SYNOPSIS OF RESEARCH

Conducted under the 2018–2019 Northern Contaminants Program:

Full Report

RÉSUMÉ DE LA RECHERCHE

effectuée en 2018–2019 dans le cadre du
Programme de lutte contre les contaminants dans le Nord :

rapport complet

Synopsis of Research Conducted under the 2018-2019 Northern Contaminants Program: Full Report

Résumé de la recherche effectuée en 2018-2019 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This is an unpublished document created internally by the Northern Contaminants Program (NCP) Secretariat.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 2018-2019 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 plcn-ncp@rcaanc-cirnac.gc.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 2018-2019 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: plcn-ncp@rcaanc-cirnac.gc.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 2018-2019 Northern Contaminants Program: Abstracts and Key Messages* provides a detailed report of the activities and preliminary results of each project funded under the NCP between April 1, 2018 and March 31, 2019.

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 2018-2019), 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 Indigenous organizations, northern territorial

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 2018-2019 dans le cadre du Programme de lutte contre les contaminants dans le Nord : résumés et messages clés* présente un résumé des activités et des résultats préliminaires de chaque projet financé dans le cadre du PLCN entre le 1 avril 2018 et le 31 mars 2019.

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 2018-2019), 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 même que le Comité de gestion du PLCN. Ce processus d'examen 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 program's usual activities, ensuring the transparency of the NCP and the timely sharing of results. More detailed project reports, describing project objectives, activities, results, and conclusions are compiled in the *Synopsis of Research Conducted under the 2018-2019 Northern Contaminants Program: Full Report*, which 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.

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 présente publication fait partie des activités habituelles des PCN assurant la transparence du programme ainsi qu'une communication rapide des résultats. Des rapports de projet plus détaillés décrivant les objectifs, les activités, les résultats et les conclusions du projet sont compilés dans le *Résumé de Recherche effectuée en 2018-2019 dans le cadre du Programme de lutte contre les contaminants dans le Nord : rapport complet*, une publication qui est disponible dans la Base de données des publications du PLCN à l'adresse www.aina.ucalgary.ca/ncp. Tous les rapports de projets 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: plcn-ncp@rcaanc-cirnac.gc.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 : plcn-ncp@rcaanc-cirnac.gc.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, Health, 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

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 NordOuest, le Nunavut, le Nunavik et le Nunatsiavut), de quatre organisations autochtones nordiques (le Conseil des Premières Nations du Yukon, la Nation decisions on the allocation of funds. The Regional Contaminants Committees in Yukon, Northwest Territories, Nunavut, Nunavik and Nunatsiavut support this national committee with region-specific expertise and advice. Funding for the NCP's budget comes from CIRNAC and Health Canada. Details about the management structures and review processes used to effectively implement the NCP, and the protocol used to publicly disseminate health and harvest information generated by the NCP can be found in the NCP Operational Management Guide (available upon request from the NCP Secretariat).

dénée, Inuit Tapiriit Kanatami et la Conférence Circumpolaire Inuite), de cinq comités régionaux sur les contaminants et du Réseau de centres d'excellence axé sur l'Arctique, ArcticNet. Le Comité de gestion est responsable de l'établissement de la politique et des priorités scientifiques du PLCN de même que des décisions finales sur l'affectation des fonds. Les comités régionaux sur les contaminants du Yukon, des Territoires du Nord-Ouest, du Nunavut, du Nunavik et du Nunatsiavut appuient ce comité national en lui fournissant de l'expertise et des conseils propres à sa région. Le financement 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 to determine the levels, geographic extent,

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 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

permettant de prendre des décisions éclairées au sujet de leur alimentation.

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

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

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

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

En 1998-1999, le PLCN a entrepris sa deuxième phase, qui s'est poursuivie jusqu'en 2002-2003 et dont les résultats ont été présentés dans le RECAC II, en 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.

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.

La publication intitulée *Troisième rapport d'évaluation des contaminants dans l'Arctique canadien : le mercure dans le Nord canadien* fait 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

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 Northern Contaminants Program 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 on Human Health 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 Northern Contaminants program (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

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 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 dans l'Arctique canadien, *Les contaminants dans 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.

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, 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.

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 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 bien-être 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.

Human Health

Santé humaine

Yukon contaminant biomonitoring: Old Crow

Biosurveillance des contaminants au Yukon : Old Crow

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- **Project location/Emplacement du projet**
  Old Crow, YK

Abstract

Wild foods are critical to the health and well-being of Indigenous communities of the Yukon and elsewhere. Therefore, Gwich'in people of the Yukon have contributed to several long-running environmental monitoring studies that track the safety and sustainability of these foods. Occasionally, these studies have shown particular traditional foods to have high levels of some types of contaminants (e.g., mercury), raising concerns for residents of Old Crow, YT about the safety of the wild foods in their territory. In this second year, we implemented a biomonitoring research project in Old Crow (February 2019). Building upon prior consultations, our research team traveled to the first participating community for data and sample collection. With the assistance of a local research coordinator and nurse, we recruited 77 participants and collected blood, urine, and/or hair samples. Participants also completed two surveys (Health Messages Survey, Food Frequency Questionnaire). Data analysis (metals in blood/urine; persistent organic

Résumé

Les aliments prélevés dans la nature sont essentiels à la santé et au bien-être des collectivités autochtones du Yukon et d'ailleurs. C'est pourquoi les Gwich'in du Yukon ont contribué à plusieurs études de surveillance de l'environnement à long terme qui permettent de suivre la salubrité et la durabilité de ces aliments. Ces études ont parfois montré que certains aliments traditionnels présentaient des concentrations élevées de certains types de contaminants (p. ex., le mercure), ce qui a suscité des inquiétudes chez les habitants d'Old Crow (YT) quant à la salubrité des aliments prélevés dans la nature sur leur territoire. Au cours de cette deuxième année, nous avons mis en œuvre un projet de recherche sur la biosurveillance à Old Crow (février 2019). S'appuyant sur des consultations préalables, notre équipe de recherche s'est rendue dans la première collectivité participante pour la collecte de données et d'échantillons. Avec l'aide d'un coordonnateur de recherche et d'une infirmière de l'endroit, nous avons

pollutants (POPs) in plasma; mercury in hair; perfluorinated compounds in serum (PFCs); dietary surveys) is currently underway. During the same visit, we also returned the results from the previous year's data collection on the refinement of the Health Message Survey and the Food Frequency Questionnaire. In collaboration with regional, territorial, and federal partners, new results of 2018-2019 will be returned to participating communities within 12 months post sampling (fall 2019/winter 2020).

recruté 77 participants et avons prélevé des échantillons de sang, d'urine ou de cheveux. Les participants ont également répondu à deux enquêtes (Enquête sur les messages en matière de santé, Questionnaire sur la fréquence de consommation alimentaire). L'analyse des données (métaux dans le sang/urine; polluants organiques persistants (POP) dans le plasma; mercure dans les cheveux; composés perfluorés (PFC) dans le sérum; enquêtes sur l'alimentation) est en cours. Lors de cette même visite, nous avons également présenté les résultats des données recueillies l'année précédente dans le cadre d'un approfondissement de l'Enquête sur les messages en matière de santé et du Questionnaire sur la fréquence de consommation alimentaire. En collaboration avec les partenaires régionaux, territoriaux et fédéraux, les nouveaux résultats de 2018-2019 seront renvoyés aux collectivités participantes dans les 12 mois suivant l'échantillonnage (automne 2019/hiver 2020).

Key messages

- A total of 77 residents from Old Crow participated in the biomonitoring project in 2019.
- Samples are currently being analyzed for mercury (hair), metals and metalloids (hair, blood, urine), POPs (plasma), and perfluorinated compounds (PFCs) in serum.
- Results will be returned to participating communities in January 2020.
- Findings from the dietary survey completed in 2017-2018 indicate that the most commonly consumed foods reported by participants from Old Crow were: caribou, moose, Chinook salmon, whitefish and low (grey) blueberries.
- Findings from the health message survey completed in 2017-2018 indicate that almost all participants (97%) from Old Crow had heard that eating traditional foods provides a significant variety and amount of nutrients.

Messages clés

- En tout, 77 résidents d'Old Crow ont participé au projet de biosurveillance en 2019.
- Les échantillons sont actuellement analysés pour le mercure (cheveux), les métaux et les métalloïdes (cheveux, sang, urine), les POP (plasma) et les PFC dans le sérum.
- Les résultats seront communiqués aux collectivités participantes en janvier 2020.
- Les résultats de l'enquête sur l'alimentation réalisée en 2017-2018 indiquent que les aliments les plus couramment consommés par les participants d'Old Crow étaient les suivants : caribou, orignal, saumon chinook, poisson blanc et bleuets nains.
- Les résultats de l'enquête sur les messages de santé réalisée en 2017-2018 indiquent que presque tous les participants (97 %) d'Old Crow avaient entendu dire que la consommation d'aliments traditionnels fournissait une variété et une quantité importantes de nutriments.

Objectives

The short-term objectives for this research project were to:

1. complete human biomonitoring research in Old Crow in partnership the Vuntut Gwitchin Government (VGG);
2. analyze metals, legacy POPs, and emerging contaminants from hair, blood, and urine samples collected from residents of Old Crow, YT;
3. refine methods for returning contaminant results to study participants; and
4. build and maintain partnerships among Yukon First Nations, territorial representatives and research scientists.

The long-term objectives of this research project are to:

- return results to each individual participant from the biomonitoring study in Old Crow;
- bring back results and key findings to the VGG; and
- work with the VGG to develop follow-up plans based upon the results from year 1 of the project.

Reaching these short- and long-term objectives will assist in the development of public health communication strategies to promote country food reliance in ways that maximize nutrient status while limiting contaminant exposure for Yukon residents. As the first biomonitoring project in the Yukon to include such a broad range of contaminants, the project is addressing a major data gap regarding contaminant exposures in Canada. The long-term objectives of this project complement ongoing community-based environmental contaminant monitoring research underway in the region.

Introduction

Wild food is an important part of the diet of 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, Kuhnlein and Chan 2000) and some dietary surveys have been conducted in the past (Berti et al. 1998, Receveur et al. 1998, Nakano et al. 2005), few human biomonitoring studies have been conducted in the territory. Previous and ongoing studies have found that cadmium and mercury levels in caribou kidneys and livers from across the Circumpolar North, are higher than in domestic animals raised for food consumption. This has prompted a health advisory from Yukon Health and Social Services, based on a health assessment from Health Canada. A maximum intake of 25 kidneys or 12 livers was recommended per person per year for caribou from the Porcupine herd. A range of chemicals continues to be monitored in the Porcupine caribou herd (cadmium, mercury, PFCs) on an annual basis under the Northern Contaminants Program. Although these caribou are an important food source, current baseline exposures to these contaminants amongst the people of Old Crow, YT are largely unknown. Hair samples were taken from 32 Old Crow residents and analyzed for mercury by CANHelp (University of Alberta) as part of a study investigating interactions between dietary exposure to mercury, H. pylori, and risk of gastric cancer. Despite low levels of mercury exposure among participants in Old Crow, it is not yet known if these levels are representative for the community as a whole. In addition, it is well established that risk perceptions can be influenced by a variety of factors including age, gender, education, occupation, worldview, and culture (Slovic and Peters 1995, Myers and Furgal 2006, Jardine et al. 2009). Prior studies have shown people's perceptions of traditional food safety to be high, with variation in the perceptions influenced by education, employment, marital status, and hunting frequency (Furgal et al. 2007). However, relatively little of this research has been based in the Yukon. Therefore, to develop effective public health messages and communication strategies, it is critical to understand the underlying factors that influence perceptions of country foods among Yukoners. Assessing perceptions of both risk and benefits of food items is particularly important because some country foods, including locally-harvested fish, are excellent nutritional sources of micro- and macronutrients such as selenium (Se) and long-chain omega-3 fatty acids (Dewailly et al. 2002, Kuhnlein and Receveur 2007). There is growing recognition of a need to balance risks and benefits when developing public health strategies related to contaminant exposures (Receveur et al. 1998, Mahaffey et al. 2011, Laird et al. 2013) and the perceptions of Northern residents must be considered as they directly influence the health messaging.

Activities in 2018-2019

NCP funding in 2018-2019 was used to work on four components of this contaminant biomonitoring research project in the Yukon.

Objective 1: build and maintain partnerships.

Discussions are ongoing with other Yukon communities that are interested in participating in a biomonitoring study, which might be expanded to new communities after the return of the results in the first participating community, Old Crow. For now, one Community Research Agreement is established between the University of Waterloo and the VGG. A Northern-based researcher (Mary Gamberg) acts as the liaison between the project team and community. A local phlebotomist, based in Whitehorse, was hired to assist with blood collection. Prior to sample collection, training materials were provided for clinic staff so that nurses and other health professionals in the region were informed about the project.

Objective 2: complete human biomonitoring research in Old Crow.

Sampling dates were determined in consultation with the VGG. Six members of the research team, including Mary Gamberg, Mylene Ratelle and graduate students (Mallory Drysdale, Sara Packull-McCormick, Connor Judge, Alyssa Sgro) travelled to Old Crow to support sample and data collection in February 2019. With the support of a local research coordinator, we randomly selected sample households to participate. The 70 participants who completed the baseline surveys in February 2018 were also invited to take part in the biomonitoring study. Walk-in participants were also welcomed to take part in the project. Participation followed an opt-in framework such that each participant was free to take part in any or all project components as they were willing. Participants provided hair, urine and/or blood samples and completed the two surveys. To facilitate the blood/urine/hair sampling, the VGG provided use of the community hall available for a week as well as an office (confidential setting) for over 2 weeks. In addition to the biomonitoring component, this visit returned the findings collected through the refinement of the Health Messages Survey and Food Frequency Questionnaire completed by participants in 2017-2018. For this, a public meeting was held in Old Crow to share the knowledge and material was prepared for distribution.

Objective 3: analyze metals, legacy POPs, and emerging contaminants from samples.

Samples are analysed in collaborator laboratories. Hair was analyzed for total mercury in the laboratory of Brian Branfireun (Biotron, University of Western Ontario). Whole blood and urine samples were analyzed for metals in the laboratory of Michele Bouchard (Université de Montréal). The fatty acid composition of whole blood will be determined in the laboratory of Ken Stark (University of Waterloo). The POPs and PFCs in plasma and serum will be quantified in the laboratory of Alain Leblanc (INSPQ). As of June 2019, we have received the results for metals in blood hair and urine, and PFCs in serum.

Objective 4: refine methods for returning contaminant results to study participants.

A results letter template was created for the return of results for individual participants from Old Crow. The aim of these letters is to provide accurate and actionable information as well as sufficient context (without making them overwhelming). Before returning the results in January 2020, Northern partners will have the opportunity to provide feedback and further refine the letters.

Community engagement

Before findings from the previous year's survey were released to the public, results were returned to each participant and the VGFN leadership received a copy of the aggregate findings. In the next year, each study participant who provided a hair, urine, and/or blood sample will receive a confidential, plain-language letter from the project team. This letter will detail an individual's contaminant exposure levels. In parallel with the individual reporting, we will host a public forum to discuss key findings, answer questions, and respond to concerns from residents of Old Crow. The development of messages, materials and presentation approaches will take into consideration the results of the analyses of the contaminants and health awareness, as well as the understanding and risk perception questions administered to all participants. Individuals with exposure levels that exceeded biomonitoring guidelines will be offered information on ways to lower exposures and will be given the opportunity to do a re-testing to determine whether contaminant levels remained elevated. This re-testing will be completed in collaboration with the local health center.

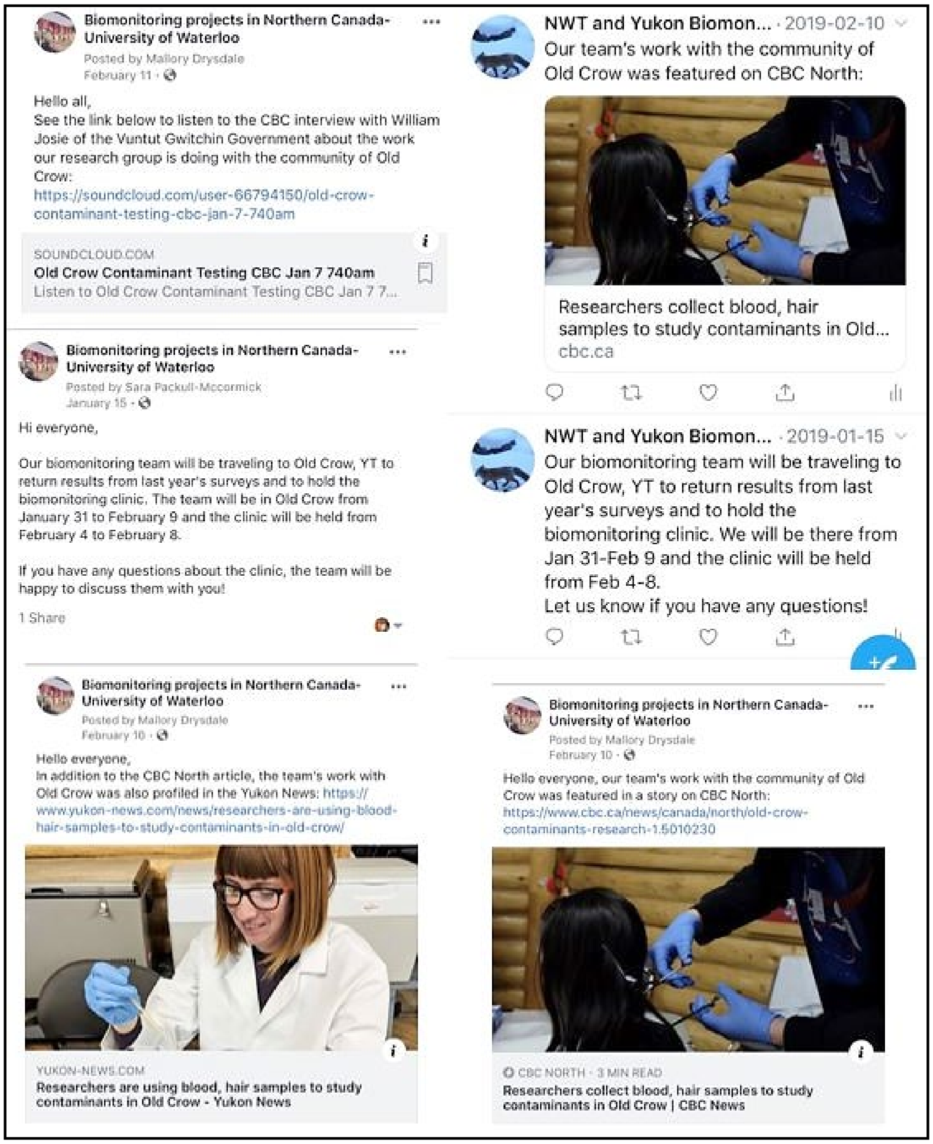
Capacity building

Northern Contaminant Program funds were used to hire a local research coordinator in Old Crow. The coordinator assisted with the implementation of the project by overseeing participant recruitment and assisting participants with completing the surveys. The coordinator received training on participant recruitment, hair sampling, urine sampling, and implementation of the surveys. The local coordinator will also be invited to assist with the return of results.

Communications

We provided our contacts with regular phone/email updates of the research progress. Additionally, Mary Gamberg, the local researcher based in Whitehorse, participates in regular meetings in the region, providing additional opportunities to liaise with other researchers, local organization members and community leaders. Additionally, we created a plain language progress report of the survey results which was provided to the VGG and made available to community members during the February 2019 clinic and community meeting. Work is underway on the design of communication materials (reports, letters) for the individuals and communities that took part in the study. Additionally, social media accounts (Facebook and Twitter) were created for the project, to be used in addition to typical communication strategies, to help us make sure community members are aware of when we arrive to do the research, when we come back to return results, and maintain contact with participants in between sample collection and the return of results. During the implementation of the biomonitoring study, Mary Gamberg also gave interviews to local media. See Figure 1 for examples of social media posts, including local media interviews, that were shared with community members. 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. Finally, the research team distributed a quarterly newsletter to community partners, local coordinators, researchers working in the same regions and government representatives.

Figure 1. Social media posts and interviews.



Indigenous Knowledge integration

The project will rely upon local and traditional knowledge communicated through the community consultations to guide the project's return of results and knowledge translation. Local perspectives provided by residents within community consultations have helped ensure that the mission and design of this research addresses the priorities and concerns of people. Additionally, the project has incorporated the knowledge of local experts in the development of the dietary surveys. This local knowledge has been crucial in ensuring that the dietary survey uses food names recognizable to participating community members. Other important aspects of local knowledge described via the dietary questionnaire include seasonality of food availability, consumption patterns and preparation methods. Furthermore, we are exploring the ways by which traditional knowledge can be incorporated into the results dissemination at both the individual and community level.

Results

Results from the 2017-2018 refinement of the surveys (the Food Frequency Questionnaire (FFQ) and the Health Messages Survey (HMS) were returned to community members of Old Crow in February 2019. The research team also implemented the main biomonitoring project for the samples and data collection.

Food Frequency Questionnaire (FFQ)

FFQ results are presented in Table 1, which shows the average frequency of consumption, meaning the number of participants who reported that they consumed the food as a proportion of the number of participants who saw the survey question. Intake frequencies of traditional foods are consumer-only values as the calculations only included the consumption frequencies recorded by people who reported eating the food. These frequencies are reported in percentiles, meaning, for example the 25th percentile represents the frequency of consumption for the 25% of participants who reported the lowest numbers. As shown in Table 1, caribou (90%), moose (90%) and Chinook salmon (77%) were consumed by the largest number of participants. Of the ten most commonly consumed land animals tissues, nine came from caribou, including cooked caribou (90%), ribs (65%), heart (64%), head (62%), bone marrow (62%), tongue (60%), smoked caribou (58%), kidney (57%) and fat (53%). The most commonly consumed fish were Chinook salmon, where 77% of participants reported consuming cooked Chinook salmon and 39% reported eating Chinook salmon smoked/dried, and whitefish, with 69% reporting consuming cooked whitefish and 39% consuming smoked/dried whitefish. The most commonly consumed foods other than meats were low (grey) blueberries and low bush cranberries. A range of preparation methods were documented for meats, including cooking, pan frying/deep frying, grilling/roasting/baking, eating raw, boiling/soup/stew, smoking/fully dried, smoking/half dried and cooking on a campfire.

Table 1. Most Commonly Consumed Foods in Old Crow from the 2017-2018 survey.

	Food Consumed	Percent Consuming (%)[a]	Mean Frequency (Days/Week)[b]	Days/Week Food Was Consumed (percentile)[b]				
				P25	P50	P75	P90	Max
1	Caribou - Cooked	90%	2.2	0.5	1.5	4	4	6.5
2	Moose - Cooked	90%	1.3	0.5	0.5	1.5	4	6.5
3	Chinook salmon - Cooked	77%	0.7	0.5	0.5	0.5	1.5	1.5
4	Whitefish - Cooked	69%	0.8	0.5	0.5	0.5	1.5	4
5	Low (Grey) Blueberries	69%	0.7	0.5	0.5	0.5	1.5	1.5
6	Caribou - Ribs	65%	1.4	0.5	0.5	1.5	4	6.5
7	Caribou - Heart	64%	0.8	0.5	0.5	0.5	1.5	4
8	Caribou - Head	62%	1.0	0.5	0.5	0.75	1.5	6.5
9	Caribou - Bone Marrow	62%	0.9	0.5	0.5	0.5	1.5	6.5
10	Low Bush Cranberries	61%	0.8	0.5	0.5	0.5	1.5	4

[a] All respondents to the FFQ completed the survey. This percentage represents the numbers of participants who reported eating the food compared to the total number of participants who took the survey.

[b] This is a consumer-only value (those who did not report consumption of a food are not represented in this value).

The majority of fish consumers ate fish less than once per week; however, a small minority of participants (4%) reported eating whitefish 3-5 times per week. The community of Old Crow has issued recommendations for consumption of loche and inconnu of 1 to 2 servings per week for children and women of childbearing age (Gamberg 2016). No children were surveyed in this study; all women of childbearing age reported consuming loche and inconnu once or less per week (i.e., within the recommendation). The majority of respondents reported fish consumption from Porcupine River (86%) and the second most common source was Crow River (36%).

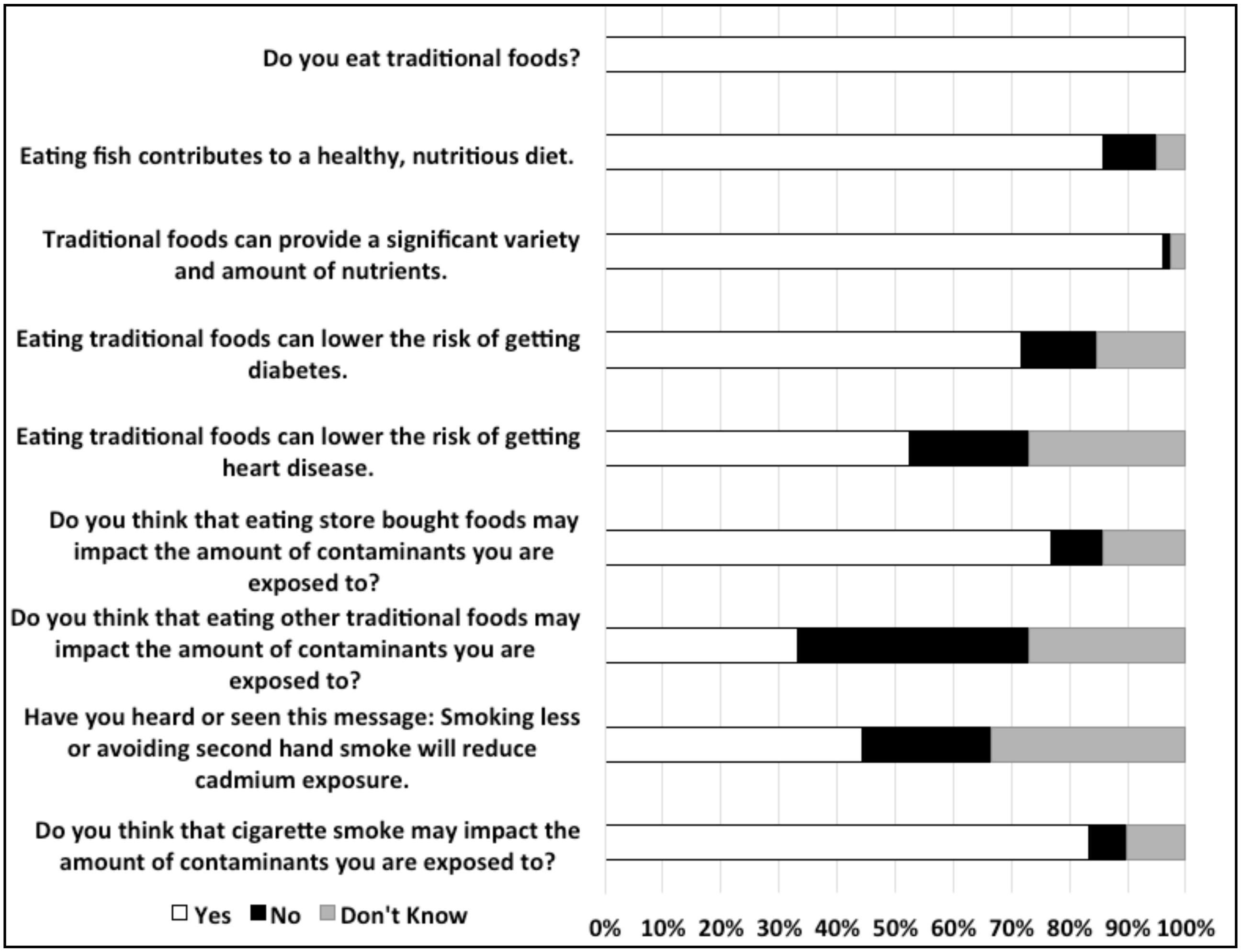
Moose and caribou were the most commonly consumed land animals. The average consumption rate of caribou is more than twice per week, with the majority of consumers reporting eating caribou more than once per week. More than a quarter of participants reported eating caribou more than 3 times per week. The average consumption rate of moose is more than once per week. Caribou were primarily from the Porcupine herd (95%), with less than 3% being reported from the Forty-Mile herd and Bonnet Plume herd. The Government of the Yukon has issued a Health Advisory for Yukon Wildlife including the maximum number of kidneys and livers per year recommended for consumption for land animals including caribou, moose, sheep, beaver, porcupine and snowshoe hare (Indigenous and Northern Affairs Canada 2010). Respondents to the FFQ generally reported low organ consumption rates (<10% and consumed once or less per week) within the recommendation for sheep, beaver, porcupine and rabbit (Indigenous and Northern Affairs Canada 2010). The majority of participants reporting consumption of moose kidney and liver (27% and 17%, respectively) ate the organ once or less per week, which may fall within the recommendation of one of each per year (Indigenous and Northern Affairs Canada 2010). Recommendations for caribou kidney and liver consumption vary depending on the herd. Over 90% of participants who ate caribou kidney (57%) and liver (27%) consumed caribou from the Porcupine herd. The majority of respondents reported caribou kidney and liver consumption rates of once or less per week, which may fall within the recommendation for the Porcupine herd of 25 kidneys or 12 livers per year (Indigenous and Northern Affairs Canada 2010). Consumption of other land mammals was generally low, with only cooked rabbit (43%), muskrat (17%) and porcupine (17%) being consumed by more than 10% of participants.

Generally, berries were the most consumed plants, and the majority of participants ate low (grey) blueberries (69%), salmonberries/cloudberries (60%) and low bush cranberries (61%). All other types of berries were eaten by less than 50% of the participants. The most commonly consumed plant were Labrador tea (23%) and spruce gum (23%). Game birds were the least commonly eaten category of traditional food, and the most popular types of birds eaten were the meat of ptarmigan (18%), Canada goose (18%) and white-winged scoter (18%).

Health Message Survey (HMS)

Baseline data was collected for the HMS in Old Crow, Yukon to learn what health messages community members were aware of and what sources of information they trusted and used. The messages considered in this survey generally address contaminants in traditional foods (caribou, fish, moose etc.) and the health benefits or risks associated with eating different foods. The majority of participants were concerned about mercury (86%) and about chlorine in drinking water (71%). A smaller majority (50 – 60%) were concerned about antibiotics in meat, lead, radioactivity and pesticides. The results also demonstrated the importance of traditional foods to the diet of community members: 100% reported eating traditional foods, and most preferred a mix of both store-bought and traditional foods (53%). The results of general questions about nutrition, smoking and health are shown below in Figure 2. The majority of participants reported hearing the message that eating traditional foods contributes to a healthy, nutritious diet (86%) and that traditional foods can provide a significant variety of nutrients (96%). Only 33% of participants believe that traditional foods may impact the amount of contaminants you are exposed to, and 44% had heard that reducing exposure to cigarette smoke will reduce cadmium exposure.

Figure 2. General Health, Smoking and Nutrition Responses to the HMS.



In general, participants had not heard health messages about caribou with high levels of cadmium, with 77% reporting not hearing this message. Participants were not concerned about caribou meat, with 60% reporting they do not think caribou meat contributes to their exposure to contaminants. However, 44% of participants thought that caribou organs contributed to their exposure to contaminants, indicating that the group was more concerned about caribou organs than caribou meat. It was found that participants were aware of health messages about fish with high levels of mercury (73% had heard this message). Participants also reported that they were aware of the messages of the health benefits of eating fish: 86% heard that "Eating fish contributes to a healthy, nutritious diet" and 81% had heard that fish is an excellent source of omega-3 fatty acids. However, fewer people had heard messages about specific fish that have high or low levels of mercury. Only 32% reported hearing the message "Grayling, pike, whitefish and salmon have very low levels of mercury". Fewer people had also heard messages about which groups of people should avoid fish with high levels of mercury (lake trout and burbot). Only 29% of participants reporting hearing that "Women of child-bearing years should limit the number of large lake trout and burbot they eat"; and 28% of participants heard the message "Children under the age of 12 should limit the number of large lake trout and burbot they eat". When asked which river or lake participants had heard had fish with high levels of mercury, the majority of respondents (68%) listed Porcupine River. Participants reported that they get health information from personal sources most often (Elders, friends or relatives), followed by professional sources, including researchers or scientists, and health care professionals (doctors, nurses and other health workers). Similarly, participants reported that they trust information about traditional foods and contaminants that came from personal sources (friends, family and Elders), as well as professionals (researchers and scientist, health care professionals, and teachers).

Biomonitoring implementation

A Community Research Agreement was created in consultation with VGG. Participants were recruited for the biomonitoring sample collection, held in Old Crow, Yukon, in February 2019, to provide biological samples, to complete the FFQ and HMS. Almost one third of the community population consented to participate. The research team spent 3 weeks in the community to implement the project. With the assistance of a local research coordinator, a total of 178 samples (49 urine, 56 blood and 73 hair) were collected from 77 community members. Chemical analyses are still ongoing. Once the analyses are completed, results will be returned to each participant in winter 2020.

Table 2. Characteristics of the participants from Old Crow in February 2019 (n=77).

Parameters	Values
Age	Range: 13 to 76 years old Mean: 44.2 years old
Sex	Males: 44.2% Females: 55.8%
Body mass index - for adults only (+18)	Range: 15.6 to 66.1 Mean: 29.3

Discussion and conclusions

This 2018-2019 NCP research focused on two elements: 1) the return of the survey results from the HMS and the FFQ, and 2) the biomonitoring component implementation. Additionally, the research team is collaborating with other researchers conducting environmental monitoring in these regions in order to better answer the question, "how are people exposed to these contaminants?". This co-located environmental monitoring work will support the refinement of a model to estimate dose reconstruction and assessment of the risk related to fish consumption. This project will inform the development of regionally-specific communication tools that promote the consumption of county foods in a way that improves food security and nutrition in Old Crow while lowering exposure to environmental contaminants. Furthermore, the biomonitoring research will provide information to help identify those who are most at risk of contaminant exposure. The dietary survey developed and evaluated through this research will provide critical information for the identification of the most significant sources of exposure for the contaminants studied in the biomonitoring project. 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 Yukon.

Expected project completion date

March 31, 2020

Project website

[Facebook: @BiomonitoringNT]

[Twitter: @NTBiomonitoring]

Acknowledgments

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References

Berti, P. R., O. Receveur, H. M. Chan and H. V. Kuhnlein (1998). "Dietary Exposure To Chemical Contaminants From Traditional Food Among Adult Dene/Metis In The Western Northwest Territories, Canada." *Environmental Research* **76**(2): 131-142.

Dewailly, E., C. Blanchet, S. Gingras, S. Lemieux and B. J. Holub (2002). "Cardiovascular Disease Risk Factors And N-3 Fatty Acid Status In The Adult Population Of James Bay Cree." *American Journal of Clinical Nutrition* **76**(1): 85-92.

Furgal, C., L. Rochette, N. Régie régionale de la santé et des services sociaux and I. n. d. s. p. d. Québec (2007). P*erception of Contaminants, Participation in Hunting and Fishing Activities, and Potential Impacts of Climate Change*, Gouvernement du Quebec, Ministeres des Communications.

Gamberg, M. (2000). Contaminants in Yukon Country Foods. *Unpublished report prepared for the Department of Indian and Northern Affairs.* Whitehorse, Yukon.

Gamberg, M. (2016). Mercury in Fish from Old Crow, Report to William Josie of Vuntut Gwitchin Government.

Indigenous and Northern Affairs Canada. (2010). "Metal of Concern Fact Sheet: Cadmium." Retrieved January 10, 2019, from https://www.aadnc-aandc.gc.ca/eng/1316038300971/1316038365744.

Jardine, C. G., A. D. Boyd and C. M. Furgal (2009). "Gender and place influences on health risk perspectives in northern Canadian Aboriginal communities." *Gender Place and Culture* **16**(2): 201-223.

Kuhnlein, H. V. and H. M. Chan (2000). "Environment And Contaminants In Traditional Food Systems Of Northern Indigenous Peoples." *Annual Review of Nutrition* 20: 595-626.

Kuhnlein, H. V. and O. Receveur (2007). "Local cultural animal food contributes high levels of nutrients for Arctic Canadian indigenous adults and children." *Journal of Nutrition* 137(4): 1110-1114.

Laird, B. D., A. B. Goncharov, G. M. Egeland and H. M. Chan (2013). "Dietary Advice on Inuit Traditional Food Use Needs to Balance Benefits and Risks of Mercury, Selenium, and n3 Fatty Acids." *Journal of Nutrition* **143**(6): 923-930.

Mahaffey, K. R., E. M. Sunderland, H. M. Chan, A. L. Choi, P. Grandjean, K. Marien, E. Oken, M. Sakamoto, R. Schoeny, P. Weihe, C. H. Yan and A. Yasutake (2011). "Balancing The Benefits Of N-3 Polyunsaturated Fatty Acids And The Risks Of Methylmercury Exposure From Fish Consumption." *Nutrition Reviews* **69**(9): 493-508.

Myers, H. and C. Furgal (2006). "Long-range transport of information: Are Arctic residents getting the message about contaminants?" *Arctic* **59**(1): 47-60.

Nakano, T., K. Fediuk, N. Kassi and H. V. Kuhnlein (2005). "Food use of Dene/Metis and Yukon children." *International Journal of Circumpolar Health* **64**(2): 137-146.

Receveur, O., N. Kassi, H. M. Chan, P. R. Berti and H. Kuhnlein (1998). Yukon First Nations' assessment of dietary benefit/risk, CINE, McGill University**:** 160 pp.

Slovic, P. and E. Peters (1995). "The role of affect and world views as orienting dispositions in the perception and acceptance of nuclear power." *Descision Research.*

Exposure to food chain contaminants in Nunavik: biomonitoring in adult and youth cohorts of the *Qanuilirpitaa* survey (Year 2)

Exposition aux contaminants de la chaîne alimentaire au Nunavik : biosurveillance des cohortes d'adultes et de jeunes de l'enquête *Qanuilirpitaa?* (année 2)

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Project location/Emplacement du projet

Nunavik, QC

Abstract

Inuit are exposed to a wide range of environmental contaminants through their diet which comprises 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, and followed by the *Qanuippitaa?* 2004 Health Survey and more recently by the *Qanuilirpitaa*? 2017 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. However, mercury and lead exposures remain topical issues, particularly among childbearing and pregnant women in Nunavik. Moreover, new chemicals are introduced each year in the market. These "New POPs and Contaminants of Emerging Concern (CECs)" now reach the Arctic food chain and very little is known about their concentrations and temporal and regional trends in Inuit. This three-year project aims at updating data on exposure to food-chain contaminants and key nutrients in a representative sample of the Inuit population of Nunavik within the framework of the *Qanuilirpitaa?* Survey, in which 1326 Nunavimmiut participated in 2017. Activities conducted in 2018-2019 included analysing a series of legacy POPs, including polychlorinated biphenyls, chlorinated pesticides and brominated diphenylethers, in plasma samples from 500 Nunavimmiut randomly selected among all *Qanuilirpitaa?* participants. In addition, key nutritional biomarkers were measured: 1) omega-3 polyunsaturated fatty acids in red blood cell membranes; and 2) selenoneine and ergothioneine (and their methylated metabolites) in whole blood samples. This project will allow Canada to maintain its role at the forefront of international biomonitoring efforts on long-range environmental contaminants exposure among circumpolar populations and it contributes to understanding the risks and benefits of country foods consumption in the Arctic.

Résumé

Les Inuits sont exposés à une vaste gamme de contaminants environnementaux par leur régime alimentaire, qui comprend d'importantes quantités de poissons et de 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?*) de 2004, et plus récemment l'Enquête de santé *Qanuilirpitaa*? De 2017. 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. Toutefois, l'exposition au mercure et au plomb reste d'actualité, notamment chez les femmes enceintes et en âge de procréer au Nunavik. En outre, de nouveaux produits chimiques sont introduits chaque année sur le marché. Ces nouveaux POP et contaminants d'intérêt émergent (CIE) atteignent maintenant la chaîne alimentaire de l'Arctique, et on en sait encore très peu sur leur concentration et les tendances temporelles et régionales chez les Inuits. Ce projet de trois ans vise à mettre à jour les données sur l'exposition aux contaminants de la chaîne alimentaire et aux nutriments clés dans un échantillon représentatif de la population inuite du Nunavik dans le cadre de l'enquête *Qanuilirpitaa*? à laquelle 1 326 Nunavimmiuts ont participé en 2017. Les activités menées en 2018-2019 comprenaient l'analyse d'une série de POP hérités, notamment les biphényles polychlorés, les pesticides chlorés et les diphényléthers bromés, dans des échantillons de plasma de 500 Nunavimmiuts sélectionnés au hasard parmi tous les participants à l'enquête *Qanuilirpitaa*? En outre, des biomarqueurs nutritionnels clés ont été mesurés : 1) les acides gras polyinsaturés oméga-3 dans les membranes des globules rouges; et 2) la sélénonéine et l'ergothionéine (et leurs métabolites méthylés) dans des échantillons de sang entier. Le projet permettra au Canada de rester à l'avant-garde des efforts internationaux

de biosurveillance axés sur l'exposition des populations des régions circumpolaires aux contaminants environnementaux transportés à grande distance, et contribuera à déterminer les risques et les avantages rattachés à la consommation d'aliments prélevés dans la nature dans l'Arctique.

Key messages

- Concentrations of PCBs, chlorinated pesticides and PBDEs were determined in plasma samples from 500 *Qanuilirpitaa?* Participants.
- N-3 polyunsaturated fatty acids (PUFAs) levels were measured in red blood cell membranes of all 1326 participants.
- Whole blood samples from all participants were analysed for selenoneine and ergothioneine - two key nutrients found in beluga mattaaq.
- Non-targeted screening of pooled plasma extracts is ongoing and may reveal the presence of contaminants of emerging concern.

Messages clés

- Les concentrations de BPC, de pesticides chlorés et de PBDE ont été déterminées dans des échantillons de plasma de 500 participants à l'enquête *Qanuilirpitaa?*
- Les acides gras polyinsaturés-3 ont été mesurés dans les membranes des globules rouges des 1 326 participants.
- Des échantillons de sang entier de tous les participants ont été analysés pour la sélénonéine et l'ergothionéine – deux nutriments clés trouvés dans le mattaaq du béluga.
- Le dépistage non ciblé des extraits de plasma mélangés est en cours et pourrait révéler la présence de contaminants d'intérêt émergent.

Objectives

The main objective of this three-year project is to update data on exposure to food-chain contaminants among Nunavimmiut. To this end, biological samples obtained in the framework of the *Qanuilirpitaa?* 2017 survey from 752 adults (31 years and older) and 574 youths (16 to 30 years old) are analysed for different families of contaminants.

The specific objectives are to:

- measure, through biomonitoring, Nunavimmiut's exposure to toxic metals [mercury (Hg), lead (Pb), cadmium (Cd)] (**year 1; completed**) and persistent organic pollutants (POPs) – organochlorine and organobromine compounds (**year 2; completed**) and per- and polyfluoroalkyl substances (PFAS) (**planned for year 3**);
- assess biomarkers of key nutrients in Nunavimmiut - namely omega-3 polyunsaturated fatty acids (n-3 PUFAs) and selenoneine/ergothioneine (**year 2**); and
- 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 (**year 3**).

Introduction

Biomarkers of contaminant exposure

Early work conducted on Baffin Island and in Nunavik has demonstrated that due to their traditional dietary habits, Inuit are exposed to unusually high doses of environmental contaminants, mainly toxic metals and organochorines (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) and various chlorinated pesticides or 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. 2012, 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, in order to follow and understand their 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. 2001, Muir et al. 2001). 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. submitted).

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 wildlife 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. submitted). However, since a high number of pregnant women and childbearing-age women continue to exhibit excessive Hg concentrations in Nunavik (Adamou et al. submitted), 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).

Pb exposure from lead-containing ammunitions also remains significantly more elevated in Nunavik than elsewhere in southern Canada and USA (Centers for Disease Control 2010, Health Canada 2013). 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, pers.comm.).

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 perfluorinated compounds (PFCs), for example perfluorooctane-sulfonate (PFOS) and related compounds. PFCs 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). Most recent data in Nunavik pregnant women show that while PFOS levels are going down, concentrations of longer-chain PFCs such as PFNA now replacing PFOS in consumer goods are increasing in the Arctic (Lemire, pers. comm.).

Between 2013 and 2016, 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 new 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.

Biomarkers of key nutrient intake

The contaminants to be monitored in the framework the current research proposal 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 health, social and cultural significance (Blanchet et al. 2000, Blanchet and Rochette 2008, Dallaire et al. 2009, Lucas et al. 2010, ITK and ICC 2012, Lemire et 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 crucial when assessing health effects of food-chain contaminants.

First, Inuit people have very high levels of n-3 PUFAs in their blood due to their high consumption of fish and marine mammals (Lucas et al. 2010). High n-3 PUFAs intake during prenatal life increases birth weight of newborns and cognitive functions in childhood (Jacobson et al. 2015). *Qanuippittaa*? 2004 data analysis also showed a beneficial association between red blood cell (RBC) n-3 PUFA concentrations and different markers of cardiometabolic functions during adulthood (Valera et al. 2009, Ayotte et al. 2011, Valera et al. 2011).

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

Second, selenium (Se) is an essential element found in exceptional concentrations in marine country foods of the Arctic, our most recent data reveal that high cord Se blood status has protective effects on visual, cognitive and behavioural outcomes in infancy and childhood despite high Hg exposure during pregnancy (see Muckle, Lemire 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. 2019). Indeed, RBC selenoneine concentration in Inuit blood was strongly associated to beluga mattaaq consumption, higher in the Hudson Strait villages, and surprisingly higher in women, even after controlling for age, region, and diet (Little et al. 2019). Selenoneine is a Se-analogue of ergothioneine, a powerful anti-oxidant, and experimental data indicate that selenoneine can promote methylmercury (MeHg) detoxification in human cells in vitro (Yamashita et al. 2013). Once in RBCs, selenoneine would bind to heme proteins (hemoglobin and myoglobin) and prevent iron oxidation and/or enhance MeHg demethylation (Yamashita and Yamashita 2010).

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 strong social network of country food exchanges, influenced 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).

Activities in 2018-2019

Biomarkers of contaminant exposure

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). These pooled samples were submitted to a **targeted analysis** (specific analytes quantified using isotope labelled standards) to quantify concentrations of compounds belonging to various families of chemicals (PCBs, chlorinated pesticides, PCDD/F, brominated flame retardants, PFAS). Results of the pooled sample analyses were obtained early in 2018 and discussed at the NNHC meeting held in May 2018. It was decided to focus additional analyses in individual samples on 1) PCBs/chlorinated pesticides/PBDEs (year 2; 2018-2019); and 2) PFASs (year 3; 2019-2020). To limit the analytical costs while still providing estimates representative of the Nunavik population, 500 plasma samples randomly selected among all participants and weights were attributed to allow for subsequent statistical analyses. Analyses of plasma samples for PCBs/chlorinated pesticides/PBDEs were completed in March 2019 and results will be presented and discussed at the next NNHC meeting.

Pooled samples are also submitted to **untargeted analyses** (semi-quantitative method – exposomics screening) using our APGC QTOF instrument and a GC-Orbitrap instrument at the laboratory of our colleagues at NILU/UiT in Tromsø. This part of the analytical work is ongoing and is being supported through additional funding obtained from a joint initiative from Université Laval/UiT The Arctic University of Norway (Screening for Emerging Arctic Health Risks to Circumpolar Human Populations - SEARCH).

Biomarkers of nutrient intake

Two key nutritional biomarkers were measured in **year 2** of the current project: red blood cell n-3 PUFAs and blood selenoneine/ ergothioneine. Ergothioneine, a sulfur analogue of selenoneine, was also be quantified in blood samples of *Qanuilirpitaa*? participants because biochemical pathways leading to selenoneine synthesis are known to also yield large amounts of ergothioneine.

Linking biomarkers measurements to characteristics of participants

During **year 3** of the project, statistical analyses will be conducted to explain biomonitoring data according to participant's country and store-bought food consumption, food security, socio-demographic status, lifestyle habits and anthropometric characteristics. The study database required to perform these analyses will be available in January 2019.

Community engagement

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 Ilisarniliriniq, Avataq and two mayors representing the communities. Representatives of INSPQ and CHU de Québec Research Centre-Université Laval are also members of the Steering Committee. The NRBHSS chairs the steering committee and is responsible for the overall survey.

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, including the potential impacts of contaminants exposure.

Capacity building and training

Capacity building and training occurred during the data collection phase of the Survey. *Qanuilirpitaa* questionnaires, developed in collaboration with multiple Inuit and scientific experts, were administered to participants by the staff onboard the Amundsen CCGS, which included several Inuit interviewers. Training of interviewers took place during a 2-day meeting in Quebec City during the spring of 2017. In the current NCP project, funds are dedicated to supporting activities of Mélanie Lemire's Research Chair, which included several presentations on contaminant related issues in Nunavik in 2018-2019 (see human health project *Exposure to food chain contaminants in Nunavik: evaluating spatial and time trends among pregnant women & implementing effective health communication for healthy pregnancies and children* - Synopsis Report).

Communication and outreach

According to the *Qanuilirpitaa*? 2017 Policy on the Management of Databases and Biological Samples set in place with Nunavik partners, the data of the study is owned by the region. In August 2018, each participant received a letter that included the results of the main laboratory tests conducted during the survey, including blood metal concentrations. These results were also sent to the participant's CLSC unless the participant indicated otherwise in the informed consent. Numerous participants had blood concentrations exceeding the *Maladies à declaration obligatoire* (MADO) thresholds, especially for mercury. Community specific recommendations were elaborated by the NRBHSS to address these exceedances.

Indigenous Knowledge

Inuit knowledge was considered throughout the development and conduct of *Qanuipirlitaa*?, from the selection of the themes to be addressed, to the development of the questionnaires used in the different themes, the interpretation of the results and finally the elaboration of the communication strategy. A total of 19 thematic reports are being prepared that will contain the main results of the survey. Each draft report will be presented at a joint meeting of the Steering Committee and the Data Management Committee in October 2019; experts from Nunavik organisations will have the opportunity to comment and suggest modifications, prior to publication by the NRBHSS in June 2020.

Results and outputs/deliverables

A first draft thematic report entitled "Exposure to environmental contaminants: metals" was prepared in which blood metal levels are presented according to sex, age groups and sub-region of residence. Results of bivariate analyses will also be included to examine the potential influence of various socio-demographic characteristics, dietary and lifestyle habits on biomarkers of metal exposure.

A second thematic report entitled "Exposure to environmental contaminants: persistent organic pollutants" will be prepared when all results of POPs analyses will be received (March 2020). This report will be published in December 2020.

Scientific articles (2) will be prepared based on these reports. In addition to the descriptive data, these reports will present the results of multivariate statistical analyses that will allow identifying the main factors associated with contaminant body burden among Nunavimmiut.

Biomarkers of nutrient intake documented in the present study will be included in the thematic report on Nutrition and in associated scientific publications.

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

Acknowledgments

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References

Adamou, T.Y., M. Riva, G. Muckle, E.A. Laouan-Sidi and P. Ayotte (2018). "Socio-economic inequalities in blood mercury (Hg) and serum polychlorinated biphenyl (PCB) concentrations among pregnant Inuit women from Nunavik, Canada." Can J Public Health 109: 671-683.

Adamou, T., M. Riva, G. Muckle, E. A. Laouan-Sidi and P. Ayotte (Submitted). "Blood mercury and plasma polychlorinated biphenyls concentrations in pregnant Inuit women from Nunavik: Temporal Trends, 1992–2017." Science of the Total Environment.

AMAP (2011). AMAP Assessment 2011: Mercury in the Arctic Olso, Arctic Monitoring Assessment Program (AMAP): pp. xiv + 193 pp.

AMAP (2015). AMAP Assessment 2015: Human Health in the Arctic. Oslo, Norway, Arctic Monitoring Assessment Program (AMAP): 178.

Ayotte, P., A. Carrier, N. Ouellet, V. Boiteau, B. Abdous, E. A. Sidi, M. L. Chateau-Degat and E. Dewailly (2011). "Relation between methylmercury exposure and plasma paraoxonase activity in Inuit adults from Nunavik." Environ Health Perspect 119(8): 1077-1083.

Blanchet, C., E. Dewailly, P. Ayotte, S. Bruneau, O. Receveur and B. J. Holub (2000). "Contribution of Selected Traditional and Market Foods to the Diet of Nunavik Inuit Women." Can J Diet Pract Res 61(2): 50-59.

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

Boucher, O., C. H. Bastien, D. Saint-Amour, E. Dewailly, P. Ayotte, J. L. Jacobson, S. W. Jacobson and G. Muckle (2010). "Prenatal exposure to methylmercury and PCBs affects distinct stages of information processing: an event-related potential study with Inuit children." Neurotoxicology 31(4): 373-384.

Boucher, O., M. J. Burden, G. Muckle, D. Saint-Amour, P. Ayotte, E. Dewailly, C. A. Nelson, S. W. Jacobson and J. L. Jacobson (2012). "Response inhibition and error monitoring during a visual go/no-go task in Inuit children exposed to lead, polychlorinated biphenyls, and methylmercury." Environ Health Perspect 120(4): 608-615.

Boucher, O., G. Muckle, P. Ayotte, E. Dewailly, S. W. Jacobson and J. L. Jacobson (2016). "Altered fine motor function at school age in Inuit children exposed to PCBs, methylmercury, and lead." Environ Int 95: 144-151.

Boucher, O., G. Muckle, J. L. Jacobson, R. C. Carter, M. Kaplan-Estrin, P. Ayotte, E. Dewailly and S. W. Jacobson (2014). "Domain-specific effects of prenatal exposure to PCBs, mercury, and lead on infant cognition: results from the Environmental Contaminants and Child Development Study in Nunavik." Environ Health Perspect 122(3): 310-316.

Braune, B., J. Chetelat, M. Amyot, T. Brown, M. Clayden, M. Evans, A. Fisk, A. Gaden, C. Girard, A. Hare, J. Kirk, I. Lehnherr, R. Letcher, L. Loseto, R. Macdonald, E. Mann, B. McMeans, D. Muir, N. O'Driscoll, A. Poulain, K. Reimer and G. Stern (2015). "Mercury in the marine environment of the Canadian Arctic: review of recent findings." Sci Total Environ 509-510: 67-90.

Centers for Disease Control (2010). Guidelines for the identification and management of lead exposure in pregnant and lactating women. Atlanta, USA, US Dept of Health and Human Services.

Chapman, L. and H. M. Chan (2000). "The influence of nutrition on methylmercury intoxication." Environ Health Perspect 108 Suppl 1: 29-56.

Collings, P., M. G. Marten, T. Pearce and A. G. Young (2016). "Country food sharing networks, household structure, and implications for understanding food insecurity in Arctic Canada." Ecol Food Nutr 55(1): 30-49.

Couture, A., B. Levesque, E. Dewailly, G. Muckle, S. Déry and J.-F. Proulx (2012). "Lead exposure in Nunavik: from research to action." International journal of circumpolar health 71.

Dallaire, F., E. Dewailly, C. Laliberte, G. Muckle and P. Ayotte (2002). "Temporal trends of organochlorine concentrations in umbilical cord blood of newborns from the lower north shore of the St. Lawrence river (Quebec, Canada)." Environ Health Perspect 110(8): 835-838.

Dallaire, F., E. Dewailly, G. Muckle, C. Vezina, S. W. Jacobson, J. L. Jacobson and P. Ayotte (2004). "Acute infections and environmental exposure to organochlorines in Inuit infants from Nunavik." Environ Health Perspect 112(14): 1359-1365.

Dallaire, R., P. Ayotte, D. Pereg, S. Dery, P. Dumas, E. Langlois and E. Dewailly (2009). "Determinants of plasma concentrations of perfluorooctanesulfonate and brominated organic compounds in Nunavik Inuit adults (Canada)." Environ Sci Technol 43(13): 5130-5136.

Dewailly, E., P. Ayotte, S. Bruneau, S. Gingras, M. Belles-Isles and R. Roy (2000). "Susceptibility to infections and immune status in Inuit infants exposed to organochlorines." Environ Health Perspect 108(3): 205-211.

Dewailly, E., P. Ayotte, S. Bruneau, C. Laliberte, D. C. Muir and R. J. Norstrom (1993). "Inuit exposure to organochlorines through the aquatic food chain in Arctic Quebec." Environ Health Perspect 101(7): 618-620.

Ethier, A. A., G. Muckle, C. Bastien, E. Dewailly, P. Ayotte, C. Arfken, S. W. Jacobson, J. L. Jacobson and D. Saint-Amour (2012). "Effects of environmental contaminant exposure on visual brain development: a prospective electrophysiological study in school-aged children." Neurotoxicology 33(5): 1075-1085.

Guo, Y. L., Y. C. Chen, M. L. Yu and C. C. Hsu (1994). "Early development of Yu-Cheng children born seven to twelve years after the Taiwan PCB outbreak." Chemosphere 29(9-11): 2395-2404.

Guo, Y. L., G. H. Lambert and C. C. Hsu (1995). "Growth abnormalities in the population exposed in utero and early postnatally to polychlorinated biphenyls and dibenzofurans." Environ Health Perspect 103 Suppl 6: 117-122.

Health Canada (2013). Risk Management Strategy for Lead Ottawa, ON, Health Canada, Canada: 64.

ITK and ICC (2012). Inuit and the Right to Food: Inuit submission to UN Rapporteur on Right to Food. Ottawa, Inuit Tapiriit Kanatami (ITK) and the Inuit Circumpolar Council (ICC): 14.

Jacobson, J. L. and S. W. Jacobson (1997). "Evidence for PCBs as neurodevelopmental toxicants in humans." Neurotoxicology 18(2): 415-424.

Jacobson, J. L., G. Muckle, P. Ayotte, E. Dewailly and S. W. Jacobson (2015). "Relation of Prenatal Methylmercury Exposure from Environmental Sources to Childhood IQ." Environ Health Perspect 123(8): 827-833.

Kannan, K., S. Corsolini, J. Falandysz, G. Oehme, S. Focardi and J. P. Giesy (2002). "Perfluorooctanesulfonate and related fluorinated hydrocarbons in marine mammals, fishes, and birds from coasts of the Baltic and the Mediterranean Seas." Environ Sci Technol 36(15): 3210-3216.

Kannan, K., J. Koistinen, K. Beckmen, T. Evans, J. F. Gorzelany, K. J. Hansen, P. D. Jones, E. Helle, M. Nyman and J. P. Giesy (2001). "Accumulation of perfluorooctane sulfonate in marine mammals." Environ Sci Technol 35(8): 1593-1598.

Kinloch, D., H. Kuhnlein and D. C. Muir (1992). "Inuit foods and diet: a preliminary assessment of benefits and risks." Sci Total Environ 122(1-2): 247-278.

Lemire, M., M. Kwan, A. E. Laouan-Sidi, G. Muckle, C. Pirkle, P. Ayotte and E. Dewailly (2015). "Local country food sources of methylmercury, selenium and omega-3 fatty acids in Nunavik, Northern Quebec." Sci Total Environ 509-510: 248-259.

Little, M,, A. Achouba, P. Dumas, N. Ouellet, P. Ayotte and M. Lemire (2019). "Determinants of selenoneine concentration in red blood cells of Inuit from Nunavik (Northern Québec, Canada)." Environ Int 127: 243-252.

Lucas, M., F. Proust, C. Blanchet, A. Ferland, S. Dery, B. Abdous and E. Dewailly (2010). "Is marine mammal fat or fish intake most strongly associated with omega-3 blood levels among the Nunavik Inuit?" Prostaglandins Leukotrienes and Essential Fatty Acids 83(3): 143-150.

Muckle, G., P. Ayotte, E. E. Dewailly, S. W. Jacobson and J. L. Jacobson (2001). "Prenatal exposure of the northern Quebec Inuit infants to environmental contaminants." Environ Health Perspect 109(12): 1291-1299.

Muir, D., A. Fisk and M. Kwan (2001). Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. S. o. Research: 208-214.

Muir, D., G. Köck, J. Reist and M. S. Evans (2001). Temporal trends of persistent organic pollutants and metals in landlocked char. S. o. Research: 202-207.

NCP (2013). Canadian Arctic Contaminants Assessment Report III (CACAR): Persistent Organic Pollutants in Canada's North. N. C. P. (NCP). Ottawa, ON, Indigenous and Northern Affairs Canada: 487.

Noren, K. and D. Meironyte (2000). "Certain organochlorine and organobromine contaminants in Swedish human milk in perspective of past 20-30 years." Chemosphere 40(9-11): 1111-1123.

Rey, M., F. Turcotte, C. Lapointe and E. Dewailly (1997). "High blood cadmium levels are not associated with consumption of traditional food among the Inuit of Nunavik." J Toxicol Environ Health 51(1): 5-14.

Ruiz-Castell, M., G. Muckle, É. Dewailly, J. L. Jacobson, S. W. Jacobson, P. Ayotte and M. Riva (2015). "Household crowding and food insecurity among Inuit families with school-aged children in the Canadian Arctic." Am J Public Health. 105: e122-132.

Rice, D. C. (2008). "Overview of modifiers of methylmercury neurotoxicity: Chemicals, nutrients, and the social environment." NeuroToxicology 29(5): 761-766.

Salamova, A., M. H. Hermanson and R. A. Hites (2014). "Organophosphate and halogenated flame retardants in atmospheric particles from a European Arctic site." Environ Sci Technol 48(11): 6133-6140.

Su, G., R. J. Letcher, J. N. Moore, L. L. Williams, P. A. Martin, S. R. de Solla and W. W. Bowerman (2015). "Spatial and temporal comparisons of legacy and emerging flame retardants in herring gull eggs from colonies spanning the Laurentian Great Lakes of Canada and United States." Environ Res 142: 720-730.

Valera, B., E. Dewailly, E. Anassour-Laouan-Sidi and P. Poirier (2011). "Influence of n-3 fatty acids on cardiac autonomic activity among Nunavik Inuit adults." Int J Circumpolar Health 70(1): 6-18.

Valera, B., E. Dewailly and P. Poirier (2009). "Environmental Mercury Exposure and Blood Pressure Among Nunavik Inuit Adults." Hypertension (Baltimore) 54(5): 981-986.

Wang LZ, Thuya WL, Toh DS, Lie MG, Lau JY, Kong LR, Wan SC, Chua KN, Lee EJ, Goh BC (2013). Quantification of L-ergothioneine in human plasma and erythrocytes by liquid chromatography-tandem mass spectrometry. J Mass Spectrom.13;48(3):406-412.

Yamashita Y, Yabu T, Yamashita M. (2010). "Discovery of the strong antioxidant selenoneine in tuna and selenium redox metabolism." World J Biol Chem. 1(5):144-150.

Yamashita M, Yamashita Y, Suzuki T, Kani Y, Mizusawa N, Imamura S, Takemoto K, Hara T, Hossain MA, Yabu T, Touhata K (2013). "Selenoneine, a novel selenium-containing compound, mediates detoxification mechanisms against methylmercury accumulation and toxicity in zebrafish embryo." Mar Biotechnol (NY) 15(5):559-570.

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 3 of 4)

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 3 de 4)

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Project locations/Emplacements du projet

- All 14 communities of Nunavik
- Quebec City, Quebec

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 four-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 de l'environnement 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 concentrations d'exposition des Inuits des régions circumpolaires a été confirmée pour la plupart des POP hérités. Malgré une tendance à la baisse découlant d'une diminution de la consommation d'aliments traditionnels, l'exposition au mercure (Hg) demeure une question cruciale, surtout chez les femmes enceintes au Nunavik. En outre, de nouvelles substances chimiques sont commercialisées chaque année. Ces « nouveaux POP » et « contaminants d'intérêt émergent (CIE) » 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, et 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 formulées pour guider les fournisseurs de soins n'ont pas été très efficaces pour réduire l'exposition au Hg de 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. Data analyses in year 2 and 3 show that 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) used to replace older ones, have increased since they were first measured in 2012. PFNA exposure levels are now more than three times higher for women in northern Canada compared to women of the same age in southern Canadian cities. Based on food questionnaire data and methylmercury (MeHg) intake estimations, beluga meat and *nikku* were 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. Study results were shared and discussed on several occasions with Inuit colleagues and communities and Nunavik and Nunavut health professionals in 2018-2019, and are currently in preparation for publication.

Ce projet de quatre ans contribuera aux efforts de biosurveillance internationaux axés sur l'exposition des femmes enceintes du Nunavik aux contaminants environnementaux transportés à grande 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 dans le cadre d'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 analyses des données des années 2 et 3 montrent que les concentrations d'exposition aux POP hérités et nouveaux visés par la Convention de Stockholm ont nettement diminué depuis qu'ils ont été mesurés pour la première fois en 1992 ou 2004, et ont continué à baisser ces 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. Les concentrations d'exposition au PFNA sont plus du triple des taux d'exposition observés 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. Les résultats de l'étude ont été partagés et discutés à plusieurs reprises avec des collègues et des collectivités inuites ainsi qu'avec des professionnels de la santé du Nunavik et du Nunavut en 2018-2019, et sont en cours de préparation en vue d'une publication.

Key messages

- Measurements in 2016-2017 indicate that 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 have increased since they were first measured in 2012.
- PFNA exposure levels are more than three times higher for women in northern Canada compared to 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. The highest exposure occurs in the summer when most beluga products are available.

Messages clés

- Les mesures effectuées en 2016-2017 indiquent que les taux de Hg et de Pb dans le sang ont diminué de 16 à 18 % depuis la dernière fois qu'ils ont été mesurés en 2013.
- Les concentrations d'exposition aux POP hérités 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 concentrations d'exposition aux composés perfluorés plus récents (PFNA, PFDA et PFuDA) ont augmenté depuis qu'ils ont été mesurés pour la première fois en 2012.
- Les concentrations d'exposition au PFNA sont plus du triple des taux d'exposition observés chez les femmes du même âge dans les villes du sud du Canada.
- La viande de béluga et le nikku sont les principales sources d'exposition au MeHg pour les femmes enceintes, quelle que soit la saison. L'exposition la plus élevée se produit en été, lorsque la plupart des produits à base de béluga sont disponibles.

Objectives

The core objective of this four-year project untitled *Nutaratsaliit qanuingisiarningit niqituinnanut – Pregnancy wellness with country foods* (NQN) is to promote healthy pregnancies and child development using the highest quality evidence possible. This project (Part A) also 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. Thus, in 2016-2018, the NQN project team aimed to recruit 100 pregnant women each year from the three sub-regions of Nunavik (Eastern Hudson, Hudson Strait and Ungava).

This project aims to:

- measure pregnant women's exposure to metals (mercury [Hg], lead [Pb], and legacy POPs, new POPs and Contaminants of Emerging Concern [CECs]);
- evaluate temporal and geographical variations in Hg exposure using sequential Hg hair analysis by cm and identify country foods responsible for the variation in exposure;
- evaluate pregnant women's nutritional status (omega-3 polyunsaturated fatty acids [PUFAs], total selenium [Se] and

selenoneine, hemoglobin [Hb], iron status and manganese [Mn]); and

- assess pregnant women's awareness of public health messages about country foods during pregnancy and contaminants previously disseminated in Nunavik.

This project also comprises an additional communication research component (Part B and C) that was put on hold for 2018-2019, and that will be continued in 2019-2020. The most up-to-date report on parts B and C can be found in the 2017-2018 Northern Contaminants Program synopsis report.

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), which is from 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). 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 the environmental concentrations of POPs (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. In the Western Arctic an increasing trend in marine mammal Hg concentrations has been observed recently (Braune et al. 2015). Since up to 23% of 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 late spring and fall (Lemire et al. 2015). Lake trout is also known to accumulate high levels of Hg (Kwan et al. 2014). This lake trout is believed to be often consumed by women in other villages, particularly during the winter, although no information was available about the consumption of lake trout in the 2004 Qanuippitaa survey. Thus, further data analysis on pregnant women's 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 the levels of the exposure that the Nunavik population has to these contaminants.

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 which, in this case, is pregnant women. This research has revealed that pregnant women may be particularly receptive to behavioral change messaging and that 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 has been identified in previous research (Bondarianzadeh et al. 2011; Morales et al. 2004). Food safety messages delivered to pregnant women by healthcare providers tend to emphasize the risk associated with the consumption of certain foods 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 for food safety in pregnancy are needed and that health professionals could benefit from food safety training (Bondarianzadeh et al. 2011).

Activities in 2018-2019

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, 2018). Laboratory analyses for POPs (legacy POPs, news POPs and CECs) and selenoneine were completed by fall 2017 and presented in Lemire et al. (2018).

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, and are presented in Lemire et al. (2017, 2018). Detailed statistical analyses to document pregnant women country food consumption, to identify seasonal local dietary sources of Hg exposure and to describe awareness about public health messages on country foods and contaminants were conducted as part the MSc project of Mariana Pontual which started in May 2017 and submitted to reviewers in May 2018. Results are detailed in Lemire et al. (2018).

Publications

Three manuscripts involving NQN data presented in previous NCP synopsis reports are in preparation. The first is led by Therese Adamou (PhD student) titled: Blood mercury and plasma polychlorinated biphenyls concentrations in pregnant Inuit women from Nunavik: Temporal Trends, 1992–2017. The second is led by Mariana Pontual (MSc student) titled: Exposure to mercury and consumption of country foods in Nunavik: Geographical and temporal trends among pregnant women. The third one focus on PFAS temporal trends (2004-2012-2017) and the writing is led by Elyse Caron-Beaudoin (Postdoctoral fellow). The summary of these results are already presented in Lemire et al. (2017, 2018).

Other capacity building, training, communication, and outreach activities in 2018-2019

Nunavik Nutrition and Health Committee (NNHC)

Findings of the project were systematically presented and discussed with NNHC members before being presented to other general or scientific audiences. Metals and POPs exposure data and time-trends were presented in November 2017 and again in May 2018, 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. These findings were discussed again in with the NNHC and the NHBHSS in October and November 2018 in preparation for the year 4 proposal for the Nunavik consultation activities details in the Indigenous Knowledge integration section.

Presentation to several other audiences via the Nasivvik Chair activities

Nutaratsaliit qanuingisiarningit niqituinnanut project history, rationale and key findings was presented to several scientific, knowledge user and decision maker audiences, including Indigenous partners, Nunavut and Nunavik health professionals, federal scientists and parliamentarians, as well as during several keynote sessions aiming at presenting contaminant issues in the Arctic, pregnant women's reality in Nunavik, the Nasivvik Research Chair program and the type of collaborative projects conducted by the team. Below is a list of these presentations.

- **Lemire M** (2019) Pregnancy Wellness with Country Foods. Maternal and Paediatric Challenges in the Arctic April 27.
- **Lemire M** and Little M (2019) Nutaratsaliit qanuingisiarningit niqituinnanut - Pregnancy wellness with country foods. NCP Beluga Working Group, Ottawa, Canada, March 15.
- **Lemire M** (2019) Unexpected Linkages Between the Coastal Ocean and Inuit Health. Gordon Research Conference on Polar Marine Science, Tuscany, Italy, March 17-22.
- **Lemire M** (2019) Jeunes, environnement et santé des Premières Nations, Conférence annuelle du Collaboratif sur la santé environnementale des enfants du Nouveau-Brunswick, Feb. 6.
- **Lemire M** (2019) Enjeux de santé environnementale en contexte autochtone au Québec : changements globaux et contaminants émergents. Institut de recherche en santé publique de l'Université de Montréal (IRSPUM), Jan 14.
- **Lemire M** (2018) Key findings from our recent research in Nunavik and among First Nation children in Quebec, Health Canada's Federal/Provincial/Territorial Food Safety Committee, Ottawa, Canada, Nov 8.

- **Lemire M** (2018) Key findings from our recent research in Nunavik and among First Nation children in Quebec, Health Canada's Health Products and Food Branch, Ottawa, Canada, Oct 30.
- **Lemire M** (2018) Parliamentary Health Research Caucus Reception on Northern and Rural Health Research in Canada, Ottawa, Canada, Oct 30.
- **Lemire M**, Little M, Ayotte P (2018) Time trends exposure to Hg in the North including short-time exposure, and Selenoneine-Hg interaction analysis in Nunavik. Health Canada's Chemicals and Environmental Health Management Bureau, Workshop on mercury in country foods, Ottawa, Canada, Aug 30.
- **Lemire M** (2018) Comprendre les effets des changements environnementaux sur la santé et promouvoir le rôle des écosystèmes nordiques pour soutenir la santé et le bien-être. Diner-conférence autochtone, Université du Québec en Abitibi-Témiscamingue, Val d'Or, Canada, March 28.

The NQN project findings were also presented and discussed with graduated students during guest lectures in Université Laval courses on Ocean's health as well as risk evaluation and management in environmental public health.

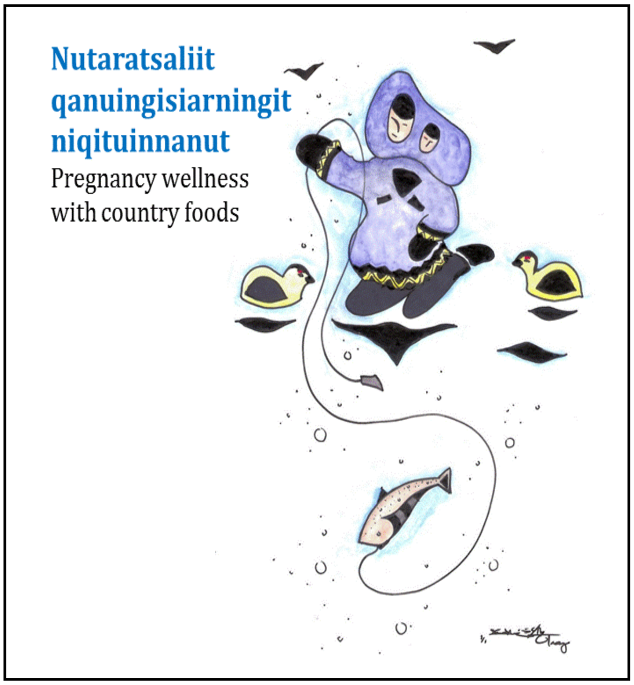
Human Health Assessment Group of the Arctic Monitoring and Assessment Programme (HHAG-AMAP)

Mélanie Lemire is the Canadian Designated Expert for the Human Health Assessment Group of the Arctic Monitoring and Assessment Programme (HHAG-AMAP). This expert group are now working with Health Canada to organise the update and next version of the AMAP Human Health report. Together with Jon Odland, Mélanie Lemire, Pierre Ayotte and Matthew Little and several AMAP colleagues, the expert group submitted a grant application for Horizon 2020 (European Union) for a new international mother-child cohort study focussing on exposomics and mercury-selenoneine interactions, based on our Nunavik findings in several coastal populations subsisting on fish and marine mammal consumption. Finally, both the NQN project and another project with First Nation children in Quebec are showing elevated and increasing human exposure to long-chain PFAS in Canada (Caron-Beaudoin et al. 2019; Lemire et al. 2018), thus providing scientific evidence for the eventual nomination of long-chain PFAS the Stockholm Convention POPs Review Committee (POPRC) by the Canadian Government. This would be the first Canadian chemical nomination to the Stockholm Convention since 2004.

Indigenous Knowledge integration

Inuit knowledge was considered at all steps while developing 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 (NQN) - Pregnancy Wellness with Country Foods, and a project logo was developed together with Ulayu Pilurtuut, a well-known Inuk artist in Kuujjuaq (see 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) to consider and include all Inuit knowledge that is relevant and useful to improve communications between researchers and community members. Project announcements via local and regional radio were done by Annie Baron in Inuktitut. When needed and available, Inuit interpreters were hired to recruit participants and translate questionnaires to participants during interviews. When developing the questionnaire and preparing the results letter, consultations were held with members of the NNHC and other health professionals in Nunavik. Similarly, when analyzing country food consumption data, consultation with NNHC members and NQN project partners were made. This was 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.



For many years, we have worked on multiple related projects to assess local sources of Hg, Pb and nutrients in Nunavik, to understand their effects on pregnancy outcomes and child development and how to best communicate this information and reduce their exposure. Together with the NRBHSS, we now propose to integrate Hg and Pb exposure assessment and counselling into pregnancy clinical follow-up across Nunavik. We may also include other contaminants and nutrients biomonitoring in these activities. To carefully plan these new joint clinical and research activities, for 2019-2020 (year 4), we will be conducting a series of information and consultation sessions with Nunavik health professionals about the NQN project to:

1. Identify their information needs and offer information sessions with respect to Hg and Pb exposures and related health outcomes;
2. Document their views on the feasibility, tools and linkages needed to integrate Hg and Pb exposure assessment and counselling into clinical activities for pregnancy follow-up;
3. Evaluate the feasibility of integrating research objectives (i.e. clinical intervention effectiveness, biomonitoring for other contaminants and nutrients) into the proposed clinical activities.

NNHC members, Midwifes of Maternity Centres in Puvirnituq, Inukjuak, Salluit, and Kuujjuaq as well as physicians, Programme Services intégrés en périnatalité et petite enfance (SIPPE) workers, nurses, and administration staff of Tulattavik and Inuulitsivik hospitals will be met between June and November 2019. According to Lucy Grey's recommendation (Nunavik Inuit Research Advisor), we will also consult pregnant women, grandmothers, Elders, and hunters in other Nunavik villages in fall 2019.

Previous NQN project findings and these consultations are critical to carefully plan and implement the joint clinical and research activities proposed here over the coming years for successful pregnant women counselling and contaminant biomonitoring for healthy pregnancies and children in Nunavik.

Results part A (Year 3)

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.

All results from the NQN project were already presented in detail in the last two NCP synopsis by Lemire et al. (2017, 2018). The three manuscripts detailed above will be submitted for publication in fall 2019.

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 must 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.

Discussion and conclusions

Although pregnant women Hg exposure is still decreasing in Nunavik, 23% of them presented blood Hg levels above 8 $\mu g \cdot L^{-1}$, 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 $\mu g \cdot L^{-1}$ in 2007-2009 (Lye et al. 2013). It is important to remember that pregnant women for the present study were recruited in October 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 also 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 two times 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 for women in northern Canada compared to women of the same age 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) (Health Canada, 2013).

Further analysis to document associations between pregnant women's 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 in parallel to the broad consultation activities previously described in the Indigenous Knowledge integration section.

Expected project completion date

Almost all laboratory and statistical analyses are concluded, and manuscripts will be submitted for publication in 2019-2020. The present project will be completed after the next fiscal year once the consultation with Nunavik health professionals, pregnant women, grandmothers, Elders, and hunters is finalised. Consultation findings will be discussed with the NRBHSS for an eventual further implementation of Hg and Pb exposure assessment and counselling into pregnancy clinical follow-up across Nunavik jointly with an additional biomonitoring component for old and new POPs and nutritional status.

Project website

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

Acknowledgments

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References

Aaronson LS, Mural CM, Pfoutz SK. 1988. Seeking information: Where do pregnant women go? Health Educ Q 15:335-345.

AMAP. 2009. Amap assessment 2009: Human health in the arctic. Oslo, Norway:Arctic Monitoring and Assessment Programme (AMAP).

AMAP. 2014. Trends in stockholm convention persistent organic pollutants (pops) in arctic air, human media and biota. By: S. Wilson, h. Hung, a. Katsoyiannis, d. Kong, j. Van oostdam, f. Riget, a. Bignert. . Oslo:Arctic Monitoring and Asessment Programme (AMAP).

AMAP. 2015. Amap assessment 2015: Human health in the arctic. Oslo, Norway.

AMAP. 2017. Amap assessment 2016: Chemicals of emerging arctic concern. Oslo, Norway.

Bondarianzadeh D, Yeatman H, Condon-Paoloni D. 2011. A qualitative study of the australian midwives' approaches to listeria education as a food-related risk during pregnancy. Midwifery 27:221-228.

Boucher O, Bastien CH, Saint-Amour D, Dewailly E, Ayotte P, Jacobson JL, et al. 2010. Prenatal exposure to methylmercury and pcbs affects distinct stages of information processing: An event-related potential study with inuit children. Neurotoxicology 31:373-384.

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

Boucher O, Muckle G, Jacobson JL, Carter RC, Kaplan-Estrin M, Ayotte P, et al. 2014. Domain-specific effects of prenatal exposure to pcbs, mercury, and lead on infant cognition: Results from the environmental contaminants and child development study in nunavik. Environ Health Perspect 122:310-316.

Boucher O, Muckle G, Ayotte P, Dewailly E, Jacobson SW, Jacobson JL. 2016. Altered fine motor function at school age in inuit children exposed to pcbs, methylmercury, and lead. Environ Int 95:144-151.

Braune B, Chetelat J, Amyot M, Brown T, Clayden M, Evans M, et al. 2015. Mercury in the marine environment of the canadian arctic: Review of recent findings. Sci Total Environ 509-510:67-90.

Caron-Beaudoin E, Ayotte P, Laouan Sidi EA, Community of Lac S, Community of Winneway - Long Point First N, Nutashkuan CTKo, et al. 2019. Exposure to perfluoroalkyl substances (pfas) and associations with thyroid parameters in first nation children and youth from quebec. Environ Int 128:13-23.

Dewailly E, Ayotte P, Bruneau S, Laliberte C, Muir DC, Norstrom RJ. 1993. Inuit exposure to organochlorines through the aquatic food chain in arctic quebec. Environ Health Perspect 101:618-620.

Dewailly E, Ayotte P, Bruneau S, Gingras S, Belles-Isles M, Roy R. 2000. Susceptibility to infections and immune status in inuit infants exposed to organochlorines. Environ Health Perspect 108:205-211.

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

Guo YL, Lambert GH, Hsu CC. 1995. Growth abnormalities in the population exposed in utero and early postnatally to polychlorinated biphenyls and dibenzofurans. Environ Health Perspect 103 Suppl 6:117-122.

Health Canada. 2013. Second report on human biomonitoring of environmental chemicals in canada: Results of the canadian health measures survey cycle 2 (2009–2011).

Jacobson JL, Jacobson SW. 1997. Evidence for pcbs as neurodevelopmental toxicants in humans. Neurotoxicology 18:415-424.

Jacobson JL, Muckle G, Ayotte P, Dewailly E, Jacobson SW. 2015. Relation of prenatal methylmercury exposure from environmental sources to childhood iq. Environ Health Perspect 123:827-833.

Kinloch D, Kuhnlein H, Muir DC. 1992. Inuit foods and diet: A preliminary assessment of benefits and risks. Sci Total Environ 122:247-278.

Kwan M, Lemire M, Pirkle C, Ricard S. 2014. Establishing community based safety guideline to protect inuit from mercury originated from consuming lake trout.Canadian High Arctic Research Station (CHARS), Aboriginal Affairs and Northern Development Canada.

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

Lemire M, Kwan M, Laouan-Sidi AE, Muckle G, Pirkle C, Ayotte P, et al. 2015. Local country food sources of methylmercury, selenium and omega-3 fatty acids in nunavik, northern quebec. Sci Total Environ 509-510:248-259.

Lemire M, Muckle G, Ricard S, Déry S, Pirkle C. 2016. The complex balance between mercury exposure and country foods benefits: Comprehensive guidelines for health practitioners in nunavik. Kuujjuaq, QC.:Nunavik Regional Board of Health and Social Services.

Lemire M, Furgal C, Ayotte P, Pirkle C, Boyd A, Muckle G. 2017. Exposure to food chain contaminants in nunavik: Evaluating spatial and time trends among pregnant women & implementing effective health communication for healthy pregnancies and children (year 1 of 4). Ontario, Canada.

Lemire M, Furgal C, Ayotte P, Pirkle C, Boyd A, Muckle G. 2018. 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 4). Ottawa, Canada.

Lye E, Legrand M, Clarke J, Probert A. 2013. Blood total mercury concentrations in the canadian population: Canadian health measures survey cycle 1, 2007-2009. Can J Public Health 104:e246-251.

McLean Pirkle C, Peek-Ball C, Outerbridge E, Rouja PM. 2015. Examining the impact of a public health message on fish consumption in bermuda. PloS one 10:e0139459.

Morales S, Kendall PA, Medeiros LC, Hillers V, Schroeder M. 2004. Health care providers' attitudes toward current food safety recommendations for pregnant women. Appl Nurs Res 17:178-186.

Muckle G, Ayotte P, Dewailly EE, Jacobson SW, Jacobson JL. 2001. Prenatal exposure of the northern quebec inuit infants to environmental contaminants. Environ Health Perspect 109:1291-1299.

Murray-Johnson L, Witte K. 2003. Looking toward the future: Health message design strategies. In: Handbook of health communication, (TL T, AM D, KI M, R P, eds). Mahwah, New Jersey:Lawrence Erlbaum Associates, 473-495.

Naughton F, Prevost AT, Gilbert H, Sutton S. 2012. Randomized controlled trial evaluation of a tailored leaflet and sms text message self-help intervention for pregnant smokers (miquit). Nicotine Tob Res 14:569-577.

Oken E, Kleinman KP, Berland WE, Simon SR, Rich-Edwards JW, Gillman MW. 2003. Decline in fish consumption among pregnant women after a national mercury advisory. Obstetrics and gynecology 102:346-351.

Winneke G, Bucholski A, Heinzow B, Kramer U, Schmidt E, Walkowiak J, et al. 1998. Developmental neurotoxicity of polychlorinated biphenyls (pcbs): Cognitive and psychomotor functions in 7-month old children. Toxicology letters 102-103:423-428.

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

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Project locations/Emplacements du projet

- Tulit'a, Sahtú Region, NT
- Déline, Sahtú Region, NT
- K'asho Got'ine, Sahtú Region, NT
- Jean Marie River First Nation, Dehcho Region, NT
- K'atl'odeeche, Dehcho Region, NT
- West Point First Nation, Dehcho Region, NT
- Ka'a'gee Tu, Dehcho Region, NT
- Sambaa K'e, Dehcho Region, NT

Abstract

Throughout the fourth and final year of the study, we returned results from previous sample collections in three additional communities. Our research team discussed results and potential future collaborations in person with local leadership as well as return results to participants through public meetings and one-to-one sessions (Tulit'a, K'asho Got'ine, Sambaa K'e, Northwest Territories). With the assistance of local research coordinators and the local health centers, we completed the re-testing and follow up for participants who had elevated levels of a contaminant. In addition to the community report, the leadership partners of each community received the regional report (Dehcho, Sahtú) which won't be shared with the public, and were invited to review and comment the final report on the Mackenzie Valley biomonitoring results. This report is now available online on our website. Over the four-year project (2015-2019), 537 participants (between ages of 6 and >80 years) from nine Dehcho and Sahtú communities took part in this research. We collected 443 hair, 198 urine and 276 blood samples. Participants also completed a health messages survey and two dietary questionnaires (24-hr Recall, Food Frequency Questionnaire). Descriptive results are available for the majority of collected data (metals in blood/urine; persistent organic pollutants (POPs) in blood; mercury in hair; dietary surveys), but biobanked samples were analysed more recently for segmental hair mercury (results returned to participants) and perfluorinated compounds (currently being analysed). Over all the biomarkers analysed (over 100), lead and polycyclic aromatic hydrocarbons (PAHs) were identified as top priorities, due to their levels above the national levels (from the Canadian Health Measure Survey). Data analysis to identify exposure determinants will be ongoing for the next few years. This multi-year collaborative project led to new research projects with local partners to answer to environmental health concerns (nutrition assessment, CIHR; food security, CIHR; water knowledge exchange, GWF). In parallel, a similar contaminant biomonitoring project in on going in the Yukon (Laird et al.).

