKinney, Birgit Braune, Derek, Muir, Laurie Chan, Marlene Evans, Robert Letcher, Niladri Basu, and James Armitage. Details available upon request to the NCP.

Capacity Building

- Participated in the Wildlife Contaminants Workshop at NAC in Iqaluit on November 23, 2017. Jean gave a presentation on the NCP and NECC to ETP students.

- Attended the ArcticNet Scientific Meeting in Quebec City, QC in December 11-15, 2017 (CIRNAC, NTI, GN-DOH). This was not funded by NCP but we participated in NCP-related activities (presentations on NCP-funded research, meetings with NCP researchers, and NCP side-meetings, etc.).

- Supported one NAC ETP student's travel to Sachs Harbour, NT to participate in a NCP-funded seal health workshop, Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Sachs Harbour, Northwest Territories (C-12) on January 28-February 3, 2018.

- Participated in the Sentinel North International Field School in Iqaluit, NU in March 8, 2018. Jean and Amy gave a 20-minute presentation on NCP, NECC, country food, and human health.

- Participated in NCP-funded capacity-building activities including: a field trip with Tanner Liang (M-23) on August 23 to collect water, soil, sediment, and moss samples; a presentation by Murray Richardson (M-26) on October 1; and the Wildlife Contaminants Workshop hosted by Jamal Shirley, Mary Gamberg, and Jennifer Provencher, Wildlife Contaminants Workshop – building contaminants research capacity in Nunavut (C-11) on November 20-24; a workshop hosted by NCP-funded researchers Hayley Hung and Alexandra Steffen (M-1, M-2, M-3) on January 24.

- Participated in the Royal Tour in Iqaluit in June 2017. Jean gave a 2-3-minute oral presentation about NCP and NECC to Prince Charles and the Minister of CIRNAC.
- Attended the NCP Results Workshop in Yellowknife, NT on September 26-28, 2017 (NTI, CIRNAC, and 2 GN-DOH representatives).
- Provided feedback on plain language summary reports prepared by PIs for community dissemination. In addition to our review of proposals and mid-year reports, the NECC reviewed PI responses, project updates, reports and presentations to hunters and trappers, posters, the dietary methyl-mercury exposure assessment tool, and draft proposals.

Results

- Feedback to researchers on communications (i.e., plain language summaries, reports, posters).
- 2017-2018 NECC Social Cultural Review Summary Report (March 2017).
- 2017-2018 NECC Mid-Year Report Review Summary Report (October 2017).
- 2018-2019 NECC Social-Cultural Review Summary Report (March 2018).

Discussion and Conclusions

The work of the NECC is on-going and will continue into 2018-2019. The NECC saw many changes: David (NGMP) and Caryn (GN-DOE, Wildlife) joined the committee in January 2018; Zoya (DFO) returned from maternity leave in May 2017; Teresa (GN-DOE, Fisheries & Sealing) is filling in for Angela who went on maternity leave in October 2017; Amber replaced Sarah and Erin at the NWMB as of November 2017; Simon is no longer with the NCP and a new member of the NCP Secretariat is yet to be confirmed; and Theresa (GN-Health) just became a member in April 2018. Nunavut still has no Inuit Research Advisor so our capacity is limited but overall, we had a successful year. In terms of the upcoming work plan, the NECC aims to increase regional representation on our committee by soliciting new members from each of Nunavut's regions: Qikiqtani, Kivalliq and Kitikmeot.

The 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, the NECC is committed to assist PIs with communicating research back to their partnering communities and encourages researchers to contact the NECC before they embark on any community consultations or communications.

The 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 NCP proposals; helping coordinate researcher meetings and presentations in Nunavut; and providing feedback to PIs on communication materials intended for community dissemination.

Expected Project Completion Date

Work is on-going.

Acknowledgements

NECC would like to thank our committee members, the students, and the community members who participated in NECC and NCP activities. We would also like to thank the Nunavut Research Institute for welcoming us again to present at the Wildlife Contaminants Workshop. Additionally, we thank the Royal Tour and the Sentinel North for inviting us to present during their events. Finally, we would like to thank NCP for their continued support.

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

Project Leader/Chef de projet
Dr. Françoise Bouchard, Public Health Director, Nunavik Regional Board of Health and Social Services (NRBHSS), P.O. Box 900, Kuujjuaq, J0M 1C0.
Tel: 819 964-2222, Fax: 819-964-2711, francoise.bouchard.reg17@ssss.gouv.qc.ca;

Kitty Gordon, Assistant Director of Public Health, NRBHSS, P.O. Box 900, Kuujjuaq, J0M 1C0.
Tel: 819 964-2222, Fax: 819 964-2711, kitty_gordon@ssss.gouv.qc.ca;

Project Team/Équipe de projet
Robert Watt, Michael Barrett/Monica Nashak, Kativik Regional Government (KRG); Ellen Avard/ Barrie Ford, Makivik Corporation, Kuujjuaq, QC; Suzanne Bruneau, Institut national de santé publique du Québec (INSPQ), Quebec, QC; Yasmine Charara, Kativik Ilisarniliriniq (KI - School Board of Nunavik); Chris Furgal, Trent University, Peterborough, ON; Elena Labranche, Jean-François Proulx, Sylvie Ricard, Marie-Josée Gauthier, NRHBSS, Kuujjuaq, QC; Christine Leblanc (Marie-Eve Guay replacement)/Alain Ishac, Ungava Tulattavik Health Centre (UTHC), Kuujjuaq, QC; Muriel Beauchamp, Inuulitsivik Health Centre (IHC), Puvirnituq, QC; Eric Loring, Inuit Tapiriit Kanatami (ITK), Ottawa, ON; To be appointed, Anguvigak- Nunavik Hunting Fishing Trapping Association (NHFTA), Kuujjuaq, QC; To be appointed, Qarjuit Youth Council, Kuujjuaq, QC; To be appointed, Saturviit Inuit Women's Association of Nunavik, Inukjuak, QC

Project Location/Emplacement(s) du projet
Nunavik, QC

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 NNHC provides guidance and acts as a liaison for researchers and agencies, from both inside and outside the region; directs work on priority issues; communicates with, and educates the public on, health and environment topics and research projects; and represents Nunavik interests at the national and international levels. All activities are conducted with the goal of protecting and promoting public health in Nunavik.

In 2017-2018, the committee has held three in-person meetings and had regular email exchanges in order to fulfill its mandate. The NNHC has worked on a number of topics related to contaminants, nutrition and environmental health, with an important focus on the *Qanuilirpitaa*? 2017 Health Survey. Regional efforts toward the reduction of lead and mercury exposures were also among main priorities for 2017-2018.

Résumé

Le Comité de la nutrition et de la santé du Nunavik (qui s'est d'abord appelé Comité des ressources sur les BPC), ou CNSN, a été mis sur pied en 1989, pour traiter de questions se rapportant aux aliments, aux contaminants, à l'environnement et à la santé au Nunavik. Depuis sa création, le Comité a élargi ses perspectives en vue d'adopter une approche plus globale des questions d'environnement et de santé qui tient compte des avantages et 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 compte des représentants d'un grand nombre d'organismes qui s'intéressent à ces questions ainsi que de ceux qui effectuent des recherches à ce sujet. Le Comité fournit une orientation aux chercheurs et organismes de la région et de l'extérieur et assure la liaison entre ceux-ci, dirige des travaux en lien avec des enjeux importants, 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 réalisées visent à protéger la santé publique au Nunavik et à en faire la promotion.

En 2017-2018, le Comité a organisé trois rencontres en personne et échangé régulièrement des courriels en vue de s'acquitter de son mandat. Le CNSN a réalisé des travaux sur divers thèmes en lien avec les contaminants, la nutrition et la santé environnementale, en mettant particulièrement l'accent sur l'Enquête sur la santé des Inuits du Nunavik Qanuilirpitaa?? 2017. Des efforts régionaux visant la réduction de l'exposition au plomb et au mercure figuraient aussi parmi les priorités en 2017-2018.

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

Messages clés

- Le Comité de la nutrition et de la santé du Nunavik est le principal organe régional chargé des questions liées à la santé et à l'environnement au Nunavik.

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*.

- Le Comité conseille le directeur de la santé publique du Nunavik à propos des activités d'information et d'éducation en lien avec la nutrition et la santé, y compris les bienfaits et les risques associés aux contaminants et aux aliments traditionnels.

- Le Comité continue de participer activement au Programme de lutte contre les contaminants dans le Nord : il étudie et finance la recherche dans la région, assure la liaison avec les chercheurs et favorise la communication des résultats des recherches d'une manière qui est appropriée et convenable pour les Nunavimmiuts.

Objectives

The general objective of this project is to address regional coordination and communication needs related to research and interventions on contaminants, nutrition and environmental health. The NNHC aims to:

- interact and liaise with NCP and other researchers working on contaminants, nutrition and environmental health to guide, support and ensure the relevancy of research for Nunavik communities;

- compile elements of public concerns and to identify regional and community research priorities and information gaps related to contaminants, nutrition and environmental health, and address these priorities in carrying them back to the NCP programs, researchers and other relevant partners;

- review research proposals and research products and provide regional feedback to researchers;

- support and maintain partnerships in various research and inform public health interventions related to country food, nutrition and health;

- encourage and support NCP research and other research in the files of contaminants, nutrition and environmental health to build northern capacity within the research projects; and,

- provide comprehensive and valuable information, in appropriate format, to Nunavimmiut as well as regional organizations and associations, on contaminants, nutrition and environmental health issues.

Introduction

In Nunavik, a group of representatives from different regional organizations concerned with health, the environment and nutritional issues has formed to address these issues and communicate with and educate the public so that it can make more informed decisions on these issues. The group, the Nunavik Nutrition and Health Committee, evolved from the PCB Committee, created in 1989 and later renamed the Food, Contaminants and Health Committee. The name has changed over the years as the group has learned of the importance 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;
- promote wise decisions by individuals and organizations in the region on these subjects;
- 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;
- review and guide the evaluation of health and nutrition research projects and programs so that they meet Nunavimmiut needs and expectations;
- facilitate exchanges between Nunavik organizations on nutrition and health activities; and,
- 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 2017-2018 year.

Activities In 2017-2018

NNHC Meetings & NCP Results Workshop

In 2017-2018, the committee have met three times in person and once by teleconference. In addition to formal meeting, a number of regular exchanges through emails occurred throughout the year. Members of the NNHC also participated to the NCP Results Workshop.

Expenses related to the organization and the holding of these meetings such as travel and room renting were covered under the NCP funding 2017-2018 for the NNHC. Salaries of the committee members, with the exception of the NNHC coordinator, are in kind contributions of the various organizations and associations.

NNHC in-person meeting: June 2017

The first meeting was in Kuujjuaq on June 12 and 13 and allowed discussion on several topics related to contaminants, nutrition and health. At this meeting, the NCP secretariat representative and the NCP management committee members summarized the funding decisions for the 2017-2018 projects to the committee and presented a draft agenda of the NCP results workshops. The committee participation to the NCP Results Workshop was discussed. The committee addressed the last steps leading to the data collections of the *Qanuilirpitaa?* 2017 Health Survey and the upcoming contaminants and nutritional analyses. Preliminary findings from the Nutaratsaliit qanuingisiarningit niqituinnanut - Pregnancy Wellness & Country Food project under NCP were presented as well as updates on zoonosis projects and the adolescent follow-up of the Nunavik Child Development Study (NCDS).

NCP Results Workshop: September 2017

This year, six members of the NNHC participated to the NCP Results Workshop in Yellowknife. The members who attended the workshop were Dre Françoise Bouchard, Elena Labranche, Robert Watt, Monica Nashak, Marie-Josee Gauthier and Eric Loring. Committee representatives made oral presentations, one on the regional highlights and priorities by Robert Watt, one on the Nunavik public health recommendations related to prenatal mercury exposure by Elena Labranche and one on the *Qanuilirpitaa*? 2017 Health Survey by Robert Watt (poster format) and Françoise Bouchard. Eric Loring has also prepared and shared a presentation on risk communication messaging. The workshop was a wonderful opportunity to learn about contaminants research work conducted all over the North as well as to hear from other northern regions about their perspectives and priorities on contaminants and health topics. The participations of four NNHC representatives was covered under the NCP funding 2017-2018 for the NNHC.

NNHC in-person meeting: November 2017

The second meeting was held in Kuujjuaq on November 1 (afternoon), 2 (all day) and 3 (morning). The first half day of the meeting was dedicated to a presentation on the overall work and outcomes of the NCDS. Gina Muckle, who came in person, did the historic of this cohort study and presented its main results. The committee felt such a presentation was necessary to provide a general portrait and a global understanding of this 30-year cohort study. This part of the meeting was open to partners and people working on files related to child development. During the November meeting, most researchers funded under NCP for 2017-2018 joined the meeting by phone or in person to provide updates on their current work and to discuss next steps. Mélanie Lemire, Thérèse Adamou and Matthew Little came to present in person respectively on the NQN-Pregnancy wellness with Country Food project, on temporal trend (1992-2013) of blood mercury and PCB concentrations among pregnant Inuit women and about new results on Selenium and Selenoneine. Dave St-Amour remotely presented on the Nunavik NeuroImaging Project (NNIP) as well. The committee discussed about the recently completed data collection phase of the *Qanuilirpitaa?* 2017 Health Survey and about the upcoming analyses and broader work to come related to the health survey. The Public Health Department updated the NNHC about the work conducted by the Nunavik Regional Working Group on Food Security and specifically the first working session on traditional food access to which a number of NNHC members participated. A discussion about the NNHC priorities for the upcoming years was hold in preparation for the 2018-2019 NCP call of proposals.

NNHC teleconference meeting: December 2017

Just before the Christmas holidays, the NNHC met by teleconference to further discuss the region priorities as well as the work plan for the years to come. Committee members had the opportunity to comment draft versions of the proposals, one for the coordination of the committee and one for the communication related work. Among the main priorities identified, there are the analyses and upcoming results from the *Qanuilirpitaa*? 2017 Health Survey and their meaningful interpretation and communication. Regional interventions toward the reduction of exposures to both lead and mercury were also recognized as important topics.

NNHC meeting: January 2018

The last NNHC meeting for 2017-2018 was held on January 30 and 31, 2018 and focussed mainly on the socio-cultural review of the 2018-2019/2020/2021 NCP proposals for the region. The committee invited the researchers who submitted proposals to the NCP and other researchers available to meet with the committee at that time so questions raised during the proposal review could be clarified with the project leaders. The committee first reviewed each proposal, determines a provisional rating and identifies questions for the project leaders. Then the committee met with the project leaders over the phone. They were invited to summarize their proposal and, when needed, to answer specific questions previously identified. The last step was to go over all proposals to provide a final socio-cultural rating and evaluate if the committee wants to modify the provisional rating based on the clarification provided. The committee finds that this way of functioning allows a more extensive comprehension of the work proposed and gives the committee a better sense of the researchers' engagement and approach. All researchers are given the opportunity to join at a certain time.

In addition of the review of the proposals, at this meeting, there was also a presentation from Lilia Tran, a biologist at the Nunavik Research Centre about results on fish health in the context of the Arctic char of Deception Bay Study.

Updates related to topics of interest for 2017-2018

Qanuilirpitaa? 2017 Health Survey

This year, the *Qanuilirpitaa?* Health Survey has been a priority for the NNHC and the whole Nunavik region. The NNHC has been and continues to be closely involved in guiding and prioritizing the analyses related to contaminants, nutrition and environmental health. The data collection component of the *Qanuilirpitaa?* 2017 Health Survey has been conducted in the summer-fall of 2017.

Qanuilirpitaa? 2017 is a vast survey, which examines the physical and mental condition of residents of all Nunavik communities, which will serve to draw a portrait of the health and well-being of Nunavimmiut. *Qanuilirpitaa* means ''How are we now?", the answer to that question is certainly a complex one and the situation has evolved considerably since the last survey, *Qanuippitaa?* 2004 (How are we?),

During the seven weeks of data collection, more than 1,300 randomly chosen participants from the fourteen communities willingly accepted to take part in the survey. They underwent clinical tests and filled-in questionnaires administered by a team of health professionals, researchers, medical technicians, and interpreters. The medical examinations and health questionnaires were conducted on board the Canadian Coast Guard Ship Amundsen. Interviews to assess social challenges in Nunavik (community component survey) were also simultaneously conducted on the land.

Through a partnership with the regional school board, few students from all schools of the region were invited to come onboard for the Amundsen during the *Qanuilirpitaa?* 2017 Health Survey data collection to experiment and learn about research.

The financial contribution of the NCP has been significant for the realization of the *Qanuilirpitaa?* 2017 Health Survey, namely through support of research projects as well as funding of three NNHC meetings for the increased regional work of 2017-2018.

The *Qanuilirpitaa?* 2017 Health Survey will generate a great number of updated information to be soon available on contaminants, nutrition and environmental health which will need to be discussed and interpreted carefully.

Mercury guidelines for health professionals and public health recommendations and interventions to reduce prenatal mercury exposure

Mercury exposure is an important public health concern for the region. Mercury guidelines for health professionals has been finalized in 2017-2018. In 2011, the Public Health Director released an advisory recommending to pregnant women and childbearing age women to reduce beluga meat consumption until mercury levels have decreased in the environment and in beluga meat specifically.

Mercury guidelines for health professionals and public health recommendations and interventions to reduce mercury exposure.

Clinical level

Regional mercury guidelines for health practitioners have been finalized in 2017-2018. These guidelines focus on the clinical follow-ups required for people with mercury blood levels of concerns. Similar to the lead guidelines, they take the form of a reference document accompanied by a practical clinical intervention guide including clinical algorithms. Expenses related to this clinical component have been under the Public Health Department budget.

Population level

Mercury exposure is a major issue in Nunavik and in the North, especially prenatal exposure. It represents an additional challenge compared to the lead issue. The sources of mercury that influence the blood levels concentrations is not dependant of the method of hunting or fishing, but is rather present in some of the country food through transfer from the environment and the food chain.

In 2011, in the context of the NCDS communication, the NNHC and the Public Health Department communicated to the general population that they strongly believe that country food is generally the best food for Nunavimmiut, including pregnant women and their children. Nunavimmiut were encouraged to widely consume country food, the only limitation being for women of childbearing age who should limit their consumption of beluga meat. The following advisory was released: "In Nunavimmiut, the main source of mercury exposure is beluga meat. Therefore, until we have evidence of a decrease of the mercury content in this specific country food, pregnant women and those of childbearing age should decrease their consumption of beluga meat."

According to preliminary results from the NCP funded NQN-Pregnancy Wellness with Country Foods project (2017), mercury levels remains a concern for a number of pregnant women and only approximately one third of the pregnant women interviewed were aware that there is a current public health recommendation related to mercury advising to reduce beluga meat consumption specifically for pregnant women and childbearing age women.

With the learnings from the past communication experience and the new information on mercury exposure and sources, it is time to reflect again and find new strategies to move forward on the mercury exposure issue.

Lead guidelines for health professionals and public health recommendations and interventions to reduce lead exposure

Lead is of major public health concern as it is well known that exposure can cause several health issues, especially for pregnant women, unborn babies and young children. Moreover, evidence is growing that there is no safe blood lead level for health effects in humans.