Résumé

Tout au long de la quatrième et dernière année de l'étude, nous avons transmis les résultats des précédentes collectes d'échantillons dans trois autres collectivités. Notre équipe de recherche a discuté des résultats et des collaborations potentielles futures en personne avec les dirigeants locaux, et a présenté les résultats aux participants lors de réunions publiques et en entretien individuel (Tulit'a, K'asho Got'ine, Sambaa K'e, Territoires du Nord-Ouest). Avec l'aide des coordonnateurs de recherche et des centres de santé locaux, nous avons effectué de nouveaux tests et un suivi avec les participants qui présentaient des concentrations élevées d'un contaminant. En plus du rapport sur la collectivité, les partenaires dirigeants de chaque collectivité ont reçu le rapport régional (Dehcho, Sahtú) qui ne sera pas partagé avec le public, et ont été invités à examiner et à commenter le rapport final sur les résultats de la biosurveillance de la vallée du Mackenzie. Ce rapport est maintenant disponible en ligne sur notre site Web. Au cours de ce projet de quatre ans (2015-2019), 537 participants (âgés de 6 ans à plus de 80 ans) de neuf collectivités du Dehcho et du Sahtú ont participé à cette recherche. Nous avons prélevé 443 échantillons de cheveux, 198 d'urine et 276 de sang. Ces derniers ont aussi rempli deux questionnaires sur les messages en matière de santé et deux sondages sur leur alimentation (relevé de 24 h et fréquence de consommation). Des résultats descriptifs sont disponibles pour la majorité des données recueillies (métaux dans le sang/urine; polluants organiques persistants (POP) dans le sang; mercure dans les cheveux; enquêtes sur l'alimentation), mais les échantillons mis en biobanque ont été analysés plus récemment pour le mercure segmentaire dans les cheveux (résultats renvoyés aux participants) et les composés perfluorés (en cours d'analyse). Sur l'ensemble des biomarqueurs analysés (plus de 100), il a été établi que le plomb et les hydrocarbures aromatiques polycycliques (HAP) étaient des priorités absolues, en raison de leurs concentrations supérieures aux concentrations nationales (d'après l'Enquête canadienne sur les mesures de santé). L'analyse des données visant à identifier les déterminants de l'exposition

se poursuivra au cours des prochaines années. Ce projet de collaboration pluriannuel a donné lieu à de nouveaux projets de recherche avec des partenaires locaux pour répondre aux préoccupations en matière de santé environnementale (évaluation de la nutrition, IRSC; sécurité alimentaire, IRSC; échange de connaissances sur l'eau, Global Water Futures (GWF). En parallèle, un projet similaire de biosurveillance des contaminants est en cours au Yukon (Laird et coll.).

Key messages

- Year 3 results were returned to participating individuals and communities in between November 2018 and March 2019. All the results of the 4-year project were returned to the communities.
- For the vast majority of participants, metal exposures fell below available health-based guidance values. In total, 3.6% of the participants were offered a re-testing due to one elevated contaminant (mercury, cadmium, or lead).
- Metals, POPs, phthalates, and arsenic species were generally in the normal ranges of exposure observed in Canada.
- Lead and polycyclic aromatic hydrocarbons (PAHs) levels were more elevated than the national levels but below guidelines associated with adverse health effects.

Messages clés

- Les résultats de la troisième année ont été communiqués aux personnes et aux collectivités participantes entre novembre 2018 et mars 2019. Tous les résultats du projet de 4 ans ont été transmis aux collectivités.
- Pour la grande majorité des participants, l'exposition aux métaux était inférieure aux critères sanitaires établis. En tout, 3,6 % des participants se sont vu proposer un nouveau test en raison d'un contaminant présent en concentration élevée (mercure, cadmium ou plomb).
- Les métaux, les POP, les phtalates et les espèces d'arsenic se situaient généralement dans les fourchettes normales d'exposition observées au Canada.
- Les concentrations de plomb et d'hydrocarbures aromatiques polycycliques (HAP) étaient plus élevées que les concentrations nationales, mais inférieures aux recommandations prévenant les effets nocifs sur la santé.

Objectives

In the **Short term** this project aims to:

- analyze the levels and determinants of contaminant exposure among project participants in the Dehcho and Sahtú regions of the Northwest Territories;
- assess baseline awareness of current contaminant messages and risk perceptions among project participants;
- return results to the individuals and communities who took part in year 3;
- evaluate the impact of public health messages on risk perceptions and awareness of contaminant issues in participating communities; and
- work with participating communities to design follow-up plans based upon the results generated from samples collected in Years 1-3 of the project.

In the **Long term** this project aims to:

- implement follow-up research and knowledge translation activities based upon the results generated from samples collected in Years 1-3 of the project.

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 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 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 to improve nutrition and food security while lessening contaminant exposure among Dehcho and Sahtú First Nations communities.

Activities in 2018-2019

NCP funding in 2018-2019 was used to work on four components of this contaminant biomonitoring research project in the Dehcho and Sahtú Regions of the Northwest Territories. The key elements of the 4 components were completed.

Component 1: ongoing biomarker data analysis

Biomarker levels were compared to biomarker results to those from nationally representative datasets (e.g., Canadian Health Measures Survey or CHMS) to identify contaminants at potentially-elevated levels. These biomarkers' data can be found on our website (https://uwaterloo.ca/human-exposure-and-toxicology-research-group/research). Data analysis are ongoing related to the biomarker results from samples collected to: identify determinants (e.g., demographic, dietary) related to biomarker levels; to refine a probabilistic mercury and nutrient model to include lake-specific contaminant, nutrient, and Food Frequency Questionnaire (FFQ) data; and to identify how the preparation and consumption of wild-harvested foods differs among regions and subpopulations. The results from the above analyses will be incorporated into a public health screening tool that can be used to characterize those most at risk of facing elevated contaminant exposures (i.e. lead and mercury) in the Northwest Territories.

Component 2: return of the results

In 2017-2018, participants from three communities took part (Tulit'a, Sambaa K'e, K'asho Got'ine) in the biomonitoring component. Each study participant who provided a hair, urine, and/or blood sample received their results via a plain-language letter. In parallel with the individual reporting, we provided a community report and hosted public forums in each community.

Component 3: follow up and biological re-testing

Individuals with exposure levels that exceed biomonitoring guidelines received general guidance on steps that may help lower their levels. Also, the research team provided participants with especially high levels of particular contaminants (i.e., Hg, Cd, and Pb) the opportunity to provide follow-up samples for biological re-testing to document if the level remained high since the original sample collection. Blood samples were collected with the support of the local Health and Social Services Authority.

Component 4: risk perception and communication

The Health Messages survey has provided details on participants' awareness of contaminant and health issues as well as their understandings and perceptions of contaminant risks. These findings interpreted by Dr. Kelly Skinner's team were considered in our reporting strategy.

Community engagement

Before 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 could not be used to identify the results of any one individual. The development of messages, materials and presentation approaches we 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 completed in collaboration with the HSSA-Dehcho, and HSSA-Sahtú.

Capacity building and training

NCP funds were used to hire 1 or 2 local research coordinators in each of the participating communities. These coordinators assisted 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 Government of the Northwest Territories Department of Health and Social Services (DHSS), Dehcho Aboriginal Aquatic Resources and Ocean Management, Sahtú Renewable Resources Board (SRRB), Dehcho and Sahtú divisions of the Health and Social Services Authority (HSSA), and other organizations with regular 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. Brochures of the Biomonitoring approach in the NT written in plain language were distributed widely. To stay in contact with interested community members, local radio stations were visited during each of our community visits and postcards were sent to participating communities and project partners at least once a year. Finally, the research team distributed a quarterly newsletter to community partners, local coordinators, researchers working in the same regions, and government representatives.

Indigenous Knowledge

The project has relied on local and traditional knowledge communicated through the community consultations completed in 2014-2018 to guide the project's return of results and knowledge translation. Local perspectives provided by residents of the Dehcho and Sahtú Regions within 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 for ensuring that the dietary survey uses the proper names for foods that will be recognized by members of the participating communities. Finally, terminology workshops were held to find ways to express key words from the Contaminant Biomonitoring project in Sahtúot'ı̨nę Yatı̨́ (North Slavey) with help from local Elders to share their knowledge with us to help with the communication process of the project. The terminology workshops helped to build important understanding and common language around relevant terms such as "contaminant" and "risk" and facilitate more meaningful language use and communication.

Results

A total of 537 participants agreed to provide samples from 9 communities (Jean Marie River, K'atl'odeeche, West Point, Deh Gah Gotie, Ka'a'gee Tu, Sambaa K'e, Tulit'a, Déline and K'asho Got'ine), representing about 18% of residents living in these communities, or 9% living in the Dehcho and Sahtú region. Between January 2016 and March 2018, a total of 917 samples were collected: 443 hair samples, 198 urine samples and 276 blood samples. Several metals, including some toxic metals (e.g. cadmium, lead) and some metal nutrients (e.g. zinc, selenium), persistent organic pollutants (POPs), and fatty acids were quantified in urine, whole blood, and/or blood plasma. Furthermore, mercury was measured in hair samples. Over 100 exposure biomarkers were quantified in human biological samples.

The results were shared with the communities and participants as per the community research agreements. The findings can be found: https://uwaterloo.ca/human-exposure-and-toxicology-research-group/research.

From the dietary survey results, we observed that participants had, on average, energy intakes of 1999 kcals and consumed 5.1% of their diet from country foods. Individuals over 50 years old consumed a higher percentage of their diet from country foods (6.4-8.2%) than younger age groups. Low intakes of some food groups and nutrients were observed dependent on age. Nutrients and food groups that were adequate and met guidelines were likely due to country food use. Approximately, one-in-three (31%) respondents reported consuming country food (e.g., caribou meat) in the previous 24 hours. Since this data collection took place between November – March of each sampling year, moose meat was the most often eaten country food reported.

Over the previous year, the five foods consumed by the largest number of participants were: moose (93%), whitefish (84%), lake trout (61%), woodland caribou (55%) and Canada goose (55%). When compared with previous research in the Northwest Territories (CINE, 1996), similar patterns in country food usage emerge. For example, whitefish and moose have remained among the most consumed foods. Interestingly, some small game (e.g. rabbit) appear to be consumed more often in participating communities.

Participants not only preferred country foods, but the majority indicated they were aware of the many nutritional and health benefits of eating country foods (e.g. country foods can provide a significant variety and amount of nutrients; eating country foods can lower the risk of diabetes and heart disease). Nearly 70% of project respondents indicated that they have heard or seen messages about fish that had high levels of mercury. Most of these individuals reported that they had been mostly informed of these messages by researcher or scientists (51%), by the radio (48%), or by a friend (46%). A total of 57% said that they had heard/seen contaminant messages about fish and mercury for lakes with site specific consumption notice. However, approximately 29% of participants reported eating fish species from a specific lake for which a consumption notice for mercury was issued for that species. Since hearing these messages, respondents reported that they decreased the amount of fish they ate (34%) and/or changed the location where they usually fish (20%).

Biomarker levels were compared to those from nationally representative datasets, such as the Canadian Health Measures Survey (CHMS) (Health Canada, 2013) and the First Nations Biomonitoring Initiative (FNBI) (AFN, 2013), to identify contaminants at potentially elevated levels. Levels of contaminants in the urine, blood and hair samples of participants were generally similar to those seen in other biomonitoring studies in Canada. Table 1 presents the level of mercury in hair. The detection rate was 99%. These hair levels (geometric mean and 95th percentile) suggest that the health risks posed by mercury have remained low for the majority of participants. Previous research in Tulit'a (Delormier, 2012) reported that 3% of participants had hair mercury levels above the health-based guidance value of 5 µg/g that indicates that follow-up testing is recommended. Similarly, 2% of participants of the Mackenzie Valley project described herein had hair mercury levels above health guidance values.

Table 1. Geometric mean (GM) and 95th percentile (P95) of mercury quantified in hair (µg/g).

	GM	P95
Mercury	0.47	2.8

For the vast majority of participants, mercury, cadmium, and lead exposures fell below the health-based guidance values available for these metals. Generally, the metal biomarkers appeared within the range of those seen in other Canadian biomonitoring studies, such as the Canadian Health Measures Survey (CHMS) (Health Canada, 2013) and First Nations Biomonitoring Initiative (FNBI) (AFN, 2013). The detection rate of metals ranged between 60-100% in urine and 0-100% in blood. Levels of some metal nutrients in urine (i.e., manganese, cobalt, selenium) and in blood (i.e., manganese, copper) appeared higher than observed in nationally representative biomonitoring studies (Table 2). Further, when results were pooled across communities and regions, the 95th percentile for particular biomarkers of toxic metals (i.e., cadmium, lead) appeared higher than those seen in the CHMS, but lower than levels associated with immediate health problems. Most participants were below the health guidance values for toxic metals. 3.6% of the participants had mercury, cadmium or lead levels above the guidance values and were offered a re-testing.

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

	Mackenzie Valley project				CHMS[1]			
	Blood		Urine		Blood		Urine	
	GM	P95	GM	P95	GM	P95	GM	P95
Aluminium	NR	44	14	40		NA		NA
Arsenic	NR	0.58	5.5	34		4.1[d]	9.2	77
Barium	NR	1.5	1.4	7.2		NA		NA
Beryllium	0.036	0.30	0.014	0.11		NA		NA
Cadmium	0.35	3.2[d]	0.32	1.3	0.31	2.6	0.40	1.9
Cesium[a]	NR	3.7	4.2	7.1		NA	4.9	NA
Chromium[c]	NR	1.3	0.47	5.4		NA		NA
Cobalt[c]	NR	0.12	0.34	1.4[d]	0.23	0.40	0.23	0.97
Copper[c]	980	1300[d]	8.8	26	900	1200	11	28
Gallium	NR	0.058	0.081	0.35		NA		NA
Iron	NA	NA	11	39	NA	NA		NA
Lead	16	70[d]	0.59	4.0[d]	13	32	0.52	1.9
Lithium	NR	5.7	17	49		NA		NA
Manganese[c]	10	19[d]	0.21	0.66[d]	9.8	15		0.36
Mercury	NR	4.7	0.38	1.8	0.72	5.6		NA
Nickel[c]	NR	0.45	1.0	4.3	0.48	1.1	1.3	4.8
Rubidium[a]	1900	2600	1500	2800		NA		NA
Selenium[c]	170	230	54	180[d]	190	240	51	130
Strontium	17	29	99	360		NA		NA
Thallium	NR	<LOD	0.12	0.39		NA	0.23	0.62
Uranium	NR	<LOD	0.0058	0.020		<LOD		0.020
Vanadium[b]	NR	<LOD	0.15	0.55[d]		NA		0.13
Zinc[c]	5600	7100	330	1200	6000	7300	320	1200

1 CHMS cycle 2.

NR. GM not reported for metals with detection rate under 50%.

NA. Not available. These metals were not measured in this type of sample.

<LOD. Below the limit of detection of the method.

a The analytical method was modified during the project and Cesium and Rubidium were removed from the analysis, therefore these results are reported for a smaller size sample (n=10 urine and 144 blood).

b The analytical method was modified during the project and Vanadium was added to the blood analysis, therefore these results are reported for a smaller size sample (n=44 blood).

c Essential element

d 95th percentile of the project above the 95th percentile from the CHMS (cycle 2)

Several POPs, especially those from organochlorine pesticides markers, appeared to be at levels above those seen in the Canadian general population biomonitoring study (CHMS). The majority of the POPs listed in Table 3 have not been used or produced in North America for decades.

Other contaminants were measured form a partial subset of the biobanked samples. Table 4 presents some of them. Arsenic biomarkers appeared similar to those from nationally representative studies. Therefore, these biobanked samples may offer insights as a regional-specific reference population for the ongoing biomonitoring work related to the Giant Mine in Yellowknife. For phthalates, the levels appeared higher than observed in the CHMS for one phthalates metabolites (MBzP, MiNP). It is notable, however, that some differences between the participants of this study and those of the CHMS were no longer observable after adjusting for creatinine levels. No arsenic species were higher than those observed in the CHMS. In addition, several polycyclic aromatic hydrocarbons (PAHs) metabolites appear higher than usually observed. In fact, some biomarkers from naphthalene, fluorine and phenanthrene appeared higher than the CHMS.

Table 3. Geometric mean (GM) and 95th percentile (P95) of persistent organic pollutants (POPs) in plasma (μg/L)[1].

	GM a,c	P95 b
PCB , Aroclor 1260	0.58	5.8
PCB105	NR	0.022[a]
PCB118	0.013	0.12
PCB138	0.033	0.33[a]
PCB146	NR	0.11[a]
PCB153	0.077	0.85[a]
PCB156	NR	0.073[a]
PCB163	0.015	0.12[a]
PCB167	NR	0.026[a]
PCB170	0.020	0.19[a]
PCB178	NR	0.053[a]
PCB180	0.054	0.70[a]
PCB183	NR	0.057[a]
PCB187	0.024	0.28[a]
PCB194	0.016	0.17[a]
PCB201	0.016	0.16[a]
PCB203	NR	0.10[a]
PCB206	NR	0.058[a]
PBDE47	0.035	0.16
PBDE99	NR	0.10[a]
PBDE100	NR	0.10[a]
PBDE153	NR	0.10[a]
cis-Nonachlor	0.0083	0.19[a]
trans-Nonachlor	0.036	0.49[a]
beta-HCH	NR	0.029
Hexachlorobenzene	0.066	0.30[a]
Mirex	NR	0.17[a]
Oxychlordane	0.014	0.16[a]
p,p'-DDE	0.30	1.7
Toxaphene Parlar #26	NR	0.083[a]
Toxaphene Parlar #50	NR	0.18[a]

1 Results were not listed for pollutants that were not detected in less than 10% of the samples. These included: PBB153, Aldrin, PCB28, PCB52, PCB66, PCB74, PCB99, PCB101, PCB128, PBDE15, PBDE17, PBDE25, PBDE28, PBDE33, alpha-Chlordane, gamma-Chlordane, gamma-HCH, p,p'-DDT.

NR. GM not reported for metals with detection rate under 50%.

a 95th percentile of the project above the 95th percentile from the CHMS (cycle 2)

Table 4. Geometric mean (GM) and 95th percentile (P95) of selected contaminants biomarkers quantified in urine (µg/L).

Parent contaminant	Biomarkers	GM	P95
Arsenic (n=26)	Dimethylarsinic acid	4.8	10
	Monomethylarsonic acid	0.53	1.2
	AsIII (arsenite)	0.37	2.0
	AsV (arsenate)	NR	0.33
Phthalates (n=26)	Mono-benzyl phthalate (MBzP)	20	84
	Mono-3-carboxypropyl phthalate (MCPP)	0.80	3.9
	Mono(2-ethyl-5-carboxypentyl) phthalate (MECPP)	8.4	24
	Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP)	7.5	20
	Mono-2-ethylhexyl phthalate (MEHP)	1.3	6.7
	Mono-(2-ethyl-5-oxyhexyl) phthalate (MEOHP)	4.3	11
	Mono-ethyl phthalate (MEP)	19	115
	Mono-isobutyl phthalate (MiBP)	9.6	28
	Mono-isononyl phthalate (MiNP)	0.39	1.0
	mono-methyl phthalate (MMP)	2.3	7.0
	Mono-n-butyl phthalate (MnBP)	15	37
Polycyclic aromatic hydrocarbons (PAHs) (n=97)	1-Hydroxyphenanthrene	0.10	0.60
	1-Hydroxypyrene	0.087	0.49
	1-Naphtol	1.3	16[a]
	2-Hydroxyfluorene	0.35	3.0[a]
	2-Hydroxyphenanthrene	0.054	0.32[a]
	2-Naphtol	5.8	30[a]
	3-Hydroxyfluorene	0.13	1.5[a]
	3-Hydroxyphenanthrene	0.068	0.52[a]
	4-Hydroxyphenanthrene	0.021	0.20[a]
	9-Hydroxyfluorene	0.21	0.83[a]
	9-Hydroxyphenanthrene	0.048	0.41[a]

NR. GM not reported for metals with detection rate under 50%.

a 95th percentile of the project above the 95th percentile from the CHMS (cycle 2)

Regional differences were investigated between the Dehcho and Sahtú regions. The Sahtú participants seemed to eat more country foods in terms of calories intake (winter daily average of 6.1 vs 4.9%). The main difference in biological levels were related to the persistent organic pollutants. Patterns in organochlorine pesticide exposure were consistently higher in the Sahtú than in the Dehcho (e.g., toxaphene, mirex and chlordane). The relationships between food use, contaminant exposures, and nutritional status is complex and we will continue working to better understand the contaminant exposure determinants in participating communities.

Data analyses are ongoing to identify determinants (e.g., demographic, dietary) of biomarker results. In a co-located environmental monitoring research, fish composition is being analysed (Heidi Swanson (University of Waterloo) and George Low (Dehcho AAROM)). A PhD student working with us, Sara Packull-McCormink, is using these data to investigate the role of country food consumption in mercury exposure, and she is creating a dose reconstruction model to link environmental data to human data.

In addition, findings from the postdoctoral fellow Mylène Ratelle, show that statistically significant non-parametric associations were observed between several PAHs biomarkers and i) the consumption of cooked meat and, ii) smoking status. Determinants (demographics, dietary, environmental) of elevated lead are being investigated, with the collaboration of Environment Canada (Kirstie Gurney) providing environmental data to better answer the communities' concern regarding lead exposure sources.

Discussion and conclusions

This 2018-2019 NCP research focused on the return of the biomonitoring results in 3 communities of the Dehcho and Sahtú Regions of the Northwest Territories. 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. Obtained through this co-located environmental monitoring work, paired Hg fish-human will support the refinement of a model to estimate dose reconstruction and assessment of the risk related to fish consumption. 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. 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 Northwest Territories biomonitoring data are being integrated in the Arctic Monitoring Assessment Programme (AMAP) Human Health report (2020) and provide baseline in a sub-arctic region where limited data were previously available.

Even after this four-year project is completed, the data analysis will be ongoing for the next few years. First, exposure determinants are being investigated. Once the remaining work is completed, the biomonitoring research team will 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. In parallel, the contaminants biomonitoring project is happening in the Yukon, which will bring increased knowledge on the contaminant exposure in the sub-arctic. Finally, the collaborations and partnerships developed through this project in the Northwest Territories will last over time and initiate new collaborative projects in the future.

Expected project completion date

March 31, 2019 (completed)

Project website

Facebook: @BiomonitoringNT

Twitter: @NTBiomonitoring

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References

Assembly of First Nations (AFN), 2013. First Nations Biomonitoring Initiative- National Results (2011), 736 pages. http://www.afn.ca/uploads/files/afn_fnbi_en_-_2013-06-26.pdf

Berti, P.R., O. Receveur, H.M. Chan, H.V. Kuhnlein (1998). Dietary exposure to chemical contaminants from traditional food among adult Dene/Metis in the western Northwest Territories, Canada. Environmental Research 76(2): 131-142.

CBC News (2018). Researchers see very reassuring early results in N.W.T. contaminants study. Accessed from: http://www.cbc.ca/news/canada/north/university-of-waterloo-contaminants-study-1.4530092

Centre for Indigenous People's Nutrition and Environment (CINE), 1996. Report on the Variance in Food Use in Dene/Metis Communities. Dene Nation, Yellowknife, NWT.

Delormier, T., 2012. Synopsis of Research-Conducted under the 2011–2012 Northern Contaminants Program. Aboriginal Affairs and Northern Development, pp: 58-69.

Environment Canada, 2010. Risk Management Strategy for Mercury. Accessed on October 10 2016: https://www.ec.gc.ca/doc/mercure-mercury/1241/index_e.htm

Dewailly, E., C. Blanchet, S. Gingras, S. Lemieux, and B. J. Holub (2002). Cardiovascular disease risk factors and n-3 fatty acid status in the adult population of James Bay Cree. American Journal of Clinical Nutrition 76(1): 85-92.

Department of Health and Social Services of the Northwest Territories (DHSS) (2016). Site Specific Fish Consumption Advice. Government of the Northwest Territories. Retrieved from: http://www.hss.gov.nt.ca/en/services/fish-consumption-guidance/site-specific-fish-consumption-advice

Department of Health and Social Services of the Northwest Territories (DHSS) (2017). Moose Organ Consumption Notice. DHSS: Yellowknife, Northwest Territories. Retrieved from: http://www.hss.gov.nt.ca/sites/www.hss.gov.nt.ca/files/resources/moose-organ-consumption-notice.pdf

Health Canada, 2013. Second Report on the Human Biomonitoring of Environmental Chemicals in Canada (CHMS). 456 pages. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/chms-ecms-cycle2/index-eng.php

Kuhnlein, H.V. and H.M. Chan (2000) Environment and contaminants in traditional food systems of northern indigenous peoples. Annual Review of Nutrition 20: 595-626.

Kuhnlein, H.V., O. Receveur, R. Soueida, G.M. Egeland (2004). Arctic indigenous peoples experience the nutrition transition with changing dietary patterns and obesity. Journal of Nutrition 124: p. 1447-1453.

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

Laird MJ (2018). Dietary Exposure Assessment and Contaminants Biomonitoring in the Dehcho Region, Northwest Territories: Exploring the Relationship Between Mercury Exposure, Omega-3 Fatty Acid Status, and Fish Consumption. M.Sc. Thesis. School of Public Health and Health Systems, University of Waterloo.

Laird MJ, Aristizabal Henao J, Reyes ES*, Stark KD, Low G, Swanson H, Laird BD. (2018) Mercury and Omega-3 Fatty Acid Profiles of Wild-Harvested Fish of the Dehcho Region, Northwest Territories: Informing Risk Benefit Assessments. Science of the Total Environment. In Press.

Nakano, T., K. Fediuk, N. Kassi, H.V. Kuhnlein (2005). Food use of Dene/Metis and Yukon children. International Journal of Circumpolar Health 64(2): 137-146.

Ratelle M, Laird MJ, Majowicz S, Laird BD (2018). Design of a Community-Based Human Biomonitoring Project in the Northwest Territories Mackenzie Valley, Canada. Environmental Health. Submitted.

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

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

Community Based Monitoring and Research

Surveillance et recherche communautaires

Understanding fish mercury concentrations in Dehcho lakes

Connaître les concentrations de mercure dans le poisson des lacs du Dehcho

Project leaders/Chefs de projet

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Project locations/Emplacements du projet

12 lakes in the NWT (McGill Lake, Tathlina Lake, Kakisa Lake, Trout Lake, Ekali Lake, Gargan Lake, Sanguez Lake, Fish Lake, Greasy Lake, Mustard Lake, Big Island Lake, Willow Lake)

Abstract

Food fishes are a central part of the traditional diet and culture of the First Nations of the Dehcho region of the NWT. Some lakes in this region have food fishes with mercury levels that are above human consumption guidelines, while others that are relatively close by have levels that are well below guidelines. Results from our previous research indicate that drivers of among-lake variation in fish mercury levels are different for each species and the these variables are subject to future climate change (e.g., landscape type in the catchment, lake water chemistry, food web structure and community composition). More study is required, however,

Résumé

Le poisson constitue un élément clé du régime alimentaire traditionnel et de la culture des Premières Nations de la région du Dehcho, dans les Territoires du Nord-Ouest. Certains lacs de la région abritent des poissons comestibles chez qui les concentrations de mercure sont supérieures aux recommandations pour la consommation humaine, alors que les poissons d'autres lacs relativement proches présentent des concentrations inférieures aux recommandations. Les résultats de nos précédentes recherches indiquent que les facteurs faisant varier les taux de mercure dans les poissons d'un lac à l'autre sont différents

to expand into the northern region of the Dehcho (Pehdzeh Ki FN), to complete the dataset that we have been building, and then to refine models such that we can predict how climate and land-use change may affect fish mercury levels in our traditional fishing lakes. In an intensive study of 6 lakes from 2018-2021, we will clarify the importance of in-lake versus catchment controls on fish Hg levels. This synopsis presents interim results from year 1 of 3; in 2018, McGill Lake and Tathlina Lake were intensively sampled.

Key messages

- Mean wet mercury concentrations in both walleye and northern pike from McGill Lake were above Health Canada's commercial sale guideline of 0.5 ppm wet weight.
- Mean wet mercury concentrations in walleye and northern pike from Tathlina Lake were slightly below Health Canada's commercial sale guideline (0.49 and 0.46 ppm wet weight, respectively).
- All Lake whitefish captured in McGill and Tathlina lakes had mercury concentrations that were below Health Canada's commercial sale guideline.
- Watershed land cover has been quantified for several lakes; watersheds differ substantially in catchment: lake area ratios and % of wetland in catchments.
- Partitioning of mercury to suspended sediment in Kakisa Lake may explain lower mercury levels in fish in this lake.

pour chaque espèce et que ces variables seront soumises aux changements climatiques futurs (p. ex., le type de paysage dans le bassin versant, la chimie de l'eau des lacs, la structure du réseau alimentaire et la composition des collectivités). Des études plus approfondies sont toutefois nécessaires pour que les recherches englobent la région nord du Dehcho (Première Nation Pehdzeh Ki), pour compléter l'ensemble de données que nous avons constitué, puis pour affiner les modèles de manière à prédire comment les changements climatiques et l'utilisation des terres ont une incidence sur les concentrations de mercure dans les poissons de nos lacs de pêche traditionnels. Dans le cadre d'une étude intensive portant sur six lacs entre 2018 et 2021, nous préciserons l'importance des témoins dans les lacs par rapport aux bassins versants pour la mesure des concentrations de Hg. Ce synopsis présente les résultats provisoires de la première année sur trois; en 2018, les lacs McGill et Tathlina ont fait l'objet d'un échantillonnage intensif.

Messages clés

- Les concentrations moyennes de mercure humide dans le doré et le grand brochet du lac McGill étaient supérieures aux recommandations pour la vente commerciale de Santé Canada de 0,5 ppm (poids humide).
- Les concentrations moyennes de mercure humide dans le doré et le grand brochet du lac Tathlina étaient légèrement inférieures aux recommandations pour la vente commerciale de Santé Canada (0,49 et 0,46 ppm (poids humide), respectivement).
- Tous les grands corégones capturés dans les lacs McGill et Tathlina présentaient des concentrations de mercure inférieures aux recommandations pour la vente commerciale de Santé Canada.
- La couverture terrestre des bassins hydrographiques a été quantifiée pour plusieurs lacs; les bassins hydrographiques diffèrent sensiblement en ce qui concerne les rapports entre la superficie des lacs et

- Most recent results continue to indicate that fish mercury levels are generally lower in lakes that are more productive – intensive data analysis on this is ongoing.

le pourcentage de zones humides dans les bassins hydrographiques.

- La répartition du mercure dans les sédiments en suspension du lac Kakisa peut expliquer les concentrations de mercure plus faibles dans les poissons de ce lac.
- Les résultats les plus récents continuent d'indiquer que les concentrations de mercure dans les poissons sont généralement plus faibles dans les lacs qui sont plus productifs – une analyse intensive des données à ce sujet est en cours.

Objectives

This project aims to:

- build on past paired lakes study (funded by Northern Contaminants Program (NCP) and Cumulative Impacts Monitoring Program (CIMP) in 2016 and 2017) to include two more lake pairs (Deep and McGill lakes and Tathlina and Kakisa lakes), such that further assessment of environmental drivers on fish Hg is possible. These additional lakes were chosen to represent community interest, and are end-members in terms of environmental gradients;
- characterize mercury and methylmercury in fish, sediment, water, invertebrates, and plankton in each of the six study lakes;
- characterize lake water chemistry and dissolved organic carbon quality and quantity to assess the relative importance of catchment contributions of carbon and mercury;
- refine estimates of lake catchment characteristics (area, slope, %forest and wetland cover) using remote sensing data products. Data will be used to determine if catchment factors influence food fish mercury concentrations; and
- continue updating the Dehcho communities by having our University of Waterloo co-lead (H. Swanson) present her current findings at the annual Dehcho Aboriginal Aquatic Resources and Oceans Management (AAROM) results workshops and other regional meetings.

Activities in 2018-2019

- Water, sediment, zooplankton, invertebrate, and fish samples were collected during on-the-land camps at Tathlina Lake and McGill Lake. Samples were processed for analyses during fall and winter 2018/2019.
  - Analyses for fish and sediments are complete; analyses of invertebrates, zooplankton, and water chemistry (carbon quality and quantity) are ongoing.
- Catchments for several lakes have been delineated, and interim quantification of catchment size and cover has been completed.
- Leveraged support from CIMP enabled us to sample water and sediment in all of the study lakes in summer 2018 (Kakisa, Tathlina, Trout, Ekali, Gargan, Sanguez, Fish, Greasy, Mustard, Big Island, Willow). This is allowing a more robust comparison (not confounded

by temporal variation) of mercury and water chemistry results among lakes.

- Results were reported to Ka'a' gee Tu FN, Jean Marie River FN, Pehdzeh Ki FN, and Liidlii Kue FN during in-person meetings in late 2018.

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 continues 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), and during face-to-face meetings that occur with each community on an annual basis. The involved First Nation Chiefs or Environmental managers signed NCP's "Approval of Consultation" during face-to-face meetings that occurred in November 2018. The project has been very successful in engaging communities, resource monitors, and youth in the past 5 years. We have engaged over 60 youth, and coordinated sampling camps that amount to > 11 weeks on the land with joint University-community sampling teams. We have held results meetings in Ft Providence, Kakisa, Jean Marie River, and Hay River (November 2018), and provided results posters to all communities.

Capacity building

Our community monitors benefit from working directly with researchers (for ~ 3 weeks each summer) from the University of Waterloo, Wilfrid Laurier University, and Western University. This occurred again in summer 2019. Community monitors were trained in a wide variety of scientific sampling and data recording techniques, and University researchers were trained and educated in traditional methods for capturing and preserving fish. Most of our monitors have received Aurora Collage certification through the 5-week environmental training course. As we have in previous projects, Dehcho Youth were engaged via partnerships. Two graduate students took part in a youth canoe trip around Kakisa Lake, and trained youth on sampling techniques. The team also discussed with youth why mercury can be high in northern food fishes, and the benefits and risks involved with eating country food.

Communications and outreach

This project was developed in direct response to concerns from the leadership of the Dehcho First Nations regarding levels of fish mercury in the region; Indigenous leaders and University researchers are working to understand why fish Hg levels are so different among lakes and how fish mercury levels will respond to climate change. The leaderships of all involved First Nations continue to support the project, and we specifically engaged the following people and groups in November 2018 (meetings) and during the field season: Gladys Norwegian, Grand Chief, Dehcho First Nations; Chief Stan Sanguez, Chief, Dieter Cazon, Liidlii Kue First Nation; Melaine Simba, Ka'a gee Tu First Nation; Chief Lloyd Chicot, Ka'a gee Tu First Nation; Chief Maurice Moses, Pehdzeh Ki First Nation.

Dehcho AAROM staff are involved with ongoing communications with communities by phone, e-mail and face-to-face meetings, and we continued to work with our member organizations on a regular basis in 2018-2019. Results from this research were communicated during face-to-face meetings in November 2018, and posters and presentations were distributed.

Each of the involved communities received a copy of the proposal and all resulting reports generated by the project.

Indigenous Knowledge

Indigenous knowledge informed the selection of lakes for study, and the communication of our research results. For example, tradition knowledge (TK) informed us about which lakes are fished for food, which are the most used and important, what species of fish we should focus on, and what the work effort would be required to catch them. This information continues to be collected on a regular basis as part of Low's AAROM program is focused on fishing projects on inland lakes with various Bands. Dehcho AAROM has developed an evolving list of fishing lakes and matched them with mercury level data and other information. Traditional knowledge and science are being used to develop a list of low-risk fishing lakes for each community - this will become available to the Dehcho communities as well as NCP and researchers.

Dehcho AAROM requires that knowledgeable Dene and Métis are hired to assist researchers with field activities; this includes choosing fishing sites, netting, appropriate camping and on-the-land practices, and preparation of fish for food (including making dry fish) after samples are taken. Working together on the land promoted the exchange of traditional knowledge information and science; on the land, traditional knowledge holders are not constrained by western approaches to formal meetings or workshops. In this way, the knowledge exchange was more appropriately timed, and allowed to progress naturally as the sampling program unfolded.

Results and outputs/deliverables

Fish mercury concentrations

Of 130 samples analyzed from McGill and Tathlina Lake, 27 exceeded Health Canada's Commercial Sale Guideline of 0.5 ppm wet weight (ww) (Table 1). Concentrations ranged from 0.04 ppm ww (lake whitefish in Tathlina Lake) to 2.04 ppm ww (an 880 mm northern pike in McGill Lake). Exceedances occurred in ~40% of walleye and northern pike captured from each of McGill and Tathlina lakes. All lake whitefish had mercury concentrations that were below Health Canada's commercial sale guideline. Detailed statistical analyses will be carried out once stable isotope and ageing analyses are complete (June 2019).

Table 1. Total mercury concentrations in fish collected from McGill and Tathlina lakes during summer 2018.

Lake	Species	Mean (ppm ww)	Range (ppm ww)	n	Percent Exceed[1]
McGill Lake	lake whitefish	0.12	0.06-0.30	23	0
	northern pike	0.60	0.17-2.04	14	43
	walleye	0.52	0.21-1.23	20	40
Tathlina Lake	lake whitefish	0.088	0.04-0.16	41	0
	northern pike	0.46	0.08-1.15	23	39
	walleye	0.49	0.15-0.97	9	44

Sediment mercury concentrations

Total mercury concentrations in sediments varied from 11.74 ppb (dry weight) in Greasy Lake to 179.18 ppb (dry weight) in Ekali Lake. Methylmercury concentrations were less than the reporting limit in several lakes, including Kakisa, McGill (offshore), Trout, Ekali, and Greasy. Percent methylmercury (of total mercury) was in general low (<5%) but was highest in inflow sediments in Tathlina and McGill lakes, and in the offshore sediments in Tathlina Lake (Table 2). Notably, fish in Tathlina and McGill lakes have relatively higher mercury concentrations.

Water mercury concentrations

Total mercury concentrations in unfiltered water varied from less than the method reporting limit (0.40 ng/L) in several lakes to 4.17 ng/L in Kakisa Lake (Table 3). Methylmercury (MeHg) concentrations in unfiltered water varied from less than the reporting limit (0.023 ng/L) to 0.108 ng/L in Deep Lake. Percent methylmercury (of total mercury) ranged more widely than in sediments, to a maximum of 13.14% in Tathlina Lake (Table 3). Lakes with higher % MeHg in water included Tathlina, McGill, and Deep. Again, this is interesting because fish mercury concentrations tend to be higher in Tathlina and McGill lakes. Deep Lake will be sampled for fish in summer 2020.

Although filtered water results are not shown (most values are less than the method reporting limit), it was obvious that most of the mercury in unfiltered water in Kakisa Lake (total mercury in unfiltered water was higher in Kakisa Lake than in any other lakes) was partitioned to suspended sediment. This may lower the amount of mercury available for methylation and uptake into the food web, and thus explain the relatively low mercury levels of fish in Kakisa Lake. Further research into this mechanism is planned for summer 2019.

Table 2. Total and methylmercury concentrations in sediments from all study lakes, which were sampled in summer 2018.

	Lake/Sample ID	Sample Location	Date Collected	Total mercury concentration (ng/g dry weight)	Methylmercury concentration (ng/g dry weight)	%MeHg
Sediments	Kakisa	Lake Middle	07-Sep-18	97.73	<MRL[a]	.
	Tathlina	River Inflow	10-Sep-18	45.73	0.515	1.126
	Tathlina	Lake Middle	15-Sep-18	100.10	0.590	0.589
	McGill	Lake Middle - Oxic	25-Aug-18	90.91	<MRL	.
	McGill	Lake Middle - Anoxic	26-Aug-18	102.20	<MRL	.
	McGill	Inflow Sediment	26-Aug-18	14.28	0.535	3.744
	McGill	McGill/Deep Connection	25-Aug-18	22.15	<MRL	.
	McGill	Mid	25-Aug-18	96.59	0.312	0.323
	Deep	Lake Middle	05-Sep-18	79.38	0.408	0.514
	Trout	Lake Middle	05-Sep-18	88.61	<MRL	.
	Ekali	Lake Middle	05-Sep-18	179.18	<MRL	.
	Sanguez	Lake Middle	05-Sep-18	120.97	0.420	0.348
	Gargan	Lake Middle	05-Sep-18	142.56	0.951	0.667
	Big Island	Lake Middle	04-Sep-18	115.79	0.544	0.470
	Willow	Lake Middle	04-Sep-18	20.90	0.379	1.813
	Mustard	Lake Middle	04-Sep-18	120.81	0.309	0.256
	Greasy	Lake Middle	05-Sep-18	11.74	<MRL	.
	Fish	Lake Middle	05-Sep-18	108.12	0.263	0.244

[a] abbreviation: MRL, method reporting limit

Table 3. Total and methylmercury concentrations in unfiltered water samples collected during summer 2018.

Sample ID	Filtered or Unfiltered	Total mercury concentration (ng/L)	Methylmercury concentration (ng/L)	%MeHg
Kakisa Mid 2018	Unfiltered	2.020	0.033	1.623
Kakisa 2018-1	Unfiltered	4.168	0.063	1.511
Kakisa 2018-2	Unfiltered	0.734	<MRL[a]	.
Kakisa Outflow 2018	Unfiltered	1.530	0.029	1.887
Tathlina inflow	Unfiltered	0.666	0.085	12.749
Tathlina Lake 2018	Unfiltered	0.712	0.094	13.144
McGill Sand Beach	Unfiltered	0.379	<MRL	.
McGill Lake Top	Unfiltered	0.739	0.082	11.093
McGill Lake Bottom	Unfiltered	0.959	0.071	7.363
Deep Lake 2018	Unfiltered	0.876	0.108	12.296
Trout 2018	Unfiltered	0.441	<MRL	.
Ekali Lake 2018	Unfiltered	0.822	0.045	5.454
Sanguez 2018	Unfiltered	0.673	0.046	6.775
Gargan Lake 2018	Unfiltered	0.893	0.079	8.828
Big Island 2018	Unfiltered	0.506	0.025	4.857
Willow Lake 2018	Unfiltered	<MRL	<MRL	.
Mustard Lake 2018	Unfiltered	0.596	0.038	6.374
Greasy Lake 2018	Unfiltered	<MRL	<MRL	.
Fish Lake 2018	Unfiltered	0.490	0.024	4.966

[a] abbreviation: MRL, method reporting limit

Catchment land cover

The authors gratefully acknowledge Lorraine Brekke, Government of Northwest Territories, in facilitating access to data. Two collections of files were used; the first set of data was a digital elevation model (DEM), and the second was land cover data.

The DEM data were collected as a joint program between the United States (National Aeronautics and Space Administration) and Japan (Ministry of Economy, Trade, and Industry). The data product used for watershed delineations is from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite. The spatial resolution of these data is 10m. Land cover data used to determine land use classifications were from the Satellite Pour l'Observation de la Terre (SPOT) 4-5 satellite. Owned by Spot Image, this is a subsidiary of Airbus Defense and Space in France. The spatial resolution of the data was 20m.

Catchment to lake area ratios varied widely among lakes, from 3.85 for Big Island Lake to 261.47 for McGill Lake. In general, lakes on the Horn Plateau had relatively small catchment area: lake area ratios. Tathlina and Kakisa lakes have the largest watershed areas, whereas Big Island, Ekali, and Sanguez have relatively smaller watershed areas. Lakes in the Mackenzie Valley lowlands, including Ekali and Sanguez, have relatively more wetlands in their catchments. As wetlands are known to have relatively high methylation rates and be sources of methylmercury, the high percentage of wetlands in the catchments of the Mackenzie Lowland lakes may contribute to higher concentrations of mercury in water and food web components that we have previously observed; further research into this causal relationship is planned for summers 2019 and 2020.

Table 4. Estimates of land cover area in catchments of several study lakes. Quantifications for remaining lakes (Gargan, Deep, Fish, Greasy, Trout) are ongoing.

Land Cover Area (km2) Classes Description	Big Island	Willow	Ekali	Sanguez	McGill	Tathlina	Kakisa	Mustard
Evergreen Conifer Forest (High density, crown closure > 20%)	0.21	3.00	0.18	0.08	0.47	57.58	60.12	1.38
Evergreen Conifer Forest (Medium density, crown closure > 12.5%)	0.47	2.41	11.20	7.35	73.21	1749.79	2224.60	0.81
Evergreen Conifer Forest (Low density, crown closure < 12.5%)	2.62	12.93	0.04	0.03	2.14	104.76	114.34	3.97
Mixed Forest (Low to high density, > 5%)	6.47	132.37	5.43	2.35	111.98	1176.62	1589.78	17.02
Deciduous Forest (Medium to high, > 7.5%)	0.02	0.09	0.06	0.02	2.38	402.84	428.08	0.02
Young Forest	0.64	0.74	0.01	0.00	0.16	130.66	176.31	1.87
Recent Disturbance	2.25	28.05	0.00	0.00	0.07	38.72	51.13	6.74
Low to Sparse Conifer/Lichen Understory	9.87	19.81	0.13	0.07	8.59	13.99	23.66	0.00
Erect Shrub	0.00	0.58	0.01	0.00	0.05	11.51	13.45	21.72
Herb - Shrub	10.05	4.00	0.14	0.07	6.84	100.90	162.96	0.15
Herbaceous	0.08	158.80	11.71	4.22	71.05	532.59	943.55	29.42
Bryoid	16.64	0.31	0.01	0.00	0.21	80.83	95.43	0.77
Barren	0.60	215.06	0.14	0.07	0.10	115.93	135.01	19.66
Herb/Shrub Wetlands	1.87	37.79	55.50	22.11	1.06	519.01	773.41	3.35
Ice	0.00	12.56	0.00	0.00	283.22	268.45	619.23	0.00
Water	14.30	124.79	4.13	1.57	8.35	441.16	667.25	17.13
Total Watershed Area (km2)	**66.09**	**753.28**	**88.68**	**37.96**	**569.88**	**5745.33**	**8078.30**	**124.00**
Lake Area (km2)	**17.15**	**121.05**	**1.77**	**1.49**	**2.18**	**538.27**	**316.13**	**21.90**
Catchment area: lake area ratio	**3.85**	**6.22**	**50.10**	**25.47**	**261.41**	**10.67**	**25.55**	**5.66**

Discussion and conclusions

The results from intensive 2018 sampling in McGill and Tathlina lakes indicate that fish mercury concentrations in McGill Lake are higher than in Tathlina Lake. Ongoing analyses will reveal the cause of spatial variation between these two lakes and other lakes included in the broader study, but results to date indicate that lakes that are more productive may have lower fish mercury concentrations; this relationship is currently strongest for walleye. All lake whitefish analyzed in 2018 from McGill and Tathlina lakes had mercury concentrations that were below Health Canada's commercial sale guideline, whereas ~40% of walleye and northern pike from each of McGill and Tathlina lakes exceeded this guideline. Catchment delineations for the study lakes are ongoing, but interim results reveal substantial among-lake differences in relative catchment size and cover that may be linked to concentrations and % methylmercury in water, sediments, and, ultimately, the food web; analyses are ongoing. Results to date, and consultations for activities in 2019 and 2020 were discussed during in-person meetings with Ka'a' gee Tu FN, Jean Marie River FN, Liidlii Kue FN, and Pehdzeh Ki FN in late November and early December 2018.

Expected project completion date

March 31, 2021

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Contaminants in traditional foods of the First Nation Na-Cho Nyäk Dun

Contaminants dans les aliments traditionnels de la Première Nation des Na-Cho Nyäk Dun

Project leader/Chef de projet

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Project locations/Emplacements du projet

- First Nation of Na-Cho Nyäk Dun Traditional Territory
- Stewart River Watershed
- Mayo, YK
- Keno, YK
- 4 waterways (Ethel Lake, Mayo Lake, Stewart River, McQuesten Lake)

Abstract

The First Nation of Na-Cho Nyäk Dun (FNNND) is concerned about the levels of contaminants in their traditional foods. This project measures the contaminant levels in moose and fish from the FNNND Traditional Territory to assess changes in contaminant concentrations from moose that were tested a decade ago and from previously tested locally harvested fish. This project will be conducted over three years beginning in 2018. Eight moose samples were collected in 2018. Harvesting and analyzing fish samples will occur 2019 and 2020. The project builds capacity within the FNNND by employing locals to aid in harvesting, preparation, and shipment of

Résumé

La Première nation des Na-Cho Nyäk Dun (PNNND) est préoccupée par les concentrations de contaminants dans ses aliments traditionnels. Ce projet mesure les concentrations de contaminants dans les orignaux et les poissons du territoire traditionnel de la PNNND afin d'établir les variations de concentration chez les orignaux analysés il y a dix ans et des poissons récoltés localement et analysés précédemment. Ce projet sera mené sur trois ans à partir de 2018. Huit échantillons d'orignaux ont été prélevés en 2018. La récolte et l'analyse des échantillons de poissons auront lieu en 2019 et 2020. Le projet renforce les capacités de la

moose and fish tissue, and organ samples. The samples are analyzed for known and emerging contaminants. NND Lands Officers and Fish and Wildlife Officers will be trained by a qualified research scientist in the preparation of samples and will be taught traditional and cultural practices by local Elders. This project will help the First Nation community and Northerners because test results will provide current data for comparison against historical data. The results will inform the community on northern contaminants and, thus, enable the First Nation to make informed decisions related to the harvest and consumption of traditional foods. Data has yet to be fully analyzed for this project.

PNNND en employant des résidents locaux pour aider à la récolte, à la préparation et à l'expédition des tissus et des organes d'orignal et de poisson. Les échantillons sont analysés pour détecter les contaminants connus et nouveaux. Un chercheur scientifique qualifié apprendra aux agents des terres et les agents de la pêche et de la faune des NND à préparer des échantillons et il apprendra des anciens les pratiques traditionnelles et culturelles. Ce projet sera utile aux collectivités des Premières Nations et aux habitants du Nord, car les résultats des tests fourniront des données récentes que l'on pourra comparer aux données historiques. Les résultats informeront les collectivités sur les contaminants dans le Nord et permettront aux Premières Nations de prendre des décisions éclairées concernant la récolte et la consommation d'aliments traditionnels. Les données n'ont pas encore été entièrement analysées pour ce projet.

Key messages

- Levels of most elements measured in moose tissues are not of concern, although, kidney cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Moose meat (muscle) does not accumulate high levels of contaminants and is a healthy food choice.
- This project is facilitating capacity building among FNNND staff and citizens and helping the community gain a deeper, shared understanding of local food sources and the factors which ultimately influence not only the health of moose and fish, but community health as well.
- Continued monitoring of contaminants in northern food systems ensures sustainable traditional aboriginal diets and consumption patterns.

Messages clés

- La teneur de la plupart des éléments mesurés dans les tissus d'orignal n'est pas préoccupante, bien que les concentrations de mercure et de cadmium dans les reins peuvent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. La viande d'orignal (muscle) n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.
- Ce projet facilite le renforcement des capacités du personnel et des membres de la PNNND et aide la collectivité à acquérir et à diffuser des connaissances plus approfondies sur les sources alimentaires locales et les facteurs qui influent non seulement sur la santé des orignaux et des poissons, mais aussi sur celle de la collectivité.
- La surveillance continue des contaminants dans les systèmes alimentaires du Nord permet de garantir la durabilité des régimes alimentaires et des modes de consommation traditionnels des autochtones.

Objectives

To measure contaminant levels in moose and fish from the FNNND Traditional Territory in order to:

- assess changes in contaminant concentrations in moose from this area from a decade ago;
- determine concentrations of emerging contaminants in Yukon moose;
- determine levels of contaminants in commonly consumed fish from the FNNND Traditional Territory;
- build capacity within FNNND for conducting contaminant-related projects and communicating contaminant information to community members; and
- develop baseline data to assist in determining the cumulative effects of climate change on contaminants in traditional foods of the FNNND.

Introduction

Traditional foods, particularly moose and fish, are an important nutritional, spiritual, and cultural resource for citizens of the First Nation of Na-Cho Nyäk Dun (FNNND) (Figure 1). The community is concerned about contaminants in these foods. Contaminant concentrations in moose have not been measured in the Yukon since the end of the NCP program which monitored between 1996 and 2004. Monitoring moose from this area now will give us an idea of whether, and how, contaminant levels have changed since that time. In addition, this project provides the opportunity to measure some emerging contaminants, e.g. PFASs and PBDEs, which have been measured in moose from southern Northwest Territories, but not in the Yukon.

Figure 1. Map of the First Nation of Nacho Nyäk Dun's Traditional Territory.

The Yukon Contaminants Committee has identified the need for information on mercury concentrations in predatory fish throughout the Territory. While mercury and other contaminants have been measured in lake trout from Kusawa Lake and Lake Laberge under NCP, little work has been done on contaminants in fish from the FNNND Traditional Territory. The analyses of fish from this area will complement the existing database on contaminants in Yukon fish.

Climate change and its effects on northern ecosystems is of great concern to FNNND and its citizens. Given that climate-related changes may influence things like wildlife exposure to, and intake of, contaminants as well as the transport and distribution of contaminants in the north, this study is particularly important at this time.

This project provides a significant opportunity for capacity building within FNNND. Multiple training sessions involving FNNND Lands and

Resources staff, as well as students, are helping to lay the groundwork so that FNNND may carry out contaminants research on Traditional Territory into the future. Overall, this project is helping to grow FNNND's internal capacity, so we are better able to conduct our own monitoring, data collection, build a robust database, and thereby make more informed resource management decisions in the future.

Activities in 2018-2019

Three separate training sessions were held to teach Lands staff, students, and community members about northern contaminants and the collection and preparation of moose and fish samples in traditional food in the Yukon.

Two separate public meetings were held for citizens in order to inform them of the project, promote participation, and update both citizens and the Lands and Resources Department on current information.

FNNND Lands and Resources staff created and distributed sample kits for moose tissue collection. These sample kits included a pamphlet describing the program; labeled bags for muscle, liver, kidney and jaw samples; recording sheets to write harvest information; and maps to identify harvest location. These were distributed throughout the 2018 hunting season by Lands and Fish and Wildlife Officers patrolling 7 days a week.

Moose samples brought by citizens were processed and shipped for analysis. Some sampling and processing equipment was purchased to enable FNNND Lands and Resources staff to process their own samples. The first fish of the year were processed, as part of the training session at Ethel Lake Culture Camp, in February 2019.

Capacity building

Building capacity within the FNNND Lands and Resources Department and FNNND citizens (especially youth and Elders) is a major component of this project. The project kicked off with a training workshop facilitated by biologist Mary Gamberg of Gamberg Consulting on August 6, 2018. Mary introduced the FNNND Lands and Resources staff to concepts of northern contaminants, their origin and proliferation in northern environments, and monitoring contaminants. This training was done with respect to the specific context of this study and its applicability to traditional local food for FNNND citizens and local non-first nation peoples. Four staff members attended this workshop.

On November 14, 2018, Mary Gamberg returned to train Lands staff on proper methods of processing moose samples. This included 'trace element clean' methods for extracting and storing muscle, liver, and kidney samples, and correct record-keeping. As well, extraction of moose teeth and analysis for aging moose was demonstrated and practiced by all four attending staff members.

The first culture camp of the year was held between February 25 and 28, 2019 at FNNND's Ethel Lake site. This camp was facilitated with Mayo's JV Clark School and students between grades 10 and 12 participated in activities which went towards school credits. Students learned how to traditionally fish for trout and burbot using set-hooks. All fish caught during the camp were used to demonstrate proper sampling protocol for the study. Mary Gamberg was again present to demonstrate to Lands Officers, students, and Elders how to extract and prepare fish samples for processing. A total of 18 people attended this demonstration and both Lands staff and students had a chance to process samples.

Communications and community engagement

The FNNND Lands and Resources Department continues to engage its citizens and local non-first nation peoples in multiple ways to keep the community informed about its projects and to facilitate cooperation and communication. Two public meetings were held in 2018 (September 13 and November 15) to inform citizens about the progress of this project. There were approximately 60 people in attendance at the

September meeting and about 35 people at the November meeting. As an incentive for boosting community participation in the survey, all hunters who submitted moose samples were entered into a draw to win a new chainsaw. This prize was drawn at the November community meeting and an FNNND citizen hunter took home the prize.

The workshop with Mary Gamberg on August 6 was followed up with a visit to FNNND's cultural site at Ethel Lake during an Uncle's Retreat event. At the camp, attendees and staff (mainly citizens of FNNND and Selkirk First Nations) gathered around the central outdoor fire where Mary Gamberg and FNNND Lands Officers talked to participants about contaminants in traditional food and introduced how our study would operate. Approximately 25 people were in attendance at the camp at that time.

The distribution of sample kits by our officers facilitated good connection with citizens and local hunters while our staff were out patrolling in the field. By engaging with the public regarding the health of local wildlife, a positive tone was often set which facilitated more discussion and sharing of information.

Traditional/local Knowledge

The FNNND Lands and Resources Department has great respect for the knowledge held by those who have spent time on the land and learned from their elders. We found that there was considerable interest among locals and Elders regarding a scientific study examining contaminants in local food sources. During community meetings, a great deal of information and concern was shared which involved not only moose and fish but touched on habitat, forage, traditional medicine and its contaminant accumulation, concern about past and current mining activity influencing habitat health, and concern about specific edible animal parts such as moose and caribou bone marrow.

At the Ethel Lake culture camp in February 2019, Mary Gamberg was again present to demonstrate to Lands Officers, students, and Elders how to extract and prepare fish samples for processing. Elders and youth were actively engaged in the demonstration, and some individuals shared old stories, traditional knowledge, and experiences. All target waterways in this study (Ethel Lake, Mayo Lake, Stewart River, and McQuesten Lake) have been fished for uncountable generations by local First Nations. As such, there is a wealth of knowledge still alive regarding fish populations, patterns, changes, diseases, etc. This information may be invaluable as we begin to acquire tangible results from this study and can compare trends in local knowledge with study findings.

Results

We estimate that between 70 and 100 sample kits were handed out to hunters over the course of the 2018 hunting season. We received a total of 8 samples back. Not each sample kit had a complete suite of sampled components (a majority lacked jaw/tooth samples). Three moose samples included jaws/teeth and the ages of harvested moose were 3, 4 and 7 years of age. Currently the moose samples are being analyzed and we are awaiting final data.

The first collection of fish from Ethel Lake in February yielded 5 fish sampled and prepared. All fish samples will be frozen and stored until the end of the year and shipped together for analysis.

Conclusions

The FNNND Lands and Resources Department is excited to have initiated this contaminant survey and looks forward to developing this program further. So far, feedback from citizens and Elders has been positive and supportive and dialogue and information sharing has been very beneficial. We hope to continue along this trend to build more capacity among staff and citizens and gain a deeper, shared understanding of our local food sources and the factors which ultimately influence not only the health of moose and fish, but our own health as well.

Expected project completion date

This project is being funded for a three-year period and is expected to conclude on April 30, 2021. However, with the capacity building and training integrated within the program, FNNND is currently assessing the feasibility of continuing monitoring of local moose and fish for contaminants into the future to create a more robust database and observe changes over time.

Acknowledgments

Research and monitoring of contaminants in fish and wildlife in northern ecosystems is the result of the many collaborators, facilitated by the Northern Contaminant Program. FNNND also wishes to acknowledge our research partners, Mary Gamberg (Gamberg Consulting, Whitehorse YT), Xiaowa Wang and Derek Muir (Environment & Climate Change Canada), Mayo District Renewable Resource Council, Northern Tutchone First Nations of Yukon, and Mark O'Donoghue (Northern Tutchone Regional Biologist, Environment Yukon).

Tłı̨chǫ Aquatic Ecosystem Monitoring Program, Whatì 2018

Projet de surveillance de l'écosystème aquatique de Tłı̨chǫ, Whatì 2018

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Project location/Emplacement du projet

Lac La Martre, Whatì, NWT

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. 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 répondre aux préoccupations que nourrit la collectivité à l'égard des changements observés dans les milieux 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 faisant appel aux connaissances du peuple tłı̨cho et aux connaissances scientifiques, pour

In September 2018, a 5-day on-the-land monitoring camp returned to Lac la Martre, near the community of Whatì, with the camp situated at the same site as the 2014 TAEMP camp location. The 2018 participants returned to locations on Lac la Martre, where sediment and water sampling occurred in 2014, to allow for comparative sampling. Elders and community members spoke about fish and aquatic ecosystem health, passed on their knowledge to participants, and ensured safe 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 processing fish and visiting grave sites, which were led by Whatì Elders. A results workshop open to the public was held in Whatì in April 2019 to present the results to camp participants and to interested community members.

Fish tissue analysis indicated that mercury levels were low in *Łıh* (lake whitefish); while in *Łıwezǫǫ̀* (lake trout), one out of twenty fish had mercury levels that exceeded the Canadian Food Inspection Agency guidelines. Both łıh and łıwezǫǫ̀ did not show levels of mercury that were considered abnormal for northern lakes. Comparison of 2018 results to 2014 results showed slightly lower mercury concentration in tissue in 2018. Analysis of water samples indicated no notable difference between 2018 and 2014 with regards to nutrient and physical parameters measured at all sample sites. Except for one site, where the Canadian Environmental Quality Guidelines (CCME) Sediment Quality Guidelines for the Protection of Aquatic Life (CCME 2014) was exceeded for copper, no other parameters exceeded guidelines in the sediments analyzed in 2018. Water and sediment results supported the expectation that water and sediment quality is “good” (i.e. not abnormal) in Lac la Martre.

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

En septembre 2018, un camp de surveillance terrestre de 5 jours est retourné au lac La Martre, près de la collectivité de Whatì, au même endroit que le camp du Programme de surveillance de l’écosystème aquatique des Tłı̨chǫ (PSEAT) en 2014. Les participants de 2018 sont retournés sur les sites du lac La Martre, où des échantillons de sédiments et d’eau ont été prélevés en 2014, afin de réaliser un échantillonnage comparatif. De plus, les jeunes ont participé à des activités. Les aînés et les membres de la collectivité ont parlé de la santé des poissons 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 en vue d’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. Par ailleurs, les jeunes ont participé à des activités culturelles, dirigées par des aînés de Whatì notamment la transformation du poisson et la visite de tombes. Un atelier ouvert au public a été organisé à Whatì en avril 2019 pour présenter les résultats aux participants du camp et aux membres intéressés de la collectivité.

L’analyse des tissus des poissons a révélé que les concentrations de mercure étaient faibles dans le *łıh* (grand corégone), tandis que dans le *łıwezǫǫ̀* (truite de lac), un poisson sur vingt présentait des concentrations de mercure dépassant les directives de l’Agence canadienne d’inspection des aliments. Le *łıh* et le *łıwezǫǫ̀* ne présentaient pas de concentrations de mercure considérées comme anormales pour des lacs du Nord. La comparaison des résultats de 2018 avec ceux de 2014 indique une concentration de mercure légèrement plus faible dans les tissus en 2018. L’analyse des échantillons d’eau n’a relevé aucune différence notable entre 2018 et 2014 en ce qui concerne les nutriments et les paramètres physiques mesurés sur tous les sites d'échantillonnage. À l'exception d'un site où les *Recommandations canadiennes pour la qualité des sédiments : protection de la vie aquatique* (CCME 2014) ont été dépassées pour le cuivre, aucun autre paramètre n'était supérieur aux recommandations relatives aux sédiments analysés en 2018. Les résultats pour l'eau et les sédiments ont permis de valider l'hypothèse selon laquelle la qualité de l'eau et des sédiments du Lac la Martre est « bonne » (c.-à.-d. non anormale).

Key messages

- The fish tissue analyses of fish species typically consumed by residents of Whatì showed that mercury levels were low in łıh while łıwezǫǫ̀ 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 Lac la Martre. No water or sediment contaminant levels were considered to be abnormal.
- Whatì community members were pleased with the implementation of the program, citing the importance of continued monitoring near their community.
- Non-statistical comparison of the 2018 to 2014 results suggests that there are no major changes in the quality of fish, water or sediment.

Messages clés

- L'analyse des tissus des diverses espèces de poisson habituellement consommées par les habitants de Whatì a montré que les concentrations de mercure étaient faibles dans le łıh tandis que la concentration dans le *łıwezǫǫ̀* était presque égale ou légèrement supérieure aux recommandations. Aucune des concentrations de contaminants mesurées dans les tissus de ces espèces de poisson n'est considérée comme anormale.
- Les résultats des analyses de l'eau et des sédiments ont permis de valider l'hypothèse selon laquelle la qualité de l'eau et des sédiments du Lac la Martre est bonne. Aucune des concentrations de contaminants mesurées dans l'eau et les sédiments n'est considérée comme anormale.
- Les membres de la collectivité de Whatì 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 2018 avec ceux de 2014 donne à penser qu'il n'y a pas eu de changements importants de la qualité du poisson, de l'eau et des sédiments.

Objectives

This program 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?"

Activities in 2018-2019

Introductory / planning workshops

On August 17, 2018, a half-day workshop was held with community members from Whatì to introduce, revisit, and discuss the TAEMP. Participants expressed interest in the TAEMP camp and having the opportunity to build on the fish camp in 2014. Participants agreed that monitoring fish, water, and sediment quality continues to be important to monitor changes near Whatì and agreed that Elders, youth and scientists can take the opportunity to work together again. Participants clarified that cultural activities need to occur (e.g. grave site visits, fish demonstrations) and that time will be allocated accordingly. There was a strong desire to ensure as much youth participation as possible occurred. Participants provided input on repeat sampling, as well as re-use of the 2014 location for the camp. Visiting staff clarified that community members want water/sediment sampling sites added further to the West of Lac la Martre in order to capture locations that are important. There was agreement that camp should occur September 10-14, 2018 (Monday- Friday). It was agreed that next planning meeting should occur on September 5, 2018 in Whatì.

On September 5, 2018, a second workshop was held in Whatì, to finalize planning for the fish camp and to deal with logistical issues. Concepts related to monitoring were re-visited, as well as the primary tasks which needed to be achieved at camp. The camp location selected was on the same island as in 2014, as it offered better options for camp set up and boat landing/launch given that either side of the island could be used in response to changes in wind.

Monitoring Camp at Lac la Martre (i.e., "fish camp")

The on-the-land phase of the TAEMP occurred from September 10 to 14, 2018. Travel to Whatì occurred on September 10; however, due to high winds, participants were not able to reach the camp until the morning of September 11. Sampling and other activities occurred September 11-14, and participants returned to Whatì on September 14. The camp foreman and assistants visited the camp on Sunday, September 9 to prepare the camp for participants. Local camp participants also remained at the camp location on September 14 to complete tear-down of the camp.

Surface water samples were taken as "grab samples". Field Staff used fresh disposable vinyl gloves at each sample site to minimize the potential for contamination from the sampler's hands. Different sample bottles were used for each laboratory analysis group including physicals, nutrients, total and dissolved metals, and microbiological analysis. All bottles (except sterile bottles) were rinsed three times with sample water before filling.

Standard physical and chemical parameters were used as water quality indicators, including temperature, pH, conductivity, clarity, turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), alkalinity, dissolved Oxygen, major nutrients, ions, and trace metals. These parameters are comparable to Aboriginal Affairs and Northern Development Canada (AANDC; now Crown-Indigenous Relations and Northern Affairs Canada) Water Resources' datasets for the Frank Channel on Great Slave Lake, the closest water quality monitoring station. Water sampling was led by the WLWB Regulatory Manager; procedures were followed to minimize contamination, such as implementation of appropriate Quality Assurance/ Quality Control (QA/QC) procedures, in accordance with instructions from the GNWT Taiga Environmental Laboratory (Taiga) located in Yellowknife.

Samples were placed in an electric cooler to preserve the integrity of the water samples. Microbiological analysis is particularly time-sensitive and samples for this analysis were taken on the day of departure and delivered to the lab in Yellowknife on the same day. Taiga performed all analyses, and Taiga is a member of the Canadian Association of Environmental Analytical Laboratories (CAEAL), a national organization established to ensure consistent laboratory quality assurance.

Sediment sampling used methods outlined in Metal Mining Technical Guidance for Environmental Effects Monitoring (Environment Canada, 2012; now Environment and Climate Change Canada), and samples were analyzed for standard physical and chemical properties as well as trace metals. Lake sediments were sampled using an Ekman grab sampler (dredge) suitable for collecting soft, fine grained sediments typically observed in the area.

Sediment samples were collected using an Ekman, transferred to a stainless-steel tray, then placed into sterile bags. Sediment samples were stored in an electric cooler along with the water samples and provided to Taiga for analysis after support Staff returned to Yellowknife. If two distinct layers of sediment were captured by the Ekman, they were sampled and submitted for analysis separately as top and bottom.

Appropriate QA/QC procedures were followed according to Taiga instructions. Field staff used fresh disposable vinyl gloves at each sample site to minimize the potential for contamination from the sampler's hands. Sediment sampling was led by the WLWB Regulatory Manager.

Fish were collected through gillnets set at locations as determined by community members given the knowledge of where fish species can be caught; nets provided fish for sample collection as well as for consumption at camp. Four gillnet sets were conducted over the course of the camp on Lac La Martre. The 4.0-inch, 4.5-inch and 5-inch nets were used to target larger fish such as łwezǫǫ̀ (lake trout; LKTR) and łıh (lake whitefish; LKWH). The number and duration of gillnet sets were subject to safety considerations and occurred close to camp.

The fish caught were identified to species, measured for total length and fork length to the nearest millimeter (mm), and weighed (g). Additional data collected included: gender, stage of maturity, and a general description of the contents of the stomach, any parasites and/or deformities. The sample size targets for tissue (for contaminants) and otoliths (for aging) were 20 łwezǫ̀ǫ̀ (LKTR) and 20 łih (LKWH) to replicate samples sizes from 2014. The species sampled also represented those typically consumed by community members, and sampling of the two species also provided a way to account for differences between benthic (bottom feeding) and predatory (feeding on smaller fish) strategies.

Results Workshop - communication and outreach

After analyses of fish, water and sediment samples were completed and support Staff had an opportunity to review the results, a public meeting was held in Whatì on April 25, 2019, to review the goals and objectives of the program, as well as present the results of the analyses, including a comparison to the 2014 results to see if any changes had occurred. Importantly, the results workshop provided an opportunity for community members to ask questions and gain clarification(s). An open format proved to be an effective and appropriate way to present results to participants and interested community members. Collaboration with HSS GNWT, along with other TAEMP partners, aided appropriate messaging and communication strategies regarding the presentation of results. This collaboration ensured community members are informed and educated on the status of contaminants, if any, in the fish they may be eating and that nutritional guidance is provided to ensure these foods continue to remain healthy choices (AMAP 2011, HSS GNWT 2014, 2016).

Community engagement, capacity building and Traditional Knowledge

Elders and youth were exposed to, and participated in, scientific sampling methods typically used to monitor aquatic ecosystems, including the following: sediment and water quality sampling as well as fish tissue sampling for contaminant analysis. On shore demonstrations and field-based activities built on knowledge transferred to community members in 2014, increased understanding of standard methods used to assess contaminants in aquatic environments, and allowed community members to have increased knowledge with regards to monitoring and research activities near Tłı̨chǫ communities.

Elders and other community members guided all aspects of the project, with Tłı̨chǫ knowledge (i.e. Traditional knowledge, or TK) incorporated throughout by design. The on-the-land component of the TAEMP provided 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. The TAEMP also offered an opportunity for visiting researchers to learn from traditional knowledge holders in a culturally appropriate on-the-land context. This form of engagement allows for building of mutual respect and trust through exchange of TK and science-based information while completing the required sampling and the various tasks needed for the operation of a traditional camp.

TAEMP Staff asked community members about their perspectives regarding how to properly utilize TK within the project. Perspectives were shared at meetings, camp, and via answers to a series of interview questions. In general, Elders were pleased with their involvement at camp and with the opportunities provided to pass on TK, for example through a gravesite visit, net repair, storytelling, and teachings related to proper behaviours while at camp and on-the-land, and the history of the struggles people underwent to survive. Youth and visiting researchers were able to observe traditional methods of preparing and cooking fish, and were able to practice these skills at the camp.

Results and outputs/deliverables

Water and sediment sampling locations were located as close as possible to 2014 sampling locations, with 3 new locations added further west of the camp at the request of community members. The weather was calm enough to sample the 2014 sites which were closer to camp; however, weather (and safety) considerations did not allow safe access to the three new water and sediment sampling locations. Through cooperation among participants, fish were caught in nets to provide food for the traditional camp, and to provide samples for analyses. Tissue samples were successfully collected from 20 łiwezǫ̀ǫ̀ (LKTR) and 20 łìh (LKWH). Elders at the camp preferred to make their tea with melted snow water that had been stored in plastic jugs since the most recent winter. Elders were curious about the water quality of their "snow water." A sample of snow water was collected and named "Whatì-Snow". This sample was analyzed for nutrients and physical parameters along with the Lac la Martre water samples. Water samples were also collected near the community dock and analyzed for bacteria, total coliforms and faecal coliforms.

Water quality

Analysis of water samples indicated no noticeable difference between 2018 and 2014 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 2018 indicated pH ranged from 8.38 to 8.47, and results showed very little difference between sampling sites (n=6); 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 8.35 to 8.39 in 2014 (n=6).

Conductivity of the water ranged from 302 to 333 microsiemens per centimeter (µS/cm) in 2018, and, in 2014, the conductivity was similar with a range of 297 to 304 µS/cm. TDS at each 2018 site had amounts ranging from 166 mg/L to 184 mg/L, with 2014 results similarly ranging from 156 mg/L to 182 mg/L. TSS in 2018 for all locations were below the detection limit of 3 mg/L. Similarly, in 2014 TSS for the majority of locations were under the detection limit of 3 mg/L, with only one location at 4 mg/L.

Most metal concentrations in Lac la Martre were very low with many measuring below method detection limits (MDL). The 2018 water samples were all better than FAL guidelines, while 2014 water samples had a few metal concentrations greater than FAL guidelines. Overall, there was minimal difference between 2014 and 2018. No samples exceeded the FAL guidelines for mercury in either 2018 or 2014.

Samples were also collected near the community dock in 2018 to assess bacteria (e.g. *Escherichia coli*, total Coliforms, and Faecal Coliforms). Faecal coliforms, *Escherichia coli* and hydrocarbon results were all below detection limit. Total coliforms detected at 27.5 MPN/100ml.

The Whatì-Snow sample pH result of 6.92 falls within the CCME FAL guidelines (6.5-9.0) (CCME 2014). Conductivity of the snow water was 8.3 µS/cm, and there was low measurable TDS at 10 mg/L. Analysis indicated that the Whatì snow water for tea sampled can be considered "soft," whereas all Lac la Martre sites sampled in 2018 would be considered "hard." Total and dissolved copper concentrations (8.6 and 7.2 µg/L, respectively) exceeded the guideline (CCME 2014) for copper (2 µg/L).

Sediment quality

Sediment samples collected in 2018 from all locations had arsenic concentrations below the CCME Sediment Quality Guidelines for the Protection of Aquatic Life interim Sediment quality guidelines (SQG) of 5.9 µg/g (CCME 2014).

The 2018 cadmium method detection limit was 1 µg/g, which is higher than the SQG for cadmium of 0.6 µg/L. All of the 2018 sediment sample results for cadmium showed a "less than" detection result, but because "less than" values were treated as results equal to the detection limit, the results may represent a false exceedance. This is identical to the 2014 cadmium results.

The 2018 mercury method detection limit was 0.1 µg/g. The SQG was 0.17 µg/g, and the Probable Effects Level (PEL) guideline was 0.486 µg/g (CCME, 2014). All of the 2018 sediment sample results for copper showed a result less than the detection limit of 0.1 µg/g; however, one sample showed a result of 0.2 µg/g, which exceeded the SQG guideline but not the PEL guideline. In 2018, one sample was collected per sampling location, except for two sites where a top and bottom sediment sample was collected as the samples had visible stratified layers. For both of those sites, the top and bottom sample results for mercury were below detection limit (<0.1 µg/g). In 2014, two locations exceeded the SQG but not the PEL guideline.

In 2018, none of the copper results exceeded SQG. Site WS-2 top and bottom results for copper were 7 and 10 µg/g, respectively, while site WS-6 top and bottom results for copper were 10 and 12 µg/g, respectively. For WS-2, the copper results were averaged to 8.5 µg/g while WS-6 was averaged to 12 µg/g. In 2014, copper concentrations exceeded ISQG of 35.7 µg/g, but not the PEL guidelines (CCME, 2014) at WS-3 (99 µg/g), WS-4 (41 µg/g), and WS-5 (41 µg/g). The PEL guideline for copper is 197 µg/g.

No other parameters exceeded the CCME SQG or PEL in the sediments analyzed.

Fish tissue

Four species of fish were caught on Lac la Martre; 21 łıh (lake whitefish; LKWH), and 27 łıwezǫǫ̀ (lake trout; LKTR), 6 *Dehdoo* (longnose sucker; LNSC) and 14 Į̨hdaa (northern pike; NRPK), for an overall total of 75 fish caught over a combined total of 85.5 hours of net sets. The łıwezǫǫ̀ (LKTR) and ı̨hdaa (NRPK) represented the common top predators, and łıh (LKWH) and dehdoo (LNSC) represented benthic invertebrate feeders. Smaller fish fauna could not be effectively sampled with the mesh size in the gillnets used. The two fish species which had tissues collected for contaminant analyses were łıwezǫǫ̀ and łıh. These two species are regularly used for consumption in Whatì and were the same species for which analyses occurred in 2014.

2018 łıwezǫǫ̀ (LKTR) results

In 2018, mercury concentrations in tissues were on average 0.282 mg/kg wwt (wet weight; 95% CI+/-0.05) ranging from 0.129 to 0.608 mg/kg wwt, with one of the twenty fish sampled over the guideline for mercury of 0.5 mg/kg, (wet weight, wwt; Health Canada, 2016). Review of mercury concentrations in muscle tissue in relation to fork length, age and weight suggest positive relationships, with the strongest positive relationship suggested with regards to age.

Łıwezǫǫ̀ (LKTR) comparison between 2018 and 2014

In 2014, mercury concentrations in tissues were on average 0.330 mg/kg wwt (wet weight; 95% CI+/-0.048) ranging from 0.202 to 0.591 mg/kg wwt. Two fish were found to have mercury concentrations above the Health Canada guideline. These were the two oldest łıwezǫǫ̀ sampled (18 and 21 years, respectively). Compared to the 2014 results trend, mercury concentrations in larger fish in 2018 are less than expected.

2018 łıh (LKWH) results

In 2018, mercury concentrations in tissues were on average 0.038 mg/kg wwt (wet weight; 95% CI+/-0.01) ranging from 0.01 to 0.061 mg/kg wwt, with none of the fish sampled having mercury concentrations above the guideline of 0.5 mg/kg, (wet weight, wwt; Health Canada, 2016). Review of mercury concentrations in muscle tissue in relation to fork length, weight and age suggest positive relationships.

Łıh (LKWH) comparison between 2018 and 2014

In 2014, mercury concentrations in tissues were on average 0.035 mg/kg wwt (wet weight; 95%

CI+/-0.007) ranging from 0.0148 to 0.0781 mg/g wwt. All of the łıh sampled fell well below the guideline for mercury of 0.5 mg/kg. Comparison of 2014 results to 2018 results suggests a slightly lower mercury concentration in tissue in 2018, as scatterplots and confidence intervals show a small degree of overlap between years. Comparison of the cumulative data sets (2018 and 2014) for łıwezǫ̀ǫ̀ and łıh show positive relationships between mercury concentration in tissue and weight, length, and age. Łıh consistently show lower concentration in their tissues than łıwezǫ̀ǫ̀, with the clearest differentiation visible with regards to age.

No deformities/abnormalities were noted in any of the fish sampled; parasites (e.g. worms and cysts) were found in majority of individuals, though not at levels considered to be abnormal. Łiwezǫ̀ǫ̀ stomach contents included *Dahts'a* (Ninespine Stickleback), dehdoo (longnose sucker), sculpin and łıh. Łıh stomach contents included small benthic snails and invertebrates.

It should also be noted that the Health Canada Guidelines provided are for retail fish (Health Canada 2016). There are no Health Canada Guidelines for fish caught for recreational or subsistence purposes.

Other fish species

There were 14 ı̨hdaa (NRPK) and 6 dehdoo (LNSC) caught in 2018; tissue samples were not collected for analyses. No other species were caught. By comparison, in 2014, 31 ı̨hdaa (NRPK) and 0 dehdoo (LNSC) were caught.

Quality assurance

Duplicate fish tissue samples were taken for both łıwezǫ̀ǫ̀ and łıh. Duplicate results are within normal limits and indicate that the samples were taken and analysed with precision

Fish growth

Overall, review of age in relation to length for the łıwezǫ̀ǫ̀ and łıh caught in Lac la Martre suggest rapid growth in approximately the first 5 years, followed by no appreciable increase in size from 10 years to maximum age; no regression analyses were performed.

Łiwezǫ̀ǫ̀ from which tissues were sampled for analyses in 2018 (n=20) were on average 590 mm in length (fork length; 95% CI+/-37.14) ranging from 448 to 780 mm. They weighed on average 2284 g (total weight; 95% CI+/-519.34) ranging from 1100 to 5510 g, and were on average 16 years old (via otolith aging; 95% CI+/-2.53) ranging from 9 to 28 years (n=19; 1 of the 20 fish could not be aged due to missing otoliths).

By comparison, łıwezǫ̀ǫ̀ sampled in 2014 (n=20) were on average 559.25 mm in length (fork length; 95% CI+/-30.78) ranging from 474 to 821 mm. They weighed on average 1905.5 g (total weight; 95% CI+/-328.66) ranging from 1020 to 4710 g and were on average 13 years old (via otolith aging; 95% CI+/-1.46) ranging from 8 to 21 years.

Łıh sampled in 2018 (n=20) were on average 438 mm in length (fork length; 95% CI+/-17.32) ranging from 380 to 499 mm. They weighed on average 954 g (total weight; 95% CI+/-109.44) ranging from 660 to 1520 g and were on average 9 years old (via otolith aging; 95% CI+/-0.77) ranging from 7 to 15 years.

By comparison, łıh sampled in 2014 (n=20) were on average 485 mm in length (fork length; 95% CI+/-25.32) ranging from 353 to 597 mm. They weighed on average 1372 g (total weight; 95% CI+/- 221.55) ranging from 400 to 2680g, and were on average 11 years old (via otolith aging; 95% CI+/-1.81) ranging from 6 to 22 years. The łıh sampled in 2018 were on average 7% smaller than in 2014.

Other fish species

In 2018, ı̨hdaa (NRPK) caught and measured (n=7) were on average 721 mm in length (fork length; 95% CI+/-68.41) ranging from 607 to 889 mm. They weighed on average 3201 g (total weight; 95% CI+/-1078.91) ranging from 1910 to 6210 g. Neither otolith for aging, or tissue samples for contaminant analyses, were collected.

By comparison, ı̨hdaa caught and measured in 2014 were on average 595.44 mm in length (fork length; 95% CI+/-122.20; n=17) ranging from 69.8 to 882 mm. They weighted on average 2687.15 (total weight; 95% CI+/-408.54; n=14) ranging from 1560-4480 g. Neither otolith for aging, or tissue samples for contaminant analyses, were collected.

Results Workshop

A results meeting open to the public was held in Whatì on April 25, 2019, and a presentation providing a comparison of the 2014 to 2018 results for fish, water and sediment was given. The results meeting was attended by a few Elders who participated in the 2018 camp, as well as a number of interested community members. With the support of school Staff, WRRB and Golder Staff shared information about the camp with students at Mezi Community School on April 26, 2019. They spoke about the health of the water and fish in Whatì, and the importance of safety.

Discussion and conclusions

The Tłı̨chǫ Aquatic Ecosystem Monitoring Program has been developed and modified continuously through a collaborative relationship among communities and agencies based in the NWT. By design, the TAEMP is based on consultation with communities near which sampling occurs. The TAEMP Partners will continue to use a collaborative approach in the future through face-to-face meetings, conference calls, and workshops, culminating in the on-the-land "fish camp" at which dialogue with community representatives occurs constantly to ensure the Program continues to meet its objectives.

The TAEMP provides an opportunity for youth and community members to conduct scientific fish monitoring at an on-the-land camp and allows their experience(s) to be combined with their Tłı̨chǫ knowledge of the environment near communities. This increases the capacity of Tłı̨chǫ people to understand the science-based methods used to assess the current and potential effects of contaminants within various ecosystems across their lands and how the results are interpreted, while simultaneously sharing Tłı̨chǫ knowledge and allowing for clarification of concepts in an on-the-land setting (e.g. similar to a field course-based approach). The TAEMP also offers an opportunity for researchers to learn from traditional knowledge holders in a culturally appropriate on-the-land context. This form of engagement allows for building of mutual respect and trust – as scientists and knowledge holders learn from one another while out on the land, recognizing each other's capabilities through regular camp operations (e.g. net setting, fish collection, fish processing for samples and food).

The TAEMP also involves staff from organizations inherently linked to Tłı̨chǫ communities, including the WRRB, 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 communities. A four-year rotation through Tłı̨chǫ communities also allows for the potential that community members will repeatedly participate in, contribute to, and learn from the TAEMP – notably the youth. The possibility for youth continuing with more specific environmental monitoring-related training is strengthened by the availability of the Marian Watershed Stewardship Program led by the TG and WLWB.

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, the first round of comparative sampling began. The comparative sampling provided data that will continue to assist addressing community concerns related to changes in the environment, and the TAEMP will continue to build on work carried out since 2010. The comparative sampling phase (2015-2018) provided data that allowed for the monitoring of changes and provided relevant information to assist in cumulative effects analyses and informed decision-making. For example, the TAEMP will contribute to the implementation of the NWT Water Stewardship Strategy (WSS) and Action Plan, and the continuing assessment of contaminant levels in traditional foods through collaboration with HSS GNWT and the Northern Contaminants Program. TAEMP will also complement 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 the related Tłı̨chǫ All-Season Road), and/or natural disturbances such as fire (Baltzer 2015). Finally, TAEMP continues to assist in the promotion, understanding, and protection of source water for Tłı̨chǫ communities.

Management of the TAEMP will be handed over to TG for the 2019 program and onward. The WRRB has led the program through its four initial baseline sampling years (2010-2014) as well as the first four comparative sampling years (2015-2018). It is anticipated that the WRRB will continue to assist the TAEMP as a partner in future years while the program is led by TG.

Expected project completion date

The Whatì portion of the TAEMP was concluded on April 26, 2019 following the conclusion of the results workshop.

Project website

https://www.wrrb.ca/

Acknowledgments

This project was guided by many Elders from the community of Whatì, and we give thanks for their dedication to the project and their interest in sharing their knowledge and expertise. We thank all the participants and support Staff who made the 2018 TAEMP on Lac la Martre a success. The Elders who participated: Francis Simpson, Joe Champlain, Madeline Champlain, Jimmy Nitsiza, Margaret Nitsiza, Lucy Nitsiza. The youth who participated from Mezi Community School: Carmen Flunkie, Rianna Nitsiza, Sabrina Football, Allison Nitsiza-Alexis and Prestley Alexis. Whatì community member support at camp: Archie Nitsiza, John Beaverho, Louisa Nitsiza, Evelyn Flunkie, Peter Nitsiza, and Lawrence Nitsiza. Translation at all meetings and at camp was provided by: Jonas Lafferty, and James Rabesca. Partner Staff who participated at camp: Laura Meinert (WRRB), Aimee Guile (WRRB), Anneli Jokela (WLWB), Francois Larouche (DFO), Lisa Marie Zoe (TG), Albertine Eyakfwo (TG), Samantha Migwi (TG) and Monica Redmond (Golder Associates); additional partner support provided by Jody Pellissey (WRRB), Sean Richardson (TG), Nicole Dion (ENR GNWT), Linna Williams (HSS GNWT), Shirley Beaverho (TG), and Staff at the Mezi Community School.

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References

Aboriginal Affairs and Northern Development Canada (AANDC). 2013. *A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program (NWT CIMP) and Audit.* Final Update March 2013 (previously updated 2009). Available at: http://sdw.enr.gov.nt.ca/nwtdp_upload/SOK_REPORT_201112__CONSOLIDATED_VC_REPORT_OCTOBER_2013.PDF

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

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

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

Government of Northwest Territories, Environment and Natural Resources (GNWT). 2016. *NWT State of the Environment Report – Highlights 2016.* Available at: http://www.enr.gov.nt.ca/sites/enr/files/state_of_environment_highlights_2016.pdf

Government of Northwest Territories, Health and Social Services (GNWT). 2016. *Northwest Territories Contaminants Fact Sheet Overview.* Available at: http://www.hss.gov.nt.ca/sites/hss/files/resources/contaminants-fact-sheets-contaminants-overview.pdf

Government of Northwest Territories, Health and Social Services (GNWT). 2017. *General Fish Consumption Guidelines for the NWT.* Available at: http://www.hss.gov.nt.ca/sites/www.hss.gov.nt.ca/files/general-fish-consumption-guidelines-nwt.pdf

Health Canada. 2017. Health Canada's *Maximum Levels for Chemical Contaminants in Foods.* Available at: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php

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

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

Mackenzie DataStream (2017). Available at: http://mackenziedatastream.ca/#/

Mackenzie Valley Environmental Impact Review board (MVEIRB), 2017. GNWT-DOT – Tlicho All Season Road – EA-1617-01[2017]. Available at: http://www.reviewboard.ca/registry/project.php?project_id=958

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

World Wildlife Fund (WWF®). 2017. *WWF®-Canada Watershed Report, Lower Mackenzie, Health.* Available at: http://watershedreports.wwf.ca/#ws-7/by/health-overall/health. Accessed April 2017

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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 sur les risques pour la santé humaine

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Project locations/Emplacements du projet

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

Abstract

Traditional country food is vital to Inuit culture and it has provided a high-quality diet for millennia. With industrial development, organic contaminant concentrations (e.g. mercury) have, at times, increased in the atmosphere and oceans and has accumulated in ecosystems and living organisms to reach the most remote Arctic regions. These contaminants are known to have adverse effects on animal and human health.

Résumé

La nourriture traditionnelle est essentielle à la culture inuite et elle a été à la source d'une alimentation de haute qualité pendant des millénaires. Avec le développement industriel, les concentrations de contaminants organiques (p. ex., le mercure) ont, à certains moments, augmenté dans l'atmosphère et les océans et se sont accumulées dans les écosystèmes et les organismes vivants pour atteindre les

Balancing the benefits that country food brings to Arctic residents (body health, mental health, and culture) with the risks associated with the eating country food that contains contaminants is challenging.

In this 2018-2019 Northern Contaminants Program (NCP) funded project, we:

- monitored contaminants (mercury and trace metals) and stable isotopes in different tissues collected from ringed seals in the spring (n=14) and fall (n=13) of 2018;
- ran statistical analyses on the 2017-2018 contaminants data (mercury and trace metals) collected from ringed seals; and
- determined the nutritional content of ringed seals based on the 2017-2018 data. Results for trace metals and stable isotopes analysis of 2018-2019 samples are not yet available and pending at the laboratory. Arctic char could not be sampled this year. POPs analysis will be performed on the last year of the project (2020-2021).

In addition to the NCP objectives, in partnership with Dr. Pierre-Yves Daoust from the University of Prince Edward Island (UPEI), we determined the occurrence of infectious pathogens in ringed seals from the 2017-2018 data (see Appendix).

The ringed seal monitoring program was completed in 2018-2019. Based on the success of this baseline study and local capacity developed, we intend to pursue narwhal monitoring in 2019-2020.

This community-based project was led by James Simonee, with the support from ARCTIConnexion, the Mittimatalik Hunters and Trappers Organization (HTO), and team members. Synopsis report was prepared by ARCTIConnexion, with the contribution of James Simonee.

régions arctiques les plus reculées. On sait que ces contaminants ont des effets nocifs sur la santé animale et humaine. Il est difficile de trouver un équilibre entre les avantages que les aliments traditionnels apportent aux habitants de l'Arctique (santé corporelle, santé mentale et culture) et les risques associés à la consommation d'aliments traditionnels contenant des contaminants.

Dans ce projet financé par le Programme de lutte contre les contaminants dans le Nord (PLCN) pour 2018-2019, nous avons :

- surveillé les contaminants (mercure et métaux traces) et les isotopes stables dans différents tissus du phoque annelé prélevés au printemps (n = 14) et à l'automne (n = 13) de 2018;
- effectué des analyses statistiques sur les données relatives aux contaminants (mercure et métaux traces) dans les échantillons prélevés sur les phoques annelés en 2017-2018;
- déterminé la teneur nutritive des phoques annelés d'après les données de 2017-2018. Les résultats de l'analyse des métaux traces et des isotopes stables des échantillons de 2018-2019 ne sont pas encore disponibles et sont en cours d'analyse au laboratoire. L'omble chevalier n'a pas pu être échantillonné cette année. L'analyse des POP sera effectuée au cours de la dernière année du projet (2020-2021).

En plus des objectifs du PLCN, en partenariat avec Pierre-Yves Daoust de l'Université de l'Île-du-Prince-Édouard (UPEI), nous avons déterminé la présence d'agents pathogènes infectieux chez les phoques annelés à partir des données de 2017-2018 (voir l'annexe).

Le programme de surveillance des phoques annelés s'est achevé en 2018-2019. Vu le succès de cette étude de base et les capacités locales acquises, nous avons l'intention de poursuivre la surveillance des narvals en 2019-2020.

Ce projet communautaire a été dirigé par James Simonee, avec le soutien d'ARCTIConnexion, de l'Organisation des chasseurs et des trappeurs de Mittimatalik et des membres de l'équipe. Le rapport de synthèse a été préparé par ARCTIConnexion, avec la contribution de James Simonee.

Key messages

- The current project, monitoring ringed seals, has continued to advance with the involvement of local researchers, mentors, and NCP researchers.
- Ringed seal monitoring has found higher Hg concentration in liver than in muscle.
- Ringed seal liver concentrations of Hg, Ar, and Cd are above recommended thresholds. There was a positive correlation between Hg concentration and age in liver. There were also higher Hg concentrations in sampled tissues in the spring than in the fall.
- The total mercury concentration was, on average, made up of 35% methylmercury (toxic).
- There was a temporal and spatial variation in food use.

Messages clés

- Le projet actuel, soit la surveillance des phoques annelés, a continué de progresser avec la participation de chercheurs locaux, de mentors et de chercheurs du PLCN.
- La surveillance des phoques annelés a révélé une concentration de Hg plus élevée dans le foie que dans les muscles.
- Les concentrations de Hg, d'Ar et de Cd dans le foie des phoques annelés sont supérieures aux seuils recommandés. On a constaté une corrélation positive entre la concentration de Hg et l'âge dans le foie. On a également constaté des concentrations de Hg plus élevées au printemps qu'à l'automne dans les tissus échantillonnés.
- La concentration totale de mercure était, en moyenne, composée de 35 % de méthylmercure (toxique).
- On a constaté une variation temporelle et spatiale dans l'utilisation des aliments.

Objectives

The aims of this project are to:

- determine seasonal/spatial variation in mercury and trace metals concentration in ringed seal and Arctic char of the Eclipse Sound; and,
- establish a baseline of POPs contamination (legacy and newer concern POPs) for ringed seals;

Introduction

In the early 2000s, mercury concentrations in ringed seal liver and kidney were well above the Health Canada guidelines (0.5 mg/kg weight tissue) in Pond Inlet (Mittimatalik) as determined by NCP scientists (Braune et al. 2015). Some POPs (e.g. brominated flame retardants (BFRs) concentrations have recently increased in marine mammal tissues in other Arctic regions as well as in human biomarkers (Rotander et al. 2012, Hoguet et al. 2013), yet no data is available in Pond Inlet.

In 2017-2018, this NCP project was the first to contribute to contaminants knowledge related to ringed seal in the region since the 2000s, and the first to integrate local observations and knowledge to contaminant science in the region. However, results from contaminants analyses were not yet available and, hence, not included in the previous synopsis report for this project.

In this 2018-2019 NCP project, we harvested additional ringed seals to increase the sample size used for contaminants analysis in this project, which will allow us to identify the factors that influence the concentration of mercury and trace metals in ringed seals. We also ran statistical analyses on the results from the 2017-2018 samples.

Local research capacity in the field of contaminants science is still very limited in Arctic communities and our project has shown, in the past, that local support and promotion of contaminant research can lead to very interesting community-based initiatives. In 2018-2019, James Simonee played an active role and showed leadership in all aspects of this project. Because of his involvement, the project objectives, progress, and results are continually shared and promoted in the community, which enables a more actual and adapted outreach approach. Again, this year we involved a team of mentors to support James, including established NCP researchers responsible for the programs core monitoring projects.

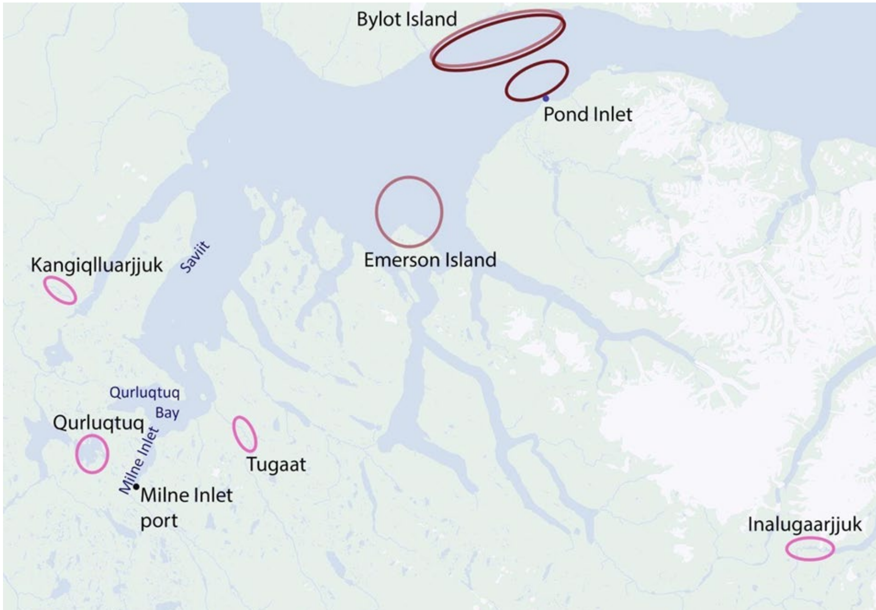
Activities conducted in 2018-2019

Mercury and trace metals concentrations, and POPs

Ringed seal

In order to determine seasonal variation in the concentration levels of ringed seals, we harvested seals in the spring (ice season) and fall (ice-free season) of 2018. Most of the seals were sampled from the Emerson Island area in the spring (Fig. 1), and from across Pond Inlet up to Bylot Island in the fall. However, we were not able to harvest seals in the Milne Inlet area as planned due to early ice forming in the fall.

Figure 1. Regional map of the study area. Pale and dark brown ellipses represent ringed seal harvest areas in spring and fall of 2018, respectively.



On-site, we recorded body measurements and collected and stored specific animal tissue (muscle, liver, blubber, fur, blood) for contaminants analyses, isotope analyses, and serology for infectious pathogen analyses. Samples were shipped to Environment Canada's Burlington lab, the University of New Brunswick's Sinlab, and the UPEI for processing. Blubber and liver samples were stored for future analysis of POPs levels.

In the fall of 2018, contaminants and stable isotopes results from 2017 were obtained and analyzed. We ran statistical models (linear regressions and ANOVAs) to determine seasonal and spatial variations in the contaminant levels found in ringed seals. We also addressed the contribution of other factors, such as the age of the seal and tissue type, to contaminant levels in these models. We ran similar analyses on the stable isotopes data to address the variation in the diet of ringed seals. Results from 2018 are pending.

In the winter of 2019, we compiled contaminants and infectious pathogens results into an easy-to-read pamphlet designed for community members and local organizations (see Appendix). Prior to releases, a copy of the pamphlet content was shared with Nunavut Department of Health and corrections were made based on their comments.

Arctic char

No anadromous (sea-run) Arctic char were sampled in 2018 as planned. Project leader James Simonee reevaluated the Arctic char objective along with the Mittimatalik HTO and, since Arctic char were already monitored in 2015-2016, priorities we reframed, resources were used for the incoming narwhal monitoring. The HTO is interested in research Arctic char in the Qurluktuk lake area nearby the Mine port. Thus, this component will be re-evaluated in the future.

Community engagement

- Project leader James Simonee is based in Pond Inlet and benefits from continuous support from community members, fellow hunters, family, and the local HTO. As an example of the support James Simonee receives, during the fall sampling, James requested the help of local hunters for the harvesting of ringed seals and the hunter's community answered immediately, allowing the project to fulfill its objectives.

- 3 assistants (Andrew Jaworenko, Jassie Simonee, and Ivan Koonoo) participated in the project. They provided help during hunting trips and the sampling ringed seals.
- Local Elders and hunters provided help and guidance throughout the duration of this project.

Capacity building and training

- Veterinarian from UPEI, Pierre-Yves Daoust, travelled to Pond Inlet during the spring to provide field work training to James Simonee and his assistants for serology sampling.
- Research mentor Vincent L'Hérault travelled to Pond Inlet in the fall to provide support and training during the project's field work.
- James Simonee and mentor Pierre-Yves Daoust travelled to Québec City in February 2019 for a one-week data analysis and report writing training at ARCTIConnexion.
- James Simonee could not travel to the Water Science and Technology Directorate lab in Burlington, Ontario, in March 2019 for a training of lab analysis, due to work duty. This activity is postponed until the 2019-2020 fiscal year.

Communications and outreach

Local

- Project progress was shared along the way with community members and the Mittimatalik HTO; progress was shared more frequently during periods of field work.
- A pamphlet showing results highlights (see Appendix) was released in March 2019.
- James Simonee presented an update of the project and the pamphlet to the Mittimatalik HTO in March 2019.

National

- General project progress was discussed with funders and partners at the 2018 ArcticNet conference held in Ottawa.
- Communications with a large public, academics and media were ensured through the ARCTIConnexion's Web Site (www.arcticonnexion.ca) and the Facebook page (www.facebook.com/ArctiConnexion).
- Metadata records were submitted to the Polar Data Catalogue in March 2019 https://www.polardata.ca/pdcinput/metadata/display?ccinRefNumber=13059.

Indigenous Knowledge

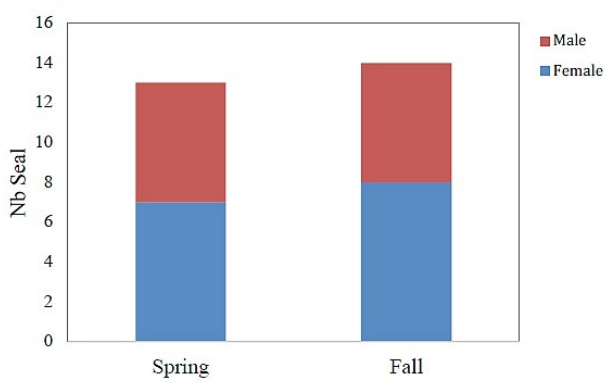
- Indigenous Knowledge was embedded in all aspects of this research project because it was led by a local hunter and supported by the hunters' community.
- The scientific design of the project (sampling areas/sites and seasons) was directed by the knowledge of James Simonee and other hunters.

Results and outputs/deliverables

2018

A total of 27 ringed seals were harvested in 2018, for a project total of 57 seals. We harvested 13 and 14 ringed seals in the spring and fall, respectively. Figure 2 shows the sex ratio for each season. At the time of this report (April 2019), lab analysis of mercury and trace metals, stable isotopes, and aging are near completion.

Figure 2. Summary of the number (Nb) of ringed seals harvested by season and gender in 2018.



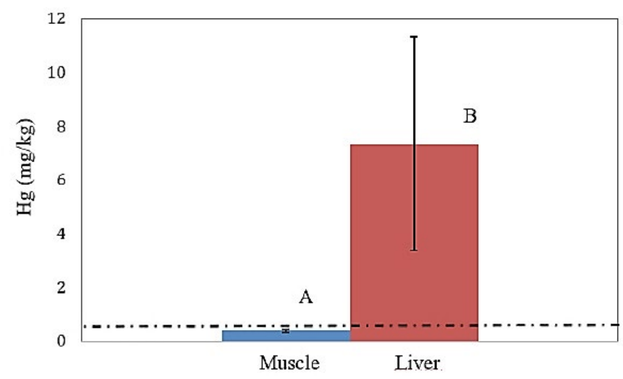
2017

To address the potential impact of metal concentration on human health, we compared our results to the thresholds determined by different international organizations (Table 1). In Canada, tolerable upper intake levels have been established for mercury but not for arsenic, lead, and cadmium (Health Canada, 2009).

2017- Among-tissue comparison

Muscle of ringed seal contained $\bar{x} = 0.38 \pm 0.06$ mg/kg (n=26; Figure 3), which is below the acceptable level for consumption (Table 1). The liver of ringed seals contained $\bar{x} = 7.34 \pm 3.97$ mg/kg (n = 26; Figure 3) which was significantly higher than the muscle ($F_{1,24} = 7.09$, $p = 0.001$, n = 26), and well above the recommended threshold for consumption (Table 1).

Figure 3. Among-tissue comparison of mercury concentration in ringed seals. Averages and standard deviations (bars) are shown. Letters over the bars indicate statistical difference. Dashed line indicates the acceptable level for consumption (0.5 mg/kg).



2017- Among-season

Mercury levels were significantly higher in the spring ($\bar{x} = 10.71 \pm 5.50$ mg/kg, n=10) than in the fall ($\bar{x} = 4{,}87 \pm 1.64$ mg/kg, n=14) ($F_{1,24}=7.32$, $p=0.01$; Fig. 4). However, spring and fall samples were not collected from the same locations, which implies that some of the among-season variation observed in mercury levels could be attributed, at least partly, to spatial variation. All other trace metals were not different among-season.

Figure 4. Among-season comparison of mercury concentration in the liver of ringed seals. Average and standard deviation (bars) are shown. Letters over the bars indicate statistical difference. Dashed line indicates the acceptable level for consumption (0.5 mg/kg).

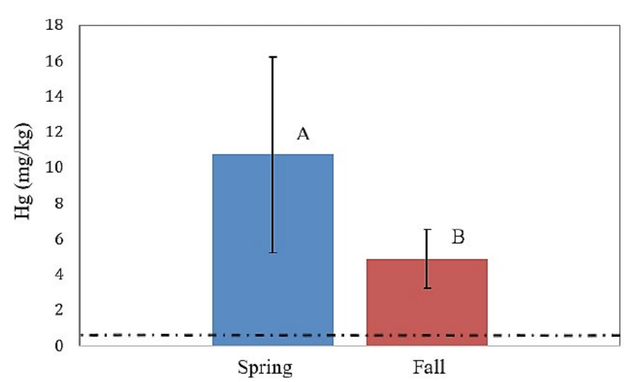
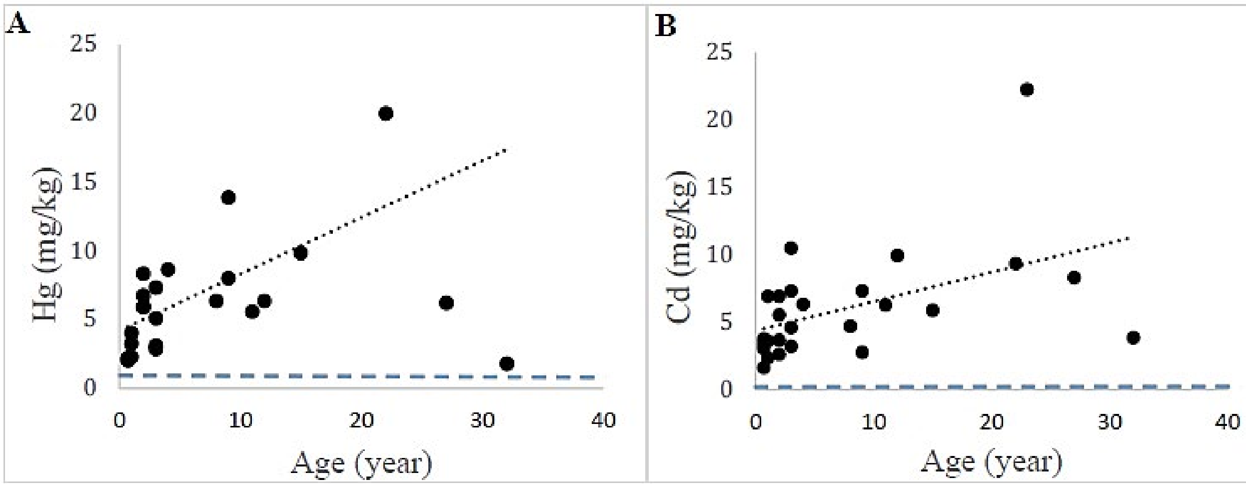


Figure 5. Linear regression (black dashed line) of the mercury (A) and cadmium (B) concentration in liver as a function of the age of the ringed seal. Dashed blue line indicates the acceptable level for consumption (Hg = 0.5 mg/kg, Cd = 0.025mg/kg)



2017- Contaminants vs age

Mercury and cadmium concentrations in liver were positively correlated to the age of the seal ($p = 0.04$, $R^2 = 0.16$; Fig. 5.A, and $p = 0.002$, R2 = 0.33; Fig. 5.B, respectively). Ringed seal liver also contained arsenic ($\bar{x} = 1.04 \pm 0.15$ mg/kg, n = 26) and lead ($\bar{x} = 0.007 \pm 0.003$ mg/kg, n = 26), which were not correlated to age. All liver samples were above the Health Canada (2009) recommended threshold for mercury, cadmium, and arsenic (Table 1).

2017- Methylmercury

The mercury concentrations measured in ringed seal livers correspond to total mercury, which contains both nontoxic inorganic Hg selenides, and toxic methylmercury (MeHg) compounds (Wagemann et al. 2000). To quantify the proportion of toxic mercury in the liver and how it relates to total mercury, we ran MeHg analysis on 10 ringed seal livers (samples balanced between season, age, and sex). MeHg concentration averaged 2.57 ± 0.40 mg/kg), which corresponds to ~35% of the total mercury on average. We ran a linear regression of MeHg as a function of total Hg to develop algorithms to predict MeHg concentration in future work. The regression was not significant, possibly due to our small sample size. In future work, it will be important to run MeHg/THg regression for different seasons and age class of ringed seal.

2017- Nutritional fact of liver

Despite its load of mercury and other metals, our results show that liver remains a valuable source of essential elements for human diet, such as iron (Table 2).

2017- Stable isotopes

We detected among-tissue variation in the isotopic ratios of ringed seals. Muscle ratios ranged from -20.8 to -18.4 ‰ in carbon ($\delta 13C$) ($\bar{x} = -19.3 \pm 0.3$ ‰), and from 15.4 to 17.6‰ in nitrogen ($\delta 15N$) ($\bar{x} = 16.2 \pm 0.2$ ‰) (Fig. 6). Liver ranged from -21.1 to -19.2 ‰ for $\delta 13C$ ($\bar{x} = -20.6 \pm 0.3$ ‰) and from 15.0 to 19.1‰ for $\delta 15N$ ($\bar{x} = 17.0 \pm 0.4$ ‰; Fig. 6). The relatively high variability in both $\delta 13C$ and $\delta 15N$ ratios suggest variability in food use. The elevated $\delta 15N$ ratios in ringed seal is typical of animals with high trophic level (top predators).

Figure 6. Variation in the isotopic ratios of carbon (δ13C) and nitrogen (δ15N) of ringed seals (n=26). Mean value ± standard deviation is provided for muscle and liver.

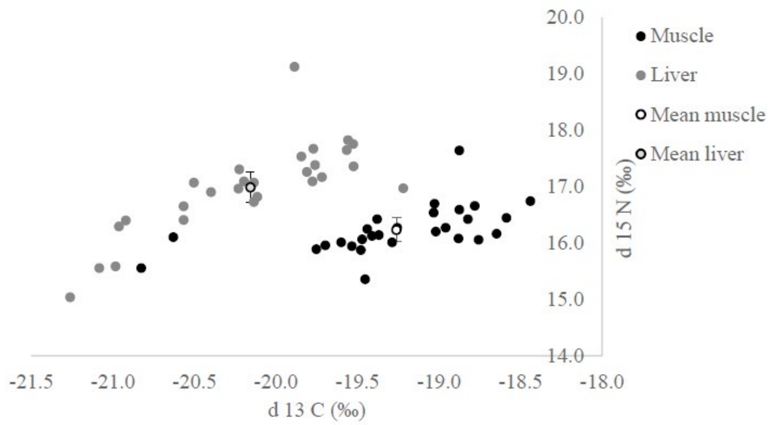


Table 2. Nutritional facts for 100 g of ringed seal liver, based on Health Canada dietary recommendations (Health Canada, 2019). % were calculated using the average value (n=26 ringed seals).

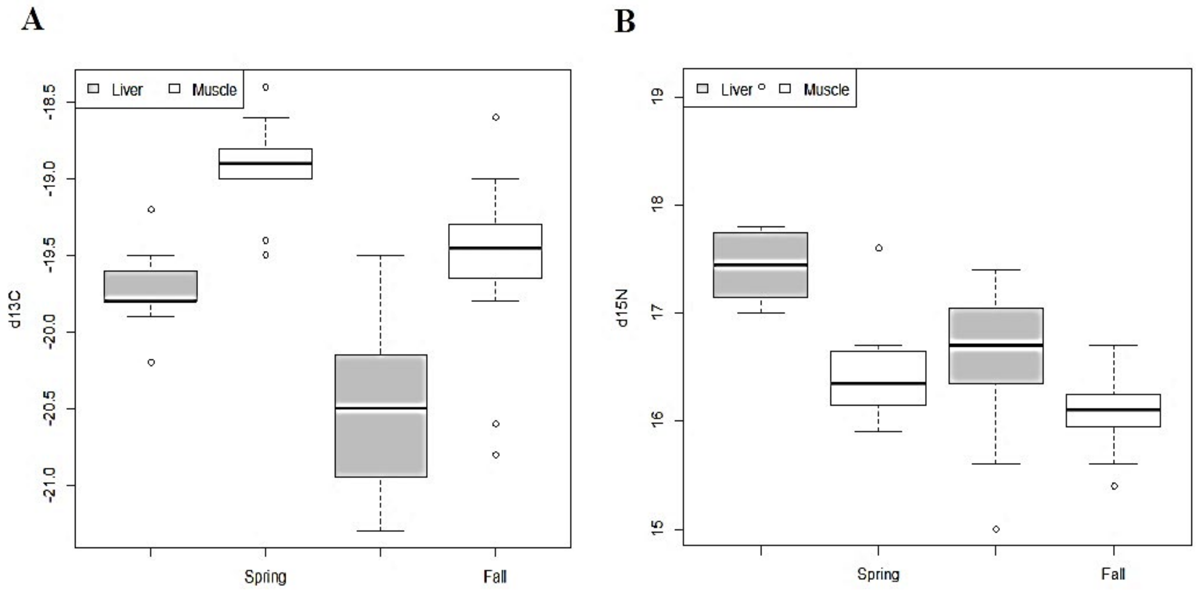
Elements	% of the Recommended Dietary Allowance*	% of the Tolerable Upper Intake Level (UL)**
Calcium	0.5	0.2
Chromium	52	-
Iron	677	120
Magnesium	5	-
Manganese	16	3
Phosphorus	42	7.3
Potassium	6	-
Selenium	1.0	0.1
Zinc	44	12

* % are for male between 19-30 years old.

** The tolerable upper intake level (UL) is the maximum usual daily intake level at which no risk of adverse health effects is expected for most of the individuals. The risk of adverse effects increases as intake exceeds the UL (Health Canada, 2017)

δ13C and δ15N varied significantly among tissue ($F_{1,54} = 59.49$, $p < 0.0001$, $F_{1,54} = 29.96$, $p < 0.0001$, $n = 26$, respectively) and season ($F_{1,54} = 35.17$, $p < 0.0001$, $F_{1,54} = 22.71$, $p < 0.0001$, $n = 26$, respectively) (Fig. 7 A, B). The interaction between tissue and season was also tested, and was not significant for δ13C, but was significant for δ15N ($F_{1,54} = 29.96$, $p < 0.0001$, n=26). This result suggests that the liver and muscle samples were significantly different from each other during a season.

Figure 7. Variation of δ13C (A) and δ15N (B) in ringed seals as a function of tissue and season. Dark line represents the median, box and arrow represent the 50% and 95% confidence interval, respectively.



Preliminary results reveal that ringed seals are not homogenous in their isotopic ratios, which reflects variation in food use. Our results suggest that food use is influenced by season and can also vary at finer time scales, as revealed by the among-tissue differences in isotopic ratios. The different turnover rates of the liver and muscle determined the rate at which the carbon and nitrogen are being assimilated. Liver tissue provided an indication of the seals' diet during the week prior to sample collection, and the muscle tissue provided an indication of the seals' diet during the past month (Hobson et al. 1996; Sinisalo et al. 2008). Importantly, spring and fall samples were collected at different locations (Fig.1), which implies that isotopic variation (and variability in food use) could be attributed, at least partly, to spatial differences in prey sources amongst other parameters.

In the context of this report, it is important to note that these results are preliminary and were conducted on raw isotopic values. Corrections for isotopic discrimination and lipid contents are typically applied to raw isotopic value, which were not performed here. In addition, further analyses involving the isotopic ratios of prey species are required to further our understanding of food use in ringed seal.

Discussion and conclusions

During the second year (2018-2019) of our seal monitoring project, our team was able to complete the collection of ringed seal samples in the Eclipse sound. Although the samples are currently being processed in the lab, we were able to conduct data analyses on the 2017 data, and provide preliminary results that are very informative:

- The muscle samples of ringed seals contained mercury concentrations below the recommended threshold provided by Health Canada;
- The liver samples of ringed seals contained concentrations of mercury, arsenic, and cadmium above the recommended Health Canada threshold and increased with age for mercury and cadmium. Methylmercury concentration corresponded to ~35% of the total mercury concentration;
- The liver of ringed seals is a valuable source of essential nutrients, but its iron level was 20% over the recommended Tolerable Upper Intake Level (UL), which may increase health risk. However, iron absorption depends on multiple factors

(e.g. vitamin intake and interaction with food type) that need to be accounted for in further studies.

- Ringed seal can use a variety of food sources in time (and space) as revealed by preliminary results stable isotopes analyses. Variation in food sources can lead to differences in contaminant levels.

Despite the preliminary nature of our results, our study revealed important trends. As confirmed by the isotopic results, the ringed seal is a top predator with a greater ability to bioaccumulate contaminants, particularly in liver. The consumption of ringed seal muscle tissue is also recommended.

Future work

- Run mercury, methylmercury, trace metals, POPs, and stable isotope analyses on the 2018 samples;
- Combine 2017-2018 in statistical analyses;
- Run stable isotopes mixed model accounting for prey signatures, test for sex (reproduction status), age, and location; and,
- Bridge scientific results with local knowledge documented earlier in this project

Expected project completion date

The ringed seal sub-project will be completed by winter 2020.

Project website

Facebook pages

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

www.facebook.com/ArctiConnexion

Website

www.arcticonnexion.ca

Acknowledgments

Board members of the Mittimatalik Hunters and Trappers Organization, Jamal Shirley at the Nunavut Research Institute, research assistants Andrew Jaworenko, Jassie Simonee and Ivan Koonoo. Hunters and Elders: Jaykolassie Kiliktee, Sam Oomik, Abraham Kunuk, Moses Konark, Joanassie Mucpa, Qamaniq Sangoya, Rodha Koonoo, Regellie Ootook, Rodha Arnakalak. The project team would also like to thank the NCP for their continued support.

References

Braune, B., Chetelat, J., Amyot, M., Brown, T., Clayden, M., Evans, M. et al. 2015. Mercury in the marine environment of the Canadian Arctic: review of recent findings. Science of the Total Environment, 509-510: 67–90.

European Commission. 2016. Arsenic in food. European Food Safety Authority, European Union. Consulted Online 2019-06-02: https://ec.europa.eu/food/safety/chemical_safety/contaminants/catalogue/arsenic_en

Health Canada. 2017. Fourth Report on Human Biomonitoring of Environmental Chemicals in Canada. Minister of Health, Ottawa, ON. Consulted online 2019-05-30: https://www.canada.ca/en/health-canada/services/

environmental-workplacehealth/reports-publications/environmental-contaminants/fourth-report-humanbiomonitoring-environmental-chemicals-canada.html

Health Canada. 2009. Dietary Reference Intakes. Minister of Health, Ottawa, ON. Consulted online 2019-05-30: https://www.canada.ca/en/health-canada/services/foodnutrition/healthy-eating/dietary-reference-intakes/tables/reference-values-elementsdietary-reference-intakes-tables-2005.html

Hobson, K.A., Schell, D.M., Renouf, D., and Noseworthy, E. 1996. Stable carbon and nitrogen isotopic fractionation between diet and tissues of captive seals: implications for dietary reconstructions involving marine mammals, Canadian Journal of Fisheries and Aquatic Science, 53: 528–533.

Hoguet, J., Keller, J.M., Reiner, J.L., Kucklick, J.R., Bryan, C.E., Moors, A.J., Pugh, R.S. and Becker, R.S. 2013. Spatial and temporal trends of persistent organic pollutants and mercury in beluga whales (*Delphinapterus leucas*) from Alaska, Science of The Total Environment, 449: 285–294.

Rotander A., Bavel, B.V., Polder, A., Rigét, F., Auðunsson, G.A., Gabrielsen, G.W., Víkingsson, ,G., Bloch, D. and Dam, M. 2012. Polybrominated diphenyl ethers (PBDEs) in marine mammals from Arctic and North Atlantic regions, 1986–2009. Environment International, 40: 102-109.

Sinisalo, T., Jones, R.I., Helle, E. and Valtonen, E.T. 2008. Changes in diets of individual Baltic ringed seals (Phoca hispida botnica) during their breeding season inferred from stable isotope analysis of multiple tissues, Marine Mammal Science, 24 (1): 159-170

Wagemann R, Trebacz E, Boila G, Lockhart WL, 2000. Mercury species in the liver of ringed seals. Sci Total Environ;261:21–32.

World Health Organization. 2017. Evaluations of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), Consulted Online 2019-06-02: https://apps.who.int/foodadditives-contaminants-jecfa-database/search.aspx?fcc=2

Appendix - Pamphlet

Environment

Food

People

Any Question?

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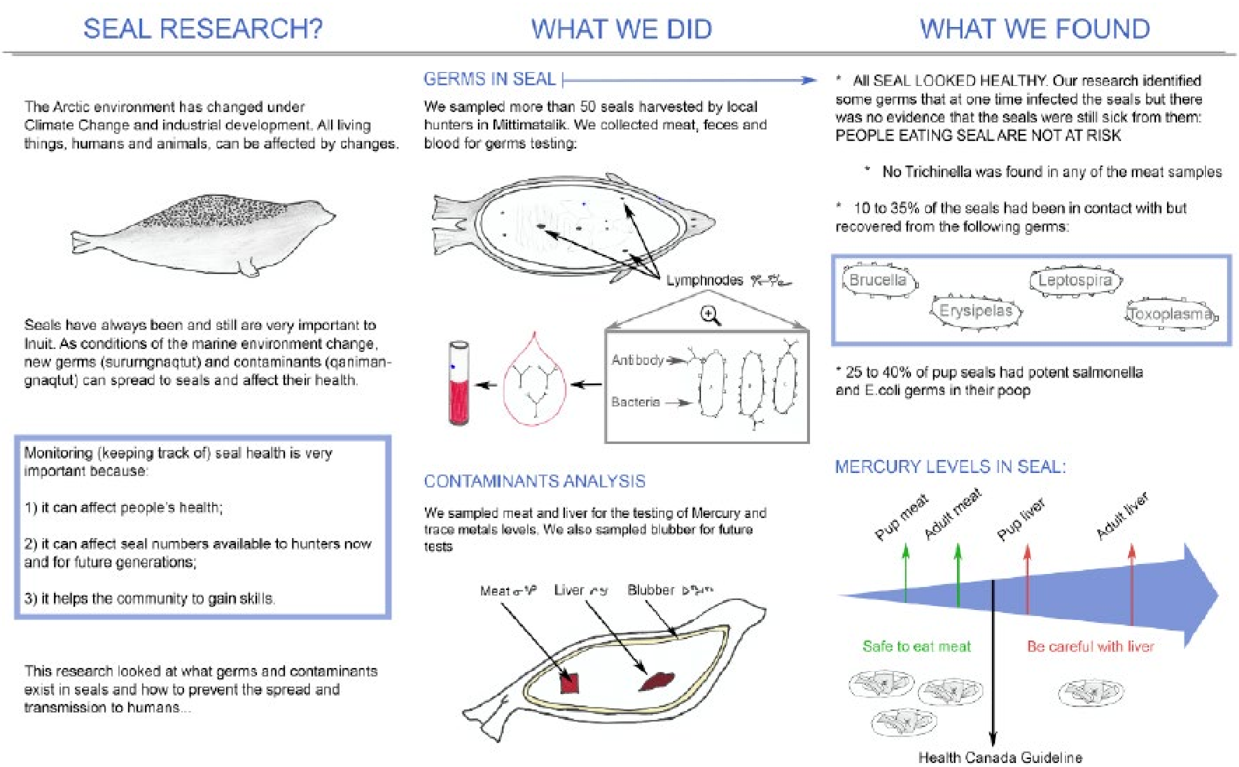
Contaminants monitoring in marine country food

Seal Health Community Monitoring in Mittimatalik

UNIVERSITY of Prince Edward ISLAND



SEAL RESEARCH?

The Arctic environment has changed under Climate Change and industrial development. All living things, humans and animals, can be affected by changes.

Seals have always been and still are very important to Inuit. As conditions of the marine environment change, new germs (surumgnaqtut) and contaminants (qaniman-gnaqtut) can spread to seals and affect their health.

Monitoring (keeping track of) seal health is very important because:

1) it can affect people's health;

2) it can affect seal numbers available to hunters now and for future generations;

3) it helps the community to gain skills.

This research looked at what germs and contaminants exist in seals and how to prevent the spread and transmission to humans...

WHAT WE DID

GERMS IN SEAL

We sampled more than 50 seals harvested by local hunters in Mittimatalik. We collected meat, feces and blood for germs testing:

Lymphnodes

Antibody

Bacteria

CONTAMINANTS ANALYSIS

We sampled meat and liver for the testing of Mercury and trace metals levels. We also sampled blubber for future tests

Meat

Liver

Blubber

WHAT WE FOUND

- ALL SEAL LOOKED HEALTHY. Our research identified some germs that at one time infected the seals but there was no evidence that the seals were still sick from them: PEOPLE EATING SEAL ARE NOT AT RISK
- No Trichinella was found in any of the meat samples
- 10 to 35% of the seals had been in contact with but recovered from the following germs:

Brucella

Erysipelas

Leptospira

Toxoplasma

- 25 to 40% of pup seals had potent salmonella and E.coli germs in their poop

MERCURY LEVELS IN SEAL:

Pup meat

Adult meat

Pup liver

Adult liver

Safe to eat meat

Be careful with liver

Health Canada Guideline

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

Mobilisation des connaissances et des observations des Inuits sur l'utilisation du territoire pour évaluer les tendances et les processus dans l'écosystème qui ont une incidence sur les contaminants

Project leaders/Chefs de projet

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Project location/Emplacement du projet

Sanikiluaq, NU

Abstract

Traditional wildlife sampling by communities has involved completing basic sampling information sheets with limited possibilities for utilizing Inuit observations that could provide important context for interpreting contaminants data. 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 order to provide context on animal ecology, diet, body condition and associated environmental conditions that could benefit contaminants research. The current phase of the project involved a review and evaluation of the results and approach from the proof-of-concept study conducted in 2017-2018, towards future implementation of a three year pilot study that will engage Inuit in systematically documenting their knowledge and observations around harvesting and sampling (e.g. diet, body condition, habitat), and incorporating these results into contaminants analysis.

Based on the feedback obtained in 2017-2018, the tools and features on the SIKU mobile app were updated and improved to better incorporate different kinds of Inuit knowledge and improve ease of use and reliability. A workshop held in September 2018 provided more detailed feedback on how privacy, intellectual property and data stewardship features of the SIKU app and platform could be designed to provide Inuit users with flexibility to accommodate informed choices as desired for different situations. These features and approaches have since been incorporated into a version 2.0 of the mobile app and online platform which has been positively received. Further approaches to synthesizing data and workflows for incorporating results into contaminants analysis as part of a three-year pilot study were designed with project team members collaborating via core NCP programs for ringed seal and polar bear. Community and project partner reviews and evaluations have indicated that the proof-of-concept phase was

Résumé

L'échantillonnage de la faune traditionnelle par les collectivités concernées a consisté à remplir des fiches d'information de base sur l'échantillonnage et à utiliser de façon limitée les observations des Inuits qui pourraient fournir un contexte important pour interpréter des données sur les contaminants. La collectivité de Sanikiluaq s'est efforcée de trouver de nouvelles méthodes pour consigner de façon systématique les connaissances inuites et les observations sur les tendances et les processus de l'écosystème. Ce projet a constitué une validation de principe importante pour l'utilisation de la nouvelle plateforme et de l'application mobile de SIKU. org pour consigner les témoignages des Inuits sur la chasse au phoque et à l'ours polaire, afin de fournir un contexte sur l'écologie animale, le régime alimentaire, l'état physique des animaux et les conditions environnementales connexes qui pourraient être utiles aux recherches sur les contaminants. La phase actuelle du projet comprend un examen et une évaluation des résultats et de l'approche de l'étude de validation de principe menée en 2017-2018, en vue de la mise en œuvre future d'une étude pilote de trois ans qui mobilisera les Inuits pour documenter systématiquement leurs connaissances et leurs observations concernant la chasse et l'échantillonnage (p. ex., le régime alimentaire, l'état physique des animaux, l'habitat), et intégrer ces résultats dans l'analyse des contaminants.

À la lumière des commentaires formulés en 2017-2018, les fonctionnalités et les outils de l'application mobile SIKU ont été mis à jour et améliorés pour mieux intégrer les différents types de connaissances inuites et améliorer leur facilité d'utilisation et leur fiabilité. Un atelier organisé en septembre 2018 a permis d'obtenir des commentaires plus détaillés sur la manière dont les fonctions de protection de la vie privée, de la propriété intellectuelle et d'intendance des données de l'application et de la plateforme SIKU devraient être conçues pour offrir aux utilisateurs inuits la flexibilité nécessaire pour faire des choix éclairés selon les différentes situations. Ces caractéristiques et approches ont depuis été intégrées dans une version 2.0

successful and is worthwhile developing into a three year pilot study, with specific outcomes to improve analysis and interpretation of ringed seal and polar bear contaminants analyses (i.e., NCP core monitoring projects *Temporal and Spatial Trends of Legacy and Emerging Organic and Metal/Elemental Contaminants in Canadian Polar Bears* - M-05 (R. Letcher, polar bears) and *Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic* - M-04 (M. Houde and D. Muir, ringed seals), and more generally establish a better role and approach for meaningfully incorporating Inuit knowledge and observations into contaminants research programs.

de l'application mobile et de la plateforme en ligne qui a été accueillie favorablement. D'autres approches de synthèse des données et des flux de travail pour l'intégration des résultats dans l'analyse des contaminants dans le cadre d'une étude pilote de trois ans ont été conçues avec la collaboration des membres de l'équipe du projet dans le cadre des programmes de base du PLCN pour le phoque annelé et l'ours polaire. Les examens et les évaluations par les collectivités et des partenaires du projet ont indiqué que la phase de validation du principe a été couronnée de succès et qu'il vaut la peine de la développer en une étude pilote de trois ans, avec des résultats précis pour améliorer l'analyse et l'interprétation des analyses des contaminants chez le phoque annelé et l'ours polaire (c'est-à-dire les projets de surveillance de base du PLCN *Tendances temporelles et spatiales des contaminants organiques et métalliques/élémentaires classiques et émergents chez l'ours blanc du Canada* – M-05 (R. Letcher, ours polaires) et *Tendances temporelles des polluants organiques persistants et des métaux chez le phoque annelé de l'Arctique canadien* – M-04 (M. Houde et D. Muir, phoques annelés), et plus généralement mieux définir le rôle et l'approche afin d'intégrer de manière significative les connaissances et les observations des Inuits dans les programmes de recherche sur les contaminants.

Key messages

- The community review and evaluation workshop in Sanikiluaq indicated strong ongoing support for the project and provided guidance on updates to the mobile app and features and next steps for the project moving forward.
- Mobile app and online platform features were developed on SIKU to support community priorities for flexibility in data stewardship, privacy, and intellectual property as well as improvements for usability on the land based on 2017-2018 testing.
- Project team members and collaborating projects have refined the approach for implementing community observations into

Messages clés

- L'atelier sur l'examen et l'évaluation par la collectivité de Sanikiluaq a indiqué un fort soutien continu pour le projet et a permis de formuler des conseils sur les mises à jour de l'application mobile et des fonctionnalités et sur les prochaines étapes d'avancement du projet.
- L'application mobile et les fonctionnalités de la plateforme en ligne ont été développées sur SIKU pour soutenir les priorités de la collectivité en matière de flexibilité dans la gestion des données, de confidentialité et de propriété intellectuelle, ainsi qu'une meilleure convivialité sur le terrain d'après les tests de 2017-2018.

analysis and interpretation for ringed seal and polar bear core monitoring programs over the next three years.

- The next phase of the project involves a 3 year pilot program that will provide observations from Inuit hunters in a large enough sample size to be a useful for incorporation into contaminants analysis by other partnering projects in year 1, as well as to evaluate seasonal and inter-annual environmental trends in years 2 and 3.

- Les membres de l'équipe du projet et les projets collaborateurs ont affiné l'approche de mise en œuvre des observations de la collectivité dans les volets analyse et interprétation pour les programmes de surveillance de base des phoques annelés et des ours polaires au cours des trois prochaines années.

- La prochaine phase du projet comprend un programme pilote de trois ans qui fournira les observations des chasseurs inuits dans un échantillon suffisamment grand pour être utile à l'analyse des contaminants par d'autres projets partenaires au cours de la première année, ainsi que pour évaluer les tendances environnementales saisonnières et interannuelles au cours des années 2 et 3.

Objectives

This project aims to:

- work with Inuit hunters, Elders and youth in Sanikiluaq to develop tools and features on the SIKU mobile app and online platform that improve the systematic collection of Inuit knowledge and observations around harvesting of seals and polar bears towards contributing Inuit knowledge that can be directly incorporated into the analysis and interpretation of contaminants research. For example, observations of diet, body condition and habitat could contribute to understanding contaminants pathways in the marine food web, or identify potential mechanisms for observations typically considered "outliers";

- build on capacity and ongoing community-driven research programs, train and employ 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;

- build linkages with the Arctic Eider Society's existing community-driven research programs and SIKU.org 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

- review and evaluate the outcomes of the proof-of-concept activities for the above objectives from year 1, and plan next steps for providing synthesis of Inuit knowledge indicators to contaminants researchers and develop three year pilot program towards a proper 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. In order to make more effective mechanistic connections between emissions and the accumulation, fate and trends of contaminant levels in tissues of high trophic level marine species such as ringed seals and polar bears, further research on factors affecting trends requires the knowledge of ecosystem changes collected over the same time periods as contaminants research and monitoring. More detailed knowledge of, for example, ringed seal and polar bear dietary profiles will define with higher resolution, the source of exposure of priority POP and metal (e.g. mercury) contaminants, and how such contaminants are influenced by factors such as changing body condition and sea ice conditions. From these perspectives, Inuit observations will directly impact the 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 will use new tools, developed with and for Inuit through the SIKU.org platform and mobile app, to systematically document local observations and indicators. This will make results accessible to community members and researchers in near-real-time for ongoing feedback and contribute to the assessment of changes over time in ecosystem components including those related to key NCP monitoring species. This will provide a direct pathway for Inuit observations of diet and body condition to be used in the analysis and interpretation of results for core seal and polar bear NCP monitoring programs.

Arctic warming and the significance of melting ice is that it affects physical and biogeochemical pathways of POPs and other contaminants. This can result in an alteration of for example, ringed seal and polar bear behaviour, habitat use and dietary profile including that of the underling aquatic food web. More recent research has shown that Arctic warming and changes in sea ice means a change in the exposure of Arctic biota, particularly in polar bear (i.e. Canadian Hudson Bay and East Greenland subpopulations; AMAP 2011, 2016, 2017, 2018), to POPs and Hg . Adipose tissue sampled from the western Hudson Bay subpopulation of polar bears at intervals from 1991 to 2007 has shown that the differences in timing of the annual sea ice breakup explained a significant proportion of the diet variation among years (i.e. via stable carbon and nitrogen isotope ratios and fatty acid signatures; McKinney et al. 2009, 2013; Letcher et al. 2018). This diet change was consistent with an increase in the consumed proportions of open water-associated seal species compared to ice-associated seal species in years of earlier sea ice breakup. The study demonstrated that climate change is a modulating influence on POP contaminants in this polar bear subpopulation and may pose an additional and previously unidentified threat to northern ecosystems through altered exposures to contaminants (McKinney et al., 2009). McKinney et al. (2013) also showed, using changes in stable carbon and nitrogen isotope ratios and fatty acid signatures, that for East Greenland polar bear over the period of 1984 to 2011 ringed seal consumption declined by 14%/decade over 28 years, and hooded seal consumption increased by 9.5%/decade over the same period. Routti et al. (2012) also demonstrated the influence of carbon and lipid sources on regional differences in liver trace elements (As, Cd, Cu, total Hg, Mn, Pb, Rb, Se, and Zn) concentrations measured in polar bears from ten Alaskan, Canadian Arctic (including Hudson Bay), and East Greenland subpopulations. A negative relationship between total Hg and carbon isotope ratios suggested that polar bears feeding in areas with higher riverine inputs of terrestrial carbon accumulate more Hg than bears feeding in areas with lower freshwater input. Mercury concentrations were also positively related to the fatty acids that are biosynthesized in large amounts in Calanus copepods. This result raised the hypothesis that *Calanus glacialis*, a microscopic Arctic aquatic crustacean, are an important link in the uptake of Hg in the marine food web and ultimately in polar bears.

Diet and local environmental conditions can be important contributors to accumulation and movement of contaminants, including trace metals (e.g. mercury; Hg) and legacy and emerging persistent organic pollutants (POPs); tracking these contaminants is a priority of NCP including in polar bears and ringed seals which are core monitoring wildlife species (AMAP, 2011, 2016, 2017, 2018; Houde et al. 2017; Letcher et al. 2010, 2017, 2018). Stomach contents can provide additional context about how trace metals and organic compounds bioaccumulate in food webs and can help contribute to risk assessment of traditional foods. Climate change is shifting animal ranges and phenology, which could have impacts on Arctic food webs and environmental 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 expands on ongoing projects, training, and tools developed for monitoring oceanographic conditions, sea ice habitats, wildlife, and contaminants in the marine food web. The approach of this project allows Sanikiluaq to simultaneously address 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 us to address them simultaneously and collaboratively, while developing capacity for similar synergies that are possible through systematically documenting and mobilizing Inuit knowledge for environmental stewardship.

Activities in 2018-2019

Community review and engagement

Review and evaluation workshop in Sanikiluaq

A workshop was held in Sanikiluaq on Sept 11, 2018 to do an additional review on the project results and approach from 2017-2018 as a focus of activities for this year at the request of NCP. The workshop involved the municipal council, hunters and trappers association and youth and hunters involved in the project. The community remains highly supportive of this project and implementing the next phase of a 3-year pilot project. The workshops focused on reviewing and evaluating the results of 2017-2018 and more recent updates to the SIKU app and platform that incorporated feedback from winter 2018. The community was encouraged to see how their feedback had been meaningfully incorporated into version 2.0 and were keen to begin using this for land use activities in future years. Additionally, the meeting spent considerable time on a detailed discussion of the Terms of Reference and Privacy Policy for the SIKU Platform more generally, including data stewardship policies that meet the parallel needs of individuals, communities, and regional organizations. There was consensus that the community supports the current planned approach which has incorporated their ongoing feedback and was further supportive of Arctic Eider Society (AES) continuing to bring this approach to Inuit organizations for further feedback and consultation. The approach is flexible enough to allow individuals to decide how and what details they share publicly on SIKU, to e.g. hide or mask locations if shared location may be sensitive, and to determine if and how they share and steward their data with regional organizations, projects, etc. Further consultations with Inuit indicated support of this approach and these data stewardship features from many other organizations; these aspects have now been directly incorporated into the SIKU platform with ongoing opportunities to improve and add additional features. This project has maintained support of Inuit self-determination in research and data stewardship.

Results and outputs/deliverables

In addition to review and evaluation of the project by the community, the project team worked with partner projects to better define how results from Inuit knowledge and observations in the app would be incorporated into NCP core contaminants research programs for ringed seals and polar bears, as well as how the approach could improve the incorporation of Inuit knowledge more generally into contaminants research. This formed the basis for a new proposal submitted to NCP as a key outcome of the review/evaluation towards moving the project into the next phase recommended by Sanikiluaq and the project team, i.e. a three year pilot program that links ringed seal and polar bear harvesting observations by Inuit directly into contaminants analyses for these species.

Discussion and conclusions

This project has developed an innovative approach to documenting Inuit knowledge and observations of ecosystem trends and processes using the SIKU.org mobile app and online platform. Using this approach this project has established a proof-of-concept for the tools and data collection in 2017-2018 and a review and evaluation that has now formed a basis for implementing a three-year pilot study. This pilot study would systematically collect Inuit observations specific to ringed seal and polar bear harvesting and sampling and incorporate these observations into contaminants analyses for core NCP monitoring programs. While simple sample collection sheets had served their purpose for many years, it is clear that this is no longer adequate means for documenting and considering the extensive knowledge and observations Inuit have during land use activities and sampling, that can contribute to better understanding the factors that affect contaminants levels in the ecosystem. As such, this project will not only improve the analysis and interpretation of contaminants for ringed seals and polar bear, but will further provide a basis for, and suite of, proven free tools and services that can more broadly improve how Inuit knowledge is collected and considered in contaminants research.

Expected project completion date

This preliminary one-year proof-of-concept project was successfully completed in March 2018; on request from NCP, 2018-2019 was focused on review, evaluation, and next steps. This phase has now been completed and there is now a clear path forward for a three year pilot program that directly links ongoing Inuit knowledge and observations with core NCP programs for ringed seals and polar bear and evaluates how this approach and Inuit knowledge it gathers can be more generally incorporated into contaminants research across the Arctic.

Project websites

www.arcticeider.com
www.siku.org
www.facebook.com/arcticeider/
www.twitter.com/arcticeider/

Acknowledgments

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. The research team would also like to acknowledge the financial support of the NCP. 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, Polar Knowledge Canada, Environment and Climate Change Canada, and the University of Manitoba.

References

AMAP, 2018. Chemicals of Emerging Arctic Concern. AMAP, Oslo, Norway.

AMAP, 2017. Chemicals of Emerging Arctic Concern. Summary for Policy Makers. Oslo, Norway.

AMAP, 2016. Temporal Trends in Persistent Organic Pollutants in the Arctic. AMAP, Oslo, Norway.

AMAP, 2011. Mercury in the Arctic. AMAP, Oslo, Norway. xiv + 193 pp Aporta, C. Taylor, D.R.F., Laidler, G.J.(eds.). 2011. Special issue of The Canadian Geographer on "Geographies of Inuit Sea Ice Use." 55,1.

Chételat, John, J. Heath, L. Arragutainaq, A. Kasudluak, G. Lameboy, R. Mickpegak and A. Nalukturuk. (2016). An east Hudson Bay Network research initiative on regional metal accumulation in the marine food web: preliminary results. Poster presentation, ArcticNet, Winnipeg, MB.

Chételat,J., J.P. Heath, Z.A. Kuzyk, L. Arragutainaq, R. Mickpegak, P. Kasudluak, A. Kasudluak, G. Lameboy 2015. A East Hudson Bay Network research initiative on regional metal accumulation in the marine food web. Poster. Northern Contaminants Program Annual Results Workshop, Vancouver, BC.

Eastwood, A., Z Kuzyk, R. Macdonald, J. Heath, J. Ehn and D. Barber. (2016). Oceanographic conditions under landfast sea ice surrounding the Belcher Islands, Southeast Hudson Bay. ArcticNet, Winnipeg, MB.

Heath, J.P. 2018. Community-Driven Research, Education and Stewardship in Hudson Bay. Special presentation to the Canadian Senate Committee on the Arctic. Ottawa, ON.

Heath, J.P. 2016. Tools for environmental stewardship with Inuit and Cree. Walrus Talks: Arctic. Canadian Museum of Nature, Ottawa.

Heath, J.P. and Arragutainaq, L. 2018. Tools and approaches for Inuit self-determination in research and sustainable development. Science, Technology and Innovation Forum, United Nations, NY.

Heath, J.P and Arragutainaq, L. 2018. Inuit-driven social media and research tools on the SIKU.org platform: developing an approach to features, intellectual property and data stewardship that benefits long-term Inuit self-determination. ArcticNet, Ottawa, ON.

Heath, J.P, Arragutainaq, L., Kownak, K. Ljubicic, G. 2017. SIKU: The Inuit Knowledge Wiki and Social Mapping Platform. Plenary talk, Arctic Change, QC.

Heath, J. and Arragutainaq, L. 2016. The Hudson Bay Consortium: environmental stewardship for the greater Hudson Bay/ James Bay region. Oral presentation, ArcticNet, Winnipeg, MB.

Heath, J., Arragutainaq, L. and J. Kudluarok 2016. The Hudson Bay Network: Community-driven research bridging jurisdictions and connected by an Interactive Knowledge Mapping Platform (IK- MAP) and social media for the north. Oral presentation, Inuit Studies Conference, St. John's, NL.

Heath, J.P and Kownak, K. 2017. SIKU: social media and mapping tools for Inuit self-determination. Google Geo for Good Summit, Mountain View CA.

Heath, J.P and Kownak, K. 2017. Enhancing resilience in the face of global change: mobilizing local and indigenous knowledge. UNESCO Workshop, Paris.

Heath, J., Ljubicic, G., and Arragutainaq, L. 2015. A Social Media Network and Interactive Knowledge- Mapping Platform for the North: Developing the tools needed to meaningfully engage communities in research and environmental stewardship. ArcticNet Annual Scientific Meeting, Vancouver. .

Houde, M., Muir, D.C.G., et al. 2017. Temporal/ spatial trends of contaminants in Canadian ringed seals: Part III. In: Synopsis of research conducted under the 2016/2017, NCP. Ottawa: INAC. Ottawa, Canada

Inuit Tapiriit Kanatami 2018. National Inuit Strategy on Research. Ottawa, ON.

ITK (Inuit Tapiriit Kanatami), 2016. Inuit Priorities for Canada's Climate Strategy: A Canadian Inuit vision for our common future in our homelands. 64 pp.

Letcher, R.J., Morris, A.D., Dyck, M., Sverko, E., Reiner, E., Blair, D.A.D., Chu, S.G., Shen, L. 2018. Legacy and new halogenated persistent organic pollutants in polar bears from a contamination hotspot in the Arctic, Hudson Bay Canada. Sci. Total Environ. 610-611:121-136.

Letcher, R.J., Dyck, M., et al. 2017. Temporal/ spatial trends of contaminants in Canadian polar bears: Part III. In: Synopsis of research conducted under the 2016/2017, NCP. Ottawa: INAC. Ottawa, Canada.

Letcher,, R.J., J.-O. Bustnes, R. Dietz, B.M. Jenssen, E.H. Jørgensen, C. Sonne, J. Verreault, M. Vijayan, G.W. Gabrielsen. 2010. Exposure and Effects assessment of persistent organic pollutants in Arctic wildlife and fish. Sci. Total Environ. 408(15):2995-3043.

Ljubicic, G. 2016. Inuit-specific ethical research considerations. Invited panel presentation for the Carleton University Institute on Ethics of Research with Indigenous Peoples: Challenges, consideration, and problem solving panel. Carleton University. Ottawa, Ontario. June 9.

Ljubicic, G. 2015. Identifying and Incorporating Locally Meaningful Indicators into the Polar Prediction Project. Invited presentation and workshop participant for the World Weather Research Program (WWRP) Polar Prediction Project (PPP): Social and Economic Research and Applications (SERA) Meeting, sponsored by the World Meteorological Organization (WMO). Ottawa, Ontario. March 12.

McDonald, M.A., Arragutainaq, L. and Novalinga, Z., 1997. Voices from the Bay: Traditional ecological knowledge of Inuit and Cree in the Hudson Bay bioregion. Canadian Arctic Resources Committee. 97 pp.

McKinney, M.A., S.J. Iverson, A.T. Fisk, E.W. Born, C. Sonne, R.J. Letcher, A. Rosing-Asvid, R. Dietz. 2013. Long-term diet change in East Greenland polar bears assessed by quantitative fatty acid signature analysis. Global Change Biol. 19: 2360-2372.

McKinney, M.A., E. Peacock, R.J. Letcher. 2009. Sea ice-associated diet change increases the levels of chlorinated and brominated contaminants in polar bears. Environ. Sci. Technol. 3:4334 -4339.

NTK/Nunavuummi Tasiujarjuamiuguqatigiit Katutjiqatigiingit. 2008. A life vest for Hudson Bay's drifting environmental stewardship. Arctic 61, 35-47.

Wilson, K., Bell, T., Ljubicic, G., Braithwaite, L., Arreak, A., and Elverum, S. 2016. How can traditional ecological knowledge and western science be effectively mobilized to understand and respond to change in Arctic environments? Poster, Arctic Observing Summit, Fairbanks, Alaska. March 15-18.

Contaminants in traditional food in the White River First Nation (WRFN) territory

Contaminants présents dans les aliments traditionnels sur le territoire de la Première nation de White River (PNWR)

Project leader/Chef de projet

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Project team/Équipe de projet

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Project locations/Emplacements du projet

- Wellesley Lake, WRFN, YK
- Fish Hole Lake, WRFN, YK
- Unnamed Lake, WRFN, YK

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 those wild foods (Gamberg, 2000) and fish, relatively few samples, including no fish, have been taken from the White River traditional territory. Concern about contaminants in fish in their traditional territory prompted the White River First Nation to initiate this project to sample fish from three local lakes to determine if contaminants are a concern for fish populations or those that are using those populations as food. Fish sampling was planned for the spring of 2019 from Wellesley, Fish Hole and Unnamed Lake in the White River traditional territory. There is no road access to these lakes, so transportation to the sites must be by snow machine in the winter. Unfortunately, there was a sudden and unseasonably warm spell immediately preceding the sampling trip,

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 présents dans ces aliments prélevés dans la nature (Gamberg, 2000) et dans les poissons, relativement peu d'échantillons, dont aucun poisson, ont été prélevés sur le territoire traditionnel de White River. Les préoccupations concernant les contaminants présents dans les poissons sur son territoire traditionnel ont incité la Première nation de White River à lancer ce projet d'échantillonnage des poissons de trois lacs locaux afin de déterminer s'il y a lieu de s'inquiéter des contaminants pour les populations de poissons ou pour les personnes qui les consomment. L'échantillonnage des

so, although the attempt was made to reach the lakes, it was unsuccessful due to overflow of the river. The field team was forced to turn back due to the unsafe travel conditions. Fish sampling has been rescheduled for early in 2020, and the analyses will be completed in one year rather than the anticipated two years.

poissons était prévu pour le printemps 2019 dans les lacs Wellesley, Fish Hole et Unnamed (lac sans nom) sur le territoire traditionnel de White River. Il n'y a pas d'accès routier à ces lacs, le transport vers les sites doit donc se faire par motoneige en hiver. Malheureusement, une vague de chaleur soudaine et inhabituelle pour la saison a précédé immédiatement le voyage d'échantillonnage : on a tenté d'atteindre les lacs, mais on n'y est pas parvenu en raison du débordement de la rivière. L'équipe de terrain a été contrainte de faire demi-tour en raison des conditions de voyage dangereuses. L'échantillonnage des poissons a été reprogrammé pour le début de l'année 2020, et les analyses seront effectuées en une année au lieu des deux prévues.

Objectives

To determine contaminant levels in fish from the White River First Nation territory to:

- Provide information to citizens of the White River First Nation regarding contaminants in these traditional foods, so that:
- they may be better able to make informed choices about food consumption. This includes providing information for health assessments and/or advisories as required;
- wildlife managers can assess possible health effects of contaminants on fish populations; and
- we can further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

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 fish, relatively few samples have been taken from the White River traditional territory and those include no fish. Concern about contaminants in fish in their traditional territory prompted the White River First Nation to initiate this project to sample fish from three local lakes to determine if contaminants are a concern for fish populations or those that are using those populations as food. Data from this project will be compared with data collected from fish from other areas of the Yukon (particularly Kusawa and Lake Laberge under the NCP-funded 'Contaminants in Yukon Lake Trout' project).

Activities in 2018-2019

Fish sampling was planned for the spring of 2019 from Wellesley, Fish Hole and Unnamed Lake in the White River traditional territory. There is no road access to these lakes, so transportation to the sites must be by snow machine in the winter. Unfortunately, there was a sudden and unseasonably warm spell immediately preceding the sampling trip, so, although the attempt was made to reach the lakes, it was unsuccessful due to overflow on the river. The field team was forced to turn back due to the unsafe travel conditions. Fish sampling has been rescheduled for early in 2020, and the analyses will be completed in one year rather than the anticipated two years.

Plans for 2019-2020

Fish and water chemistry data will be collected from the three lakes. Swanson and/or Gamberg will accompany the fishing party to collect fish, take samples, exchange information regarding contaminants in the environment in general and fish in particular and indigenous knowledge regarding fish and the environment. They will also train First Nations (FN) citizens in the correct procedures for collecting and storing samples for contaminant analysis and fish otoliths for aging the fish. Fish will be analyzed for toxic metals and essential elements and will be aged using the otoliths. Data will be analyzed and summarized in a synopsis report as well as a plain language summary and presented to the citizens of the White River First Nation at a public meeting.

Capacity building

Due to the unsuccessful fishing trip, the capacity building portion of this project has yet to begin. However, during the fishing trip planned for early in 2020, sample collections will be done by White River First Nation citizens, under the guidance of experienced NCP researchers (Mary Gamberg and/or Heidi Swanson). The citizens will be trained in specific collection and sample storage techniques, building capacity within the community for further research of this type.

Communications

The communications portion of this project will commence once fish have been sampled and analyzed.

Indigenous/local Knowledge

This program relies on the Indigenous Knowledge of the White River First Nation when collecting fish for sampling. In all cases, local fishers use Indigenous Knowledge when fishing, ultimately submitting samples and providing food for their families and communities.

Results and conclusions

There are no results from this project to report at this time.

Expected project completion date

This is a 2-year project and is expected to be completed by April 30, 2020.

Acknowledgments

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References

Gamberg M. Contaminants in Yukon Country Foods. Unpublished report prepared for the Department of Indian and Northern Affairs, Whitehorse, Yukon 2000. 95 pp.

Taku River Tlinget First Nation Traditional Foods Contaminant Monitoring Program

Programme de surveillance des contaminants dans les aliments traditionnels de la Première nation Taku River Tlinget

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- **Project location/Emplacement du projet**
  Taku River Tlinget First Nation Territory, Canada

Abstract

Traditional foods are an important source of nutrition and have spiritual, social, and cultural significance for the Taku River Tlingit First Nation (TRTFN). This project was planned to determine contaminant levels in moose, and two commonly harvested fish species within TRTFN Traditional Territory. The data collected will be used to determine whether these species remain safe food choices and to provide baseline data to see if contaminant levels are changing over time. TRTFN Land Guardians worked with hunters to collect samples from 10 moose in the fall of 2018 and will collect samples from grayling and lake trout from the TRTFN Traditional Territory during the summer of 2019. Moose samples are currently being analyzed for a suite of 38 elements, including cadmium and mercury, and a suite of emerging contaminants. Two workshops with the TRTFN Land Guardians started the process of building capacity with

Résumé

Les aliments traditionnels sont une source importante de nutrition et ont une importance spirituelle, sociale et culturelle pour la Première Nation des Tlingits de Taku River (PNTTR). Ce projet a été établi pour déterminer les concentrations de contaminants chez l'orignal et deux espèces de poissons couramment pêchées sur le territoire traditionnel de la PNTTR. Les données recueillies serviront à déterminer si ces espèces restent des choix alimentaires sûrs et à fournir des données de référence pour déterminer si les concentrations de contaminants évoluent dans le temps. Les gardiens des terres de la PNTTR ont travaillé avec les chasseurs pour prélever des échantillons de 10 orignaux à l'automne 2018 et ils prélèveront des échantillons d'ombres communs et de touladis sur le territoire traditionnel de la PNTTR au cours de l'été 2019. Les échantillons d'orignaux

respect to contaminants knowledge and skills for processing samples for contaminant analysis. We anticipate a continuation of this capacity building process with a fish processing workshop in early summer of 2019. After the workshop we will proceed with fish collections and processing. We look forward to communicating the results of the moose tissue analyses (and eventually the fish analyses) with community members and using those results for planning efficient and relevant environmental monitoring in our traditional territory.

sont actuellement analysés pour une série de 38 éléments, dont le cadmium et le mercure, et une série de contaminants émergents. Deux ateliers organisés avec les gardiens des terres du PNTTR ont permis d'entamer le processus de renforcement des capacités en matière de connaissances et de compétences relatives au traitement des échantillons pour l'analyse des contaminants. Nous prévoyons poursuivre ce processus de renforcement des capacités avec la tenue d'un atelier sur la transformation du poisson au début de l'été 2019. Après l'atelier, nous procéderons à la collecte et au traitement des poissons. Nous sommes impatients de communiquer les résultats des analyses des tissus d'orignaux (et éventuellement des analyses de poissons) aux membres de la collectivité et d'utiliser ces résultats pour planifier une surveillance environnementale efficace et pertinente sur notre territoire traditionnel.

Key messages

- Samples were collected from 10 moose from the Atlin area in the fall of 2018.
- Moose tissue samples are currently being analyzed for a range of contaminants.
- Two contaminant workshops were held in Atlin in the fall of 2018, one on contaminants in the environment and one focusing on moose sample preparation.

Messages clés

- Des échantillons ont été prélevés sur 10 orignaux de la région d'Atlin à l'automne 2018.
- Les échantillons de tissus d'orignal sont actuellement analysés pour détecter toute une série de contaminants.
- Deux ateliers sur les contaminants ont été organisés à Atlin à l'automne 2018, l'un sur les contaminants dans l'environnement et l'autre sur la préparation des échantillons d'orignal.

Objectives

The goals of this project are to:

- measure contaminants in moose, grayling, and lake trout to determine the levels of contaminants so that community members can make informed choices about consuming those foods;
- provide training to the First Nation related to contaminant monitoring project design as well as collecting and processing sampling for contaminants analysis;
- develop baseline data to assist in determining the cumulative effects of climate change on contaminants in traditional foods of the Taku River Tlingit First Nation (TRTFN); and
- fill data gaps for contaminants in the Traditional Territory of the TRTFN.

Introduction

Traditional foods are an important source of nutrition and have spiritual, social, and cultural significance for the TRTFN. The NCP blueprint for community-based monitoring has identified the need to monitor contaminants in traditional foods that may pose a risk to human health, and for which recent contaminant information is not available. This project will focus only on species that are dietary staples for the Taku River Tlingit First Nation (TRTFN). To date, there has been no contaminants research within TRTFN traditional territory despite the area's ecological linked to Yukon, with Atlin Lake being the largest source of the Yukon River Watershed. However, there has been substantial research on contaminants within the Yukon portion of the watershed.

Heavy metals such as mercury, lead, and cadmium have been identified in the NCP blueprint for annual community-based monitoring. Past research by Gamberg (2005) found that some moose in Yukon had high renal cadmium levels. As a result, Yukon Health has recommended limiting consumption of Yukon moose kidneys and livers to one/ person/year (Gamberg, 2005). The Yukon Contaminants Committee has identified the need for research on mercury concentrations in predatory fish species (e.g. lake trout) from lakes and rivers throughout the Territory where these fish are commonly harvested. Mercury in northern fish can pose a risk to human health (Lockhart et al., 2005). Mercury levels in lake trout have been monitored for over twenty years in Yukon (Kusawa Lake and Lake Laberge) and results from this study will complement this already existing data set for lake trout in the North.

Activities in 2018-2019

As part of this project, a wildlife contaminant training session was given to the Land Guardians of the TRTFN on August 13-14, 2018 in Atlin, BC by Mary Gamberg. The training session provided background information on contaminants, what they are, where they come from, how they move through the environment, and how they accumulate in wildlife. During the workshop we developed communication skills by exploring ways of using this knowledge when accompanying moose hunters to collect samples for contaminant analysis. Posters were created and distributed to solicit samples from moose hunters in the Atlin area for this project and the Land Guardians spoke to community members personally about the project to increase awareness. After the workshop, sample kits were distributed, and samples were received from 10 moose from the area.

A second training session for the TRTFN Land Guardians was held with Mary Gamberg on January 18, 2019. During this workshop, the Land Guardians were shown laboratory procedures for tissue processing, including 'clean' laboratory practices, preparing tissues for contaminant analysis, and aging moose teeth.

All moose samples were processed during this workshop and all moose teeth were aged. Moose kidney, liver, and muscle samples were sent to the National Laboratory for Environmental Testing (NLET), where they are currently being analyzed for a suite of 38 elements (all tissues), polybrominated diphenyl ethers, and per- and polyfluorinated alkyl substances (liver).

Plans for 2019-2020

Two freshwater fish species (lake trout, grayling) will be monitored from four lakes in the Atlin area (Atlin, MacDonald, Tagish, and Surprise Lake; Figure 1) in the summer of 2019. TRTFN Land Guardians will work over the summer to collect all the fish samples using gill nets and fishing rods. Grayling will be taken from Atlin, MacDonald Lake, and Surprise Lake. Lake trout will be taken from Atlin Lake and the upper portion of Tagish Lake. A total of 30 fish samples (6 from each site) will be collected. Mary Gamberg will travel to Atlin in June of 2019 to train TRTFN Land Guardians and other interested community members in contaminant sample extraction protocols for fish. Morphometrics will be taken for each fish (length, weight, gender) and otoliths will be extracted for aging by North/South Consulting, Winnipeg. Muscle samples will be sent to NLET for testing for a suite of 38 elements (including mercury) and stable isotopes.

Figure 1. Monitoring lakes near Atlin BC.
a) Atlin Lake, b) MacDonald Lake, c) Surprise Lake, d) Tagish Lake.

Capacity building

The Land Guardian program was established to reassert TRTFN jurisdiction and stewardship within our Traditional Territory while monitoring land activities to inform decision-making. Since it was created in 2013, the TRTFN Land Guardian program has successfully delivered two Aboriginal Fund of Species at Risk (AFSAR) projects, and two British Columbia Capacity Initiative projects (another is on-going). The TRTFN also works cooperatively with BC Forests Lands and Natural Resources, BC Conservation Officer Service, Environment Yukon and other agencies and First Nations, including Tahltan, Kaska, Teslin Tlingit Council, and Carcross/Tagish First Nations. TRTFN Land Guardians conduct regular monitoring patrols to observe, record and report information on land and wildlife, as well as support the implementation of the Wóoshtin wudidaa Atlin Taku Land Use Plan. Land Guardians monitor changes in the landscape and wildlife and act as a liaison with other governments, TRTFN citizens, and the general public. The Land Guardian program plays a key role in helping to determine the effects of climate-induced impacts in the Traditional Territory and to disseminate information to TRTFN citizens about climate change, its impacts and possible strategies for adaptation. As part of this project, the Land Guardians spent time on the land completing outreach activities with hunters and educating them about the project. Two contaminant workshops increased the capacity of the Land Guardians by increasing their knowledge about contaminants in the environment, with a focus on contaminants in moose. The workshops also developed their skills for tissue processing for contaminant analysis and moose teeth aging.

Communications

This synopsis report will be shared with the community, the Takhu Atlen Conservancy and the Yukon Contaminants Committee. The plain language summary will be shared on the Takhu Atlen Conservancy Facebook page and website. More targeted communication will happen when we have results from the laboratory analyses.

Traditional/local Knowledge

This project relies on the traditional knowledge of Taku River Tlingit Land Guardians who accompanied moose hunters on their hunts and will be collecting samples of the freshwater fish for analysis.

Results

About 30 sample kits were distributed to local hunters during the 2018 hunting season. We received samples from a total of 10 moose, most of which included all requested tissues (kidney, liver, muscle and jaw), but some lacked collection information such as gender. Of the 10 moose, 5 were bulls and 5 were unknown gender. Teeth were included for 8 of the moose, and the ages ranged from 2-8, averaging 4 years old.

Conclusions

The moose collections were successful in the fall of 2018, reaching the target number of 10 individuals. Two workshops with the TRTFN Land Guardians started the process of building capacity with respect the knowledge and skills required to process samples for contaminant analysis. We anticipate a continuation of this capacity building with a fish processing workshop in the early summer of 2019 and subsequent fish collections and processing. We look forward to communicating the results of the moose tissue analyses (and eventually the fish analyses) with community members and using those results for planning efficient and relevant ongoing environmental monitoring in our Traditional Territory.

Expected project completion date

This is a 3-year project and is expected to be completed by April 30, 2021.

References

Gamberg M, Palmer M, Roach P. Temporal and geographic trends in element concentrations in moose from Yukon, Canada. Sci Total Environ 2005: 351/352: 530-538.

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

Community monitoring of plastic pollution in wild food and environments in Nunatsiavut

Surveillance communautaire de la pollution par les plastiques dans les milieux et les aliments prélevés dans la nature au Nunatsiavut

Project leaders/Chefs de projet

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Project location/Emplacement du projet

Nain, Nunatsiavut

Abstract

Marine plastics act as sponges for contaminants such as methylmercury, polychlorinated biphenyls (PCBs), and other persistent organic pollutants. When marine plastic is ingested, these chemicals collect in an animal's tissues (bioaccumulation) and build up in the food chain; contaminant levels are much higher in animals that eat other animals (biomagnification). As a result, contaminant levels can be high in some wild food species which can be concerning for the people of Nunatsiavut who depend on wild food for its nutritional and cultural significance. To date, we have found plastics in water; on shorelines; and ingested by Arctic char in Nain, Nunatsiavut; though precise amounts are still to be determined. Early sampling has indicated where future sampling should take place and the type of sample sizes

Résumé

Les plastiques marins agissent comme des éponges en ce qui concerne les contaminants comme le méthylmercure, les biphényles polychlorés (BPC) et d'autres polluants organiques persistants. Lorsque le plastique marin est ingéré, ces substances chimiques s'accumulent dans les tissus de l'animal (bioaccumulation), puis dans la chaîne alimentaire; les concentrations de contamination sont beaucoup plus élevées chez les animaux qui mangent d'autres animaux (bioamplification). Par conséquent, les concentrations de contaminants peuvent être élevées dans certaines espèces d'aliments prélevés dans la nature, ce qui peut être préoccupant pour les habitants du Nunatsiavut qui dépendent des aliments prélevés dans la nature pour leurs qualités nutritives et leur importance culturelle. À ce jour, nous

required to acquire robust baselines. This program is continuing to grow and sample more locations and areas of concern.

avons trouvé des plastiques dans l'eau, sur les côtes et dans l'estomac de l'omble chevalier à Nain, dans le Nunatsiavut, bien que les quantités précises restent à déterminer. Les premiers échantillonnages ont indiqué où les futurs échantillonnages devraient avoir lieu et la taille d'échantillon nécessaire pour obtenir des qqdonnées de référence solides. Ce programme continue d'évoluer et l'échantillonnage se poursuit dans les sites et les zones préoccupantes.

Key messages

- Arctic char has been found to ingest plastics in the Nain region. We are working to obtain a sound sample size to determine a valid baseline, and have decided to sample char at multiple points in the season.
- Plastics have been found in the surface waters around Nain. These are almost exclusively concentrated around the wharf, an inhabited area. These findings have resulted in a new sampling design to divide wharf-adjacent, nearshore, and offshore environments in sampling.
- Plastics have been found on shorelines around Nain. Approximately 80% of anthropogenic debris was plastic, in line with global averages. Despite Nain's plastic bag ban in 2009, a significant amount (higher than provincial average) of film plastic was recorded, mainly from sources other than carrier bags.
- Training workshops have been successful with a range of age groups and show a high interest and knowledge in the community.

Messages clés

- On a constaté que l'omble chevalier ingérait des plastiques dans la région de Nain. Nous nous efforçons d'obtenir une taille d'échantillon suffisante afin d'obtenir des données de référence valables, et avons décidé d'échantillonner l'omble à plusieurs moments de la saison.
- Des matières plastiques ont été trouvées dans les eaux de surface autour de Nain. Elles sont presque exclusivement concentrées autour du quai, une zone habitée. Ces découvertes ont donné lieu à un nouveau plan d'échantillonnage consistant à tenir compte des différents environnements : près du quai, sur le littoral et au large.
- Des matières plastiques ont été trouvées sur les côtes autour de Nain. Environ 80 % des débris anthropiques étaient du plastique, ce qui correspond aux moyennes mondiales. Malgré l'interdiction des sacs plastiques à Nain en 2009, une quantité importante (supérieure à la moyenne provinciale) de films plastiques a été relevée, provenant principalement de sources autres que les sacs de transport.
- Les ateliers de formation ont été couronnés de succès, suscité la participation de différentes tranches d'âge, stimulé un niveau élevé d'intérêt et apporté des connaissances au sein de la collectivité.

Objectives

In the short term this project aims to:

- establish the first all-Indigenous research team associated with Memorial University to conduct research on contaminants;
- identify key community members to train and collaborate with for monitoring marine plastics, particularly in food webs; and
- create plain-language literature review, with factsheet, on state of knowledge of microplastics research in the Circumpolar North, and contaminants of concern in Labrador.

In the long term this project aims to:

- establish a baseline for marine and freshwater microplastics in three key Nunatsiavut communities (Nain, Rigolet, and one other) in key species caught for food, on shorelines, and in water. This baseline will describe the presence, distribution, and types of marine plastics in each medium;
- situate findings among other plastic pollution research in the Circumpolar North;
- build capacity so that community members can use both citizen science/kitchen science and laboratory tools to monitor marine plastics in wild food and in environments for long-term, community-led monitoring;
- use best practices of reporting contaminants in country foods in partnership with Nunatsiavut Government (Usher, 1995; Furgal & Pijogge, 2003), discuss results and state of science with community members in public report back meetings, where we determine how to interpret results together;
- create a short, common-language, and translated report on findings and discussions for Inuit communities (distributed via Nunatsiavut Government) and general audiences (distributed online); and
- develop strong relationships in the community so that Dr. Liboiron remains available for troubleshooting, further student training, etc., beyond the project timeline.

Introduction

Rational for monitoring marine plastics and associated chemical loads

This project has two main goals: monitor contaminant levels and trends in the Arctic, including emerging contaminants of concern such as plastics; ensure training, knowledge, and long-term capacity for monitoring plastic pollution remains in Nunatsiavut communities.

Nunatsiavut is a subarctic region of the Canadian province of Newfoundland and Labrador and part of the homelands of Inuit people. Many people in the region rely on the aquatic environment for sustenance and livelihoods. Plastics are contaminants of concern both because they do not belong in ecosystems, and because they act as a vector for moving a range of industrial chemicals into food webs. While marine and freshwater plastics accumulate in water, sediment, and on shorelines, the area of primary concern for people in Nunatsiavut are plastics in food webs.

Samples from surface water and shorelines were obtained in this project. These water and shoreline studies will serve as comparisons to the types and amounts of plastics found ingested by wild food. The study will address the following questions:

- Which species are ingesting plastics? How much and what kind?

- Are shoreline and surface water plastics similar to or different than those found in animals?
- Do plastics in different locations carry similar or different chemical loads in terms of type and concentration?
- Can we make links between plastics on shorelines, surface water, and in animals caught for food in terms of origin or sources?

Community project

This project can stand on its own but is ideally the first stage in a long-term monitoring project whereby community participants continue to monitor plastics in their food web without using outside scientists. To increase community participation, this project emphasizes "kitchen" science methods and training. This expands not only the geographic reach of where marine plastic monitoring can occur, but who is able to participate in environmental research. Ensuring capacity sharing so people in Nunatsiavut can carry out their own investigations is part of enhancing scientific sovereignty, where Inuit govern their lands employing tools and knowledges that support their goals.

Activities in 2018-2019

In 2018-2019, preliminary results of plastic ingestion from 30 Arctic char from Nain found that the fish had ingested microplastics. We require a larger sample size to create a baseline ingestion measure for this species. We have been working to partner with other scientists and fishers in the area to obtain at least 100 Arctic char gastrointestinal tracts without extra harvesting required. Preliminary samples from the open ocean around Nain found few plastics, while sampling around the wharf in Nain revealed a higher density of plastics characteristic of paint chips, cigarette butts, sewage outflow, and other local sources (figure 1). These results have led us to adjust our sampling protocol to include offshore (figure 2), nearshore, and wharf-adjacent zones (figure 2). A comprehensive shoreline dataset shows that roughly 80% of shoreline debris in Nain is plastic, in line with global averages. The data also shows that film plastics from bags are a significant source of waste despite a carrier bag ban in Nain in 2009; most of these film plastics appear to have sources other than carrier bags. These findings are the first to characterize marine plastics in the area and point to where this coming year's scientific activities should focus. At this stage of the project, data is for local use to direct future research, though a report of the program overall (not specific findings) was shared at the Labrador Research Forum (May 2019). Moreover, a series of training sessions in Nain as well as at the Labrador Lands and Waters Summer camp, have been held with high attendance, and we are hoping to recruit more highs school youth into the project on a long-term basis. As of April 2019, we have hired a full-time summer Inuit researcher and part time during the academic year.