Clinical level

In 2017-2018, the Public Health Department and the NNHC have been reviewing the regional lead guidelines for health professionals. These guidelines focus on the clinical follow-ups required for people with lead blood levels of concerns. They take the form of a reference document accompanied by a summarized clinical intervention guide. The revision of the guidelines was completed by March 2018. Expenses related to this clinical work have been under the Public Health Department budget.

Population level

Before describing the work accomplished for 2017-2018, some background information will be presented regarding the lead issue in Nunavik.

The region has a history of past awareness and strong mobilization on the issue. Indeed, in 1999, when results from a lead isotope ratios study identifying lead ammunition as the main source of lead in Nunavimmiut, a Regional Coalition for the Banning of Lead Shot was born of a regrouping of the NRBHSS, the Hunting, Fishing and Trapping Association, the Makivik Corporation and the Kativik Regional Government and a voluntary ban of lead-shots in Nunavik was established.

Blood lead levels have significantly declined over time since 1992. The trend suggests that the decrease started in 1999-2000, following the adoption of national and regional measures to limit the use of lead shots. However, lead maternal levels remain higher than the Canadian average.

In 2011, when results of the Nunavik Child Development Study (NCDS), which have observed adverse effects of prenatal and childhood exposures were communicated, the NNHC and the public health reiterated its position to avoid the use of lead shots.

A project on the availability and use of lead ammunition conducted in the summer of 2016, by a medical student, has shown that lead ammunition were then currently available and used is most Nunavik communities. On November 2016, Public Health Department representatives made an in-person presentation about this updated information to the Nunavik Hunting Fishing and Trapping Association (NHFTA) annual regional assembly which was simultaneously broadcasted on air in the region. At this meeting, the NHFTA has adopted a resolution to fully support a ban on the sale and use of lead-based ammunitions. The resolution also encourages the promotion of non-toxic alternatives, including the realization of a communication campaign and the evaluation of the possibility to include lead-free alternatives in subsidized programs. In the fall of 2016, an NHFTA member and a midwife asked if it was possible to look at the issue of lead contamination of migratory birds during their migration out of Nunavik. This work was conducted in 2017 by an internship student under the public health and the Nasivvik research chair. Funding for the realization of this presentation and the two student projects (inventory and use of lead ammunition 2016 & lead contamination of migratory birds during their migration out of Nunavik 2017) have been under the Public Health Department budget.

Preliminary results from the NCP funded NQN-Pregnancy Wellness with Country Foods project (Fall 2017) has shown that less than one-fifth of the women interviewed were aware that the public health advises hunters to avoid lead-based shots and use non-toxic alternatives.

Almost two decades had passed since the 1999 consensus on the ban of lead shots and according to recent work lead ammunition are now widely available and significantly used in the region. Awareness of the issue appears to also be low at the moment. For these reasons, the NNHC strongly believe there is a real need to reiterate collective and political efforts on the lead issue. The NNHC has begun communication work in 2017-2018 and wishes to pursue efforts for the reduction of lead exposure in the months and years to come.

At the end of 2017-2018, the committee and the Public Health Department produced, on time for the goose hunting season, two animated videos and two audio capsules to promote country food and the use of lead-free ammunition. These videos and audio capsules encouraged hunters to use lead-free ammunitions to enjoy all the benefits of country food without being exposed to the harmful health effects of lead. The videos and audio capsules were aired mainly on social media using Facebook. Funding for the two animated videos and the two audio capsules were covered, half by the Public Health Department budget and half by the NNHC funding, for NNHC 2017-2018. The lead issue will be a priority for the NNHC for 2018-2019 and, among other things, a broader communication campaign will be developed for the next hunting season.

Contaminants messaging and awareness within public health initiatives and programming

The NNHC being an advisory committee to the director of Public Health, it allows contaminants information from the NNHC and the NCP to be taken into consideration in various ways in public health programming.

Through Health Canada programs, such as the Canadian Prenatal Nutrition Program, the Nutrition North Canada program and the Aboriginal Diabetes Initiative (with a Food Security component), the Nunavik public health supports a number of regional and local initiatives aimed at promoting and increasing the access to country food and healthy store-bought foods. The input of the NNHC expertise is essential in designing public health initiatives related to country food. For example, country foods with low mercury content are systematically prioritized in initiatives targeting at-risk population groups, such as the distribution of Arctic Char to pregnant women.

Under these programs, Public Health also delivers regional training on nutrition promotion and community kitchens to community workers in charge of local initiatives (this training has been done yearly since 2013, with the exception of 2017; the next one is scheduled for April 24-25, 2018). Communication messages and tools developed under the NNHC about contaminants, nutrition, and country food, are valuable tools used in these training activities. It allows the NNHC to build capacity within the region on contaminants issues.

Expenses related to this work were covered under Health Canada programs. The NCP financial contribution was specific to working hours for the NNHC coordinator. The funded work of the coordinator was to make the link between the NNHC and the public health interventions work in order to ensure the congruence between action, research and messaging.

Development of the Nunavik regional food policy

The NNHC has worked in partnership with the Nunavik Regional Working Group on Food Security (NRWGFS) since its creation in December 2015. The NNHC role is to provide expertise on issues related to contaminants and risk/benefits of country food consumption, in the development of a regional policy on food security.

The NRWGFS includes representatives of the main regional organizations and associations, and is coordinated by the NRBHSS. The mandate of this group is to identify short- and long-term solutions for improving access to, and availability of, food in Nunavik, specifically through the development of a regional policy on food security. The region current process to improve food security is part of a broader movement across Inuit Nunangat, where food insecurity rates are significantly higher than the rest of Canada.

On October 2017, the NRWGFS organized the first regional working session toward the development of this regional policy. Eighty people from various backgrounds across Nunavik gathered in Kuujjuaq to create a common plan to improve access to traditional food and better support harvesters. Participants included local coordinators of the Hunter Support Program, mayors, health workers, hunters, youth, elders, representatives of regional organizations and associations, as well as Fédération des coopératives du Nouveau-Québec and Air Inuit representatives.

Four NNHC members participated in this event and contributed to the discussions. Food from the land is central to Nunavimmiut way of life, identity and food security. This is why the NRWGFS decided that traditional food access would be the focus of the conversation for this regional working session. Over the two-day event, held on October 25 and 26, workshops, panels and testimonies covered many issues, such as wildlife health and management, transmission of knowledge and practices of harvesting and traditional food preparation to future generations, and access to traditional food for specific populations (e.g., pregnant women, elders, children etc.).

The NRWGFS, through the NRBHSS, receives funding from Health Canada programs. Financial contribution for the NCP program was limited to working hours of the NNHC coordinator to ensure the NNHC contribution to the Nunavik food policy work and vice versa.

Open Letter

An open letter has been published in the Nunatsiaq News and the Inuit Magazine (on-board magazine of Air Inuit) to acknowledge and thank Nunavimmiut who have participated in contaminants research, over the last thirty years. The letter underlined the fact that Nunavimmiut who participated in these studies directly helped to reduce exposure to POPs in the Arctic and worldwide. This was accomplished through its use by the Inuit Circumpolar Council, the Government of Canada and other organizations to advocate for the global ban on production and use of POPs, leading to the adoption of the Stockholm Convention in 2004. The letter also mentions that the Minamata Convention was ratified by Canada on April 7, 2017 and entered into force shortly after. It concludes by calling for the continuation of this ongoing collaboration with Nunavimmiut to monitor the efficacy of global effort aimed at reducing mercury in wildlife and protecting health.

The letters were co-signed by Elena Labranche (on behalf of the NNHC members), Mélanie Lemire (Titular of the Nasivvik Research Chair and Assistant Professor at Université Laval, on behalf of Gina Muckle, Chris Furgal, Amanda Boyd, Richard Bélanger, Michel Lucas, Catherine Pirkle, professors for the Université Laval, Trent University, Washington State University and the University of Hawai'i at Manoa) and by Sarah Kalhok Bourque Chair – NCP – CIRNAC on behalf of the NCP Management Committee.

Discussion And Conclusion

We believe that there is a great need to pursue the inter-organizational collaboration and communication through the committee's work on the important issues of food, contaminants, nutrition and health. The committee will keep maintaining its relationship and regular exchanges with the research-project leaders, including NCP researchers.

In the coming years, members of the committee will continue working on various files related to the committee's topics of interest, including the establishment of regional interventions addressing contaminants exposure, the promotion of healthy eating, the development of a regional food-security policy/strategy and the contaminants and nutrition component of the *Qanuilirpitaa?* 2017 Health Survey. Interventions will include all aspect from data analyses to the interpretation and communication of results.

Indeed, for 2018-2021, the NNHC's main priorities will be the use of the *Qanuilirpitaa?* 2017 Health Survey results as well as the development and implementation of communication strategies to reduce contaminants exposure, specific to lead and mercury, while promoting and preserving the consumption of country food.

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 especialy grateful to the Northern Contaminants Program (NCP) for its essential support. The NNHC also acknowledge the contribution of the regional organizations providing in kind for ongoing support and funding of its activities related to health, contaminants and nutrition in the region.

Northern Contaminants Researcher

Chercheur spécialiste des contaminants

- **Project Leader/Chef de projet**
  Liz Pijogge, Nunatsiavut Government, P.O Box 70, Nain, NL A0P 1L0.
  Tel: (709) 922-2380; Fax: (709) 922-2504; Email: liz.pijogge@nunatsiavut.com
- **Project Team/Équipe de projet**
  Rodd Laing, Nunatsiavut Government; Rudy Riedlsperger, Nunatsiavut Government; Carla Pamak, Nunatsiavut Government; Joey Angnatok, Nunatsiavut Government; Eva Obed, Nunatsiavut Government; Derek Muir, Environment and Climate Change Canada, Burlington, ON

- **Project Location/Emplacement(s) du projet**
  Nain, NL

Abstract

The Northern Contaminants Researcher (NCR) is a core component of the Nunatsiavut Government. Based at the Nain Research Centre, within the Environment Division of the Department of Lands and Natural Resources, the NCR works inter-departmentally and across communities, in part through the Nunatsiavut Government Research Advisory Committee (NGRAC) to help Inuit of Nunatsiavut better understand contaminants within the region. This includes some Northern Contaminants Program (NCP) funded projects and how these projects relate to Inuit health and wellbeing. In partnership with the Nunatsiavut Government Research Advisory Committee, the NCR disseminates essential information on contaminants and research projects throughout the region and is the first point of contact for contaminants related information. This project is a prescribed priority activity within the NCP and builds on the capacity that has been developed in the region to facilitate an even

Résumé

Le chercheur spécialiste des contaminants dans le Nord est une composante fondamentale du gouvernement du Nunatsiavut. Affecté au Centre de recherche de Nain à la Division de l'environnement du ministère des Terres et des Ressources naturelles, le chercheur spécialiste des contaminants dans le Nord travaille à l'échelle interministérielle et dans les collectivités, en partie par l'entremise du Comité consultatif de la recherche du Nunatsiavut (CCRN), pour aider les Inuits du Nunatsiavut à mieux comprendre les contaminants dans cette région. Son activité concerne notamment certains projets financés par le Programme de lutte contre les contaminants dans le Nord (PLCN) et la façon dont ils contribuent à la santé et au mieux-être des Inuits. En partenariat avec le Comité consultatif de la recherche du gouvernement du Nunatsiavut, le chercheur spécialiste des contaminants dans le Nord diffuse de l'information essentielle sur les contaminants et les projets de recherche menés dans la région et sert de personne-ressource

greater level of management and ownership of research in Nunatsiavut. This position ensures the continuation of the NGRAC, as well it complements other NCP research programs ongoing or previously implemented in the region, including water, air, ringed seal and arctic char monitoring. All our monitoring programs include an Indigenous Knowledge component, as this knowledge is essential to properly understanding trends and issues, and is the best record of historical information throughout our region.

All our NCP research programs are coordinated through the NCR at the Nain Research Centre on an annual basis. This ensures there is a trusted, consistent point of contact who will actively engage Nunatsiavimmiut while disseminating contaminants related information within the context of the many other related issues and initiatives in the region.

principale pour obtenir des renseignements sur les contaminants. Ce projet concerne une activité prioritaire prescrite dans le PLCN et prend appui sur les capacités qui ont déjà été développées dans la région pour augmenter la gestion et l'appropriation de la recherche au Nunatsiavut. Cette position assure la continuité du CCRN, en plus de compléter d'autres programmes de recherche du PLCN déjà mis en œuvre dans la région, dont des projets de surveillance de l'eau, de l'air, du phoque annelé et de l'omble chevalier. Tous nos programmes de surveillance comportent un volet relatif aux connaissances autochtones, celles-ci étant essentielles pour bien comprendre les tendances et les enjeux, en plus de constituer le meilleur registre des renseignements historiques dans l'ensemble de la région.

Tous nos programmes de recherche financés dans le cadre du PLCN sont coordonnés sur une base annuelle par le chercheur spécialiste des contaminants dans le Nord du Centre de recherche de Nain. Ceci permet de s'assurer qu'il existe un point de contact stable et de confiance qui mobilise activement les Nunatsiavimmiuts tout en diffusant de l'information sur les contaminants dans le contexte des nombreux autres enjeux et initiatives connexes dans la région.

Key Messages

- The NCR continues to be the main contact for any concerns relating to contaminants, health and environmental issues. Any individual expressing interest in contaminants, which is becoming more common, will have the opportunity to be trained in the field and research opportunities will be provided to them.
- The NCR continues to build capacity through the community freezer and the Going Off, Growing Strong program (Aullak Sangilivalliannatuk), traditional hunting and through collaboration with educators in the communities.

Messages clés

- Le chercheur spécialiste des contaminants dans le Nord continue d'être la principale personne-ressource pour toute préoccupation en lien avec les contaminants, la santé et l'environnement. Quiconque se dit intéressé par les contaminants, une préoccupation de plus en plus répandue, aura l'occasion d'être formé sur le terrain et se verra offrir des occasions de recherche.
- Le chercheur spécialiste des contaminants dans le Nord continue de renforcer les capacités grâce au congélateur communautaire et au Programme « Going off Growing Strong (Aullak sangilivallianginnatuk), à la chasse traditionnelle et à la collaboration avec des éducateurs de la collectivité.

- The NCR employs focused health messaging, based on the results of the Inuit Health Survey and Integrated Regional Impact Studies (IRIS) 4 report.
- The NCR continues to work effectively with coworkers including the Inuit research Advisor (IRA), Research Manager and Community Outreach Manager to achieve NCP objectives.

- Le chercheur spécialiste des contaminants dans le Nord emploie des messages ciblés sur la santé fondés sur les résultats de l'Enquête sur la santé des Inuits et du rapport de l'Étude d'impact régionale et intégrée (IRIS) 4.
- Le chercheur spécialiste des contaminants dans le Nord continue de collaborer efficacement avec ses collègues, y compris le conseiller en recherche inuite, le gestionnaire de la recherche et le gestionnaire de la sensibilisation communautaire afin de réaliser les objectifs du PLCN.

Objectives

The NCR aims to:

- remain the first point of contact for all communities in Nunatsiavut regarding contaminant-related information;
- share information in different types of media to promote the importance of country foods as well as discussing contaminant levels in Nunatsiavut;
- continue to promote alternative country foods as the decline in the George River caribou herd has caused a shift in diet;
- develop a multi-year, broad research project that investigates the diet shift of Nunatsiavimmiut from caribou to seal and char, and that specifically investigates the effect of this shift on individuals' health and wellbeing (through partnership with many agencies);
- continue to foster a relationship built on trust with Inuit in Nunatsiavut in regards to sharing information on contaminants;
- continue to increase ownership of contaminant-related research by collaborating with partners that support the building of capacity in our region;
- work with schools and educators to engage youth in contaminant-related research;
- manage the contaminants section of our Nain Research Centre website; and,
- continue to address the concerns of Nunatsiavimmiut through partnerships and research projects.

Introduction

Research conducted throughout the Nunatsiavut region has demonstrated that contaminants are present in the traditional foods that are being consumed, which has resulted in concern from Nunatsiavummiut. However, contaminants are also only one of many factors that influence food choices, nutrition and health in the region. One of the priority issues of the NCR, through the NCP, is to provide information to Inuit to help inform decisions made by individuals, communities and the region regarding the consumption of country foods. The trusted delivery of this information is crucial to the NCP's primary objectives.

The NCR continues to build capacity through the community freezer and the Going Off, Growing Strong program (Aullak Sangilivalliannatuk), traditional hunting and through collaboration with educators in the communities. The NCR has worked with colleagues, educators and researchers to engage youth in the Going Off, Growing Strong program and students in the schools using scientific and Indigenous knowledge and the school's curriculum. This has provided students with a variety of information including traditional skills to live off the land, the origins of contaminants, and what their effects are on our ecosystems as well as teaching scientific and life skills that may be used in the future, personally and professionally.

The NCR continues to work effectively with coworkers including the Inuit research Advisor (IRA), Research Manager and Community Outreach Manager to address any concerns raised by community members as they relate to research and contaminants.

The NCR focuses on the following messaging, based on the results of the Inuit Health Survey and Integrated Regional Impact Studies (IRIS) 4 report:

- country foods are great sources of nutrients that are vitally important to Inuit health;
- Arctic char is the number one source of selenium, polyunsaturated fats and omega-3 fatty acids for Labrador Inuit
- contaminant exposure levels for Inuit in Nunatsiavut are generally below guideline levels of concern;
- Inuit in Nunatsiavut (especially young people) should continue eating country foods because the health benefits are greater than the risks.

Equally as important, the NCR focuses on the above health messages as part of a larger team creating and implementing programs in relation to Inuit health, country foods and the environment (including contaminants) across Nunatsiavut.

Activities in 2017-2018

Community Engagement

In collaboration with the Inuit Research Advisor and the Community Outreach Manager have held several community luncheons showing the importance of traditional foods.

Capacity Building and Training

All programs through the Environment Division, within the Nunatsiavut Government, directly engages harvesters, youth, researchers and advisors by encouraging collaboration, building capacity, providing training and job opportunities, and thus, enhancing research in Nunatsiavut. The NCR continues to build connections through the direct involvement in the Going Off, Growing Strong program, providing knowledge and encouragement that benefits our youth, enhancing their confidence and independence. Local harvesters not only train our youth to hunt for Inuit traditional food, they also show the youth how to prepare traditional foods for themselves and their families. Hunting and food preparation training includes learning to use tools that are necessary to survive off the land and how to be safe while doing so. With these skills, they will be able to provide for their families and teach future generations.

Communications and Outreach

The NCR presented her role at the Nunatsiavut Research Centre in Nain from April 30- May 3, 2017- Labrador Research Forum, Happy Valley-Goose Bay

'Understanding Contaminants in Nunatsiavut in relation to Inuit Health and Well being- The Northern Contaminants Researcher role.' Slide Show Presentation.

Liz Pijogge attended the September 2017- NCP Results Workshop in Yellowknife, NT, as part of the NCR. There she presented a poster titled *'Northern Contaminants Researcher: Helping to Protect Nunatsiavut from Long Range Contaminants.'*.