Community engagement

- Community meetings to determine areas of concern were held at the start of the project, and our preliminary char sampling, trawling, and shoreline studies have helped focus geographic and sample size scopes.
- In August 2018, Liboiron and Pijogge held the first public meeting and a series of workshops on how to identify marine plastics in animals caught for food using everyday materials (kitchen strainers, tubs, magnifying glasses). The workshops were well-attended by children, adults, and Elders.
- In the summer of 2018, project members gave demonstrations to the science youth camp in Nain.
- The program was presented in May 2019 at the Labrador Research Forum, where attendance is comprised of roughly 50% Labrador community members. It was well received, and the room was full.

Figure 1. Plastics recovered from surface water around the wharf in Nain, Nunatsiavut.

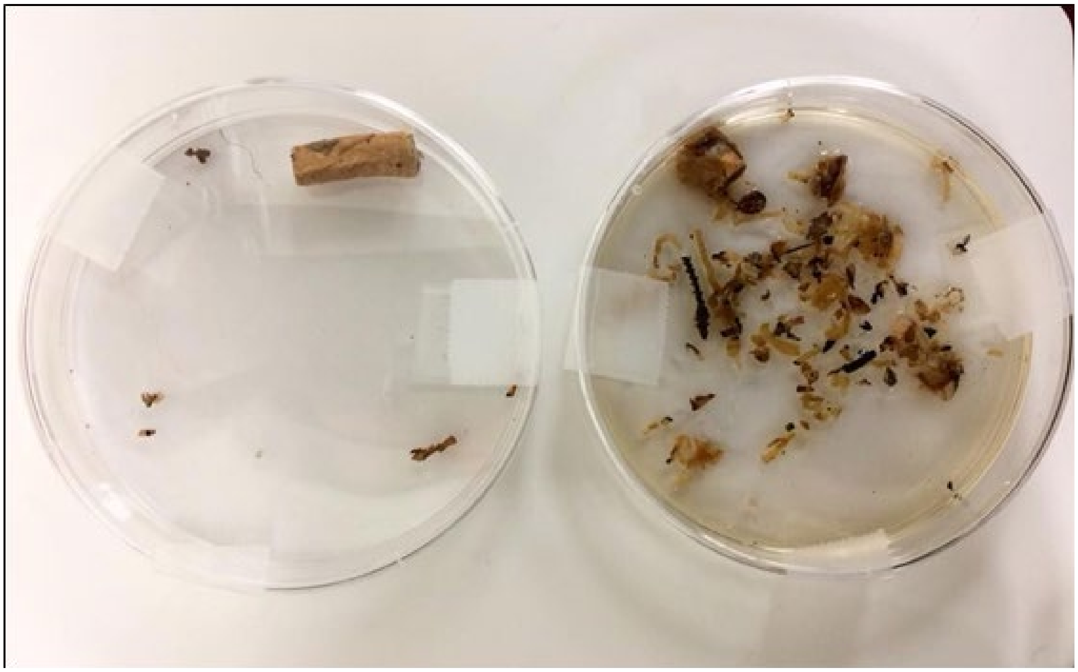

Figure 2. Surface trawling for marine plastics off the wharf in Nain, Nunatsiavut (left). Surface water trawl training workshop in St. John's, NL (right).

Capacity building and training

- In fall 2018 and 2019, Liz Pijogge joined Max Liboiron in St. John's for on-boat trawling and ingestion analysis training.
- Throughout 2018-2019, Liz Pijogge has been gathering gastrointestinal (GI) tracts from Arctic char caught by fishers for food.
- A young community member was trained and attended lab meetings with Max Liboiron for the fall of 2018 and winter 2019, but has decided to leave the project to pursue other opportunities. In spring 2019, we hired two more Inuit youth to work on the project and gather samples.
- In April 2019, both Max Liboiron and Liz Pijogge were recognized as experts in Arctic plastic research and were invited to participate in the The Arctic Monitoring Assessment Programme (AMAP)'s special group on plastics.
- In July 2019, an Inuk student on the project, Natasha Healey, conducted a training workshop on building and using citizen science trawls at the Labrador Lands and Waters Science camp (Figure 3).

Figure 3. Natasha Healey, Inuit team member, leads a workshop in Goose Bay for the Labrador Lands and Waters Science Camp (Left).

Communications and outreach

- While communication within the team is ongoing, results have not yet been shared with the wider Nain and Nunatsiavut communities because of the issue with sample sizes and locations—the data is not conclusive enough to be dependable at this stage.
- The overall program (rather than results) was shared at the Labrador Research Forum (May 2019), with both Max Liboiron and Liz Pijogge in attendance.

Indigenous Knowledge

This project relies heavily on Liz Pijogge's knowledge of the Nain area for sampling. She has devised a new char sampling design that targets char at different parts of their life cycle and feeding areas, and has been working with fishers to obtain fish GI tracts from catches to reduce the need for more kills. While we depend on this knowledge for study design and analysis, it is not captured in writing for public or academic circulation.

Discussion and conclusions

In a three-year project, early results can be used to temper and nuance the following years, and Inuit community members can move in *and out* of the project as needed. The largest adjustment we have had to make is how to maintain a community based, goal-driven project while personnel have changed, and weather has hampered several efforts to collect samples. In terms of sample collection, this has put us "behind," while in terms of training a wide range of community members it has put us "ahead" of anticipated timelines due to increased opportunities for training initiatives.

We have been surprised by the amount of plastics we have found so far, and the finding that most plastics appear to be local in origin. These findings appear to be counter to the discourse around plastics moving into the Arctic from the south, though plastic items still come to the North from the south. Because of early unanticipated findings, we are refining our sampling designs and protocols. We believe this makes the work more appropriate to locale. Early work on the circumpolar scientific literature review (one of our short term objectives) on plastics has shown that Canada is behind other nations in terms of monitoring plastic pollution in the North and it has become clear that these Northern Contaminants Program (NCP) studies will be significant in the global literature for characterizing northern plastics across media in a single region over several years.

Expected project completion date

April 2021.

Acknowledgements

We would like to express gratitude to the Northern Contaminants Program for funding and support of this three-year project. The Nunatsiavut government, particularly Liz Pijogge, Rodd Laing, and Paul McCarney have been important partners and collaborators. Memorial University has dedicated space and equipment, and Max Liboiron and Natasha Healey are affiliated with the university. In addition, a deep thank you to everyone who has participated in training workshops, introducing their knowledge and questions to the process in Nain, at the Labrador Research Foruåm, and in the Labrador Lands and Waters Science Camp.

Contaminant monitoring and community interests in the Lower Northwest Passage

Surveillance des contaminants et intérêt de la collectivité dans la partie inférieure du passage du Nord-Ouest

Project leaders/Chefs de projet

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Project locations/Emplacements du projet

- King William Island, NU
- Rasmussen Basin, NU
- Chantrey Inlet, NU

Abstract

Inuit households in Nunavut face moderate to severe food insecurity at a time when accelerated warming of the Arctic sea ice appears to have increased access to several fish species. In a project supported by Genome Canada, we are currently investigating stocks of char and whitefish populations with the goal to integrate traditional knowledge (TK) with leading-edge genomic science. However, community members, particularly in Gjoa Haven, have asked that these fish be monitored for metal, legacy organic pollutants and other contaminants to ensure that they are safe to eat. Thus, we are monitoring these contaminants, and evaluating beneficial vitamin D levels that are important for the building of strong bones. Fish are caught by Elders, active harvesters, and youth from the waters

Résumé

Les ménages inuits du Nunavut sont confrontés à une insécurité alimentaire modérée à grave, même si le réchauffement accéléré de la glace de mer dans l'Arctique semble avoir favorisé l'accès à plusieurs espèces de poisson. Dans un projet appuyé par Génome Canada, nous étudions les populations d'omble et de corégone dans le but d'intégrer les connaissances traditionnelles aux connaissances scientifiques de pointe en génomique. Cependant, les membres de la collectivité, en particulier à Gjoa Haven, ont demandé que ces poissons soient examinés en vue de détecter le métal, des polluants organiques hérités et d'autres contaminants afin de s'assurer qu'ils peuvent être consommés sans danger. Ainsi, nous surveillons ces contaminants et évaluons la concentration bénéfique de vitamine D, qui est

near the Lower Northwest Passage with sample preparation performed by trained community members. Whitefish from this area are among the most northerly populations studied and their contaminant levels are unknown. Char from the Lower Northwest Passage have also not been monitored for many years. This push from the community to evaluate the relative contamination levels in different types of fish will facilitate the community's wellbeing, food security, and offer the prospect of increased prosperity should they chose to build a sustainable fishery in this region of the Lower Northwest Passage.

Approximately 500 Arctic char, lake whitefish, cisco (*C. autumnalis* and *C. sardinella*), and lake trout were sampled from Inuit subsistence fishing sites on and near King William Island by Elders and youth. All study species except for lake trout generally showed average levels of mercury below subsistence guidelines (0.2 ppm). Of concern for routine consumption, however, was that almost 7 out of 10 lake trout had mercury levels that exceeded Canadian subsistence guidelines. Legacy organic pollutants appear to be at low levels that raise no unease, and collected microplastics have yet to be characterized. Workshops on dietary choices shared TK and discussions about climate change and contaminants. Community youth have been trained, fishers have been hired, and community engagement on this integrated and truly collaborative project has been integral to its success.

essentielle à la solidification des os. Des aînés, des pêcheurs actifs et des jeunes récoltent le poisson dans la partie inférieure du passage du Nord-Ouest, tandis que des membres formés de la collectivité préparent les échantillons. La population de corégones de cette région est l'une des plus septentrionales parmi les populations étudiées et les concentrations de contaminants que ces poissons contiennent sont inconnues, mais l'omble n'a pas été surveillé depuis de nombreuses années. Les ombles du passage inférieur du Nord-Ouest n'ont pas non plus été surveillés depuis de nombreuses années. Cette collaboration de la collectivité pour évaluer les concentrations relatives de contaminants chez différents types de poissons contribuera au bien-être de la collectivité, favorisera la sécurité alimentaire et offrira des perspectives de prospérité accrue s'il est décidé de développer la pêche durable dans cette région de la partie inférieure du passage du Nord-Ouest.

Environ 500 ombles chevaliers, grands corégones, ciscos (C. *autumnalis* et C. *sardinella*) et touladis ont été prélevés sur des sites de pêche de subsistance inuits sur l'île du Roi-Guillaume et à proximité par des aînés et des jeunes. Toutes les espèces étudiées, sauf le touladi, présentaient généralement des concentrations moyennes de mercure inférieures aux recommandations de subsistance (0,2 ppm). Toutefois, pour la consommation courante, il est préoccupant de constater que près de 7 touladis sur 10 présentaient des concentrations de mercure supérieures aux recommandations canadiennes en matière de subsistance. Les polluants organiques hérités semblent être à des concentrations faibles ne suscitant aucune préoccupation, et les microplastiques recueillis doivent encore être caractérisés. Les ateliers sur les choix alimentaires ont permis de diffuser les connaissances traditionnelles et de discuter des changements climatiques et des contaminants. Les jeunes de la collectivité ont été formés, des pêcheurs ont été embauchés et la mobilisation de la collectivité dans ce projet intégré et véritablement collaboratif a été essentielle à son succès.

Key messages

- Assay of more than 500 salmonids at traditional fishing sites on or near King William Island show that lake whitefish, cisco, and Arctic char have low levels of mercury concentrations (ranging from 0.07-0.12 ppm, n ~300) with lake trout showing higher average levels and exceeding 0.3 ppm, n~ 200.
- Variation in mercury levels were explained by factors such as age (determined by otolith analysis) in all fish species, as well as selenium levels and carbon isotope signatures, the latter indicating their position in the food chain, in both Arctic char and cisco. Results suggest the bioaccumulation of mercury.
- Traditional ecological knowledge, support from the Gjoa Haven Hunters and Trappers Association, and community youth training as well as workshops have been crucial to ensuring the completion of this project. The interest shown by community Elders to analyze fish from subsistence fishing sites has also been an asset to this project.

Messages clés

- L'analyse de plus de 500 salmonidés sur les sites de pêche traditionnels de l'île King William ou à proximité montre que le grand corégone, le cisco et l'omble chevalier présentent de faibles concentrations de mercure (de 0,07 à 0,12 ppm, n ~ 300), le touladi présentant des concentrations moyennes plus élevées dépassant 0,3 ppm, n ~ 200.
- La variation des concentrations de mercure s'explique par des facteurs tels que l'âge (déterminé par l'analyse des otolithes) chez toutes les espèces de poissons, ainsi que par les concentrations de sélénium et les signatures des isotopes de carbone, ces dernières indiquant leur position dans la chaîne alimentaire, tant chez l'omble chevalier que chez le cisco. Les résultats semblent indiquer une bioaccumulation du mercure.
- Les connaissances écologiques traditionnelles, le soutien de l'Association des chasseurs et des trappeurs de Gjoa Haven, la formation des jeunes de la collectivité ainsi que les ateliers ont été essentiels pour assurer la réalisation de ce projet. L'intérêt manifesté par les anciens de la collectivité pour l'analyse des poissons provenant des sites de pêche de subsistance a également été un atout pour ce projet.

Objectives

The aim of this project is to:

- sample Arctic char, lake trout, lake whitefish, and cisco ssp. by community fishers from traditional subsistence fishing sites in the Lower Northwest Passage (identified by workshops using mapping techniques);
- obtain good sample preparation by community youth (some trained in the 2017 Government of Nunavut (Nunavut Community Aquatic Monitoring Program (N- CAMP)) sessions held in May 2017);
- assess the concentration of 61 elements including selected toxic elements, such as Hg, Cd, As, Ag, and Pb, as well as essential elements such as Se, Mg, and Ca from each site. In addition, Vitamin D will also be assayed as well as selected persistent organic pollutants (POPs);
- analyze certified reference materials for quality assurance allowing the contaminant data to be added to NCP datasets;
- collect water samples for assessment of microplastics; and
- complete face-to-face interviews as well as workshops on the perception of the dietary choices by community member in association with a harvest study. This will allow the research team to gather data on hunting success, food sharing, and the role concerns about the influence of contaminant levels have on dietary choices. Information will be shared, evaluated, and interpreted with the community of Gjoa Haven and with interested harvesters from other communities in the Lower Northwest Passage (LNWP).

Introduction

In Arctic ecosystems, anthropogenic pollutants including persistent organic pollutants (POPs), are of particular concern. Arctic freshwater, marine, and terrestrial ecosystems have been contaminated by the long-range transport of POPs and mercury (Hg) via the global circulation of air and water (DeWit et al., 2004; AMAP, 2011, Muir et al., 2013; Braune et al., 2015). Imported fuel and other commercial products and poor waste handling as well as the thawing of the permafrost has resulted in the release of chemicals and metals leading to bioaccumulation or biomagnification potential, which ultimately determines chemical exposure and toxicity. Fish, in addition to humans, are amongst the top predators in Arctic ecosystems. As a result, it has long been recognized that the health of fisheries is directly linked to the aquatic food web, including contaminants associated with individual species (McKinney et al., 2012). It is not known how climate change, future commercial shipping, energy and mineral extraction, tourism, and anthropogenic change will impact contaminant levels in the LNWP. This information is critical for the health of this ecosystem, for community wellness, and to inform management decisions. Indeed, an assessment of contaminants is essential for the Nunavummiut to have confidence in their country food so that the consumption of country food from their harvesting efforts can be safely encouraged and promoted. Because community members are so well-informed, they are concerned about contaminants in their traditional foods. Indeed, it has been suggested that Inuit families may opt for more expensive, and likely less nutritious, “store-bought” foods (Pearce et al., 2009) if they are concerned about contaminants. Contaminant assessment is also critical for any future effort to establish a sustainable fishery, and for any robust socio-economic strategy for this resource. Marketing of “clean” aquatic food sources, even locally, would be a key step to food security, economic prosperity, maintenance of stable resources, and for employment opportunities. Thus, it is important to ascertain contaminant levels in Arctic char, whitefish, lake trout, as well as cisco, aby-catch species.

The Hunters and Trappers Association of Gjoa Haven, located on King William Island in the LNWP, requested that efforts be made to determine if the fish they catch for subsistence consumption are relatively free of anthropogenic contaminants. Thus, this project is directly in response to the need for the community to know. They are fully aware that northern communities may be exposed to higher Hg and POP levels, compared with southern Canadians (Donaldson et al., 2010). Of particular concern, are increases in Hg levels noted in Arctic fish and wildlife (Braune et al., 2015). The Northern Contaminants Program (NCP) has been assessing levels of POPs and Hg across the Canadian Arctic since the early 1990s, including limited measurements on sea-run char from the LNWP (Evans et al., 2015). However, Arctic char collected from Gjoa Haven was last assayed for mercury in 2004 and to our knowledge there have been no follow-up studies or monitoring of other contaminants since that time. As well, no values were reported for other subsistence fish species, including lake whitefish, char, cisco and lake trout leaving a knowledge gap. An additional contaminant of emerging concern, microplastics, can also directly impact food webs and fish health and be a source of POPs in the ocean. A preliminary estimate of these levels in the LNWP is also important both to the communities and to all Canadians.

Against this backdrop of anthropogenic change, important questions emerge that directly affect the Nunavummiut. For example, what impact will increased access to fish resources have on their food security? Some factors affecting “country food” access, include loss of traditional ecological knowledge, the high costs of harvesting equipment, rapid human population growth, changing food preferences, changing climatic conditions that restrict access to harvesting areas and impact wildlife, as well as the perception of harm done to country foods, making them less desirable. In order to fully understand the impact of the perception of contaminants in fisheries resources to either local food security or to the development of a sustainable fishery, there must be first an understanding of what we know about traditional uses, practices and rules concerning the harvest and distribution of local fishery resources.

Activities and results (2018-2019)

Arctic char (*Salvelinus alpinus*, Inutituk name: iqaluk), lake whitefish (*Corgonus clupeaformis*, Inutituk names: kakkiviaqtuuq and pikugtuuq), cisco (*C. autumnalis* and *C. sardinella*, Inutituk names: kavihilik and anaaqtiq, respectively), as well as lake trout (*S. namaycush*, Inutituk name: ihok) were sampled by community fishers from traditional subsistence fishing sites on and near King William Island using nets, hand lines and spears. A total of approximately 500 fish were used for morphometric measurements (except under extreme conditions) and otoliths were obtained for age determinations. Muscle samples were assayed for 61 elements including Hg and selenium as well as a subset for nitrogen and carbon stable isotope signatures. Some char and whitefish were also assayed for persistent organic pollutants (POPs) as well as nutrient analysis, including vitamin D. After one year, only the morphometrics, ages, Hg and metal levels are close to completion since this was the highest priority for the community, but POP and other assays are ongoing and will be reported in 2020. Microplastics were collected from the waters of the lower Northwest Passage but these have yet to be chemically identified due to technical difficulties.

For Hg, all study species except for lake trout generally showed average levels of Hg, below subsistence guidelines (0.2 ppm), as seen in Table 1. Arctic char shared high trophic positions with lake trout (as determined by the stable isotope analysis) but had higher selenium levels, consistent with foraging in the sea. Of concern for routine consumption, however, lake trout Hg levels (95.6% of this total mercury was assayed as methylmercury, which is the bioreactive mercury of concern to humans) exceeded Canadian subsistence guidelines in 7 out of every 10 fish caught (aged 8-45 years old). Preliminary results were discussed in a "contaminants meeting" with representatives from the Government of Nunavut and Health Canada in Ottawa in December 2018.

Community engagement, communication, and Indigenous Knowledge

A workshop, which took place on King William Island, concentrated on dietary choices, traditional ecological knowledge, and cooking techniques. It was held over a three-day period in August 2018 and was augmented with discussions by community members on climate change and contaminants. It was led by Project Collaborator Stephan Schott and attended by Project Co-Leader, Virginia Walker at a local fishing weir or haput (Figure 1) where community youth were hired to fish, as directed by Elders. At approximately the same time, Project Co-Leader James Qitsaliuk was with additional hired youth sampling at more distant fishing sites. Some of the weir workshop activities, youth and Elder fishing and preparing samples for analysis, were documented in a film "Iqalukmuit". The first screening of this film was in Gjoa Haven (20 min; filmed and directed by S. Wolfe, with edits made by S. Wolfe, J. Chapman and S. Schott; available online at GSC QF8478) at a follow-up meeting in a local hall. Some youth had not been to the weir previously, thus, this was an opportunity for Elders to share traditional ecological knowledge with community youth. The analysis of the data from this workshop is on-going and will be integrated into a publication on knowledge coevolution (Chapman and Schott and others) currently in draft for submission. Reports, in the form of mini posters on the low levels of mercury and POPs in Arctic char as well as the high levels of vitamin D, were distributed to a community fisher and the Hunter and Trapper's Association for wider distribution in January 2019. These mini posters were similar to the poster displayed for an ArcticNet conference.

In addition to the workshop held at the weir, as well as an ice-fishing sampling trip in May, other group information-sharing meetings were held in May and August 2018 in the hamlet of Gjoa Haven to empower the community. These were supplemented by face-to-face interviews to assess the influence of the research results on their view of country food, their food-sharing economy and any role it might play in the potential development of their fishing resources. A translator was hired for many of these meetings. Informal discussions were also held at community events including at a feast and at community activities dedicated to human wellness. Formal meetings were advertised on the radio and through the Hunters and Trappers Association.

We are working to integrate the contaminant data into our publicly available on-line Atlas of the marine resources (see http://tsfn.gcrc.carleton.ca/index.html), if this is approved by the Government of Nunavut. We have already transferred the elemental data to the Polar Database so that it is accessible. The project team presented a talk at the Government of Nunavut Fisheries and Sealing Workshop. The team also presented at the ArcticNet conference

Table 1. Number of fish sampled for age, length, weight and mercury levels (Hg) with mean and standard deviations shown; details of the mean mercury levels have been provided to the Government of Nunavut as well as Health Canada but the Government of Nunavut has requested time to consider these results before release and thus they cannot be shown in this report.

Species	Number	Age Range	Age (years)	Length (mm)	Weight (g)	Average Hg (ug•g-1 ww)
Arctic char	194	5-33	14.3±0.7	622±18	3064±251	below 0.1
lake trout	130	8-62	25.2±1.6	641±20	3375±294	above 0.3
cisco spp.	100	2-47	15.1±1.5	340±18	524±72	below 0.1
lake whitefish	92	4-47	21.1±2.2	397±10	940±84	above 0.1 but below 0.2

Figure 1. Fishing at a traditional weir on King William Island, to the left is the weir and to the right, Brent Puqiqnak from Gjoa Haven shows the iqaluk fished from the haput, which was subsequently tested for contaminants and found to be of no concern for consumption.

in 2018 with additional data to be presented at that venue in December 2019 as well as at the Inuit Studies Conference in October 2019. These are excellent venues for communications. Our project facilitated the attendance of Gjoa Haven residents in the conference held on December 2018 in Quebec City, where they presented their own poster (harvest study facilitator and a high school youth apprentice).

Capacity building

Capacity building is a priority with our project as evidenced by several initiatives:

Youth training in communication

This is evidenced by the Genome Canada Towards a Sustainable Fishery for Nunavummiut project facilitating the attendance of a high school student and a youth hired to oversee the harvest study, at the ArcticNet Conference in 2018 and the invitation to a second high school student to attend the upcoming conference in 2019.

Youth training in fishing

As mentioned, during the weir sampling expedition, youth were trained in fishing by Elders and also trained in scientific sampling techniques. Project Co-Leader James Qitsualik trained additional youth in the sampling of Arctic char and lake whitefish using nets at onshore mainland fish sites. We participated in the Government of Nunavut N-CAMP training in May 2017, and some of those individuals have been hired to sample for this contaminants project. Some of those trained as part of this project have trained other community members in scientific sampling. This training in scientific sampling is a requirement for protocols developed by for Department of Fisheries and Oceans, and these community fishers are now satisfying this government requirement at test commercial fishing sites.

Youth training in social science data gathering and analysis

We established a youth apprenticeship program associated with the harvest study. This program trains two high school students, for a year each, in essential skills in data management, geomatic tools, mapping, data analysis, interpersonal skills, human resource management and the economics of harvesting. A former apprentice has now been hired as year-round harvest study facilitator and helps train the high school apprentices.

Community information sharing

Community information sharing involved discussions of contaminant movement in the North and the sources of contaminants. This information is being transmitted to community wellness groups including the pre-natal classes by community Elders.

Hunting trips with Elders

As part of the larger Genome Canada project, fishers and hunters have been hired ($200 per day) and these hunters in turn are taking out their children and grandchildren on the land to fish, and thus, they have a high degree of engagement and are motivated to communicate their traditional knowledge to youth.

Discussion and conclusions

Results of the mercury and metal contamination in the different focal species of fish have been provided to the Polar Database so that it can be accessible when finalized. The POP assays have been completed but they are not yet in a presentable form, but this should be done in the coming months. This data will then also be uploaded to the database. Because of the concern over the mercury levels in lake trout, we are continuing to assay samples from these fish for mercury from different bodies of water in the region as they become available from local fishers. A meeting in the Gjoa Haven community, where these results will be disseminated, and to be held in conjunction with the Government of Nunavut, Department of Health representatives, is in the planning stage for August 2019.

Project completion

It is anticipated that this NCP community project will be completed, as planned, by the end of the 2019-2020 project year.

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References

Arctic Monitoring and Assessment Programme (AMAP): AMAP Assessment 2011 pp xiv-193
Braune B, Chétetalt J, Amyot M, Brown, T. Clayden M, Evans, M, Fisk A, Gaden A, Girard, C, Hare A, Kirk J, Lehnherr I, Letcher R, Loseto L, Macdonald, R, Mann E, McMeans B,Muir D, O'Drscoll N, Poulain A, Reimer K, Stern G (2015) Mercury in the marine environment of the Canadian Arctic: review of recent findings. Science of the Total Environ 509/510:67-90

de Wit CA, Fisk AT, Hobbs KE, Muir DCG, Gabrielsen GW, Kallenborn R, et al. AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic. Oslo, Norway: Arctic Monitoring and Assessment Programme (AMAP); 2004. p. xvi +310.

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

Evans MS, Muir DCG, Keating J, Wang X (2015) Anadromous char as an alternate food choice to marine animals. A synthesis of Hg concentrations, population features and other influencing factors. Sci. Total Environ, 509/510: 175-194

McKinney MA, McMeans BC, Tomy GT, Rosenberg B, Ferguson SH, Morris A, Muir DCG, Fisk AT (2012) Trophic transfer of contaminants in a changing Arctic marine food web: Cumberland Sound, Nunavut, Canada. Environmental Science & Technology 46: 9914-22.

Muir, DCG et al. (2013) Persistent Organic Pollutants in Canada's North, Chapter 4, pp. 273- 422.

Pearce T, Smit B, Duerden F, Ford JD, Goose A, Kataoyak F (2009) Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada, Polar Record pp.1-21.

Sources of methylmercury, perfluoroalkyl substances, and polychlorinated biphenyls to ringed seal food webs of Lake Melville, Northern Labrador

Sources de méthylmercure, de substances perfluoroalkylées et de biphényles polychlorés des réseaux trophiques du phoque annelé du lac Melville dans le nord du Labrador

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Project locations/Emplacements 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. Of particular concern is methylmercury (MeHg), the toxic form of mercury that biomagnifies through food webs. Increases in methylmercury concentrations are projected from hydroelectric power development on the Churchill River. Lake Melville is 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. This study uses combined analyses of mercury (Hg), MeHg, carbon (C), and nitrogen (N) stable isotopes with perfluorinated alkyl substance (PFAS) and PCB congener analyses. This will 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 as a result of further climate-induced alterations. This will provide a baseline MeHg concentrations, sources and food web dynamics, which is important for understanding how climate changes and flooding for the hydroelectric power production will alter MeHg levels in Lake Melville.

Ninety-eight seal samples were collected during harvests by local hunters between 2013-2018 and are being analyzed for mercury and methylmercury. A subset of these samples are being analyzed for mercury stable isotopes, PFASs, and PCBs. Average concentrations of total mercury (THg) in seal tissues collected in 2017 and 2018 were comparable, with average concentrations of 945 ng/g ± 334 (2017) and 942 ng/g ± 314 (2018) from muscle samples, and 44,556 ng/g ± 43,706 (2017) and 44,784 ng/g ± 43,665 (2018) from liver samples (Figure 4). Average MeHg concentrations in the liver and muscle of Lake Melville seals collected between 2016-2018 were 1,041 ± 1,032 and 558 ± 501 ng/g wet weight (ww), respectively, with 20 of 24 liver samples and 15 of 24 muscle samples surpassing the Canadian frequent consumer

Résumé

Les riverains du lac Melville se préoccupent des concentrations de contaminants dans les aliments qu’ils récoltent dans la nature. Le méthylmercure (MeHg), la forme toxique du mercure qui se bioamplifie dans les réseaux alimentaires, est particulièrement préoccupant. On prévoit une augmentation des concentrations de méthylmercure en raison de l’exploitation de l’énergie hydroélectrique sur le fleuve Churchill. Le lac Melville est un lieu d’étude unique de l’Arctique parce qu’il est alimenté à la fois par les eaux fluviales et océaniques et parce qu’il a un historique de contamination aux BPC par des sources locales, comme la base aérienne de Goose Bay. Cette étude s’appuie sur des analyses combinées des isotopes stables du mercure (Hg), du MeHg, du carbone (C) et de l’azote (N) et des analyses des substances perfluoroalkylées (PFAS) et des congénères de BPC. Les travaux permettront d’établir l’importance relative des sources locales par rapport aux sources régionales et terrestres et aussi par rapport aux sources marines pour ce qui est de la contamination des réseaux alimentaires des phoques annelés du lac Melville, avant l’aménagement hydroélectrique et en raison d’autres modifications induites par le climat. On obtiendra ainsi des concentrations de référence de MeHg, les sources et la dynamique du réseau alimentaire, des éléments importants pour comprendre comment les changements climatiques et les inondations découlant de la production d’énergie hydroélectrique vont modifier les concentrations de MeHg dans le lac Melville.

Des chasseurs locaux ont prélevé 98 échantillons de phoques entre 2013 et 2018, lesquels sont analysés pour le mercure et le méthylmercure. Un sous-ensemble de ces échantillons est aussi en cours d’analyse pour détecter des isotopes stables de mercure, les PFAS et les BPC. Les concentrations moyennes de mercure total (HgT) dans les tissus des phoques prélevés en 2017 et 2018 étaient comparables, et les concentrations moyennes étaient de 945 ng/g ± 334 (2017) et de 942 ng/g ± 314 (2018) dans les échantillons de muscles, et de 44 556 ng/g ± 43 706 (2017) et de 44 784 ng/g ± 43 665

guideline of 200 ng/g ww. Average MeHg concentrations in Lake Melville ringed seals are within the range of those recently reported for 14 communities across the Canadian high and sub-Arctic (average muscle mercury concentrations between 2007-2011 were 107-1,070 ng/g) (Brown et al. 2016). Results from mercury stable isotope analyses demonstrate that Lake Melville seals obtain food from both inland and marine sources. PFAS analyses on seal tissues is almost complete for the 2018 samples. Analyses of seals collected in 2017 for PFASs show that adult ringed seals in Lake Melville have 67 ± 12 ng/g wet weight 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 concentrations were observed in pups than in adults and were associated with higher trophic level and terrestrial feeding. We are continuing this project in 2019-2020 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.

(2018) dans les échantillons de foie (figure 4). Les concentrations moyennes de MeHg dans le foie et les muscles des phoques du lac Melville prélevés entre 2016 et 2018 étaient respectivement de 1 041 ± 1 032 et de 558 ± 501 ng/g (poids humide), et 20 échantillons de foie sur 24 et 15 échantillons de muscles sur 24 dépassaient la recommandation canadienne de 200 ng/g (poids humide) pour les consommateurs fréquents. Les concentrations moyennes de MeHg chez les phoques annelés du lac Melville se situent dans la fourchette des données récemment déclarées pour 14 collectivités du Haut-Arctique et de la région subarctique canadienne (les concentrations moyennes de mercure dans les muscles entre 2007 et 2011 étaient de 107 à 1 070 ng/g) (Brown et coll. 2016). Les résultats des analyses des isotopes stables de mercure montrent que les phoques du lac Melville obtiennent leur nourriture à partir de sources intérieures et marines. Les analyses des PFAS dans les tissus des phoques sont presque terminées pour les échantillons de 2018. L'analyse d'échantillons prélevés en 2017 visant à détecter des PFAS indique 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 pour les phoques annelés de régions plus au nord, notamment de Resolute, Sachs Harbour et Pangnirtung. Les concentrations de PFAS étaient plus élevées chez les petits que chez les adultes et ont été associées à un niveau trophique supérieur et à une alimentation terrestre. Ce projet se poursuivra en 2019-2020 pour analyser des échantillons prélevés sur des phoques adultes et visera à rechercher une gamme complète de contaminants et à mesurer des marqueurs de l'état de santé des phoques, ce qui renforcera les ensembles de données de référence. Les résultats serviront à évaluer les répercussions des travaux d'aménagement hydroélectrique sur les animaux sauvages servant à l'alimentation des habitants de la région et à prévoir les répercussions 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. Of particular concern is methylmercury (MeHg), the concentration of which is predicted to increase as a result of hydroelectric power development on the Churchill River.
- This project analyzes mercury (Hg), methylmercury (MeHg), carbon (C) and nitrogen (N) stable isotopes, perfluorinated alkyl substances (PFASs), and polychlorinated biphenyls (PCBs) in the Lake Melville food web, which includes ringed seals.
- Information from the project allows for the determination of 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 2016-2018 were 1,409 ± 1,740 and 830 ± 1,100 ng/g wet weight (ww), respectively, 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 wet weight total PFAS, which is comparable to ringed seals in other areas in Labrador (Nain: 45±6 ng/g), Hudson Bay (Arviat: 71±8 ng/g) and the Beaufort Sea (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.

Messages clés

- Les riverains du lac Melville se préoccupent des concentrations de contaminants dans les aliments qu'ils récoltent dans la nature, tels que le phoque annulé. Le méthylmercure (MeHg), dont la concentration devrait augmenter en raison de l'exploitation de l'énergie hydroélectrique sur le fleuve Churchill, est particulièrement préoccupant.
- Ce projet analyse les isotopes stables du mercure (Hg), du méthylmercure (MeHg), du carbone (C) et de l'azote (N), les substances perfluoroalkylées (PFAS) et les biphényles polychlorés (BPC) dans la chaîne alimentaire du lac Melville, qui comprend les phoques annelés.
- Les résultats du projet permettent de déterminer l'importance relative des sources locales par rapport aux sources régionales et terrestres et aussi par rapport aux sources marines pour ce qui est de la contamination des réseaux alimentaires des phoques annelés du lac Melville, avant l'aménagement hydroélectrique et autres changements d'origine climatique encore indéterminés.
- Les concentrations moyennes de MeHg dans le foie et les muscles des phoques du lac Melville prélevés entre 2016 et 2018 étaient respectivement de 1 409 ± 1 740 et 830 ± 1 100 ng/g (poids humide), et sont comparables à celles récemment observées ailleurs 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 valeurs des phoques annelés d'autres régions du Labrador (Nain – 45 ±6 ng/g), de la baie d'Hudson (Arviat – 71 ±8 ng/g) et de la mer de Beaufort (Ulukhaktok – 51 ± 6 ng/g), mais est généralement plus élevé que celles des phoques annelés de régions plus au nord, notamment de Resolute, Sachs Harbour et Pangnirtung.

- 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.

- Certains types de PFAS, de SPFO et de perfluorocarboxylates à chaîne longue étaient présents en concentrations plus importantes chez le phoque annelé du lac Melville par rapport 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 d'aménagement hydroélectrique sur la faune entrant dans le régime alimentaire des habitants de la région.

Objectives

This project aims to:

- differentiate among global versus local, and terrestrial versus marine sources of methylmercury (MeHg), perfluoroalkyl substances (PFASs), and polychlorinated biphenyls (PCBs) to ringed seals using analyses of carbon, nitrogen, mercury stable isotopes, and PFASs and PCBs congeners in ringed seal tissues;
- determine concentrations of methylmercury, PFASs, and PCBs in ringed seals of Lake Melville, Northern Labrador before further climate-induced changes and reservoir creation for hydroelectric power development take place in the region;
- examine the bioaccumulation and biomagnification of PFASs in the Lake Melville ringed seal food web by analyzing water, plankton, fish, and other food web samples;
- determine the effects of contaminant exposure on ringed seal health by evaluating relationships between Hg, 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".

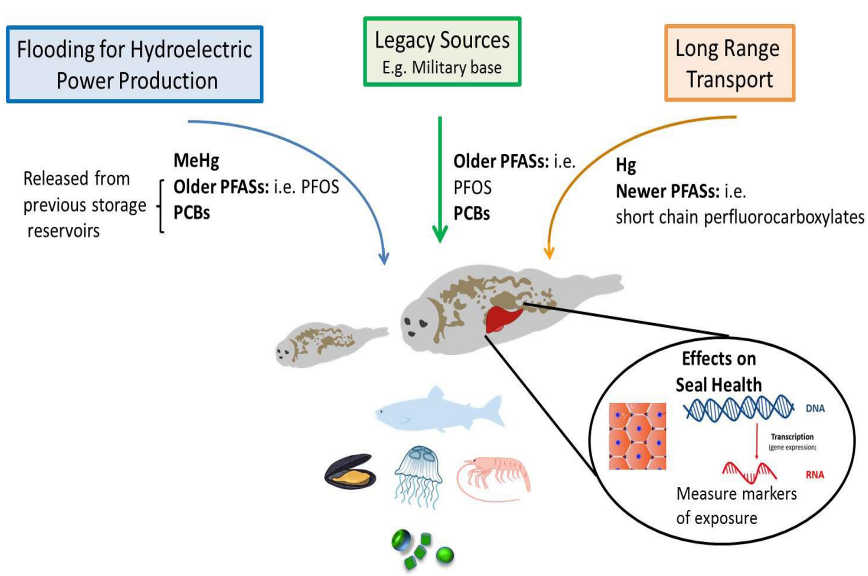
Introduction

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 country foods they harvest, particularly methylmercury (MeHg), and the projected increases in MeHg originating from past and future hydroelectric power development on the Churchill River. In addition to mercury (Hg) and MeHg, other contaminants of potential concern in the region include "new" synthetic chemicals such as perfluoroalkyl substances (PFASs) and legacy contaminants, such as polychlorinated biphenyls (PCBs), which could be re-mobilized from flooding for hydroelectric power production.

In addition to local environmental changes from hydroelectric power production, Lake Melville is also experiencing regional environmental changes due to climate change, including temperature increases and changing ice conditions, including later freeze up, earlier melt, and decreased ice thickness. Climate induced changes can alter contaminant cycling as well as feeding and reproduction behaviors, which can impact trophic position and thus contaminant levels in top predators. Lake Melville is an ecosystem at the crossroads of numerous environmental stressors and is an ideal site to track contaminants with differing local versus global sources, transport pathways, and biomagnification processes in a key traditional food species.

In this project, we are utilizing combined analyses of Hg, MeHg, carbon (C) and nitrogen (N) stable isotopes with PFAS and PCB congener analyses. This combined analyses will be used 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

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, C and N 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.



interest (e.g., immunity, stress responses, etc). We have recently secured funding for 2019-2020 to continue this project as a community based monitoring project. 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.

Activities in 2017-2019

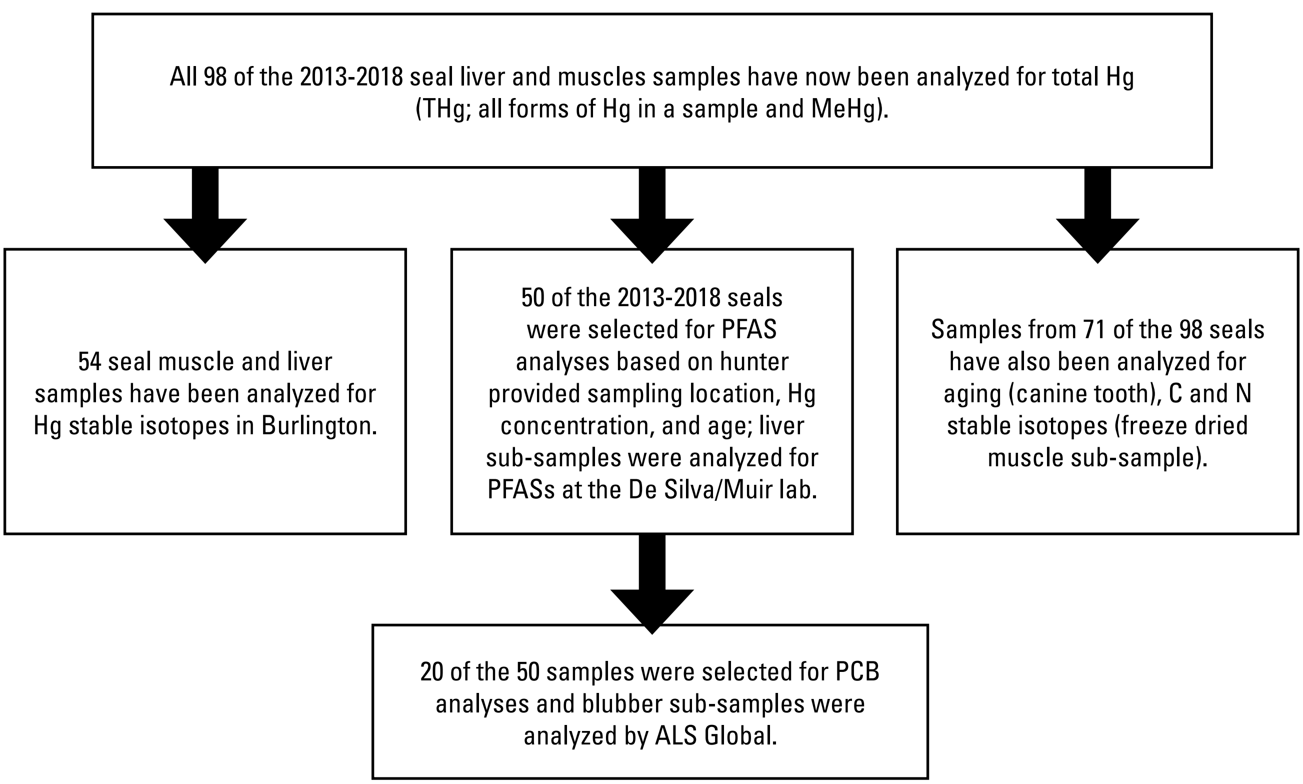
Sampling and analyses

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 2013-2018. Muscle, liver, blubber, kidney, stomach, and jaws were sampled from 98 individuals (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”. Details on the sample analyses 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 were too warm) and 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

Figure 2. Flowchart showing sampling analysis on the 2013-2018 seal samples.



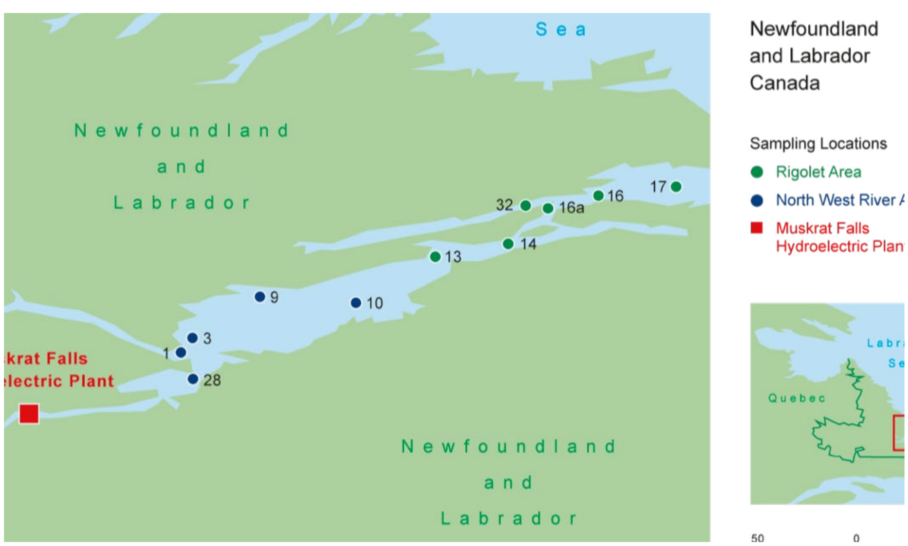
et al. 2015, Li et al. 2016, and Calder et al. 2016, key fish species (cod, northern pike, and Arctic char) were also collected. A subset of these fish are now being analyzed for PFASs at the De Silva/Muir lab in Burlington. In August 2016 and June 2017, we sampled the base of the food web (plankton) as well as lower food web organisms at six sites and analyzed them for THg and MeHg, Hg isotopes and PFASs as well as C and N isotopes (Figure 3). In 2018, we repeated this sampling in late June when productivity is generally higher 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). Traditional knowledge on productive zones of Lake Melville from field team members Liz Pijogge 2016-2018 (Nain resident), Kevin Gear (2016-2017; Northwest River resident), David Blake (2018; Northwest River resident), Martin Shiwak (2016; Rigolet resident), Carl Michelin (2017; Rigolet resident) and David Wolfrey (2018; 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 collected water from six to nine sites in 2016, 2017, and 2018 (Figure 3). 2016 and 2017 water PFAS analyses is complete while 2018 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 which included dissections (collection of blubber, liver, jaw, muscle, stomach, kidney samples), preservation methods (immediate freezing of tissue samples), recording of morphometric data (length, weight, blubber thickness), age, gender, and status of tissues. In June 2017 and 2018, Liz Pijogge (Nunatsiavut Government), Amber Gleason (ECCC), Kevin Gear (2017) and Dave Blake (2018) (Northwest River resident) and Carl Michelin (2017) and David Wolfrey (2018) (Rigolet resident) carried out a field season to collect plankton and water

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 2017/2018. Krill, jellyfish, scallops, and urchins were also collected at sites 16a and 32.



from Lake Melville. Gleason provided training to team members on clean techniques to avoid sample contamination (i.e. wearing supplied powder free gloves, double bagging samples), as well as training on the use of plankton nets and plankton sieves for plankton size fractionation. This training increased exposure to several specialized sampling techniques needed for evaluating contaminants in traditional country food species.

Communications

Project team members from the Environment Division of the Nunatsiavut Government coordinated communications with the communities involved in the project. In 2017 and 2018, 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 2017/2018 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 presented at national and international conferences and workshops, including the Society of Ecotoxicology and Chemistry (SETAC) conference in Sacramento USA, the Arctic Change conference in Quebec City, and the NCP Results Workshop in Yellowknife.

Indigenous Knowledge integration

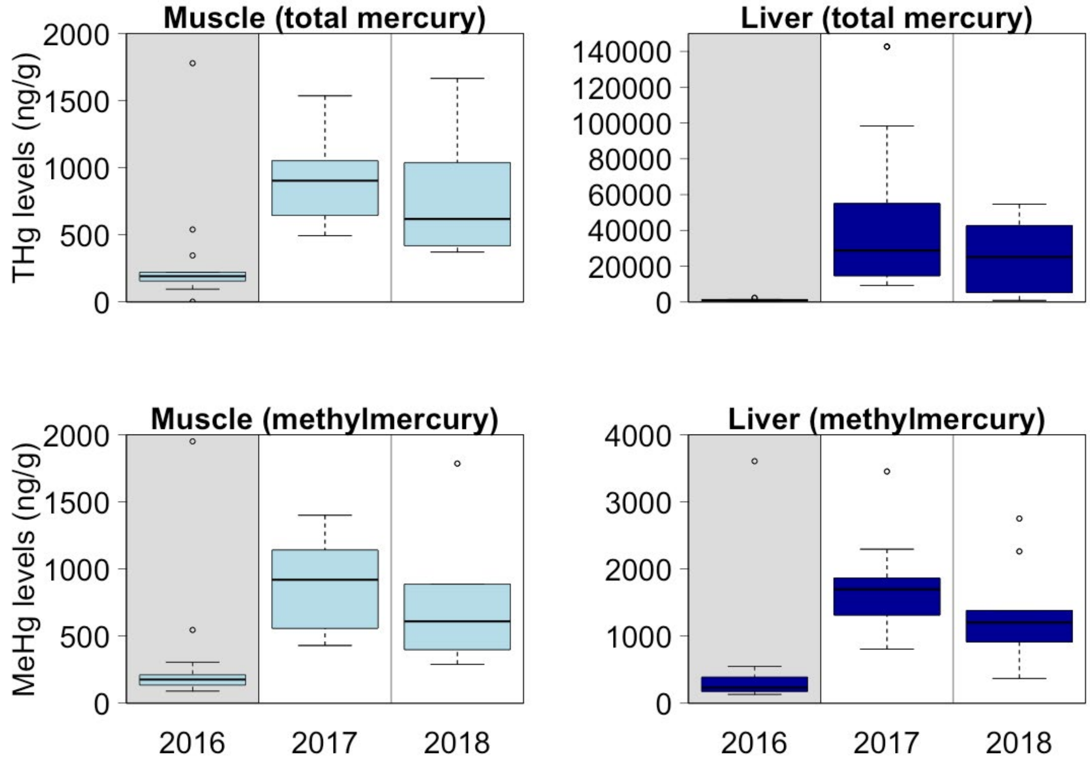
All seal collections are carried out during community harvests (nunalinni pinasuannik) and, therefore, completely rely on Indigenous knowledge, including knowledge of when and where to collect samples and any potential changes in ringed seal populations and/or habitat. In 2017 and 2018, the project also 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 2013-2018 (n = 98 samples collected) with excellent morphometric data, information on age and gender, and kill location recorded. This project also relies on Indigenous knowledge of field team members (Liz Pijogge, Kevin Gear, Dave Blake, Carl Michelin and David Wolfrey) for collections of water, plankton, and lower food web organisms, and for 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 concentrations of THg in seal tissues collected in 2017 and 2018 were comparable, with average concentrations of 945 ng/g ± 334 (2017) and 942 ng/g ± 314 (2018) from muscle samples, and 44,556 ng/g ± 43,706 (2017) and 44,784 ng/g ± 43,665 (2018) from liver samples (Figure 4). Average MeHg concentrations in the liver and muscle of Lake Melville seals collected between 2016-2018 were 1,409 ± 1,740 and 830 ± 1,100 ng/g wet weight (ww), respectively, with 20 of 24 liver samples and 15 of 24 muscle samples surpassing the Canadian frequent consumer guideline of 200 ng/g ww. Average MeHg concentrations in Lake Melville ringed seals are within the range of those recently reported for 14 communities across the Canadian high and sub-Arctic (average muscle mercury concentrations between 2007-2011 were 107-1,070 ng/g) (Brown et al. 2016). Aging from the 2017 collections shows that adult seals were primarily sampled in 2017 and although aging is not complete for 2018, the length/girth and THg/MeHg data suggests that adult seals were primarily sampled in 2018 as well. Thus, there is a significant difference in THg and MeHg concentrations in the seal tissues (muscle and liver) between the 2016 and 2017/2018 seal samples (Figure 4). This discrepancy is due to the seals collected in 2016 being predominately juvenile, compared to the seals collected in 2017 and 2018 being predominately adult seals.

Figure 4. THg (ng/g wet weight) and MeHg (ng/g wet weight) concentrations in seal tissues (muscle and liver) collected in Lake Melville in June 2016, 2017 and 2018.



The THg and MeHg in various plankton size fractions (80-153, 153-500, and >500 µm) varied greatly along the Lake Melville freshwater-marine gradient (Figure 5). Average concentrations of THg and MeHg in plankton (all size fractions) collected in 2018 were 46.4 ± 23.2 and 8.7 ± 7.6 ng/g, respectively, which is very similar to the 2016-2017 results of 40.5 ± 21.4 and 9.2 ± 12.7 ng/g. THg in plankton (size fraction 153-500 µm) at western/in-land terrestrial sites (such as sites 1, 3 and 9) were significantly higher in 2018 (69.1 ± 8.1 ng/g) compared to 2017 (33.9 ± 6.4 ng/g). As with previous years, the %MeHg in 2018 plankton for all three size fractions (80-153, 153-500, >500 µm) were highest at western/in-land sites (such as sites 1, 3 and 9) influenced by freshwater/terrestrial inputs and then decreased moving east with increasing marine influence (Figure 6). In food web organisms collected at a marine-influenced site (site 32), %MeHg increased between 2017 to 2018 in the scallops, from 42.9 % (134.8 ng/g) to 59.3 % (169.2 ng/g) respectively, and in urchins from 5.1 % (8.0 ng/g) to 10.9 % (15.1 ng/g) respectively. Other food web organisms collected in 2018 include mussels and clams, with 24.5 % (37.5 ng/g) and 35.3 % (124.8 ng/g) of MeHg respectively. These concentrations and patterns are similar to those observed in 2013 by Schartup et al. (2015), who also collected plankton in late June.

Figure 5. THg and MeHg concentrations in various plankton (omajuit imâni) size fractions (80-153, 153-500, and >500 µm) collected across a freshwater/terrestrial and marine gradient (Figure 3) (going from left to right) in Lake Melville in June 2016, 2017 and 2018.

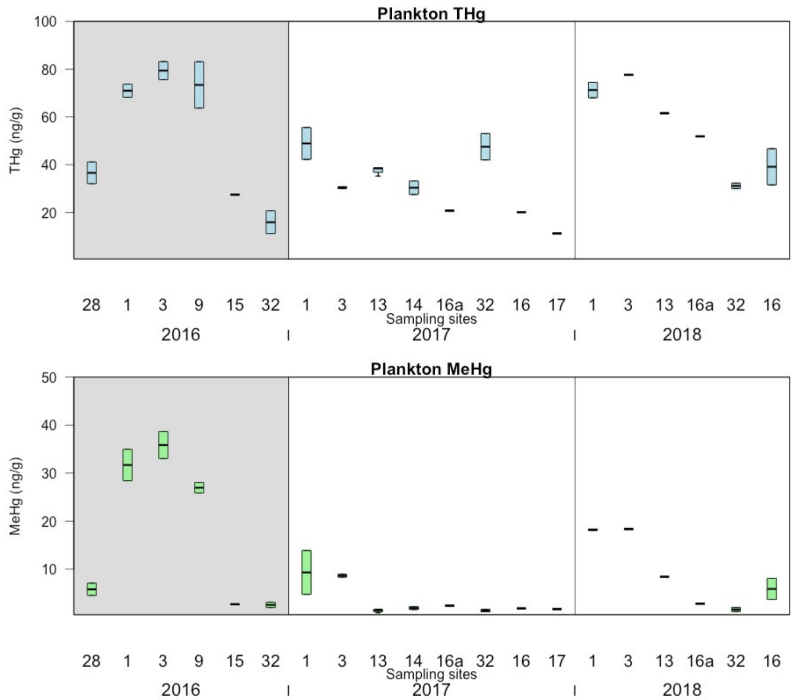
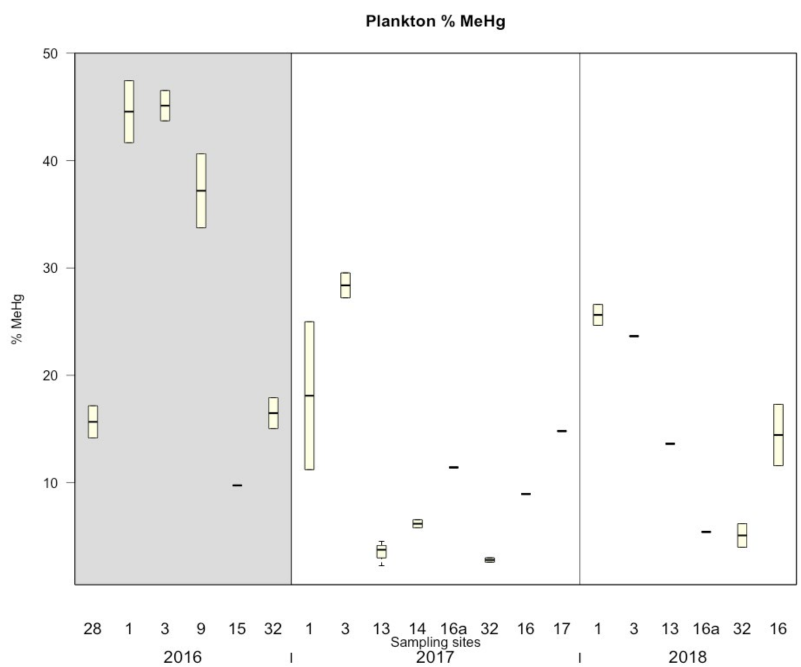


Figure 6. % MeHg in various plankton (omajuit imâni) size fractions (80-153, 153-500, and >500 µm) collected across a freshwater/terrestrial and marine gradient (Figure 3) in Lake Melville in June 2016, 2017 and 2018.



As suggested by Li et al. (2016) for the Lake Melville fish food web, results of more complete food web THg, MeHg, Hg, C and N isotope analyses 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 7). The data shown in Figure 7 highlights the scatter observed in the juvenile seals (pink cross circles and orange filled circles). It is intriguing that the adult seals have lower N-15 stable isotope signature but higher methylmercury concentrations. This is as with the 2017 adult seals, there is a positive correlation between MeHg and N-15 levels which suggests that the MeHg levels in the adult seals is a result of biomagnification through the diet of prey items. In contrast, the juvenile seals do not have a positive correlation between MeHg and N-15 levels, as their MeHg levels are a result of maternal-pup transfer during the nursing period (Newsome et al., 2006).

Hg stable isotope analyses of the Lake Melville food web demonstrates that seals have higher δ202Hg values (x axis; Figure 8) 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. Similar phenomenon is observed in some human studies. Plankton have much lower δ202Hg and δ199Hg 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 δ202Hg and δ199Hg in plankton reflects 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 δ202Hg and δ199Hg 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 7. MeHg concentrations versus trophic position, as indicated by δ^{15N} (‰), in Lake Melville seals collected 2013-2015 (pink cross circles), 2016 (filled orange circles) and 2017 (purple triangles). log10 MeHg (lipid weight in muscle) versus δ15N for 2016 and 2017.

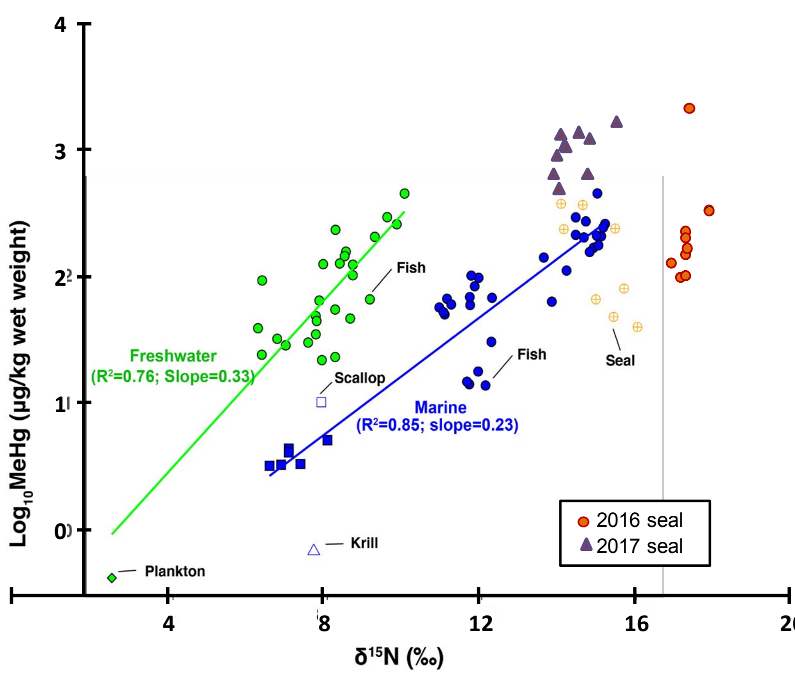


Figure 8. Stable Hg isotope composition of the Lake Melville food web, including sediment, plankton (omajuit imâni), mussels, scallops (matsojak), jellyfish, krill (kingupvaujâtuit), marine and freshwater fishes (minnigiak), and seals (natsiap).

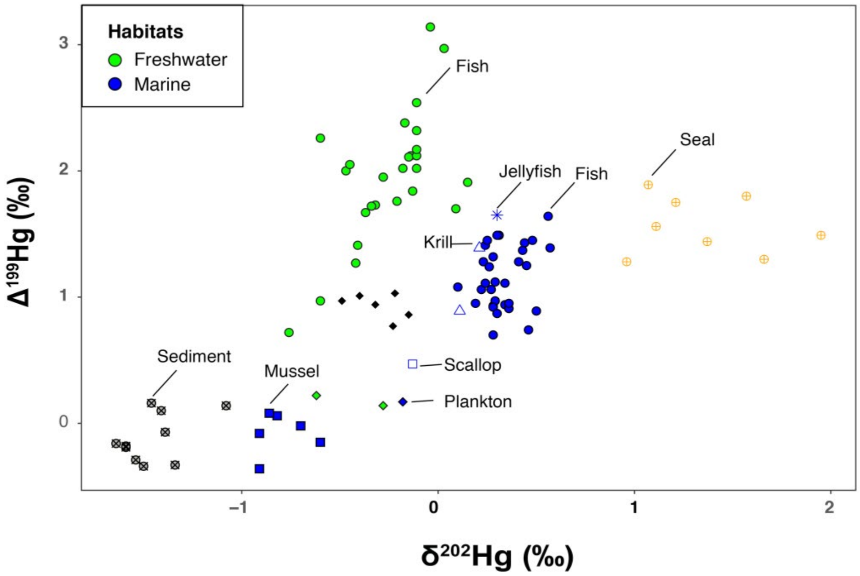
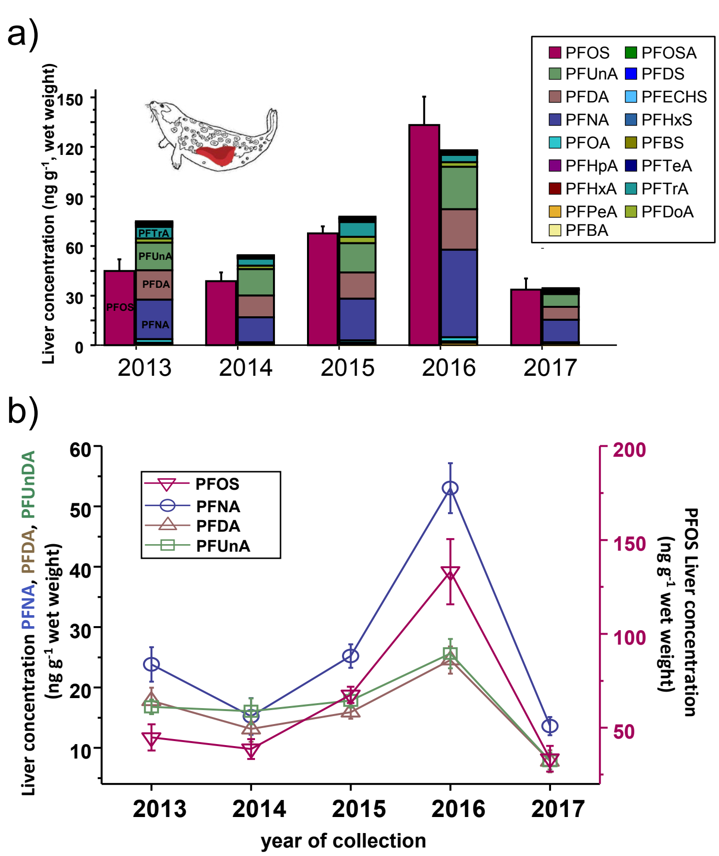


Figure 9. a) Average PFOS concentration and distribution of other PFAS in ringed seal liver collected 2013-2017 and b) temporal variation using average and standard error PFOS, PFNA, PFDA, and PFUnDA without any adjustment for age, length or isotopes.



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 9). 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.

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 fish tissue for fish health and for mammalian health, the FEQG is 4.6 ng/g 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 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 and 2018 proposal. The precise aging of these seals confirms that 7 out of the 10 seals were between the ages of 2 and 8 years and 3 seals are in the 0 to 1 year range. Age of seals is indeed related to their PFAS levels as the 2017 samples (i.e. older seals) had lower concentrations of PFAS (Figure 9b). Thus, lower PFAS concentrations were associated with larger (and likely older) animals (Figure 10). 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).

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, wet weight liver)	Age (years)
Lake Melville	2016	9	86 ±4	251 ±26	<1
Lake Melville	2017	10	129 ±3	68 ±12	4 ±1
Arviat[a]	2014	14	109 ±3	71 ±8	7 ±2
Ulukhaktok[a]	2010	9	117 ±3	50 ±6	12 ±3
Nain[a]	2016	10	119 ±2	45 ±6	4 ±2
Pangnirtung[a]	2011	14	117 ±3	28 ±6	2 ±0.4
Resolute[a]	2016	8	126 ±3	26 ±3	Pending
Sachs Harbour[a]	2014	10	116 ±3	21 ±3	6 ±2

[a] Data provided by Magali Houde and Derek Muir

Figure 10. Relationship of PFAS concentration in liver with seal body length indicating higher concentrations in smaller seals.

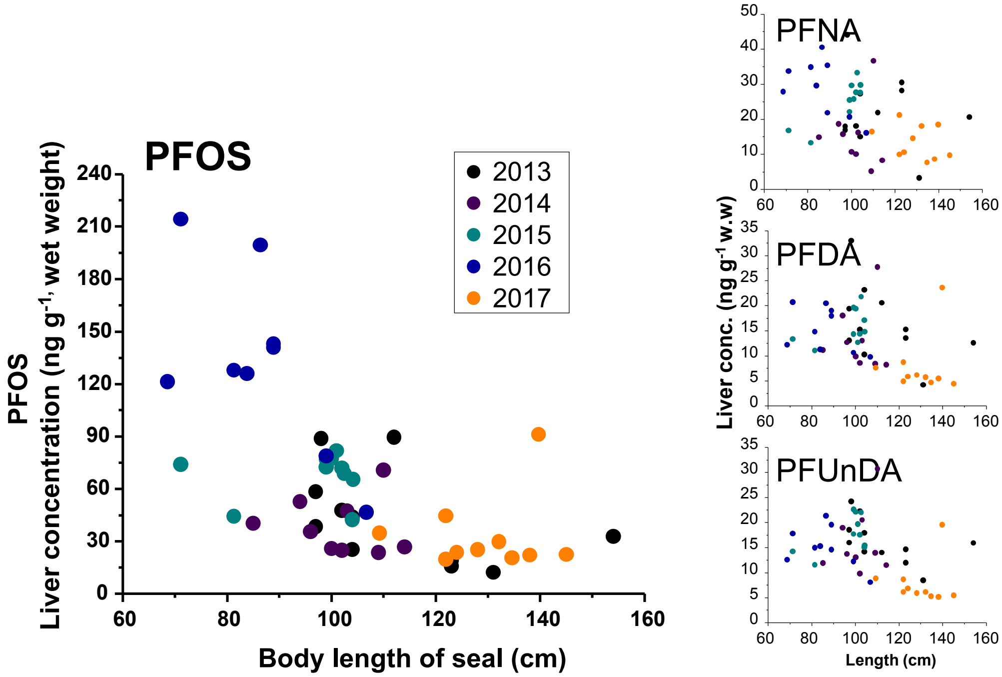
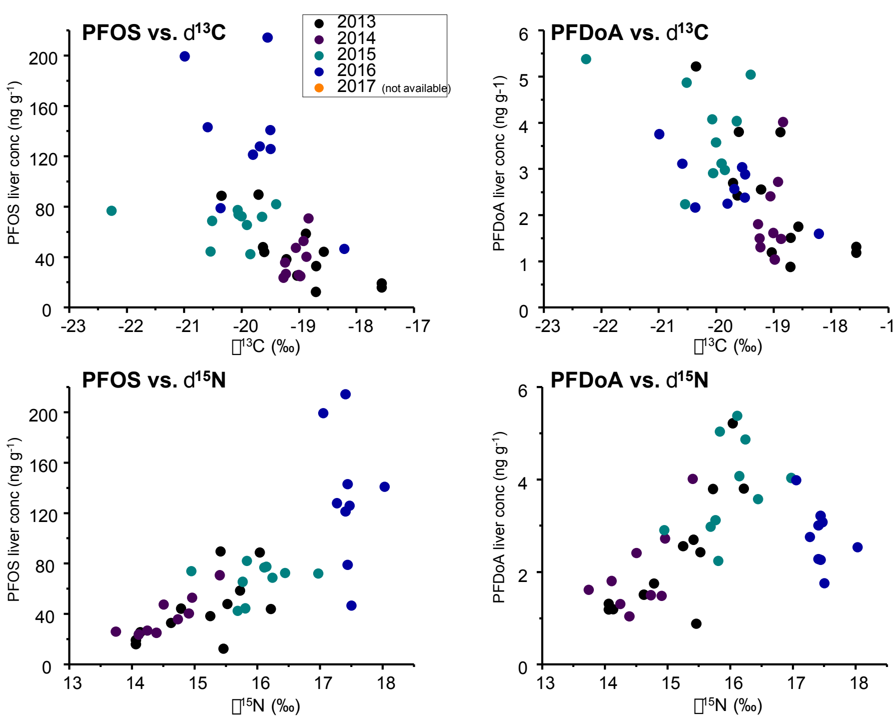


Figure 11. PFOS and PFDoA concentrations versus dietary strategy (δ13C) and trophic position (δ15N) in Lake Melville seal livers. Negative correlations with δ13C suggest greater PFAS from terrestrially feeding seals and higher trophic level. PFNA, PFDA, PFUnDA, PFDoA, PFTrDA, PFTeDA, and PFOS were all negative correlated with δ13C (Spearman correlation coefficient < -0.44, p<0.05). PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoA, PFTrDA, PFTeDA, PFHxS, PFOS, PFDS were positively correlated with δ15N (Spearman correlation coefficient>0.32, p<0.05).



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 11), 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 11) suggesting seals with a more terrestrial feeding strategy (i.e. more negative d13C) have higher levels of PFAS.

In summary, in Lake Melville seals, determinants of PFAS were age (using length as a proxy), trophic status (using d15N) and terrestrial feeding (d13C). In a similar study on polar bears in Svalbard, Tartu et al. (2017) reported that higher PFAS concentrations were correlated to d15N diet; however, unlike our study, higher PFAS were noted in more marine-based feeding (higher d13C). 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. 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 versus 19±5 ng/g PFOS).

Expected project completion date

Results from 2017-2019 funding will be complete within 6 months; however, we plan to carry out this research over the long-term (5-10 years) to track the impact of flooding for hydroelectric power production and climate change on Lake Melville food webs.

Acknowledgments

We are grateful to the hunters in the communities of Northwest River and Rigolet for their participation in this project. We would like to acknowledge the Northern Contaminants Program, Environment and Climate Change Canada, Harvard University, and the Nunatsiavut Government for the funding to produce the data within this report. We finally acknowledge 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.

References

Brown, T.M., Muir, D.C.G, Ferguson, et al. 2016. Mercury and cadmium in ringed seals of the Canadian Arctic: Influence of location and diet. Sci. Tot. Environ. 545-546:503-511.

Butt, C.M., Berger, U., Bossi, R., Tomy, G.T. 2010. Levels and trends of perfluorinated compounds in the Arctic environment. Sci. Tot. Environ. 408:2936-2965.

Calder, R. S. D., Schartup, A. T., Li, M., et al. 2016. Future impacts of hydroelectric power development on methylmercury exposures of Canadian indigenous communities. Environ. Sci. Technol. 50: 13115–13122.

Dehn, L.A., Sheffield, G.G., Follmann, E.H., et al. 2005. Trace elements in tissues of phocid seals harvested in the Alaskan and Canadian Arctic: Influence of age and feeding ecology. Can. J. Zool. 83:726-746.

Environment and Climate Change Canada. 2017. Canadian Environmental Protection Act, 1999 Draft Federal Environmental Quality Guidelines for Perfluorooctane Sulfonate (PFOS). Accessed May 2018. http://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=38E6993C-1

Gebbink, W., A., Bossi, R, Riget, F. F. et al. 2016. Observation of emerging per- and polyfluoroalkyl substances (PFASs) in Greenland marine mammals. Chemosphere 144 : 2384-2391.

Grønnestad, G., Villanger, G. D., Polder, A., et al. 2016. Maternal transfer of perfluoroalkyl substances in hooded seals. Environment Toxicology and Chemistry 36: 763–770.

Riget., F., Vorkamp, K., Bossi, R., et al. 2016. Twenty years of monitoring of persistent organic pollutants in Greenland biota. A review. Environmental Pollution 217: 114-123.

Letcher, R.J., Bustnes, J.O., Dietz, R., Jenssen, B.M., Jorgensen, E.H., Sonne, C. 2010. Exposure and effects assessment of persistent organohalogen contaminants in arctic wildlife and fish. Sci. Total Environ. 408: 2995-3043

Li, M., Schartup, A. T, Valberg, A. P., Ewald, J. D., Krabbenhoft, J. D., Yin, R., Balcom, P. H., Sunderland, E. M. 2016. Environmental origins of methylmercury accumulated in subarctic estuarine fish indicated by mercury stable isotopes. Environ. Sci. Technol. 50: 11559–11568.

Newsome, S.D., Etnier, M.A., Aurioles-Gamboa, D. 2006. Using carbon and nitrogen isotope values to investigate maternal strategies in northeast pacific otarids. Marine Mammal Science, 22, (3): 556-572.

Riget, F., Bossi, R., Sonne, C., Vorkamp, K., Dietz, R. 2013. Trends of perfluorochemicals in Greenland ringed seals and polar bears: Indications of shifts to decreasing trends. Chemosphere 93: 1607–1614.

Routti, H., Gabrielsen, G.W., Herzke, D., Kovacs, K.M., Lydersen, C. 2016. Spatial and temporal trends in perfluoroalkyl substances (PFAS) in ringed seals (*Pusa hispida*) from Svalbard. Environ. Poll. 214:230-238.

Schartup, A.T., Balcom, P.H., Soerensen, A.L., Gosnell, K.J., Calder, R.S.D., Mason, R.P., Sunderland, E. 2015. Freshwater discharges drive high levels of methylmercury in Arctic marine biota. Proc. Natl. Acad. Sci. 112:11789-94.

Tartu, S., Bourgeon, S., Aars, J., Andersen, M., Lone, K., Munro Jenssen, B., Polder, A., Thiemann, G. W., Torget, V., Welker, J. M., Routti, H. 2017. Diet and metabolic state are the main factors determining concentrations of perfluoroalkyl substances in female polar bears from Svalbard. Environ. Poll. 229: 146-158.

Mercury in Yukon fish

Le mercure dans les poissons du Yukon

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Project locations/Emplacements du projet

8 lakes in Yukon Territory (Dezadeash Lake, Kathleen Lake, Kluane Lake, Laberge Lake, Morley Lake, Simpson Lake, Wolf lakes Lake, Gazetted Snafu Lake)

Abstract

In this study, we capitalized on existing fish sampling and harvest initiatives to opportunistically analyze mercury in fish from Dezadeash, Kathleen, Kluane, Laberge, Morley, Simpson, and Wolf Lakes in Yukon Territory. Past sampling on mercury in fish has largely been limited to Laberge, Kusawa, and Kluane Lakes, so this was a significant opportunity to increase the number of lakes for which fish mercury data exist. Samples were made available through Yukon Government's SPIN program (Summer Profundal Index Netting; fish assessment program), Parks Canada's SPIN program, the Yukon Government burbot population assessment, the Kluane Lake Fish Derby, and a harvest camp at Simpson Lake. Indigenous fishers were invited to participate in SPIN programs, led the harvest camp at Simpson Lake, and helped process fish that were collected from Dezadeash Lake. All samples have been analyzed for total mercury. Of 253 samples analyzed, only 8 exceeded Health Canada's

Résumé

Dans cette étude, nous avons tiré parti des initiatives existantes en matière d'échantillonnage et de récolte de poissons pour analyser de manière opportuniste le mercure dans les poissons des lacs Dezadeash, Kathleen, Kluane, Laberge, Morley, Simpson et Wolf situés sur le territoire du Yukon. Par le passé, comme l'échantillonnage du mercure dans les poissons se limitait en grande partie aux lacs Laberge, Kusawa et Kluane, notre démarche a permis d'augmenter le nombre de lacs pour lesquels il existe des données sur le mercure dans les poissons. Les échantillons ont été prélevés dans le cadre du programme SPIN du gouvernement du Yukon (*Summer Profundal Index Netting* – index des poissons des zones profondes pris au filet en été), du programme SPIN de Parcs Canada, de l'évaluation de la population de lottes du gouvernement du Yukon, du Kluane Lake Fish Derby, et du camp de récolte au lac Simpson. Les pêcheurs autochtones ont été invités à

guideline for commercial sale (0.5 ppm wet weight). Of these 8 fish, 7 were lake trout, and 1 was a northern pike. All lake whitefish, burbot, round whitefish, and inconnu analyzed had mercury levels that were below Health Canada's commercial sale guideline.

participer aux programmes SPIN, ont dirigé le camp de récolte au lac Simpson et ont aidé à traiter les poissons qui ont été prélevés dans le lac Dezadeash. Tous les échantillons ont été analysés pour le mercure total. Sur les 253 échantillons analysés, seuls 8 dépassaient la recommandation de Santé Canada pour la vente commerciale (0,5 ppm (poids humide)). Sur ces 8 poissons, 7 étaient des touladis et 1 était un grand brochet. Tous les grands corégones, les lottes, les ménominis ronds et un inconnu analysés présentaient des taux de mercure inférieurs à la recommandation de Santé Canada pour la vente commerciale.

Key messages

- Of 253 fish analyzed (including 6 species from 8 lakes), only 3% exceeded the Health Canada guideline for commercial sale of fish (0.5 ppm wet weight).
- All round whitefish, lake whitefish, and inconnu analyzed were below the Health Canada guideline.
- All burbot from Dezdeash Lake and lake trout from Kluane Lake were below the Health Canada guideline.

Messages clés

- Sur les 253 poissons analysés (dont 6 espèces de 8 lacs), seuls 3 % dépassaient la recommandation de Santé Canada pour la vente commerciale des poissons (0,5 ppm (poids humide)).
- Tous les corégones ronds, les grands corégones et les inconnus analysés présentaient des concentrations inférieures à la recommandation de Santé Canada.
- Toutes les lottes du lac Dezdeash et tous les touladis du lac Kluane présentaient des concentrations inférieures à la recommandation de Santé Canada.

Objectives

Determine mercury levels in fish that are incidental mortalities of the SPIN sampling program and the burbot population assessment, and investigate:

- magnitude of among-lake variation in key food fish species – e.g., lake trout, lake whitefish and burbot; and
- drivers of among-lake variation. Fish mercury levels will be related to fish size, fish age, and stable isotope ratios.

Introduction

To predict effects of climate change on fish mercury levels in Yukon, we must first understand what factors are driving differences in fish mercury levels among lakes. Mercury levels in freshwater food fish reflect a complex interaction of physical, chemical, and biological factors, and many of these factors will be affected by climate change. Ongoing research in the Dehcho region of the Northwest Territories is showing that among-lake differences in fish mercury levels are driven by the amount of algae in lakes, size of lakes and catchments, land cover in catchments, and lake water chemistry. The best predictors of among-lake differences in fish mercury differ among species, however, when placing the results of a recent (2015) NCP-funded study on fish mercury levels in Kluane Lake, YT, into a larger regional context, we found that size-standardized (at 555 mm fork length) mercury levels in lake trout in Yukon lakes varied by more than 10-fold (figure 1). The drivers of this variation are unknown, and in some cases, data are > 10 years old. In this study, we are proposing to capitalize on samples that will be made available through Yukon Government's SPIN program (Summer Profundal Index Netting; fish assessment program) to further investigate among-lake variation in fish mercury levels in Yukon, and begin to assess what variables are driving among-lake differences. This value-added, collaborative research project will allow Indigenous peoples to choose the safest and healthiest sources of fish in Yukon lakes.

Figure 1. Size-standardized (at 555 mm fork length) mercury levels in lake trout from Kluane Lake (orange, far left), and from all other lakes for which mercury and fork length data were available in Yukon (yellow), Northwest Territories (blue), and Nunavut (green). The solid dashed line represents the commercial sale guideline (0.5 ppm wet weight). The dashed red line represents 0.2 ppm wet weight. Note: at the time of the study, we were unable to access data for either Kusawa Lake or Laberge Lake.

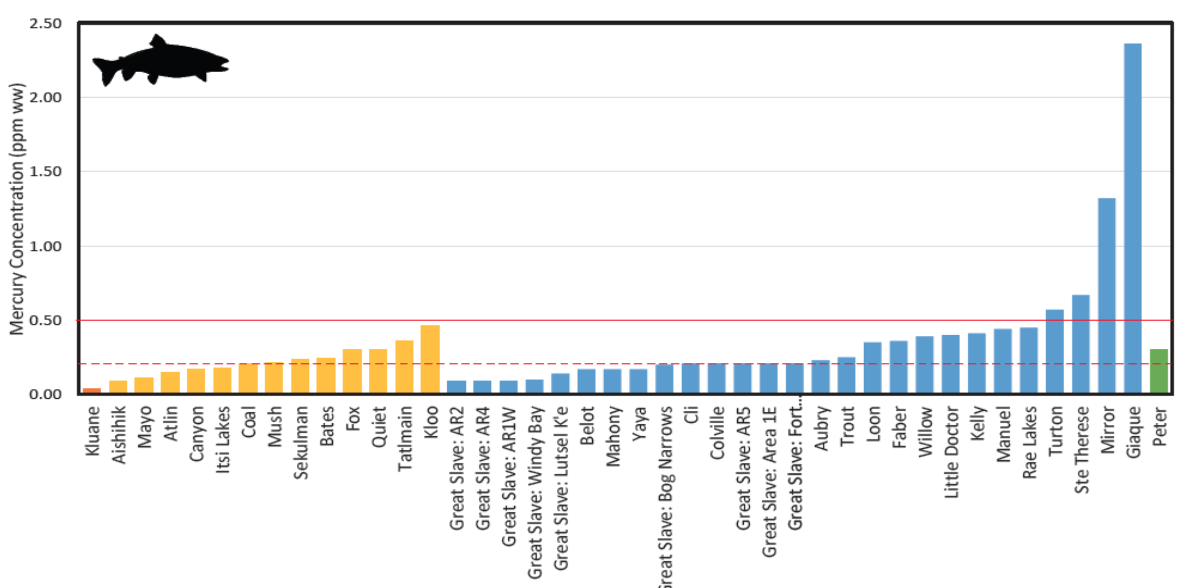
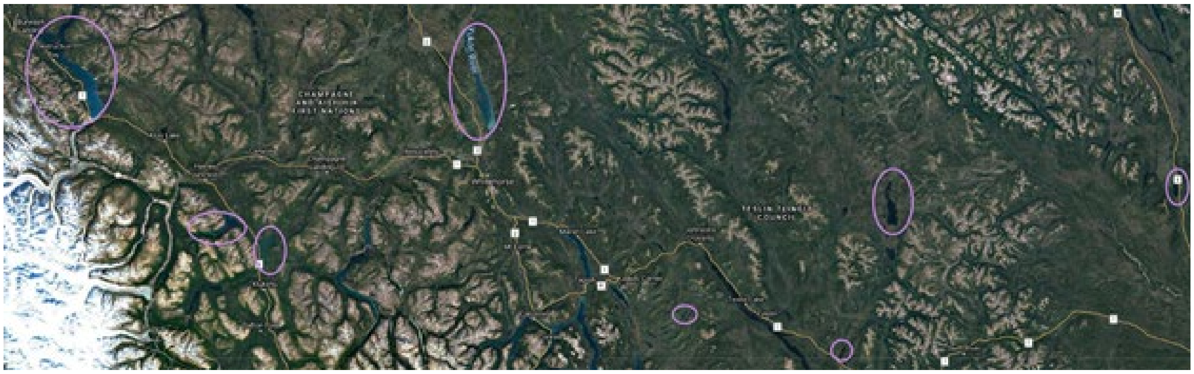


Figure 2. Image of the 8 study lakes.



Activities in 2018-2019

Fish samples from 8 lakes (Figure 2) were collected and submitted to University of Waterloo for analysis of total mercury from several programs, including SPIN programs, a burbot population assessment, a derby, and a harvest camp. Analyses of mercury and stable isotope ratios was completed, and mercury levels in fish were related to stable isotope ratios and fish size for each lake and species.

Community engagement

As this project relied on incidental samples provided by Yukon Government (YG), they were the lead agency in consulting communities prior to the SPIN surveys. Mary Gamberg led communication with the Yukon Contaminant Committee and First Nations within whose traditional territory fish were sampled.

During all stages of the project, the *NCP Guidelines for Responsible Research* were followed in addition to research protocols defined by First Nations Partners. Protocols such as the adoption of OCAP (Ownership, Control, Access, Possession) were and will be adhered to, allowing principles to be adopted and upheld throughout the project duration.

Capacity building

This project relied on opportunistic provision of samples from YG and Parks Canada, who regularly invite First Nations and Renewable Resource Council members to join them on their surveys. In addition, Gamberg participated in a harvest camp with the Liard First Nation (Simpson Lake). During this time, she demonstrated how to extract otoliths and to take fish samples in a trace-element-clean way for contaminant analysis. Conversations about contaminants were frequent during the camp, as many of the fishers were interested in what contaminants were of concern and how they get in the fish.

Communications

This project was developed in direct response to a request from the Yukon Contaminants Committee. Once lake selection was finalized, the lead sampling agencies consulted with appropriate First Nations and resource councils to determine their interest and level of support. This is normally done as part of the regularly scheduled SPIN surveys and burbot population surveys. All the groups listed as Clients/Partners will be sent the results of the project in the form of an NCP synopsis report and plain language summaries. Gamberg was available locally, throughout the project to provide updates to the Yukon Contaminant Committee, affected First Nations and others with concerns or questions regarding the project.

Results and outputs/deliverables

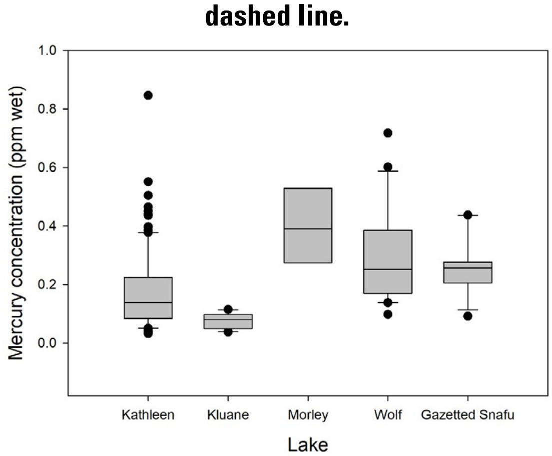
Of 253 dorsal muscle samples analyzed, only 8 exceeded Health Canada's Commercial Sale Guideline of 0.5 ppm wet weight (Table 1). Concentrations ranged from 0.032 ppm ww (lake trout in Kathleen Lake) to 1.082 ppm ww (a 900 mm northern pike in Lake Laberge). Exceedances occurred in 7 lake trout (3 from Kathleen Lake, 2 from Morley Lake, 2 from Wolf Lake) and 1 northern pike (Lake Laberge). All fish from Dezadeash (burbot; n = 21), Kluane (lake trout; n = 13), and Simpson lakes (northern pike; n = 4, round whitefish; n = 2) were below the Health Canada mercury guideline. All inconnu, lake whitefish, and round whitefish analyzed had mercury concentrations that were below guideline. All lake trout from Kluane Lake had mercury concentrations that were well below guideline (Figure 3).