Indigenous Knowledge

All research projects and Nunatsiavut Government associated programs are designed and based on Indigenous Knowledge. Research programs are developed at a community level, designed to address local concerns and to enhance Inuit health and wellbeing. The Northern Contaminants Researcher is an Inuk born and raised in Nunatsiavut, and is integral to the development of these programs, the integration of Indigenous knowledge (IK), including verification, and ensures that TK is used and collected in all contaminant related research programs. Traditional and cultural values are at the forefront of all decisions made by the NCR and the Nain Research Centre.

Results and Outputs

The NCR Co-chaired the NGRAC social and oversaw the cultural review of NCP proposals. The NCR also continued to use the Nain Research Centre website (www.nainresearchcentre.com), by disseminating information about contaminant and research related activities in Nunatsiavut with monthly blogs. Furthermore, the NCR was an active participant in both the ArcticNet conference and the NCP committee meetings.

The NCR traveled to 3 communities to discuss ongoing projects. The NCR also hosted 2 of country food celebration events in communities where contaminants information was actively disseminated within the context of the benefits of country food.

Through all of these activities the NCR has been an integral part of the NCP and has improved the awareness of contaminant related research in country food in Nunatsiavut.

Project website (if applicable)

www.nainresearchcentre.com
www.facebook.com/nainresearchcentre/

Acknowledgements

The Northern Contaminants Researcher acknowledges the NCP for their funding support in 2017-2018.

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**
  Carla Pamak, Nunatsiavut Inuit Research Advisor, Nunatsiavut Government, P.O. Box 70, Nain, NL, A0P 1L0, Tel: (709) 922-2380; Fax: (709) 922-2504; Email: carla_pamak@nunatsiavut.com
- **Project Team/Équipe de projet**
  Rodd Laing, Nunatsiavut Government; Elizabeth Pijogge, Nunatsiavut Government

- **Project Location/Emplacement(s) du projet**
  Nunatsiavut, Canada

Abstract

The Inuit Research Advisor for Nunatsiavut continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science and represent 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).

Résumé

Le conseiller en recherche inuite (CRI) du Nunatsiavut demeure la première personne-ressource lorsqu'il s'agit de mieux coordonner les efforts de la collectivité et les travaux scientifiques liés à l'Arctique et de représenter une nouvelle façon de mettre en commun les connaissances et de faire participer les Inuits à la science de l'Arctique. Le gouvernement du Nunatsiavut incite les chercheurs à consulter les gouvernements des cinq collectivités inuites du Nunatsiavut (Rigolet, Makkovik, Postville, Hopedale et Nain) ainsi que ses ministères 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.

Together with IRAs in the other Inuit regions of Canada, the Nunatsiavut IRA works towards achieving a new way of knowledge sharing and engagement of Inuit in Arctic science in the region. In addition to NCP support, the program is co-funded by ArcticNet and the Nunatsiavut Government.

Key Messages

- The IRA co-coordinates the Nunatsiavut Government Research Office, serving as the first point of contact for all researchers conducting work in Nunatsiavut and requiring contact with or assistance from the Nunatsiavut Government.
- The IRA is the Chair and administrator of the Nunatsiavut Government Research Advisory Committee (NGRAC). The IRA has communicated with over 54 researchers from 1st April 2017 to 31st March 2018. This year the IRA has chaired 12 NGRAC meetings one of which was a face-to-face meeting in Nain.
- The IRA served as a 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 assisting researchers in the field obtaining samples; 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.

De concert avec les CRI des autres régions inuites du Canada, le CRI du Nunatsiavut s'efforce de promouvoir une nouvelle façon de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique dans la région. Le financement des activités est assuré conjointement par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet et le gouvernement du Nunatsiavut.

Messages clés

- Le CRI coordonne le bureau de la recherche du gouvernement du Nunatsiavut. Il fait office de premier point de contact pour tous les chercheurs qui mènent des travaux au Nunatsiavut et qui doivent communiquer avec le gouvernement du Nunatsiavut ou obtenir son aide.
- Le CRI est le président et l'administrateur du comité consultatif de la recherche du Nunatsiavut. Le CRI a communiqué avec plus de 54 chercheurs du 1er avril 2017 au 31 mars 2018. Cette année, il a présidé 12 réunions du Comité consultatif de la recherche du Nunatsiavut. L'une d'elles était une réunion en personne tenue à Nain.
- Le CRI a joué le rôle d'agent de liaison, de personne-ressource et d'assistant pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, il a mis les chercheurs en contact avec les personnes ou organisations pertinentes, par exemple les ministères du GN et les administrations des collectivités inuites du Nunatsiavut, aidé les chercheurs à recueillir des échantillons et formulé des suggestions relatives aux propositions et plans de recherche.
- Le CRI a également assuré la liaison avec des partenaires comme l'Inuit Tapirit Kanatami, le Conseil circumpolaire inuit (Canada), les administrations des collectivités inuites et les sociétés communautaires inuites du Nunatsiavut, des chercheurs, des étudiants et divers organismes.

Objectives

The IRA aims to:

- improve the coordination and operation of the Nain Research Center;
- continue development and management of the Nunatsiavut Government research consultation process;
- direct engagement (through implementation) in several specific regionally-led research programs, rather than solely focusing on overall research coordination and facilitation. This includes evaluation of the community freezer program in Nain and the ongoing Going Off, Growing Strong youth engagement program;
- 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; and,
- together with the IRA coordinators, and ITK and ICC Canada, ensure that projects funded by the Northern Contaminants Program (NCP) and ArcticNet have addressed local realities and concerns, integrated Inuit knowledge, and undergone sufficient and meaningful consultation with Inuit.

Introduction

The Inuit Research Advisor provides guidance and recommendations related to Inuit needs, priorities, policy development, and research to NCP and ArcticNet. The Nain Research Centre is a hub for community and regionally-owned research in Nunatsiavut, including contaminants related research, and requires operational coordination. Efficient coordination results in enhanced benefits for community members with respect to research. The Inuit Research Advisor also focuses 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' results in greater awareness of research and a better understanding of research results generally, and contaminants related issues, specifically.

Activities in 2017-2018

- 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, the Nunatsiavut IRA participated in numerous teleconferences and attended training/workshop in Ottawa.
- Attended Arcticnet's Inuit Advisory Committee teleconferences.
- Participated in numerous teleconferences as a member of the Inuit Qaujisarvingat National Committee and attended 2 face-to-face meetings in Ottawa.
- Reviewed NCP proposals along with members of NGRAC for Nunatsiavut.

Community Engagement

- 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.

Capacity Building and Training

- Actively participated in several specific regionally-led research programs, including evaluation of a community freezer program in Nain with associated contaminants research and the Going Off Growing Strong program.
- Assisted researchers with hiring of local research assistants, school visits and holding open houses

Communications and Outreach

- Attended NCP's Results workshop in Yellowknife and presented on research happening in Nunatsiavut as well as presented a poster during the poster session.
- Attended ArcticNet's, annual scientific meeting in Quebec City and presented/co-presented during ArcticNet's student day activities.

Indigenous Knowledge

There is a need to use both Traditional and Western knowledge as we address research and science in the Arctic and Sub-Arctic. The role of the IRA is to liaise with scientists and the NG, to develop links with Indigenous knowledge holders and to integrate Indigenous knowledge into research planning. In addition, the Nunatsiavut Environmental Protection Act, which is the first of its kind across the Canadian Arctic, places a high emphasis on Inuit Knowledge, culture and values as a basis for environmental decision-making. As a result, many of the newly developed research programs led out of the Nain Research Centre focus on Inuit Knowledge and Inuit relationships, and values associated with the environment. The Inuit Research Advisor is heavily involved in the on-the-ground implementation of these new research initiatives, which involve gathering Inuit Knowledge and values as well as focusing on ways in which the Knowledge and values are transmitted to decision-makers and between generations.

Results

The IRA program in Nunatsiavut continues to provide a coordinated process by which Inuit and researchers can become connected for more effective and meaningful research in the disciplines of environmental science, contaminants and human health.

Expected Project Completion Date

Ongoing.

Acknowledgements

The IRA would like to acknowledge the funding support from the NCP.

Inuit Research Advisor for the Inuvialuit Settlement Region: Duties and NCP support for 2017-2018

Conseiller en recherche inuite (CRI) pour la région désignée des Inuvialuits : fonctions et soutien du PLN en 2017-2018

- **Project Leader/Chef de projet**
  Shannon O'Hara, Inuit Research Advisor, Inuvialuit Regional Corporation (IRC), Bag Service #21, Inuvik, NT, X0E 0T0. Tel: (867) 777-7026; Fax: (867) 777-4023; Email: sohara@inuvialuit.com
- **Project Team/Équipe de projet**
  Duane Smith, Inuvialuit Regional Corporation; Jennifer Parrott, Inuvialuit Regional Corporation

- **Project Location/Emplacement(s) du projet**
  Inuivialuit, NT

Abstract

The main purpose of this project is to support the Inuit Research Advisor (IRA) position in the Inuvialuit Settlement Region (ISR) including travel to participate in NCP related meetings, such as the biennial Results Workshop and Social and Cultural review. Planned and unplanned activities were conducted in Inuvik, Yellowknife and Ottawa. This position also ensures that there are appropriate consultation practices in the region, as the IRA advises NCP researchers and project leaders with improving their social, cultural and economic aspects of their work in Inuvialuit communities.

Activities that were completed by the IRA include, organizing and presenting at the NCP biennial Results Workshop (RW) in Yellowknife from September 26-28 (as a separate contribution agreement), hosting two NCP Cultural events during the RW on September 26-27 (in lieu of Dene Nation), attending the

Résumé

Ce projet vise principalement à appuyer le conseiller en recherche inuite (CRI) dans la région désignée des Inuvialuits (RDI), y compris dans ses déplacements pour participer aux réunions en lien avec le PLCN, par exemple l'atelier biennal sur les résultats et l'examen socioculturel annuel. Des activités (à la fois planifiées et improvisées) ont été menées à Inuvik, Yellowknife et Ottawa. Ce poste assure aussi la mise en place de pratiques de consultation appropriées dans la région, car le CRI fournit des conseils aux chercheurs et aux chargés de projets du PLCN sur l'amélioration des aspects sociaux, culturels et économiques de leur travail dans les collectivités inuvialuites.

Parmi les activités exécutées par le CFRI, notons : organiser l'atelier semi-annuel sur les résultats du PLCN de Yellowknife du 26 au 28 septembre (dans le cadre d'une entente de contribution distincte) et donner une

Fall Management Committee meeting in Ottawa on behalf of the Chair of the NWT Regional Contaminants Committee (NWT RCC) from October 17-19, and attending the NWT RCC Social and Cultural Review in Yellowknife from February 6-8, 2018.

présentation lors de l'atelier; organiser deux événements culturels du PLCN durant l'atelier sur les résultats les 26 et 27 septembre (à la place de la nation dénée); participer au Comité de gestion d'automne d'Ottawa au nom du Comité régional des contaminants (CRC) des T.N.-O. du 17 au 19 octobre; et prendre part à l'examen socioculturel du CRC des T.N.-O. du 6 au 8 février 2018.

Key Messages

- The IRA continues to participate and serve as a representative of the IRC in key NCP activities. (e.g. 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 served as liaison, contact, and assistant to research projects taking place in Inuvialuit Settlement Region.
- There is a need to change the governance structure within the NCP to be more equitable to all regions engaged in NCP research. Inuvialuit is the only Inuit region without a guaranteed seat on the Management Committee, partially due to ISR not having its own RCC, and partially due to the current terms of reference and governance processes regarding how the Chair and Co-chair are selected annually. The IRA will work with the Northern Contaminants Program to ensure that these issues are communicated and addressed.

Messages clés

- Le CRI continue de participer aux principales activités du PLCN et d'agir en qualité de représentant 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).
- Le CRI a joué le rôle d'agent de liaison, de personne-ressource et d'assistant dans le cadre des projets de recherche menés dans la région désignée des Inuvialuits.
- Il faut changer la structure de gouvernance du PLCN pour qu'elle soit plus équitable envers l'ensemble des régions qui mènent des recherches en lien avec le PLCN. L'Inuvialuit est la seule région inuite sans siège garanti au Comité de gestion, en partie parce que la RDI ne possède pas son propre CRC, et en partie en raison du mandat et des processus de gouvernance actuels concernant la sélection annuelle du président et du coprésident. Le CRI collaborera avec le Programme de lutte contre les contaminants dans le Nord pour veiller à ce que ces problèmes soient pris en compte et résolus.

Objectives

The IRA aims to:

- Complete the review of the 2017-18 NCP Call for Proposals;
- review NCP proponent proposals through early consultation by researchers, i.e., ISR based researchers;
- attend to all NCP teleconference calls for review of documents and advisories (if released) and to deal with issues as they arise;
- work towards building the research calendar in SharePoint to share within the Corporate group (IRC Research unit and the Joint Secretariat);
- organize the NCP Annual Results Workshop;
- prepared presentations (oral) for the NCP Annual Results Workshop; and,
- travel for NCP specific meetings and events.

Introduction

Inuit Research Advisors are highly involved with research that impacts Inuit from across Inuit Nunangat and within their own regions. This is a result of being integrated within the research funding landscape both regionally and nationally through Inuit Tapiriit Kanatami, NCP, ArcticNet and now the new Crown-indigenous and Northern Affairs (CIRNAC) Community Based Climate Monitoring Program. IRAs also represent their regions on national Inuit research initiatives such as the development of the National Inuit Research Strategy, the National Inuit Climate Change Strategy (ITK), and the Inuit Legacy on Research document (Inuit Advisory Committee, ArcticNet). IRAs have also contributed to various territorial/ provincial and regional initiatives, such as reviewing Territorial and National Park Management Plans, inputting Inuit perspective into new policy and the renewal of strategies and procedures for engaging Inuit (anti-poverty, food security, climate change, suicide prevention). Regionally, IRAs act as frontline workers for researchers, students and community organization to consult within Inuvialuit and also support Inuvialuit who want to conduct research. Lastly, in addition to IRAs being engaged at all levels of research, IRAs also lead and take part in regional research projects and initiatives that are priority areas for our host land claims organizations in the subject areas of climate change, food security, and capacity building.

Activities in 2017-2018

Community Engagement

- The IRA engaged with the NWT wide community via the NCP Annual Results Workshop.

Capacity Building and Training

- The IRAs took another course through the University of Ottawa Continuing Education department. Training was organized by ITK- IRA Coordinator, Kendra Tagoona. Both Shannon and Carla took “Effective Management of Project Stakeholders”, which is the second of the 4-part course of policy to action training. The IRAs will complete the other two courses in 2018-19.
- Shannon took Inuvialuit Final Agreement (IFA) 101 for Co-Management Boards in March 2018 that really helped shape the vision for research in the ISR.
- Separate from IRA work, Shannon is also a Director on the Environmental Impact Screening Committee (EISC) and was also certified in Board Orientation and Administrative Law with the NWT Board Forum, which took place also in March 2018.

Communications and Outreach

- Shannon communicated with various NCP researchers and Project leaders throughout the year. Many of these consultations happened in December 2017 at the Arctic Change conference in Quebec City, prior to the NCP Call for Proposals for 2018-19.
- Shannon consulted with include all of project PI's that submitted proposals, such as Hayley Hung, Sonja Ostertag, Lisa Loseto, Brian Liard, and various others.
- Shannon hosted two cultural events during the NCP Annual Results Workshop.

Indigenous Knowledge

- The use of Indigenous knowledge is a cornerstone to the social and cultural review of proposals each year and thus NWT RCC members provide advice on best to incorporate IK into all research projects that we review.

Results and Outputs/Deliverables

- The IRA completed the mid-year review report and submitted it to NCP.
- The IRA completed an end of year synopsis report and submitter it to NCP.
- The IRA attended all of mandatory and requested NCP events throughout the year.
- The IRA coordinated the NCP Annual Results Workshop that was held in Yellowknife from September 26-28, 2018.

Discussion and Conclusions

This year, the IRA took on more roles and responsibilities than in previous years and thus signed two contribution agreements with NCP. One for the IRA duties and one to coordinate the NCP Annual Results Workshop. In addition, the IRA attended the fall Management Committee (MC) meeting, fulfilling the co-chair's duties; the Chair was not available to attend for personal reasons. This year has been a great learning opportunity and helped the IRA understand in inner workings of the NCP and in doing so has identified areas for improvement for Indigenous partners in the NWT. The areas for improvement that are particularly important are the areas of governance and Indigenous priorities.

This year NWT RCC members discussed the governance structure of the Committee as it is laid out in the Terms of Reference (TOR). It was determined that the governance structure was a concern for most Indigenous regions. The concerns stemmed from the election process in the NWT requiring Indigenous groups to compete to obtain either one of the two Chair positions. Inuvialuit, as with other groups, feel that we have had a limited capacity to voice our concerns or provide input into decision making on projects taking place in the ISR. There were also concerns related to funding for capacity building and the opportunity to represent their region at the MC. The IRC is currently working with NCP to address some of these concerns.

Expected Project Completion Date

Ongoing

Project website (if applicable)

www.inuvialuit.com

Acknowledgments

IRC would like to acknowledge the NWT RCC for allowing the IRA to coordinate and lead the fall NCP Annual Results Workshop. Thank you for everyone who took the time to help with the Cultural events hosted by the IRA including the performers, volunteers and fellow committee member who gave a helping hand before and during both events. The IRC would also like to acknowledge the funding and support from the NCP.

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

Project Leader/Chef de projet

Markusi Qisiiq, Director, Renewable Resources, Environment, Lands& Parks Department, Kativik Regional Government, PO Box 9, Kuujjuaq, Qc J0M 1C0
Tel: (819) 964-2961 ext. 2277; Fax: (819) 964-0694; Email: mqisiiq@krg.ca

Monica Nashak, Environmental Technician, Renewable Resources, Environment, Lands& Parks Department, Kativik Regional Government, PO Box 9, Kuujjuaq, Qc J0M 1C0
Tel: (819) 964-2961 ext. 2276; Fax: (819) 964-0694; Email: mnashak@krg.ca

Michael Barrett, Associate Director, Renewable Resources, Environment, Lands& Parks Department, Kativik Regional Government, PO Box 9, Kuujjuaq, Qc J0M 1C0
Tel: (819) 964-2961 ext. 2271; Fax: (819) 964-0694; Email: mbarrett@krg.ca

Project Team/Équipe de projet

Nunavik Nutrition and Health Committee (NNHC); Makivik Corporation; Inuit Tapiriit Kanatami (ITK); ArcticNet

Project Location/Emplacement(s) du projet

Nunavik, QC

Abstract

The Nunavik Inuit Research Advisor (IRA) continues to serve as the first step in a coordinated approach to facilitate community involvement and coordination of Arctic science in Nunavik. The IRA position is housed within the Renewable Resources, Environment, Lands and Parks Department of the Kativik Regional Government (KRG) and works closely with the Nunavik Nutrition and Health Committee (NNHC), the Nunavik Board of Health and Social Services (NRBHSS), the Kativik School Board (KSB), and the Makivik Research Center. The objective of the IRA position is to help facilitate research, at the program level,

Résumé

Le poste de conseiller en recherche inuite au Nunavik (CRI) est toujours la première étape d'une approche concertée en matière de participation communautaire et de coordination des sciences arctiques au Nunavik. Le CRI travaille à l'Administration régionale Kativik (Service des ressources renouvelables, de l'environnement, du territoire et des parcs) 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, le conseil scolaire de Kativik (CSK) et le Centre de recherche de Makivik. Il est chargé de faciliter les recherches dans le

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 support, the Nunavik IRA position is co-funded by ArcticNet.

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 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.

Key Messages

The Nunavik Inuit Research Advisor (IRA) is a continued essential link between the Nunavik residents and the scientific research community. This coordinated collaboration enhances and benefits both parties by ensuring the perspectives and needs of Nunavimmiut are met and its needs and interests represented.

Messages clés

Le conseiller en recherche inuite (CRI) du Nunavik assure une liaison permanente essentielle entre les résidants du Nunavik et les milieux de la recherche scientifique. Cette collaboration concertée bénéficie aux deux parties et renforce celles-ci en tenant compte des points de vue et des besoins ainsi qu'en représentant les besoins et les intérêts des Nunavimmiuts.

Objectives

The Nunavik IRA aims to:

- make research more specific to the needs and interests of Nunavimmiut;
- provide input and direction from a Nunavimmiut perspective with respect to proposals and research to the NCP;
- assist researchers and Nunavik communities to coordinate and share information;
- have the IRA and the NNHC (Nunavik Nutrition and Health Committee) be one of the first points of contact for NCP researchers working in Nunavik;
- act as a voice in the NCP proposal process and communication of NCP health information to Nunavik communities as a member the Nunavik Nutrition and Health Committee; and,
- continue to meet and advise community governments and members as well as researchers to ensure research needs are being met.

Introduction

In Nunavik, a group of representatives from different regional organizations concerned with health, the environment, education and nutritional issues has formed to address concerns regarding contaminants as well as communicate 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 NNHC which is then transmitted to the NCP, ArcticNet, Inuit Tapiriit Kanatami (ITK) and Inuit Circumpolar Conference (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 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 by 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 2017-2018

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.

For the period April 1, 2017 to November 2017, Robert Watt was the Nunavik Inuit Research Advisor. From December 2017 to March 2018, Monica Nashak, KRG 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 June 12-13, which focussed on the review of the 2017-2018 NCP proposals. Other topics addressed 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, the BRIGHT (*Bridging Global change, Inuit Health and the Transforming Arctic Ocean*) project under Sentinel North and zoonosis testing.

Robert Watt travelled to Kuujjuaraapik for "*Qanuilirpitaa Ship Voyage Departure*". He was very active in the steering Committee of the Health survey.

Both Monica and Robert participated in the 25th anniversary NCP Results Workshop, held in Yellowknife on September 26-28. During this workshop, a poster session on the Qanuilirpitaa 2017 Health Survey was presented.

Monica participated in the NNHC meeting held in Kuujjuaq on November 1-3, 2017. Topics discussed included the Call for Proposals on multi-year agreements, including the Nunavik Child Development Study, Nunavik Neuroimaging Project, and Early Pregnancy Project.

Monica participated in the NNHC meeting held in Kuujjuaq on January 31- February 1, 2018. The committee reviewed 26 proposals in total.

The Nunavik IRA activities were included in the Renewable Resources Department Activity Reports presented at each of the four public KRG Regional Council meetings held in 2017-18, which were broadcasted in all 14 Nunavik communities in Inuktitut.

Communications and Outreach

Communications and Outreach were achieved through various ways including but not limited to distribution of promotional materials from ArcticNet and NCP throughout Nunavik. Giving reports to KRG Regional Council meetings, participating in NNHC activities and attending workshops and meetings. Active in the in "*Qanuilirpitaa Ship Voyage Departure*". Provided, assisted, coordinated, and engaged in many other outreach and communication concerning the Nunavik community needs and interests with researchers.

Northern Capacity Building and Training:

The Nunavik Inuit Research Advisor act as a mentor to local students that were hired by the KRG. In collaboration with the NNHC, the Nunavik Inuit Research Advisor also facilitates community involvement, participation, training and education through research programs.

Indigenous Knowledge and Consultation

Additionally, the IRA regularly consults and communicates with the Northern Villages, the Nunavik Landholding Corporations, the Nunavik Research Centre, Makivik, Anguvigaapiit Hunters and Trappers Association the Makivik Corporation as well as the ITK and ICC.

Discussion and Conclusions

The Nunavik Inuit Research Advisor provides input and direction from a Nunavimmiut perspective through active engagement with Arctic scientific researchers and its community members. Coordination, participation and communication of specific Nunavik needs and interests is essential and its achievement reached through active engagements.

Expected Project Completion Date

This project is ongoing.

Acknowledgements

Acknowledgments to all Nunavik members, NNHC members, NRBHSS, Makivik Corporation, ITK, ICC, NCP and KRG Council Members.

Wildlife Contaminants Workshop – building contaminants research capacity in Nunavut

Atelier sur les contaminants des espèces sauvages – accroître la capacité en matière de recherche sur les contaminants au Nunavut

Project Leader/Chef de projet

Jamal Shirley, Manager, Research Design: Nunavut Research Institute Nunavut Arctic College Iqaluit, Nunavut, X0A 0H0. Email: jamal.shirley@arcticcollege.ca

Mary Gamberg, Research Scientist: Gamberg Consulting, 708 Jarvis St., Whitehorse, YT Y1A 2J2. Email: mary.gamberg@gmail.com

Jennifer Provencher, Weston Post-Doctoral Fellow in Northern Research: Acadia University-National Wildlife Research Centre, 1125 Colonel By Drive, Ottawa, ON, K1A 0H3. Email: jennifpro@gmail.com

Jason Carpenter, Senior Instructor: Environmental Technology Program, Nunavut Arctic College, PO Box 1720, Iqaluit, NU, X0A 0H0. Email: jason.Carpenter@ArcticCollege.ca

Project Team/Équipe de projet

Amie Black, Environment and Climate Change Canada, Ottawa, ON; Amy Caughey, Dept of Health, Government of Nunavut, Iqaluit, NU; Pierre-Yves Daoust, University of Prince Edward Island, Charlottetown, PEI; Sharon Edmunds- Potvin, Nunavut Tunngavik Inc., Iqaluit, NU; Magali Houde, Environment and Climate Change Canada, Montreal, QC; Michele Leblanc-Havard, Dept of Health, Government of Nunavut, Iqaluit, NU; Mark Mallory, Acadia University, Wolfville, NS; Jayne Murdoch-Flowers, Dept. of Health, Government of Nunavut, Iqaluit, NU; Derek Muir, Environment and Climate Change Canada, Burlington, ON; Mary Ellen Thomas, Nunavut Research Institute, Iqaluit, NU

Project Location/Emplacement(s) du projet

Iqaluit, NU

Abstract

In November 2017, the project team successfully delivered the 11th annual Wildlife Contaminants Workshop (WCW) to students of Nunavut Arctic College's Environmental Technology Program (ETP) in Iqaluit, Nunavut. The WCW employs an experiential training approach tailored for the learning needs, preferences, and strengths of ETP students, and is structured to enhance students' knowledge of environmental contaminants research, communication, and assessment within broader contexts of ecosystem, public and wildlife health. In 2017, the WCW combined lectures, interactive lab activities, and group discussions around wildlife contaminants monitoring, risk communication, and the links between wildlife and human health. Students learned how contaminant trend monitoring programs are designed and carried out, and they learned survey techniques to document Inuit knowledge and observations about wildlife health. Students were also trained in methods for tissue sampling of ringed seal and Arctic char and learned traditional Inuit techniques for ringed seal butchering and necropsy. Students utilized the Nunavut Research Institute's (NRI) new Direct Mercury Analyzer to measure total mercury concentrations in seal and char tissue samples collected during the workshop. The workshop also included interactive learning modules on health risk communication in Nunavut, with special emphasis on ensuring country food safety in the context of addressing Nunavut's food security challenges.

Résumé

En novembre 2017, l'équipe de projet a présenté avec succès le 11e Atelier annuel sur les contaminants des espèces sauvages (ACES) aux étudiants du Programme des technologies environnementales (PTE) du Collège de l'Arctique du Nunavut à Iqaluit, au Nunavut. L'ACES emploie une approche expérientielle en matière de formation qui est adaptée aux besoins, aux préférences et aux forces des étudiants du PTE. De plus, l'Atelier est structuré pour améliorer les connaissances des étudiants sur la recherche et l'évaluation des contaminants environnementaux, ainsi que sur la communication des risques connexes, dans le contexte plus vaste de la santé des écosystèmes, du public et de la faune. En 2017, l'ACES combinait exposés magistraux, activités interactives en laboratoire et discussions en groupe sur la surveillance des contaminants chez les espèces sauvages, la communication des risques et les liens entre les espèces sauvages et la santé humaine. Les étudiants ont appris comment les programmes de surveillance des tendances de contamination sont conçus et réalisés, ainsi que comment mener des enquêtes visant à documenter les connaissances des Inuits et leurs observations sur la santé des espèces sauvages. Les étudiants ont aussi reçu une formation sur les méthodes d'échantillonnage de tissus de phoque annelé et d'omble chevalier et ont appris les techniques traditionnelles inuites d'abattage et d'autopsie du phoque. Les étudiants ont utilisé le nouvel analyseur de mercure de l'Institut de recherche du Nunavut pour mesurer les concentrations totales de mercure dans les tissus de phoque annelé et d'omble chevalier prélevés durant l'Atelier. L'ACES comportait également des modules d'apprentissage interactif sur la communication des risques liés à la santé au Nunavut, l'accent étant particulièrement mis sur la sécurité des aliments prélevés dans la nature compte tenu des problèmes de sécurité alimentaire au Nunavut.

Key Messages

- The Wildlife Contaminants Workshop was held in Iqaluit in November 2017.
- The workshop focused on Arctic char and ringed seals in 2017.
- Several activities were improved upon in 2017 based on past workshop evaluations.
- Emphasis was put on having students learn skills to sample and test tissues for mercury using a direct mercury analyser that is situated in Iqaluit.

Messages clés

- L'Atelier sur les contaminants des espèces sauvages a eu lieu à Iqaluit en novembre 2017.
- En 2017, l'atelier portait principalement sur l'omble chevalier et le phoque annelé.
- Plusieurs activités ont été améliorées en 2017 dans la foulée des évaluations d'ateliers antérieurs.
- La priorité était d'enseigner aux étudiants comment échantillonner et analyser des tissus pour y détecter du mercure en utilisant un analyseur de mercure situé à Iqaluit.

Objectives

The core objectives of the 2017 Wildlife Contaminants Workshop were to provide ETP students with:

- core knowledge of contaminants research in the Arctic, an increased understanding of the NCP, and the ability to interpret and contextualize information on contaminants;
- hands-on training in laboratory methods for tissue sampling and analysis of contaminants in Arctic char and ringed seals, which represent 2 key country food species important across Nunavut;
- the opportunity to interact and learn directly from NCP researchers working on projects in the region and to gain essential skills to engage with contaminants research in the future; and,
- the opportunity to interact and learn directly from community members and holders of local and Indigenous knowledge related to wildlife health (ringed seals).

The 2017/18 workshop also served to:

- provide an opportunity for NCP researchers to present their work in a Northern context, and to engage and discuss their research directly with students and Inuit knowledge holders in a collaborative learning environment; and,
- co-develop with students, a series of questions that could be used to engage students and youth in conversations with hunters to promote the incorporation of Indigenous knowledge into wildlife monitoring studies.

Introduction

The NCP has identified communication of contaminants related science to students and the general public as an area of importance. In particular, NCP has identified the need to communicate contaminants science to northerners that allows individuals to make informed choices with regards to country foods. NCP also recognizes that contaminants information needs to be presented within the context of larger education programs in order to reach the most diverse and appropriate target audiences. The NCP blueprint states that communication efforts should focus on incorporating information about contaminants within the context of other relevant information and concerns. With these goals in mind, the Wildlife Contaminants Workshop aims to deliver an integrated learning experience that incorporates contaminants, wildlife ecology, physical processes in the Arctic, and climate change to be delivered to the ETP students at the NAC (Provencher et al., 2013).

The ETP is Nunavut's only accredited post-secondary environmental training program and has an annual enrollment of approximately 30 students who hail from across Nunavut's 25 communities. The WCW is an experiential training model that employs a variety of tailored hands-on, interactive methods to build awareness, competency, knowledge, and skills within this core group of frontline environmental practitioners. The WCW teaches fundamental aspects of environmental contaminants research, communication, and assessment within the broader context of ecosystem, public and wildlife health, and in relation to Inuit knowledge, values, and practical skills.

The WCW has been delivered since 2007 and our training approach has been refined over time to address the unique learning needs, preferences, and strengths of ETP students. Since 2016 the WCW has become an integral part of the ETP curriculum (a graduation requirement for students) and it is structured to provide knowledge and skills that complement the learning objectives for other core ETP courses. Upon graduation, many ETP students return to their home communities in Nunavut to work as conservation and fisheries officers, land use and environmental assessment officers, research coordinators, HTA managers, etc. They are often called upon to support NCP research efforts, including assisting in designing and executing field research, facilitating community consultations, and supporting efforts to communicate research results. Graduates also work in regulatory agencies, regional Inuit organizations, and other organizations directly responsible for developing research policy and strategy and for reviewing and approving contaminants research activities. The broad foundational training provided through the WCW is designed to help ETP students succeed in these diverse roles when they enter Nunavut's workforce.

Experts from both NCP supported environmental monitoring and research programs and the Nunavut Environmental Contaminants Committee (NECC) are closely involved in planning and delivery of the WCW. This allows workshop participants the opportunity to directly interact with NCP researchers and the NECC in order to better learn about current NCP programs, and how the NCP contributes to our understanding of contaminants in the Arctic. Local elders and experienced hunters from the Iqaluit Amarok Hunters and Trappers Organization are engaged each year in the workshop to share their knowledge, perspectives, and practical skills related to wildlife health. The WCW also includes learning modules focused on the context of food security in relation to country food in Nunavut, and the challenges in developing health risk messaging that balances the benefits and risks of country food consumption.

Activities in 2017-2018

Monday – Monday morning started with some introductory material about contaminants and an overview of NCP, which helped prepare students for the analytical work they would be doing in the following days. These lectures were given by Mary Gamberg and Jennifer Provencher. Classes in the afternoon at the NAC were cancelled due to inclement weather

Tuesday – Classes at the NAC were cancelled due to inclement weather.

Wednesday – Wednesday morning focused on the dissections of Arctic char and ringed seals through hands-on activities. Jean Allen from CIRNAC started the day off talking about NCP and its role in contaminants research globally. Glenn Williams then led the dissection of the ringed seal, incorporating traditional and local knowledge into the sample collection methodology (Figure 1). He was assisted by Magali Houde. Jennifer and Mary led the dissections of the Arctic char. The first year students then dissected Arctic char in teams to practice their dissection and contaminant tissue sampling skills. Classes at the NAC in the afternoon were cancelled due to inclement weather.

Figure 1: Magali Houde and Glenn Williams working with the NAC ETP students to dissect and sample a ringed seal during the Wildlife Contaminants Workshop.

Thursday – The morning sessions focused on the dissections of the ringed seals (Glenn and Magali) and Arctic char (Mary and Jenn) with the students attending a different session than they did the previous day (Figure 2). The Arctic char session included the training of second year ETP students to use the Direct Mercury Analyzer (led by Jamal Shirley; Figure 3). In the afternoon, Jean Allen gave an overview lecture about NCP. A series of lectures were then given that covered contaminants in wildlife (Mary) and ringed seals (Magali), pathogens and parasites in wildlife in relation to contaminants (Pierre-Yves Daoust) and marine plastics in Nunavut (Jennifer). Pierre-Yves Daoust gave a well-attended public lecture on the Thursday evening (November 23rd) about his project examining the Bowhead hunt in Nunavut with NTI and Glenn Williams.

Figure 2: Mary Gamberg demonstrating to the NAC ETP students how to remove otoliths from Arctic char sampled for contaminants.

Figure 3. Jamal Shirley teaching the NAC ETP students how to load and run the Direct Mercury Analyzer at the Nunavut Research Institute.

Friday – The last day of the workshop aimed to synthesize many of the ideas that have been covered throughout the week and focus on allowing the students to practice and develop their own contaminants communication skills. In the morning, we reviewed and discussed the results from the char and ringed seal samples that the students ran using the Direct Mercury Analyzer. The results were reviewed in relation to expected levels given what is known about mercury levels in ringed seals and Arctic char, and in relation to the known geographic patterns in Nunavut (led by Jennifer). Amy Caughey (GN Health) then led a session on the importance of considering contaminants in country foods in the context of overall health and nutrition. This included the importance of communicating both the risks and benefits of country food items. Steven Lonsdale (from QIA), who is a graduate from the ETP, spoke to the students about his current job with QIA, and the importance and challenges of communicating research to communities.

Communications

For the community lecture component there was a translator present to allow students and participants to communicate in English or in Inuktitut. This supported participants so that they felt more comfortable communicating with each other, and engaging in discussions. It will also allow students and community members to learn the Inuktitut names and terms used for wildlife and contaminants.

Results and Outputs/Deliverables

In 2017, the students developed a set of questions that could be used when collecting issues from hunter sampled ringed seals to collect additional traditional and local knowledge information about the health and environmental conditions of the animals. While this questionnaire is in development with the students and being refined, the version developed in the workshop can be found in Table 1 within the Appendix.

Discussion and Conclusions

Although this project did not include an evaluative portion this year, it was clear by the end of the week that the students were more comfortable talking about contaminants and had an increased vocabulary and greater understanding of contaminant dynamics within ecosystems and wildlife. The interaction with NCP researchers and a recent ETP graduate gave the students invaluable insight into research as a discipline and potential career path. Overall, this workshop builds a core understanding of contaminants research among Nunavut's future environmental managers and decision makers, and increases their capacity to effectively interpret, evaluate and convey contaminant information to other community members.

The workshop is planned to be offered again in September 2018, with a focus on seabirds and plastics in the marine environment. Hands-on activities will include seabird dissections (including the assessment of ingested plastics and the measurement of mercury using the Direct Mercury Analyzer), an assessment of marine plastics on the local shoreline, and the development of a community-based monitoring program for microplastics in Nunavut. A series of assessment tools will be developed in 2018 to allow this workshop to become fully integrated into the 2nd year ETP environmental studies course beginning in 2019.

Expected Project Completion Date

This project was completed in November 2017.

Acknowledgments

We would like to thank all those that make the workshop a reality each year. In addition, the funding from NCP, there are many individuals in Iqaluit that work to ensure the workshop is a success, including Jean Allen, Amy Caughey, and especially Joshua Kango and the Amarok HTO. Glenn Williams has contributed an essential part of the workshop for several years and we are very thankful to him. We are also thankful to Iqaluit hunters Alex Flaherty and Jackie Takpanie who provided the fish and seals in 2017.

References

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Appendix - Table 1

Questions developed by the ETP students that should be asked in relation to ringed seals

Questions that should be asked of hunters every 1-2 years.

1. a) How many years have you been hunting?

   b) Have you noticed any changes over the last 20 years in the following:

i) ringed seal habitat	YES or NO
ii) ringed seal diet	YES or NO
iii) the taste of ringed seal	YES or NO
iv) the health of ringed seal	YES or NO
v) the number of infections ringed seals have	YES or NO
vi) the average size of ringed seal	YES or NO

   c) If you answered yes to any of the above, please explain.