Table 1. Total mercury concentrations in fish muscle collected from several lakes in Yukon Territory during summer 2018.

Lake	Species	Mean (ppm ww)	Range (ppm ww)	n	Percent Exceed[1]
Dezadeash Lake	burbot	0.201	0.062-0.483	21	0
Gazetted Snafu	lake trout	0.264	0.092-0.438	11	0
Kathleen Lake	lake trout	0.177	0.032-0.846	113	3
	round whitefish	0.270	0.180-0.419	31	0
Kluane Lake	lake trout	0.076	0.0.38-0.114	13	0
Lake Laberge	inconnu	0.299	0.209-0.419	5	0
	lake whitefish	0.075	0.038-0.101	10	0
	northern pike	1.082	NA	1	100
Morley Lake	lake trout	0.387	0.151-0.570	7	29
	lake whitefish	0.07	0.04-0.128	8	0
Simpson Lake	northern pike	0.292	0.166-0.413	4	0
	round whitefish	0.097	0.072-0.121	2	0
Wolf Lake	lake trout	0.293	0.098-0.718	20	10
	lake whitefish	0.06	0.04-0.087	7	0

[1] Percentage of fish (of total analysed from that lake) that exceeded the Health Canada Commercial Sale Guideline

Figure 3. Box plots of raw mercury concentrations (parts per million wet weight) in lake trout muscle tissue collected from Yukon lakes in summer 2018. Health Canada's Commercial Sale Guideline of mercury (0.5 ppm wet weight) is shown as a red dashed line.



Statistical analyses were best suited to the data from Kathleen Lake, as sample sizes were highest for this lake. Mercury levels in lake trout from Kathleen Lake were significantly and positively related to both fish size and trophic position, but the best predictor was trophic position, as inferred from d15N ratios (Table 2). While fork length explained 12% of the observed variation (Linear regression, t = 4.05, p<0.0001, df = 1,111), d15N ratios explained 62% of the observed variation in total mercury concentrations in lake trout from Kathleen Lake (Linear regression, t = 13.39 p<0.0001, df = 1, 111) (Figure 4). Further, there was a significant and negative relationship between d15N ratios and d13C ratios in lake trout from Kathleen Lake (Linear regression, t = -5.61, p<0.0001, df = 1,111, R2 = 0.22), indicating that lake trout that fed more offshore (more negative d13C ratios) occupied a higher trophic position (and had higher mercury concentrations). Mercury levels in round whitefish from Kathleen Lake were positively and significantly related to d15N ratios, indicating that mercury increased with trophic position. Interestingly, mercury levels in round whitefish were not related to fish size (Table 2).

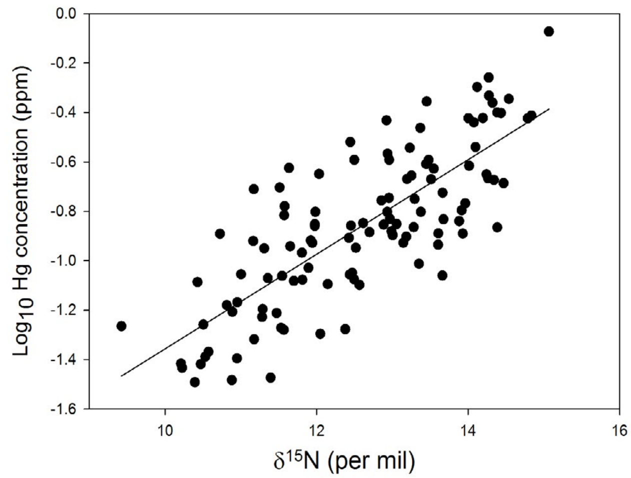
Other significant correlations included a positive relationship between mercury levels and fish size in burbot from Dezadeash Lake. Mercury levels in burbot from Dezadash Lake were also positively and significantly related to d15N ratios and negatively and significantly related to C:N ratios (Table 2). This means that burbot in Dezadeash Lake have higher mercury levels when they are larger and feed at a higher trophic position, and that mercury levels decrease with increasing lipid content.

In Gazetted Snafu Lake and Wolf Lake, mercury levels in lake trout were positively and significantly related to fish size. Mercury levels in lake trout in Wolf Lake were also positively related to d13C ratios; this indicates that lake trout that feed more offshore have lower mercury levels than those that feed more inshore in Wolf Lake, which is opposite to what is commonly observed (Table 2).

In general, mercury levels in lake whitefish were not significantly related to covariates. In Morley Lake, however, mercury levels in lake whitefish increased significantly with fish size. Interestingly, mercury levels in lake trout from Morley Lake were not related to fish size, they did increase significantly with trophic position (Table 2).

Statistical analyses for many of the other lake/species combinations should be regarded with caution, as sample sizes were often quite low. Table 2 summarizes significant correlates of fish mercury levels for each lake and species combination. Mercury levels were correlated with fish length, size, and stable isotope ratios. Age data were only available for Simpson Lake and Lake Laberge.

Figure 4. Mercury concentrations in lake trout muscle tissue from Kathleen Lake as a function of d15N, an index of trophic position (Linear regression, t = 13.39, p<0.0001, df = 1,11, R2adj = 0.66). Lake trout feeding at a higher trophic position had higher mercury concentrations



Discussion and conclusions

The results to date indicate that mercury concentrations in fish from a variety of Yukon lakes are in general below Health Canada's commercial sale guideline; only 8 of 253 fish had mercury concentrations greater than 0.5 ppm wet weight. All lake whitefish, round whitefish, burbot and inconnu tested had mercury levels below guideline. Four northern pike from Simpson Lake and 13 lake trout from Kluane Lake also had mercury levels below guideline. Of the 8 exceedances, 7 were lake trout, and 1 was a northern pike. In Kathleen Lake, mercury levels in lake trout were better predicted by trophic position than by fish size. lake trout that fed more offshore, on a pelagic-based food web, also had higher mercury levels than lake trout that fed on a more benthic-derived food web. In Dezadeash Lake, mercury levels in burbot were related to fish size, trophic position, and lipid content, and for other lake/species combinations, fish size and trophic position were most often the best correlates of mercury level (if any were significant). Results are being communicated to all partners and to Indigenous groups that use the sampled lakes for subsistence fishing.

Table 2. Results of correlation analyses between fish mercury levels and fish length, weight, age (Lake Laberge only) d15N, d13C, and C:N ratios (indicator of lipid). Analyses were not conducted for Simpson Lake, or for northern pike and inconnu from Lake Laberge due to low sample size.

Species	Lake	Covariates					
		Length	Weight	$d^{15}N$	$d^{13}C$	C:N	Age
lake trout	Gazetted Snafu	p=0.016, r=0.83	p=0.0075, r=0.75	n.s.[1]	n.s.	n.s.	n.s.
	Kathleen	p=0.0001, r=0.35	P-0.0024, r=0.29	p<0.0001, r=0.79	p<0.0001. r=-0.42	n.s.	n.s.
	Kluane	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Morley	n.s.	n.s.	p=0.025, r=0.82	n.s.	n.s.	n.s.
	Wolf	p=0.0007, r=0.71	p=0.0010, r=0.69	n.s.	p=0.027, r=0.49	n.s.	n.s.
round whitefish	Kathleen	n.s.	n.s.	p=0.0005, r=0.578	n.s.	n.s.	n.s.
lake whitefish	Laberge	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Morley	p=0.0074, r=0.85	p=0.026, r=0.77	n.s.	n.s.	n.s.	n.s.
	Wolf	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
burbot	Dezadeash	p<0.0001, r=0.90	p<0.0001, r=0.86	p<0.0001, r=0.85	n.s.	p=0.0014, r=-0.71	n.s.

[1] abreviation: n.s., not significant

Expected project completion date

December 31, 2019

Acknowledgments

Little Salmon Carmacks First Nation, Liard First Nation, Champagne-Aishihik First Nation, Kluane First Nation, Kluane Lake Athletic Association, Council of Yukon First Nations, Indigenous fishers who participated in SPIN work on all sampled lakes, First Nations who worked with YG on SPIN-sampled lakes, Parks Canada, and YG Fisheries staff who collected most of the samples. We would also like to thank the NCP for their funding and support.

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

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Project team/Équipe de projet

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Project locations/Emplacements 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 persistent organic pollutants (POPs) 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 of these pollutants are decreasing, increasing or not changing over time; where these pollutants 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 to test atmospheric models that explain how contaminants move from sources in the South to

Résumé

L'atmosphère est la voie la plus rapide pour les polluants organiques persistants (POP) d'atteindre l'Arctique. Depuis 1992, ce programme de surveillance mesure les polluants organiques dans l'air de l'Arctique. La variation des concentrations de polluants organiques au fil du temps aide les chercheurs à déterminer si les concentrations atmosphériques de ces polluants diminuent, augmentent ou sont stables dans le temps, la provenance des polluants, les quantités par région et les conditions climatiques qui influencent leur déplacement vers l'Arctique. Les résultats de ce projet servent à négocier et à évaluer les accords internationaux de lutte contre les polluants organiques et à mettre à l'essai des modèles atmosphériques qui expliquent le

the Arctic. Starting in 1992, we have monitored POPs at Alert, Nunavut. In 2006, the program was extended 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. Additionally, a passive flow-through sampler (FTS) specifically designed for use in cold environments has been deployed at Little Fox Lake, Yukon, since August 2011. Here, we updated the time trends of selected halogenated flame retardants (HFRs) from data collected at Alert during 2008 to 2016.

déplacement des contaminants du Sud vers l'Arctique. Depuis 1992, nous surveillons les POP à Alert, au Nunavut. En 2006, le programme a été élargi 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 perfluoroalkylées et polyfluoroalkyliques (PFAS) utilisées dans les produits antitaches. De plus, un échantillonneur passif à circulation continue spécialement conçu pour être utilisé dans un climat froid est installé au lac Little Fox, au Yukon, depuis août 2011. Nous y avons mis à jour les tendances temporelles de certains produits ignifuges halogénés (RFH) à l'aide des données recueillies à Alert entre 2008 et 2016.

Key messages

- Air monitoring for organic pollutants at Alert, Nunavut, and Little Fox Lake, Yukon, and measurements are ongoing.
- Air concentrations of some halogenated flame retardants (HFRs) started to decline or level off at Alert from 2008 to 2016.

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 certains produits ignifuges halogénés (RFH) ont commencé à diminuer ou à se stabiliser à Alert entre 2008 et 2016.

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 their 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; and
- contributing information for the evaluation of the overall effectiveness of provisions outlined in the Stockholm Convention on POPs and the Long-Range Transboundary Air Pollution (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. current-use pesticides (CUPs), PFASs used as stain-repellents and new flame retardants (FRs) were included in Arctic air measurements at Alert since 2006. In this report, time trends of selected HFRs measured in air at Alert are updated up to 2016.

Activities in 2018-2019

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. Time trends of HFRs (i.e. non-BDE FRs) in air at Alert up to 2016 were analyzed.

Scientific communications

The air monitoring results of hexachlorobutadiene (HCBD) and CUPs measured at Alert has been included in two scientific publications "Balmer, J. E., Hung, H., Vorkamp, K, Letcher, R. J., Muir, D. C. G. (2019) Hexachlorobutadiene (HCBD) contamination in the Arctic environment: A review. Emerging Contaminants, 5: 116-122" and "Balmer, J. E., Morris, A. D., Hung, H., Jantunen, L., Vorkamp, K., Rigét, Evans, M., Houde, M., Muir, D. C. G. (2019) Levels and trends of CUPs in the Arctic: An updated review, 2010-2018. Emerging Contaminants, 5: 70-88", respectively, as part of a special issue in *Emerging Contaminants* to present chapters in the Arctic Monitoring and Assessment Programme (AMAP) Chemicals of Emerging Arctic Concern (CEAC) Assessment as scientific publications.

A paper summarizing atmospheric levels and trends of polycyclic aromatic hydrocarbons (PAHs) measured in air at three AMAP Arctic stations, namely Alert (Canada), Zeppelin (Svalbard/Norway) and Pallas (Finland) has been published: "Yu, Y., Katsoyiannis, A., Bohlin-Nizzetto, P., Brorström-Lundén, E., Ma, J., Zhao, Y., Wu, Z., Tych, W., Mindham, D., Sverko, E., Barresi, E., Dryfhout-Clark, H., Fellin, P., Hung, H. (2019) Polycyclic aromatic hydrocarbons not declining in Arctic air despite global emission reduction. Environ. Sci. Technol., 53, 2375–2382." This paper showed that PAHs in Arctic air has not been declining although global emissions have been decreasing. PAH levels in Arctic air may be sustained by volatilization due to a warming climate and the increase in forest fire events.

Air samples collected at Alert were screened for synthetic musk compounds (SMCs) and none were found in most samples. Results have been published in "Wong, F., Robson, M., Melymuk, L., Shunthirasingham, C., Alexandrou, N., Shoeib, M., Luk, E., Helm, P., Diamond, M. L., Hung, H. Urban sources of synthetic musk compounds to the environment. (2019) Environmental Science: Processes & Impacts, 21: 74 – 88". It was concluded that it is unlikely that the SMCs are subjected to long-range transport.

Our project leader, Hayley Hung, presented the time trends of PFASs, emerging FRs, PAHs and other chemicals measured at Alert and Little Fox Lake in two oral presentations at the 38th International Symposium on Halogenated Persistent Organic Pollutants (POPs) (DIOXIN) Conference in Krakow in August 2018 and at the 29th Inter-American Congress of Chemical Engineering/68th Canadian Chemical Engineering Conference in Toronto in November 2018. She has also presented these results at a lunch time seminar at the Université du Québec à Rimouski (UQAR) on November 2, 2018.

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).

1. Iqaluit, January 2018

On January 24, 2018, Sandy and Hayley conducted a half-day guest lecture with a half-day hands-on activity session to students in the Environmental Technology Program (ETP) at the Nunavut Arctic College (NAC). We had great discussions with our partners at the school. We met with Jamal Shirley to discuss ideas on how to develop a co-leadership project for the passive mercury sampling project. We also had a fruitful meeting with the Nunavut Environment Contaminants Committee (NECC) on January 25 to update our project plans to better address the needs of the community with respect to those plans. We returned to the NAC in January/February 2019 for a similar lecture. In response to last year's cultural review recommendations, we will return to the NAC in Iqaluit once every two years, which will align with the ETP program's curriculum (a two-year program) and visit another community college to conduct the same workshop. We will visit Cambridge Bay in January 2020 and conduct a similar workshop with the ETP program at the NAC there.

2. Whitehorse, February 2018

Hayley visited Whitehorse February 4 to 7, 2018. She gave two lectures at the Yukon College regarding contaminants in Arctic air, one for the course of "Yukon Source Water Protection & Watershed Stewardship" and another for the course of "Environmental Change and Community Health" (both course with Instructor Larry Gray). She also gave a presentation at the weekly meeting of the Environment Directorate at the CIRNAC office in Whitehorse and met with the Regional Contaminants Committee (RCC) during their proposal review meeting to answer questions related to this proposal. Hayley also met with Derek Cooke (TKC) and Jamie Thomas to work on the draft IK report.

3. Nain, October 2018

Sandy and Hayley visited Nain from September 25 to 27, 2018. We have tried to contact the high school to give a presentation to the science class before the trip but could not reach the Principal by phone. The community had no power, phone connection and water for an extended period of time before our trip which hindered our abilities to pre-plan visits within the community. Both Carla Pamak and Liz Pijogge helped us in contacting the school, but a presentation could not be scheduled during our visit. During this trip, we conducted a site visit and deployed the mercury passive air sampler and performed a site inspection. We met with Liz Pijogge, Carla Pamak and Rudy Riedlsperger to discuss issues related to the sample shipments of the project, discuss the new mercury passive air samplers and discuss the new shelter for the XAD-PAS with the wind spoilers. We also visited with Rodd Liang to update him on our latest accomplishments within the passive sampling project. We would like to acknowledge Carla and Liz's help during our visit and hosting us at the Nain Research Center to reduce the cost of the trip.

4. Whitehorse, February 2019

February 24-27, 2019, Hayley, Sandy and Geoff travelled to Whitehorse. Hayley and Sandy met with the Yukon Contaminants Committee (YCC) to discuss about the NCP projects, discuss the implementation of the new mercury passive sampling project and their plans to communicate project results. Sandy and Hayley gave two lectures at the Yukon College at Instructor Larry Gray's courses about contaminants in the Arctic. Sandy and Geoff went to the Little Fox Lake site with their local partner Dylan Nordin from Laberge Environmental and performed their annual site visit and maintenance.

6. Iqaluit, February 2019

Sandy, Hayley and Liisa visited Iqaluit again between February 3 and 6 to conduct a half-day guest lecture with a half-day hands-on activity session with students in the ETP at the Nunavut Arctic College. Unfortunately, due to a leak in the lab, we were unable to fully complete the hands on activities in the lab but met with the students in the classroom for some experiments and great discussion. 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 Council of Yukon First Nations (CYFN), in consultation with Derek Cooke (TKC), to undertake an IK subproject under M-03 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. On 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: 1. General knowledge of contaminants in the north, 2. knowledge of weather patterns, 3. forest fires, 4. mining, and 5. environmental change. Jamie prepared a draft report summarizing the discussions. The team worked with Jamie to summarize her findings from the interviews in a final report. The report has been finished and, through TKC, we will seek approval from the Elders for release of this report. We are hoping to be able to share the report with all RCCs and the NCP Secretariat in 2019.

Results and outputs/deliverables

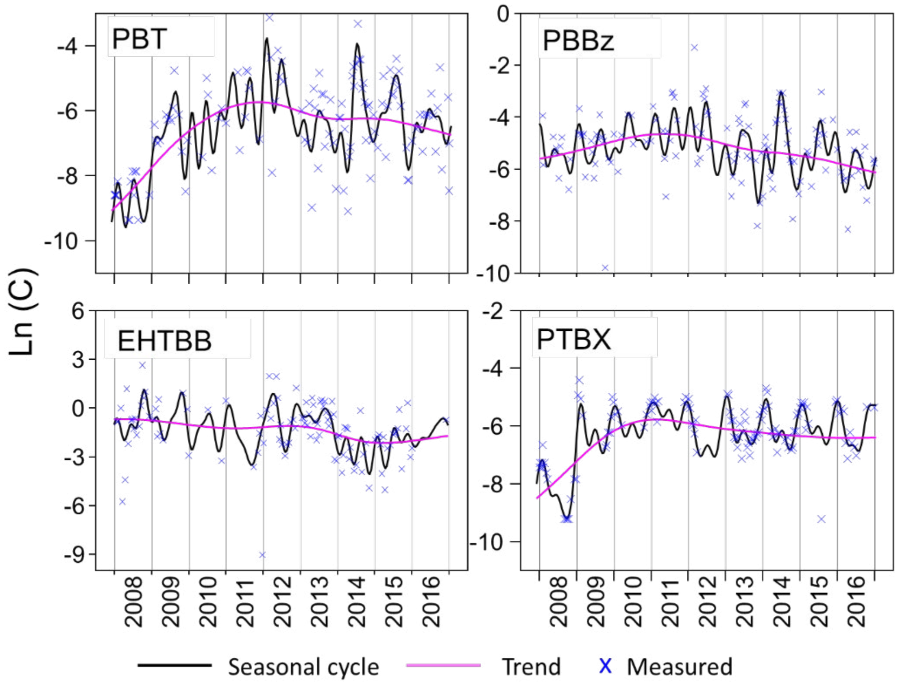
The air samples were analyzed for halogenated flame retardants (HFRs). These HFRs do not include polybrominated diphenyl ethers (PBDEs). Target HFRs were: 2,4,6-tribromophenyl allyl ether (TBP-AE or ATE), 2-bromoallyl-2,4,6-tribromophenyl ether (TBP-BAE or BATE), tetrabromochlorotoluene (TBCT), pentabromotoluene (PBT), hexabromobenzene (HBBz), 2,2',4,5,5'-pentabromobiphenyl (BB-101), pentabromobenzyl acrylate (PBBA), dechlorane plus syn/anti (DDC-CO syn/anti), octabromotrimethylphenylindane (OBTMPI or OBIND), 2-ethylhexyl-2, 3, 4, 5-tetrabromobenzoate (EHTBB), tetrabromo-*p*-xylene (PTBX), pentabromobenzene (PBBz), bis(2-ethylhexyl)tetrabromophthalate (BEH-TEBP), 1,2-Bis(2,4,6-tribromophenoxy)-ethane (BTBPE), pentabromoethylbenzene (PBEB), and 2,3-dibromopropyl 2,4,6-tribromophenyl ether (TBP-DBPE or DPTE).

In summary, many of the target HFRs were found in the air but their detection frequencies were less than 50%. TBCT, DPTE and OBTMPI were not detected at all. The HFR concentrations were generally very low compared to PBDEs and the blank levels varied significantly from year to year. Therefore, the data presented here have been blank-corrected using the annual average field blank values before the trends were developed. This data handling method differs from that for other chemicals, for which no blank correction is done. When no blank correction is done, all values below the detection limit are replaced by 2/3 instrument detection limit.

Time trends of HFRs from 2008 to 2016 in air at Alert were derived using the digital filtration method. HFRs that were detected in more than 50% of the samples were analyzed. Details of the analytical method, time trends analysis and data treatment are given in Wong et al. (2018). Results are presented for PBT, PBBz, EHTBB and PTBX in Figure 1.

Figure 1 shows that EHTBB and PBBE exhibited decreasing trends with half-lives ($t_{1/2}$) of 4.1 and 8.1 years (y) respectively. PBT and PTBX showed increasing trends with doubling times of ($t2$) of 4.2 and 6.9 y respectively. Although PBT and PTBX showed overall increasing time trends, visual inspection of their trends indicated that their concentrations were levelling off since 2010.

Figure 1. Time trends of PBT, PBBz, EHTBB and PTBX in air in Alert from 2008 to 2016. X-axis is the year of sampling; y-axis is air concentration (*C*, pg/m3) in natural logarithmic (Ln) form.



Discussion and conclusions

As PBDEs are being phased out, many new flame retardants are put into the market, even though little is known about their movements in the environment. For example, DP-45, Firemaster 550 and Firemaster BZ-54 were used to replace the Penta-BDE mixture. The major components of these commercial products are EHTBB and BEH-TEBP. Here, we found that EHTBB was one of the most frequently detected FR in air at Alert, with detection frequency of 54%. Other replacement FRs were found in the air at Alert but their levels were low. Similar observations were reported in air at Little Fox Lake, Yukon by Yu et al., (2015) and it was suggested that these chemicals may have come from sources in East Asia, Russia, the Pacific, as well as Northern Canada.

Air concentrations of PBBz at Alert appeared to be higher in the summer than winter which indicates secondary emission is the source. On the other hand, PTBX showed an opposite trend in which its concentration was higher in the winter than in summer (Figure 1). PTBX may undergo enhanced photo-degradation in the summertime. Air concentrations of PBT and EHTBB did not show obvious seasonality in which their levels were sporadic throughout the year. The occurrence of these chemicals in Arctic air are mainly due to ongoing primary emissions.

Expected project completion date

Ongoing

Project website

Meta data of this project are included in the Polar Data Catalogue (https://www.polardata.ca/) PDC Record #762 and 10855

Air monitoring data at Alert are provided in the AMAP database of EBAS (http://ebas.nilu.no/)

Acknowledgments

We would like to thank the Northern Contaminants Program (NCP) for supporting the atmospheric measurement at Alert and Little Fox Lake. ECCC's Chemicals Management Plan (CMP) co-funded the analysis of emerging contaminants in Arctic air samples. The authors would also like to thank the Canadian Forces Station (CFS) Alert for supporting sample collection.

References

Wong, F., Shoeib, M., Katsoyiannis, A., Echardt, S., Stohl, A., Bohlin-Nizzetto, P., Li, H., Fellin, P., Su, Y., Hung, H. 2018. Assessing temporal trends and source regions of per- and polyfluoroalkyl substances (PFASs) in air under the Arctic Monitoring and Assessment Programme (AMAP), Atmos. Environ. 172, 65-73.

Yu, Y., Hung, H., Alexandrou, N., Roach, P., Nordin, K. Multiyear measurements of flame retardants and organochlorine pesticides in air in Canada's western sub-Arctic. Environ. Sci. Technol., 2015, 49, 8623 – 8630.

Mercury measurements at Alert and Little Fox Lake

Mesure du mercure à Alert et au lac Little Fox

Project leader/Chef de projet

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Project team/Équipe de projet

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Project locations/Emplacements du projet

- Little Fox Lake, YK
- Alert, NU

Abstract

Mercury (Hg) is a priority pollutant of concern in Canada, especially in Arctic regions. The Arctic primarily receives Hg via long range transport from regions that are mainly from outside of Canada. Through this project we have collected 24 and 11 years of atmospheric Hg concentration measurements at Alert, NU and Little Fox Lake, YK, respectively. These are some of the world's longest records of Hg in the atmosphere and provide significant information on the long-term trends of this toxic chemical in Canadian air. Our results from atmospheric Hg concentration measurements at Alert, Nunavut show a median decreasing trend of 1.37 ± 0.21% per year from 1995 to 2018. In contrast, Hg concentrations at Little Fox Lake, Yukon show an increasing median trend of 0.96 ± 0.31% per year from 2007 to 2018. These measured trends reflect both the increases in Hg emissions that come into Canada in the western Arctic and the global leveling off of Hg emissions as seen in the high Arctic. The project team worked with the Regional Contaminants Committees in both

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. Grâce à ce projet, nous avons recueilli des mesures de la concentration atmosphérique de Hg sur 24 et 11 ans à Alert (Nunavut) et Little Fox Lake (Yukon), respectivement. Ces mesures sont parmi les plus anciennes au monde et fournissent des informations importantes sur les tendances à long terme de cette substance chimique toxique dans l'air canadien. 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 1,37 ± 0,21 % par année entre 1995 et 2018. En revanche, les concentrations de mercure mesurées au lac Little Fox, au Yukon, montrent une tendance médiane à la hausse (+0,96 % ± 0,31 % par année de 2007 à 2018). Ces tendances mesurées

Nunavut and the Yukon to discuss project plans and ideas for this work. Also, the project team travelled to Whitehorse and Iqaluit to work with students on improving their understanding of the transport and fate of contaminants in the Arctic air.

reflètent à la fois l'augmentation des émissions de Hg qui arrivent au Canada dans l'ouest de l'Arctique et la stabilisation mondiale des émissions de Hg, comme on le constate dans le Haut-Arctique. 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. L'équipe du projet s'est également rendue à Whitehorse et à Iqaluit pour travailler avec des étudiants afin d'améliorer leurs connaissances sur le transport et le devenir des contaminants dans l'air arctique.

Key messages

- Atmospheric mercury concentration measurements have been collected at Alert, Nunavut since 1995 and at Little Fox Lake, Yukon since 2007. Alert is the longest record of mercury in the atmosphere in the Arctic.
- Gaseous elemental mercury levels at Alert have decreased annually from 1995 to present and at Little Fox Lake have increased annually from 2007 to present.
- The trends assessed using the data collected in the program can be used to reflect changes in regional and global Hg emissions.
- The data collected as part of this program is 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 données recueillies à Alert sont les plus anciennes sur le mercure dans l'atmosphère de l'Arctique.
- Les concentrations de mercure élémentaire gazeux à Alert diminuent chaque année depuis 1995 et augmentent chaque année depuis 2007 au lac Little Fox.
- Les tendances évaluées à l'aide des données recueillies dans le cadre du programme peuvent être utilisées pour refléter les changements dans les émissions régionales et mondiales de Hg.
- Les données scientifiques recueillies dans le cadre de ce programme servent 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 and in the sub-Arctic at the Little Fox Lake 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

Mercury (Hg) is considered a priority pollutant in Canada (CEPA, 1999), a pollutant of concern by the Arctic Council and a contaminant of mutual concern for the Great Lakes Water Quality agreement in Canada. Canadian anthropogenic emissions of Hg to the air have decreased 85% between 1990 and 2010 but ambient air levels have not matched this decrease. Rather, ambient air levels fell in the range of between 10 and 26% from 1995 to 2011 (Steffen et al., 2016). While ambient levels are not expected to directly match emission trends due to the complex biogeochemical behaviour of Hg and the level of natural and re-emissions of Hg, there has been a stark contrast between emission reductions and ambient trends. Global emissions of anthropogenic Hg are changing over time by increasing in some areas and decreasing in others. This is important to understand because 95% of the anthropogenic Hg deposited in Canada comes from sources outside of the country, (Steffen et al., 2016) thus, assessing where the Hg comes from may determine if the levels are going up or down. 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, impacting ambient trends over time. Thus, monitoring of atmospheric Hg is required to evaluate both global and regional changes to the Hg cycle as a result of anthropogenic climate change and human activities.

In 2015, Europe and North America produced a combined total of 7.4% of the world's Hg emissions. East, Southeast and South Asia produced a combined total of 48.7% and South America and Su-Saharan Africa produced a combined total of 34.6% of the world's total anthropogenic Hg emissions (UNEP, 2019). 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; Streets et al., 2019). Atmospheric Hg deposition in the Arctic region is predominantly influenced by the long-range transport from East Asia and Africa (UNEP, 2019). Thus, changes in emissions from regions such as Asia and Africa 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 Hg input from the Pacific Rim (Durnford et al., 2010). The same modelers have shown that Alert is also impacted by East Asia, Europe and North America.

The Minamata Convention on Mercury was ratified in 2017 and, as part of this convention, Canada will contribute data about Hg levels in Arctic regions to evaluate how well the convention, as currently employed, is able to reduce Hg 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.

The data collected by this Northern Contaminants Program (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 2018-2019

Research Activities

Ground-based continuous atmospheric measurements of total gaseous mercury (TGM), gaseous elemental mercury (GEM), reactive gaseous mercury (RGM) and particulate mercury (PHg) continued at Alert. Weekly checks were performed by the Global Atmospheric Watch Station (GAW) lab operator and student, and data is continuously monitored for quality assurance by Geoff and Greg Skelton. Geoff and Sandy made a technical and scientific trip in April/May 2018 and a second technical trip was made in November 2018 by Geoff. Continuous measurements of TGM were also made at Little Fox Lake through 2018-2019, Laberge Environmental Services continued to oversee the site and provide weekly technical support. A technical site and communications/ teaching visit was made in February 2019. A workshop/teaching trip was made to Iqaluit in February 2019.

At Alert, both a secondary speciation system and a stand-alone TGM analyzer collected Hg measurements in the spring of 2018. This was a continuation of experiments performed in 2017 to determine if RGM was capable of passing through filter media and being measured on a TGM system. This research will lead to a better understanding of exactly what species are being measured.

Manual GEM samples for isotope analysis were collected on carbon traps on a weekly basis at Alert for the period of one year. Samples were sent to U of T for analysis.

Data from both sites for 2018 has been reviewed and QC'd for quality control using a newly developed SQL method for flagging. An internal contracting issue with procurement has held up the final export of data for publication by Greg Skelton but this will be done as soon as a new contract is in place. All data up to 2017 is available at the links listed in the links section. 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. All snow samples have been sent to Greg Lawson, Water Science and Technology Branch in Burlington, Ontario. The snow collected as part of the transect project were sent to the University of Alberta for analysis of major ions. Results will be analysed in conjunction with the mercury in snow samples next fiscal year (FY).

Communications, community engagement, capacity building and Indigenous Knowledge

In 2018/2019, Hayley, Geoff and Sandy visited Whitehorse in February 2019. Hayley and Sandy gave lectures at the Yukon College and met with the YCC to discuss the ongoing work of the project. They discussed the idea of a passive Hg sampling project led by Yukoners or Northerners and will continue these discussions. For the past 2 years Hayley and Sandy had been working with Derek Cooke Ta'än Kwach'än Council (TKC) and Jamie Thomas (student), to undertake an Indigenous Knowledge (IK) subproject (under NCP project - *Passive Air Sampling Network for Organic Pollutants and Mercury* – M-03) to improve our knowledge and input from IK on the program. An initial report was provided to Sandy and Hayley from interviews with 4 local Elders. The questions and discussion were based on 5 themes including: 1. general knowledge of contaminants in the north; 2. knowledge of weather patterns; 3. forest fires; 4. mining and 5. environmental change. Hayley and Sandy are still working through the report and putting it together and should have it delivered in FY 2019-2020. Before we share the report, we first want to share it with the participating Elders and have their approval to discuss and share with others. We hope to be able to share the reports with all Regional Contaminants Committees (RCCs) and the NCP Secretariat in early 2019, depending on the outcomes from the discussions with the participating Elders.

Sandy was again part of the Canadian delegation for the second Conference of the Parties (COP2) of the Minamata Convention on Mercury. This is a global multilateral environmental agreement that aims to reduce the harm of Hg the humans and the environment. Canada is a party to this convention and northern Indigenous community members are considered a vulnerable population to the exposure of Hg. Sandy was part of the negotiating team to forward the requirements of Article 22: Effectiveness Evaluation (EE), that will enable Parties to assess how effective the measures taken under the convention are in reducing global Hg. Sandy also presented the M-03 - *Passive Air Sampling Network for Organic Pollutants and Mercury* project at a knowledge lab held by the UN Environment during the COP2 meetings. This provided an opportunity for our NCP programs to be highlighted to other communities around the world who are also considered vulnerable populations, and demonstrates that we can be leaders in the monitoring of Hg transport and deposition to areas of the globe that are not responsible for producing Hg contamination.

In January 2019, Sandy, Hayley and Liisa went to Iqaluit to conduct a half-day guest lecture with a hands-on activity session to students in the Environmental Technology Program at the Nunavut Arctic College. They also met with the NECC to discuss their communication, capacity building and IK plans. Initial discussions about a Nunavut or Northern led program were discussed and it was decided that more discussions would be warranted to get a better idea of how to work out that kind of project.

Primarily, as part of the M-03 project, Sandy and Hayley visited Nain from September 25 to 27, 2018. Prior to visiting Nain, we tried to contact the local high school to make arrangements for a presentation to the science class but could not reach the school principal by phone. We later found out that the community had no power, phone connection and water for an extended period of time before our trip. Both Carla Pamak and Liz Pijogge helped us in contacting the school but a presentation could not be scheduled during our visit. During this trip, we conducted a site visit to where the samplers are collecting air and deployed a fresh mercury passive air sampler. We met with Liz Pijogge, Carla Pamak and Rudy Riedlsperger to discuss issues related to the sample shipment of the project, and discuss the new Hg passive air samplers and the new shelter for the XAD-PAS with the wind spoilers. We would like to thank Carla and Liz for their help during our visit and for hosting us at the Nain Research Center. We also had a brief visit with Rodd Laing, Director of Environment at the Nunatsiavut Government and updated him on our project plans within NCP.

Results

Figure 1a shows the total gaseous mercury (TGM) and gaseous elemental mercury (GEM) daily averages for Alert from 2007 to 2018 and Figure 1b for shows TGM at Little Fox Lake from 2007 to 2018. We have 24 years of this quality-controlled data from Alert (not shown) and 11 years of data from Little Fox Lake. Figure 2 shows a time series of daily Hg mean concentration levels for the speciation data from Alert including reactive gaseous mercury (RGM) and particulate mercury (PHg) from Alert for the period of 2007 to 2018. Figure 3 shows the Mann-Kendall Seasonal trend analysis for atmospheric Hg at Alert during 2 time periods: 1995-2018 and 2007-2018. Figure 4 shows the Mann-Kendall Seasonal trend analysis for atmospheric Hg at Little Fox Lake. Figure 5 shows as experiment from Alert of a TGM and GEM analyzer setup to assess what Hg species are predominantly collected.

Figure 1a (top) and Figure 1b (bottom). TGM and GEM daily averaged time series for Alert (a) and TGM time series for Little Fox Lake (b) from 2007 to 2018.

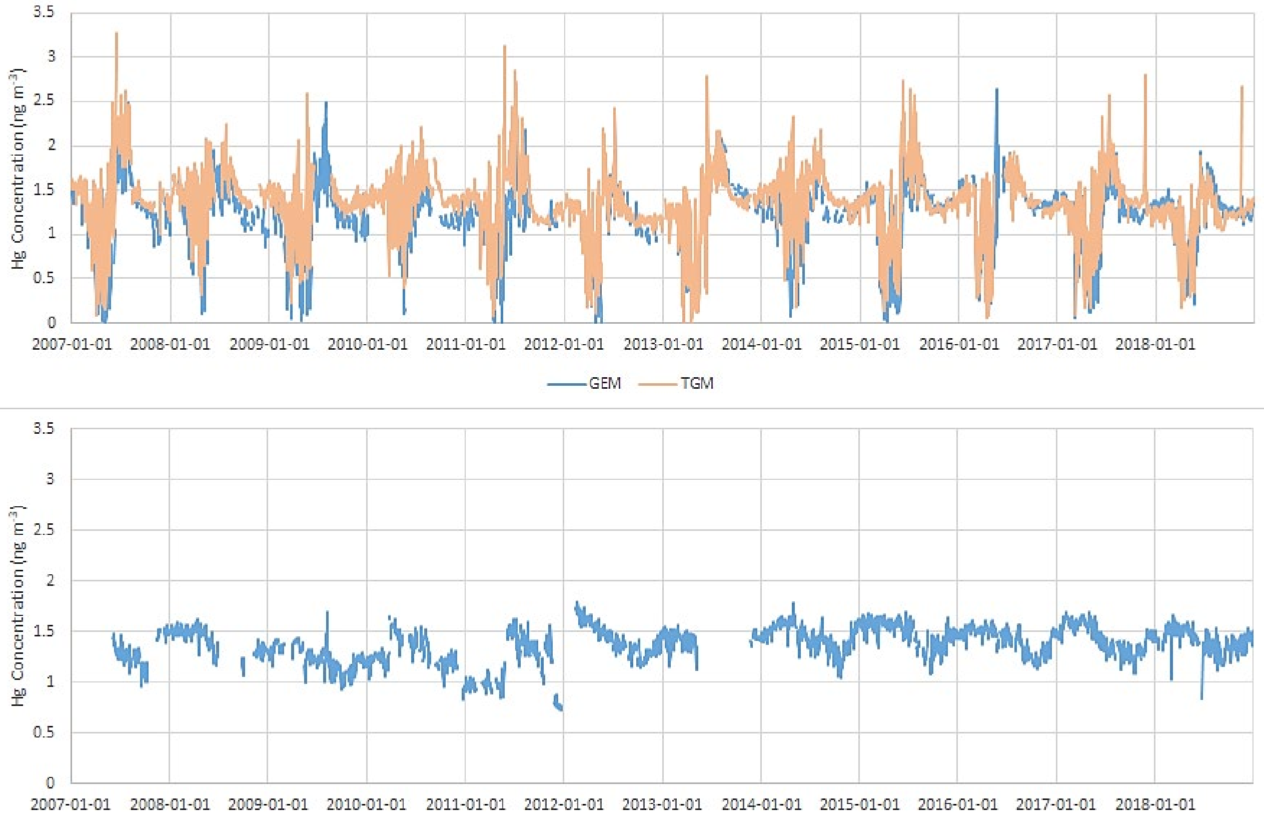


Figure 2. Daily averaged concentration of Reactive Gaseous Mercury and Particulate Bound Mercury measurements in Alert, NU during the 2007-2018 period.

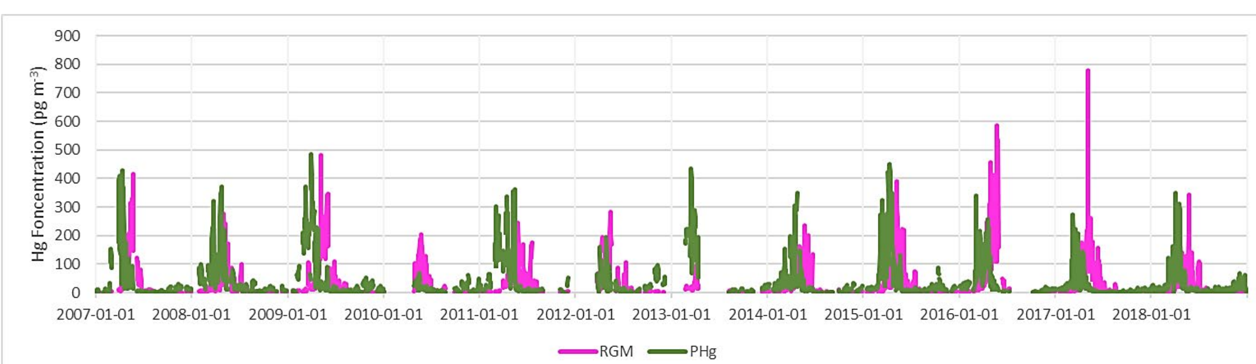


Figure 3. Mann-Kendall monthly trend analysis for TGM observations in ng m-3yr-1 from Alert for the period of 1995-2018 (dark blue) and 2007-2018 (light blue).

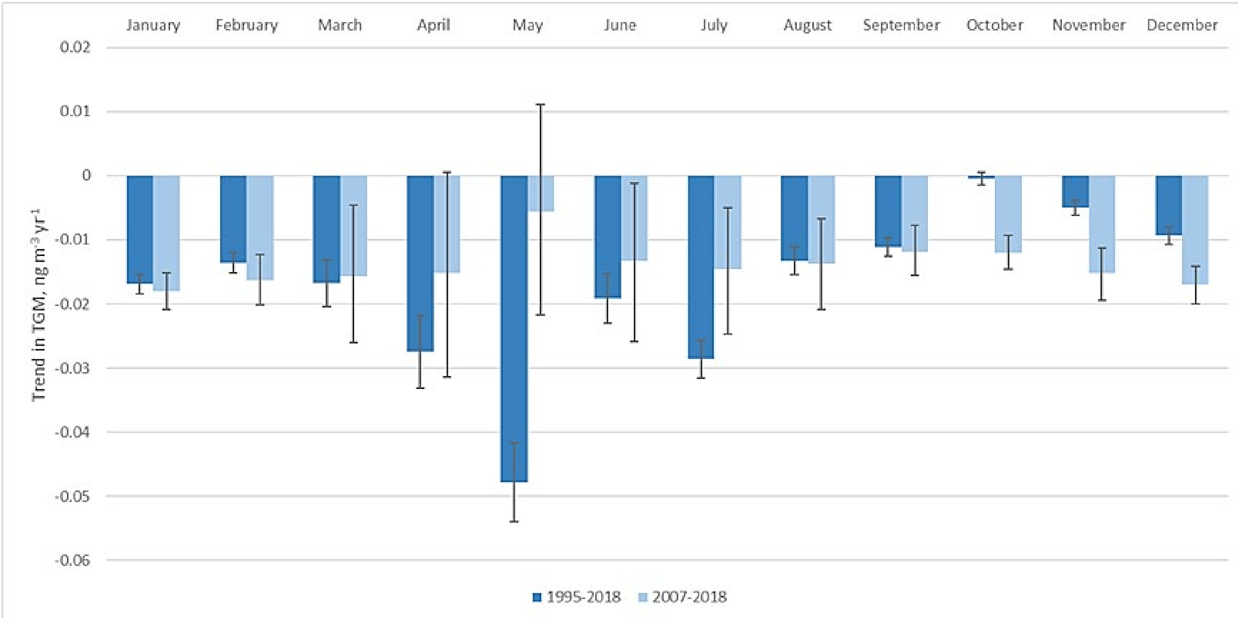


Figure 4. Mann-Kendall monthly trend analysis for TGM observations in ng m-3yr-1 from Little Fox Lake, YT for the period of 2007-2018.

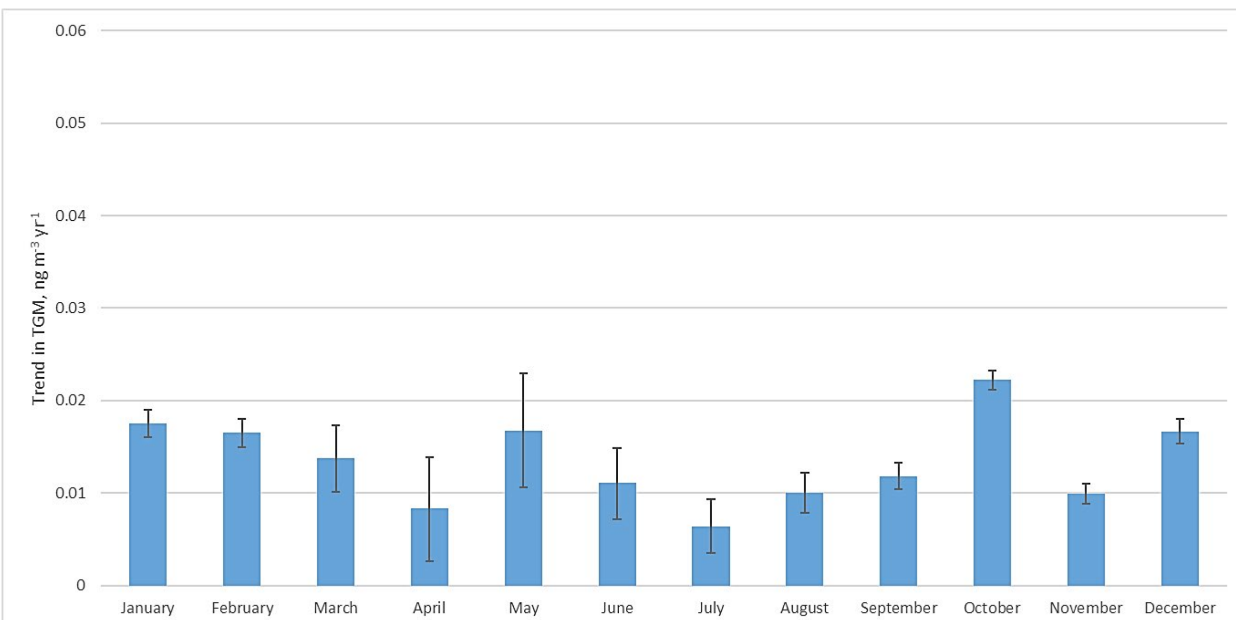
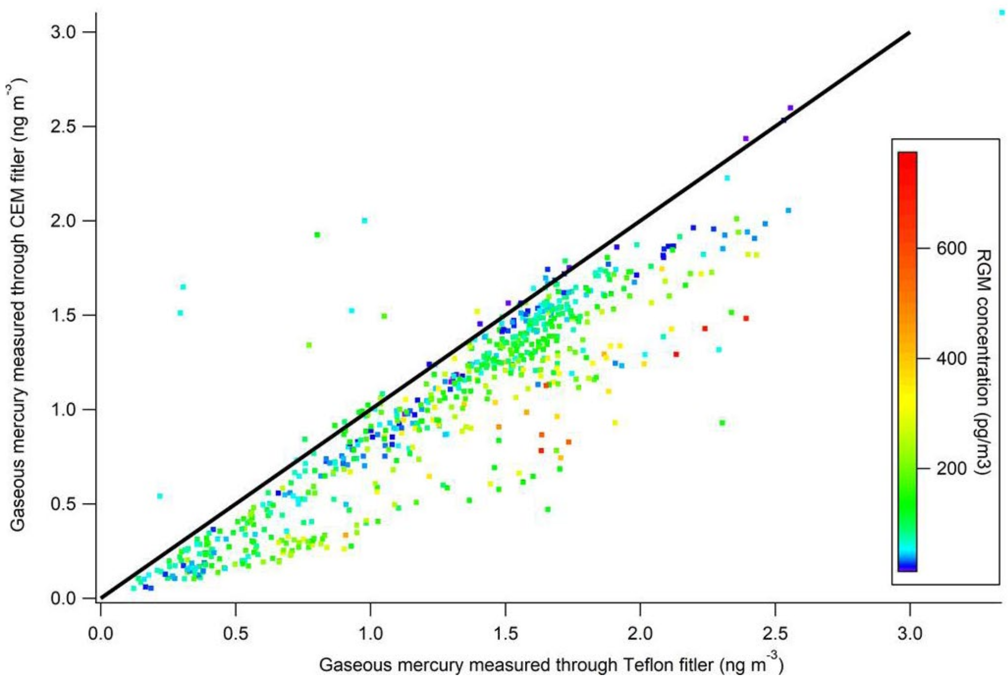


Figure 5. Concentrations of GEM (air filtered through Cation Exchange Membrane) versus TGM (air filtered through Teflon filter) using 2 instruments simultaneously at Alert, Nunavut spring 2018 and 2019.



Discussion and conclusions

The focus of this past year was on the long-term measurements at each site and to undertake an analysis of the concentration trends over time. As such, the time series presented here are only for the overlapping times between 2007 to 2018 and do not include the 1995 to 2007 data from Alert, which has been shown in the past. Figure 1 shows the continuation of the long-term record of atmospheric Hg measurements at Alert and Little Fox Lake over an 11-year period. Figure 1a is a plot of both daily GEM and TGM concentrations collected at Alert. This plot shows the very slight difference between TGM and GEM and this is further discussed below. Also, shown in Figure 1a is the distinct seasonal variation which includes the springtime loss of GEM from the air and the summertime release of TGM from the ecosystem to the air. The figure shows that there remain seasonal signature patterns in the data that are known to be driven by various factors. Figure 1b shows the daily mean concentration of Hg at Little Fox Lake. In this figure, there is a slight seasonal variation but, overall, the concentrations do not vary significantly. Figure 2 shows the time series of 3 atmospheric Hg species over the 2007-2018 time period. This plot shows that the sequence of GEM removal from the atmosphere in the spring is coupled with the increases of both PHg and RGM.

The TGM long term data have been used to calculate concentration trends over time. The concentration trends are shown as bar graphs in Figures 3 and 4 for Alert and Little Fox Lake, respectively. If the bar is above the zero line, the trend is increasing and if the bar is below the zero line then the trend is decreasing. Since 1995, the concentration of TGM at Alert has decreased by 1.37 ± 0.21% per year and, since 2007, it has decreased by 0.97 ± 0.57% per year. TGM at Little Fox Lake since 2007 has increased by 0.96 ± 0.31% per year. The decreases reported at Alert reflect the generally accepted Northern Hemispheric declines in Hg resulting from changes in emissions from Europe and North America (Streets et al., 2019). The increases shown at Little Fox Lake are in contrast to what has been reported in the literature (Nguyen et al., 2019) for sites closer to Asian sources but are in keeping with emission trends from Asia. In support of the trend results from the western Arctic at Little Fox Lake an analysis of the TGM data from Whistler Mountain (BC) was conducted. Results from this site also show an increasing trend of 1.35% per year since 2008 which are similar to Little Fox Lake, albeit slightly higher. Both Little Fox Lake and Whistler receive air masses directly from East and South East Asia as well as from North America, whereas; Alert receives air masses from a combination of Asia, Europe and North America. Global Hg emissions have been on the rise since the mid-1990s but have started to level off primarily because of reduction in European and North American emissions, emission controls in east Asia, and changes in growth in fossil fuel consumption (Streets et al., 2019). The change in the decreasing trend from Alert to a smaller decrease supports these reports (Figure 3). However, the increases reported from Little Fox Lake and Whistler are in line with reported Asian emissions increases since the air masses received at these sites are often from that region. Since emissions are changing within various regions, it is not surprising that different locations on the receiving end of these emissions are reporting differing trends. Further, not only have the overall trend changed at Alert from 1995-2018 and 2007-2018, it can also be seen (Figure 3) that the trends from Alert have shifted at certain times of the year. The trends from January to March, August and September have remained similar over the 2 time periods but from April to July there appears to be less of a decreasing level of TGM in the air. In contrast, from October to December the trends in TGM appear to be decreasing more in the latter years than when all 24 years are included. We currently don't have a full understanding of what is driving the monthly changes, thus, a full analysis into all the different factors will have to be undertaken. For now, we are reporting that there is a distinct change in the trends at Alert that may be partially explained by emissions changes but is yet to be determined.

Measurements of GEM have been made at Alert using 2 different methods. Since 1995, using a stand-alone Tekran 2537, a standard Teflon filter has been placed at the inlet. In 2002, the Tekran speciation system was additionally introduced to Alert measurements which removes all the RGM before measurement of the Hg analyzer (Tekran 2537). Over this period the terms GEM and TGM were often used interchangeably as it was believed that at Alert the RGM would not pass through a Teflon filter and be measured by the Tekran 2537 instrument (Steffen et al., 2002). Alert provides a unique environment in the springtime to study not only the chemistry of the atmosphere but how the instruments are making measurements and what is collected. During the spring there is considerable RGM present to undertake investigation of how this Hg species reacts with differing materials. Recent studies undertaken in Alert used different filter materials in front of both the speciation system inlet and a TGM monitoring system to verify what mercury species make it through the filters and what do not. We compared the most common filter types, a Teflon filter (thought to remove RGM and PHg) and a Cation Exchange Membrane (CEM) style filter (known to collect all RGM from the atmosphere). Results from these experiments have demonstrated that we collect and measure 59.3% of the RGM on a speciation system after passing through a Teflon filter, while a CEM style filter captures 96.8% of the RGM. These two types of filters were further tested in front of the stand-alone systems and the results are shown in Figure 5. RGM concentrations from the speciation system are plotted by colour with the GEM concentrations collected through the CEM and Teflon filters on the y and x axes, respectively. This plot shows that during low concentrations of RGM good agreement between the systems was observed. However, during periods with higher concentrations, the Teflon filter system measured higher GEM concentrations then the CEM filter system. These results demonstrate that a portion of the RGM that passes through the Teflon filter is captured by the stand-alone analyzer and suggests that we are not only reporting GEM but also some other RGM species as well. Hence, the change from GEM to TGM in our terminology. As mentioned above in Figure 1a, a slight difference in the GEM and TGM concentrations from Alert is evident. This difference, we believe, is a result of the different materials used as inlets on the 2 separate instruments (the speciation (GEM) and the stand-alone analyzer (TGM)) that is discussed here. We will continue to use the terms as TGM and GEM for each inlet system to differentiate how the samples have been collected. This change has no impact on the reported data, simply on the terminology that has been used.

Expected project completion date

Ongoing

Project data and links

The data from this project 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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References

Durnford D, Dastoor A, Figures-Nieto D, Ryjkov A. Long range transport of mercury to the Arctic and across Canada. Atmospheric Chemistry and Physics 2010; 10: 6063-6086.

Nguyen LSP, Sheu G-R, Lin D-W, Lin N-H. Temporal changes in atmospheric mercury concentrations at a background mountain site downwind of East Asia continent in 2006-2016. Science of the Total Environment 2019; 686: 1049-1056.

Pacyna JM, Travnikov O, De Simone F, Hedgecock IM, Sundseth K, Pacyna EG, et al. Current and future levels of mercury atmospheric pollution on a global scale. Atmospheric Chemistry and Physics 2016; 16: 12495-12511.

Steffen A, Morrison H, Kos G, O'Driscoll N, Arp P, St Louis VL, et al. Canadian Mercury Science Assessment - Summary of Key results. In: Steffen A, editor. Environment and Climate Change Canada, Gatineau, Canada, 2016, pp. 39 pp.

Steffen A, Schroeder WH, Bottenheim J, Narayan J, Fuentes JD. Atmospheric mercury concentrations: measurements and profiles near snow and ice surfaces in the Canadian Arctic during Alert 2000. Atmospheric Environment 2002; 36: 2653-2661.

Streets DG, Horowitz HM, Zifeng L, Levin L, Thackray CP, Sunderland EM. Global and regional trends in mercury emissions and concentrations, 2010-2015. Atmospheric Environment 2019; 201: 417-427.

Passive air sampling network for organic pollutants and mercury

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

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Project locations/Emplacements du projet

- Inuvik/Mackenzie Delta, NT (68° 21.417' N, 133° 42.832'W)
- Fort Resolution, NT (61°10' N, 113°45'W)
- Cambridge Bay, NU (69°7.844'N, 105°3.395'W)
- Kuujjuaq, QC (58° 14.6' N, 68°21'W)
- Iqaluit, NU (63°44' 27.5"N, 68°27'56.7"W)
- Nain, NL (56° 31' 30.9»N, 61°43' 29.3» W)
- Northwest River, NL (53°31.5' N, 60°8.5'W)

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 how contaminants 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, POP 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 a shed to house 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 enhances communication between the project team and local communities as well as creates training opportunities for Northern students. Field tests for developing a passive mercury air sampler have been completed and were sent to the sites for deployment starting July 2018. 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 interviewed four Elders for this research. The team worked with Jamie in summarizing her findings from the interviews in a final report. The report has been finished and, through Ta'än Kwach'än Council (TKC), we will seek approval from the Elders for release

Résumé

Ce projet vise à mesurer les contaminants atmosphériques, dont les polluants organiques persistants (POP) et le mercure, à sept endroits du Nord canadien. Avant le début du projet en 2014, ces contaminants atmosphériques étaient mesurés au Canada 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 mieux comprendre comment les contaminants sont transportés dans l'air à partir des régions du Sud jusqu'à l'Arctique, ainsi que l'évolution des concentrations de contaminants.

Dans le cadre de ce projet, les mesures des 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 classiques d'échantillonnage, les échantillonneurs constituent un moyen économique et nécessitant peu d'entretien pour surveiller les contaminants atmosphériques parce qu'ils ne comportent pas de pompe et ne nécessitent donc pas d'électricité ni d'abris, contrairement aux échantillonneurs habituels 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 améliore la communication entre l'équipe de projet et les populations locales et crée des occasions de formation pour les étudiants du Nord. Les essais sur le terrain en vue de mettre au point un échantillonneur passif de mercure dans l'air ont pris fin et des échantillonneurs ont été envoyés sur les sites pour un déploiement à partir de juillet 2018. Un étudiant du Nord, Jamie Thomas, a été

of this report. We are hoping to be able to share the report with all Regional Contaminants Committees (RCCs) and the NCP Secretariat in 2019.

embauché pour mener une recherche sur le savoir autochtone dans la région du Yukon qui pourrait être mis à profit dans les projets de surveillance atmosphérique des POP et du mercure. Jamie a interrogé quatre anciens pour cette recherche. L'équipe a travaillé avec Jamie pour résumer les résultats de ces entretiens dans un rapport final. Le rapport est terminé et, par l'intermédiaire du Conseil de Ta'än Kwach'än (TKC), nous demanderons l'approbation des aînés pour la publication de ce rapport. Nous espérons pouvoir partager le rapport avec tous les comités régionaux des contaminants (CRC) et le secrétariat du PLCN en 2019.

Key messages

- Mercury passive air samplers have been sent to seven Arctic sites and sampling started in July 2018. POPs air sampling continues at all seven sites.
- Project leaders visited Iqaluit (Nunavut), Whitehorse (Yukon) and Nain (Nunatsiavut) 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 and the Yukon College.
- Organophosphate esters (OPEs) flame retardants were found in passive air samples collected at five Arctic sites. Tris(1-chloro-2-propyl) phosphate (TCIPP) was the most abundant OPEs detected at all sites.

Messages clés

- Des échantillonneurs passifs de mercure ont été envoyés à sept sites de l'Arctique et l'échantillonnage a commencé en juillet 2018. L'échantillonnage de l'air pour détecter les POP se poursuit sur les sept sites.
- Les chefs de projet se sont rendus à Iqaluit (Nunavut), à Whitehorse (Yukon) et à Nain (Nunatsiavut) 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 par différentes activités de communication et de renforcement des capacités, notamment en donnant des conférences au Collège de l'Arctique du Nunavut et au Collège du Yukon.
- Des produits ignifuges à base d'esters d'organophosphate (EOP) ont été trouvés dans des échantillons d'air passifs prélevés sur cinq sites de l'Arctique. Le phosphate de tris (1-chloropropan-2-yle) (TCIPP) était le plus abondant des EOP détectés sur tous les sites.

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 air sampling methods that will provide scientific information on the spatial distribution and input of these contaminants to the Arctic environment. For the last two decades, air monitoring programs were limited to continuous monitoring of POPs and mercury at Alert and Little Fox Lake and POPs at a few satellite stations for 1-2 years. Expanding the spatial distribution of air monitoring within the Canadian Arctic is extremely valuable for further constraining atmospheric models of pollutant transport, chemistry and deposition, since current validation data is so sparse. This project aims to achieve this objective using passive air sampling methods which are low-cost, low-maintenance and easy to deploy at multiple locations.

It builds upon the two 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 chemicals and is ideal for sampling in locations with relatively low air concentrations of organic contaminants, such as the Arctic.

Activities in 2018-2019

Samples collected in 2015 have been analyzed by Dr. Fiona Wong at the Organics Analysis Laboratory (OAL) in Downsview. Most of the organochlorine pesticides (OCs), polybrominated diphenyl ethers (PBDEs) and other halogenated flame retardants (HFRs) were non-detectable in the passive air samples. Some PCBs, volatile pesticides and industrial chemicals were found in air at 5 Arctic passive sampling stations. The highest levels of these chemicals were generally found at the most populated site of Iqaluit and Inuvik. The lowest levels were found at Fort Resolution. A draft information sheet was compiled and sent for comments and input from the RCCs before dissemination to the communities.

The PUF-PAS samples from 2015 have also been analyzed for organophosphate esters (OPEs). Results are reported below.

From the samples collected in 2015 and 2016, it was found that the levels collected by the PUF-PAS were very close to the detection limits. Also, due to the open design of the PUF-PAS shelter, there is strong entrainment of wind at windy Arctic locations, making it difficult to determine the sampling rates and sample volumes. Therefore, we have discontinued the use of this type of sampler at the Arctic sites by the end of 2018. In order to reduce the wind effect, a new set of XAD-PAS shelters have been made with wind dampening spoilers on the bottom (Gong et al. 2017). These shelters were sent to the sites in July 2018 to replace the existing shelters. The XAD-PAS will be changed in the summer and be used from July to July every year from now on.

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 have started to deploy the mercury passive sampler at the 7 sites in July 2018.

Last year, Fort Resolution site operators Rosy Bjornson, Kathleen Fordy and Shawn Mckay noticed that there were increasing human activities in the area of the sampling site on Mission Island. Rosy, Shawn and Kathleen then scouted out 3 other locations where we can move the samplers and we have decided to move them to a site close to an abandoned fire tower which is not visible from the road (proposed site location: 60.99748 N, 113.78242 W). Rosy has contacted several departments to try to obtain approval to move the samplers to this site, but no department has accepted responsibility for the approval. Through Diane Giroux (ATK), we have sought guidance from Chief Balsillie and he approved the move to this new location. Unfortunately, in July 2019, Kathleen found out that the fire tower will be demolished in the near future which could cause contamination to the samples, so we have decided to keep the sampling site on Mission Island for now.

At Inuvik, the samplers are currently co-located with the National Air Pollution Surveillance (NAPS) Network site next to the Aurora Research Institute (ARI) in the middle of town. It is not ideal as it would be better to collect the samples at a more regionally representative site outside of town. After discussion with Erika Hille (ARI) and the site operators, we would like to move the samplers to the Upper Air Station outside of town. Hayley has contacted several representatives of the Upper Air Station and found that there will be constructions at the Upper Air Station this year, so it is not a good idea to move the samplers this year. We will continue to follow-up on this matter to try moving the site to the Upper Air Station.

Scientific communications

Our project leader, Hayley Hung, presented preliminary results of hexachlorobutadiene (HCBD), a-hexachlorocyclohexane (α-HCH) and 2,4-dibromoanisole, polychlorinated biphenyls (PCBs), pentachloroanisole(PCA) and OPEs at two oral presentations at the 38th International Symposium on Halogenated Persistent Organic Pollutants (POPs) (DIOXIN) Conference in Krakow in August 2018 and at the 29th Inter-American Congress of Chemical Engineering/68th Canadian Chemical Engineering Conference in Toronto in November 2018. She has also presented these results at a lunch time seminar at the Université du Québec à Rimouski (UQAR) on November 2, 2018.

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).

1. Iqaluit, January 2018

On January 24, 2018, Sandy and Hayley conducted a half-day guest lecture with a half-day hands-on activity session to students in the Environmental Technology Program (ETP) at the Nunavut Arctic College. We had great discussions with our partners at the school. We met with Jamal Shirley to discuss ideas on how to develop a co-leadership project for the passive mercury sampling project. We also had a fruitful meeting with the Nunavut Environmental Contaminants Committee (NECC) on January 25 to update our project plans to better address the needs of the community with respect to those plans. We returned to the Nunavut Arctic College (NAC) in January/February 2019 for a similar lecture. In response to last year's cultural review recommendations, we will return to the NAC in Iqaluit once every two years, which will align with the ETP program's curriculum (a two-year program), and visit another community college to conduct the same workshop. We will visit Cambridge Bay in January 2020 and conduct a similar workshop with the ETP program at the NAC there.

2. Whitehorse, February 2018

Hayley visited Whitehorse February 4 to 7, 2018. She gave two lectures at the Yukon College regarding contaminants in Arctic air, one for the course of "Yukon Source Water Protection & Watershed Stewardship" and another for the course of "Environmental Change and Community Health" (both courses with Instructor Larry Gray). She also gave a presentation at the weekly meeting of the Environment Directorate at the CIRNAC office in Whitehorse and met with the Regional Contaminants Committee (RCC) during their proposal review meeting to answer questions related to this proposal. Hayley also met with Derek Cooke (TKC) and Jamie Thomas to work on the draft IK report.

3. Nain, October 2018

Sandy and Hayley visited Nain from September 25 to 27, 2018. We have tried to contact the high school to give a presentation to the science class before the trip but could not reach the Principal by phone. The community had no power, phone connection and water for an extended period of time before our trip which hindered our abilities to pre-plan visits within the community. Both Carla Pamak and Liz Pijogge helped us in contacting the school but a presentation could not be scheduled during our visit. During this trip, we have conducted a site visit and deployed the mercury passive air sampler and performed a site inspection. We met with Liz Pijogge, Carla Pamak and Rudy Riedlsperger to discuss issues related to the sample shipments of the project, discuss the new mercury passive air samplers and the new shelter for the XAD-PAS with the wind spoilers. We also visited with Rodd Liang to update him on our latest accomplishments within the passive sampling project. We would like to acknowledge Carla and Liz's help during our visit and for hosting us at the Nain Research Center to reduce the cost of the trip.

4. Whitehorse, February 2019

February 24-27, 2019, Hayley, Sandy and Geoff travelled to Whitehorse. Hayley and Sandy met with the Yukon Contaminants Committee (YCC) to discuss about the NCP projects, discuss the implementation of the new mercury passive sampling project and their plans to communicate project results. Sandy and Hayley gave two lectures at the Yukon College at Instructor Larry Gray's courses about contaminants in the Arctic. Sandy and Geoff went to the Little Fox Lake site with their local partner Dylan Nordin from Laberge Environmental and performed their annual site visit and maintenance.

6. Iqaluit, February 2019

Sandy, Hayley and Liisa visited Iqaluit again between February 3 and 6 to conduct a half-day guest lecture with a half-day hands-on activity session with students in the ETP at the Nunavut Arctic College. Unfortunately, due to a leak in the lab, we were unable to fully do the hands-on activities in the lab but met with the students in the classroom for some experiments and great discussion. 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 the Council of Yukon First Nations (CYFN), in consultation with Derek Cooke (TKC), to undertake an IK subproject under M-03 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: 1. General knowledge of contaminants in the North, 2. knowledge of weather patterns, 3. forest fires, 4. mining, and 5. environmental change. Jamie prepared a draft report summarizing the discussions. The team worked with Jamie in summarizing her findings from the interviews in a final report. The report has been finished and, through TKC, we will seek approval from the Elders for release of this report. We are hoping to be able to share the reports with all RCCs and the NCP Secretariat in 2019.

Results and outputs/deliverables

We have analysed the PUF-PAS collected in 2015 for 17 organophosphate esters (OPEs). The target OPEs were: tri-ethyl phosphate (TEP), tri-n-propyl phosphate (TPrP), tri-n-butyl phosphate (TBP), tris(2-chloroethyl) phosphate (TCEP), tris(1-chloro-2-propyl) phosphate (TCIPP), tris (1,3-dichloro-2-propyl) phosphate(TDCPP), 2-ethylhexyl diphenyl phosphate (EHDPP), tris (2-butoxyethyl) phosphate (TBOEP), tris-2-ethylhexyl-phosphate (TEHP), triphenyl phosphate (TPhP), tri-para-tolyl phosphate (TpTP), tri-*meta*-tolyl phosphate (TmTP), tri-*octa*-tolyl phosphate (ToTP), tris (2-isopropylphenyl) phosphate (T2IP), tris(3,5-dimethyl) phosphate (T35DMPP), tris (2,3-dibromopropyl) phosphate (TDBPP), and tris(4-tert-butylphenyl)phosphate (TTBP).

We present the results in units of pg/PUF/day. There was one field blank analyzed for each site. Trace levels of OPEs 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), Nain (NA). Downsview (DV) is the urban site.

In general, the sum of OPEs for all sites, from highest to lowest amount pg/PUF/day) were: DV (7400) > IN (1800) > IQ (900) > NA (220) > FR (150) > KU (140). The most detected OPEs were: TEP, TBP, TCEP, TCIPP, TDCPP, EHDPP, TPhP and ToTP. The spatial distribution of selected OPEs is shown in Figure 1.

Discussion and conclusions

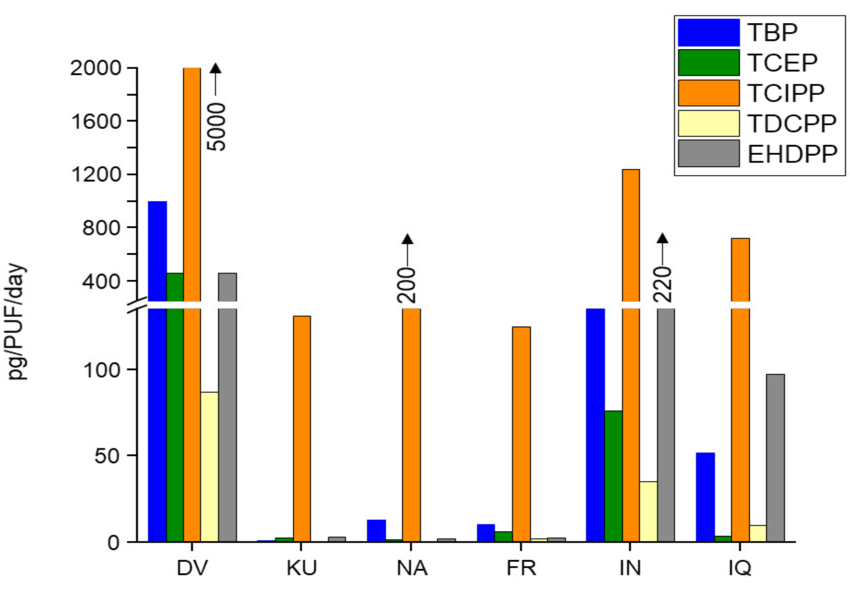
OPEs collected by PUF-PAS in 2015

Our findings are in line with those reported in the literature in which OPEs were commonly found in air in the Canadian Arctic. For example, Rauert et al. (2018) reported that TCEP, TCIPP, TPhP were found in air at Alert, Nunavut. Sühring et al. (2016) found several OPEs (TCEP, TCIPP, TDCIPP, TPhP, EHDPP) in air collected over the Canadian Arctic Ocean. OPEs concentrations in air in the urban site, DV, were higher than in the Arctic sites. Previous studies have reported higher atmospheric OPE levels were associated with urban sites (Rauert et al., 2018). This is expected as it is known that cities are hotspots for flame retardants. Most of the flame-retardant inventory is found indoors where household products, furniture and electronics are stored (Harrad and Diamond, 2006).

We also observed that TCIPP is the most abundant OPE in all of our sampling sites. Similar dominance of TCIPP in remote and urban air have been reported (Wong et al., 2017; Rauert et al., (2018). The ubiquity and abundance of TCIPP in the environment is likely due to their widespread application as flame retardants in plastics and polyurethane foam products.

In conclusion, we have found OPEs in air in all of our Arctic sampling sites. The most highly populated sites of IN and IQ showed the highest concentrations of OPEs; especially the IN site where the sampling location is within the town. It is not clear whether these chemicals are coming from long-range atmospheric transport or local emissions. We will continue to analyze the passive air samples for OPEs.

Figure 1. Spatial distribution of OPEs in PUF-PAS deployed in 2015 in Arctic. Unit is pg/PUF/day. Each sample were deployed for about 90 days. Abbreviations for sites: DV = Downsview, KU = Kuujjuaq, NA = Nain, FR = Fort Resolution, IN = Inuvik, IQ = Iqaluit.



Expected project completion date

Ongoing

Project website

Meta data of this project are included in the Polar Data Catalogue (https://www.polardata.ca/) PDC Record #12055

It is planned that when the passive air sampling data are finalized, they will be released in the Government of Canada Open Data Portal.

Acknowledgments

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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, Nunavut Government); Nain and Northwest River – 2 sites (Rodd Laing and Liz Pijogge, Nunatsiavut Government); Inuvik (Joel McAlister, Bessie Rogers, Annika Trimble, Edwin Amos, Greg Elias, 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).

References

Harrad, S.J., Diamond, M.L. 2006. Exposure to polybrominated diphenyl ethers

(PBDEs) and polychlorinated diphenyls (PCBs): current and future scenarios.

Atmos. Environ, 40, 1187-1188.

Gong, P., Wang, X., Liu, X., & Wania, F. (2017). Field calibration of XAD-based passive air sampler on the Tibetan Plateau: Wind influence and configuration improvement. Environmental Science & Technology, 51(10), 5642-5649.

Rauert, C., Schuster, J. K., Eng, A., Harner, T. 2018. Global atmospheric concentrations of brominated, chlorinated flame retardants and organophosphate ester. Environ. Sci. Technol, 52, 2777-2789.

Sühring, R., Diamond, M. L., Scheringer, M., Wong, F., Pućko, M., Stern, G., Burt, A., Hung, H., Fellin, P., Li, H., Jantunen, L. M. 2016. Organophosphate esters in Canadian Arctic air: occurrence, levels and trends. Environ. Sci. Technol, 50, 7409-15.

Wong,F., de Wit, C. A., Newton, S. N. 2018. Concentrations and variability of organophosphate esters, halogenated flame retardants, and polybrominated diphenyl ethers in indoor and outdoor air in Stockholm, Sweden. Environ. Pollut, 240, 514-522.

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

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

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Project locations/Emplacements du projet

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

Abstract

The major questions that this project is addressing are: 1) how are concentrations of legacy contaminants and other persistent organic pollutants (POPs), as well as mercury, changing over time in ringed seals? and 2) are trends similar across Inuit Nunangat? The presence and trends of new and emerging contaminants are also investigated. The

Résumé

Ce projet porte principalement sur les questions suivantes : 1) de quelle façon les concentrations de contaminants hérités et d'autres POP ainsi que le mercure évoluent-elles au fil du temps chez le phoque annelé; 2) les tendances sont-elles semblables partout dans l'Inuit Nunangat? La présence et les tendances des contaminants émergents sont aussi étudiées. Le projet consiste

project currently involves annual sampling at Sachs Harbour, Resolute Bay, Arviat, and Nain. All sampling is done by local hunters and coordinated by Hunters and Trappers Associations/Committees in each community.

Results of this core monitoring project indicated that concentrations of legacy compounds such as polychlorinated biphenyls (PCBs), Dichlorodiphenyltrichloroethane (DDT), Chlordane, and Hexachlorocyclohexane (HCH) continued to decline slowly in ringed seals. Trends for flame retardants and results indicated very slow decreases of both Polybrominated diphenyl ethers (PBDEs) and Hexabromocyclododecane (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 perfluorooctane sulfonate (PFOS) and perfluoroalkyl carboxylic acids (PFCAs) in liver of ringed seals from Resolute Bay, Arviat and Sachs Harbour have declined between the mid-2000s to 2011, but have increased in recent years at some locations. Mercury concentrations in liver and muscle varied from year to year but overall were not increasing. Moreover, the mean methylmercury (MeHg) concentrations found in the liver of seals ranged between 1.4 and 2.5 µg/g. The annual measurements of contaminants in Arctic ringed seals have demonstrated that these pinnipeds (flipper-footed marine animals) 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 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 elementary and middle schools in Arviat, Nunavut. Scientists also attended a one-day Inuit Qaujimajatuqangit Workshop presented by the Aqqiumavvik Society. This complementary project (Northern Contaminants Program [NCP] project CB-12 - *Contaminant monitoring and community interests in the lower Northwest Passage*) allowed NCP research scientists working on contaminants in ringed

actuellement à faire des échantillonnages annuels à Sachs Harbour, Resolute Bay, Arviat et Nain. Tous les prélèvements sont effectués par des chasseurs locaux et coordonnés par les associations ou comités de chasseurs et de trappeurs de chaque collectivité.

Les résultats de ce projet de surveillance de base ont indiqué que les concentrations de composés hérités tels que les biphényles polychlorés (BPC), le dichlorodiphényltrichloroéthane (DDT), le chlordane et l'hexachlorocyclohexane (HCH) continuaient à diminuer lentement chez les phoques annelés. Les tendances pour les produits ignifuges et les résultats ont révélé une très lente diminution des éthers polybromodiphényléthers (PBDE) et de l'hexabromocyclododécane (HBCD) dans la graisse des phoques de Sachs Harbour, Arviat et Resolute. Une collecte supplémentaire à Nain est nécessaire afin d'établir des tendances temporelles. Les tendances pour les substances perfluoroalkylées (PFAS) indiquent que les concentrations de perfluorooctanesulfonate (SPFO) et d'acides perfluoroalcanecarboxyliques (PFCA) dans le foie des phoques annelés de Resolute Bay, Arviat et Sachs Harbour ont diminué entre le milieu des années 2000 et 2011, mais ont augmenté ces dernières années à certains endroits. Les concentrations de mercure dans le foie et les muscles varient d'une année à l'autre, mais, dans l'ensemble, n'augmentent pas. En outre, les concentrations moyennes de méthylmercure (MeHg) trouvées dans le foie des phoques se situaient entre 1,4 et 2,5 µg/g. Les mesures annuelles des contaminants chez les phoques annelés de l'Arctique ont montré que ces pinnipèdes (animaux marins à nageoires) sont de très bons indicateurs de l'évolution des utilisations et de la production de substances chimiques largement incorporées dans les produits de consommation et industriels.

Depuis 2016, des activités de sensibilisation des collectivités ont été ajoutées à ce projet de surveillance à long terme. Cette année, un atelier éducatif d'une journée sur la santé des phoques annelés a été organisé avec succès dans les écoles primaires et secondaires d'Arviat, au Nunavut. Les scientifiques ont également seals to share information about their work, and provided opportunities for Elders to share their knowledge of seal ecology and traditional methods of captures and skinning with students and researchers. This event employed a combination of short interactive presentations, laboratory activities, group discussions, storytelling, games, and art activities to teach participants core concepts on contaminants and health of ringed seal from both scientific and Inuit perspectives. Synergies between the two NCP projects from Environmental Monitoring and Communications, Capacity and Outreach programs provide great opportunities to enhance local capacity building, communications and the integration of Inuit Knowledge in contaminants research on ringed seals.

participé à un atelier inuit d'une journée sur le Qaujimajatuqangit, présenté par la société Aqqiumavvik. Ce projet complémentaire (projet CB-12 du Programme de lutte contre les contaminants dans le Nord [PLCN] – *Surveillance des contaminants et intérêts communautaires dans la partie inférieure du passage du Nord-Ouest*) a permis aux chercheurs du PLCN travaillant sur les contaminants chez les phoques annelés de partager des informations sur leur travail, et a donné l'occasion aux aînés de partager leurs connaissances sur l'écologie des phoques et les méthodes traditionnelles de capture et de dépouillage avec les étudiants et les chercheurs. À cette fin, on a employé une combinaison de courtes présentations interactives, d'activités de laboratoire, de discussions de groupe, de récits, de jeux et d'activités artistiques pour enseigner aux participants les concepts fondamentaux sur les contaminants et la santé des phoques annelés, tant du point de vue scientifique que du point de vue des Inuits. La synergie entre les deux projets du PLCN tirés des programmes de surveillance environnementale et de communications, et de capacité et de sensibilisation offre de bonnes occasions d'améliorer le développement des capacités à l'échelle locale, les communications et l'utilisation du savoir inuit dans les études des contaminants chez le phoque annelé.

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.
- Increases of perfluoroalkyl substances have been observed in liver of seals in recent years at some locations.
- Synergies between NCP Environmental Monitoring and Communications, Capacity and Outreach programs provide opportunities to enhance local capacity building, communications and the use of traditional ecological knowledge in contaminants research on ringed seals.

Messages clés

- Les concentrations de composés hérités comme les BPC, le dichlorodiphényltrichloroéthane (DDT), les chlordanes et l'hexachlorure de benzène (HCH) continuent de diminuer dans la graisse 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.
- Une augmentation des concentrations de substances perfluoroalkylées a été observée dans le foie des phoques en certains endroits.
- La synergie entre les deux projets du PLCN tirés des programmes de surveillance

environnementale et de communications, et de capacité et de sensibilisation offre de bonnes occasions d'améliorer le développement des capacités à l'échelle locale, les communications et l'utilisation du savoir inuit dans les études des contaminants chez le phoque annelé.

Objectives

This project aims 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 Government Research Advisory Committee;
- present results and organize sessions on northern contaminants at national and international meetings; and
- collaborate with the project team organizing a health in ringed seal workshop in Arviat, Nunavut to engage youth, Elders and scientific researchers in learning about ringed seal health from both Inuit Knowledge and scientific perspectives (in relation to the CB-12 project, Contaminant monitoring and community interests in the lower Northwest Passage, by Dominique Henri and Magali Houde; Communications, Capacity and Outreach).

Introduction

The ringed seal is the most abundant Arctic pinniped with a circumpolar distribution and has been a key biomonitoring animal for examining spatial and temporal trends of persistent organic pollutants (POPs) and mercury in the Arctic since the 1970s. This project began in April 2004 under NCP Phase III and follows up earlier projects on ringed seals (Muir and Lockhart 1994; Muir 1996; Muir, Kwan et al. 1999; Muir, Fisk et al. 2001; Muir, Kwan et al. 2003). Results for POPs and heavy metals including mercury are available going back to the 1980s, and earlier in some cases.

Because ringed seals are an important species harvested by hunters each year in almost all communities in Nunavut, 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 of ringer seals has generally been high.

In this 2018-2019 report, update trends of legacy compounds, perfluoroalkyl substances (PFAS) and mercury in ringed seal tissues are presented. Outreach activities in the community of Arviat are also discussed.

Activities in 2018-2019

In 2018, ringed seal samples were successfully collected by hunters in the communities of Arviat (n=20), Sachs Harbour (n=16), Resolute Bay (n=14), and Nain (n=15). 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 2018-2019, legacy POPs were determined in ringed seal samples i.e., organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs) and brominated flame retardants (PBDEs). Polyfluoroalkyl substances (PFAS), mercury, multi-element and methylmercury (MeHg) analyses were also conducted on liver. In addition to mercury, knowledge of the concentrations of two elements, selenium and cadmium, is particularly of interest. Methylmercury 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. Results for short-chain chlorinated paraffins (SCCP) conducted in 2017 blubber samples were also provided this year and will be presented in this synopsis.

Chemical analyses

Analyses of organic chemicals in the 2018 samples were conducted by the Quebec Laboratory for Environmental Testing (QLET, ECCC, Montreal). Extraction and cleanup procedures 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 by high-resolution mass spectrometry. PCBs and PBDEs were analyzed by gas chromatography low-resolution mass spectrometry and PFAS were analyzed using liquid chromatography tandem mass spectrometry (Derek Muir's lab). Total mercury in muscle was determined in Derek Muir's lab by Direct Mercury Analyzer using EPA method 7473 (US Environmental Protection Agency 2007). Thirty-four elements were determined in liver by Inductively Coupled Plasma-Mass spectrometry (ICP-MS) by the National Laboratory for Environmental Testing (NLET, Burlington). 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 (NLET).

Quality assurance (QA) and statistical analyses

The NLET lab is certified by Canadian Standards Association and are participating annually in the NCP Interlab comparisons. QLET works using the same procedures and participated in the NCP Interlab in 2018-2019. 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.

Capacity building

In October 2018, Magali Houde, Dominique Henri (Wildlife and Landscape Science Directorate), 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 seals workshop held in Arviat. Moreover, Derek Muir visited Resolute Bay in August 2018 and met with the community members and the Hunters and Trappers Association.

Communications

Regular communications were conducted with the Hunters and Trappers of Arviat, Resolute Bay, 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 2019 to each participating community after review by the Nunavut Environmental Contaminants Committee. Co-leaders of the project visited Resolute Bay in August 2018 and Arviat in October 2018 and met with the Hunters and Trappers Organization, the local schools (children and professionals) as well as Elders. Scientists also attended a one-day Inuit Qaujimajatuqangit Workshop presented by the Aqqiumavvik Society. Results of this project were also presented at national and international meetings (e.g., ArcticNet, Society of Environmental Toxicology and Chemistry, Dioxin 2018) and at invited seminars.

Indigenous Knowledge

Effective communication and engagement between researchers and northern community members is central to NCP. The Nunavut Environmental Contaminants Committee (NECC) had suggested in 2015 to increase community engagement as part of this ongoing work. Community outreach components were therefore added to this project in 2016 in collaboration with Dominique Henri, a traditional knowledge expert at ECCC. The ultimate objectives of this work are 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), Sachs Harbour (2018) and Arviat (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 involved in this core monitoring project and to work towards better integrating Inuit Knowledge to contaminants research and training of local capacity.