2. Do you have any other concerns about Ringed Seals health in this region?

Questions that should be asked of the hunters for each seal sampled.

3. What were the ice conditions when this seal was hunted? (Circle all that apply)

No ice	Thin ice (greater than 1.5m)	Thick ice (less than 1.5m)
Wet	Slushy	Brittle
New ice	Multi-year ice	First year ice

4. Did the ringed seal show any signs of parasites or injuries? (Circle all that apply)

Skin infections	Fused or deformed bones	Parasites in any of the internal tissues	Nodules or unusual bumps on any organs
External parasites on the skin	Organs that were an unusual color or texture	Skin infections	Other ____________

If you circled any of the above, please explain: ______________________________

____

____

5. Is there anything nearby that could affect the health or diet of this seal? For example, sewage outflows? Moored vessels?

Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Sachs Harbour, Northwest Territories

En apprendre davantage sur la santé du phoque annelé grâce à la science sur les contaminants et aux connaissances traditionnelles des Inuits : un atelier éducatif à Sachs Harbour, Territoires du Nord-Ouest

Project Leader/Chef de projet

Dominique Henri, Wildlife Science and Indigenous Knowledge Specialist, Environment and Climate Change Canada, 105 McGill Street, 7th Floor, Montréal (QC), H2Y 2E7.
Tel: (514) 496-9024; Email: dominique.henri@canada.ca

Magali Houde, Research Scientist, Environment and Climate Change Canada, 105 McGill Street, 7th Floor, Montréal (QC), H2Y 2E7. Tel: (514) 496-6774; Email: magali.houde@canada.ca

Jennifer Provencher, Postdoctoral Researcher, Acadia University, Department of Biology
33 Westwood Ave, Wolfville (NS), B4P 2R6,
Tel: (613) 998-8433; Email: jennifer.provencher@canada.ca

Project Team/Équipe de projet

Karen Bibby, Inualthuyak School, Sachs Harbour, NWT; Kyle Wolki, Sachs Harbour Hunter and Trapper Committee, Sachs Harbour, NWT; Kristin Hynes, Fisheries Joint Management Committee, Inuvik, NT; Jeff Kuptana, Hunter, Sachs Harbour, NWT; Amie Black, Environment and Climate Change Canada, Ottawa, ON; Cassandra Debets, University of Manitoba, Winnipeg, MB; Mick Appaqaq, Arctic College Environmental Technology Program, Iqaluit, NU; Maeva Giraudo, Environment and Climate Change Canada, Montreal, QC; Steven Ferguson, Fisheries and Oceans Canada, Winnipeg, MB; Chris Furgal, Trent University, Peterborough, ON; Eric Loring, Inuit Tapiriit Kanatami, Ottawa, ON; Derek Muir, Environment and Climate Change Canada, Burlington, ON; David Yurkowski, University of Manitoba, Winnipeg, MB

Project Location/Emplacement(s) du projet

Sachs Harbour, NT

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. On January 31st, 2018, we delivered an educational workshop on ringed seals in Sachs Harbour, Northwest Territories, where annual core monitoring of ringed seals takes place under the Northern Contaminants Program (NCP). This workshop was held at the Inualthuyak School with the objective of engaging students, elders, scientific researchers, school personnel and the local Hunters and Trappers Committee in learning about ringed seals from both Inuit knowledge and scientific perspectives. The workshop allowed NCP research scientists working on contaminants in ringed seals to share information about their work with students from the Inualthuyak School, and Sachs Harbour community members. It also provided an opportunity for Inuvialuit elders to share their knowledge with students and researchers in seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game. This one-day event employed a combination of short interactive presentations, laboratory activities, group discussions, storytelling, games, and art activities to teach participants core concepts, issues and methodology related to the study and understanding of ringed seal health from both scientific and Inuit perspectives. One student from the Arctic College Environmental Technology Program (ETP) in Iqaluit, and one graduate student from the University of Manitoba, co-led the Sachs Harbour workshop as a way to increase the capacity of northern students and early career scientific researchers to meaningfully engage with community members in contaminants research. During the workshop, the ETP student was responsible for implementing a student-developed hunter survey created during the 2017 NCP Wildlife Contaminants Workshop held at the Nunavut Arctic College in Iqaluit. This survey was developed to collect Inuit knowledge that may be associated with contaminants in ringed seals, and can be administered by local

Résumé

Ce projet s’appuie sur l’intérêt commun des Nunavummiuts et des chercheurs scientifiques d’améliorer les communications et de renforcer les capacités de la collectivité relativement à la recherche menée sur les contaminants chez le phoque annelé. Le 31 janvier 2018, nous avons organisé un atelier éducatif sur le phoque annelé à Sachs Harbour (Territoires du Nord-Ouest), où se tiennent les activités de surveillance de base du phoque annelé dans le cadre du PLCN. L’atelier a eu lieu à l’école Inualthuyak et visait à fournir aux élèves, aux aînés, aux chercheurs, au personnel scolaire et au Comité local des chasseurs et trappeurs un apprentissage interactif sur le phoque annelé s’appuyant sur les connaissances inuites et scientifiques. L’atelier a permis aux scientifiques du PLCN qui mènent des recherches sur les contaminants dans les phoques annelés de transmettre des données issues de leurs travaux aux élèves de l’école Inualthuyak et aux membres de la collectivité de Sachs Harbour. L’atelier a aussi permis aux aînés inuvialuits de transmettre aux étudiants et aux chercheurs leurs connaissances sur l’écologie du phoque et sur les méthodes traditionnelles d’abattage des phoques, de préparation de la peau et de dépistage d’anomalies dans le gibier récolté. Cet événement d’une journée avait recours à de courtes présentations interactives, des activités en laboratoire, des discussions de groupe, des récits, des jeux et des activités artistiques pour enseigner aux participants les concepts fondamentaux, les enjeux et les méthodes en lien avec l’étude et la compréhension de la santé du phoque annelé des points de vue scientifique et inuit. Un étudiant du Programme des technologies environnementales (PTE) du Collège de l’Arctique d’Iqaluit et un étudiant diplômé de l’Université du Manitoba assuraient la codirection de l’atelier de Sachs Harbour afin de permettre aux étudiants du Nord et aux chercheurs scientifiques en début de carrière de prendre sérieusement part à la recherche sur les contaminants avec les membres de la collectivité. Durant l’atelier, l’étudiant du PTE était chargé de la mise en œuvre d’un questionnaire à l’intention des chasseurs qu’ils ont élaboré dans le cadre de l’Atelier sur les

students to help increase their involvement in local research. Lastly, through a series of discussions and a written survey, the project aimed to identify best communication practices for contaminants research and inform the development of innovative methods of community engagement around contaminants monitoring in wildlife. This project will contribute to expanding collaboration and communication between northern residents and researchers working on contaminants in Sachs Harbour and Inuit Nunangat.

contaminants des espèces sauvages du PLCN de 2017 au Collège de l'Arctique du Nunavut d'Iqaluit. Le questionnaire a été élaboré dans le but de recueillir des connaissances inuites pouvant être reliées à la présence de contaminants dans les phoques annelés. Il peut en outre être utilisé par les étudiants locaux pour accroître leur participation à la recherche locale. Enfin, grâce à une série de discussions et à un questionnaire écrit, le projet visait à établir les pratiques de communication appropriées et à inspirer l'élaboration de méthodes novatrices en matière de mobilisation communautaire pour la surveillance des contaminants chez les espèces sauvages. Ce projet contribuera à accroître la collaboration et la communication entre les résidants du Nord et les chercheurs menant des travaux sur les contaminants à Sachs Harbour et dans l'Inuit Nunangat.

Key Messages

- An educational workshop on ringed seals involving students, elders, scientific researchers, school personnel, and the local Hunters and Trappers Committee was held at the Inualthuyak School, Sachs Harbour, NWT, in January 2018.
- Students, elders, school personnel, and community members worked together with scientific researchers to increase understanding of contaminants in ringed seals and learn from Inuvialuit knowledge about seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game.
- Local students actively engaged with several types of interactive classroom activities (presentations, laboratory activities, group discussions, storytelling, games, and art activities), and school personnel welcomed researcher engagement in the classroom.
- Best practices for sharing information about contaminants research with northern schools through workshops include: having a flexible approach to workshop programming, developing teaching tools that can be easily adapted to various age

Messages clés

- Un atelier éducatif sur le phoque annelé auquel participaient des étudiants, des aînés, des chercheurs, du personnel scolaire et le Comité local des chasseurs et des trappeurs a eu lieu à l'école Inualthuyak de Sachs Harbour (Territoires du Nord-Ouest) en janvier 2018.
- Les étudiants, les aînés, le personnel scolaire et les membres de la collectivité ont collaboré avec des chercheurs pour faire progresser les connaissances sur les contaminants dans les phoques annelés et pour transmettre aux étudiants et aux chercheurs leurs connaissances sur l'écologie du phoque et les méthodes traditionnelles d'abattage des phoques, de préparation de la peau et de dépistage d'anomalies dans le gibier récolté.
- Les étudiants locaux ont participé activement à plusieurs types d'activités d'apprentissage en classe (présentations, activités en laboratoire, discussions de groupe, récits, jeux et activités artistiques), et le personnel scolaire accueillait favorablement la participation des chercheurs en classe.

groups, preparing educational material that can be left with teachers once the workshop is over, taking the time to introduce concepts that are new to students (e.g., contaminants, bioaccumulation, biomagnification), and implementing a mix of hands-on activities and short presentations.

- Participation of one student from the Arctic College Environmental Technology Program in Iqaluit and one graduate student from the University of Manitoba contributed to increasing the capacity of northern students and early career scientific researchers to meaningfully engage with community members in contaminants research in Inuit Nunangat.

- We implemented a student-developed hunter survey for collecting local/ Indigenous knowledge that may be associated with contaminants in ringed seals. This survey can be administered by local students to help increase their involvement in contaminants research.

- Diverses pratiques exemplaires ont été mises en œuvre pour transmettre, aux écoles du Nord, de l'information sur la recherche liée aux contaminants, par exemple : une approche souple en matière de programmation des ateliers; des outils d'enseignement qui s'adaptent aisément à divers groupes d'âge; du matériel pédagogique qui peut être remis aux enseignants après l'atelier; la présentation des concepts nouveaux pour les étudiants (p. ex. les contaminants, la bioaccumulation, la bioamplification); et la mise en œuvre d'un mélange d'activités pratiques et de courtes présentations.

- La participation d'un étudiant du Programme des technologies environnementales (PTE) du Collège de l'Arctique d'Iqaluit et d'un étudiant diplômé de l'Université du Manitoba Sachs Harbour a permis de renforcer la capacité des étudiants du Nord et des chercheurs scientifiques en début de carrière de s'engager sérieusement dans la recherche sur les contaminants dans l'Inuit Nunangat avec les membres de la collectivité.

- Nous avons créé et distribué un questionnaire à l'intention des chasseurs en vue de recueillir des connaissances locales/ traditionnelles pouvant dénoter la présence de contaminants dans les phoques annelés. Le questionnaire peut être distribué et géré par les étudiants locaux pour accroître leur participation à la recherche sur les contaminants.

Objectives

The project aimed to engage youth, elders and scientific researchers in learning about ringed seal health from both Inuit knowledge and scientific perspectives through an educational workshop held at the Inualthuyak School in Sachs Harbour, Northwest Territories, in January 2018.

In the short-term, this workshop aims to:

- provide an opportunity for scientists working on contaminants in ringed seals to share information about their work with northern youth, in particular through synthesized messaging about seal ecology and contaminants;
- provide an opportunity for knowledge exchange among Inuit youth, elders, hunters, and scientists about (a) seal ecology, (b) traditional methods for butchering seals, preparing seal skin, identifying abnormalities in harvested game, and (c) country food, contaminants and human health;
- increase the engagement and interest of northern students in contaminants research and traditional seal harvesting;
- develop a survey that workshop participants can use to collect local/ Indigenous knowledge about ringed seal health in relation to contaminants;
- develop and foster leadership abilities among northern youth by having a student from the Nunavut Arctic College co-lead the workshop;
- develop and foster community engagement capacity and leadership among the scientific community by having an early career researcher working in northern contaminants co-lead the workshop;
- identify appropriate communication practices for engaging and communicating with Inuit youth as part of contaminants research;
- provide a forum for northern students to learn more about science career pathways and opportunities; and,
- create and package educational material related to contaminants in wildlife for northern teachers to use in classrooms (including sharing existing educational material supported by NCP).

Over the long-term, this educational project will expand collaboration and communication between northern residents and scientific researchers working on contaminants in Sachs Harbour and Inuit Nunangat. This project focuses on intergenerational and interdisciplinary learning about ringed seal ecology and ongoing contaminants research on this species. Its core long-term objective is to increase the capacity of northern residents (with a focus on youth) to engage in and better understand ongoing scientific research on northern contaminants.

Introduction

For over two decades, the NCP has funded 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, scientific researchers involved in this project have communicated results to community members mostly through reports and annual community visits. In 2016, the Nunavut Environmental Contaminants Committee (NECC) suggested increasing community engagement as part of this ongoing work. This suggestion sparked the development of this project. Dominique Henri, Magali Houde and Jennifer Provencher (Project Leaders) decided to lead the development of a collaborative project that would directly address a shared interest among northern 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 long-term research program supported under the NCP.

Effective communication and engagement between researchers and northern community members is central to the success and meaningfulness of contaminants research projects conducted in northern Canada (CC&O Blueprint, 2018/2019). 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 meaningful engagement with 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), Inuit, in particular, have a strong interest in understanding and playing an active role in wildlife research projects and to see their knowledge contribute meaningfully to such initiatives (Gilchrist et al. 2005; Henri et al. 2010; ITK 2018). However, while efforts have been made to promote greater community engagement in scientific research in northern Canada, recent studies suggest that there is still room for enhancing the involvement of northerners in Arctic science (Brunet et al. 2014; ITK 2018). Importantly, there is a desire among early career researchers to engage in northern community outreach activities and to build more capacity in this area (Provencher et al. 2013; Tondu et al. 2014). This project therefore contributes to addressing needs identified by both northern communities and researchers 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 contribute the the development of innovative communication and engagement methods related to contaminants monitoring in wildlife.

In 2016/2017, a first ringed seal workshop (supported by NCP) was successfully held in Resolute, Nunavut (please refer to 2016/2017 synopsis report for more information). The workshop implemented in Sachs Harbour in 2017/2018, NWT, was designed based on lessons learned and feedback received from participants to the Resolute workshop.

Activities in 2017/2018

The workshop held in 2017/2018 in Sachs Harbour, NWT, was entirely dedicated to community engagement, capacity building and training, communication and outreach, and the application of Inuit knowledge to contaminants research on ringed seals.

Community Engagement

Workshop planning and co-design

From September 2017 to January 2018, workshop program and content were co-developed by scientific researchers, Inualthuyak School personnel, representatives from the Sachs Harbour Hunter and Trappers Committee (HTC; Betty Haogak, Kyle Wolki and Jeff Kuptana), and other project team members. Dominique Henri (ECCC) oversaw the workshop co-design process, and project reporting activities. The workshop funded by NCP took place on Wednesday, January 31st, 2018, at the Inualthuya School in Sachs Harbour, Northwest Territories. The scientific team co-leading and present at the workshop was composed of: Magali Houde (ECCC), Maeva Giraudo (ECCC), Cassandra Debets (University of Manitoba), and Mick Appaqaq (Arctic College ETP student).

On Tuesday January 30th, upon arrival in Sachs Harbour, the scientific team met with the Inualthuyak School principal, Karen Bibby. The team also visited the Hamlet Office and the Sachs Harbour Hunters and Trappers Committee to talk about the workshop and ongoing wildlife contaminants research around the community, and finalize workshop logistics. The attendance of two local elders at the workshop, Betty Haogak and John Keogak, was confirmed. The scientific team had originally planned to conduct a ringed seal dissection guided by these two local elders during the workshop. Unfortunately, local hunters were unable to hunt a ringed seal and this activity was cancelled. Therefore, the team met in the evening to discuss, revise, and finalize workshop programming.

Workshop delivery

On Wednesday, January 31st, the scientific team conducted the workshop and worked with 11 students from kindergarten to grade 9. Throughout the day, the team used small PowerPoint presentation modules to introduce and/or conclude each of the activities in order to keep the workshop as interactive as possible. The workshop started with team members introducing themselves and their work/studies, and a short slide show about contaminants and wildlife in the Arctic. Topics covered included: sources and pathways of contaminants, bioaccumulation, biomagnification, and Arctic food webs.

After this introduction, John Keogak and Betty Haogak (Figure 1) talked with students about ringed seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game. Most of the students expressed that their families had little interest in seal hunting. John Keogak and Betty Haogak both confirmed that they felt seal harvest might no longer happen in their community in the future. They explained that elders are the main hunters/consumers of seal in Sachs Harbour, and most local students attending the workshop mentioned that they had never tasted seal meat.

Figure 1. Betty Haogak (left), an Inuvialuit elder from Sachs Harbour, and Magali Houde (right), research scientist with ECCC, shared their knowledge about ringed seals with students during the workshop (picture shared with permission).

Workshop leaders and students then divided into two groups. Mick Appaqaq and Magali Houde completed a local/ Indigenous knowledge survey with John Keogak and Betty Haogak (please refer to 'Indigenous Knowledge' section below for more details about this survey), while other participants went to the gym to play the *Arctic food web game*. Each student was a different animal in an Arctic food chain and everyone started with a few elastic bands that represented contaminants. When students met a person who was higher on the food chain, they had to transfer the contaminants (one elastic band at a time) in the right direction (from lower to higher trophic level animals). When they met someone of the same level, they just moved on. After about three to five minutes, everyone stopped and put all their elastic bands into the right animal jar (Figure 2). Lower trophic level plants and animals had less contaminants (elastic bands) compared to upper level animals. Researchers discussed these results with students, and explained the concepts of bioaccumulation and biomagnification. Right after this game, Maeva Giraudo showed students a poster representing an Arctic food web, and invited them to stick different animals onto the poster to further consolidate learning about food chains and webs.

Figure 2. The *Arctic food web game* was used to teach Inualthuyak School students about bioaccumulation in Arctic food webs through play (left). Students also learned about ringed seal body parts (English and Inuvialuktun) through the use of an interactive poster (right) (picture shared with parental permission).

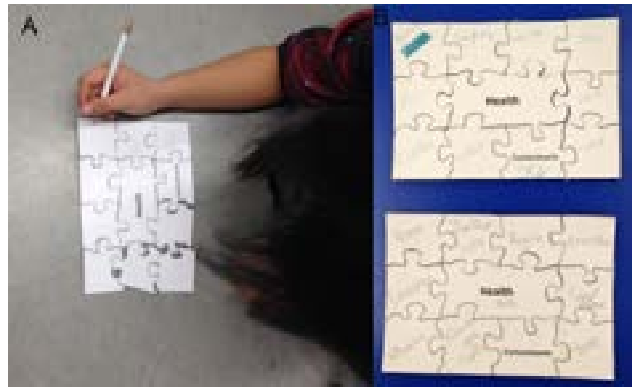
After these two games were completed, Mick Appaqaq made a short presentation on ringed seal biology and health. He used an interactive poster to teach students about ringed seal body parts in English and Inuvialuktun (Figure 2). Cassandra Debets then delivered an interactive presentation about scientific research on ringed seals, using hydrophone recordings of ringed seals, underwater recordings of marine mammals taken around Sachs Harbour (courtesy of Stephen Insley, Wildlife Conservation Society Canada), and an animation of tagged seals from Ulukhaktok. She also showed students a satellite tag used by researchers for understanding ringed seal movements and distribution. Students from all ages really enjoyed hearing marine mammal recordings and learning about how ringed seal tagging is done by researchers and what we can learn from it.

In the early afternoon, two types of interactive laboratory stations were set up by the scientific team who explained the activities and answered questions from students. Students were divided into two groups (younger group and older group), which rotated between stations. Activities were specifically adapted to the two age groups and were quite popular. First, students could observe plankton (*Daphnia magna*) using a magnifying glass and light table, and had an opportunity to feed daphnids with algae (Figure 3). Magali Houde and Maeva Giraudo answered questions. In addition, Cassandra Debets made a brief presentation about what ringed seals eat and how researchers use ringed seal stomach contents to better understand seal diet. She then invited students to dig through a fake ringed seal stomach (made of Jell-O) to find various types of beads (Figure 4). Each type of bead represented an animal that ringed seals can eat. Older students could record their findings into datasheets. This activity was designed in replacement of the ringed seal dissection activity that could not take place in the absence of a seal.

Figure 3. Inualthuyak School students feeding plankton (daphnids) with algae and observing plankton using a magnifying glass and light table with the assistance of Mick Appaqaq (top) and Magali Houde (bottom) (pictures shared with parental permission).

Figure 4. Interactive game teaching students about ringed seal diet: Inualthuyak School students put on their gloves to dig in a ringed seal stomach (made of Jell-O) looking for preys (beads) (picture shared with parental permission).

Figure 5. A student completed the *Health-contaminants puzzle* activity (left). Examples of completed *Health-contaminants puzzles* by students adding in different themes that are related to human health in addition to contaminants (right).



Once laboratory activities were completed, students were invited to participate in a discussion about human health and contaminants or in an art activity, depending on their preference. Maeva Giraudo led an activity aiming to discuss the relationship between human health, country food, and contaminants using the *Health-contaminants puzzle* (Figure 5). Students were encouraged to discuss different aspects of their lifestyle that contributed to their overall health (e.g., sleep, exercise, family, friends, country food, etc.), and invited to write down their thoughts on a piece of puzzle. The nutritional benefits of eating country food were also briefly discussed with the students. As part of the art activity, students were invited to color small ringed seals made of paper and invited to stick their drawings on a large map showing ringed seal geographic distribution, which led to a discussion about where ringed seals live around the Arctic (Figure 6).

To wrap up the day, the scientific team played in the gym with students and RCMP officers. In the evening, Magali Houde attended a meeting of the Sachs Harbour HTC. She briefly discussed the workshop that took place earlier during the day, presented results from the core ringed seal monitoring program supported by NCP, and talked about the possibilities of continuing such work in collaboration with the community. She also answered concerns and questions from HTC members.

Workshop assessment

On Thursday, February 1st, the scientific team (Houde, Giraudo, Debets and Appaqaq) went back to the school to conduct a workshop assessment with school personnel (i.e., Karen Bibby, principal, Nick Kopot, and Deanna, teachers) through informal discussions. The feedback received was very positive and some suggestions were made for improving the delivery of our activities in future years (e.g., taking more time to introduce new concepts such as contaminants, bioaccumulation, and biomagnification and mentioning these concepts various times during the day). The Inualthuyak School personnel overall enjoyed the presentations and activities proposed to students and welcomed the researchers' engagement in the classroom. Maeva Giraudo

Figure 6. Combining art and science to learn about ringed seal distribution. Inualthuyak School students colored paper ringed seals (right) and glued them on a ringed seal distribution map (left) (pictures shared with parental permission).

left a written workshop assessment survey to be filled by school personnel. She also shared with teachers some educational material (posters) that could be used in future classroom activities to consolidate and expand learning that took place during the workshop. Upon workshop completion, all members of the scientific team completed an *Instructor debrief guide* aiming to document their perspectives on what worked well (best practices), and how this workshop could be improved (lessons learned) in future years.

Capacity Building and Training

A key objective of this workshop was to build capacity among Sachs Harbour community members to engage in contaminants research. All the activities conducted with Sachs Harbour community members were described in the 'Community Engagement' section above (i.e., delivery of a one-day workshop at the school, involvement of various community partners in workshop planning, and meetings with various community organizations). In addition, Mick Appaqaq, a student from the Arctic College Environmental Technology Program (ETP) in Iqaluit, and Cassandra Debets, a doctoral candidate from the University of Manitoba conducting research on ringed seals, co-led the Sachs Harbour workshop as a way to increase the capacity northern students and early career scientific researchers to meaningfully engage with northern community members in contaminants research. Jennifer Provencher engaged with the Aurora College about student participation in the event but unfortunately the timing was not ideal for their busy semester that was already underway. The college connected us with Greg Elias, an Aurora College alumni working as Conservation Officer in Sachs Harbour.

Communications and Outreach

In addition to communications and outreach activities that were conducted in collaboration with Sachs Harbour community members (please refer to 'Community Engagement' section above), conference presentations were made about this project in 2017/2018. A poster entitled *Learning about ringed seal health from contaminants science and Inuit Qaujimajatuqangit: an educational workshop in Resolute, Nunavut* was presented at the Arctic Change Conference in Québec City, December 2017, and at the NCP Results Workshop in Yellowknife in September 2017. Oral presentations entitled *Trends of legacy and emerging contaminants in ringed seals from the Canadian Arctic: When science and Indigenous* *knowledge meet* were also made by Houde at SETAC North America in Minneapolis, November 2017, and at the NCP Results Workshop. We also hope to make a presentation about this project at the 2018 ArcticNet conference in Ottawa.

Indigenous Knowledge

This workshop provided an opportunity for two Inuvialuit elders from Sachs Harbour (Betty Haogak and John Keogak) to share their knowledge with students and researchers in seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game. Moreover, during the workshop Mick Appaqaq (ETP student) was responsible for 'pilot-testing' a student-developed hunter survey designed during the 2017 NCP Wildlife Contaminants Workshop held at the Nunavut Arctic College. This survey was developed by ETP students in Iqaluit for collecting local/ Indigenous knowledge that may be associated with contaminants in ringed seals, and can be administered by northern students to help increase their involvement in local research. With support from Magali Houde, Mick Appaqaq asked survey questions to Betty Haogak and John Keogak during the workshop, recorded their answers, and worked with other researchers to summarize what questions worked well, and what questions needed to be adjusted in order to collect the right information. A report summarizing results from this 'pilot' local/ Indigenous knowledge survey will be shared with project collaborators and partners by the end of August 2018 (see 'Results and Outputs/Deliverables section below' for details).

Results and Outputs/Deliverables

A number of community members from Sachs Harbour participated in the workshop held at the Inualthuyak School (see 'Community Engagement' section for details). Students, school personnel, and elders took part in the workshop. Additionally, Sachs Harbour HTC members contributed to workshop planning and attended a meeting during which project information was shared. The school workshop was completed in January 2018. By the end of August 2018, we will finalize a full project report (i.e., including a summary of project activities, results from the pilot Indigenous knowledge survey, feedback received from participants and researchers, and a coloured poster summarizing the project) that we intend to share with NCP, other project partners, and interested individuals/organizations. Main project outcomes are:

- students, elders, school personnel, and community members worked together with scientific researchers to increase understanding of contaminants in ringed seals and learn from Inuvialuit knowledge about seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game;
- local students actively engaged with several types of interactive classroom activities (presentations, laboratory activities, group discussions, storytelling, games, and art activities) and school personnel welcomed researcher engagement in the classroom;
- participation of one ETP student and one graduate student contributed to increasing the capacity of northern students and early career scientific researchers to meaningfully engage with community members in contaminants research in Inuit Nunangat; and,
- we 'pilot-tested' a student-developed hunter survey for collecting local/ Indigenous knowledge that may be associated with contaminants in ringed seals. This survey can be administered by local students to help increase their involvement in contaminants research.

Discussion and Conclusions

This ringed seal 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 a workshop which included topics such as Arctic food webs and the importance of country food. Through this workshop, we were able to identify a number of best practices for sharing information about contaminants research with northern schools through workshops, including:

- having a flexible approach to workshop programming (being able to make last minute changes depending on the interests and needs of students and teachers, and local circumstances);
- developing teaching tools that can be easily adapted to various age groups (and dividing students into smaller groups according to age for certain activities);
- preparing additional educational material that can be left with teachers;
- taking the time to introduce new concepts through interactive activities; and,
- conducting a mix of interactive hands-on activities and short presentations.

Active participation of students of various ages during workshop activities, and feedback received from community members and scientific researchers indicated the interest of all parties to continue this work. This positive feedback has 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. In fall 2018 (pending NCP funding), we propose to carry out a similar workshop in Arviat, Nunavut, another community contributing to the long-term core ringed seal monitoring program under NCP. Our ultimate goal would be to hold an educational workshop in all four communities that contribute to this core monitoring project (i.e., Resolute, Sachs Harbour, Arviat and Nain). Workshop rotation between communities could be ongoing in the future.

Expected Project Completion Date

The 2017/2018 edition of the ringed seal workshop will be fully completed by December 2018.

Acknowledgments

We would like to thank the Inualthuyak School in Sachs Harbour, NWT, for their hard work in planning and hosting the workshop, especially Karen Bibby and Nick Kopot. We are grateful to the Sachs Harbour HTC and Kyle Wolki, who supported and helped carry out the workshop. Thanks to John Keogak and Betty Haogak who shared their knowledge about seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game. Thanks also to Jeff Kuptana for his support of ringed seal sampling activities. Finally, we would like to that the NCP for their funding and support.

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Program Coordination and Indigenous Partnerships

Coordination du programme et partenariats autochtones

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

- **Project Leader/Chef de projet**
  James MacDonald, Senior Analyst, Natural Resources and Environment, Council of Yukon First Nations, 2166 Second Avenue, Whitehorse, Yukon, Y1A 4P1
  Tel: (867) 393-9200, ext 9235; Fax: (867) 668-6577; Email: James.Macdonald@cyfn.net
- **Project Team/Équipe de projet**
  Yukon First Nations; Members of the Yukon Contaminants Committee, including: Mary Vanderkop, Ainslie Ogden, and Dr. Brendan Hanley, Yukon Government; Mary Gamberg, private consultant and researcher; Ellen Sedlack, Government of Canada; Derek Cooke, Ta'an Kwäch'än Council
- **Project Location/Emplacement(s) du projet**
  Whitehorse, YK

Abstract

As with the previous year, the Council of Yukon First Nations (CYFN) has continued to be an active member of the Northern Contaminants Program (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 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) siège activement au Comité de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN). Notamment, il répond aux demandes de renseignements, participe aux réunions et aux activités du Comité des contaminants du Yukon, informe les conseils des Premières Nations du Yukon et des ressources renouvelables au sujet de l'appel de propositions annuel, tient à jour le site Web du PLCN au Yukon et collabore 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 which 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 such research and contributing Indigenous knowledge.

Messages clés

- Nos aliments traditionnels prélevés dans la nature 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 susceptibles de poser des problèmes sont rejetés dans l'atmosphère et dans l'eau.
- Les effets des changements climatiques sur la mobilité des contaminants et les besoins en matière de charge en contaminants doivent faire l'objet d'un suivi.
- Les travaux liés au PLCN sont toujours pertinents aux échelons 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

The Council of Yukon First Nations aims to:

- enhance the confidence of Yukon First Nations in making informed decisions about traditional country food consumption and other health related factors;
- ensure that Yukon First Nations are aware of the latest research regarding the transportation of long-range contaminants to the Yukon Territory and the effects of those contaminants on the environment and human health;
- ensure that the programs offered by – and the research done for – the NCP meets the needs of Yukon First Nations; and,
- 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 on addressing northern community concerns because 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 for the NCP; 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 harvest country foods.

Activities in 2017-2018

Over the past year, the CYFN participated in NCP Management Committee meetings held in Ottawa in October to review the call for proposals, the funding envelopes and to advise the Program on the Yukon Contaminants Committee's activities and recommendations. The CYFN also attended the spring Management Committee meeting in Nain, Labrador, in April 2018.

As part of a revised mandate by its Leadership Board, the CYFN has shifted its focus of the activities and projects it undertakes. As a result, the CYFN no longer administers the operating aspects of the Little Fox Lake air quality monitoring site. However, the CYFN continues to support the project through proposal review and through meeting with the researchers annually.

Northern Capacity Building and Training

The CYFN participated in the work of the Yukon Contaminants Committee, which met several times over the course of the reporting period, including in November 2017 and February 2018. The Committee met with researchers, discussed communications on contaminants issues and reviewed proposals submitted to the NCP that wanted to conduct research in the Yukon Territory. The CYFN worked with researchers to disseminate information on their research and engaged with communities in all aspects of their work. The Yukon Contaminants Committee reviewed each of the proposals for projects to take place in or connected to the Yukon, made comments, and generally assessed the value of those projects. These assessments were relayed through recommendations to the NCP Secretariat and later to the Management Committee.

There were some opportunities for Northern Capacity Building and Training provided to Shailyn Drukis, the CYFN Climate Change Community Liaison, who signaled an interest in the NCP. Shailyn attended the Results Workshop in Yellowknife on behalf of the CYFN in September 2017 and the February 2018 meeting of the regional contaminants committee in Whitehorse. In addition, the CYFN assisted Yukon Contaminants Committee member Derek Cooke with travel to Quebec City, Quebec, to attend the annual ArcticNet conference in December 2017.

James MacDonald and Ellen Sedlack both attended the CYFN General Assembly in Carcross, Yukon in June 2017 and were available to answer any questions about the NCP and its Yukon chapter. Moreover, information was provided to Yukon communities on the NCP program and funding opportunities. This was directly related to the contaminants workshop that was held in March 2017 in Whitehorse and is forming the basis for new interest and new projects from the Yukon.

Communications

The CYFN maintains and updates the website www.northerncontaminants.ca. The site documents activity carried out by researchers active on contaminant issues in the Yukon Territory and provides information on contaminants of concern. Currently, the content of this website is under development with a view to updating and expanding its scope, including a description of the Yukon Contaminants Committee and a description of the projects undertaken in recent years. The revised website is expected to be launched in summer 2018. This work is being done with the assistance of the researchers whose work will be portrayed on the site.

A scoping call was hosted by the CYFN with the web contractor, Mary Gamberg and Ellen Sedlack in February 2017 with a view to discussing short-term and long-term deliverables. Some of the short-term deliverables are complete but the bulk of the updates will occur during the 2018-19 cycle.

Indigenous Knowledge

The CYFN did not participate in Indigenous knowledge committee meetings, as there is no such committee yet established. However, the CYFN did review submitted proposals during the social and cultural review on February 5, 2018, with an eye to Indigenous knowledge components and made comments as appropriate to other members of the Yukon Contaminants Committee and to the NCP Secretariat.

Results

- Attended Management Committee meetings to recommend funding for potential NCP projects.
- Attended the NCP Results Workshop in Yellowknife, Northwest Territories, in September 2017.
- Communicated information on contaminants and the NCP to Yukon First Nations.
- 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 2018 Management Committee meeting in Nain, Labrador.
- Attended the NCP proposal review integration meeting and reviewed and commented on the proposals of the other Aboriginal organizations as requested by the Secretariat.
- Reviewed and developed the northerncontaminants.ca website with assistance from Mary Gamberg and Ellen Sedlack.
- Met with Environment and Climate Change Canada researcher Hayley Hung to discuss the Little Fox Lake air monitoring site.
- Met with local researcher Mary Gamberg on her projects, and assisted with refining the communication pieces attached to that research.

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. Concerns about Moose and Caribou mercury levels have been heard from Yukon First Nation communities. 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

Ongoing.

Project website (if applicable)

www.northerncontaminants.ca

Acknowledgments

The CYFN would like to acknowledge the in-kind and funding support received by the NCP and its Secretariat, along with the contributions of all the members of the Yukon Contaminants Committee. Special thanks go out to Ellen Sedlack for her contribution to assisting the CYFN with maintaining its involvement in the NCP through the recently completed renewal of its corporate mandate.

Dene Nation participation in the national NCP Management Committee (NCPMC) and Northwest Territories Regional Contaminants Committee (NWTRCC)

Participation de la Nation dénée au Comité de gestion national du PLCN et au Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO)

- **Project Leader/Chef de projet**
  Trevor Teed, Director, Lands and Environment, Dene National/AFN Regional (NWT) Office
  5120-49th Street, P.O. Box 2338, Yellowknife, NT X1A 2P7
  Tel: (867) 873-4081 (extension 29); Fax: (867) 920-2254; Email: lands@denenation.com
- **Project Team/Équipe de projet**
  Bill Erasmus, Dene National Chief/AFN Regional Chief NWT; Aleksandra Taskova, Coordinator, Lands and Environment, Dene National/AFN Regional Office (NWT)
- **Project Location/Emplacement(s) du projet**
  Dene National Office, Yellowknife, NT

Abstract

Dene Nation received funding from the Northern Contaminants Program (NCP) through the Program Coordination and Indigenous Partnerships envelope for the fiscal year 2017-2018. The funds supported its participation in the NCP Management Committee and the NWT Regional Contaminants Committee (NWTRCC). Additional funds were provided for the Dene Nation Land and Environment Committee to attend the NCP Results Workshop at Yellowknife during September, 2017. Unfortunately, the entire committee could not attend.

The Dene Nation participated in two NCP Management Committee meetings at Ottawa, ON, attended NWTRCC meetings and

Résumé

La Nation dénée a reçu du financement dans le cadre du PLCN, de l'enveloppe de coordination des programmes et partenariats avec les Autochtones, pour l'exercice 2017-2018. Ces fonds ont appuyé la participation de la Nation dénée au Comité de gestion du PLCN et au CRCTNO. Des fonds supplémentaires ont été accordés pour permettre au Comité des terres et de l'environnement de la Nation dénée de participer à l'atelier sur les résultats du PLCN à Yellowknife, qui a eu lieu en septembre 2017. Malheureusement, l'ensemble du comité n'a pas pu y assister.

La Nation dénée a participé à deux réunions du Comité de gestion du PLCN à Ottawa, en Ontario, ainsi qu'aux réunions du CRCTNO et

participated in teleconferences. In addition, the Dene Nation reported to the Dene Leadership meetings and to the Dene National Assembly. Information sharing enhanced communication between the Dene National office and its communities. Communications with the NWTRCC was maintained.

Dene Nation is also engaged with revamping its website (denenation.com) to allow easier access for its membership to information on contaminants. The revamped site is expected to be complete by the end of May 2018.

à des téléconférences. De plus, elle a présenté des rapports lors de réunions des dirigeants dénés et à l'Assemblée nationale de la Nation dénée. Ces échanges d'information ont permis d'améliorer la communication entre le Dene National Office et les communautés dénées. Les communications avec le CRCTNO ont été maintenues.

La Nation dénée s'emploie également à remanier son site Web (denenation.com) afin de faciliter l'accès de ses membres à l'information sur les contaminants. La refonte du site devrait être achevée d'ici la fin de mai 2018.