Results

Sample collection and hunter observations

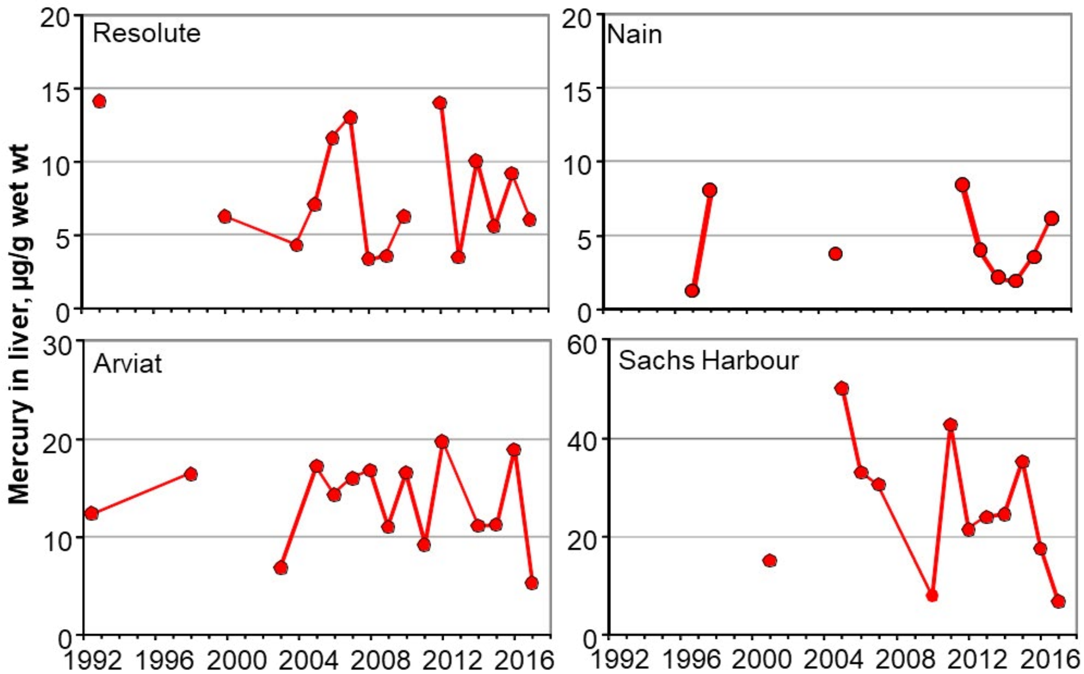
In 2018 the requested information on gender, girth, length, and blubber thickness was provided for all animals, except for three seals. The identification of the gender of the seals provided by hunters in the field was in agreement with results for DNA. Overall, the information provided by the hunters was excellent considering the logistical challenges they face in having to harvest and dissect the animals in the field.

Mercury

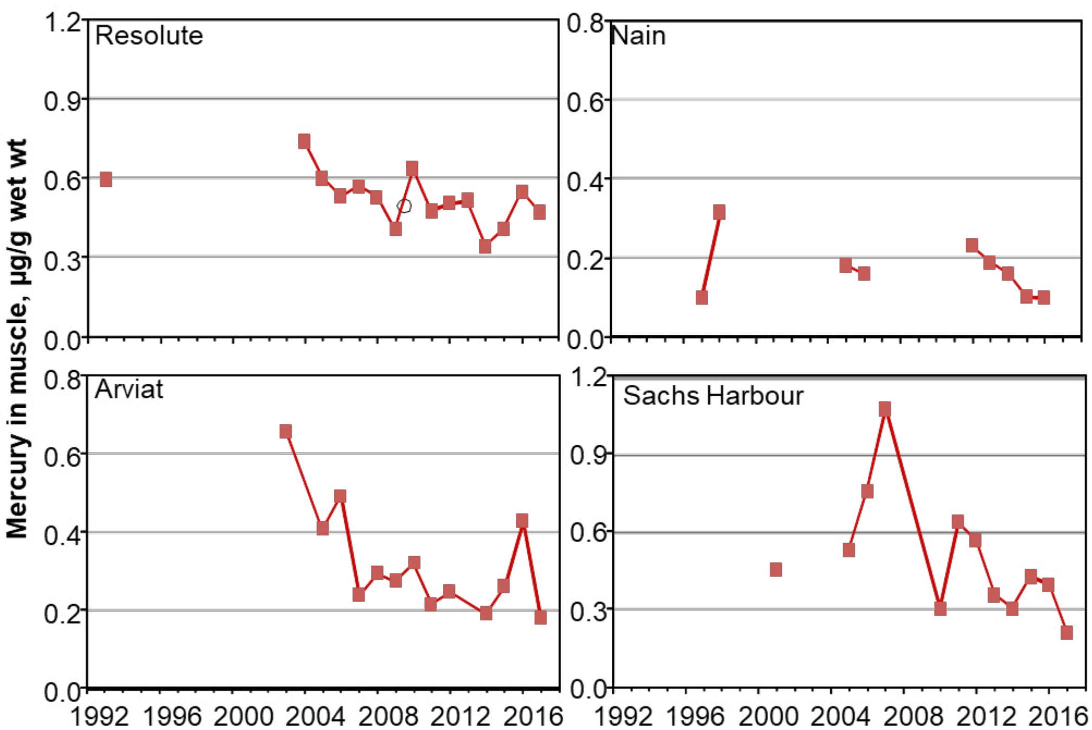
Trends in concentrations of mercury in ringed seal liver and muscle for the four communities were updated with samples from 2017 and results are shown in Figure 1. Results are for adults (4+ years) which show little variation of concentrations with age. Average mercury concentrations in muscle were generally lower in the period 2010-2016 compared to the late 1990s and early 2000s, however, differences were not statistically significant. Concentrations of mercury in liver were more variable than in muscle. Continued annual sampling and comparison with climate and food web related variables may help discern reasons for this variation. Mercury results from the past 20 years are currently being analyzed in relation to environmental parameters in preparation for a scientific manuscript.

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



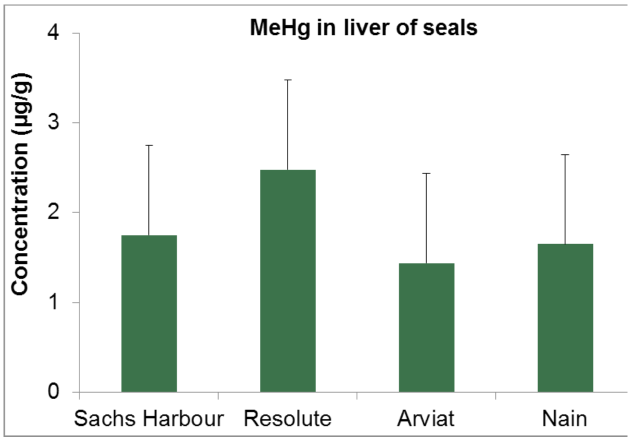
B) Muscle



Methylmercury

Methylmercury was analyzed in liver of seals in 2017 (Figure 2). Mean concentrations were similar in seals from Sachs Harbour, Arviat and Nain (ranging between 1.4-1.8 μg/g) and around 2.5 μg/g in seals from Resolute Bay. Results for 2018 are pending.

Figure 2. Mean concentrations (μg/g wet weight) of MeHg in liver of ringed seals collected in 2017.



Legacy compounds

Temporal trends of PCBs and organochlorine pesticides in blubber of ringed seals were updated to 2016 and published in Houde et al. 2019. Concentrations of most chemical groups have been slowly declining at all sites; percentages of annual decrease are presented in Table 1. The highest decrease rates (up to -9.1%/year for ǵHCH) were found in seals from the Hudson Bay region where all chemicals investigated have significantly decreased since 1986. Significant increases in concentrations of Hexachlorobenzene (HCB) in seals from Labrador and β-HCH in Sachs Harbour, NT and Arctic Archipelago were observed. Site-specific and contaminant-specific associations between climate pattern (i.e., Arctic Oscillation, North Atlantic Oscillation, and Pacific/North American pattern) and mean ice-coverage (total, first-year ice, and old-ice) were found (Houde et al. 2019).

Table 1. Percentages (%) of annual changes of contaminant concentrations in blubber (corrected for age by sex) in ringed seals. Increasing trends are highlighted in bold and non-significant trends in *italics*. n/a indicates that trends were not analyzed due to small sample size.

	Beaufort Sea Sachs Harbour (1988-2016)		Hudson Bay (1986-2016)		Arctic Archipelago (1972-2016)		Nunatsiavut, Labrador (1998-2016)	
	% per year	p-value	% per year	p-value	% per year	p-value	% per year	p-value
α-HCH	-4.8%	<0.0001	-9.1%	<0.0001	-5.4%	<0.0001	-9.1%	<0.0001
β-HCH	0.6%	*0.2127*	-2.1%	<0.0001	2.8%	<0.0001	-2.7%	*0.1787*
Lindane	-4.6%	<0.0001	-8.4%	<0.0001	-3.9%	<0.0001	-8.8%	<0.0001
ΣHCHs	-3.5%	<0.0001	-8.2%	<0.0001	-3.7%	<0.0001	-6.5%	<0.0001
Oxychlordane	-1.1%	*0.0594*	-6.6%	<0.0001	-1.4%	0.0003	-2.1%	*0.1617*
ΣCHLs	-2.6%	<0.0001	-7.3%	<0.0001	-2.4%	<0.0001	-3.4%	0.0087
HCB	-1.7%	<0.0001	-2.4%	<0.0001	-0.3%	*0.1622*	2.7%	0.0075
ΣCBz	-1.5%	0.0004	-4.4%	<0.0001	1.3%	<0.0001	4.5%	0.0007
Dieldrin	-2.5%	<0.0001	-4.4%	<0.0001	-1.6%	<0.0001	-6.0%	<0.0001
Toxaphene	-4.3%	<0.0001	-5.7%	<0.0001	-2.8%	<0.0001	n/a	n/a
t-Nonachlor	-2.6%	0.0061	-7.1%	<0.0001	-2.5%	<0.0001	n/a	n/a
CB99	-0.4%	*0.3779*	-5.7%	<0.0001	-1.6%	<0.0001	-2.9%	0.0038
CB153	0.7%	*0.3166*	-1.5%	0.0200	-1.6%	<0.0001	-3.7%	0.0013
CB180	1.1%	*0.1110*	-7.1%	<0.0001	-3.0%	<0.0001	-6.5%	<0.0001
ΣtetraCB	-3.6%	<0.0001	-5.7%	<0.0001	-2.7%	<0.0001	-4.7%	<0.0001
ΣpentaCB	-2.0%	0.0054	-6.0%	<0.0001	-1.8%	<0.0001	-4.6%	0.0010
ΣhexaCB	-1.4%	0.0121	-5.9%	<0.0001	-2.1%	<0.0001	-3.7%	0.0006
ΣheptaCB	-3.1%	<0.0001	-7.8%	<0.0001	-2.8%	<0.0001	-7.1%	<0.0001
ΣoctaCB	-3.7%	<0.0001	-7.8%	<0.0001	-2.4%	<0.0001	-8.5%	<0.0001
Σ10PCBs	-1.1%	0.0397	-5.8%	<0.0001	-1.9%	<0.0001	-3.8%	0.0003
ΣPCBs	*-1.2%*	*0.0665*	-5.1%	<0.0001	-0.8%	0.0023	-5.0%	<0.0001
p,p′-DDE	-1.6%	0.0081	-7.2%	<0.0001	-2.3%	<0.0001	*-2.3%*	*0.0755*
ΣDDTs	-2.5%	<0.0001	-7.8%	<0.0001	-3.6%	<0.0001	-2.7%	0.0315

Flame retardants

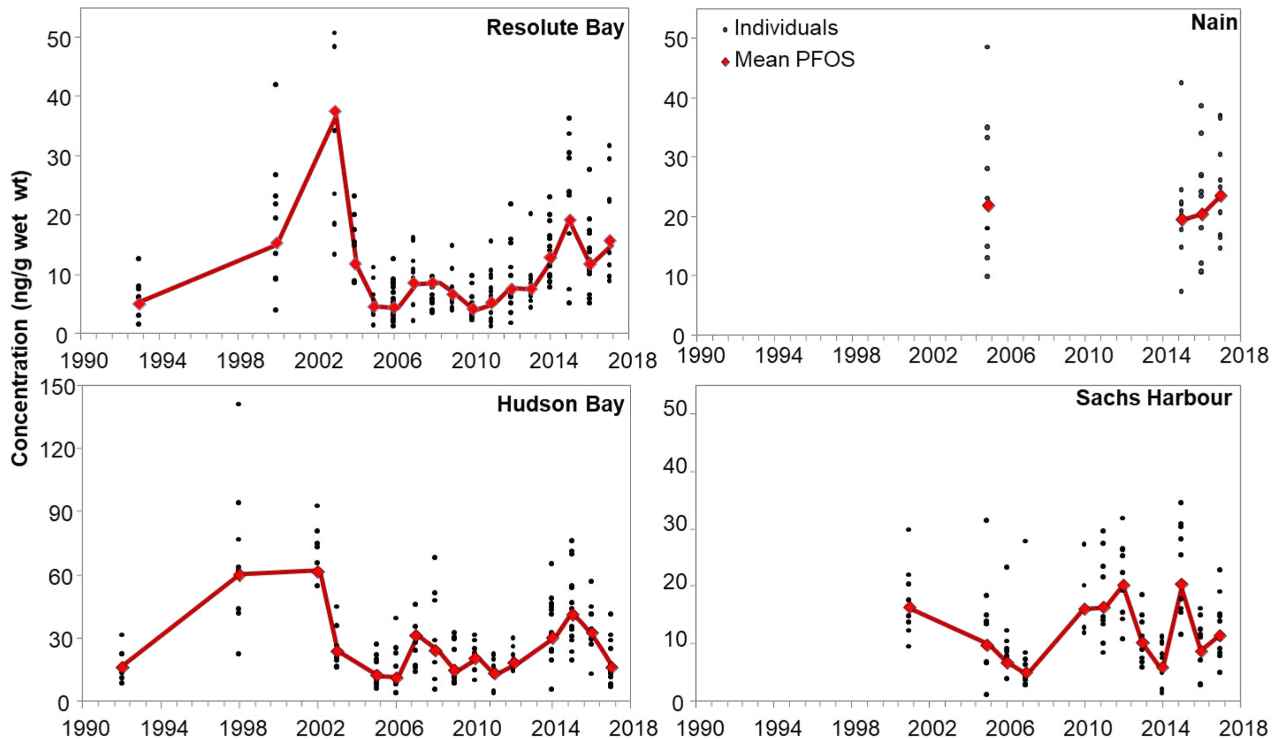
The trends of polybrominated diphenyl ethers (PBDEs) and other emerging flame retardants (1990s-2014) were published in 2017 in a peer-review journal (Houde et al. 2017). Results from trends up to 2016 indicated very slow decrease of PBDEs and hexabromochlorodecane (HBCD) in blubber of seals for Sachs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

Perfluoroalkyl substances (PFAS)

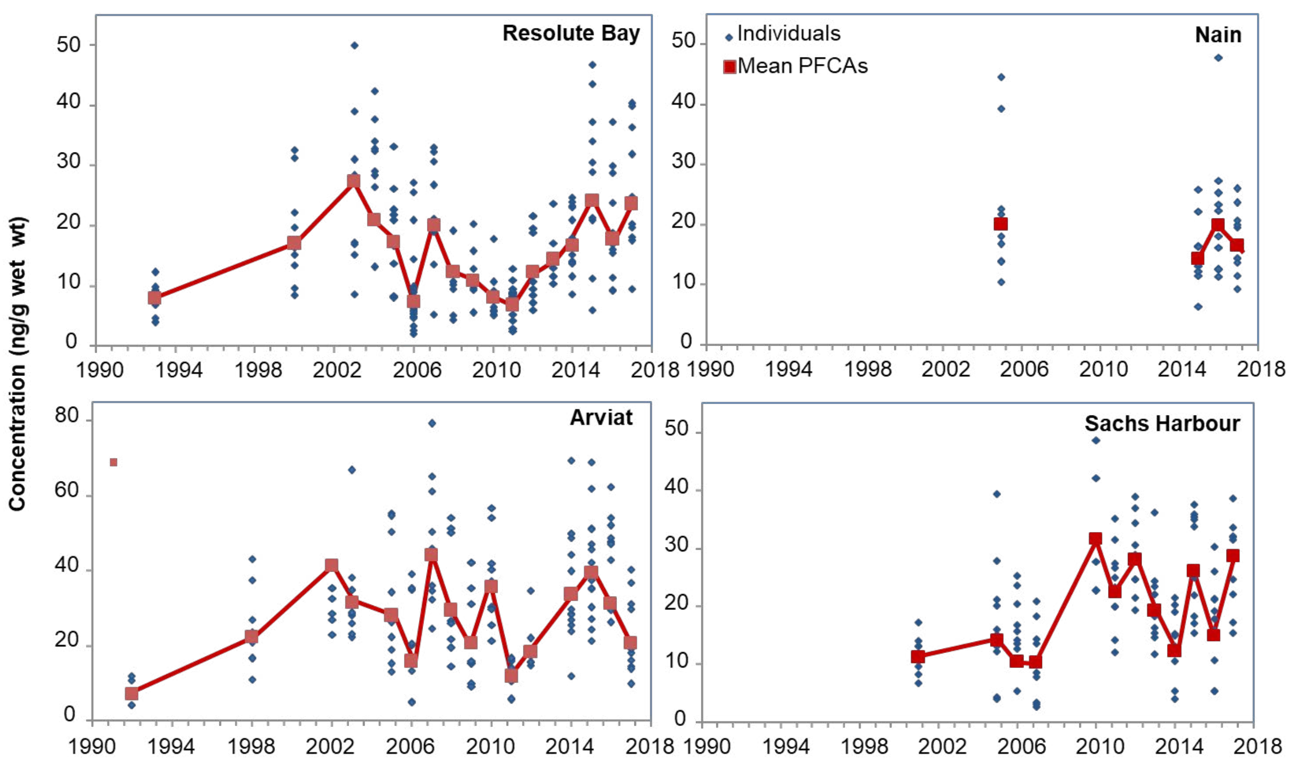
Trends for polyfluoroalkyl substances (PFAS) indicated that concentrations of PFOS and perfluorocarboxylic acids (PFCAs) in liver of ringed seals from Resolute Bay declined over the period mid-2000s to 2011, but have increased in recent years (2011-2016) (Figure 3). An increase in PFOS was also observed in seals from Nain. Moreover, new PFAS (e.g., F53B, PFONS, PFOUdS, DONA) have been detected at low concentrations (<1 ng/g w.w.) in ringed seals. These substances are replacements for PFASs that have been banned (e.g., PFOS) or phased out (e.g., PFOA and other PFCAs with 8 or more fluorinated carbon chain).

Figure 3. Temporal trends (1970s/1990s-2017) of A) perfluorooctane sulfonate (PFOS) and B) the sum of perfluorocarboxylic acids (PFCA, C7-C14) in liver of ringed seals from three different regions of Inuit Nunangat.

A)



B)



Short-chain chlorinated paraffins (SCCP)

Results for SCCP (C10 to C13) in blubber of seals were reported for 2017 at two sites. The mean concentrations in Arviat were 30.5±24.7 and 21.6±26.4 ng/g lipid weight in seals from Sachs Harbour with C11 and C12 homologue groups dominating the congener profile.

Discussion and conclusions

Results of this core monitoring project indicate that concentrations of legacy chemicals, such as PCBs, DDT, Chlordane, and HCH continued to decline slowly in blubber of ringed seals across Inuit Nunangat. Trends for flame retardants and results indicated a very slow decrease of PBDEs and HBCD in blubber of seals for Sachs Harbour, Arviat, and Resolute Bay. Moreover, concentrations of PFOS and perfluoroalkyl carboxylic acids in liver of ringed seals have declined over the period mid-2000s to 2011 but increases were observed in recent years at some locations.

To increase communication with communities and ultimately better integrate Inuit Knowledge to this long-term study, a health in ringed seal workshop (in collaboration with Dominique Henri) is annually organized in communities involved in the project (Arviat visited in the fall of 2018). Students, Elders, school personnel, and community members worked together with scientific researchers to increase understanding of contaminants in ringed seals and learn from local knowledge about seal ecology and traditional methods for capturing and skinning seals. Synergies between the two NCP projects from Environmental Monitoring and Communications, Capacity and Outreach programs provide opportunities to enhance local capacity building, communications and the use of Indigenous Knowledge in contaminants research on ringed seals. We plan to organize a similar workshop in the fourth community contributing to the NCP core ringed seal monitoring project in Nain, Labrador in 2019.

Expected project completion date

This is an on-going core monitoring project.

Acknowledgments

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References

Addison, R. F. and Smith, T. G. 1974. Organochlorine residue levels in arctic ringed seals : variation with age and sex. *Oikos* 25 (3), 335-337.

Houde, M., Wang, X., Colson, T.-L.L., Gagnon, P., Ferguson, S.H., Ikonomou, M., Dubetz, C.,

Addison, R.F., Muir, D.C.G. 2019. Persistent organic pollutants in ringed seals (*Phoca hispida*) from the Canadian Arctic. *Science of the Total Environment* 665: 1135-1146.

Houde, M., Wang, X., Ferguson, S.H., Gagnon, P., Brown, M., Tanabe, S., Kunito, T., Kwan, M., Muir, D.C.G. 2017. Spatial And temporal trends of flame retardants in ringed seals (*Phoca hispida*) across the Canadian Arctic. *Environ. Pollut.* 223, 266-276.

Muir, D. and Lockhart, L. 1994. Contaminant trends in freshwater and marine fish. *Synopsis of research conducted under the 1993/1994 Northern Contaminants Program. Environmental Studies Report, No. 72.* Ottawa, Canada. Indian and Northern Affairs Canada. pp. 264-271.

Muir, D. C. G. 1996. Spatial and temporal trends of organochlorines in Arctic marine mammals. *Synopsis of Research Conducted Under the 1994/95 Northern Contaminants Program, Environmental Studies No. 73*. Ottawa, Canada. Indian and Northern Affairs Canada. pp. 135-146.

Muir, D., Kwan, M. et al. 1999. Spatial trends and pathways of POPs and metals in fish, shellfish and marine mammals of Northern Labrador and Nunavik. *Synopsis of Research Conducted Under the 1998/99 Northern Contaminants Program.* Indian and Northern Affairs Canada. Ottawa, Canada. pp 165-171.

Muir, D., Fisk, A. et al. 2001. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2000-2001 Northern Contaminants Program.* Indian and Northern Affairs Canada. Ottawa, Canada. pp 208-214.

Muir, D., Kwan, M. et al. 2003. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2001-2002 and 2002-2003 Northern Contaminants Program.* Indian and Northern Affairs Canada. Ottawa, Canada. pp 318-327.

Muir, D. and Wang, X. 2014. Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic. *Synopsis of research conducted under the 2013-2014 Northern Contaminants Program.* Ottawa, ON, Aboriginal Affairs and Northern Development Canada. pp. 187-194.

US Environmental Protection Agency. 2007. EPA Method 7473 (SW-846). *Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry.* Washington, DC, United States. 17 pp.

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 hérités et émergents chez l'ours blanc du Canada

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Project locations/Emplacements du projet

Sample collections from harvested bears for this project were done by hunters via HTO partners from several Nunavut communities in Hudson Bay (Rankin Inlet, Whale Cove, Arviat and Sanikiluaq) and norther Baffin Bay (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 into the 2018-2019 fiscal year, on a biennial or annual basis, this project continues to examine trends and changes over time and between communities of NCP priority persistent (legacy and emerging) organic and elemental pollutants (POPs) in polar bears. More specifically, this project focuses on the southern (SHB) and western Hudson Bay (WHB; Nunavut) polar

Résumé

L'ours blanc (*Ursus maritimus*) est le superprédateur de l'écosystème et du réseau alimentaire marins de l'Arctique. À partir de 2007 et sur une base biennale ou annuelle jusqu'à l'exercice 2018-2019, ce projet a examiné les tendances et les variations dans le temps et entre les collectivités des polluants organiques persistants (POP) et élémentaires (hérités et émergents) prioritaires pour le PLCN chez les ours polaires. Plus précisément, ce projet se concentre sur les sous-populations

bear subpopulations. Priority contaminant data sets for this project now span over 10 years (2006-2018), which is revealing interesting trends. For example, legacy POPs (industrial chemicals and pesticides e.g., PCB, CHL, HCH, CBz and DDT) levels, and especially PCBs and CHLs, remain consistently high in polar bear fat. For WHB bears, ΣPBDE flame retardant levels in fat rapidly increased up until 2000-2003, and in more recent years continued to increase, but more slowly, with levels that were generally greater in the SHB compared to the WHB bears. Some fluorinated surfactant chemicals called per-/poly-fluoroalkyl substances (PFASs), like the highly accumulating PFOS, continue to be at high levels in bear liver, and at levels comparable to CHLs. Over the period of 2007 to 2018 for both subpopulations, there were significant changes in PFAS levels; the direction and magnitude of changes in PFAS depends on the PFAS. Total mercury (THg) levels in liver samples collected from 2006 to 2018 were generally higher in the WHB compared to the SHB bears. There were no significant trends of THg concentration change over this period for bears from either SHB or WHB. To more clearly reveal and understand the reasons for changes over time in POP levels in Hudson Bay polar bears, the collected data included age, sex, body condition, time of collection, lipid content, diet and food web structure indicators, and indicators of climate change (sea ice conditions, temperature, etc.). An example of the climate-related results showed higher THg and POP levels in polar bears were most often associated with changes in the sea ice such as earlier freeze ups, shorter ice-free periods, and greater seasonal sea ice coverages.

In 2018 the principle investigator (PI) of this project travelled to the Rankin Inlet and Arviat communities to discuss contaminants and other important polar bears issues with hunters, and also participated in information exchanges with students and other community members in Arviat. The results of this project are being used locally (communities), regionally (Hudson Bay), nationally, and internationally, as polar bears are top predator consumers in the marine food web. Because of their status as top predators,

d'ours polaires du sud de la baie d'Hudson (SBH) et de l'ouest de la baie d'Hudson (OBH; Nunavut). Les ensembles de données sur les contaminants prioritaires pour ce projet couvrent maintenant 10 ans (2006-2018), ce qui révèle des tendances intéressantes. Par exemple, les concentrations de POP hérités (produits chimiques industriels et pesticides, dont les BPC, CHL, HCH, CBz et DDT), et en particulier les BPC et les CHL, restent constamment élevés dans la graisse des ours polaires. Pour les ours de l'OBH, les concentrations de ΣPBDE ignifuges dans la graisse ont rapidement augmenté jusqu'en 2000-2003, et ces dernières années, ils ont continué à augmenter, mais plus lentement, avec des concentrations généralement plus élevées chez les ours du SBH que chez les ours de l'OBH. Certains agents de surface fluorés appelés substances per-/polyfluoroalkylées (PFAS), comme le SPFO qui s'accumule fortement, continuent d'être présents à des concentrations élevés dans le foie des ours, et à des concentrations comparables aux CHL. Au cours de la période de 2007 à 2018, pour les deux sous-populations, on a observé des changements importants dans les concentrations de PFAS; le sens et l'ampleur des variations de PFAS dépendent de la nature des PFAS. Les concentrations de mercure total (HgT) dans les échantillons de foie prélevés entre 2006 et 2018 étaient généralement plus élevées chez les ours de l'OBH que chez les ours du SBH. Aucune tendance significative de l'évolution des concentrations du HgT n'a été observée au cours de cette période chez les ours du SBH ou de l'OBH. Pour mieux saisir et comprendre les raisons des variations dans le temps des concentrations de POP chez les ours polaires de la baie d'Hudson, les données recueillies comprenaient l'âge, le sexe, l'état corporel, le moment de la collecte, la teneur en lipides, les indicateurs de régime alimentaire et de structure du réseau alimentaire, ainsi que les indicateurs du changement climatique (état de la glace de mer, température, etc.). Un exemple de résultats liés au climat a montré que des concentrations plus élevées de HgT et de POP chez les ours polaires étaient le plus souvent associées à des changements dans la glace de mer, p. ex., des gelées plus précoces, polar bears inform scientists about contaminants in the Arctic and if the contaminants are affecting the health of polar bears. The 2018-2019 results demonstrate that POP and mercury monitoring needs to continue to assess for any unpredictable changes in the levels of exposure and possible health implications for these bears. Indigenous peoples from participating communities are integral partners in this project at all levels, including polar bear harvesting and sample collection, provision of field and Indigenous Knowledge (IK) and ongoing communication exchange. Their provision of knowledge is required to best understand and interpret POP/Hg data in polar bears as there are many factors that influence changes over time and between subpopulations.

des périodes sans glace plus courtes et des couvertures de glace de mer saisonnière plus importantes.

En 2018, le chercheur principal de ce projet s'est rendu dans les collectivités de Rankin Inlet et d'Arviat pour discuter des contaminants et d'autres problèmes importants liés aux ours polaires et aux chasseurs, et a également participé à des échanges de données avec des étudiants et d'autres membres de la collectivité d'Arviat. Les résultats de ce projet sont utilisés au niveau local (les collectivités), régional (la baie d'Hudson), national et international, car les ours polaires sont les principaux prédateurs consommateurs dans la chaîne alimentaire marine. En raison du statut de superprédateur des ours polaires, les données sur ces animaux permettent aux scientifiques de mieux connaître les contaminants présents dans l'Arctique et les effets de ces contaminants sur la santé des ours polaires. Les résultats de 2018-2019 montrent que la surveillance des POP et du mercure doit se poursuivre afin d'évaluer toute variation imprévisible des concentrations d'exposition et les éventuelles conséquences sur la santé de ces ours. Les peuples autochtones dans les collectivités participantes sont des partenaires à part entière de ce projet à toutes les étapes, y compris pour la récolte et la collecte d'échantillons d'ours polaires, leur connaissance du terrain et le savoir autochtone, et les liens de communication continue. Leur apport en connaissances est nécessaire pour mieux comprendre et interpréter les données sur les POP et le Hg chez les ours polaires, car de nombreux facteurs influent sur les changements au fil du temps et entre les sous-populations.

Key messages

- Over the last 10 years, regardless of the year sampled (including 2018) or the subpopulation, SPCB concentrations in polar bear fat were by far the highest relative to other legacy POPs (SPCBs, SCHLs, SHCHs, SCBzs and SDDTs) or other POPs that were measured.

Messages clés

- Au cours des dix dernières années, peu importe l'année d'échantillonnage (y compris 2018) ou la sous-population, les concentrations de BPC dans la graisse des ours polaires étaient de loin les plus élevées par rapport aux autres POP hérités (∑BPC, ∑CHL, ∑HCH, ∑CBz et ∑DDT) ou aux autres POP qui ont été mesurés.

- For WHB bears from 1991 to 2018, SPBDE flame retardant concentrations in the fat rapidly increased up until 2000-2003. From 2003 to 2018 the rate of increase slowed by 5 to 10 times; SPBDE concentrations were generally greater in the SHB compared to the WHB bears.

- Among all the PFASs analyzed in liver collected from 2006 to 2018, the concentrations were consistently the greatest for PFOS and C9, C10 and C11 PFCAs; and greater in SHB compared to WHB bears.

- Over the period of 2007 to 2018 for both subpopulations, more PFCAs and PFSAs showed significant linear relationships for the SHB bears than for the WHB bears, e.g. PFOS exhibited no obvious trend in the WHB bears whereas for SHB bears PFOS decreased significantly.

- THg concentrations in liver samples collected from 2006 to 2018 were generally higher in the WHB compared to the SHB bears, and with no significant trends of change over this period.

- Climate variables and factors were influential in the temporal trends of some contaminants, for example, changes in the concentrations of THg and legacy POPs in polar bears were most often associated with increasing sea ice presence (earlier freeze ups, shorter ice free periods, and greater seasonal sea ice coverages).

- Pour les ours de l'OBH de 1991 à 2018, les concentrations de ∑PBDE ignifuges dans la graisse ont rapidement augmenté jusqu'en 2000-2003. De 2003 à 2018, le taux d'augmentation a été 5 à 10 fois plus lent; les concentrations de ∑PBDE étaient généralement plus élevées dans le SBH que dans l'OBH.

- Parmi tous les PFAS analysés dans les foies prélevés entre 2006 et 2018, les concentrations étaient systématiquement les plus élevées pour le SPFO et les PFCA à C_9, C_{10} C_{11}, et plus élevées chez les ours du SBH que chez ceux de l'OBH.

- Au cours de la période 2007-2018, pour les deux sous-populations, un plus grand nombre de PFCA et de PFSA étaient associés à une relation linéaire plus significative pour les ours du SBH que pour les ours du SBH. Par exemple, le SPFO n'a pas montré de tendance manifeste chez les ours du SBH, alors que pour les ours du SBH, le SPFO a diminué de manière significative.

- Les concentrations de HgT dans les échantillons de foie prélevés entre 2006 et 2018 étaient généralement plus élevées chez les ours de l'OBH que chez les ours du SBH, et aucune tendance significative de changement n'a été observée au cours de cette période.

- Les variables et facteurs climatiques ont eu une influence sur les tendances temporelles de certains contaminants. Par exemple, les changements dans les concentrations de HgT et de POP hérités chez les ours polaires ont été le plus souvent associés à une présence accrue de glace de mer (gel plus précoce, périodes sans glace plus courtes et couverture de glace de mer saisonnière plus importante).

Objectives

This project aims to:

- establish monitoring, continue to monitor, or monitor with increased resolution, the (retrospective) temporal trends and changes of NCP priority, new and emerging POPs that are currently regulated or under review for regulation (e.g. Stockholm Convention on POPs). Monitoring of POPs will occur in polar bears within the two management zones in Hudson Bay (southern and western), in the 2018-2019 fiscal year;
- incorporate both scientific and Indigenous Knowledge, to examine the influence of diet/food web structure and trophic position (using carbon and nitrogen stable isotopes and fatty acid profiles as ecological tracers), sex, age, lipid content, time of sample collection and climate change variables on POP temporal trends in Hudson Bay polar bears;
- provide information to Hudson Bay Inuit communities participating in the study, and other communities, on the levels, changes, fate and potential effects of POPs in polar bears; and
- archive the remaining Hudson Bay polar bear tissue samples, as well as tissues collected in northern Baffin Bay (for future contaminant monitoring), in Environment and Climate Change Canada's National Wildlife Specimen Bank (ECCC-NWSB), NWRC.

Introduction

Mercury (Hg) and a growing array of chlorinated, brominated and especially fluorinated POPs, have proven to be anthropogenic contaminants that are transported to the (Canadian) Arctic and accumulate in biota. In some cases, levels of these compounds in tissues and blood have been shown to be related to an array of immunological, reproductive, developmental and, endocrine effects (AMAP 2011, AMAP 2016, AMAP 2017, AMAP 2018, Routti et al. 2019). These bioaccumulative POPs (and/or their precursors and degradation products) and Hg are transported via global atmospheric and/or oceanic pathways and processes that result in deposition in the Arctic. They are found in Arctic endothermic top predators, particularly 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, Brown et al. 2018, Morris et al. 2016). POP and Hg levels are generally very high in polar bears and thus constitute effect risks, despite the polar bear's relatively high ability to bio-transform compounds via hepatic enzymatic processes to excrete them (AMAP 2018, AMAP 2017, Bechshøft et al. 2019, 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 important sentinel and monitoring species for legacy and emerging POPs and Hg. The levels of POPs are generally the highest in the polar bear compared to other Arctic wildlife (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, historic levels of some legacy POPs such as PCBs decreased prior, and up to, 2000 but have since remained relatively unchanged up to 2017 (Letcher et al. 2018a). 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, and in some cases for the first time, in the liver and fat of polar bears (AMAP 2017, Boisvert et al. 2019; Letcher et al. 2018a, 2018b).

For 2018-2019, polar bears samples were analyzed for emerging POPs as part of an ongoing annual monitoring project. Annual analysis of chemicals, that are priorities to national and international regulatory programmes or agreements, is important to determine if they are present in the Arctic 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, Strategic Approach to International Chemicals Management (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 substances are POPs listed or 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), hexachlorobutadiene (HCBD; Annex A as of 2015), and pentachlorophenol (PCP) and its salts and esters (Annex A as of 2015). POPs just listed this year (May 2019) are dicofol and perfluorooctanoic acid (PFOA and its salts and related compounds), while perfluorohexane sulfonic acid (PFHxS) and its salts and related compounds are under review.

This polar bear monitoring continues to integrate and better understand the influence of climate change variables (e.g. sea ice conditions and temperature) on POP and Hg dynamics and trends in Hudson Bay, which has been shown to be particularly affected by Arctic warming. For example, over a decade ago we showed that over the 1991-2007 period changes in sea ice in western Hudson Bay were linked to shifts in the diet of polar bears. These 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., 2009, 2010, 2011a, 2011b).

Arctic ecosystems face multiple challenges at local and regional scales, among them changes and the potential stress of changes in climate and exposure to anthropogenic chemical contaminants proven to be POPs (AMAP, 2018; Dietz et al., 2016; Ferguson et al., 2015; Letcher et al., 2010; Ma et al., 2016; McKinney et al, 2013, 2015). The continued warming of the Arctic has been demonstrated by the 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, including the introduction of new species and loss of existing species. Research has shown that Arctic warming and changes in sea ice means changes in exposure to POPs and Hg to Arctic biota, particularly in the polar bear (i.e. Canadian Hudson Bay and East Greenland subpopulations) (AMAP, 2018; McKinney et al., 2015; Routti et al.,2019).

Activities in 2018-2019

Field sampling

Validated 2017 and 2018 Nunavut Wildlife Research Permits (NWRPs) were in place for polar bear sample collections during the harvests that occurred over the late 2017 / early 2018 period and carried out by communities in Hudson Bay and Baffin Bay. The NWRPs were prepared and evaluated in collaboration with communities via the NDE (Wildlife Management Research: Markus Dyck and Jasmine 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) are participants in this project (updated by Markus Dyck (GN-NDE)):

- Western Hudson Bay (Keewatin Region): Rob Harmer (Regional NDE manager)
- Arviat: Joe Saviqataaq Jr. (CO), Thomas Alikaswa (HTO Chairperson), Andrea Ishalook (HTO Manager)
- Rankin Inlet: Johanne Coutu-Autut (CO) and Daniel Kaludjak (CO), Brian Sigurdson (HTO Chairperson), Clayton Tartak (HTO Manager)
- Whale Cove: Vacant (CO) (Rob Harmer and Johanne Coutu-Autut temporary COs), Simon Enuapik Sr. (HTO Chairperson), Lisa-Grace Jones (HTO Manager)
- Southern Hudson Bay (Qikiqtaaluk Region):
- Sanikiluaq: Daniel Qavvik (CO), Peter Kattuk (HTO Chairperson), Lucassie Arragutainaq (HTO Manager)
- Baffin Bay (Qikiqtaaluk Region): Scott Johnson, (Regional NDE manager)
- Clyde River: Bruce Jerry Hainnu (CO), Jerry Natanine (HTO Chairperson), Gordon Kautuq (HTO Manager)
- Pond Inlet: George Koonoo (CO), Jaykolassie Killiktee (HTO Chairperson), Daisy Koonoo (HTO Manager)
- Qikiqtarjuaq: Jacoobie Audlakiak (HTO Chairperson), Alison Kopalie (HTO Manager)

Community hunters and COs collected a grand total of 80 (adult and sub adult) polar bear fat, liver and/or muscle sample sets during quota-based harvests in winter 2017-2018. Samples were from 26 western Hudson Bay polar bears (Arviat [n=10; 6 males and 4 females], Rankin Inlet [n=9; 8 males and 1 female] and Whale Cove [n=7, 5 males and 2 females]). From southern Hudson Bay (Sanikiluaq) a total of 23 (n=14 males and n=9 females) Hudson Bay bears samples were collected. Also, this project involved the opportunistic collection of tissue samples of fat, liver and/or muscle sample sets from a total of 31 bears from Baffin Island/Bay. More specifically, these samples were collected from Clyde River (n=14; 7 males and 7 females), Pond Inlet (n=10; 4 males and 6 females) and Qikiqtarjuaq (Broughton Island; n=7; 5 males and 2 females). All of these samples were collected by local hunters in participating communities via interaction with local HTOs and COs. All samples were sent from communities to NDE offices in Igloolik where they were documented and processed.

Sample preparation, archiving and analysis

Jasmine Ware (NDE) arranged to ship the 2017-2018-collected tissue sub-samples to the NWRC in Ottawa on June 26, 2018. 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), fatty acid (FA), and carbon and nitrogen stable isotope (SI) analysis. This occurred in October 2018 after the return of Letcher Group technician, David Blair, from parental leave. As of March 31, 2019, all required analyses have been completed for legacy and new POPs, THg (and other metals) and FAs. Carbon and nitrogen SI and exact ages (via bear teeth) will be completed in 2019. Remaining sub-sample portions were archived and are currently stored in ECCC's National Wildlife Specimen Bank (ECCC-NWSB) at the NWRC in Ottawa for future considerations (e.g. future retrospective monitoring of legacy and new/emerging POPs and metals). The Letcher lab also participated in the last NCP quality assurance and quality control inter-laboratory round (Myers et al., 2017).

Presentations, reports and other activities

In 2018 the PI (Robert Letcher) was a major contributor and lead on several chapters (i.e. OPEs, PAHs, HCBD, FRs, PFASs and/or naturally occurring halogenated products (HNPs)) of an AMAP report on chemicals of emerging Arctic concern (AMAP, 2017), which was fully published in January of 2018. Based on the chapter content of this report, several papers were published in peer-reviewed journals (see the reference list).The PI, Robert Letcher, is also the co-lead (with Rune Dietz) and major contributor to another AMAP report on POPs and mercury exposure and effects in Arctic wildlife and fish, which was completed and published in October 2018 (AMAP, 2018). A presentation summarizing the Arctic Monitoring Assessment Programme (AMAP) report on POPs and mercury effects was made by Robert Letcher and Rune Dietz (Aarhus University, Roskilde, Denmark) at the AMAP 32nd Working Group Meeting of the Heads of Delegations (HoDs) held in Kiruna, Sweden, September 25-27, 2018. A session was also led by Robert Letcher and Dietz at the Arctic Biodiversity Congress held in Rovaniemi, Finland, October 9-12, 2018, and titled, "*AMAP 2018 - Biological Effects of Contaminants in Arctic Wildlife & Fish*".

For the 2018-2019 period, Dr. Letcher continued to be the primary supervisor of Dr. Morris throughout his NCP-supported (project N-01 - *Coordination and Administration of the Northern Contaminants Program*) NSERC VF based at the NWRC, and co-supervised by Drs. Birgit Braune, John Chételat (both at ECCC, NWRC), and Mary Gamberg (Gamberg Consulting). This project focuses on establishing what relationships exist between a suite of climate change variables and temporal trends of contaminants in polar bears, seabirds, caribou, and freshwater biota, as well as analyzing the performance of temporal trend data sets of key POPs for the NCP. We are also contributing these results to the development of the AMAP report that is currently underway on POPs and climate change in the Arctic.

We also completed ground-breaking studies on POPs (Letcher et al. 2018b) relative to metabolomics profiles in Hudson Bay bears (Morris et al. 2018, 2019). Drs. Morris and Letcher applied and were awarded funding in the 2018-2019 year for separate NCP support to expand on the study of contaminants-metabolomics profiles in high Arctic versus Hudson Bay bears and also to compare the bears to ringed seal prey. This project was done in collaboration with Magali Houde and Derek Muir, via core monitoring project M-04 - *Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic* (See 2018-2019 Synopsis Report for NCP project M-22 - *A comparative assessment of relationships between priority contaminants and metabolomic profiles in polar bears (Ursus maritimus) and ringed seal (Pusa hispida) prey from Canadian High Arctic and Hudson Bay locations*).

Capacity building

Via Dr. Letcher, ECCC has had a long running, cooperative working relationship with the Department of Environment (NDE), Government of Nunavut, with respect to polar bear contaminants research and monitoring. In the 2018-2019, this project cooperated in building capacity and expertise in scientific sampling during the winter 2018 harvests in Hudson Bay and Baffin Bay. As detailed in the valid 2017 and 2018 NWRPs, and in cooperation with Markus Dyck and Jasmine Ware in the NDE, as was necessary, Dr. Letcher arranged and sent directly to NDE a supplementary number of sampling kits that coincides with the number of bears required for these management zones and within the allowable hunting quota for communities involved (Hudson Bay and Baffin Bay). For the hunters in each community, and via the HTOs, each sampling kit contained simple and easy to read sampling instructions in both English and Inuktitut. 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 2018-2019 in the mid-year status report, which was then circulated to and reviewed by the NECC, all polar bear harvests completed in 2018 were led and carried out by local hunters and HTOs in the participating Nunavut communities in Hudson Bay (i.e., Arviat, Whale Cove, Rankin Inlet and Sanikiluaq) and Baffin Bay (i.e. Pond

Inlet, Qikiqtarjuaq and Clyde River). For these regional sample collections, the participating project team members in the NDE continued to provide training to members of the HTOs that were involved. Hunters were compensated for the sampling. In other capacity building, NSERC Visiting Fellowship Dr. Adam Morris focused on assessing the effects of climate change on contaminant trends in key species from the terrestrial (caribou) and marine environments (polar bears, seabirds) from the Hudson Bay region. These data are currently in preparation in a paper for submission and publication in a peer-reviewed journal (Morris et al. 2020b unpublished data).

Communications

The NDE requires that for all bears harvested a hunter kill return sheet be completed and submitted. On the kill sheets, the hunters have the opportunity to provide general observational comments. These kill sheets assist to optimize information exchange and communication, and consequently assist with capacity building and the utilization of Indigenous Knowledge (IK). We provided available kill sheets for polar bears harvested in 2018 to the NECC.

From October 21-30, 2018, Letcher travelled to the western Hudson Bay region (Kivalliq). On Oct. 23rd in Arviat and then on Oct. 25th in Rankin Inlet, pre-arranged meetings occurred with HTOs and members, and Letcher presented to and exchanged knowledge with COs and HTO members. The 2-hour meeting in Arviat was dominated by discussions on bear-community interactions and human safety concerns due to the recent (summer 2018) fatalities in this community. Also present at the meeting was Jennifer Provencher (ECCC-CWS), and Dominique Henri and Magali Houde (ECCC-S&T Branch). In both Arviat and Rankin Inlet, the importance of IK for individual bear information on e.g. bear body condition and the frequency and locations of bear sightings was also discussed. Letcher also gave a brief presentation on recent findings on contaminants in polar bears. A pre-arranged meeting on October 29th with the Whale Cove HTO and members did not occur due an inability to travel to the community because of poor weather which resulted in the cancellation of flights between Rankin Inlet and Whale Cove. Regardless, presentation material was e-mailed to the Whale Cove HTO Manager (Lisa Jones) by Letcher while he was stranded in Rankin Inlet.

Letcher was also part of a Regional NCP ringed seal and IK Workshops that were held in Arviat from October 22-25. The ringed seal workshop was organized with the two Arviat community schools, which included ringed seal dissections by local hunters, brief presentations to students, and hands-on class activities that informed students about ringed seals and their ecology and in relation to chemical contaminants. Amie Black (ECCC-S&T Branch) led the NCP funded project. Several individuals were involved in the workshop including the present polar bear PI (Rob Letcher), Magali Houde and Dominique Henri (ECCC-S&T Branch), Jennifer Provencher (ECCC-CWS), and others from DFO (e.g. Steve Ferguson), the University of Manitoba and the University of Windsor. All of these individuals, along with others from NCP-CIRNAC and Mary Gamberg (NCP consultant researcher), held an NCP Expo the afternoon of October 24th at the local community centre in Arviat with booths set up on seals, caribou and polar bears. The event was well attended by the community, especially by students and teachers from the local schools. In the evening of October 24th, the NCP researchers gave a series of presentations on contaminants in ringed seal (Steve Ferguson, DFO), caribou (Mary Gamberg) and polar bear (Rob Letcher) as part of an Arviat community feast (about 100 people in attendance). An IK Workshop was held October 25th with two Arviat Elders and others including Rob Letcher, Magali Houde, Dominique Henri, Jennifer Provencher and Mary Gamberg.

With respect to UNEP's Stockholm Convention of POPs, the PI (Letcher) continued to communicate and discuss data needs for priority chemicals in time for the annual POPs Review Committee (POPRC) meetings. Working with Eva Kruemmel (ScienTissiME; independent consultant for the ICC) and within ECCC, this project continued to contribute information on POPs in (Hudson Bay) polar bears to the POPRC process, which is reviewing, assessing and recommending to the Conference of the Parties (COP) on chemical listings and changes to current listings to the Convention. In part due to polar bear data contributions, several newer NCP priority chemicals have now been listed in annexes of the Stockholm Convention on POPs. Among these POPs are Deca-BDE (BDE-209; added to Annex A in 2017), SCCPs (added to Annex A in 2017), PCNs (added to Annexes A and C in 2015), and pentachlorophenol/pentachloroanisole (PCP/PCA; added to Annex A in 2015). The last meeting (POPRC14) was held September 17-21 (2018) in Rome, Italy. The POPRC adopted the risk profile on perfluorohexane sulfonic acid (PFHxS), and its salts and related compounds, and moved the chemical to the next review stage requiring a risk management evaluation. The POPRC also adopted the risk evaluation on perfluorooctane carboxylic acids (PFOA, and its salts and related compounds), and recommended to the COP that it consider listing the chemical in Annex A of the Convention. The Stockholm Convention COP-9 met from April 29 – May 3, 2019, and listed dicofol (no exemptions) and PFOA (with several exemptions) in Annex A for elimination. For PFOS and its salts and related compounds (including PFOSF) the COP amended Annex B to the Convention to end or restrict several currently still allowed uses/acceptable purposes of PFOS (e.g. in fire-fighting foams). However, one acceptable purpose for PFOS (for insect baits), and a specific exemption (for its use in fire-fighting foams) still exist, which are both uses in open applications, and very polluting.

This project and the PI Letcher have contributed to and been part of numerous papers and reviews published in peer-reviewed journals (published, accepted or submitted). There were also several international Arctic reports (AMAP, 2016, 2017, 2018) published, as well as a report that was submitted to the NCP in April 2018 for inclusion in the Synopsis of Research Conducted Under the 2017-2018 Northern Contaminants Program (Letcher et al. 2018a). There were numerous oral and poster presentations at conferences or workshops. For example, presentations were made and a ringed seal workshop/expo booth was set-up at the 2018 NCP ringed seal Workshop held in Arviat, NU (October 2018). Presentations were also made at the Society of Environmental Toxicology and Chemistry North America (SETAC-NA) 2018 conference in Sacramento, CA, U.S.A. in November 2018. In 2018 NCP-supported polar bear contaminant research and monitoring was also the subject of numerous Canadian and U.S. media articles.

Indigenous Knowledge (IK) integration

Incorporating IK, on an annual basis, into this ongoing contaminant 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 2017-2018 collection of samples was carried out exclusively by hunters in the participating Hudson Bay and Baffin Bay communities and in coordination with the PI and involved agencies in Nunavut. This project worked within the guidelines of the allowable hunting quotas for each of the HTOs and communities. This project continued to seek any IK that could be provided in the information provided by the hunters such as ecological information on behavior (e.g. observations of unusual dietary events other than ringed seal predation), body condition and population numbers as provided to wildlife COs and biologists. It should be noted that polar bears are consuming country food at similar trophic levels as people in the communities. The inclusion of IK continues to be vitally important in the understanding contaminant variations and changing trends (diet and habitat), despite the link to shared resources (e.g. contaminant exposure from seal). This supports a two-way integration of knowledge.

Letcher is a team member of a community-based NCP-funded project led by Dr. Joel Heath of the Arctic Eider Society, which is building on existing community-driven research programs and an Interactive Knowledge Mapping Platform (SIKU). Building on existing capacity in Sanikiluaq, the project is training and employing local hunters, and utilizing IK, to collect data on wildlife and sea ice observations during land-use activities, including the meaningful involvement of youth in research and monitoring efforts. This initiative continues to facilitate the systematic collection by hunters of observations on the body condition and diet of important food species (including for ringed seal and polar bear) through participatory methods and photos of harvested animals, their organs and stomach contents. Based on the feedback obtained in 2017-2018, the tools and features on the SIKU mobile app were updated and improved to better incorporate different kinds of IK and improve ease of use and reliability. A workshop held in September 2018 provided more detailed feedback on how privacy, intellectual property and data stewardship features of the SIKU app and platform could be designed to provide Inuit users with flexibility to accommodate informed choices as desired for different situations. These features and approaches have since been incorporated into a very recent version 2.0 of the mobile app and online platform, which has been positively received. Further approaches to synthesizing data and workflows for incorporating results into contaminants analysis as part of a 3-year pilot study were designed with project team members collaborating via core NCP monitoring projects M-05 - *Temporal and Spatial Trends of Legacy and Emerging Organic and Metal/Elemental Contaminants in Canadian Polar Bears* (Robert Letcher, polar bears) and M-04 - *Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic* (Magali Houde and D.C.G. Muir, ringed seals). Community and project partner review and evaluation have indicated that the proof-of-concept phase was successful and is worthwhile developing into this 3 year pilot study with specific outcomes to improve analysis and interpretation of ringed seal and polar bear contaminants data set, and more generally establish a better role and approach for meaningfully incorporating IK and observations into contaminants research programs.

Results and outputs/deliverables

Regardless of the year sampled or the subpopulations, SPCB concentrations in polar bear fat were by far the highest relative to other legacy POPs (SPCBs, SCHLs, SHCHs, SCBzs and SDDTs) (Table 1, Figure 1). The composition of all legacy POPs were relatively consistent between years. From 1991 to the present, lipid corrected SPCB concentrations (but uncorrected for other variable, e.g. age, sex and diet) remained high for WHB bears, with no decrease over the last 26 years (Table 1, Figure 1). From 2006 to the present, the same was true for SHB bears, but SPCB concentrations decreased at a rate of -4.6%/year over the last decade, which was statistically significant (Morris et al. 2020a, unpublished data).

Only the main congeners of the Penta- and Octa-BDE technical mixtures were detected at frequencies > 80 % in the fat of WHB and SHB bears, and accounted for > 90 % of the SPBDE concentration (Table 1, Figure 1). BDE-209 was detected in 2009 and 2012 but was otherwise only found sporadically throughout the monitoring period and up to 2017-2018. Of the non-PBDE halogenated FRs, only a-HBCDD and BB-153 were detected consistently (> 80 %), though several were also detected sporadically (PBEB, HBB, BB-101) (Morris et al. 2020a, unpublished data). Using breakpoint analysis, priority tetra-hexaBDE congeners and SPBDE concentrations from the early 1990s to the early 2000s increased significantly in the WHB bears (rate of +15-16 %/year), and afterward the increase continued but an » 5 - 10 times slower rate of +2.1-5.2 %/year. There was no apparent temporal increase or decrease of SPBDE concentrations for the SHB bears from 2006 to 2017 (Table 1, Figure 1).

When uncorrected for e.g. age, sex and diet, and for all Hudson Bay bears over the period of 2007-2018, among the 22 PFASs analyzed (in liver) the concentrations were consistently the greatest for PFOS and SPFCAs (low levels of PFOA but mostly longer chain length C9-C13 PFCAs) (Table 1, Figure 1) (Letcher et al. 2020, unpublished data). C9-C13 PFCAs were the highest concentration PFCAs for all years, and higher in SHB compared to WHB bears (Table 1, Figure 1). In the liver and in all WHB and SHB bear samples from 2007 and including up to 2018, PFOS concentrations were consistently greater than for SPFCAs. PFOS concentrations were generally comparable to SCHL concentrations for all bears and years studied (Table 1, Figure 1).

Concentration changes over the period of 2007 to 2018, without adjustment or filtering by demographic category, were examined by linear regression, and there were significant changes for bears from both subpopulation but depending on the PFCA and PFSA (Letcher et al. 2020, unpublished data). More PFCAs and PFSAs showed significant linear relationships for the SHB bears than for the WHB bears. For example, PFOS exhibited no discernible trend in the WHB bears (0.30 % yr-1), whereas for SHB bears PFOS decreased significantly with an annual rate of -5.8 % yr-1 and a half-life of 12 yr. (Figure 2). Also, with the exception of PFHxS, SHB bears had linear negative relationships with annual rates and half-live for C11–C13 PFCAs (-7.0 to -8.3 % yr-1, t1/2 = 8.0–9.5 yr.), FOSA (-46 % yr-1, t1/2 = 1.1 yr.), and the SPFAS and SPFSA [-4.4 and 5.7 % yr-1, t1/2 = -15 and 12 yr., (respectively)] (Figure 2). In contrast to the SHB bears, the temporal trends of PFAS concentrations in the WHB bears generally increased over time although not all were significant (Figure 2).

The temporal trend linear regressions of PFCA/PFSA concentrations with d15N (trophic level) adjustment as well as for no adjustment are shown in Figure 4 (Letcher et al. 2020, unpublished data). Although the linear regression for C9-PFNA was insignificant for both subpopulations, subdividing and/or d15N adjusting the data produced a number of significant linear regressions in the WHB bears, with significant rate of concentration increase for WHB subadults, d15N-adjusted subadults, WHB females (all ages), subadult females, and d15N-adjusted subadult females (range of 6.7–14 % yr-1). The d15N adjustment also accelerated the rate of annual increase for PFDA (5.8–8.3 % yr-1; subadults and d15N-adjusted subadults), SPFAS (4.0–6.0 % yr-1; subadults and d15N-adjusted subadults), and SPFCA (6.0–8.0 % yr-1; subadult females and d15N-adjusted subadult females). PFOS concentrations in WHB for the same group (d15N-adjusted subadults) increased significantly (4.4 % yr-1) up to 2015/2016 only (identical change for the SPFSA).

Table 1. Temporal trends of the arithmetic mean (and SE) concentrations of ∑PCBs, ∑CHLs, ∑HCHs, SCBzs, SDDTs and SPBDEs in fat tissue, and SPFCAs and PFOS and THg in liver tissue in polar bears from southern and western Hudson Bay. Contaminant data from samples collected in 1991 to 2007 has been reported in McKinney et al. (2009, 2010) and Routti et al. (2011). All contaminant data from 2008 to 2018 is unpublished. The data has not been corrected for sex, age or diet (if applicable).

Southern Hudson Bay

	ΣPBDE			ΣCBz		ΣHCH		ΣDDT		ΣCHL		ΣPCB		ΣPFCA			PFOS		THg		
	ng/g (lipid wt)													ng/g (wet wt)					µg/g (dry wt)		
Year	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	n	Mean	SE	Mean	SE	n	Mean	SE
2006/07	8	109	21	212	19	341	23	179	41	2091	703	8022	1305	2	1519	305	2971	662	2	42	7
2007/08	13	74	5.6	156	11	167	12	157	10	1434	209	4821	395	12	600	59	1452	126	12	17	2
2009/10	25	87	8	152	10	240	13	199	34	1854	310	7497	1146	25	1280	84	2466	161	25	19	2
2010/11	9	99	13	286	33	360	32	254	37	2470	449	9208	1286	9	814	66	1715	186	9	18	2
2011/12	10	91	9.0	172	18	234	22	161	28	2266	339	4178	608	10	643	54	1302	196	10	n/a	--
2012/13	23	104	8.5	242	28	244	25	223	44	2214	281	7060	1019	23	998	93	1974	209	23	21	2
2013/14	24	77	10	194	12	213	12	166	18	1771	192	4640	375	24	816	53	1255	98	24	18	2
2014/15	10	144	54	200	36	207	50	145	17	2355	1109	9397	4764	10	972	107	1658	243	10	30	4
2015/16	10	78	5.9	167	21	253	16	176	24	1294	172	4791	436	10	936	58	1742	144	10	22	2
2016/17	10	97	12	141	28	300	43	185	49	1129	214	4656	813	10	838	80	1175	152	10	23	3
2017/18	10	85	7.0	151	11	191	25	156	19	1472	295	7951	694	10	786	65	1353	128	10	18	2

Western Hudson Bay

	ΣPBDE			ΣCBz		ΣHCH		ΣDDT		ΣCHL		ΣPCB		ΣPFCA			PFOS		THg		
	ng/g (lipid wt)													ng/g (wet wt)					µg/g (dry wt)		
Year	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	n	Mean	SE	Mean	SE	n	Mean	SE
1991/92	14	6.8	0.5	224	17	310	16	341	25	2693	201	3555	250	--	--	--	--	--	--	--	--
1992/93	15	7.6	0.5	311	25	392	17	478	35	2837	206	3543	272	--	--	--	--	--	--	--	--
1994/95	15	11	1.1	239	22	332	15	421	54	2874	296	3943	574	--	--	--	--	--	--	--	--
1995/96	15	11	1.0	188	7.9	327	13	445	31	2666	207	3317	315	--	--	--	--	--	--	--	--
2001/02	8	34	4.9	231	28	218	30	143	30	3053	519	5230	1151	--	--	--	--	--	--	--	--
2003/04	12	62	13	289	49	307	30	129	21	2389	462	7415	763	--	--	--	--	--	--	--	--
2007/08	12	50	10	242	37	241	22	124	38	2615	715	5972	1446	11	382	41	837	82	11	24	4.7
2009/10	9	59	18	252	71	335	60	185	73	2483	873	8336	2480	9	537	62	1071	132	9	24	2.7
2010/11	2	44	6.1	175	40	227	21	170	9.1	1726	28	1608	163	3	364	32	580	48	3	22	1.4
2011/12	10	58	11	371	57	282	27	190	46	3600	622	3996	866	9	554	68	1050	143	9	28	4.4
2012/13	12	61	6.1	416	56	297	34	235	54	3627	642	6829	813	12	683	53	1268	96	12	42	5.0
2013/14	17	38	4.3	334	42	289	23	97	22	1830	215	5025	888	17	577	52	878	71	17	24	3.1
2014/15	10	90	20	359	35	230	45	231	75	3635	663	7878	1069	11	605	35	1019	99	11	35	6.6
2015/16	9	56	9.3	309	51	198	18	135	18	2399	604	3924	844	9	618	48	1091	97	9	26	4.5
2016/17	9	56	9.1	434	91	204	29	133	43	2626	403	4391	492	9	500	52	667	56	9	30	5.8
2017/18	10	47	12	309	54	223	33	166	42	1842	316	5017	1192	10	638	51	996	67	10	40	6.0

Figure 1. A comparison of the temporal trends of the arithmetic mean concentrations of SPCBs, SCHLs, SHCHs, SCBzs, SDDTs and SPBDEs in fat tissue (ng·g-1 lipid weight), and SPFCAs and PFOS (ng·g-1 wet weight) and THg (µg·g-1 dry weight) in liver tissue in polar bears from southern (top figure) and western (bottom figure) Hudson Bay (see also Table 1). Contaminant data from samples collected in 1991 to 2007 has been reported in McKinney et al. (2009, 2010) and Routti et al. (2011). All contaminant data from 2008 to 2018 is unpublished. The data has not been corrected for sex, age or diet (if applicable).

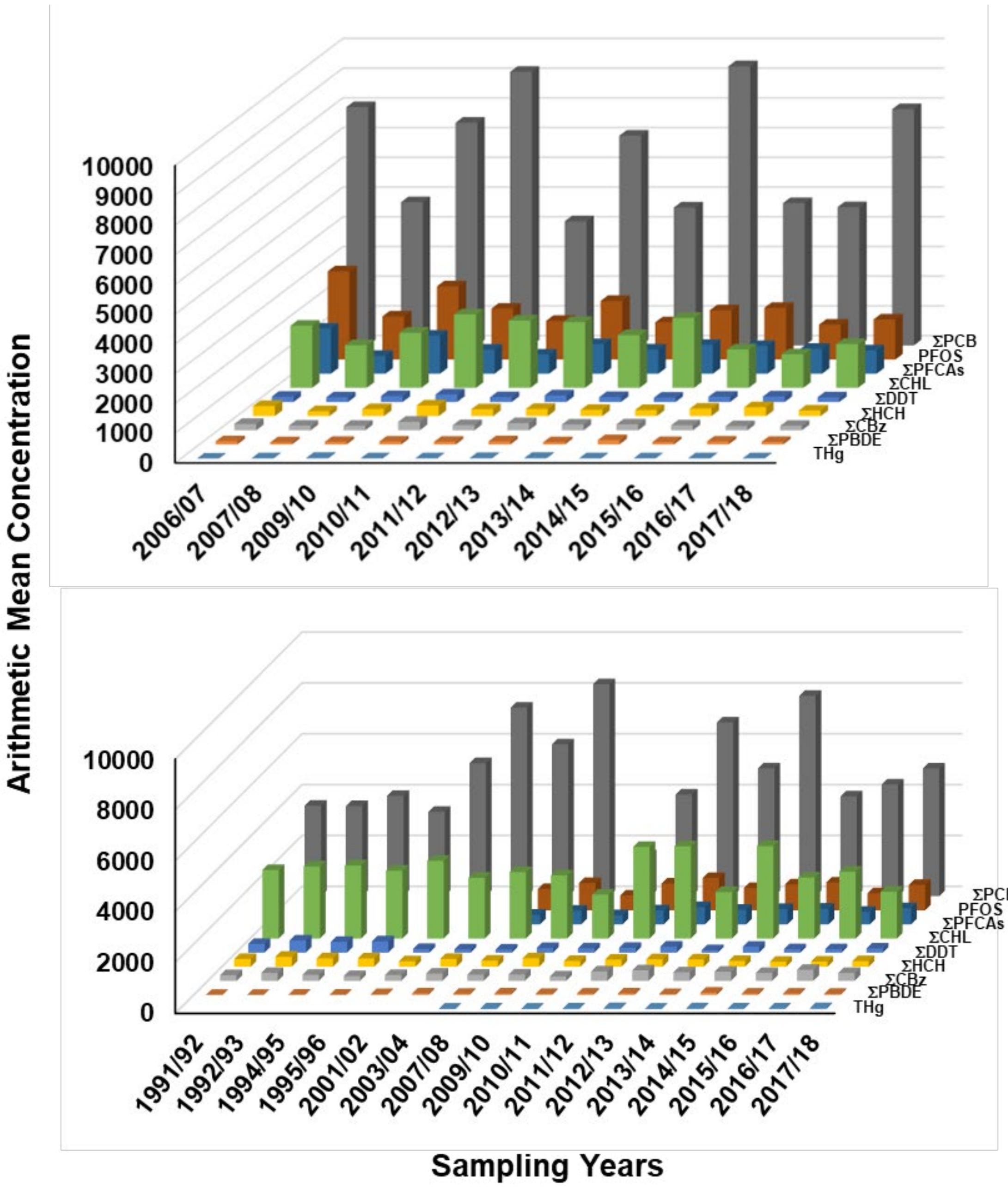
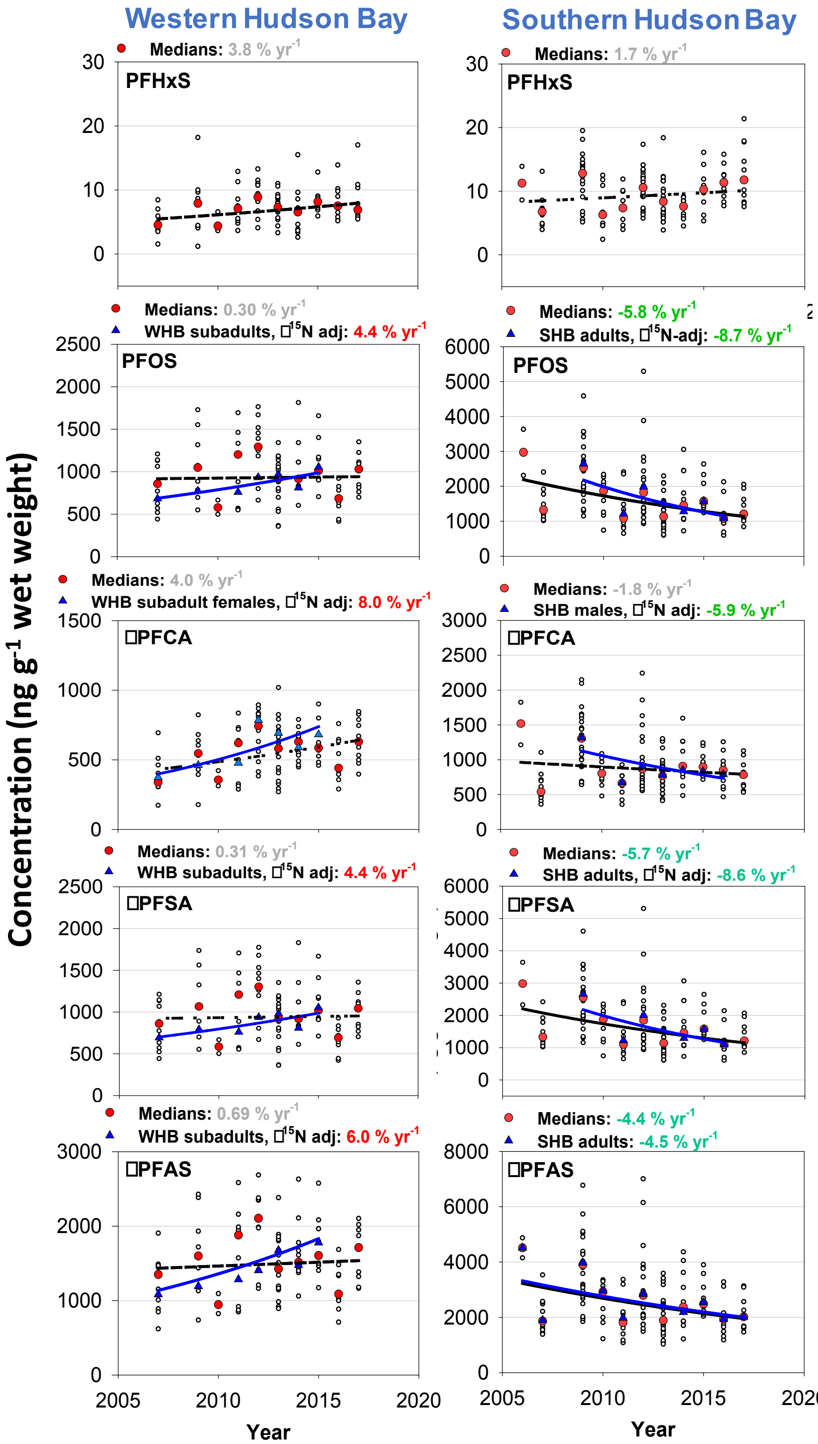


Figure 2. Linear regression analysis of LN PFAS concentrations (medians, ng·g-1 wet weight) in polar bear liver samples from the western and southern Hudson Bay subpopulations. Red circles represent unadjusted values with their annual rates of change (greyed rates of change are insignificant). If relationships for subdivided and/or d15N adjusted concentrations were significant, they are also shown. White circles are the unadjusted, individual concentrations.

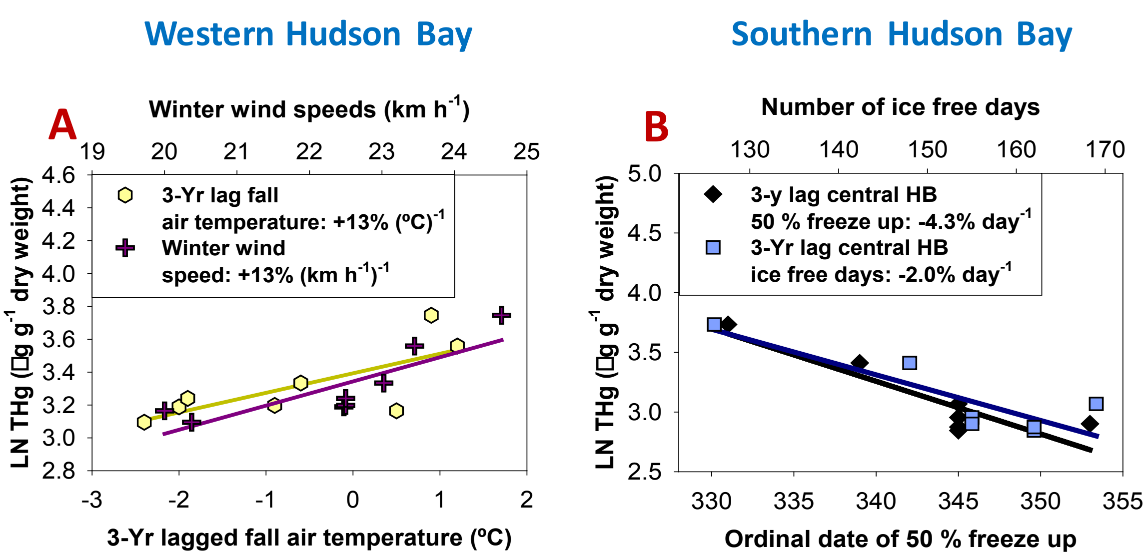


THg concentrations in the liver collected in 2018 from bears from WHB and SHB were retrospectively comparable to concentrations in samples from years going back to 2007 (Table 1, Figure 1). Similar to previous years, in 2018 liver samples the THg concentrations were generally higher in the WHB bears compared to the SHB bears. Linear regressions of THg concentrations with year were not significant for SHB or WHB bears.

Temporal trends data is also being assessed for the relationships between contaminant concentrations and a range of climate and weather factors in the SHB and WHB bears (Morris et al. 2020a, unpublished data). Contaminants included those used for performance monitoring by the NCP due to their varied physicochemical properties, toxicological relevance to wildlife and humans, and high detection frequencies including total mercury (THg), a-HCH, *p,p*'-DDE (DDE), and CB-153 (and new POPs BDE-47 and PFOS not presently discussed). General linear models (GLMs) were used to assess the temporal changes of contaminants in polar bear tissues over the last 8 to 14 years, while also testing the effects of weather/climate covariates over the same time frames and with time-lags up to 3 years (i.e., annual mean concentrations were paired with climate variables 1 to 3 years prior to the year of contaminant sampling).

As mentioned, linear regressions of THg concentrations with year were not significant for SHB or WHB bears. In the multivariate models, the concentrations of THg were best explained by weather or climate factors alone. The best fit models for SHB bears all dealt with sea ice, and showed that later freeze-up dates (i.e. longer ice free periods) 3 years prior to contaminant sampling were related to lower concentrations of THg (Figure 3b), while greater ice cover in the fall resulted in increased concentrations. For WHB bears, the best fit models showed that greater winter wind speeds, greater fall air temperatures 3 years prior, and higher amounts of summer precipitation in the year preceding sampling were all related to increasing THg concentrations (Figure 3a).

Figure 3. (A) Liver concentrations of THg (µg·g-1 dry weight) in WHB polar bears as a function of winter wind speeds (top axis) and lags in the fall air temperatures. Liver concentrations of THg (µg·g-1 dry weight) in SHB polar bears as a function of sea ice factors in the liver SHB polar bears. The number of ice-free days (top axis) in (B) were calculated between the 50 % break up date and the 50 % freeze up date.

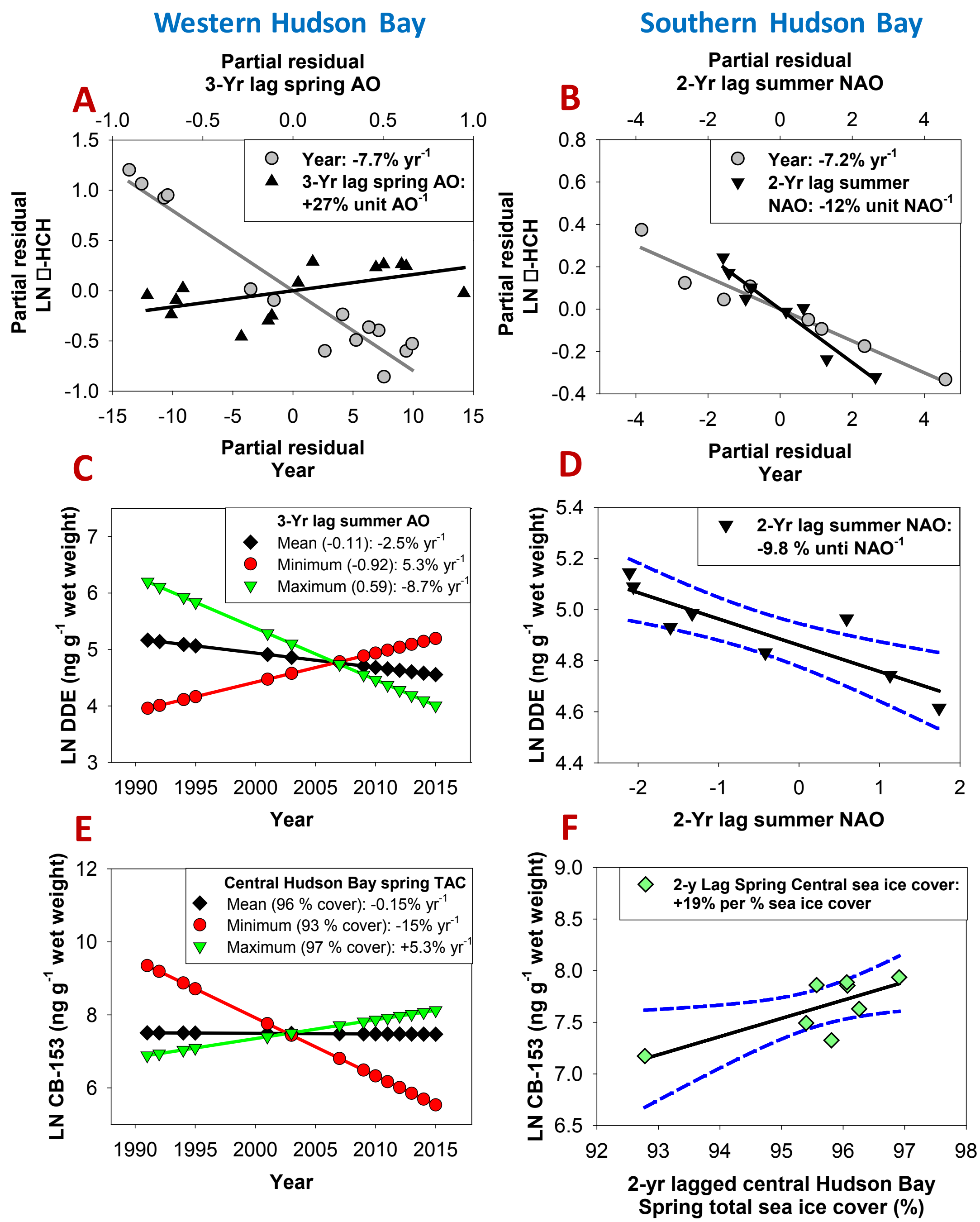


Climate and weather factors and temporal trends of legacy POP concentrations (ng·g-1 ww) were inconsistent for the contaminants studied. Concentrations of a-HCH decreased significantly in linear regressions with year in both WHB and SHB (-6.0 to -7.5 % yr-1). In separate models, there were strong multivariate relationships between concentrations of a-HCH, year and time-lagged values of the spring (Arctic Oscillation (AO) or the summer North Atlantic Oscillation (NAO), for WHB and SHB respectively (Figures 4a, b). Greater values of the spring AO 3 years prior to sampling were related to greater a-HCH concentrations in WHB bears, while in contrast greater summer NAO indices 2 years prior to sampling were related to decreased a-HCH concentrations in SHB bears. Both the trends with year from those models in WHB and SHB bears showed decreases at more comparable rates after the GLM compensated for the effects of the oscillation indices (-7.7 and -7.2 % yr-1, respectively). Similar to THg, higher wind speeds were also associated with greater a-HCH concentrations in the WHB bears.

The *p,p'*-DDE concentrations decreased significantly with year alone for WHB bears (-4.0 % yr-1), however, the trend plateaued and was not significant for SHB bears (-0.94 % yr-1). Greater values of the summer AO or NAO indices 3 and 2 years prior to sampling (respectively) were related to decreasing concentrations of *p,p'*-DDE in WHB and SHB bears (Figure 4c and d, respectively). However, for the WHB bears most of the other relationships were opposite for the time-lagged annual and fall oscillation indices. That is, greater time-lagged values of the annual, spring and fall AOs or NAOs were related to greater concentrations of *p,p'*-DDE. Like a-HCH, both year and an increasing spring AO 3 years prior to sampling were significantly related to *p,p'*-DDE concentrations in the WHB bears, which were also decreasing with time while increasing with greater spring AO indices. Again, this showed the important effect of seasonality in the responses to these oscillation indices.

CB-153 did not show a significant linear trend with year for either subpopulation of bears, and year was only significant in models for the WHB animals. However, when considering climate and weather factors, greater air or land surface temperatures were related to lower concentrations of CB-153 in the bears. Also, greater spring total sea ice coverage (TAC) was related to greater concentrations of CB-153 in both the SHB and WHB bears when considered in different models with a 2-year time-lag and no time-lag, respectively (Figures 4e and f, respectively).

Figure 4. Examples of the best-fit relationships of concentrations of legacy POPs (ng·g-1 wet weight) with climate and weather factors in the SHB and WHB polar bears. (A) and (B): Partial regression plots for a-HCH with oscillation indices (AO and NAO, 2 and 3 years time-lagged) where the line slopes are equivalent to their regression coefficients. (C) and (D): Interaction plots for p,p′-DDE with the average, minimum and maximum values of the summer AO (3-years time-lagged), and a linear regression with the summer NAO (2-years time-lagged). (E) and (F): Interaction plots for CB-153 with the average, minimum and maximum values of the spring total accumulated sea ice coverage (TAC %) and a linear regression of the spring TAC (%) 2 years prior to sampling in SHB.



Discussion

Octa- and Penta-BDE production was banned in North America and Europe in 2003/2004, and the compounds were listed under Annex A of the Stockholm Convention on POPs in 2009. For the WHB bears and from 1991 to 2018 (Table 1), piecewise regression analysis demonstrated consistent reductions in the rate of increase of PBDEs consistent with timing of North American production bans on these PBDE formulations.

To our knowledge, since 2011 there have been no studies on the temporal trends of PFAS concentrations in polar bears from any subpopulation and for Hudson Bay the last PFAA temporal trend study was on 1972 to 2002 samples from northern Baffin Island, Canada, and Barrow, Alaska (Smithwick et al. 2006). These results are consistent with Letcher et al. (2018b) who reported on two time-point comparisons of PFAAs in SHB bears collected in 2013-2014 with data reported from 2002 samples by Martin et al. (2004). They reported that over this decade period the mean PFOS levels decreased by 59 % but ΣPFCA levels were 44 % higher. Smithwick et al. (2006) reported PFCA/PFSA temporal trends based on bears harvested from 1972 to 2002 from northern Baffin Island, Canada, and Barrow, Alaska. In contrast to the present 2007-2018 temporal results, in the Smithwick et al. (2006) study, concentrations of PFOS and C9 to C11 PFCAs showed an exponential increase whereas FOSA decreased, between 1972 and 2002. Dietz et al. (2008) reported for East Greenland bears sampled from 1984-2006 that PFOS and C9-C13 PFCA levels significantly increased. Over the period of 1984-2011, Rigét et al. (2013) reported for East Greenland bears that PFOS accounted for 85 to 92 % of the total PFAA concentrations, and PFOS concentrations increased up to 2006 with doubling times of approximately 14 years, and then decreased up to 2011. PFHxS and FOSA levels also decreased from 2006 to 2011.

Phase-outs of C8 fluoroalkyl chemistry occurred in 2002, and there has been increasing regulation, e.g. PFOS listed under Annex B in 2009 in the SC-POPs. Although some decreasing temporal trends were observed, in general the PFCA/PFSA concentrations in Hudson Bay bears remained high over the period of 2006 to 2018 (Table 1, Figures 1 and 2). This indicated that there are other PFCA/PFSA sources, production, precursor degradation and/or climate change-food web shifts that have resulted in stable accumulation in Hudson Bay bears via their food web (e.g. ringed seals). As of 2018, the levels of PFSAs and PFCAs in the Hudson Bay polar bear liver remain high, likely influenced by ongoing production of e.g. PFOS. Smaller scale production of PFOS-related compounds has been taking place in China and Brazil since the early 2000s (Wang et al., 2017). Liu et al. (2015) estimated the industrial and domestic environmental releases of PFOA and its salts in China from 2004 to 2012. The changing diet over time of Hudson Bay polar bears probably influenced the present temporal trends of PFASs. For East Greenland bears sampled between 1984 and 2011, quantitative fatty acid signature analysis and fatty acid carbon isotope patterns were used to assess diets of East Greenland polar bears over the period of 1984 to 2011 (McKinney et al., 2013). Diet estimates on average indicated that polar bears mainly consumed ringed seals (47 %), harp seal (31 %) and hooded seals (17 %). Clearly more studies are warranted to continue monitoring the temporal trends of PFAS in polar bears, and also fate and accumulation, and their prey as well as in other exposed Arctic wildlife.

On a dry weight basis, median THg concentrations in liver samples collected in 2018 from WHB and SHB bears were comparable to concentrations in samples from each year going back to 2007 (i.e. » 18 to 40 mg/g dry weight). There is clearly a need to continue annual monitoring of THg in Hudson Bay bears in light of UNEP's Minamata Convention on Mercury, which came into force in 2017. With respect to climate change, the present results showed that greater concentrations of THg and the legacy POPs in polar bears were most often associated with increasing sea ice presence (earlier freeze ups, shorter ice free periods, and greater seasonal sea ice coverages) (Figures 2 and 3). Polar bears in WHB feed heavily on the blubber of marine mammals and particularly that of (ringed) seals via use of the sea ice platform (Stirling and Derocher, 2012). This may explain why more sea ice was related to greater concentrations of contaminants. Over the years of study, seasonal sea ice coverage has decreased and freeze-up dates have come later around Hudson Bay (but are highly variable), which appear to be related to decreased concentrations of some contaminants in polar bears based on the models presented here, at least in the shorter term. However, these climate-related effects may be moderated by bears feeding on more contaminated open-water seals during ice free periods, which should result in greater concentrations with less sea ice cover (McKinney et al. 2009, 2013). Also, polar bears have been reported to consume lower quality dietary items from terrestrial sources during ice free periods (Gormezano and Rockwell, 2013), which may also result in changes in exposure and accumulation of POPs, Hg and other (unknown) contaminants. Polar bear condition (e.g., fatness) and survival are also known to decline with earlier ice break up and longer ice-free periods (Stirling and Derocher, 2012). This may offset any positive impacts of lower contaminant exposure over time, depending on availability of other food sources and adaptation of the bears to changing conditions.

The latitude and longitude of the SHB (e.g., Sanikiluaq, NU = 56.5°N, 79.2°W) and WHB (e.g., Churchill, MB = 58.8°N, 94.2°W) polar bears puts them in a unique position in terms of the NAO and AO, as these subpopulations are between the center of the high (temperate) and low (Arctic) pressure zones that characterize these indices (although they fluctuate annually, seasonally, monthly and daily) and lie within the latitudes of the westerly winds in North America (35-65°N). Positive oscillation indices are related to a larger pressure gradient between the Arctic (> 65-80°N) and temperate zones, with a stable polar vortex in the north, stronger westerlies, and a more northward jet stream with strong storm tracks pushing air from mid-latitude Asia, Europe and North America into the North (https://www.ncdc.noaa.gov/teleconnections, Ma et al. 2016). The present polar bear results showed that concentrations of the POPs studied decreased with greater time-lagged summer oscillation indices (Figure 3). However, other models showed consistent increases in concentrations with greater time-lagged spring, fall or annual oscillation indices. The increased contaminant levels in the present polar bears with increasing annual AO or NAO were consistent with recent observations of increasing concentrations of POPs in high-Arctic seabirds with increasing annual NAO (Foster et al. 2019), though these results were contaminant specific. It is easier to understand effects related to local weather factors such as air temperature, wind speed and precipitation, which are often closely tracked by phases of the oscillation indices, however these tended to produce weaker or insignificant models compared to the NAO and AO in many cases, so a combined interpretation remains necessary.

POP and Hg exposure for Hudson Bay polar bears is becoming increasingly complex in terms of the growing number of POPs and if variable influence of climate change variables and factors. New/emerging POPs require further annual monitoring and selective retrospective temporal examination to understand longer-term trends, sources, fate and exposure to polar bears.

Expected project completion date

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

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hunt by Indigenous peoples. Many thanks to the hunters and trappers organizations and conservation officers for coordinating sample collection.

References

AMAP, 2018. AMAP Assessment 2017: Biological Effects of Contaminants on Arctic Wildlife and Fish, Arctic Monitoring and Assessment Programme (AMAP), Co-Leads: R. Dietz and R.J. Letcher, Oslo, Norway, vii+84pp.

AMAP, 2017. AMAP Assessment 2016: Chemicals of Emerging Arctic Concern. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi+353pp

AMAP, 2016. AMAP Assessment 2015: Temporal Trends in Persistent Organic Pollutants in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vi+71pp.

AMAP, 2011. AMAP Assessment 2011: Mercury in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xiv + 193 pp.

Bechshøft, T.Ø. (*Post-Doctoral Fellow*), Derocher, A.E., Viengkone, M., Routti, H., Aars, J., Letcher, R.J., Dietz, R., Sonne, C., Jenssen, B.M., Richardson, E., Lunn, N.J. 2018. Where's the ecology in polar bear ecotoxicology and contaminant exposure studies: A systematic review. *Environ. Rev.* 26: 1-12.

Boisvert, G. (*MSc student*), Letcher, R.J. (*corresponding author*), Sonne, C., Rigét, F.F., Dietz, R. 2019. Bioaccumulation and biomagnification of perfluoroalkyl acids and major precursors in East Greenland polar bears and their ringed seal prey. *Environ. Pollut.* 252, 1335-1343.

Brown, T.M., Macdonald, R., Muir, D.C.G., Letcher, R.J. 2018. The distribution and trends of persistent organic pollutants and mercury in marine mammals from Canada's Eastern Arctic. *Sci. Total Environ.* 618: 500-517.

Daugaard-Petersen, T., Langebæk, R., Rigét, F.F., Dyck, M., Letcher, R.J., Hyldstrup, L., Bech Jensen, J.-E., Dietz, R., Sonne, C. 2018. Persistent organic pollutants and penile bone mineral density in East Greenland and Canadian polar bears (*Ursus maritimus*) during 1996–2015. *Environ. Int.* 114: 212-218.

Dietz, R., Sonne, C., Letcher, R.J., Jenssen, B.M. 2016. IPY Bear Health: Polar Bear (*Ursus maritimus*) Circumpolar Health Assessment in Relation to Persistent Pollutants and Climate Change, R. Kallenborn, G. di Prisco, D. Walton, S. Barr (eds.), In: *From Pole to Pole: Implications and Consequences of Anthropogenic Pollution in Polar Environments*, Springer-Verlag (Heidelberg, Germany), Chap. 11, pp. 203-227.

Dietz, R., Gustavson, K., Sonne, C., Desforges, J.-P., Rigét, F.F., McKinney, M.A., Letcher, R.J. 2015. Physiologically-based pharmacokinetics modelling of immune, reproductive and carcinogenic effects from contaminant exposure in polar bears (*Ursus maritimus*) across the Arctic. *Environ. Res.* 140: 45-55.

Dietz, R., Sonne, C., Basu, N., Braune, B., O'Hara, T., Letcher, R.J., Scheuhammer, T., Andersen, M., Andreasen, C., Andriashek, D., Asmund, G., Aubail, A., Baagøe, H., Born, E.W. 2013. What are the toxicological effects of mercury in Arctic biota? *Sci. Total Environ.* 443: 775-790.

Dietz, R., Bossi, R., Rigét, F.F., Sonne, C., Born, E.W. 2008. Increasing perfluoroalkyl contaminants in East Greenland polar bears (*Ursus maritimus*): A new toxic threat to the Arctic bears. *Environ. Sci. Technol.* 42: 2701–2707.

Dietz, R., Desforges, J.-P., Gustavson, K., Sonne, C., Rigét, F.F., Born, E.W., Letcher, R.J. 2018. Immune, reproductive, and carcinogenic risk assessment in East Greenland polar bears (*Ursus maritimus*) during the period 1983°13. *Environ. Int.* 118: 169-178

Ferguson, S.H., Archambault, P., Matley, J., Robert, D., Darnis, G., Geoffroy, M., Suzuki, K., Falardeau, M., Harwood, L.A., Slavik, D., Grant, C., Link, H., Asselin, N.C., Reist, J.D., MacPhee, A., Majewski, A.R., Sawatzky, C.D., Atchison, S., Loseto, L.L., Letcher, R.J., Macdonald, R.W. 2015. Arctic Change: Impacts on Marine Ecosystems and Contaminants. In: G. Stern and A. Gaden (eds.), *From Science to Policy in the Western and Central Canadian Arctic: IRIS of Climate Change and Modernization*. Chap. 4, pp. 201-254.

Foster, K., Braune, B., Gaston, A.J., and Mallory, M.L. 2019. Climate influence on legacy organochlorine pollutants in Arctic seabirds. *Environ. Sci. Technol.* 53: 2518-2528.

Gormezano, L.J., Rockwell, R.F. 2013. Dietary composition and spatial patterns of polar bear foraging on land in western Hudson Bay. *BMC Ecology* 13: 51.

Letcher, R.J., Morris, A.D., Blair, D., Dyck, M. 2020. Temporal changes of perfluoroalkyl acid and precursor contaminants in polar bears from western and southern Hudson Bay sub-populations. In preparation.

Letcher, R.J., Dyck, M., *et al.* 2018a. Temporal/spatial trends of contaminants in Canadian polar bears: Part III. In: *Synopsis of research conducted under the 2017/2018, NCP.* Ottawa: INAC. Ottawa, Canada.

Letcher, R.J., Morris, A.D., Dyck, M., Sverko, E., Reiner, E., Blair, D.A.D., Chu, S.G., Shen, L. 2018b. Legacy and new halogenated persistent organic pollutants in polar bears from a contamination hotspot in the Arctic, Hudson Bay Canada. *Sci. Total Environ.* 610-611: 121-136.

Letcher, R.J., Bustnes, J.-O., Dietz, R., Jenssen, B.M, Jørgensen, E.H., Sonne, C., Verreault, J., Vijayan, M., Gabrielsen, G.W. 2010. Exposure and effects assessment of persistent organic pollutants in Arctic wildlife and fish. *Sci. Total Environ.* 408: 2995-3043.

Liu, Y., Richardson, E.S., Derocher, A.E., Lunn, N.J., Lehmler, H.-J., Li, X., Zhang, J.Y., Martin, J.W. 2018. Hundreds of unrecognized halogenated contaminants discovered in polar bear serum. Angewandte Chemie 57: 16401-16406.

Ma, J., Hung, H., MacDonald, R.W. 2016. The influence of global climate change on the environmental fate of persistent organic pollutants: A review with emphasis on the Northern Hemisphere and the Arctic as a receptor. *Global Planet Change* 146: 89–108.

Martin, J.W., Smithwick, M.M., Braune, B.M., Hoekstra, P.F., Muir, D.C., Mabury, S.A. 2004. Identification of long-chain perfluorinated acids in biota from the Canadian Arctic. *Environ. Sci. Technol.* 38: 373–380.

McKinney, M.A., Pedro, S., Dietz, R., Sonne, C., Fisk, A.T., Letcher, R.J. 2015. Ecological impacts of global climate change on persistent organic pollutant and mercury pathways and exposures in arctic marine ecosystems: A review. *Current Zool.* 61: 617-628.

McKinney, M.A., Iverson, S.J., Fisk, A.T., Sonne, C., Rigét, F.F., Letcher, R.J., Arts, M.T., Born, E.W., Rosing-Asvid, A., Dietz, R. 2013. Global change effects on the long-term feeding ecology and contaminant exposures of East Greenland polar bears. *Global Change Biol.* 19: 2360–2372.

McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Gabrielsen, G.W., Peacock, E., et al. 2011a. Regional contamination versus regional diet differences: Understanding geographic variation in brominated and chlorinated contaminant levels in polar bears. *Environ. Sci. Technol.* 45: 896-902.

McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Gabrielsen, G.W., Peacock, E., Sonne, C. 2011b. Flame retardants and legacy contaminants in polar bears from Alaska, Canada, East Greenland and Svalbard, 2005-2008. *Environ. Int.* 37: 365-374.

McKinney, M.A., Stirling, I., Lunn, N.J., Peacock, E., Letcher, R.J. 2010. The role of diet in the temporal patterns and trends (1991-2007) of brominated flame retardants and organochlorines in western Hudson Bay polar bears. *Sci. Total Environ.* 408: 6210-6222.

McKinney, M.A., Peacock, E., Letcher, R.J. 2009. Sea ice-associated diet change increases the levels of chlorinated and brominated contaminants in polar bears. *Environ. Sci. Technol.* 43: 4334–4339.

Morris, A.D., Letcher, R.J., Dyck, M., Chandramouli, B., Cosgrove, J. 2019. Concentrations of legacy and new contaminants are related to metabolomic profiles in Hudson Bay polar bears. *Environ. Res.* 168: 364-374

Morris, A.D., Letcher, R.J., Braune, B.M., Gamberg, M., Chételat, J., Stow, J. 2020b. Contaminant concentrations are related to climate and weather factors in the Hudson Bay: A cross-species comparison. In preparation.

Morris, A.D., Letcher, R.J., Blair, D., Dyck, M. 2020a. Halogenated contaminants and temporal trends in polar bears from the two major subpopulations in Hudson Bay, Canada. In preparation.

Morris, A.D., Letcher, R.J., Dyck, M., Chandramouli, B., Cosgrove, J. 2019. Concentrations of legacy and new contaminants are related to metabolomic profiles in Hudson Bay polar bears. *Environ. Res.* 168:364-374.

Morris, A.D., Letcher, R.J., Dyck, M., Chandramouli, B., Fisk, A.T., Cosgrove, J. 2018. Multivariate statistical analysis of metabolomics profiles in tissues of polar bears (*Ursus maritimus*) from the Southern and Western Hudson Bay subpopulations. *Polar Biol.* 41: 433-449

Morris, A.D., Muir, D.C.G., Solomon, K.R.S., Letcher, R.J., McKinney, M.A., Fisk, A.T., McMeans, B., Teixeira, C., Wang, X., Duric, M. 2016. Current use pesticides in seawater and their bioaccumulation behavior in polar bear-ringed seal food chains of the Canadian Arctic. *Environ. Toxicol. Chem.* 35: 1695–1707.

Myers, A., Reiner, E. 2017. NCP and AMAP Interlaboratory Study (NCP/AMAP – Phase 11). Report prepared by Ontario Ministry of Environ. & Climate Change, Toronto, ON. 74 pp.

Rigét, F.F., Bignert, A., Braune, B., Dam, M., Dietz, R., Evans, M., Green, N., Gunnlaugsdóttir, H., Kucklick, J., Letcher, R.J., Muir, D., Schuur, S., Sonne, C., Stern, G., Tomy, G., ZZ

Temporal trends of mercury and halogenated organic compounds (legacy and emerging) in three beluga populations landed at Hendrickson Island NT, Sanikiluaq NU and Pangnirtung NU

Tendances temporelles des concentrations de mercure et des composés organiques halogénés (hérités et émergents) dans trois populations de bélugas, à l'île Hendrickson (T.N.-O.), à Sanikiluaq (Nunavut) et à Pangnirtung (Nunavut)

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Project Locations/Emplacements du projet

- Hendrickson Island (HI), NT (near Tuktoyaktuk)
- Sanikiluaq (SQ), NU
- Pangnirtung (PG), NU

Abstract

The program has undergone the first year of a transition with new leadership and team members. The new members worked together to develop a cohesive plan to support project objectives that closely align with Northern Contaminants Program (NCP) and community partner priorities. The overarching objectives of

Résumé

Le programme a connu une première année de transition avec de nouveaux dirigeants et membres de l'équipe. Les nouveaux membres ont travaillé ensemble pour élaborer un plan cohérent afin de soutenir les objectifs du projet qui s'alignent étroitement sur les priorités du Programme de lutte contre les contaminants

this project remain the same, that is, to continue 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). In addition, a secondary objective was to emphasize communication and outreach by strengthening partnerships with the three beluga harvesting communities. As a first step, we focused our efforts on strengthening partnerships with the community of Pangnirtung, Nunavut. Dr. Cortney Watt visited the community and has begun to develop a relationship with the Pangnirtung Hunters and Trappers Association (HTA) on all related beluga research. Positive outcomes have included obtaining samples since the 2010 collections. Ongoing work to strengthen partnerships, communications and sampling continues. The Beluga Working Group (NCP/DFO chaired) was developed in recognition of the challenges in communication as it relates to human health combined with the variability of health messaging across the Inuit Nunangut. This team brings together regional health authorities, community co-management boards, human and beluga health experts and the M-07 (Temporal trends of mercury and halogenated organic compounds (legacy and emerging) in three beluga populations landed at Hendrickson Island NT, Sanikiluaq NU and Pangnirtung NU) team to address the communication challenge of risk-benefits of beluga consumption. The development of the risk communication team helped build and align the new M-07 team by considering broader linkages across the regions, across disciplines and with community partners. Early work by the team includes the creation of a metadata table on state of knowledge and results on fluorinated compounds, with remaining analysis underway at this time. We continue to strive towards a solid long term contaminant dataset that can bridge into broader beluga health questions and integrate Traditional Knowledge on the observed climate change impacts on belugas.

dans le Nord (PLCN) et des partenaires communautaires. Les objectifs globaux de ce projet restent les mêmes, à savoir continuer à surveiller les concentrations de contaminants dans trois populations de bélugas afin d'évaluer les tendances spatiales et temporelles du mercure et des composés organiques halogénés (y compris les composés hérités et nouveaux), ainsi que les paramètres biologiques et alimentaires (p. ex., les isotopes stables, la taille, l'âge). En outre, un objectif secondaire était de mettre l'accent sur la communication et la sensibilisation en renforçant les partenariats avec les trois collectivités de bélugas. Dans un premier temps, nous avons concentré nos efforts sur le renforcement des partenariats avec la collectivité de Pangnirtung, au Nunavut. Cortney Watt, Ph. D., a visité la collectivité et a commencé à établir des liens avec l'Association des chasseurs et des trappeurs de Pangnirtung pour toutes les recherches sur le béluga. Parmi les résultats positifs, mentionnons l'obtention d'échantillons depuis les collectes de 2010. Les travaux en cours pour renforcer les partenariats, les communications et l'échantillonnage se poursuivent. Le groupe de travail sur le béluga (présidé par le PLCN/MPO) a été mis sur pied en reconnaissance des difficultés de communication concernant la santé humaine et la variabilité des messages de santé dans l'ensemble de l'Inuit Nunangut. Cette équipe réunit les autorités sanitaires régionales, les conseils de cogestion communautaires, des experts en santé humaine et en santé des bélugas et l'équipe M-07 (Tendances temporelles des concentrations de mercure et de composés organiques halogénés [hérités et émergents] dans trois populations de bélugas débarqués à Hendrickson Island [Nunavut], Sanikiluaq NU et Pangnirtung NU) pour relever le défi de la communication des risques et avantages de la consommation de bélugas. La mise en place de l'équipe de communication des risques a permis de construire et d'orienter la nouvelle équipe M-07 en envisageant des liens plus larges entre les régions, les disciplines et les partenaires communautaires. Les premiers travaux de l'équipe comprennent la création d'un tableau de métadonnées sur l'état des connaissances et les résultats concernant les composés fluorés, les analyses restantes étant en cours. Nous nous efforçons toujours d'obtenir à long terme un ensemble un ensemble de données rigoureuses sur les contaminants qui permet de faire le lien avec des questions plus générales sur la santé des bélugas et d'intégrer les connaissances traditionnelles sur les effets observés des changements climatiques sur les bélugas.

Key Messages

- Year one of the M-07 new research team has been a great success with samples collected from all three locations, subsampled to be shipped across expert labs for processing for contaminants, age and dietary biotracers.
- The start of strengthened relations and partnerships with the community and HTA of Pangnirtung NU, enabling sample collection and effective communication.
- Perfluoroalkyl Substances (PFAS) were analysed and results for PFOSA revealed a continued decline over time, and interestingly variability in concentrations across the three beluga populations, with highest levels in Sanikiluaq whales that dominated the PFASs at 78% of the total.
- Analyses for other contaminants are pending at this time, however, in the absence the team has developed a summary table of contaminants and other measurements for these three beluga populations.
- Creation of Beluga Working Group address challenges of communications specific to human health implications by developing a communications plans on presenting project related information and results, including health messages from the regional health authorities.

Messages clés

- La première année a été un grand succès, car la nouvelle équipe de recherche M-07 a prélevé des échantillons sur les trois sites, échantillons qui ont été regroupés en sous-groupe pour être envoyés dans des laboratoires spécialisés en vue d'une analyse des contaminants, de l'âge et des biotraceurs alimentaires.
- L'établissement de relations et de partenariats renforcés avec la collectivité et l'Association des chasseurs et trappeurs de Pangnirtung NU, a permis une collecte d'échantillons et une communication efficace.
- Les substances perfluoroalkylées (PFAS) ont été analysées et les résultats pour le PFOSA ont révélé une baisse continue dans le temps, et, fait intéressant, une variabilité des concentrations dans les trois populations de bélugas, avec les concentrations les plus élevées chez les baleines de Sanikiluaq, qui étaient associées à la plus grande proportion de PFAS, avec 78% du total.
- Des analyses pour d'autres contaminants sont en cours, mais en l'absence de ces analyses, l'équipe a élaboré un tableau récapitulatif des contaminants et d'autres mesures pour ces trois populations de bélugas.
- La création du groupe de travail sur le béluga permet de relever les défis de communication concernant les conséquences sur la santé humaine, avec l'élaboration d'un plan de communication sur la présentation des informations et des résultats liés au projet, y compris les messages des autorités sanitaires régionales.

Objective

The aims of this study 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,
- continue to maintain some of the longest datasets for contaminants in beluga whales collected in partnership with northern communities hunting beluga whales from three populations at key harvest locations: Hendrickson Island (HI) in the Inuvialuit Settlement Region, Sanikiluaq in Southern Hudson Bay and Pangnirtung in the Eastern Arctic

Introduction

Inuit lead subsistence lifestyles includes harvesting beluga whales. As a result, this project addresses questions and concerns regarding the health of beluga whale and the implications for health of Inuit who traditionally consume them. As the environment changes at the global scale (climate change) and the local scale (industrial activities), we suspect beluga may be exposed to more stressors and more contaminants that require ongoing monitoring. Maintaining current data on contaminant levels on these three representative locations allows for the assessment of both temporal and spatial trends for bioaccumulating chemical substances in particular metals, organic compounds including legacy and emerging chemicals. Results also assist with the assessment of the effectiveness of international treaties and bans for chemicals (e.g. Stockholm Convention). Lastly, we are able to assess trends in contaminants in context of the Arctic's numerous changes and stressors, in particular climate change, that are influencing carbon flow, food web dynamics and ecosystems at large. Ascribing drivers to trends remains a challenge given the duality of regional and local drivers influencing fate, transport and exposure of contaminants to belugas and other higher trophic species.

Activities in 2018-2019

Communications and Engagement

Western Arctic/Hendrickson Island: Due to the new beluga telemetry program in the Western Arctic based out of Hendrickson Island there has been slightly less attention given to the health program with communicating with boards and communities. While health is raised at all meetings, emphasis on the beluga telemetry and survey program often results in less time discussing the program (Table 1). Also important to note that Dr. Lisa Loseto has deferred bringing the ECCC team to the field due to the request of the Tuktoyaktuk Hunters and Trappers Committee (HTC) to keep the research camps small while multiple programs operate in 2018 and 2019 at Hendrickson Island.

Table 1: Western Arctic presentations to communities and co-management boards. Presentations are not solely focused on NCP outputs, rather all beluga research in the Inuvialuit Settlement region (e.g. telemetry, health, habitat, other).

Meeting	Date	Location	Presenter	Audience
Fisheries Joint Management Committee (FJMC)-DFO Science Meeting	January 16, 2018	Winnipeg. MB	Loseto, MacPhee	FJMC
Summer Field Planning Meeting with Inuvik HTC (IHTC)	April 6, 2018	Inuvik, NT	Loseto, MacPhee	IHTC
Summer Field Planning Meeting with Aklavik HTC (AHTC)	March 12, 2018	Aklavik, NT	Loseto, MacPhee, Pokiak, Way-Nee	AHTC
Summer Field Planning Meeting with Inuvik HTC	April 16, 2018	Inuvik, NT	Loseto, Murray, O-Corry-Crowe	IHTC
Summer Field Planning Meeting with Tuktoyaktuk HTC (THTC)	April 23, 2018	Tuktoyaktuk, NT	MacPhee	THTC
Inuvialuit Game Council (IGC)	August 31, 2018	Whitehorse, YT	Loseto	IGC
FJMC-DFO Science Meeting	January 15, 2019	Winnipeg. MB	Loseto, MacPhee	FJMC
FJMC-DFO Science Meeting	January 16, 2019	Winnipeg. MB	Jenkins (toxoplasma)	FJMC
Inuvialuit Game Council	March 7, 2019	Inuvik, NT	MacPhee	IGC
International Beluga Conference	March 13, 2019	Mystic, CT, USA	Loseto, Noksana, Way-Nee, Ruben	International Science Community
Summer Field Planning Meeting with Aklavik HTC	March 12, 2019	Aklavik, NT	MacPhee,	AHTC
Summer Field Planning Meeting with Inuvik HTC	March 13, 2019	Inuvik, NT	MacPhee	IHTC
Summer Field Planning Meeting with Tuktoyaktuk HTC	March 14, 2019	Tuktoyaktuk, NT	MacPhee	THTC

In addition to meetings listed in Table 1, there has been confirmation by Inuvialuit Co-management boards (FJMC, IGC) to support and co-lead on the second beluga summit, tentatively scheduled for February 2021 in Inuvik. And there was a recent publication about the past meeting and plans for the next meeting in the Above and Beyond Magazine. http://arcticjournal.ca/health-science/science/the-beluga-summit/

Pangnirtung

A fact sheet was distributed to the community of Pangnirtung in September 2018 highlighting contaminant results from this program. Following this, a few questions arose about the safety of eating beluga, and a radio announcement was made by the manager of the Hunters and Trappers Association (HTA) to alleviate any concerns. A meeting with the Pangnirtung HTA was held in November 2018 to discuss the beluga sampling program in Pangnirtung and to highlight the many collaborative studies that use the various tissues collected. Contaminant results were not presented at that meeting as it was considered a stepping stone to improve collections in the community; however, a member from Government of Nunavut (GN) health was in attendance in case any questions or concerns were raised regarding contaminant levels or the fact sheet that had been previously distributed. The Pangnirtung HTA was very supportive of the sampling program and had no questions regarding the contaminant results. A meeting with the HTA following the 2019 field season is tentatively planned, and inclusion of ECCC and presentation of contaminant results would be highlighted at that time.

Sanikiluaq

We received a letter of support from the Sanikiluaq HTA and have set up an Eastern Arctic Whale Ice-Entrapment program specifically with Sanikiluaq due the number of ice entrapments reported by the community over the past 20 years. A trip to the community to provide updates is planned for either fall 2019 or winter 2020 – arrangements are in progress.

Beluga Working Group communications

In the fall of 2018 a new working group was developed to address the communications resulting from this project, and more broadly to support the human risk-benefits communications to Inuit across Inuit Nunangat about beluga consumption. Recognizing the ongoing challenge for the M-07 project team is they are often asked on issues of human health and food safety for which they do not have any expertise or authority. They are reliant on the regional health authorities to generate these messages which can then be communicated by the project team as part of their communication activities. As such the NCP Beluga Working Group was being formed to help overcome these challenges and to provide support to regional health authorities and the beluga project team to help with the assessment of human health risks and the development of communication plans and materials, including those related to beluga and human health.

The working group objectives are to:

support regional health authorities in the assessment of human health risks related to long-range contaminants in beluga, and the development of related communications materials, including consumption advisories if necessary;

support the DFO led project team in the development of communications plans and materials that effectively communicate project related information and results, including health messages from the regional health authorities, to communities and other key audiences; and,

share knowledge and experience across regions, promote cooperation and shared use of technical resources for the purpose of risk assessment and communications.

Since the proposal of this working in the fall of 2018 there have been two teleconferences and one face to face meeting that occurred a day prior to the NCP management committee meeting (March 18, 2019). It is important to note that the team has identified diseases and other contaminants be considered as well as the nutrients. Membership for this group has included the M-07 team who study contaminants in beluga whales across regions. This group also included disease/veterinarians, regional health authorities, human health researchers, representatives from each of the Arctic regions who hunt belugas, Health Canada, Inuit Tapiriit

Kanatami (ITK), Inuit Circumpolar Council (ICC) and the NCP secretariat. The spring face-to-face meeting allowed for all regional Health authorities to share their needs and directions for this group and set a framework for next steps. Actions in preparation for the meeting included a metadata table of information available on these three populations that supported discussion on gaps and next steps. Immediate next steps include HC working on a risk assessment for compound available and the identification of the need to analyze additional tissue samples that are more representative for human consumption.

Capacity Building - Field Program and Sample Collections

Hendrickson Island

As in past years a partnership with DFO, the FJMC and the Tuktoyaktuk Hunters and Trappers Committee supported the beluga sampling program by hiring a Senior beluga monitor (Lionel Kikoak), Junior Beluga monitor (Rex Noksana), youth monitor (James Pokiak-Thrasher) partnered with a DFO team at Hendrickson Island.

In total, 28 whales were sampled by the FJMC Beluga Monitors at Hendrickson Island from 01 July to 09 August 2017 (40 day period). Of these, 9 whales were sampled by the science team for additional tissue collections. Of the 28 whales sampled overall, only 2 were confirmed female and no females were sampled by the science team. Standardized measurements were recorded for colour, total length, fluke width, blubber thickness (dorsal, anal) and half girth (dorsal, anal). Standard tissue collections included blubber (with skin –1 frozen and one in dimethyl sulphoxide (DMSO) preservative for genetics), muscle, liver, blood, milk (if present), lower jaw and eyeballs. Ageing and genetics work will be completed at DFO in Winnipeg.

Traditional and local ecological indicators were collected as a part of the core monitoring program, where key information about whale behaviour, condition and weather was recorded by the beluga monitors. These indicators were developed as part of a research project led by Sonja Ostertag (DFO) through a series of community consultations and interviews. Data collection sheets were updated this year to reflect feedback from the previous year.

Additional research samples were collected in partnership with the regular beluga monitoring program. Researchers collected samples that require additional handling or storage (e.g., serum and plasma separated from whole blood and stored at -80°C) as well as microplastic samples. Details on these additional collections are outlined below.

Three whole stomachs and intestinal segments were sampled from whales as part of the pilot study on microplastic exposure in belugas. Additional samples were collected by the science team to measure ecological indicators (biomarkers), including blubber and blood (serum and plasma) to study stress hormones (e.g., cortisol) and diet (fatty acids, stable isotopes) in harvested whales (Table 2). Diet and stress indicators are being measured at the Freshwater Institute in Winnipeg.

Table 2. List of various health indicators that will be measured from beluga tissue samples.

Health Indicator	Tissue Sample	Collaborator
Diet indicators	Blubber, muscle, liver, milk	Lisa Loseto, DFO
Contaminant levels and trends	muscle, liver, blubber/skin	Magali Houde, Jane Kirk, Amila De Silva ECCC
Health indicators/ hormones (i.e. sex and cortisol)	Blood, blubber, liver, urine	Lisa Loseto, DFO
Disease: Parasites (Toxoplasma and Trichinella), bacteria, worms (nematodes)	heart, diaphragm, muscle, brain, tongue, blood, spleen	Emily Jenkins, USask
Disease: viruses	Blood, urine	Ole Nielsen, DFO

Spleen was additionally sampled for a pilot study to identify the presence of bartonella, a bacterium whose DNA has been detected in dead and hunted beluga. The spleen has been identified as the ideal organ to test for the presence of *bartonella sp.* DNA.

Pangnirtung

As in previous years, DFO initiated a contract for beluga hunt sample collection with the Pangnirtung HTA that compensates hunters for their time to sample their beluga and complete a sampling kit. In total, 12 beluga whales were sampled through the community based sampling program in July 2018. To supplement these collections, a radio announcement was made in November 2018 asking community members to provide a sample of hunted beluga from their freezers. Another 12 beluga skin and blubber samples were collected. This may be an alternative method to obtain samples if the sampling program during the hunt is not successful. However, liver and muscle samples would be difficult to collect using this method since most community members would only keep the skin and blubber for consumption. To improve participation and highlight the collections program, Cortney Watt will travel to Pangnirtung and assist with beluga hunt collections in July 2019.

Sanikiluaq

As in previous years, whale collections kits were sent to the HTA and a contract set up to pay for hunter samples (60 @ $150/whale) as well as a hunt monitor ($3000 for beluga monitor @ $150/day) for both spring and fall hunts. Over 30 whale samples were collected from the community in 2018-2019.

Indigenous Knowledge

Knowledge held by local Inuit on beluga health, behaviour and habitat are critical to the holistic understanding of belugas. We have worked to engage and bridge this knowledge in several ways. Specific projects have included those by Ostertag/Loseto on the development of TEK/LEK indicators for beluga health and habitat monitoring (Ostertag et al., 2018). The program worked closely with the communities of Tuktoyaktuk, Inuvik and Paulatuk as well as the co-management board FJMC, to implement the newly defined TEK/LEK beluga health indicators in the beluga long term monitoring program. Recently, Devin Waugh completed his MSc on beluga TEK in Tuktoyaktuk that described traditional preparation methods of beluga and the impacts of climate change on the beluga hunt (Waugh et al., 2018). Our interest on including Indigenous Knowledge in our programs was highlighted in our efforts for the 'co-production' of knowledge on beluga whales by bringing together knowledge holders from the scientific communities and northern communities at our Beluga Summit (Inuvik, NT Feb 2016). Bringing knowledge bodies together, from IK and western science has greatly strengthened knowledge in beluga and the relationship among knowledge holders in Inuvialuit communities and the scientific community.

DFO is working with Sanikiluaq HTO to assist with analyzing and publishing their recorded beluga TK knowledge that was collected in the 1990s. The Nunavut Wildlife Management Board has ongoing discussions with Pangnirtung hunters to develop an IQ study of the Cumberland Sound beluga population based on oral history.

Laboratory Analyses

In fall 2018 the DFO team confirmed with the ECCC team on sample needs (tissue type, quantity, storage methods, shipping methods) for analyses below.

Mercury Analyses

Liver, muscle and skin were prepared for analyses. Livers were homogenized prior to analyses. Sub-samples of liver and muscle will be freeze dried and percent moisture determined. SKIN? Total mercury (THg) analyses of freeze-dried liver and muscle will be carried out using a direct Mercury Analyzer at the Canadian Center for Inland Waters (CCIW) Hg Analytical

Laboratory in Burlington, ON. Similarly, methyl mercury (MeHg) analyses will be carried out by nitric acid digestion followed by aqueous phase ethylation and cold vapor atomic fluorescence spectrophotometry using a Brooks Rand MERX automated MeHg analyzer.

Fluorinated Compounds

A full range of perfluoroalkyl substances (PFASs) were determined by the De Silva lab at CCIW. The analyte list included C4 to C14 perfluoroalkylcarboxylates and C4 to C10 perfluoroalkanesulfonates. The procedure uses isotopically-labeled internal standards (13C and 18O PFAS) for extraction of 0.2 g wet liver homogenate by liquid extraction in acetonitrile. Further cleanup is conducted using granulated carbon (Reiner et al. 2012, Lescord et al. 2015). The final 0.5 ml extract is analyzed by liquid chromatography - negative electrospray tandem mass spectrometry (HPLC-MS/MS) using a fluorinated stationary phase. In addition to method blanks, spike and recovery, and replicates, standard biological reference material, NIST SRM-1946 fish homogenate, will be used. In addition, De Silva participates annually in the NCP organized inter-laboratory analysis for PFAS in biological tissues and standards.

HOC's: The "new/emerging" contaminants we propose to analyze in 2018-2019 (a non-POP year) in beluga blubber samples were brominated flame retardants (BFRs), selected current use pesticides, and polychlorinated naphthalenes (PCNs). Blubber samples were shipped from DFO to the Quebec Laboratory for Environmental Testing (QLET, ECCC) and extracted using USEPA Method 1699 (USEPA 2007) The lab is currently finishing the organic analyses and results for 2018 are expected in May 2019.

Selenoid Compounds

This year we ran a pilot assessment of the measurement of selenoneine (organic form of selenium) along with the Se-analog ergothioneine, a powerful antioxidant that together may be providing protection against MeHg toxicity. Findings from NHS participants found high levels of selenoneine that is believed to be a dietary source from beluga maktaq (Ayotte et al., 2016).

Results

As described above in the *Beluga Working Group communications*, the team created a summary table of all information available for the three beluga populations that was shared at the March 2019 face to face meeting. The table has provided a starting point for the team to grow from, anchor new observations and support the development of new hypotheses going forward (Table 3). At this time, many analysis of tissue continue to be underway with aims for completion of May and June 2019. Below we share results from contaminants we have completed in advance of the April 30, 2019 deadline.

In addition to contaminants we process samples for other metrics to assist with understanding exposure via diet, specifically measuring stable isotopes (δ15N and δ13C) in liver and muscle as well as fatty acid profiles of beluga blubber tissue. These samples are currently being processed for analysis at the Freshwater Institute and will be completed in June 2019. Additionally, this year we developed a partnership with Dr. Pierre Ayotte to determine if selenoneine and Se-methylselenoneine compounds could be found in belugas (samples from Hendrickson Island sent). These compounds are believed to provide protection against MeHg toxicity in humans and identifying if beluga is in important source of these compounds to Inuit is important. The lab recently analysed beluga skin samples from Nunavik (Hudson Strait) and Nunavut (Arviat) to determine their content of selenoneine and Se-methylselenoneine using a HPLC-ICP-MS/MS method developed in our laboratory (Achouba et al., 2019). We also determined the total Se content samples by ID-ICP-MS/MS after an acid digestion. Results revealed that selenoneine is also the major Se compound in beluga mattaaq with a median concentration of 1.8 µg Se/g wet wt. (range = 1.2 - 7.4 µg Se/g; n=5). Selenoneine represented 54% (median) of total Se, with values ranging from 44 to 74%. We obtained similar results for mattaaq samples from beluga whales hunted near Arviat (West Hudson Bay Coast). Se-methylselenoneine was not detected in any of the samples.

The same methods are now being used to analyses beluga samples from Hendrickson Island (Inuvik, Northwest Territories). Total Se and selenoneine content is being assessed in skin, liver and muscle samples from 8 different animals. In addition to providing data on selenoneine content of beluga skin from another location in the Canadian Arctic, our project will yield the first results on selenoneine content in beluga liver and muscle.

Perfluoroalkyl Substances (PFAS)

Perfluoroalkyl carboxylates (PFCAs, C4 to C14), perfluoroalkyl sulfonates (PFSAs, C4, C6, C7, C8, and C10), perfluorooctanesulfonamide (FOSA) were analyzed in beluga liver collected in 2018 from HI (n=8), PG (n=7), and SQ (n=9). Using a one-way ANOVA with post hoc Bonferroni analysis, total PFAS (∑PFAS) concentrations were statistically higher in HI (81±9 ng/g wet weight, w.w.) and in SQ beluga, 88±8 ng/g w.w. compared to the PG belugas, 49±15 ng/g w.w. (Figure 1). Emerging PFAS including monochloro-perfluorooctane sulfonate (Cl(CF2)8SO3-, **8Cl-PFOS**) and the major monochloropolyfluoroalkyl ether sulfonate component in F53B (Cl(CF2)6OCF2CF2SO3-, **9Cl-PF3ONS**) was site-specific: 0.64±0.27 ng/g 8Cl-PFOS in SQ and 0.11±0.01 ng/g 9Cl-PF3ONS in HI.

Figure 1. Concentration of targeted PFAS in 2018 beluga whale livers from 3 different locations: HI, PG, and SQ. Analytes in green are perfluoroalkylcarboxylates (PFCAs), in blue are perfluoroalkyl sulfonates (PFSAs), in purple is perfluorooctanesulfonamide (FOSA). Two emerging PFAS are monochloro-perfluorooctane sulfonate (8Cl-PFOS, observed in SQ) and F53B, a monochloropolyfluoroalkyl ether sulfonate, observed in HI.

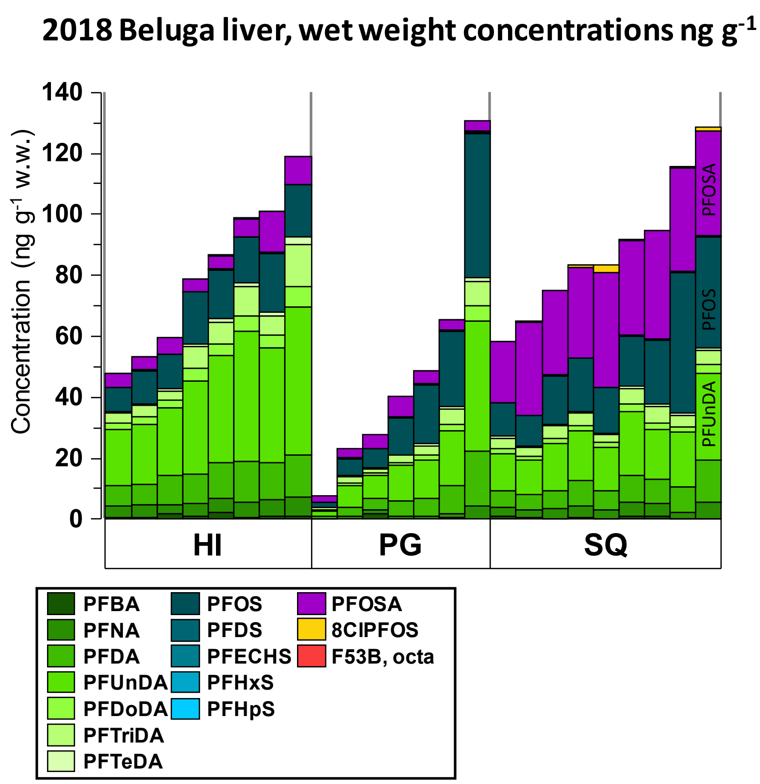
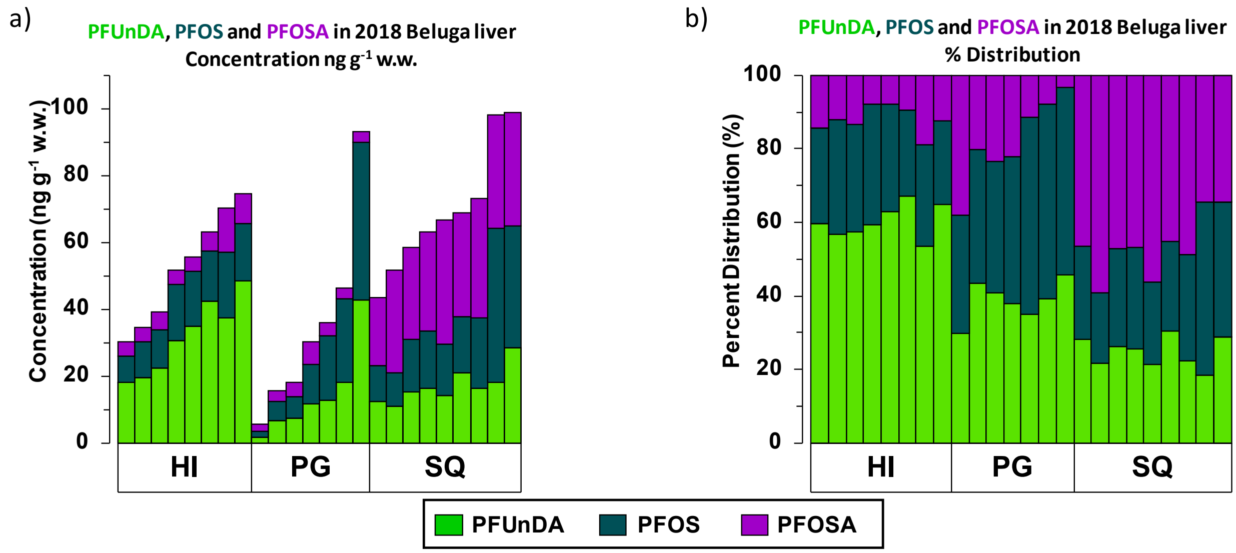


Figure 2. Distribution of PFUnDA, PFOS and PFOSA in 2018 beluga whale liver samples from 3 different locations, expressed as a) wet weight concentration and b) percent composition on a mass basis.



The dominant PFAS were perfluoroundecanoate (PFUnDA), perfluorooctane sulfonate (PFOS), and FOSA. These three PFASs represented 65% of ∑PFAS in HI, 71% in PG, and 78% in SQ (Figure 2). PFUnDA was statistically higher in HI compared to PG, however PFOS was not significantly different between any of the sites. PFOSA was significantly different in all populations.

Adding the PFUnDA and PFOS data obtained for 2018 beluga livers to previous data sets, we see that PFOS is declining in all sites: in HI since 2011, in SQ since 2005, and in PG since 2016 (Figure 3). The temporal trend in PFUnDA concentrations is varied. There was no apparent decline in PFUnDA in beluga from HI and SQ in the last 10 years, however, PFUnDA closely followed the declining trend in PFOS in the PG site since 2016. These results are consistent with PFAS monitoring in other Arctic biota in which declining PFOS concentrations have been observed over the last decade and ambiguous temporal trends in long chain PFCAs such as PFUnDA and perfluorononanoate (PFNA). The significance of such results suggest continued emissions of PFCA precursors.

Figure 3. Natural log transformed concentrations of PFOS (circle) and PFUnDA (square) in beluga livers from three sites. Symbols represent mean and error bars are standard error. In HI, all data prior to 2014 was obtained from Smythe et al. In SQ, 2000 to 2001 data obtained from Kelly et al. and 2003 to 2013 data was obtained from Smythe et al. In PG, all data presented prior to 2011 was obtained from Smythe et al. The present study reports 2012 to 2018 data in PG, 2018 data in SQ & HI.

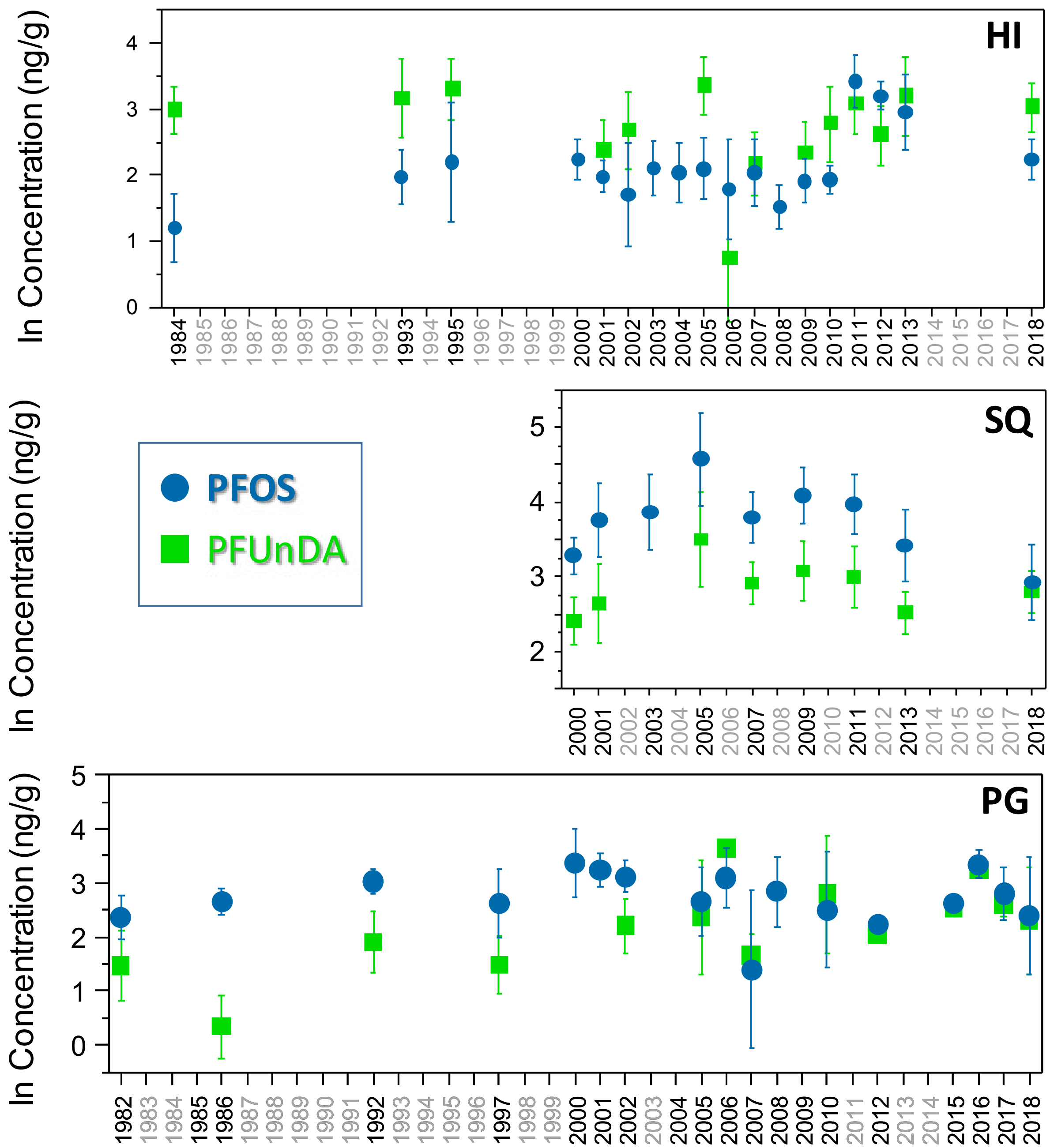


Table 3: Biological and contaminant information available for Arctic beluga whale populations.

Locations	Hendrickson Island, NWT		Sanikiluaq, NU		Pangnirtung, NU		Notes
Estimated population number	~40,000 (based on 1992 survey, new survey planned for 2019)		~60,000 (depends on which stock is hunted: WHB 60K, EHB 3K, JB 4K, Belchers may have a stock of their own)		~1,150		New survey in 2019
Status	Not at Risk		WHB Special Concern (EHB Endangered)		Listed as threatened		
Biological data							
Age	1988 to present (average 30)		Aged up to about 2010		Subset aged (average 23)		Moved from GLG to AA
Sex	Typically males		Should have genetic sex		~40% female and 60% male		
Length	Average 407cm; range 152 to 552cm		Data available (small whales)		Average 370cm, range 86-540 cm		
Diet indicators	Measured annually (SI, FA and HBI)		Past measures of SI and FA. Unpublished manuscript (T Kelley) for Sani data		Measured annually (SI and FA)		
Health indicators (hormones, vitamins)	Cortisol, sex, thyroid (pending), vitamins, transcriptnomics		NA		Cortisol		
Diseases							
Parasites	Toxoplasma, trichinella, lung worms, brucella		Brucella serology old		Unknown		
Bacteria, viruses	Herpes virus						
Contaminants							
	Year of collection	**Concentrations**	**Year of collection**	**Concentrations**	**Year of collection**	**Concentrations**	
Polychlorinated biphenyls (PCB)	2015 (M)	Blubber (ng/g lw) 1643	2013 (9F, 1M)	Blubber (ng/g lw) F-499; M-741	2010 (n=3)		Planned for 2019 all three locations
Organochlorine pesticides	2015 (M)	Blubber (ng/g lw) DDT: 1519 HCH: 199 Chlordanes: 1557	2013 (9F, 1M) 2015 data quality to be assessed	DDT: F-414;M-575 HCH: F-61;M-40 Chl: F-305; M-240	1996, 1997 1996 (geometric means) 2010 (n=3)	Blubber (ng/g lw) DDT, M: 5375 F: 1974 HCH M: 223, F: 101 Chlordanes M: 1446, F: 723 Data to be assessed	2018 samples submitted for analyses at ECCC, all 3 sites
Flame retardants Polybrominated diphenyl ethers (PBDE) Halogenated flame retardants (HFR)	2013 (geometric means)	Blubber (ng/g lw) PBDE: 13.8	2013	Blubber (ng/g lw) PBDE: 27	2008	Blubber (ng/g lw) PBDE: 21.5	Planned for 2019, all 3 sites 2018 ECCC, all 3 sites
Polychlorinated naphthalenes (PCN)							2018 ECCC, all 3 sites
Short-chains chlorinated paraffines (SCCP)							Planned for 2019, all 3 sites
Polyfluoroalkyl substances (PFAS)	2013 (geometric means)	Liver (ng/g ww) PFCAs: 65.4 PFOS: 27.9	2013	Liver PFCAs: 20.9 PFOS: 30.4	2010	Liver PFCAs: 25.3 PFOS: 12.2	2018 ECCC, all 3 sites
Mercury (total)	2017 (means) N=30, no age, 4.1m)	Muscle (µg/g ww) M: 1.0 F: 0.6 Liver, M: 17.1, F: 13.3 Skin: M: 0.44, F: 0.24	2015 (no funds for 2017)	Muscle (µg/g ww) M: 0.6 Liver: M: 7.7 Skin: M: 0.18 Mean age: 18, size: 3.3 m, n=10	2010 N=3, no age (2.7, 3.6, 4m)	Muscle (µg/g ww) M: 0.93 Liver: M: 8.6 Skin: M:0.18	2018 ECCC, all 3 sites
Methyl mercury	2010	Muscle (µg/g ww) M: 0.94 (81% of total) Liver M: 1.4 (10% of total) Skin: M: 10.3 (83%)					2018 ECCC, all 3 sites
Microplastics		Measured but not reported yet					

References

Stern et al. 2005, Legacy organochlorines, 1993-2001 for 15 sites including HI, Sani, Pang and East Whitefish

Loseto et al., 2015. Hg trends,1981-2012 for East Whitefish and HI

Noel et al. 2018 Legacy organochlorine trends, 1989-2015 for HI

Smythe et al. 2018 Emerging organochlorine trends (PBDE, HBCD, PFAS), 1984-2013 for HI, 1982-2010 for Pang, 2003-2013 for Sani

Discussion and Conclusions

We are excited to have a year with samples available from all three monitoring locations. We owe this in part to dedication made with team members and the community and HTA of Pangnirtung NU. We continue to strengthen partnerships at all three locations, while strengthening the partnerships among the new team. Currently the team is preparing collaborative plans on result reporting and communications (also in partnership with the Beluga Working Group).

With results available for the fluorinated compounds we note important spatial and temporal observations that are triggering further investigation. For example we will assess dietary biotracers (i.e. stable isotopes and fatty acids) to determine how differences in diet may be driving the spatial trends. To address some of the temporal questions as well as potential differences among labs and differences we will have our new labs run some of the historical samples for a comparison and quality assessment/quality control.

Acknowledgements

We thank the Sanikiluaq HTO and Pangnirtung HTA for organizing sample collections and the hunters from Sanikiluaq and Pangnirtung for sample collection. We thank the community of Tuktoyaktuk and the Tuktoyaktuk HTC, our research partners, without whom, we could not carry out the beluga research program at Hendrickson Island. We thank the IGC, the FJMC and JS staff for supporting the regional beluga monitoring program. We are grateful to all the beluga hunters who share their whale with us to allow to sample and study it.

References

Achouba A, Dumas P, Ouellet N, Little M, Lemire M, and Ayotte P. 2019. Selenoneine is a major selenium species in beluga skin and red blood cells of Inuit from Nunavik. Chemosphere. In press.

Ostertag, S., Loseto, L.L., Snow, K., Lam, J., Hynes, K., Gillman, V. 2018. “That’s how we know they’re healthy”. The inclusions of Indigenous Knowledge in beluga health monitoring in the Inuvialuit Settlement Region. Arctic Science, 4: 292-320.

Waugh, D., Pearce, T., Ostertag, S., Collings, P., Loseto, L. 2018. Inuvialuit Traditional Ecological Knowledge of Beluga Whale (*Delphinapterus leucas*) Under Changing Climatic Conditions in Tuktoyaktuk, NT. Arctic Science, 4: 242-258.

Temporal trends of contaminants in Arctic seabird eggs

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

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Project Locations/Emplacements du projet

- Prince Leopold Island Migratory Bird Sanctuary (PLI), NU
- Coats Island, NU

Abstract

Contaminants are monitored in Arctic seabird eggs as an index of contamination of Arctic marine ecosystems. Eggs of thick-billed murres and northern fulmars have been collected from Prince Leopold Island in the Canadian high Arctic since 1975 making it the longest-running contaminants monitoring program for seabird eggs in the circumpolar Arctic. Eggs of thick-billed murres are also sampled from Coats Island in northern Hudson Bay as a comparative low Arctic monitoring location. Every five years (i.e. 2018), eggs of five seabird species are collected at Prince Leopold Island to corroborate temporal trends of contaminants. Concentrations of PCBs and DDT generally declined from 1993 to 2013 in eggs of five species of seabirds breeding on Prince Leopold Island. PFOS and PFCAs continued to decrease in the fulmar eggs but, although PFOS also continued to decrease in the murre eggs, PFCAs

Résumé

Nous surveillons les concentrations de contaminants dans les œufs des oiseaux marins en Arctique à titre d'indice de contamination des écosystèmes marins de l'Arctique. Des œufs de guillemot de Brünnich et de fulmar boréal sont recueillis sur l'île du Prince Léopold dans l'Arctique canadien depuis 1975, ce qui en fait le plus ancien programme de surveillance des contaminants des œufs d'oiseaux de mer dans l'Arctique circumpolaire. Des œufs de guillemot de Brünnich sont également prélevés sur l'île Coats, dans le nord de la baie d'Hudson, qui constitue un site de surveillance comparatif du Bas-Arctique. Tous les cinq ans (p. ex., en 2018), des œufs de cinq espèces d'oiseaux de mer sont recueillis sur l'île Prince Leopold afin de corroborer les tendances temporelles des contaminants. Les concentrations de BPC et de DDT ont généralement baissé de 1993 à 2013 dans les

appear to be levelling off. Concentrations of $\sum_{67}$PCN also continued to decrease. Climate change is affecting concentrations of both organochlorines and total mercury in seabird eggs from Prince Leopold Island.

œufs de cinq espèces d'oiseaux de mer se reproduisant sur l'île Prince Leopold. Les SPFO et les PFCA ont continué à diminuer dans les œufs de fulmar mais, bien que les SPFO aient également continué à diminuer dans les œufs de guillemot, les PFCA semblent se stabiliser. Les concentrations de ∑67NPC ont également continué à s'abaisser. 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 PCBs and DDT generally declined from 1993 to 2013 in eggs of five species of seabirds from Prince Leopold Island.
- Concentrations of PFOS and PFCAs continued to decrease in the fulmar eggs but, although PFOS also continued to decrease in the murre eggs, PFCAs appear to be levelling off.
- Concentrations of polychlorinated naphthalenes continue to decline in eggs of thick-billed murres from Prince Leopold Island.
- Increased concentrations of total mercury in murre eggs from Prince Leopold Island are correlated with increasingly positive North Atlantic Oscillation conditions, heavier snowfall, and cooler summer temperatures.
- In fulmar eggs, increased concentrations of total mercury also correlated with positive North Atlantic Oscillation conditions and cooler summer temperatures but with the added influence of reduced summer sea ice concentration.

Messages clés

- Les concentrations de BPC et de DDT ont généralement diminué de 1993 à 2013 dans les œufs de cinq espèces d'oiseaux de mer de l'île Prince Leopold.
- Les concentrations de SPFO et de PFCA ont continué à diminuer dans les œufs de fulmar, mais bien que le SPFO ait également continué à s'abaisser dans les œufs de guillemot, les PFCA semblent se stabiliser.
- La concentration des naphtalènes polychlorés (NPC) poursuit sa baisse dans les œufs des guillemots de Brünnich de l'île Prince Leopold.
- L'augmentation des concentrations de mercure total dans les œufs de guillemots de l'île Prince Léopold est corrélée avec des conditions de plus en plus positives de l'oscillation nord-atlantique, avec des chutes de neige plus importantes et avec des températures estivales plus fraîches.
- Dans les œufs de fulmar, les concentrations accrues de mercure total sont également corrélées avec des conditions positives de l'oscillation nord-atlantique et des températures estivales plus fraîches, mais avec l'influence supplémentaire de la réduction de la concentration de glace de mer en été.

Objectives

The aim of this project is to:

- monitor legacy and new contaminants in seabird eggs as an index of contamination in Arctic marine ecosystems; and
- as 2018 is the 5th year in a five-year sampling cycle, collect eggs of three species of seabirds (black-legged kittiwake, black guillemot, glaucous gull) in addition to the two species (northern fulmar, thick-billed murre) sampled annually from Prince Leopold Island, as well as sampling eggs of 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*), northern fulmars (*Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) from Prince Leopold Island in Lancaster Sound, Nunavut, have been monitored for contaminants since 1975 (Braune et al. 2019), and eggs of thick-billed murres from Coats Island in northern Hudson Bay have been monitored since 1993 (Braune et al. 2014, 2015a). Also starting in 1993, we have been monitoring contaminants in eggs of glaucous gulls (*Larus hyperboreus*) and black guillemots (*Cepphus grylle*) from Prince Leopold Island to better align the Canadian program with other international monitoring activities under the Arctic Monitoring and Assessment Programme (AMAP).

Eggs are analyzed for legacy persistent organic pollutants (POPs; biennially as of 2014), total mercury (Hg; annually), and the murre and fulmar eggs from Prince Leopold Island are also analyzed annually for polybrominated diphenyl ethers (PBDEs) and perfluoroalkyl substances (PFASs), and biennially for polychlorinated dibenzo-*p*-dioxins (PCDDs) and furans (PCDFs) as well as coplanar PCBs (polychlorinated biphenyls). 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, 2019) 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 2018-2019

Sample collection/analysis

Eggs of northern fulmars (*n*=15), thick-billed murres (*n*=15), black-legged kittiwakes (*n*=15) and glaucous gulls (*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, as prescribed in the Blueprint. However, no black guillemot eggs were collected from Prince Leopold Island, as planned, due to a late breeding season and a short window of opportunity due to inclement weather and abnormally thick fog conditions.

As of 2014, legacy POPs are analyzed on a biennial basis in even years for this project. Although all eggs sampled in 2018 were scheduled to be analyzed for legacy POPs (e.g. PCBs, DDT, chlordanes, chlorobenzenes, etc.), PBDEs and HBCD, and murre and fulmar eggs from Prince Leopold Island were to be analyzed for PCDDs, PCDFs and non-*ortho* PCBs, NCP funding for those analyses was deferred to 2019. However, 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, as per the Blueprint. Eggs are also being individually analyzed for total Hg and stable isotopes of nitrogen (15N/14N) and carbon (13C/12C).

Analytical methods

Total Hg analyses are being carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario, using a Direct Mercury Analyzer (DMA-80) for solid samples according to NWRC Method No. MET-CHEM-THg-01A. Analyses of PFASs (10 PFCAs and 4 PFSAs) were carried out by the 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 by ALS Environmental, Burlington, ON, using the GC/HRMS isotope dilution method. 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 (Laboratory Services, OCRL) and ALS Environmental participate 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 and Jupie Angootealuk from Coral Harbour were 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. The Annual Wildlife Contaminants Workshop was held at the Nunavut Arctic College in Iqaluit in fall 2018. The Workshop included a marine bird module where students attended a lecture that highlighted seabird contaminant monitoring work in Nunavut, and then took part in bird dissections where they were trained to collect tissues for contaminants research. There was also an opportunity for students to dissect birds over the weekend to increase their skills further.

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 on 4-5 April 2018, where she presented a general overview of the work at Prince Leopold Island, a plain language field report for 2017 (English-Inuktitut), and plans for the 2018 field season. She made a brief presentation to the ACMC explaining why we needed to open a field camp in 2018 to do our work. The ACMC supported a one-year permit. Amie also went to the Qarmartalik School in Resolute Bay to help with their breakfast program on 4 April 2018 and to speak with both junior and senior science classes on contaminants monitoring at Prince

Leopold Island, as well as discuss employment opportunities through the Inuit Field Research Assistance program. Phil Thomas (ECCC, Ottawa), co-PI, met with the Resolute Bay HTO and the Sulukvait ACMC on 15-16 January 2019 and provided copies of our 2018 field report for Prince Leopold Island (English-Inuktitut). He made a brief presentation to the ACMC asking for support to continue the research on marine birds at Prince Leopold Island in 2019 and discussed the upcoming 2020 proposed wildlife dissection workshop in Resolute Bay in collaboration with Magali Houde (ECCC). The ACMC supported the continuation of the research and encouraged a multi-year permit application in 2020. On 16 January 2018, Phil visited the Qarmartalik School in Resolute to help out with their morning breakfast program. He had the opportunity to meet with staff and discuss on-the-land youth-Elder camps, workshops and seminars he has given to other Indigenous communities in the past, and was encouraged to consider organizing similar activities in collaboration with the school and the local HTO.

Paul Smith (ECCC, Ottawa), who also has a field camp on Coats Island, met with the Coral Harbour (Aiviit) HTO and ACMC, first by phone on 11 April 2018, and then in person on 13 April to present some of our contaminant monitoring results and discuss plans for the 2018 field season. Paul also participated in a radio call-in show to field questions from the community and he participated in two community open houses where our research was presented and discussed in an informal setting.

Digital and hard copies of the most recent translated Coastlines newsletter (Coastlines 2016-2018), which contains plain-language summaries on marine bird research including our Arctic work, were sent to HTOs/HTAs in Nunavut, as well as Inuit organizations, government departments, and funding organizations that deal with the environment. Annual reports of our results to date are made to the NCP each year and results will continue to be published in a peer-reviewed scientific journals and presented at conferences/workshops

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. In response to ACMC concerns regarding tourist boat activity near the colonies on Prince Leopold Island, we set up three cameras in 2018 to monitor tourist boat activity and any potential disturbance they may cause to the bird colonies. We are increasing the number of cameras by 5 (total of 8) in 2019 and plan to retrieve the equipment on PLI during our next site visit. We are also taking note of the community's observations on changing numbers of birds seen in the area as well as changing local weather patterns, which may help us with data interpretation. During discussions at the open houses in Coral Harbour in April 2018, we came to understand that the community is strongly supportive of seeing the marine areas around Coats Island designated as a Marine Protected Area; a proposal recently put forward by Fisheries and Oceans Canada. Our work would contribute baseline contaminants information to support that designation.

Results

Temporal trends

Concentrations of ∑35PCB and ∑DDT declined from 1993 to 2013 in eggs of five species of seabirds breeding on Prince Leopold Island except for ∑DDT in kittiwake eggs which showed no change (Figure 1). Declines in the glaucous gull eggs were most pronounced, likely associated with glaucous gull diet and trophic status. ∑PFCA increased from 1975 to 2008 in the fulmar eggs and 2010 in the murre eggs, followed by a dramatic decline in the fulmar eggs but more of a leveling off in the murre eggs (Figure 2). PFOS showed no clear directional trend between 1975 and 2007, but concentrations peaked in 2008-2009 followed by a rapid and steady decrease in both the murre and fulmar eggs to mean concentrations in 2018 that were below those recorded in 1975 (Figure 3). Concentrations of ∑67PCN continue to decrease (Figure 3).

Figure 1. Mean annual concentrations of ´∑35PCB and ∑DDT (µg g-1 lipid wt. ± standard error) in eggs of glaucous gulls, black-legged kittiwakes, thick-billed murres, northern fulmars and black guillemots from Prince Leopold Island, Nunavut, 1993-2013. Source: Braune et al. 2019.

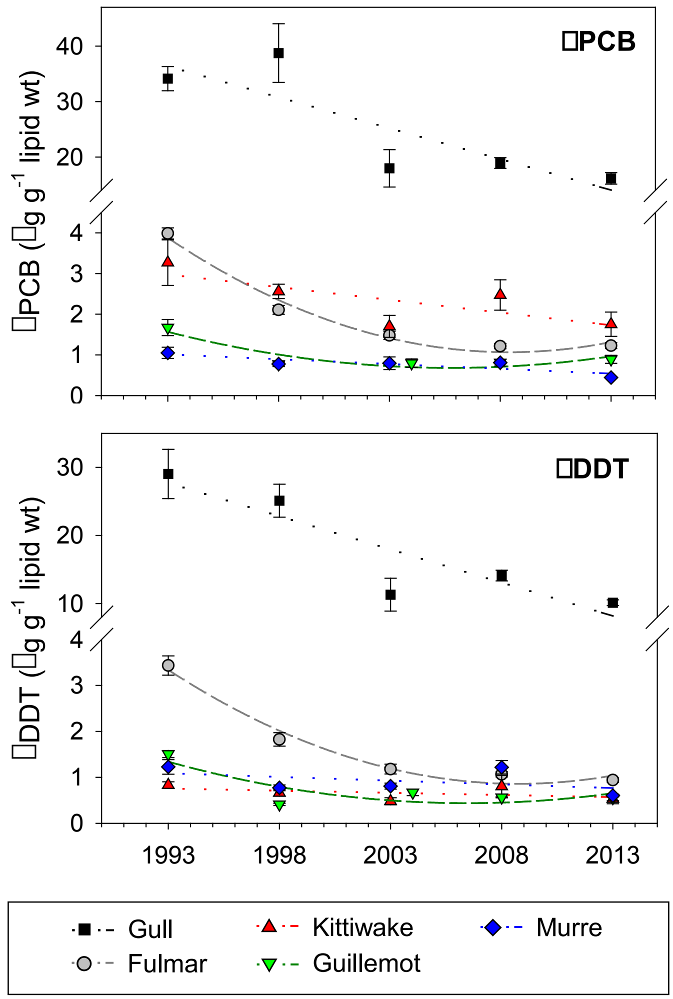
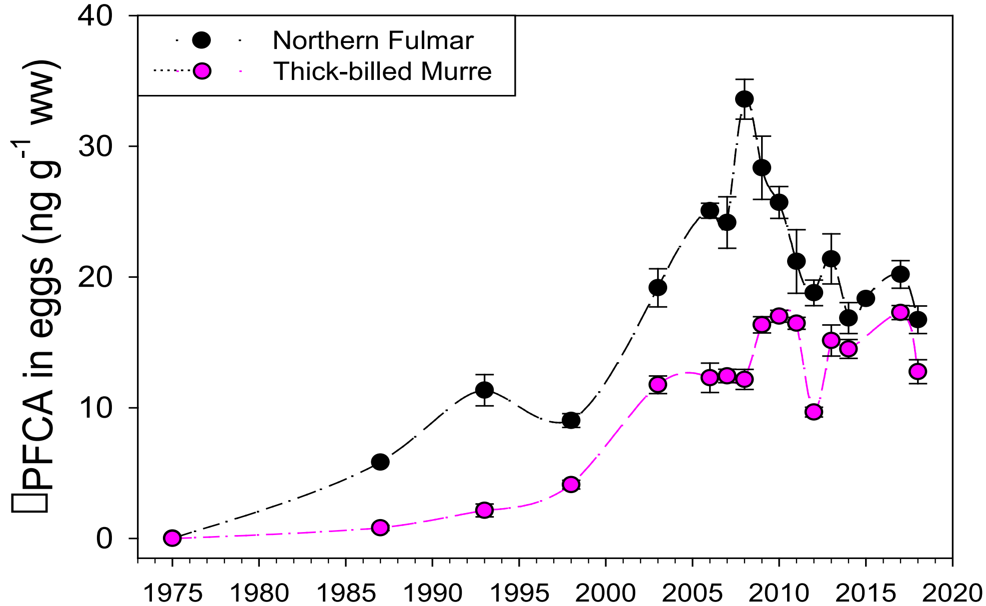


Figure 2. Mean annual concentrations (± standard error) of total perfluorinated carboxylates (∑PFCA) and PFOS in eggs of northern fulmars and thick-billed murres from Prince Leopold Island, 1975-2018. ∑PFCA = Sum C6 to C14.



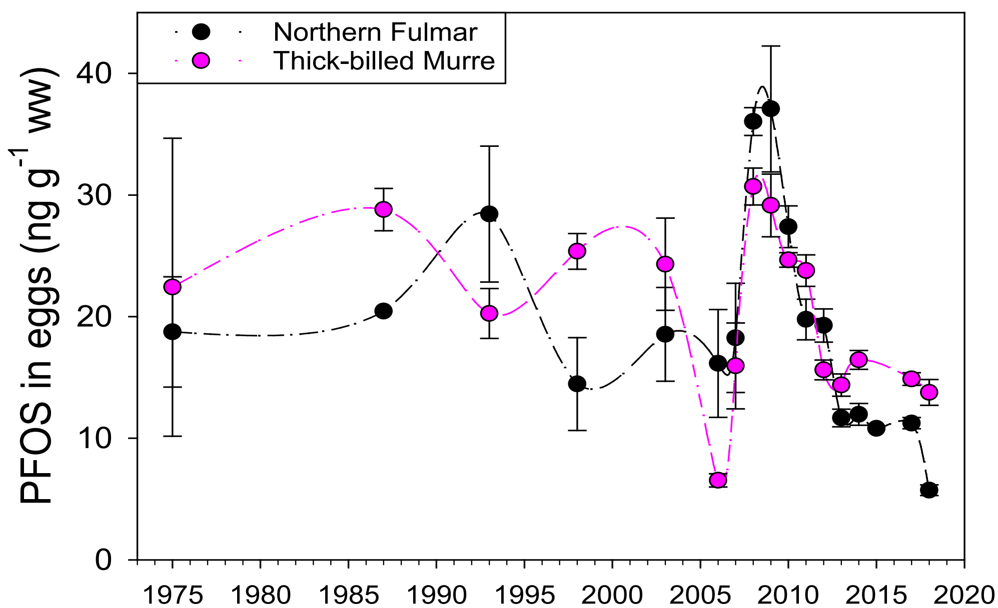
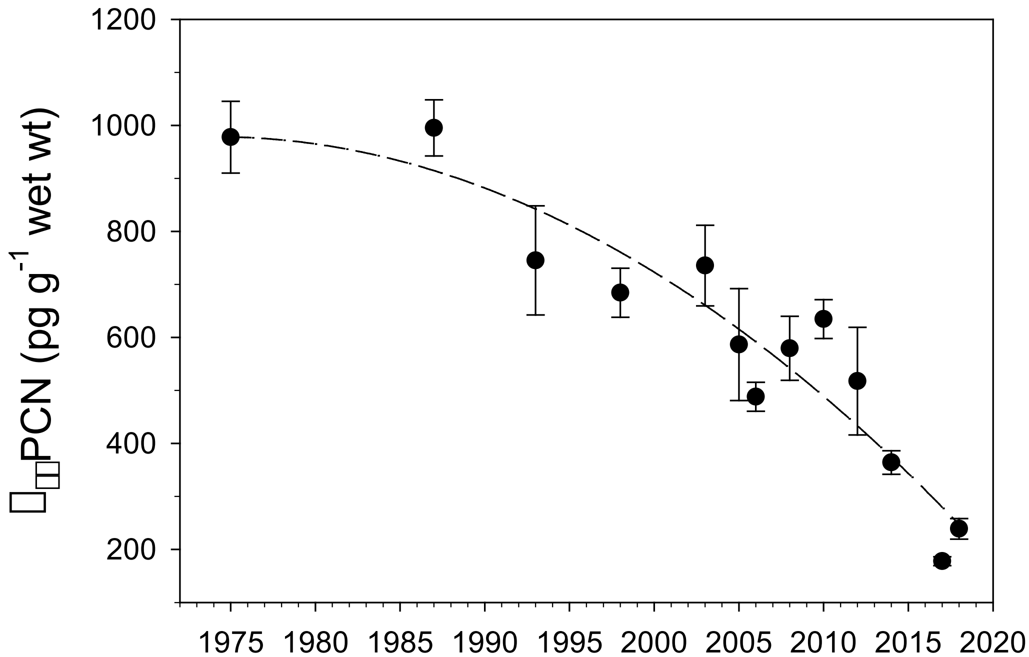


Figure 3. Mean annual concentrations of ∑67PCN (pg g-1 wet wt. ± standard error) in eggs of thick-billed murres from Prince Leopold Island, Nunavut, 1975-2018.



Effects of climate change on mercury temporal trends

We examined the influence of weather/climate on inter-annual total Hg variability. For both fulmars and murres, after time lags of 2 to 7 years, the most parsimonious models included North Atlantic Oscillation (NAO), temperature and, additionally, for murres, snowfall and for fulmars, sea ice. Thus, Hg concentrations in murre eggs increased following years of NAO+ circulation and heavier snowfall and, in fulmar eggs, Hg concentrations also increased following years with NAO+ circulation, cooler summer temperatures and reduced summer sea ice cover.

Discussion and conclusions

As shown by trends in eggs of three seabird species from 1975 to 2015, declines of the major legacy organochlorines in seabirds from Prince Leopold Island occurred during the 1970s to 1990s followed by little change during the 2000s (Braune et al. 2019). The declines during the 1970s and 1980s resulted from the implementation of global and regional conventions which regulated or banned the use of most of the legacy POPs reported in our study (NCP 2013; Wöhrnschimmel et al. 2016). The major legacy organochlorines compared among five species of seabirds breeding on Prince Leopold Island either declined or showed no trend between 1993 and 2013 (Braune et al. 2019) likely because, with fewer time points (i.e. five) over a shorter time frame (1993-2013) which followed the period of dramatic declines, the temporal trends compared among the five species had already plateaued and were less defined. Declines in the glaucous gull eggs were most pronounced, likely associated with glaucous gull diet and trophic status (Braune et al. 2019). The declines in the legacy organochlorines are consistent with decreases observed in other Arctic biota (Rigét et al. 2019).

∑PFCA concentrations showed an increase followed by a decrease in the murre and fulmar eggs from Prince Leopold Island and PFOS also showed a sharp decline after 2008-2009 (Figure 2). The increase in ∑PFCA concentrations in both murre and fulmar eggs up to 2008-2010 is consistent with observed increases in other arctic species monitored into the early 2000's (Braune and Letcher 2014), and the decreasing trend in PFOS concentrations after the mid-2000's is consistent with trends seen in other Arctic biota (Rigét et al. 2019). The recent declines in ∑PFCA and PFOS in the fulmar and murre eggs may reflect a delayed response to the manufacturing phase-out of PFOS and PFOA by the 3M Company between 2000 and 2002 (Butt et al. 2010). In 2009, PFOS was added to the Stockholm Convention on POPs and, although PFCAs are not yet regulated under the Convention, PFOA and its related compounds are proposed for listing (http://www.pops.int/TheConvention/ThePOPs/ChemicalsProposedforListing/tabid/2510/Default.aspx).

Concentrations of ∑67PCN also 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) and was added to the Stockholm Convention on POPs in 2015 (Vorkamp and Rigét 2017), there is evidence that emissions to the environment continue from combustion sources and through volatilization from old products containing PCNs and PCB mixtures, the latter containing PCNs as impurities (Vorkamp and Rigét 2017).

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, Rigét 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, particularly for the legacy organochlorines, was related to changing emission patterns. However, the data suggest that with increasingly NAO+ conditions (fulmars) and increasing rainfall (murres), concentrations of certain organochlorines have increased (Foster et al. 2019). Similarly, THg concentrations in murre eggs increased following years of NAO+ circulation and heavier snowfall, and in fulmar eggs, THg concentrations also increased following years with NAO+ circulation, cooler summer temperatures and reduced summer sea ice concentration. 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

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References

Bidleman, T.F., P.A. Helm, B.M. Braune and G.W. Gabrielsen. 2010. Polychlorinated naphthalenes in polar environments – a review. *Sci. Total Environ.* 408: 2919-2935.

Braune, B.M. and R.J. Letcher. 2014. Temporal trends of perfluorinated sulfonate and carboxylate compounds in seabird eggs from the Canadian Arctic. *Organohalogen Cmpd.* 76: 138-141.

Braune, B.M. and M.L. Mallory. 2017. Declining trends of polychlorinated dibenzo-*p*-dioxins, dibenzofurans and non-*ortho* PCBs in Canadian Arctic seabirds. *Environ. Pollut.* 220: 557-566.

Braune, B.M. and D.C.G. Muir. 2017. Declining trends of polychlorinated naphthalenes in seabird eggs from the Canadian Arctic, 1975-2014. *Environ. Sci. Technol.* 51: 3802-3808.

Braune, B.M., A.J. Gaston, K.A. Hobson, H.G. Gilchrist and M.L. Mallory. 2014. Changes in food web structure alter trends of mercury uptake at two seabird colonies in the Canadian Arctic. *Environ. Sci. Technol.* 48: 13246-13252.

Braune, B.M., A.J. Gaston, K.A. Hobson, H.G. Gilchrist and M.L. Mallory. 2015a. Changes in trophic position affect rates of contaminant decline at two seabird colonies in the Canadian Arctic. *Ecotox. Environ. Safe.* 115: 7-13.

Braune, B.M., R.L. Letcher, A.J. Gaston and M.L. Mallory. 2015b. Trends of polybrominated diphenyl ethers and hexabromocyclododecane in eggs of Canadian Arctic seabirds reflect changing use patterns. *Environ. Res.* 142: 651-661.

Braune, B.M., A.J. Gaston and M.L. Mallory. 2016. Temporal trends of mercury in eggs of five sympatrically breeding seabird species in the Canadian Arctic. *Environ. Pollut.* 214: 124-131.

Braune, B.M., A.J. Gaston and M.L. Mallory. 2019. Temporal trends of legacy organochlorines in eggs of Canadian Arctic seabirds monitored over four decades. *Sci. Total Environ.* 646: 551-563.

Butt, C.M., U. Berger, R. Bossi and G.T. Tomy. 2010. Levels and trends of poly- and perfluorinated compounds in the arctic environment. *Sci. Total Environ.* 408: 2936-2965.

Dorresteijn, I., A.S. Kitaysky, C. Barger, Z.M. Benowitz-Fredericks, G.V. Byrd, M. Shultz and R. Young. 2012. Climate affects food availability to planktivorous least auklets *Aethia pusilla* through physical processes in the southeastern Bering Sea. *Mar. Ecol. Progr. Ser.* 454: 207-220.

Falandysz, J., K. Chudzynski, M. Takekuma, T. Yamamoto, Y. Noma, N. Hanari and N. Yamashita. 2008. Multivariate analysis of identity of imported technical PCN formulation. *J. Environ. Sci. Health A* 43: 1381-1390.

Foster, K.L., B.M. Braune, A.J. Gaston and M.L. Mallory. 2019. Climate influence on legacy organochlorine pollutants in arctic seabirds. *Environ. Sci. Technol.* 53: 2518-2528.

Kilanowicz, A., K. Sitarek, M. Skrzypinska-Gawrysiak and A. Sapota. 2011. Prenatal developmental toxicity of polychlorinated naphthalenes (PCNs) in the rat. *Ecotoxicol. Environ. Saf.* 74: 504-512.

Loseto, L.L., G.A. Stern and R.W. Macdonald. 2015. Distant drivers or local signals: where do mercury trends in western Arctic belugas originate? *Sci. Total Environ.* 509-510: 226-236.

Macdonald, R.W., T. Harner and J. Fyfe. 2005. Recent climate change in the Arctic and its impact on contaminant pathways and the interpretation of temporal trend data. *Sci. Total Environ.* 342: 5-86.

McKinney, M.A., B.C. McMeans, G.T. Tomy, B. Rosenberg, S.H. Ferguson, A. Morris, D.C.G. Muir and A.T. Fisk. 2012. Trophic transfer of contaminants in a changing arctic marine food web: Cumberland Sound, Nunavut, Canada. *Environ. Sci. Technol.* 46: 9914-9922.

NCP, 2013. *Canadian Arctic Contaminants Assessment Report on Persistent Organic Pollutants – 2013*. Muir, D., Kurt-Karakus, P., Stow, J. (Eds.). Northern Contaminants Program, Aboriginal Affairs and Northern Development Canada, Ottawa, ON.

Rigét, F., R. Dietz and K.A. Hobson. 2012. Temporal trends of mercury in Greenland ringed seal populations in a warming climate. *J. Environ. Monit.* 14: 3249-3256.

Rigét, F., K. Vorkamp, K.A. Hobson, D.C.G. Muir and R. Dietz. 2013. Temporal trends of selected POPs and the potential influence of climate variability in a Greenland ringed seal population. *Environ. Sci. Processes Impacts* 15: 1706-1716.

Rigét, F., A. Bignert, B. Braune, M. Dam, R. Dietz, M. Evans, N. Green, H. Gunnlaugsdóttir, K.S. Hoydal, J. Kucklick, R. Letcher, D. Muir, S. Schuur, C. Sonne, G. Stern, G. Tomy, K. Vorkamp and S. Wilson. 2019. Temporal trends of persistent organic pollutants in Arctic marine and freshwater biota. *Sci. Total Environ.* 649: 99-110.

Vorkamp, K. and F. Rigét. 2017. Polychlorinated napthalenes. pp. 173-180 in: *AMAP Assessment 2016: Chemicals of Emerging Arctic Concern.* Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Wöhrnschimmel, H., M. Scheringer, C. Bogdal, H. Hung, A. Salamova, M. Venier, A. Katsoyiannis, R.A. Hites, K. Hungerbuhler and H. Fiedler. 2016. Ten years after entry into force of the Stockholm Convention: what do air monitoring data tell about its effectiveness? *Environ. Pollut.* 217, 149-158.

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

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Project Locations/Emplacements du projet

Cambridge Bay, Nunavut. The focus is on the sea-run char fishery at Cambridge Bay with additional char samples provided from the commercial fisheries harvests at other locations (Lauchlan, Halovik, Palikyak, Ekalluk, and Jayco Rivers in 2018). We are collaborating in a companion study at Greiner Lake, the primary lake at Cambridge Bay and where the sea-run char caught in the local domestic fishery are believed to reside when not in the sea. This study includes smaller lakes.

Abstract

This core biomonitoring study investigates trends in mercury concentrations in sea-run Arctic char from the domestic fishery at *Ekaluktutiak* (Cambridge Bay). Of particular interest, is how mercury concentrations are changing from year to year because of changes in climate, mercury released into the air from urban and industrial areas, and possible changes in the char diet. We also have been investigating mercury in char from various commercial

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). Il est particulièrement intéressant de voir comment les concentrations de mercure changent d'année en année en raison des changements climatiques, du mercure rejeté dans l'air par les zones urbaines et industrielles, et des changements possibles

fisheries' harvest areas to provide information on these fish and better investigate change.

We have found that mercury concentrations are low in sea-run char and tend to be higher in larger fish. They also tend to be higher in thinner, rather than heavier fish. We believe that fish may put on less weight in colder years when they have less food to eat while in the sea. We also have been working with university researchers on studies related to fish in Greiner Lake with our focus being mercury in these fish. We have found higher concentrations of mercury in lake whitefish and lake trout than in char. Their higher concentrations are believed to be related to where the fish are feeding and slower growth rates. We met with the Ekaluktutiak Hunters and Trappers Organization (HTO) in March 2019 and copies of posters that more easily show our study findings with respect to mercury in fish to the HTO.

dans le régime alimentaire de l'omble. Nous avons également étudié le mercure dans l'omble provenant de diverses zones de pêche commerciale afin d'obtenir des données sur ces poissons et de mieux étudier les changements.

Nous avons constaté que les concentrations de mercure sont faibles dans l'omble anadrome et ont tendance à être plus élevées dans les poissons plus gros. Elles ont également tendance à être plus élevées dans les poissons plus maigres, plutôt que dans les poissons plus gros. Nous pensons que les poissons peuvent prendre moins de poids pendant les années froides, lorsqu'ils trouvent moins de nourriture en mer. Nous avons également travaillé avec des chercheurs universitaires sur des études relatives aux poissons du lac Greiner, en nous concentrant sur le mercure présent dans ces poissons. Nous avons trouvé des concentrations de mercure plus élevées dans les poissons blancs et les touladis que dans les ombles. Selon nous, ces concentrations plus élevées sont liées aux lieux d'alimentation et à des taux de croissance plus lents. Nous avons rencontré l'Organisation des chasseurs et trappeurs d'Ekaluktutiak en mars 2019 et avons remis des affiches qui décrivent clairement les résultats de notre étude sur le mercure dans les poissons.

Key messages

- Mercury concentrations remain very low in sea-run char from the Cambridge Bay domestic fishery.
- Mercury concentrations were low in fish obtained from the commercial fisheries at other locations in the Victoria Island area.
- Mercury concentrations are slightly higher in char living in Greiner Lake than char feeding in the sea.
- Mercury concentrations are higher in lake whitefish and lake trout than in char from Greiner Lake. These two species of fish are near the northern extent of their geographic range and may be experiencing some stress. We think higher mercury concentrations are related to slow growth rates although feeding behavior is also important.

Messages clés

- Les concentrations de mercure demeurent très faibles chez l'omble chevalier anadrome provenant de la pêche locale à Cambridge Bay.
- Les concentrations de mercure étaient faibles dans les poissons capturés par la pêche commerciale dans d'autres endroits de la région de l'île Victoria.
- Les concentrations de mercure sont légèrement plus élevées chez les ombles du lac Greiner que chez les ombles se nourrissant dans la mer.
- Les concentrations de mercure étaient plus élevées dans le corégone de lac et le touladi que dans l'omble du lac Greiner. Ces deux espèces de poissons vivent près de

l'extrémité nord de leur aire de répartition géographique et peuvent subir un certain stress. Selon nous, les concentrations de mercure plus élevées sont liées à des taux de croissance lents, bien que le comportement alimentaire soit également important.