Key Messages

- The Dene Nation participated on NCP Management Committee.
- The Dene Nation participated on the NWTRCC.
- The Dene Nation provided advice to NCP on contaminant issues in the communities.
- The Dene Nation liaised on NCP activities within 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 aim of the Dene Nation participation in NCP 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;
- involve Dene Nation Lands & Environment Committee;
- work closer with the Dene regions;
- work closer with the other Indigenous regions; and
- to participate fully in all activities of the NWTRCC and NCPMC.

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.

Funds provided to the Dene Nation under the NCP for 2017-2018 allowed the Dene Nation to work with the NCP Secretariat and other Indigenous Partners to address contaminant issues in research and monitoring projects, perform a social/cultural review of proposals, and to participate in initiatives to update the NCP Blueprint for Communications, Capacity and Outreach.

Funding also enabled Dene Nation to consider internal capacity and coordination issues, and for the Dene Nation and the NWTRCC to bring the Dene Nation Environment Committee to Yellowknife to attend the NCP Results Workshop. The intent is that committee members will be prepared to inform the Dene communities about the NCP funded projects and to get community input to future studies needed in the Dene regions.

Activities

The Dene Nation participated in the NWTRCC and the NCP Management Committee meetings and teleconferences scheduled between April 01, 2017 and March 31, 2018 and all NWTRCC meetings during the fiscal year including the February 6-8, 2018 meeting to review proposals. The Dene Nation also attended the Management Committee Meetings in Ottawa April 11 & 12, 2017 and October 17-19, 2017 meeting. The Dene Nation and some of its Environment Committee attended the NCP Results Workshop at Yellowknife, September 26-28, 2017. Lastly, The Dene Nation confirmed two members (Akaitcho and Dehcho regions) to its Land and Environment committee and an acting member representing the Gwich'in.

Community Engagement

Community engagement took place more often between the regions that named a person to the Land & Environment Committee than with regions that did not name members. There was some engagement between Dene Nation and some of the Chiefs and the Dene Leadership meetings but little other engagement took place.

Capacity Building and training

Capacity building was evident only with the members of the land & Environment Committee whom attended the Results Workshop.

Communications and Outreach

Communications and outreach initiatives occurred through emails and Facebook. The Dene Nation website has been upgraded and once the author completes training in May 2018, the site will be fully operational.

Indigenous Knowledge

The Dene Nation did not contribute Dene Knowledge to NCP projects. However, at the management committee meetings and at NWTRCC meetings, Dene Nation is supportive of projects in which Indigenous Knowledge is incorporated.

Results and Deliverables

Dene Nation participated in all NWTRCC, NCPMC, teleconferences and Result Workshop sessions.

Discussion/Conclusions

The funding from the NCP supported the Dene Nation to participate in two NCP Management Committee meetings, an NCP Results Workshop, a NWTRCC proposal review meeting, and several teleconferences.

Some members of the Dene Nation's Environment Committee were able to take part in and attend the Results workshop in Yellowknife. The timing of the release of funds for the Contribution Agreement with the Dene Nation created some issues.

Dene Nation engaged with its Leadership at the Dene National Assembly, where the NCP

Secretariat presented to the membership, and at three subsequent Leadership meetings. These engagements led to the Dene National Chief sending a letter about its issues with the NCP to Minister Bennett during February 2018 and a follow-up letter to Minister Bennett was also sent with an attached Motion of support by the Dene Leadership which was unanimously passed.

Expected Project Completion Date:

Ongoing

Acknowledgements

The Dene Nation would like to thank the NCP and other involved parties on their continued funding and/or support.

Inuit Tapiriit Kanatami National Coordination

Coordination nationale d'Inuit Tapiriit Kanatami

Project Leader/Chef de projet

Eric Loring, Senior Environment Researcher and Policy Advisor, Department of Environment and Wildlife, Inuit Tapiriit Kanatami, Ottawa, Ontario K1P5E7
Tel: 613 238 8181 X234; Email: loring@itk.ca

Project Team/Équipe de projet

John Cheechoo (Director), Environment and Wildlife Department, Ottawa, Ontario, Inuit Tapiriit Kanatami; Dr. Scot Nickels (Director), Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC) Ottawa Ontario; Inuit Circumpolar Council-Canada; Nunavut Environment Contaminants Committee (NECC); NWT Regional Contaminants Committee (NWTRCC); Nunatsiavut Government Research and Advisory Committee (NGRAC); Nunavik Nutrition and Health Committee (NNHC)

Project Location/Emplacement(s) du projet

- Ottawa, ON
- Inuit Nunangat, Canada

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 to the Northern Contaminants Program.

As the national political voice of Canadian Inuit, ITK continues to play multiple roles within the NCP. ITK provides guidance and direction to Crown-Indigenous and Northern Affairs (CIRNAC) and the other NCP partner's (Health Canada (HC), Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), etc.), bringing Inuit interests to 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. Also, ITK is dedicated to

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. ITK fournit conseils et orientations à RCAANC et à d'autres partenaires du PLCN (Santé Canada, Pêches et Océans Canada, Environnement et Changement climatique Canada, entre autres), dans le but d'accroître l'intérêt des Inuits envers le comité de gestion et de liaison du PLCN dont nous sommes membres. En conséquence, le PLCN peut mieux répondre aux besoins et mieux réagir aux préoccupations des Inuits. De plus, ITK s'emploie à faciliter des communications

facilitating appropriate, timely communications regarding contaminants in the North. Working with their Inuit partners at the Inuit Circumpolar Council (ICC)-Canada, ITK also works on the international stage to persuade nations to reduce the generation and use of persistent organic pollutants (POPs) and heavy metals (mercury) that end-up in the Inuit diet. Lastly, ITK works with other research programs to ensure that research on contaminants is conducted in a coordinated approach.

Keys Messages

- The ITK national coordinator continues to provide a voice for Inuit Nunangat during NCP discussions;
- The ITK national coordinator continues to be an active and constructive member of the NCP Management Structure, ensuring that the contaminants issue and NCP research and results are communicated to Inuit and that Inuit are represented at key regional, circumpolar and international meetings and initiatives;
- The ITK national coordinator continues to contextualize contaminant information in a broader communication process using the Inuit Knowledge Centre and other ITK structures (i.e. National Inuit Committee on Health (NICoH));
- The ITK national coordinator continues to develop the confidence of Inuit in making informed decisions about country food use; and
- The ITK national coordinator continues to coordinate contaminants activities with other research programs.

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. Enfin, ITK collabore avec d'autres programmes de recherche pour veiller à ce que la recherche sur les contaminants soit menée de façon concertée.

Messages clés

- Le coordonnateur national d'ITK continue de se faire le porte-parole d'Inuit Nunangat dans les délibérations du PLCN.
- Le coordonnateur national d'ITK continue d'être un membre actif et constructif de la structure de gestion du PLCN. Il veille à ce que les questions relatives aux contaminants et les recherches du PLCN soient communiquées aux Inuits, et à ce que les Inuits soient représentés aux principales réunions ainsi que dans les initiatives importantes à l'échelle régionale, circumpolaire et internationale.
- Le coordonnateur national d'ITK continue de contextualiser les renseignements relatifs aux contaminants dans un contexte de communication plus vaste par l'intermédiaire du CSI et des autres structures d'ITK (p. ex. le Comité inuit national de la santé [CINS]).
- Le coordonnateur national d'ITK continue de renforcer la confiance des Inuits afin de leur permettre de prendre des décisions éclairées au sujet de la consommation des aliments prélevés dans la nature.
- Le coordonnateur national d'ITK continue de coordonner les activités sur les contaminants avec d'autres programmes de recherche.

Objectives

Short Term

In the short term, as an NCP partner, the ITK aims to:

- participate in the NCP through contribution to the Management Committee, Regional Contaminant Committees and NCP review Teams;
- participate in the ArcticNet general meeting/ Research Management Committee (RMC) and Integrated Regional Impact Studies (IRIS) preparations, and review of IRIS reports;
- participate with Inuit Research Advisors, their teleconferences and in person meetings;
- participate in the Nasivvik Research Chair in Ecosystem Approaches to Health program;
- promote and provide NCP information to regular ITK Board of Directors (BOD) meetings;
- participate in, and provide a voice for, NCP at Public Health Task Group, National Inuit Committee on Health, Inuit Early Childhood Development Programs, National Inuit Food Security Group, Canada's Chemical Management Plan and Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC);
- participate in the National Inuit Climate Change Committee, National Wildlife Committee meetings, Health Canada/ CIRNAC Climate Change Programs;
- help researchers and continue with mentorship and education;
- ensure that the NCP incorporates and addresses Inuit specific concerns/needs related to contaminants research;
- facilitate the awareness of, and access to, general information on contaminants among Inuit communities;
- facilitate the exchange and coordination of activities and information among Inuit organizations at various levels;
- develop priorities, and investigate issues, within the NCP framework and incorporate NCP concerns into the Inuit Knowledge Centre;
- contextualize contaminant information in a broader communication process using the Inuit Knowledge Centre and other working groups (i.e. NICoH, Public Health, Food Security, Climate Change);
- develop the confidence for Inuit in making informed decisions about country food use;
- continue to be an active and constructive member of the NCP management structure, ensuring that contaminants issue and NCP research and results are communicated to Inuit and that Inuit are represented at key regional, circumpolar and international meetings and initiatives;
- coordinate contaminants activities with other research programs; and,
- develop training programs and mentorship for Inuit.

Long Term

In the long term, as an NCP partner, the ITK aims to:

- 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 environmental and wildlife issue affecting Inuit;
- support the enhancement of Inuit capacity to better address environment and wildlife priorities;
- develop training programs and mentorship to Inuit; and,
- provide a voice for Inuit of Canada during discussions.

Introduction

The story of contaminants in the Arctic can be one of fear of the unknown for the Inuit; research carried out under NCP has shown that the contaminants of most concern for Inuit are persistent organic pollutants (POPs) and heavy metals, like mercury. The concern of these contaminants comes from the fat-rich marine country foods diet that Inuit depended upon, both for nutritious food and sustaining a lively culture. As a result, there are places in the Canadian Arctic where 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 in Nunavik show that Inuit children are experiencing subtle negative effects due to prenatal exposure to Polychlorinated biphenyls (PCBs) and mercury. Inuit want, and have the right, to know what is happening to the health of Inuit, and to the health of the Arctic environment. With this alarming data, it is critical that there is Inuit involvement in all aspects of the Northern Contaminants Program in order to provide advice, direction and information to Inuit.

Activities in 2017-2018

Funding from the NCP to ITK comes from the funding National Coordination envelop, 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. For a complete itemized list of activities please see Appendix A.

Our main body of work continues to focus on the Regional Contaminants Committee (RCC) which is the heart of the NCP. Although illness forced 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 ITK. 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 the ITK Health and Social Economic Development Department to bring concerns to the Inuit Public Health Task Group. Last year, with formation of the Wildlife and Environment department, we developed stronger regional wildlife contacts through which we vet NCP environment contaminants 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 guide ICC in their global efforts to eliminate mercury use.

ITK also participated in all of the NCP management meetings, as well as various review committees, such as the Human Health review, the Environment Trends, Community Base Monitoring and Research, and Communication and Capacity Outreach teams. This year there was close to 40 projects that are took place in the Inuit regions including: 4 proposals in the Human Health folder, 6 proposals in the Community Based Monitoring and Research folder,

23 proposals in the Environmental Monitoring and Research Folder (12 core project and 11 new projects), and 9 proposals in the Education and Communication folder. ITK involvement in these projects ranged from minimum advisory role to very intensive project supervision.
ITK has guided researcher in various

environmental monitoring programs on how to communicate to communities, translating scientific information, making links to other research programs, encouraging capacity building and funding. ITK will continue to assist both the researchers and the Inuit regions and communities with the conclusion of these projects.

Participation on these committees provided a voice for the Inuit of Canada, developed priorities and issues within NCP framework, developed confidence for Inuit in making informed decisions on their food, and coordinated contaminant activities with other research programs, such as ArcticNet and Nasivvik, to ensure that the message of contaminants are placed in a wider context and conducted in a responsible manner throughout the Arctic. The ITK also provided support, via teleconference calls, for the Inuit Research Advisors (IRA's), who are partially funded by the NCP. The main objective of this support was 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 making good informed decisions about their food use.

Community Engagement

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 it to better respond to the needs and wishes of Inuit with respect to the design and delivery of specific projects. ITK involvement also allows the program to respond to Inuit needs and wishes while defining the Canadian positions in international processes.

Capacity Building and Training

ITK has continued to work with the NCP partners and Inuit in the regions to enhance the level of involvement and employment of community members in all NCP activities. Extensive use is made of local capabilities, and a mix of small and large projects has been useful in capacity building and skills bases at the community level as well, local people gain training and employment through working with researchers.

Capacity building at the regional level has also been successful, primarily through involvement in policy and research activities with ITK and the other regional organizations. Development of co-management and wildlife policy has been particularly useful under the general rubric of the NCP. Capacity building and training are fundamental to each objective in this project. Further, an intended outcome is the training of youth and thus youth are a targeted audience. Throughout the life of the project youth will be engaged via ITK's Youth Coordinator and the National Inuit Youth Council. Additionally, eLearning is an emerging tool to support knowledge exchange and capacity building and it is a priority of the NCP as well as ITK's and Inuit Qaujisarvingat: The Inuit Knowledge Centre. Capacity will be built at the researcher level as well, with training and other opportunities for researchers to work directly with ITK. Capacity will be built at the regional level with ITK participation at the RCC's and helping with transfer of knowledge to the newer members of the committees.

Training Inuit Researchers

With the launch of the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC) and the recent Amaujaq National Centre on Inuit Education and the announcement of the High Arctic Research Station there are more activities, training and education available to Inuit, such as the IRAs, frontline workers, and community representatives. With the ultimate goal of ensuring that research in the North is led and developed by Inuit, ITK, with support from the NCP, will continue in its process of mentoring, training and foster Inuit researchers at the National, Regional and Community level.
It's vital that training activities are conducted and viewed at this scale (National-Regional-Community), this is the established network that Inuit have organized and developed in order to use information generated at the

community level to inform policy at the national-international level as well as take information developed at the National level and bringing it back to the community. When any link of this network is compromised information flow is jeopardized. With the influx of research from various arctic programs, such as the NCP, ArcticNet, Nasivvik and IPY, it is critical that we continue to find ways to mentor engage and train Inuit.

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 the NCP and into ITK programs for instance updating messaging for the original NIQIIT course. The Project Team will also utilize forums at ITK like the recently launched Amaujaq National Centre for Inuit Education and the National Inuit Educational Strategy and 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 at 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

Inuit Research Advisors

The Inuit Research Advisors are a key component to the success of the NCP. For the IRA to continue to be successful the recent IRA training manual outlined the need for 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 with NCP researchers and NCP frontline workers to establish needs and address concerns.

Itemized activities list

The ITK activities related to capacity building and training for the year include:

- developing of a Climate Change Strategy using NCP research;
- helping to finish the Inuit research strategy with IKC;
- continuing the upkeep of IKC Online Contaminants Course (www.inuitknowledge.ca);
- forming a close working partnership with the Inuit Knowledge Centre (IKC). Using this relationship, the ITK was able to use the NCP as a "model" program for other research program development. As well, the IKC provided guidance to the NCP to direct both the program and researchers towards valuable research initiative and projects. The ITK also trained Inuit at the community and regional level so they can be more active members on NCP research.
- teaching Inuit students at Nunavut Sivuniksavut which is a unique eight-month college program based in Ottawa. The college program 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;
- continuing to play a key role with ArcticNet to ensure that the research being conducted there avoids overlap or duplication and to assisted with the ArcticNet students association to complete research in Inuit communities. This student mentorship has been very successful as evidence by the past Inuit Award recipients, such as Lisa Loseto and Shawn Donaldson, who have continued to work with NCP, ArcticNet and Inuit communities in their research; and,
- continuing work with Carleton University related to the teaching of Arctic and Inuit contaminant issues to university students (presentation of this year's presentation is available)

Communication and outreach

The ITK 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.

Communications and outreach activities include:

- ITK weekly management meetings providing updates to ITK directors and President on NCP research which will feed into ITK Executive speeches and policy forums and social media;
- continuing to work with the Chief medical officers to explain the NCP program and research when needed; and,
- Providing critical updates to other programs like Inuit early childhood development and food security

Indigenous Knowledge

As well as active participation in the above committees and forums, ITK will continue to be available for ad hoc review committees generated by NCP research, will work and provide input into the NCP Assessment Reports (this year's Synopsis of Research report) and provide direction and information to Canada's other programs dealing with contaminants issues, most notably Environment Canada's Chemical Management Plan and Commission for Environmental Cooperation (CEC) and the Metal Mining Effluent Regulations Sub-group.

Long Term Activities

- ITK has now developed a Research Team at ITK which discusses NCP research issues on a weekly basis which will feed into the Inuit Knowledge Centre, department of health and social economic, communications and ITK Executive speeches and policy forums.
- ITK has been working with the Chief medical officers to explain the NCP program. This will continue each year as updates and information items when needed.
- Inuit Knowledge Centre (IKC) will have great benefit to the future of the NCP in helping guide and direct 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. This year deliverable includes the development of a National Inuit Strategy on research (https://itk.ca/national-strategy-on-research/).
- ITK is 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.

In relation to contaminant issues, ITK continues to be the national voice of Inuit, and with partnerships and through our board ITK continues to operate on both the national and the circumpolar and international stages. ITK continues to provide advice and direction to

Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC), additional federal agencies, the territorial governments, and other partners in the NCP. This advice and direction brings national and international perspectives and representing the interests of Inuit to NCP managers and liaison committees. We believe firmly that our involvement in the program enables it 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.

Results

Part of our responsibilities with the NCP funding is to consult with the principal investigators and communities that will be engage in research in Inuit regions. This year there was close to 40 projects that took place in the Inuit regions. ITK involvement in these projects can range from minimum advisory role to very intensive project supervision. ITK has guided researcher in various environmental monitoring programs on how to communicate to communities, translating scientific information, making links to other research programs, encouraging capacity building. Going forward, ITK will continue to assist both the researchers and the Inuit regions and communities to communicate the conclusions of these projects. To accomplish this ITK was committed to providing a coordination role for Inuit to attend the NCP Risk Communication Workshop.

Long Term goals continue to be successfully fulfilled due to the long term nature of this research program. Now with renewed connections to wildlife and environment organizations in Inuit Nunangat, we will determine, identify, and implement environmental and wildlife research and policy priorities for Inuit Nunangat over the next years. At the same time, we will use the tools and expertise established from ITK's Health and Social Development department to maintain and strengthen working relations among Inuit regions on matters not only of environment and wildlife research related, but health concerns and data as well. To do this, ITK will communicate regularly with the appropriate departments of the Regional Inuit Organizations in order to keep them informed of national and international developments on environmental, wildlife, and human health issues and policy.

NCP and Inuit regions have developed a very strong network to communicate NCP research. ITK will seek regional direction for the purposes of developing departmental strategies and action plans, and work collaboratively with other ITK departments, as well as with ICC Canada, Pauktuutit National Inuit Women of Canada, and the National Inuit Youth Council on environment, wildlife, and human health research and policy related developments and initiatives. Thereby, ITK working with the regions can provide a voice for Inuit of Canada during NCP discussions, as well as informing and educating regional Inuit organizations about the Northern Contaminants Program and pertinent national and international initiatives on Arctic contaminants

As well as working closely with Inuit regions, ITK will continue to foster relationships and our networks with government departments, other national aboriginal organizations, non-governmental organizations, and academic institutions on a case-by-case basis to advance the interests of Inuit.

One of the biggest roles that we can play is to continue with our education and support of scientists engaging Inuit communities in meaningful consultation, the responsible return of research results and feasible modes of capacity development in concert with research activities.

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 from 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.

Discussion and Conclusions

In a time of great turn over and changing personally, ITK's engagement to the NCP committees has been the one constant over the last 20 years. This has provided each of the contaminants committee with some record of history. This year, ITK worked with each of the four regional committee's (Nunatsiavut, Nunavik, Nunavut, and the NWT), engaged with the NCP review teams, helped with the development of the new Risk Communication Subcommittee, participated and helped with any issues that NCP needed assistance with. As it did this year, ITK will continue to sit on all contaminant committees (Nunatsiavut, Nunavik, Nunavut and Inuvialuit) and NCP Management and Human Health, Community Based Monitoring, and Education and Outreach review teams and bring to these discussions and committees information learned from participation with the Inuit Public Health Task Group, Food security committee, mental wellness committees, early childhood development, Inuit Health Survey, National Inuit Committee on Health, Nasivvik, ArcticNet, FNIB community based climate change program, youth programs like NS and the National Inuit Youth Committee. Support from the NCP will continue to allow ITK to participate in all these initiatives and be able to bring a contextualization to the NCP program and other national programs like Chemicals Management Plan and Commission for Environment Cooperation (CEC) and to Inuit regions.

Expected Project Completion Date

Ongoing

Project Websites

www.itk.ca

http://www.inuitknowledge.ca/

http://30214.vws.magma.ca/index.php

Appendix A – Itemized List of Activities

General NCP Activities:

- 2 Management meetings
- 3 NNHC meetings
- 2 NECC meetings
- 2 NWT meetings
- 2 NGRAC meetings
- 4 Human Health Review team meetings
- 3 Community Monitoring meetings
- 1 Community Outreach meeting

General meetings

- ITK BOD
- Chan proposal meeting
- IKC meetings
- NICOH
- Food Security Working Group
- Gina Muckle Results group
- CINE meeting
- 3 Chemical Management plan
- CEC program
- Alaska health forum
- ITK public Health meetings
- ArcticNet IRIS meetings

Other NCP activities included

- Providing information to the National Food Security committee
- Providing information to the National Inuit Climate Change Committee
- Providing information to the national Inuit Committee on Health
- Working with the Museum of Nature Arctic Gallery and providing direction to the contaminants exhibit
- Participation on webinars both in Canada and Alaska providing NCP examples of risk communication and appropriate research methods
- Worked with a Northern Wildlife Health Group (with Brett Elkin) providing guidance and direction to the group
- Participated at the Northern Health Forum in Quebec City
- Worked with the NNHC in guiding and communicating results from Nunavik researchers for both publications, meetings and community use.
- Participated at the Food Security meeting in Nain Labrador
- Participated on the Minamata mercury discussions
- Help develop and participate a communication subcommittee for the chemical management plan
- Participated in ArcticNet legacy meetings
- Presentation to Carleton University and to Senior Government Executives for their preparation on their Arctic Tour.
- Worked with Carleton students on NCP issues for class projects

Inuit Circumpolar Council – Canada Activities in Support of Circumpolar and Global Contaminant Instruments and Activities 2017- 2018

Conseil circumpolaire inuit – Activités du Canada visant à appuyer les instruments et les activités de lutte contre les contaminants circumpolaires et mondiaux 2017-2018

- **Project Leader/Chef de projet**
  Tom Sheldon[1], Inuit Circumpolar Council – Canada, 75 Albert St, Suite 1001, Ottawa, Ontario, K1P 5E7
  Tel: (613) 563-2642/direct (613) 258-9471; Fax: (613) 565-3089;
  Email: tsheldon@inuitcircumpolar.com
- **Project Team/Équipe de projet**
  Eva Kruemmel, ScienTissiME, Barry's Bay, ON; Stephanie Meakin, Inuit Circumpolar Council – Canada, Ottawa, ON; Selma Ford, Inuit Circumpolar Council – Canada, Ottawa, ON
- **Project Location/Emplacement(s) du projet**
  Ottawa, ON

1 The project leader is now Eva Kruemmel, ScienTissiME/ICC Canada, email: ekruemmel@scientissime.com
La chargée de projet est maintenant Eva Kruemmel, ScienTissiME/ICC Canada, email: ekruemmel@scientissime.com

Abstract

This report outlines ICC Canada's activities funded by the Northern Contaminants Program (NCP) in the fiscal year 2017-2018. 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

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 2017-2018. Le CCI Canada travaille à l'échelle nationale et internationale en vue de 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

Persistent Organic Pollutants (POPs) is ongoing, with ICC Canada attending the 13th POP Review Committee (POPRC) in October 2017, and participating in a panel discussion during the first Conference of the Parties of the Minamata Convention on Mercury. ICC Canada continued to support Arctic Council activities and attended several meetings of the Arctic Monitoring and Assessment Programme (AMAP). ICC Canada was very active on the Sustaining the Arctic Observing Networks (SAON) Board, the SAON Executive Committee, and continued working on the organizing committee of the Arctic Observing Summit (AOS).

activités se rapportant au Programme des Nations Unies pour l'environnement (PNUE). Les travaux se rapportant à la Convention de Stockholm sur les polluants organiques persistants (POP) sont en cours, et le CCI Canada a assisté à la 13e réunion du Comité d'examen des POP en octobre 2017, en plus de participer à une table ronde lors de la première Conférence des Parties de la Convention de Minamata sur le mercure. Le CCI Canada a continué d'appuyer les activités du Conseil de l'Arctique et participé à plusieurs réunions du Programme de surveillance et d'évaluation de l'Arctique (PSEA). Le CCI Canada jouait un rôle fort actif au sein du Conseil des réseaux Sustaining the Arctic Observing Networks (SAON) et du comité exécutif des SAON, et continue de collaborer au comité d'organisation du sommet sur l'observation de l'Arctique.

Key Messages

- ICC Canada actively supported NCP by working on the Management Committee, Environmental Monitoring, Human Health and CBM technical review committees.
- ICC Canada attended the 13th POP Review Committee (POPRC) meeting, provided input in POPRC working group documents, and informed the NCP and AMAP about POPRC work.
- ICC Canada attended a panel discussion during the first Conference of the Parties (COP-1) of the Minamata Convention and provided information on how Inuit are impacted by mercury in the Arctic, as well as outlined monitoring activities in the Arctic under NCP and AMAP.
- ICC Canada actively contributed to the Arctic Council related work, attended the Arctic Monitoring and Assessment Programme (AMAP) Working Group and Heads of Delegation meetings, SAON meetings, teleconferences of the SAON Executive Committee and teleconferences of the Arctic Observing Organizing (AOS) Committee.

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.
- Le CCI Canada a assisté à la 13e 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 et le Programme de surveillance et d'évaluation de l'Arctique (PSEA) au sujet des travaux du Comité.
- Le CCI Canada a participé à une table ronde durant la première Conférence des Parties (COP-1) de la Convention de Minamata et a fourni de l'information sur les répercussions du mercure dans l'Arctique sur les Inuits, et défini les activités de surveillance menées dans l'Arctique en vertu du PLCN et du PSEA.
- Le CCI Canada a contribué activement aux travaux reliés au Conseil de l'Arctique, a assisté aux réunions du groupe de travail du PSEA et des chefs de délégation, aux réunions des SAON, aux téléconférences du comité exécutif des SAON, et aux téléconférences de Comité d'organisation de l'observation dans l'Arctique.

- 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). Follow-up work is planned for the fiscal year of 2018-2019.

- 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). Des travaux de suivi sont prévus à l'exercice 2018-2019.

Objectives

Short-term

The short-term aim of the Inuit Circumpolar Council is to:

- ensure Inuit are aware of global, circumpolar and national activities and initiatives on contaminants;
- 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; and,
- ensure that scientific research in the Arctic is addressing Inuit needs and is done with Inuit support and involvement.

Long-term

The long-term aim of the Inuit Circumpolar Council is 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; and,
- 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 grown 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 from the Northern Contaminants Program (NCP) of Crown-Indigenous Relations and Northern Affairs Canada has enabled ICC Canada to work effectively on addressing the issue of contaminants in the Arctic. ICC Canada is part of the NCP Management Committee, is directly involved with contaminant research in the Arctic, works within the Arctic Monitoring and Assessment Programme (AMAP) of Arctic Council, and represents Inuit at the United Nations Environment Programme (UNEP) and related meetings.

Activities in 2017-2018

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 2017-2018.

Northern Contaminants Program (NCP)

ICC Canada has been very active in the NCP, reviewed NCP proposals and participated in teleconferences/meetings of the Environmental Monitoring, Human Health, and CBM technical review teams, and provided comments for the NCP blueprints. ICC Canada attended Management Committee meetings in Ottawa on April 10 – 12, and October 17 - 19, 2017, and the Results Workshop in Yellowknife (September 26 - 28, 2017), where Stephanie Meakin gave a panel presentation (see Section 6 for details) and chaired the final plenary session on International Action and Partnerships. ICC Canada provided input into the NCP strategic plan. No new work of the NCP sub-committees took place in 2017-2018. Additionally, 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.

Arctic Monitoring and Assessment Programme (AMAP)

General

ICC Canada participated in the AMAP Working Group meeting (and the Heads of Delegation (HoD) meeting preceding it) on September 11th – 14th, 2017, in Reykjavik, Iceland, as well as the AMAP HoDs meeting February 7th – 9th, 2018 in Wendake, Quebec. ICC reviewed and provided input into AMAP documents before and after the meetings, in particular for AMAP reports, such as the Arctic Ocean Acidification, Chemicals of Emerging Arctic Concern and Contaminants of Biological Effects Assessment, and provided briefings about the meetings to the NCP Regional Contaminant Committees (RCCs).

Together with ICC Alaska, ICC Canada started working on an Inuit knowledge framework document, which is still in development. ICC Canada also attended the AMAP International Conference on Arctic Science (Bringing Knowledge to Action), which took place on April 24 – 27th, 2017 in Reston, Virginia; chaired a session on organic contaminants; gave a presentation on contaminant risk communication in the circumpolar Arctic and internationally (a summary of Chapter 6 of the last AMAP Human Health Assessment); and was part of a panel discussion (see below).

Further, at the last AMAP WG meeting, ICC Canada proposed the development of a pilot project to advance Indigenous participation and the utilization of Indigenous knowledge in the follow-up work for the SWIPA (Sea, Water, Ice and Permafrost in the Arctic) assessment. ICC will continue to work with its partners (including Sami Council, and the Canadian and Danish governments) towards the implementation of this pilot project. This pilot project will also feed into the development of the framework development.

Adaptation Actions for a Changing Arctic (AACA-C)

ICC Canada was part of AMAP's Integration Team of the Adaptation Actions for a Changing Arctic (AACA), reviewed drafts of two regional assessments, coordinated activities with the other ICC offices, took part in developing the summary for policy makers, and was a speaker in a panel discussion on AACA Baffin Bay/Davis Strait region at the AMAP conference.

Sustaining the Arctic Observing Network (SAON)

ICC Canada participated in teleconferences of the SAON Executive Committee, SAON Board, as well as teleconferences of the AOS organizing committee. ICC Canada also attended a workshop on June 27th – 28th 2017 in Frascati, Italy (with travel support from the European Space Agency), where the development of SAON's strategic framework and implementation plan was started. ICC particularly ensured that Indigenous knowledge, community-based monitoring and ethical research remain at the center of SAON's activities. This work is ongoing, and ICC Canada continues to participate and provide input.

Eva Kruemmel represents ICC on the SAON Board, the SAON Executive Committee, was a co-chair of the Arctic Observing Summit (AOS) that took place in Fairbanks, Alaska, in March 2016, and a member of the organizing committee of the AOS that took place in Davos, Switzerland in June 2018.

Arctic Council Health Expert Groups

ICC Canada is active in health expert groups of the Sustained Development Working Group (SDWG) and AMAP: the Arctic Human Health Expert Group (AHHEG) and the Human Health Assessment Group (HHAG), respectively. HHAG decided to publish the AMAP 2015 Health Assessment in the International Journal of Circumpolar Health, and Eva Kruemmel and co-author Andy Gilman prepared the associated manuscript for the risk communication chapter (which ICC Canada has been co-leading, with funding support from Health Canada). The paper was published as part of a special issue in December 2016 (see References for full citation).

ICC Canada attended the adjacent meetings of both health expert groups in Inari, Finland: AHHEG met September 30th, 2017, with a joined meeting taking place on October 1st, and a HHAG meeting on October 2nd. ICC Canada also attended the AMAP HHAG meeting on February 27th – March 1st in Quebec City, and reviewed associated documents and provided comments.

As already mentioned above, ICC participated in the AMAP conference: Bringing Knowledge to Action in Reston, Virginia and presented on the contaminant risk communication work. ICC Canada also attended the HHAG meeting prior to the AMAP conference on April 23 – 24th, 2017.

Persistent Organic Pollutants (POPs) Expert Group

ICC Canada fully reviewed the technical chapters of the Chemicals of Emerging Arctic Concern assessment and provided comments. ICC Canada's comments are aimed to provide an Inuit perspective on the assessments content, and included updates related to activities of the Stockholm Convention on POPs and the POP Review Committee. ICC Canada further submitted text for a section on knowledge gaps (co-authored with ICC Alaska, Saami Council, and Jennifer Provencher of Environment and Climate Change Canada) in the POPs/Hg Biological Effects assessment, had several teleconferences on the topic with the AMAP secretariat, assessment lead and co-authors, and made further edits to the contribution.

United Nations (UN) related Activities

Minamata Convention

The first Conference of the Parties (COP-1) of the Minamata Convention on Mercury took place September 25 – 29, 2017 in Geneva, Switzerland. Eva Kruemmel was invited to represent ICC in a panel discussion and to speak about how Inuit are affected by mercury, and about mercury monitoring in the Arctic. Eva Kruemmel was also invited to represent ICC at the ad-hoc Expert Group on Effectiveness Evaluation of the Minamata Convention which met March 5 – 9th, 2018 in Ottawa, and gave a presentation. At the meeting, a draft report on a framework needed for an effectiveness evaluation of the Minamata Convention was developed, which was then submitted for the consideration of COP-2 in November 2018. Travel for both meetings was supported by the United Nations Environment Programme (UNEP).

Stockholm Convention

Due to a lack of funding and capacity, ICC was not able to attend the 8th Conference of the Party (COP) of the Stockholm Convention, April – May 2017 in Geneva, Switzerland, as this meeting overlapped with the AMAP conference in Reston, Virginia.

Persistent Organic Pollutants Review Committee (POPRC)

NCP funds allowed ICC Canada to participate in activities of the Stockholm Convention's POP Review Committee (POPRC) in 2017. ICC Canada worked in contact groups and intersessionally to provide input on risk profiles of several POP candidates. Eva Kruemmel attended the 13th POPRC meeting, which took place in Rome, Italy, on October 17 – 20, 2017, and helped organize an AMAP side event at the meeting, which featured Hayley Hung (NCP scientist, Environment and Climate Change Canada) presenting on Chemicals of Emerging Arctic Concern. ICC Canada further actively participated in discussions of contact groups and had discussions at the meeting with government and other representatives to point out contaminant concentrations in the Arctic which are of concern for Inuit.

Other mercury and POPs related work

A paper on the mercury isotope results (Historical variations of mercury stable isotope ratios in Arctic glacier firn and ice cores, Zdanowicz et al.) got published in August 2016 (see full citation in References). 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. This work is used to feed into ICC Canada's general activities, in particular with regards to NCP, AMAP and the Minamata Convention, and is used in policy development and ICC Canada's consultation and communication efforts.

Communication

ICC Canada participated in the ArcticNet Scientific Conference that took place on December 11 - 15, 2017 in Quebec City. In addition to attending a number of side meetings, ICC Canada Vice President of International Affairs, Herb Nakimayak, gave a plenary presentation entitled "The Arctic We Want" which mentioned the Northern Contaminants Program as a current model upon which to build partnerships that support and advance Inuit self-determination in research. ICC Canada has been improving its web presence with a revamped website (http://www.inuitcircumpolar.com) and has Facebook and Twitter accounts. ICC Canada is hoping to publish newsletters soon that give regular updates and brief overviews of the most recent activities. Further communication efforts that are being conducted as part of ICC Canada's regular work include, the preparation of meeting reports, press releases, newsletter contributions, briefing notes, presentations, reporting on ICC's work in face-to-face meetings, teleconferences etc.

Summary of presentations given during 2017/18

- EM Kruemmel. Invited panel contribution on the Canadian Archipelago-Greenland Region. AMAP International Conference on Arctic Science. 26th April 2017, Reston, Virginia, USA.
- EM Kruemmel. "Communicating contaminant risk in the circumpolar Arctic and internationally". AMAP International Conference on Arctic Science. 27th April 2017, Reston, Virginia, USA.
- EM Kruemmel. Invited panel contribution on how Inuit are affected by mercury. Thematic session on "Water – Aquatic environments, livelihoods and food", First Conference of the Parties, Minamata Convention on Mercury, September 27th, 2017 Geneva, Switzerland.
- EM Kruemmel. Invited presentation "How Inuit are affected by mercury in the Arctic and involvement in monitoring activities". Minamata Convention on Mercury ad-hoc Expert Group on Effectiveness Evaluation, March 5th, 2018, Ottawa, Canada.
- S Meakin. Invited panel presentation: "ICC and 25 years of NCP Partnership: From Stockholm to Minamata and Beyond" NCP Results Workshop, September 26, 2017, Yellowknife, NWT.
- H Nakimayak. "The Arctic We Want". Plenary presentation during ArcticNet International Arctic Change Conference, December 11 - 15, 2017, Quebec City.

Discussion and Conclusions

With support from NCP, ICC Canada worked successfully in many international fora to ensure that Inuit perspectives were brought forward. Examples include POPRC-13, where ICC Canada contributed Arctic research (such as from NCP and AMAP) and outlined how Inuit are impacted by those POPs which are under review. At POPRC-13, the committee decided to recommend two new industrial chemicals (deca-BDE and SCCPs) for addition to Annex A of the Stockholm Convention, and advanced a perfluorinated compound (PFHxS) further in the review process. ICC Canada continues to be engaged in the Minamata Convention, participated in a panel at COP-1 and explained how Inuit are impacted by mercury in the Arctic, was invited to the ad-hoc Expert Group on Effectiveness Evaluation, and presented on monitoring activities conducted by NCP and AMAP in the Arctic. At the Arctic Council, ICC Canada contributed to and reviewed AMAP assessments (such as the Chemicals of Emerging Arctic Concern and the Biological Effects assessments) and actively contributed to other related initiatives, such as SAON, AACA, and the AMAP scientific conference. ICC Canada supported the NCP with contributions to 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.

Project website

ICC Canada's website: www.inuitcircumpolar.com

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