Objectives

This project aims to:

continue our mercury trend monitoring of sea-run Arctic char from the domestic fishery at Ekaluktutiak with a focus of investigating the role of climatic variability in affecting trends;

obtain fish from the stock assessment studies being conducted by Fisheries and Oceans Canada (Les Harris) to investigate differences in mercury concentrations in Arctic char between various river/lake systems used by the commercial fisheries, allowing us to extend our mercury temporal and spatial trend assessments;

continue our mercury investigations of Arctic char, lake trout, and lake whitefish in Greiner Lake in collaboration with the Ekaluktutiak Hunters and Trappers Organization (HTO), Milla Rautio, and Michael Power and provide data to Nunavut Health for assessment and the provision of consumption advice;

continue to collaborate with Milla Rautio and Michael Power in their/our Polar Knowledge ecosystem studies of Greiner Lake and other lakes in the watershed; the focus of the Polar Knowledge study is on food webs and essential fatty acids while Environment and Climate Change Canada's focus is on mercury;

visit Ekaluktutiak to discuss the findings of the sea-run Arctic char project, conduct sampling, and provide training as opportunities present themselves; and

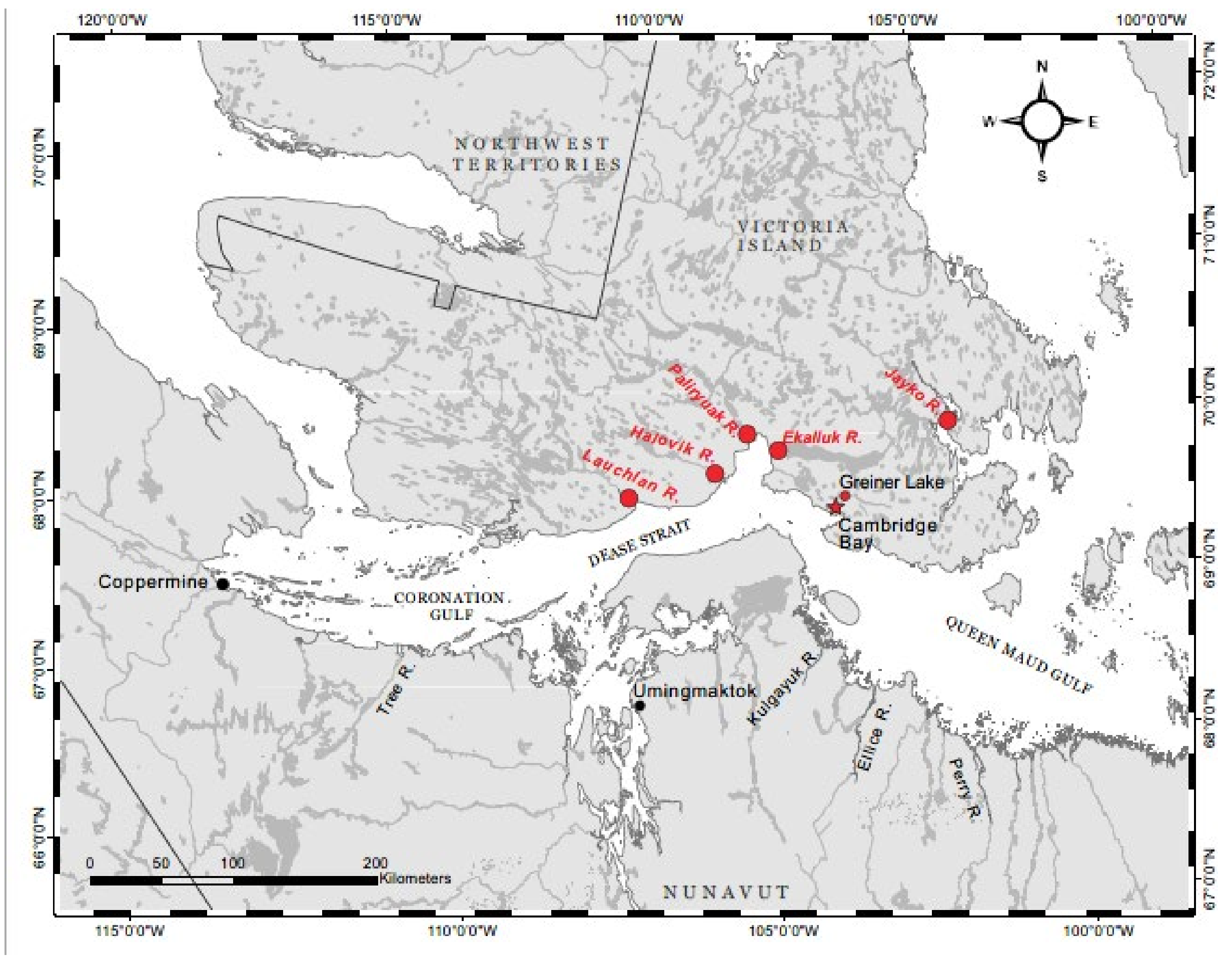
provide contributions to the Arctic Monitoring and Assessment Program (AMAP) on mercury trends, including the upcoming 2021 Assessment Report.

Introduction

This sea-run Arctic char study at Cambridge Bay is part of Northern Contaminant Program's Marine Ecosystems Trend Monitoring Program and was first established in 2004 (Evans 2011, Evans and Muir 2014, Evans et al. 2015). It continues to this day despite reductions in funding and support for the original program which included more sea-run char locations in other regions of the Arctic and persistent organic chemicals. Sea-run char are highly important in the Inuit diet, second only to caribou in daily dietary intake (Laird et al. 2013, Hu et al. 2017). In addition to calories, they provide essential fatty acids and selenium which may offer some protection against the adverse impacts of high mercury intake from marine mammals. 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 approximately 100 -150 km of the community (Lockhart et al. 2005, Evans et al. 2015). This region (Figure 1) is remarkably productive for char, most likely because of high primary productivity in the sheltered embayments around Victoria Island and the mainland, and excellent inland habitats (lakes, rivers) which support the large standing stocks of fish. Cambridge Bay is also the site of the Canadian High Arctic Research Station (CHARS), which has become a growing hub for the investigation of many aspects of the freshwater and marine environment, including responses to climate change. This new research station complements the research station established at 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 (Chételat et al. 2015, Barst et al. 2016, Cabrerizo et al. 2018, Hudelson et al. 2019). Cambridge Bay presents additional research opportunities, e.g. comparisons of responses of landlocked, resident, and sea-run char populations in marine and freshwater environments, with freshwater environments expected to be more responsive to climate change.

This project focusses on the Arctic char harvested from the domestic fishery at Cambridge Bay by community members. In 2018, fishers selected by the Ekaluktutiak HTO (EHTO) provided 20 fish from this fishery. In addition, staff from the Department of Fisheries and Oceans (DFO) provided char samples from five commercially harvested rivers where DFO is conducting stock assessment studies. These locations (Figure 1) were the Elluice River on the mainland (south of Queen Maud Gulf), Lauchlan River/Byron Bay, Palikyak River/Surrey River (north of the Dease Strait and discharging into Wellington Bay), and the Jayco and Ekalluk Rivers (north of Cambridge Bay); all of which were investigated in 2018. The Ekalluk is the outflow river for Ferguson Lake, a large (562 km2) lake of much historic importance (Norman and Friesen 2010).

Figure 1. Map of the Victoria Island and the mainland showing locations of primary rivers supporting char fisheries. Sites from which fish samples were provided are shown in red.



Sea-run char are harvested from Freshwater Creek (the outflow from Greiner Lake) during their spring and fall migrations. Cambridge Bay community members regularly fish this lake, which also supports lake trout, lake whitefish, and least cisco populations. This lake and its broader watershed has become the focal site for various limnological studies as part of the expanding Canadian High Arctic Research Station program (Anonymous 2015). Since 2014, we have arranged for the annual collection of lake trout and Arctic char from this lake with fish provided in recent years by university researchers primarily Dr. Milla Rautio and Michael Power, as part of collaborative Polar Knowledge and ArcticNet funded studies. Since 2017, lake whitefish and cisco have also been provided by these researchers working with community fishers, These data are adding to the past research conducted on sea-run and landlocked Arctic char populations in northern Canada, and lake trout in the broader Cambridge Bay area, including differences in mercury bioaccumulation as a function of species and migratory behavior (Gantner et al. 2010, Swanson et al. 2010, Swanson et al. 2011, van der Velden et al. 2013a, van der Velden et al. 2013b).

Activities in 2018-2019

Community engagement

Sea-run char collections were arranged through the HTO who decided which community fishermen would provide these fish. We also engaged with the HTO during our NCP proposal development. Based on our successful collaborations with the HTO, we were able to develop new collaborations with university researchers seeking Polar Knowledge and ArcticNet funding. These partnerships were broadened to meet community interests. These proposals have been successful, in part based on letters of support received, and has resulted in new fish and other studies being conducted on Greiner Lake. The mercury results have been shared with the community and the community has become more directly involved in the fish and other sampling on Greiner and other lakes.

Capacity building and training

Capacity building has occurred through various means. The primary means has been the discussion of factors affecting mercury concentrations in fish, e.g. diet and fish size, through email and telephone exchanges, and sharing results in posters and reports. Information also has been shared during a visit to Cambridge bay that included speaking with the HTO and more informal conversations with community members. More training has come from the Rautio-led Polar Knowledge and ArcticNet studies, which has included sharing information during fish and other collections made on Greiner Lake. Dr. Rautio also has had youth assisting in the laboratory processing samples at the end of the day. The focus has been on the sampling of Greiner and other lake ecosystems.

Communications and outreach

Communications throughout the year are by telephone and email to the HTO. These communications are based on discussing proposal development, licensing, arrangements for sea-run char collections, and study results. Proposal development includes not only the NCP char project but ArcticNet and Polar Knowledge projects led by Dr. Rautio. Marlene visited Cambridge Bay in February 2019 and met with the HTO during their monthly evening meeting and discussed study results for the NCP and related studies. Plain language posters which provide a pictorial information of study findings were provided and have been well received. Posters were vetted by the Nunavut Department of Health, Nunavut Environmental Contaminants Committee, and the Kitikmeot Regional Clinical Dietitian.

Indigenous Knowledge

The sea-run char are obtained from the domestic fishery. We rely on Indigenous knowledge for the collection of our fish samples with respect to timing and location. Indigenous knowledge has proved very important in our collaborative Rautio-led study of Greiner Lake and lakes in its broader watershed. As a consequence of that knowledge and a community request, an additional lake was been added to the Rautio led study in summer 2019. Local fishermen have also shared information on other lakes (including landlocked) that they routinely fish for char which potentially could also be investigated.

Fish collections

In August 2019 sea-run Arctic char were harvested by community fishermen and sent to Saskatoon for analysis. Les Harris provided 150 fillet samples from five char stocks in the Cambridge Bay area for mercury and stable isotope analysis. Resident char, lake trout, and lake whitefish were collected by Milla Rautio from Greiner Lake and lake trout and char from two smaller lakes as part of her "Ecosystem Health of Freshwater" studies; these collections were made in collaboration with community members. These samples were provided to us for mercury and stable isotope analyses.

Other collections and sample sharing

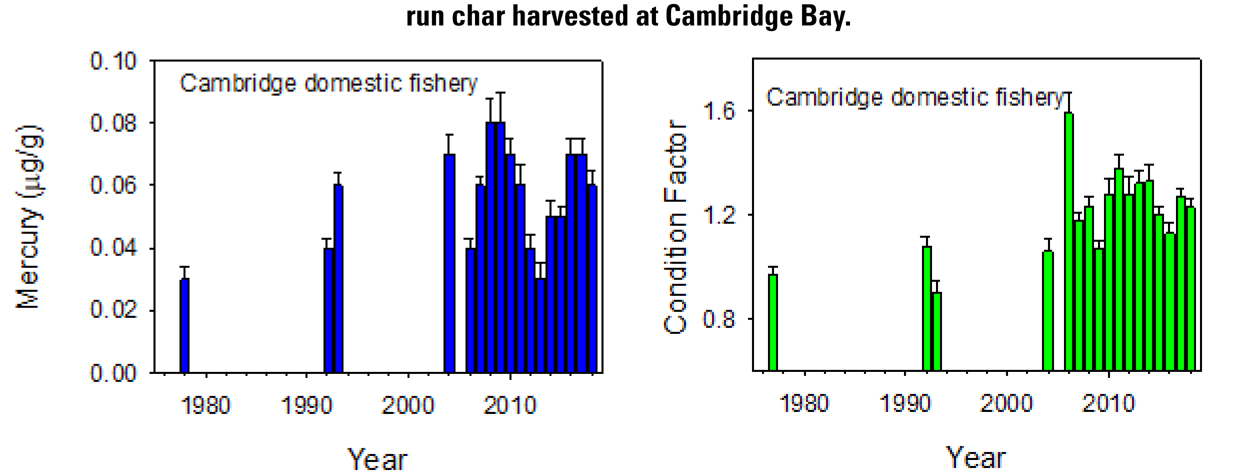
Plankton, various benthic invertebrates, forage fish, and plant and algal mat material were collected at Greiner Lake and the Experimental Lake watershed in August 2018 to investigate trophic pathways and fatty acids. Local community members participated in these collections. Samples have been shared with Environment and Climate Change Canada (ECCC) for stable isotope and mercury analyses. Milla has analyzed 2017 and will analyze 2018 food web collections, including lake trout and char from Greiner Lake for fatty acids. These collections are being used to build a database for trophic pathways within Greiner and other lakes, therefore, contributing to the larger watershed ecology program. Food web samples collected in 2017 were recently analyzed for mercury with 2018 collections to be analyzed shortly. Fatty acid data will provide information on the benefits of consuming Greiner Lake fish to balance messaging based on risk from their mercury concentrations.

Results and discussion

Temporal variability in mercury in sea-run char

There is a long-term, although sporadic, record of mercury concentrations in sea-run char harvested from Cambridge Bay (Figure 2). The first measurement of mercury was made in 1977 with measurements made again in 1992 and 1993; more frequent measurements began with the initiation of this NCP study in order to investigate temporal trends and factors that influence mercury concentrations. Since only fish length and weight were measured in the early studies, only these variables and associated condition factors can be used in trend analyses. Mercury concentrations in char were

Figure 2. Temporal variability (mean ±1 standard error) in mercury concentrations and condition factor in sea-run char harvested at Cambridge Bay.



lower in 1977 than in recent years although variability was high over 2004-2018 (Figure 2). Concentrations increased from 2006 to 2009 and then declined from 2010-2015 before beginning to increase again. Condition factor was highest in 2006, declined, and then peaked again over 2010-2014. Variations in mercury concentration in sea-run char over 1977-2018 were best explained by condition factor (r = -0.42) and fork length (r = 0.24); condition factor was negatively correlated with fish length (r = 0.25).

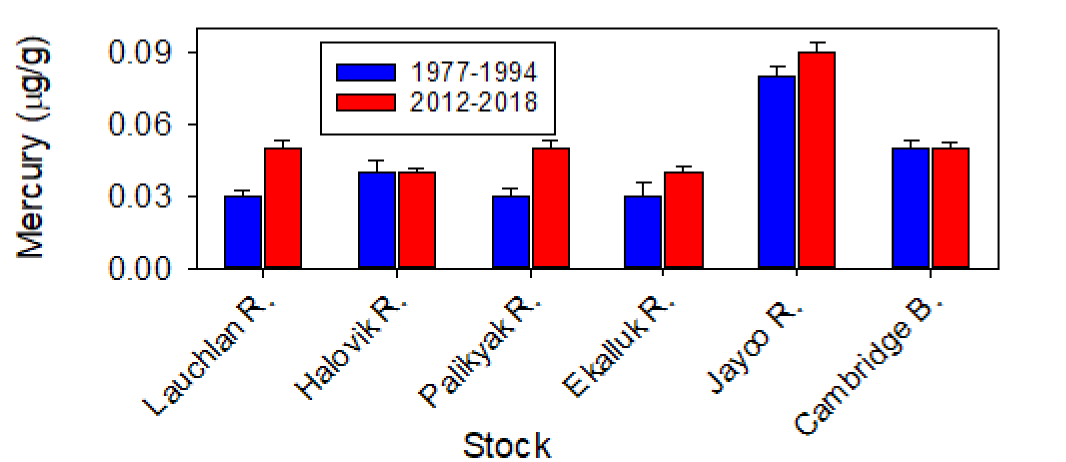
There was a weak trend of increasing mercury in char from Cambridge Bay when length and condition factor were included in the model (Equation 1), although the year and fork length terms were only significant at p = 0.05 and p = 0.07. When the analysis was limited to 2004-2018, year was no-longer a significant term at p = 0.21 (Equation 2). Overall, these analyses suggest that factors that contribute to a reduction in char condition factor contribute to an increase in mercury concentrations in these fish. Cold springs have been implicated as such a factor because of their impact on food supply (Evans et al. 2015).

Log Hg = -8.701 + 0.004*Yr. + 0.000*FL - 0.324*CF (r = 0.15; F=10.888; p=0.000; n = 170). Equation 1

Log Hg = -1.027 + 0.000*FL - 0.383*CF (r = 0.24; F=24.61; p=0.000; n = 154). Equation 2

Arctic char, provided by Les Harris from various other fish stocks allow us to explore differences in mercury concentration between stocks and, ideally, make full use of the 1977-1994 historic mercury in char data set to assess temporal trends. Over 2012-2018, char was provided from one location in 2012, two in 2014, four in 2016 and five in 2018. Preliminary analyses have been conducted with these data and there is evidence that fish mercury and length relationships differ between some locations. For example, mercury concentrations tend to be higher in fish from the Jayco River than elsewhere (Figure 3), possibly in part because resident fish are included in the catch. Mercury concentrations and condition factor tended to be higher in fish in recent years than 1977-1994.

Figure 3. Mean (±1 standard error) mercury concentrations in five stocks of char harvested from the commercial fishery and the domestic fishery at Cambridge Bay over 1977-1994 and 2012-2018. See Figure 1 for site locations.



Greiner Lake fish and sea-run char at Cambridge Bay

Over the past few years, we have been characterizing Arctic char, lake trout, lake whitefish and least cisco harvested in Greiner Lake with respect to life history features and mercury concentrations (Table 1). Sea-run char tend to be larger and older than summer-caught char from Greiner Lake, but with lower mercury concentrations. Summer caught char from Greiner Lake had food in their stomachs, indicative of a resident population.

In contrast to char, mercury concentrations were relatively high in lake trout with fish approaching or exceeding the 0.5 μg/g mercury commercial sale guideline (Table 2). Higher concentrations may in part be related to these fish being small, old and slow growing most likely because they are the northern limit of their distribution range. Mercury concentrations also were relatively high in lake whitefish, which had also fed primarily in the offshore, but also were old (Lockhart et al. 2005). We observed similar mercury concentrations of 0.2 μg/g in lake whitefish in other northern lakes although concentrations typically are substantially lower.

While char provided to us in fall 2015 were from Greiner Lake, we were informed that these fish had been feeding in the sea in the summer. Since char have reported average arsenic concentrations of 0.2-1.0 μg/g versus substantially lower average concentrations of 0.01-0.01 μg/g for landlocked populations (Evans et al. 2005), we investigated this by examining the arsenic concentrations in the lake-caught char provided to us in the fall. In 2015, arsenic concentrations averaged 0.86 ± 0.28 μg/g versus an annual average of 0.87 ± 0.46 μg/g in 2004 to 1.19 ± 0.93 μg/g in 2012 for fish harvested from the sea.

Table 1. Biological features and mercury concentrations of Arctic char caught in Cambridge Bay (sea-run) over 2014-2018. Data are shown as means ± 1 standard error. *char were caught in Greiner Lake in fall 2015 but based on their arsenic concentrations and Indigenous knowledge are believed to be sea-run fish. See text for additional explanation.

Location/Yr.	N	Fork Length (cm)	Condition Factor	Age (yr.)	δ13C (‰)	δ15N (‰)	Hg (μg/g)	As (μ/g)
Cambridge Bay								
2014	10	658±90	1.3±0.2	12.8±3.4	-24.0±0.4	14.4±0.8	0.05±0.02	1.03±0.34
2015*	12	610±62	1.2±0.1	10.4±1.5	-24.5±0.8	14.6±0.3	0.05±0.01	0.86±0.28
2016	20	707±83	1.1±0.2	13.6±3.2	-23.7±0.7	14.9±0.4	0.07±0.02	0.97±0.34
2017	15	652±88	1.3±0.1	15.3±4.1	-23.8±1.1	14.8±0.7	0.07±0.02	1.01±0.34
2018	20	632±60	1.2±0.1	11.7±4.1	-24.1±0.7	14.4±0.7	0.06±0.02	1.13±0.34
Greiner 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	
2016	15	510 ± 158	1.1 ± 0.1	9.2 ± 2.6	-24.9 ± 1.6	11.4 ± 2.2	0.08 ± 0.04	
2017	18	405 ± 162	1.1 ± 0.1	-	-	-	0.10 ± 0.04	
2018	21	424±54	1.0 ± 0.2	-	-	-	0.10±0.04	

Table 2. Biological features and mercury concentrations of lake trout, lake whitefish, and least Arctic char caught in Greiner Lake over 2014-2018. Data shown as mean (±1 standard error).

Species/Year	N	Fork Length (cm)	Condition Factor	Age (yr.)	δ13C (‰)	δ15N (‰)	Hg (µg/g)
Lake trout							
2014	15	501 ± 19	1.3 ± 0.1	22.7 ± 8.7	-25.5 ± 0.7	11.3 ± 0.6	0.40 ± 0.09
2015	9	593 ± 143	1.3 ± 0.2	29.7 ± 6.5	-26.5 ± 1.0	11.8 ± 1.5	0.51 ± 0.32
2016	20	567 ± 99	1.5 ± 0.1	28.7 ± 8.4	-25.7 ± 1.1	11.3 ± 1.1	0.49 ± 0.43
2017	15	578 ± 29	1.3 ± 0.1	25.6 ± 9.5	-	-	0.50 ± 0.19
2018	3	528 ± 83	1.0 ± 0.2	-	-	-	0.40 ± 0.30
Lake whitefish							
2017	21	403 ± 39	1.3 ± 0.2	14.4 ± 6.1	-30.6 ± 1.0	11.3±0.3	0.25 ± 0.13
2018	13	272 ± 99	1.2±0.3	-	-	-	0.15 ± 0.16
Least cisco							
2017	28	223 ± 40	0.1	-	-	-	0.10 ± 0.02

Polar Knowledge studies (Rautio, Power, Grosbois, Evans)

The Greiner Lake food web has been characterized based on carbon and nitrogen isotopes. Littoral zone carbon sources appear particularly important for char, while cisco and lake whitefish feed more on pelagic carbon sources. Fatty acid concentration and composition also has been characterized. A manuscript has been written by Guillaume Grosbois based on 2017 collections entitled "Stocks, production and transfer of polyunsaturated fatty acids in an Arctic lake food web" and was submitted for publication. The submission is now in revision.

Conclusions

Mercury concentrations are low in the sea-run char investigated in our study. They may increase if fish condition factor decreases due to physiological stress, including food limitations. Few fish had mercury concentrations approaching 0.2 µg/g and these appear to be resident char which do not go out to sea. Mercury concentrations are elevated in lake trout which are near the northern limit of their geographic range. These fish also are old and small. Slow growth rates and advanced age probably account for their high mercury concentration. Warming trends, if they improve the productivity of these northern waters, may result in decreased mercury concentrations in these fish through improved growth rates.

Expected completion date

Ongoing core biomonitoring study.

Acknowledgements

This study was supported by the Northern Contaminants Program as a core biomonitoring project. This, in turn, has led to successful partnerships and an expansion of studies around char populations with funding provided by Polar Knowledge and Environment and Climate Change Canada under its Climate Change and Atmospheric Contaminants Program. The Univeristé du Québec à Chicoutimi and the University of Waterloo conducted extensive sampling in Greiner Lake. They have provided a number of fish and food web samples for mercury and stable isotope analyses. CHARS provided field and laboratory support. Beverley Maksagek, with the Ekaluktutiak Hunters and

Trappers Organization, has played a major role in interfacing between the researchers and HTO. This includes arranging for fish collections by local fishermen, recommending fishermen to assist in the sampling by the Polar Knowledge Research team, and communication of results to community members including refining poster design. Jimmy Haniliak Jasmin Tiktalek, Tommy Ekpakohak and Richard Ekpakohak all contributed to the success of the field seasons through their sampling and sharing of Indigenous Knowledge. Maureen Mayhew, Amy Caughey and Chantal Langlois with the Nunavut Department of Health and Jean Allen with the Nunavut Environmental Contaminants Committee provided helpful comments on poster design.

References

Anonymous. 2015. Towards the Development of the Canadian High Arctic Research Station (CHARS) as a Centre for Science and Technology in Canada and the Circumpolar North. Page 135.

Barst, B. D., M. Rosabal, P. G. C. Campbell, D. G. C. Muir, X. Wang, G. Köck, and P. E. Drevnick. 2016. Subcellular distribution of trace elements and liver histology of landlocked Arctic char (*Salvelinus alpinus*) sampled along a mercury contamination gradient. Environmental Pollution **212**:574-583.

Cabrerizo, A., D. C. G. Muir, G. Köck, D. Iqaluk, and X. Wang. 2018. Climatic Influence on Temporal Trends of Polychlorinated Biphenyls and Organochlorine Pesticides in Landlocked Char from Lakes in the Canadian High Arctic. Environmental Science & Technology.

Chételat, J., B. Braune, J. Stow, and S. Tomlinson. 2015. Special issue on mercury in Canada's North: Summary and recommendations for future research. Science of the Total Environment **509-510**:260-262.

Day, A. C., and L. N. Harris. 2013. Information to support an updated stock status of commercially harvested Arctic Char (*Salvelinus alpinus*) in the Cambridge Bay region of Nunavut, 1960-2009. 068, Freshwater Institute, Department of Fisheries and Oceans Canada, Winnipeg, MB.

Evans, M. S. 2011. Temporal trends and spatial variations in persistent organic pollutants and metals in sea-run char from the Canadian Arctic. Aboriginal Affairs and Northern Development Canada, Ottawa.

Evans, M. S., and D. Muir. 2014. Temporal Trends and Spatial Variations in Persistent Organic Pollutants and Metals in Sea-Run Char from the Canadian Arctic. Aboriginal Affairs and Northern Development Canada, Ottawa, ON.

Evans, M. S., D. Muir, W. L. Lockhart, G. Stern, M. Ryan, and P. Roach. 2005. Persistent organic pollutants and metals in the freshwater biota of the Canadian Subarctic and Arctic: An overview. Science of the Total Environment **351–352**:94-147.

Evans, M. S., D. C. G. Muir, J. Keating, and X. Wang. 2015. Anadromous char as an alternate food choice to marine animals: A synthesis of Hg concentrations, population features and other influencing factors. Science of the Total Environment **509-510**:175-194.

Gantner, N., M. Power, D. Iqaluk, M. Meili, H. Borg, M. Sundbom, K. R. Solomon, G. Lawson, and D. C. Muir. 2010. Mercury concentrations in landlocked Arctic char (*Salvelinus alpinus*) from the Canadian Arctic. Part I: Insights from trophic relationships in 18 lakes. Environmental Toxicology and Chemistry **29**:621-632.

Hu, X. F., B. D. Laird, and H. M. Chan. 2017. Mercury diminishes the cardiovascular protective effect of omega-3 polyunsaturated fatty acids in the modern diet of Inuit in Canada. Environmental Research **152**:470-477.

Hudelson, K. E., D. C. G. Muir, P. E. Drevnick, G. Köck, D. Iqaluk, X. Wang, J. L. Kirk, B. D. Barst, A. Grgicak-Mannion, R. Shearon, and A. T. Fisk. 2019. Temporal trends, lake-to-lake variation, and climate effects on Arctic char (Salvelinus alpinus) mercury concentrations from six High Arctic lakes in Nunavut, Canada. Science of the Total Environment **678**:801-812.

Laird, B. D., A. B. Goncharov, G. M. Egeland, and H. Man Chan. 2013. Dietary Advice on Inuit Traditional Food Use Needs to Balance Benefits and Risks of Mercury, Selenium, and n3 Fatty Acids. The Journal of Nutrition **143**:923-930.

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

Norman, L., and T. M. Friesen. 2010. Thule fishing revisited: The economic importance of fish at the Pembroke and Bell sites, Victoria Island, Nunavut. Geografisk Tidsskrift-Danish Journal of Geography **110**:261-278.

Schindler, D., H. Welch, J. Kalff, G. Brunskill, and N. Kritsch. 1974. Physical and chemical limnology of Char Lake, Cornwallis Island (75 N lat.). Journal of the Fisheries Board of Canada **31**:585-607.

Swanson, H., N. Gantner, K. A. Kidd, D. C. G. Muir, and J. D. Reist. 2011. Comparison of mercury concentrations in landlocked, resident, and sea-run fish (*Salvelinus spp.*) from Nunavut, Canada. Environmental Toxicology and Chemistry **30**:1459-1467.

Swanson, H. K., K. A. Kidd, and J. D. Reist. 2010. Effects of Partially Anadromous Arctic Charr (*Salvelinus alpinus*) Populations on Ecology of Coastal Arctic Lakes. Ecosystems **13**:261-274.

van der Velden, S., B. Dempson, M. Evans, D. Muir, and M. Power. 2013a. Basal mercury concentrations and biomagnification rates in freshwater and marine foodwebs: effects on Arctic charr (*Salvelinus alpinus*) from eastern Canada. Science of the Total Environment **444**:531-542.

van der Velden, S., M. S. Evans, J. B. Dempson, D. C. G. Muir, and M. Power. 2013b. Comparative analysis of total mercury concentrations in anadromous and non-anadromous Arctic charr (*Salvelinus alpinus*) from eastern Canada. Science of the Total Environment **447**:438-449.

Temporal trends of persistent organic pollutants and mercury in landlocked char in High Arctic lakes

Tendances temporelles des polluants organiques persistants et du mercure chez l'omble chevalier dulcicole des lacs de l'Extrême-Arctique

Project leaders/Chefs de projet

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Project locations/Emplacements du projet

- Cornwallis Island near Resolute, NU
- Ellesmere Island, Lake Hazen, Quttinirpaaq National Park

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 2018, 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

Résumé

Cette étude à long terme porte sur les tendances temporelles relatives au mercure, à d'autres éléments traces et à des polluants organiques persistants (POP), hérités et nouveaux, qui sont présents chez l'omble chevalier dulcicole. En 2018, 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

of 2005-2018 concentrations of mercury in char declined in Hazen, Resolute and Hazen Lakes but concentrations have levelled off or increased slightly in Char, North and Small lakes. Concentrations of fluorinated substances have increased in Char, North, Amituk and Hazen lakes since 2015 mainly due to greater amounts of perfluorinated carboxylates which are atmospheric degradation products of volatile fluorinated compounds. Perfluorooctane sulfonate (PFOS) which has been banned or phased out since the mid-2000s, has not increased. During 2018-2019 we published two scientific papers which investigated factors influencing mercury and POPs in landlocked char. Longer ice duration was associated with higher levels of mercury in char muscle while differences in concentrations of POPs and mercury among lakes were related do dissolved organic carbon.

Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. Dans l'ensemble, les résultats montrent qu'au cours de la période 2005-2018, les concentrations de mercure dans l'omble ont diminué dans les lacs Hazen, Resolute et Hazen, mais que les concentrations se sont stabilisées ou ont légèrement augmenté dans les lacs Char, North et Small. Les concentrations de substances fluorées ont augmenté dans les lacs Char, North, Amituk et Hazen depuis 2015, principalement en raison de quantités plus importantes de carboxylates perfluorés, qui sont des produits de dégradation atmosphérique de composés fluorés volatils. Le perfluorooctanesulfonate (SPFO), qui est interdit ou progressivement éliminé depuis le milieu des années 2000, n'a pas augmenté. En 2018-2019, nous avons publié deux documents scientifiques qui examinent les facteurs influant sur le mercure et les POP dans l'omble dulcicole. Une durée plus longue des glaces a été associée à des concentrations plus élevées de mercure dans les muscles de l'omble, tandis que les différences de concentrations de POP et de mercure entre les lacs étaient liées au carbone organique dissous.

Key messages

- Concentrations of mercury in landlocked Arctic char still show overall declining trends, in some cases since the 1990s. However, levels have recently levelled off or increased slightly.
- Concentrations of perfluorinated substances have increased in all lakes since 2015.
- The year to year variation in concentrations of mercury in landlocked Arctic char appears to be influenced by ice duration.

Messages clés

- Les concentrations de mercure dans l'omble chevalier dulcicole montrent toujours des tendances globales à la baisse, dans certains cas depuis les années 1990. Toutefois, les concentrations se sont récemment stabilisées ou ont légèrement augmenté.
- Les concentrations de substances perfluorées ont augmenté dans tous les lacs depuis 2015.
- La variation d'une année sur l'autre des concentrations de mercure dans l'omble chevalier dulcicole semble être en lien avec la durée des glaces.

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, Babaluk et al. 2004, 2008, Power, Dempson et al. 2012), and, therefore, can serve as a sentinel species for changes in atmospheric inputs of toxic and bioaccumulative contaminants, such as persistent organic pollutants (POPs) and mercury. The condition and diet of the char also provides information on the impacts of climate change on Arctic lakes. Analysis of landlocked char over the past 25 years has provided information on the range and time trends of chemical contaminants in Arctic freshwater systems (Muir, Kurt-Karakus et al. 2013; Chételat, Amyot et al. 2015) which complements studies on marine mammals and seabirds from the same regions. The analysis builds on landlocked char collections begun in Resolute Lake in 1997 (Köck, Babaluk et al. 2004, Muir, Wang et al. 2005) and also builds on previous data for Char Lake, Amituk Lake, and Lake Hazen, from pre- or early NCP studies (Muir and Lockhart 1994, Fisk, Hobbs et al. 2003) in the 1990s. This temporal trend study has also 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, Muir et al. (2010), (2010); Drevnick et al.2013; and Lescord et al.(2015, 2015). North and Small lakes were sampled initially as part of these food web studies on mercury (Gantner, Power et al. 2010) and we have continued sampling to follow temporal trends in a broader suite of lakes.

In 2018-2019 two peer-reviewed papers based on results from this study were published. Hudelson et al. (2019) used mercury data for Arctic char from 6 lakes. They found that average mercury in char was significantly inversely correlated with dissolved and particulate organic carbon concentrations in water. Neither watershed area nor vegetation cover explained differences in char mercury among lakes. The average mercury in char from Resolute, Meretta and North lakes exhibited a strong positive correlation with sea ice duration measured in Resolute Bay (by the Canadian Ice Service). Thus, longer ice duration was associated with higher mercury, possibly because of differences in prey availability with more ice cover and less evasion of mercury. Cabrerizo et al. (2018) studied the temporal trends and climate related parameters affecting the fate of polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in four lakes of the study lakes. They found that concentrations of PCBs and OCPs in char from the last two decades were positively correlated with inter-annual variations of the North Atlantic Oscillation (NAO). Higher concentrations of POPs in Arctic char were observed in 3 of the 4 lakes during positive NAO phases which are characterized by greater northward transport of air masses from the mid-latitudes.

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 and Amituk Lakes 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, Köck et al. 2016, 2017).

Activities in 2018-2019

Sample collection

Char were successfully collected in early August 2018 from Amituk, Char, Hazen, North, Small, and Resolute lakes. At Lake Hazen, Parks Canada staff at Quttinirpaaq National Park (QNP) caught fish by jigging through the ice in mid-June as they had done in the past (2011-2015). The 20 char from Lake Hazen were dissected at the QNP Hazen camp and tissue samples plus fish heads were frozen (-20 °C in the camp freezer). They were shipped first to Resolute and then by air cargo and courier to Burlington. Otoliths from the Hazen char were removed in Burlington. At Resolute, all fish were dissected within a few hours of collection and samples (skin-on fillets, liver, stomach contents) were frozen in Resolute, 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 analyzed by ICP-MS (NLET 2002). Mercury in char muscle was analyzed by the Muir research lab with a Direct Mercury Analyzer using US EPA Method 7473 (US EPA 2007). Certified biological reference materials for mercury and multi-element analysis included DOLT-2, DORM-2 and TORT-2 from National Research Council of Canada.

Char muscle (+ skin) samples collected in Amituk and Hazen lakes in 2018 were homogenized under clean room conditions and submitted for analysis of emerging and new POPs including halogenated flame retardants (HFRs) and perfluorinated alkyl substances (PFASs) as planned under the NCP Call for Proposals (2018-2019). Legacy POPs were not determined. The analytical methodology followed US EPA Method 1699 (US EPA 2007). 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 % lipid and flame retardants (HFRs). Sample extraction has been completed and results of GC-MS/MS analysis of HFRs being conducted by the NLET organics lab are pending.

PFASs including C4 to C15 perfluorocarboxylates (PFCAs) and C4 to C12 perfluoroalkane sulfonates were determined in the 2018 char muscle samples. The methodology followed that described in Lescord et al. (2015). The extraction procedure involved addition of mass-labeled internal standards (13C2 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 homogenized lake trout, was used for the HFR, and PFAS analyses.

Stable isotope analyses

Muscle from all fish analyzed for mercury and POPs were analyzed for stable isotopes of carbon (d13C) and nitrogen (d15N) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA)

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 successfully in the NCP interlab comparison for 2018-2019 (Cozzarin, DeOliveira et al. 2019) and in previous programs (Myers and Reiner (2016), (2017)).

Statistical analyses

Results for mercury and PFASs 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.

Capacity building

The project depends on the help of local people in the Hamlet of Resolute. Debbie Iqaluk was hired to work again on the project in 2018. Debbie has been a key part of the project since it started in the late 1990s. Her knowledge of the char biology, gained from years of fishing for them in the lakes around Resolute, has been essential for successful collections each year. Her work included dissecting the fish in the laboratory at Polar Shelf as well as leading the field work by advising on placement of nets and timing of the fishing activity.

Communications and engagement

Muir met with the Manager of the Hunters and Trappers Association (HTA) office and with the President of the HTA Philip Manik during his trip to Resolute in early August 2018 as well as informally with members of the HTA. A summary of results of the work in 2018 was sent to the Resolute Bay HTA on January 31, 2019 along with a Community Engagement Form. A signed Engagement Form was received in late February 2019. In August 2018, results on PFASs and HFRs) in landlocked Arctic char were presented at the 38th International Symposium on Halogenated Persistent Organic Pollutants (Krakow, Poland) and by team member Ana Cabrerizo at POLAR2018, a conference of the International Arctic Science Committee in June 2018 (Davos, Switzerland). A poster was also presented at the ArcticNet Scientific Meeting, Ottawa in early December 2018 by team member Xiaowa Wang.

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 2018 are shown graphically in Figure 1 for the 6 lakes that are consistently monitored in this study. The 2-year moving average (red line) suggests declining concentrations in char in all lakes, except Small Lake, over the period 2005 to 2013. However, as the moving average shows, the decline is not a steady one. Mercury concentrations in char have levelled off in some lakes (Resolute, Char, and Amituk, 2015-2018) whereas there has been a significant increase in another (North (2012-2018). Small Lake showed a sharp increase over the period 2007 to 2013 but a leveling off since then. In Lake Hazen mercury concentrations in the 2018 samples were very similar to those in 2017, while the overall declining trend continued.

Figure 1. Trends of mercury (geometric means ± standard errors) in landlocked char from Resolute, Amituk, Hazen, Char, Hazen, Small and North lakes (early 90s-2018). All results are length adjusted using analysis of covariance. Red lines represent 2 year moving averages.

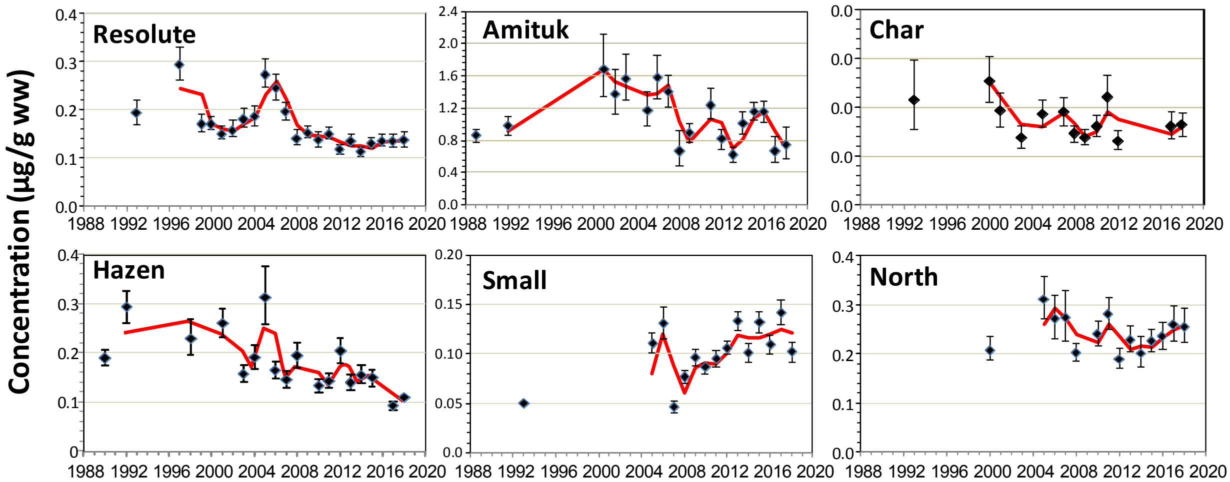


Table 1. Environmental half-lives (t1/2) and % change per year (%/y) of mercury in Arctic char from Hudelson et al and also using 2005 as a starting point for all lakes. * indicates a >95% probability of a declining trend for the time period.

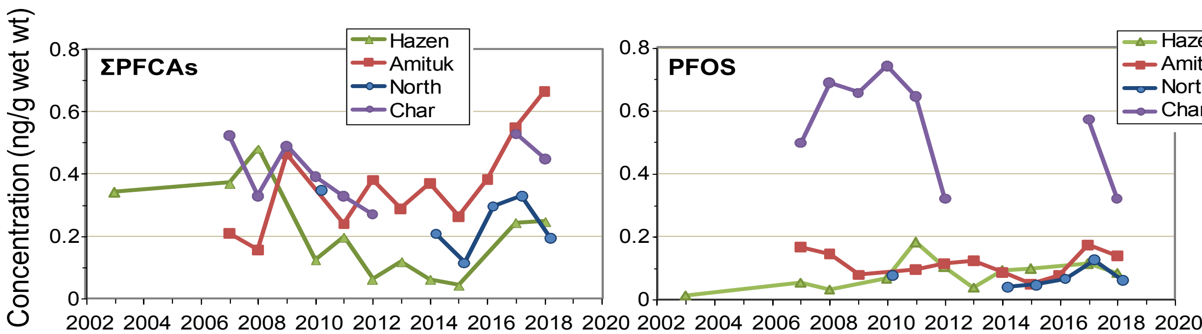
Lake	Amituk		Char		North		Resolute		Small	Hazen	
Period	2001-2018	2005-2018	1992-2018	2005-2018	2000-2018	2005-2018	1993-2018	2005-2018	2005-2018	1992-2018	2005-2018
# sampling years	16	13	13	9	14	13	22	14	14	18	12
t1/2 (yrs.)	18.4	21.6	25.7	108	307	59.7	64.5	14.9	24.1	24.7	14.9
%/y	-3.8*	-3.2*	2.7	-0.6	-0.2	-1.2	-1.1*	-4.6*	2.9	-2.8*	-4.7*

The mercury data for 5 lakes (Amituk, Char, North, Resolute and Small) were studied in detail by Hudelson et al. (2018) using length adjusted geometric mean concentrations. Using almost all sampling years, they found significant declining mercury concentrations in Amituk and Resolute Lake and no significant trends in Char, North or Small (Table 1). Since all lakes had samples starting in 2005 the trends over 2005-2018 were also examined. The percent declines were similar in Amituk and Hazen, but were more rapid in North and Resolute Lakes for the period 2005-2018.

POPs

Trends of total PFCAs with 7 to 11 carbon chains, and PFOS) in Arctic char from Hazen, Amituk, Char, and North Lake are shown in Figure 2. PFOS has declined in Lake Hazen from the mid-2000s, however, it has remained the same or increased slightly in Amituk and North Lake. Char Lake has higher concentrations of PFOS probably due to its proximity to the airport. A study of soils around the airport and within the catchments of Small and Resolute lakes showed higher concentrations of PFOS than sites that were further away (North Lake and Amituk Lake) probably due to past contamination from the airport where PFOS was used in fire-fighting foams (Cabrerizo, Muir et al. 2018).

Figure 2. Trends of total (C8-C13) perfluorocarboxylates (ΣPFCAs) and PFOS in landlocked char muscle from Hazen, Amituk, and North lakes (early 2000s – 2018). Symbols represent geometric means. Error Bars are omitted for clarity.



Discussion and conclusions

A goal of the NCP Environmental Monitoring program 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). As of 2018 datasets for ΣPCBs and mercury in char associated with Lake Hazen, Resolute Lake and Amituk Lake are able to detect changes of 5 to 10% per year at 80% power given the current between-year variation, according to the AMAP PIA (Plot and Image Analyses) statistics program (Bignert 2007). Given that percent annual declines of mercury are slow, (1.1 to 4.7% /yr.; Table 1) more than 10 years are needed to confirm this change with high confidence. Power analysis on the perfluoros data has not yet been done due to the variation in concentrations over the years (Figure 2) but it will be investigated in future years.

As this project continues, we are beginning to better understand the lake to lake and year to year variation in mercury and POPs in landlocked char. Perhaps the most important recent insight has been the strong positive correlation of mercury with sea ice duration measured in Resolute Bay (by the Canadian Ice Service). Unfortunately, ice duration was not measured in any of the lakes, however, as Resolute Bay is only 1 km from Resolute Lake, semi-enclosed and similar in surface area, it is a reasonable proxy for the lake. Further work is needed to obtain ice duration information for the study lakes to follow up this observation. There has been a lot of study of ice out times in Canadian Arctic lakes recently using satellite imagery (Sharma, Blagrave et al. 2019) and mean ice free area is available for Lake Hazen (Lehnherr, St. Louis et al. 2018). We may be able to involve the community in an ice duration study. The influence of Resolute airport, which is within the catchment of Resolute Lake and near Char Lake, is also better understood now. The major contaminant associated with the airport is PFOS which was previously shown to be 50-fold higher in Resolute char compared to Small or North Lake (Lescord, Kidd et al. 2015) and remains elevated (Muir et al. unpublished data).With continued monitoring, including studies encompassing water and soil sampling, we hope to be able to better explain these trends of mercury and POPs in the Arctic char.

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References

Bignert, A. (2007). PIA statistical application developed for use by the Arctic Monitoring and Assessment Programme. (available from www.amap.no). Oslo, No, Arctic Monitoring and Assessment Programme: 13

Cabrerizo, A., D. C. G. Muir, A. De Silva, X. Wang, S. Lamoureux and M. Lafreniere (2018). "Legacy and emerging persistent organic pollutants (POPs) in terrestrial compartments in the High Arctic: sorption and secondary sources." Environ. Sci. Technol. 52: 14187–14197.

Cabrerizo, A., D. C. G. Muir, G. Köck, D. Iqaluk and X. Wang (2018). "Climatic Influence on Temporal Trends of Polychlorinated Biphenyls and Organochlorine Pesticides in Landlocked Char from Lakes in the Canadian High Arctic." Environmental Science & Technology 52: 10380–10390.

Chételat, J., M. Amyot, P. Arp, J. M. Blais, D. Depew, C. A. Emmerton, M. Evans, M. Gamberg, N. Gantner, C. Girard, J. Graydon, J. Kirk, D. Lean, I. Lehnherr, D. Muir, M. Nasr, A. J. Poulain, M. Power, P. Roach, G. Stern, H. Swanson and S. van der Velden (2015). "Mercury in freshwater ecosystems of the Canadian Arctic: Recent advances on its cycling and fate." Science of the Total Environment 509-510: 41-66.

Cozzarin, F., F. DeOliveira, H. Malle and R. Reeves (2019). Report for Crown-Indigenous Relations and Northern Affairs Canada NCP/AMAP 12 QA/QC Study 2018-2019. IQM-2019-04 (revised 2019-07-11). Burlington, ON, Environment and Climate Change Canada: 514 pp.

Fisk, A. T., K. E. Hobbs and D. C. G. Muir (2003). Contaminant Levels and Trends in the Biological Environment. Canadian Arctic Contaminants Assessment Report II. Ottawa, Indian and Northern Affairs Canada. : 202 pp.

Gantner, N., D. C. Muir, M. Power, D. Iqaluk, J. D. Reist, J. A. Babaluk, M. Meili, H. Borg, J. Hammar, W. Michaud, B. Dempson and K. R. Solomon (2010). "Mercury Concentrations in Landlocked Arctic char (Salvelinus alpinus) in the Canadian High Arctic: Part II. Influence of lake biotic and abiotic characteristics on geographic trends in 27 populations." Environ. Toxicol. Chem. 29(3): 633-643.

Gantner, N., M. Power, G. Lawson, D. Iqaluk, M. Meili, G. Köck, H. Borg, M. Sundbom, K. R. Solomon and D. C. G. Muir (2010). "Mercury Concentrations in Landlocked Arctic char (Salvelinus alpinus) in the Canadian High Arctic: Part I - insights from trophic relationships in 18 lakes." Environ. Toxicol. Chem. 29(3): 621-632.

Hudelson, K. E., D. C. G. Muir, P. E. Drevnick, G. Köck, D. Iqaluk, X. Wang, J. L. Kirk, B. D. Barst, A. Grgicak-Mannion, R. Shearon and A. T. Fisk (2019). "Temporal trends, lake-to-lake variation, and climate effects on Arctic char (Salvelinus alpinus) mercury concentrations from six High Arctic lakes in Nunavut, Canada." Science of The Total Environment 678: 801-812.

INAC (2005). Northern Contaminants Program, Call for Proposals 2005-2006. Ottawa ON, Indian and Northern Affairs Canada 74.

Köck, G., J. Babaluk, B. Berger, D. Bright, C. Doblander, M. Flannigan, Y. Kalra, L. Loseto, H. Miesbauer, D. Muir, H. Niederstätter, J. Reist and K. Telmer (2004). Fish from sensitive ecosystems as bioindicators of global climate change - "High-Arctic 1997-2003". Innsbruck, Austria, Veröffentlichungen der Universität Innsbruck,.

Lehnherr, I., V. L. St. Louis, M. Sharp, A. Gardner, J. P. Smol, S. L. Schiff, D. C. G. Muir, C. A. Mortimer, N. Michelutti, C. Tarnocai, K. A. St. Pierre, C. A. Emmerton, J. Wiklund, G. Köck, S. Lamoureux and C. H. Talbot. (2018). "The world's largest High Arctic lake responds rapidly to climate warming." Nature Communications 9: 1290. DOI: 1210.1038/s41467-41018-03685-z.

Lescord, G. L., K. A. Kidd, A. De Silva, C. Spencer, M. Williamson, X. Wang and D. C. G. Muir (2015). "Perfluorinated and Polyfluorinated Compounds in Lake Food Webs in the Canadian High Arctic." Environ. Sci. Technol. 49: 2694–2702.

Lescord, G. L., K. A. Kidd, J. L. Kirk, N. J. O'Driscoll, X. Wang and D. C. G. Muir (2015). "Factors affecting biotic mercury concentrations and biomagnification through lake food webs in the Canadian high Arctic." Science of the Total Environment 509-510: 195-205.

Muir, D. and L. Lockhart (1994). Contaminant trends in freshwater and marine fish. Synopsis of research conducted under the 1993/1994 Northern Contaminants Program. Environmental Studies Report, No. 72. Ottawa, Indian and Northern Affairs Canada: 264-271.

Muir, D., X. Wang, D. Bright, L. Lockhart and G. Köck (2005). "Spatial and Temporal Trends of Mercury and other Metals in Landlocked Char from Lakes in the Canadian Arctic Archipelago." Sci. Total Environ. 351-352: 464-478.

Muir, D. C. G., G. Köck, J. Kirk and X. Wang (2016). Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic. Synopsis of research conducted under the 2015-2016, Northern Contaminants Program. Ottawa, ON, Aboriginal Affairs and Northern Development Canada: pp. 261-270.

Muir, D. C. G., G. Köck, J. Kirk and X. Wang (2017). Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked char in the High Arctic. Synopsis of research conducted under the 2016-2017, Northern Contaminants Program. Ottawa, ON, Aboriginal Affairs and Northern Development Canada: in press.

Muir, D. C. G., P. Kurt-Karakus, J. Stow, J. Blais, B. Braune, E. Choy, M. Evans, B. Kelly, N. Larter, R. Letcher, M. McKinney, A. Morris, G. Stern and G. Tomy (2013). Occurrence and Trends in the Biological Environment. Chapter 4. Persistent Organic Pollutants in Canada' s North. D. C. G. Muir, P. Kurt-Karakas and J. E. Stow. Ottawa ON Aboriginal Affairs and Northern Development Canada: pp 273-422.

Myers, A. and E. Reiner (2016). Northern Contaminants Program and Arctic Monitoring and Assessment Arctic Monitoring Interlaboratory Study (NCP/AMAP – Phase 10). Toronto ON, Ontario Ministry of Environment & Climate Change: 65 pp + Appendix.

Myers, A. and E. Reiner (2017). Northern Contaminants Program and Arctic Monitoring and Assessment Programme Interlaboratory Study (NCP/AMAP – Phase 11). Toronto ON, Ontario Ministry of Environment & Climate Change: 74 pp + Appendix.

NLET (2002). Standard Operating Procedure for the Analysis of Total and Dissolved Trace Metals in Water by In-bottle Digestion and Inductively Coupled Plasma-Mass Spectrometry and Inductively Coupled Plasma-Optical Emission Spectrometry. SOP 02-2002. Burlington ON, National Laboratory for Environmental Testing, NWRI.

Power, M., B. J. Dempson, W. Doidge, W. Michaud, L. Chavarie, J. D. Reist, F. François Martin and A. E. Lewis (2012). Chapter 7. Arctic charr in a changing climate: predicting possible impacts of climate change on a valued northern species. Nunavik and Nunatsiavut: From Science to Policy. An integrated Regional Impact Study of Climate Change and Modernization. M. Allard and M. Lemay, ArcticNet Inc., Quebec City, Canada, 303p.

Power, M., J. D. Reist and J. B. Dempson (2008). Fish in high-latitude Arctic lakes. Polar Lakes and Rivers Limnology of Arctic and Antarctic Aquatic Ecosystems. W. F. Vincent and J. Laybourn-Parry. Oxford, UK, Oxford University Press: 249-268.

Sharma, S., K. Blagrave, J. J. Magnuson, C. M. O'Reilly, S. Oliver, R. D. Batt, M. R. Magee, D. Straile, G. A. Weyhenmeyer, L. Winslow and R. I. Woolway (2019). "Widespread loss of lake ice around the Northern Hemisphere in a warming world." Nature Climate Change 9(3): 227-231.

US EPA (2007). Method 1699: Pesticides in Water, Soil, Sediment, Biosolids, and Tissue by HRGC/HRMS. EPA-821-R-08-001. Washington DC, US Environmental Protection Agency, Office of Science and Technology: 96.

US EPA (2007). Method 7473. Mercury in Solids and Solutions By Thermal Decomposition, Amalgamation, and Atomic Absorption Spectrophotometry. Washington, DC, US Environmental Protection Agency.

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

Tendances spatiales et à long terme des contaminants organiques persistants et des métaux chez le touladi et la lotte des Territoires du Nord-Ouest

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Project locations/Équipe de projet

- Domestic fishery at Lutsel K'e (East Arm Region of Great Slave Lake);
- Commercial fishery operating out of Hay River (West Basin Region of Great Slave Lake); and
- Domestic fishery at Fort Resolution (West Basin Region of Great Slave Lake), located on the Slave River delta.

Abstract

Our study is measuring trends in mercury, other metals, and persistent organic contaminants (POCs) in lake trout and burbot from three locations in two regions of Great Slave Lake. In fall 2018, 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 also were obtained from the domestic fishery at Fort Resolution

Résumé

Notre étude mesure les tendances des concentrations de mercure, d'autres métaux et de contaminants organiques persistants (COP) dans le touladi et la lotte à trois endroits dans deux régions du Grand lac des Esclaves. À l'automne 2018, les touladis ont été récoltés par des pêcheurs locaux pratiquant la pêche domestique à Lutsel K'e (bras est du lac) et par des pêcheurs pratiquant la pêche

(West Basin). Moreover, with other funding, we continued to investigate mercury concentrations in burbot at Lutsel K'e and northern pike at Fort Resolution. Average mercury concentrations continue to remain below 0.5 µg/g. Mercury concentrations in fish are continuing to show a gradual trend of increase although the causal factors are not fully understood. In March 2019, we met with several community organizations to discuss our study results, share posters of our findings and to discuss potentially new studies and community partnerships. We continued to work with Fort Resolution on their water intake and Resolution Bay studies.

commerciale dans la rivière Hay (bassin ouest). Les spécimens de lotte ont également été obtenus de pêcheurs locaux à Fort Resolution (bassin Ouest). En outre, grâce à d'autres sources de financement, nous avons continué à étudier les concentrations de mercure dans la lotte à Lutsel K'e et dans le grand brochet à Fort Resolution. Les concentrations moyennes de mercure restent inférieures à 0,5 µg/g. Les concentrations de mercure dans le poisson continuent d'augmenter progressivement, bien que les facteurs de causalité ne soient pas encore totalement connus. En mars 2019, nous avons rencontré plusieurs organismes communautaires pour parler de nos résultats d'études et de la conception d'affiches présentant nos conclusions. Nous avons aussi discuté d'éventuels projets, soit des nouvelles études et des partenariats communautaires. Nous poursuivons notre collaboration avec les habitants de Fort Resolution sur leur prise d'eau et sur les études à Resolution Bay.

Key messages

- Mercury concentrations remain relatively low (average <0.5 µg/g) in lake trout, burbot, and northern pike from Great Slave Lake.
- Mercury continues to show a trend of increase in lake trout and burbot; a trend of increase has also been detected in northern pike.
- Several factors affect mercury concentrations in fish including their length, age, weight, and feeding and the most important factor varies by species and location. These differences probably are related to where the fish is feeding in the lake, its genetic features (e.g. fast or slow-growing fish), fishing pressures, and the features of its environment.
- Warming trends continue, although recent years have not been exceptionally warm.
- Persistent organic pollutant concentrations are declining, particularly in West Basin fish, based on our last collections made in 2017. Fish will be analyzed for persistent organic pollutants in 2019.

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.
- Le mercure continue de montrer une tendance à la hausse chez le touladi et la lotte; une tendance à la hausse a également été observée chez le grand brochet.
- Plusieurs facteurs influent sur les concentrations de mercure dans les poissons, notamment leur longueur, leur âge, leur poids et leur alimentation, le facteur le plus important variant selon les espèces et les lieux. Ces différences sont probablement dues à plusieurs facteurs : à l'endroit où le poisson se nourrit dans le lac, ses caractéristiques génétiques (p. ex., poissons à croissance rapide ou lente), les pressions exercées par la pêche et les caractéristiques de son environnement.
- Les tendances au réchauffement se poursuivent, bien que les dernières années n'aient pas été exceptionnellement chaudes.

- Les concentrations de polluants organiques persistants sont à la baisse, en particulier chez les poissons du bassin de l'Ouest, d'après nos derniers prélèvements effectués en 2017. Les poissons seront analysés pour les polluants organiques persistants en 2019.

Objectives

This project aims to:

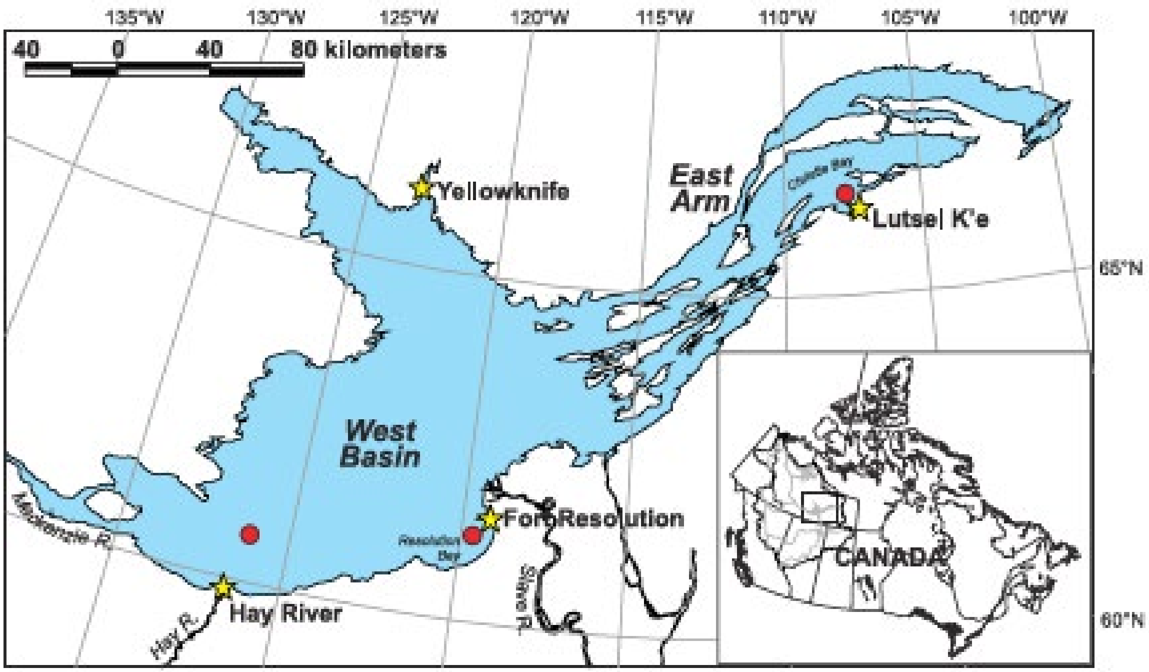
- determine mercury, metals and persistent organic contaminants (POCs) concentrations in lake trout harvested from two locations (West Basin near Hay River, East Arm at Lutsel K'e) and burbot harvested from one location (West Basin at Fort Resolution) in 2018 to further extend our long-term POCs and 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 POCs and contribute information to AMAP expert work groups for trend monitoring of POCs and mercury.
- continue to work with Fort Resolution in their water quality monitoring of Resolution Bay water. Continue to provide support, where requested, to other community monitoring projects.
- work with other researchers including Xinhua Zhu in his fish community monitoring in the Hay River and Fort Resolution areas.
- Communicate results to communities and the commercial fisheries in a timely manner.

Introduction

This study is part of NCP's Environmental Trend Monitoring Program which is evaluating the success of the Stockholm Convention on Persistent Organic Pollutants and the Minamata Convention on mercury. Legacy POCs concentrations are slowly declining in the environment, with trends differing with the species and location investigated (Rigét et al. 2010, Muir et al. 2013). Mercury concentrations appear to be increasing in biota 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) although trends of decrease have been observed for some landlocked and sea-run char populations (Evans et al. 2015, Hudelson et al. 2019). Mercury trend assessments are of particular concern given the large number of consumption advisories that have been issued in recent years for lakes along the Mackenzie River for predatory fish species. Research on new and emerging POCs is also critical including on perfluorocarboxylic acids (PFCA*s*), polybrominated diphenyl ethers (PBDEs) and novel brominated flame retardants (BFRs).

Under NCP, we have been investigating POCs in Great Slave Lake fish since the early 1990s; mercury studies began in 1998 but archived samples have been retroactively analyzed for mercury. Our monitoring is conducted in the low-productivity waters of the East Arm (Figure 1) where direct atmospheric inputs are presumed to be the primary source of contaminants entering the lake, and the more productive waters of the West Basin which is

Figure 1. Map of Great Slave Lake, major regions, and communities. Red dots show sampling locations.



under profound influence from the Slave River. The West Basin also is commercially fished. Lake trout are being monitored because of their importance in commercial (operating out of Hay River) and domestic fisheries of Great Slave Lake, including Lutsel K'e. Lake trout are pelagic, cold-water stenotherms (Scott and Crossman 1998). East Arm lake trout are older and slower growing than West Basin fish but have slightly lower mercury concentrations (Evans and Muir 2013). Mercury concentrations are below the 0.5 µg/g commercial sale of fish guideline and the concentration commonly used to set consumption advisory guidelines. This is in contrast to many small to medium size lakes in the Great Slave Lake area and along the Mackenzie River where mercury concentrations are high and consumption advice has been issued (Evans et al. 2005).

Burbot are being monitored because their lipid-rich liver is a highly prized food item and consumption advisories based on their toxaphene concentrations were issued or considered including the East Arm of Great Slave Lake. Burbot are sedentary predators and may be most responsive to conditions occurring at the sediment-water interface while lake trout may respond more to conditions occurring at the thermocline (Rawson 1951, Scott and Crossman 1998). Burbot are being monitored at Resolution Bay by the community of Fort Resolution, Slave River delta. 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). We also have been monitoring northern pike for mercury trends at Fort Resolution under ECCC programs. 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 (Evans et al. 2005, Lockhart et al. 2005, Chételat and Braune 2012). Mercury was monitored briefly (1998-2002) in northern pike at Lutsel K'e. In 2018, our fish collections focused on mercury analyses: persistent organic contaminants are monitored every second year (odd years).

Activities in 2018-2019

Community engagement

Community engagement has focused on discussions around the overall purpose of the study, results and their presentation in a form that is understandable and accessible to community members. At Fort Resolution, this engagement has included Rosy Bjornson (DKFN Resource Management Coordinator), Diane Giroux (AAROM coordinator) and Shawn Mackay and Arthur Beck (Fort Resolution Metis Nation). At Lutsel K'e, our discussions have been with Lauren King and Ray Griffith with the Lutsel K'e Wildlife and Environmental Committee. At Hay River, communications have been with Peter Redvers and Patrick Riley with the Hay River/K'atl'odeeche Dene First Nation (KDFN), Becky Cayen with the West Point First Nation, Chris Heron with the NWT Metis Nation) and George and Mike Low (Deh Cho AAROM coordinator). Discussions also have been held with Tim Heron (Fort Smith Metis) with a focus on results communications and Machel Thomas with the Yellowknife's Dene Nation. A series of discussions were held with community members primarily at Hay River and Fort Resolution regarding a Cumulative Impact Monitoring Program proposal submission based on a remote sensing study of Great Slave Lake (led by Caren Binding with ECCC) and logistic support in the ground-truthing aspects of this study were it to be funded. These discussions occurred as part of our discussion of the 2018 mercury results. We offered to analyze fish for mercury based on community interest and the nature of their study, as we have done over the years including lake trout at Stark Lake (issue with skinny lake trout), walleye at Trout Lake (issue with skinny walleye), and pike, walleye and lake whitefish as part of Buffalo Lake studies related to fish stock and inconnu. We agreed to analyze fish from Buffalo Lake (Tourangeau River mouth) for mercury.

Capacity building and training

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 which now include water quality monitoring at the domestic water intake and Resolution Bay, and the angler survey at the little Buffalo River. We also worked with Tyson Russell (Fisheries and Oceans) and Patrick Riley with the K'atl'odeeche Dene First Nation on the analysis of fish harvested from the Tourangeau River, a tributary of Buffalo Lake.

Communications and outreach

Contributions were made to a number of scientific publications including Balmer et al. (2019) which focuses on current use pesticides, Muir et al. (2019) on poly- and perfluoroalkyl substances and Rigét et al. (2019) on temporal trends in organic pollutants. Contributions also were made to the Muir-led chapter on "Trends and biological effects of environmental contaminants in Lake Char" for the book "Lake Char *Salvelinus namaycush*: Biology, Ecology, Distribution, and Management". In August 2018, Marlene participated in and contributed to Health Canada mercury workshop on mercury in country foods. In December, she and other collaborators participated in the AMAP mercury workshop which is working towards a 2021 state of the environment report. A poster on major findings from the Great Slave studies was presented at the November 4-8, 2018 SETAC conference in Sacramento, California.

Community visits were held in late February and March at Lutsel K'e, Fort Resolution, and Hay River to discuss recent results and to provide copies of posters displaying the 2018 mercury results with comparisons to 2017 results. At Fort Resolution, Marlene met with Rosy Bjornson, Diane Giroux, and Shawn Mackay and committee members. At Lutsel K'e, she met with Ray Griffith and members of the Wildlife and Environment Committee. At Hay River, she met with Patrick Riley, Environmental

Program Manager with the K'atl'odeeche First Nation, Becky Cayen with the West Point First Nation and community members and Chris Heron and staff at the NWT Metis Nation. In Yellowknife, she met with Tawanis Testart and Ron Breadmore with the Contaminants and Remediation Division of the Crown-Indigenous Relations and Northern Affairs Canada to discuss Stark Lake and with Machel Thomas with the Yellowknife's Dene Nation to discuss NCP studies and potential Cumulative Impact Monitoring Program studies. She also has been in communication with community members about possible remote sensing studies on Great Slave Lake which would investigate temporal and spatial variability in dissolved organic carbon, total suspended solids, and chlorophyll in Great Slave Lake regarding historic changes and how those changes were influenced by the changing climate.

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 we are contacted about issues regarding 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).

Fish collections

In autumn 2018, lake trout were collected by Ernest Boucher from Lutsel K'e and by Stacy Linington with the commercial fishery operating out of Hay River. In addition, burbot were collected by Gab Lafferty from Fort Resolution. These fish were shipped whole to Saskatoon as part of the current NCP biomonitoring program. These collections contribute to our data base that began with collections in 1993. As in past years, we continued burbot collections at Lutsel K'e and northern pike collection at Fort Resolution for mercury trend assessments. Length, weight, and sex were determined for all fish from each location. Liver and gonad weights were also determined and the presence of parasites and/or disease (cysts, etc.) noted. Aging structures (otoliths) were removed from each fish and submitted for analyses. A fillet sample, the liver, and stomach were retained from each of the fish. All fish were aged and carbon and nitrogen stable isotope analyses were conducted. Ten of the lake trout (Lutsel K'e, Hay River) and burbot (Fort Resolution) were selected for metal analyses; all fish were analyzed for mercury. A subset of 5 fish of each species and location were selected for PBDE and PFCA analyses. Mercury and metal analyses have been completed.

Results and discussion

Overall features of 2018 fish collections

As in past years, average mercury concentrations in lake trout, burbot and northern pike fillet remained below the 0.5 μg/g guideline for the commercial sale of fish. In addition, the basic features of the fish populations remained the same as in previous years (Evans et al. 2013). In 2018, lake trout from the commercial fishery were, on average, larger but younger than lake trout from the domestic fishery at Lutsel K'e. This is indicative of a faster growth rate for West Basin than East Arm fish most likely due to the higher productivity of West Basin than East Arm waters and the commercial fishery itself. Commercial fisheries increase fish mortality and selectively capture larger fish which tend to be older. This reduces the average age of the fish population, reduces competition among fish, and results in increased fish growth rates. Mercury concentrations were slightly greater in fish from the commercial fishery than at Lutsel K'e. In contrast, burbot from Fort Resolution were larger and older than Lutsel K'e burbot. Lutsel K'e burbot have higher carbon isotope ratios than West Basin burbot, suggesting a greater reliance on nearshore carbon sources. Northern pike had the highest average mercury

Table 1. Biological features of the lake trout, burbot and northern pike collected in 2018 from the West Basin (Commercial fishery for lake trout, Fort Resolution for northern pike and burbot) and the East Arm (Lutsel K'e). Data are shown as the mean ± 1 standard deviation.

Location/species.	N	Fork Length (mm)	Condition Factor	Age (yr.)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Hg (µg/g)
West Basin							
Lake trout	20	664 ± 88	1.15 ± 0.11	11.7 ± 3.0	-29.7 ± 0.8	12.4 ± 0.4	0.23 ± 0.08
Burbot	24	692 ± 52	0.67 ± 0.07	12.8 ± 2.4	-28.9 ± 0.5	12.3 ± 0.3	0.18 ± 0.06
Northern pike	20	687 ± 53	0.78 ± 0.07	8.6 ± 2.3	-28.4 ± 0.4	11.9 ± 0.3	0.28 ± 0.10
East Arm							
Lake trout	22	645 ± 71	1.14 ± 0.26	20.2 ± 5.5	-28.8 ± 1.9	11.8 ± 0.6	0.22 ± 0.11
Burbot	15	562 ± 62	0.77 ± 0.08	10.2 ± 3.1	-23.0 ± 1.6	11.4 ± 0.5	0.14 ± 0.05

concentration and were the youngest fish on average. Northern pike and burbot have lower condition factors than lake trout because the former two species are narrow-bodied. Since condition factor is a measure of fish weight divided by fish length, narrow fish will have lower condition factors than wide-bodied fish.

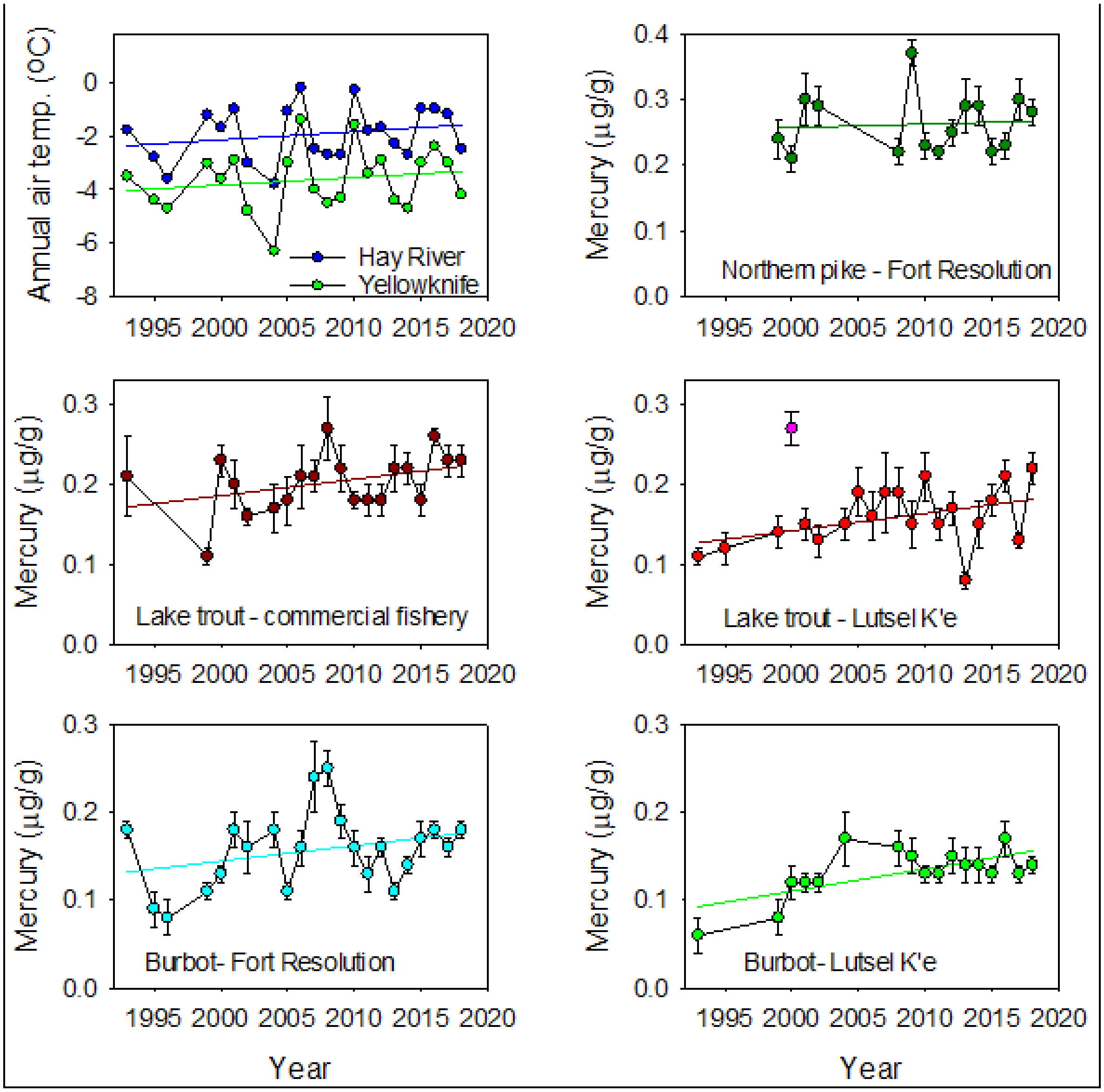
Temporal variability in annual mean air temperature and mercury concentrations in fish

Previous studies have reported increasing mercury concentrations in lake trout and burbot from Great Slave Lake and burbot from the Mackenzie River at Fort Good Hope, while declining trends have been observed in landlocked char in some lakes on Cornwallis Island and some sea-run char populations (Carrie et al. 2010, Evans et al. 2013, Evans et al. 2015, Hudelson et al. 2019). These increases have occurred during a period of long-term warming although the role of warming trends in affecting mercury trends is complex and varies with the species and ecosystem. Warming may result in an increase in lake productivity which through various mechanisms could result in greater mercury methylation rates and increased mercury concentrations in fish. Alternately, improved growth rates of fish with a greater food supply may counteract this (through growth dilution of mercury) resulting in a decrease in mercury concentrations as may be occurring with char. Higher mercury concentrations in fish appear to be associated with cold rather than warm years and low rather than high condition factor. Similarly, Hudelson et al. (2019) observed that higher mercury concentrations in landlocked char were associated with years with longer sea ice cover but not annual air temperature.

Warming trends for the Great Slave Lake area were examined for the 1993-2018 period using mean annual air temperatures at Hay River, on the south shore of the lake and Yellowknife on the north shore (Figure 2). On average, air temperatures are 1.8°C cooler at Yellowknife than Hay River. Highest annual air temperatures occurred in 2006 and 2010 with cooling temperatures over 2011-2014 followed by two warmer years with 2018 again cold. While there was a weak trend of temperature increase (0.03°C/yr.) this trend was not significant ($p>0.05$). Extending the trend analyses back a few years would result in a more significant trend of warming.

Lake trout from the commercial fishery exhibited a significant although weak trend of mercury increase over 1993-1998 (Figure 2). The analyses were run with various influencing variables. There was a statistically significant trend of mercury increase in lake trout with higher mercury concentrations associated with larger fish and cooler air temperatures at Hay River (Table 1); fish length was not determined in 1993.

Figure 2. Mean (±standard error) in mercury concentrations in lake trout, burbot, and northern pike as determined in our studies. Also shown are mean annual air temperatures ad Hay River and Yellowknife.



There also was a significant but weak trend of mercury increase in lake trout over 1993-2018 (Figure 2). Fish analyzed in 2000 had particularly high mercury concentrations that is without explanation and is treated as an outlier. Mercury concentrations in Lutsel K'e lake trout are most strongly correlated with fish age and length. When fish length and age were included in our regression analyses, there was a significant trend of mercury increase in lake trout with higher concentrations associated with larger and older fish (Table 1); temperature was not a statistically significant term. Lake trout at Lutsel K'e tend to be old, with a mean age of 17 years, but a mean fork length of 600 mm. These fish have variable growth rates with some as young as 11 years but others as old as 28 years; mercury concentrations range from 0.07-0.21 µg/g. It is highly probable that genetic diversity of East Arm lake trout is high and there are forms that vary in growth and feeding characteristics as in Great Bear Lake (Chavarie et al. 2016a, Chavarie et al. 2016b, Chavarie et al. 2016c) which may affect their mercury concentrations.

Table 2. 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. YR =year, TL = total length, FL = fork length, AG = age, HRAT = mean annual air temperature at Hay River, n = the number of fish in the analyses, R2 = the amount of variation explained by the model, and p = the significance level. See text for additional explanation.

Species/Location	Period	Equation	n	F-ratio	R2	p
Lake trout						
West Basin	1995-2018	Log Hg = -7.497 + 0.003*YR + 0.001*FL – 0.022*HRAT	207	51.032	0.43	0.000
East Arm	1993-2018	Log Hg = -6.952 + 0.003*YR + 0.001*FL + 0.017*AG	192	60.05	0.49	0.000
Burbot						
West Basin	1995-2018	Log Hg = -9.264 + 0.004*YR + 0.001*TL	243	35.85	0.23	0.000
East Arm	1999-2018	Log Hg = -12.237 + 0.006*YR + 0.023*AG – 0.025*HRAT	200	14.05	0.18	0.000.
Northern pike						
West Basin	1996-2018	Log Hg = -8.652 +0.004*YR + 0.033*AG - 0.021 HRAT	281	50.37	0.35	0.000

Burbot showed a trend of mercury increase at Fort Resolution and Lutsel K'e over 1993-2018 (Figure 2). When fish length was included in the model (fish length was not measured in 1993) there was a significant trend of mercury increase for Fort Resolution burbot over 1995-2018 (Table 2); air temperature was not a significant influencing factor. For Lutsel K'e burbot, there was a significant trend of mercury increase when age was included in the model. Average air temperature at Hay River was a significant explanatory variable with higher mercury concentrations associated with cooler years (Table 2).

Mercury concentrations in northern pike exhibited no trend over 1996-2018 when only year was considered as an influencing variable. Higher mercury concentrations were more strongly correlated with fish age ($r = 0.56$) than fish length ($r = 0.41$). There was a significant trend of mercury increase when pike age was included in the model, with annual air temperature at Hay River also a significant explanatory term, again a negative term.

Other studies

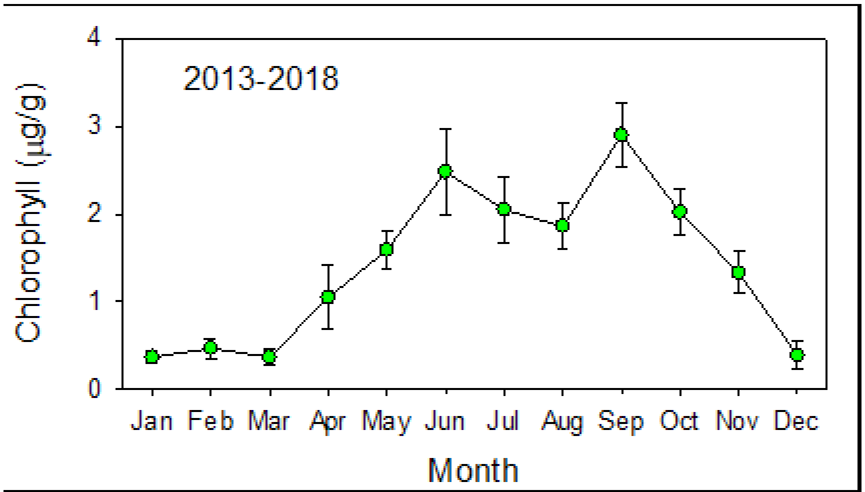
Sediment cores

Analyses and interpretation continued on the two sediment cores collected from Great Slave Lake in March 2014, one offshore of Hay River and the other Fort Resolution. These two cores differ in some of their features including the timing of when diatoms began to appear in the record. While warming trends are believed to be the primary factor affecting time trends in diatoms, other factors, including Slave River flow, may also have some importance and are being investigated. Year-end funding was received for the analyses of one of these cores for persistent organic contaminants.

Water intake study

The water intake monitoring at Fort Resolution continued with Kathleen Fordy continuing to record the routine parameters measured by the plant operator and to filter water for chlorophyll analyses through much of 2018. Average monthly chlorophyll concentrations over 2013-2018 are generally low (Figure 3) throughout most of the year, generally <2 µg/l, and in agreement with past studies (Fee et al. 1985, Evans and Muir 2016). Concentrations gradually rise through spring with the increase in day length and warming temperatures and ice loss to peak in June. This is followed by a decline in July and August which is probably related to increased turbidity with Slave River flow, sediment resuspension in the shallow waters of the bay, and zooplankton grazing. Concentrations peak in September and then decline through the fall and early winter.

Figure 3. Average monthly (± 1 standard error) chlorophyll concentrations in the water intake (untreated) for the drinking water supply at Fort Resolution over 2013-2018.



Conclusions

Contaminant concentrations remain low in the Great Slave Lake fish investigated in this study. Mercury concentrations are increasing in lake trout, burbot and northern pike, possibly in response to warming trends and enhanced lake productivity. However, because our regression analyses show that air temperature is a negative rather than positive term in our regression models, the role of climate variability in affecting mercury concentrations in fish remains unclear. While we have focused our consideration of fish length in exploring mercury trends in fish, other variables such as fish age and weight are proving to provide more insight into how environmental features, including climate change, are influencing mercury in fish.

Expected project completion date

Ongoing

References

Balmer, J. E., A. D. Morris, H. Hung, L. Jantunen, K. Vorkamp, F. Rigét, M. Evans, M. Houde, and D. C. G. Muir. 2019. Levels and trends of current-use pesticides (CUPs) in the arctic: An updated review, 2010–2018. Emerging Contaminants 5:70-88.

Braune, B., J. Chételat, M. Amyot, T. Brown, M. Clayden, M. Evans, A. Fisk, A. Gaden, C. Girard, A. Hare, J. Kirk, I. Lehnherr, R. Letcher, L. Loseto, R. Macdonald, E. Mann, B. McMeans, D. Muir, N. O'Driscoll, A. Poulain, K. Reimer, and G. Stern. 2015. Mercury in the marine environment of the Canadian Arctic: Review of recent findings. Science of the Total Environment 509–510:67-90.

Carrie, J., F. Wang, H. Sanei, R. W. Macdonald, P. M. Outridge, and G. A. Stern. 2010. Increasing Contaminant Burdens in an Arctic Fish, Burbot (*Lota lota*), in a Warming Climate. Environmental Science & Technology 44:316-322.

Chavarie, L., W. J. Harford, K. L. Howland, J. Fitzsimons, A. M. Muir, C. C. Krueger, and W. M. Tonn. 2016a. Multiple generalist morphs of Lake Trout: Avoiding constraints on the evolution of intraspecific divergence? Ecology and evolution 6:7727-7741.

Chavarie, L., K. Howland, C. Gallagher, and W. Tonn. 2016b. Fatty acid signatures and stomach contents of four sympatric Lake Trout: Assessment of trophic patterns among morphotypes in Great Bear Lake. Ecology of Freshwater Fish 25:109-124.

Chavarie, L., K. Howland, P. Venturelli, B. C. Kissinger, R. Tallman, and W. Tonn. 2016c. Life-history variation among four shallow-water morphotypes of lake trout from Great Bear Lake, Canada. Journal of Great Lakes Research 42:193-203.

Chételat, J., and B. Braune. 2012. Mercury in Canada's North. III, Ottawa.

Cott, P. A., A. L. Amos, M. M. Guzzo, L. Chavarie, C. P. Goater, D. C. G. Muir, and M. S. Evans. 2018. Can traditional methods of selecting food accurately assess fish health? Arctic Science 4:205-222.

Evans, M., and S. Landels. 2015. Radionuclide and metal analysis of fish muscle from Stark Lake, NWT.

Evans, M., D. Muir, R. B. Brua, J. Keating, and X. Wang. 2013. Mercury trends in predatory fish in Great Slave Lake: the influence of temperature and other climate drivers. Environmental Science & Technology 47:12793-12801.

Evans, M. S., W. L. Lockhart, L. Doetzel, G. Low, D. Muir, K. Kidd, G. Stephens, and J. Delaronde. 2005. Elevated mercury concentrations in fish in lakes in the Mackenzie River Basin: The role of physical, chemical, and biological factors. Science of the Total Environment 351-352:479-500.

Evans, M. S., and D. Muir. 2013. Spatial and long-term trends in persistent organic contaminants and metals in lake trout and burbot from the Northwest Territories. Aboriginal Affairs and Northern Development Canada, Ottawa,ON.

Evans, M. S., and D. C. G. Muir. 2016. Persistent organic contaminants in sediments and biota of Great Slave Lake, Canada: Slave River and long-range atmospheric source influences. Journal of Great Lakes Research:233-247.

Evans, M. S., D. C. G. Muir, J. Keating, and X. Wang. 2015. Anadromous char as an alternate food choice to marine animals: A synthesis of Hg concentrations, population features and other influencing factors. Science of the Total Environment 509-510:175-194.

Fee, E. J., M. P. Stainton, and H. J. Kling. 1985. Primary production and related limnological data for some lakes of the Yellowknife, NWT area. Department of Fisheries.

Hudelson, K. E., D. C. G. Muir, P. E. Drevnick, G. Köck, D. Iqaluk, X. Wang, J. L. Kirk, B. D. Barst, A. Grgicak-Mannion, R. Shearon, and A. T. Fisk. 2019. Temporal trends, lake-to-lake variation, and climate effects on Arctic char (Salvelinus alpinus) mercury concentrations from six High Arctic lakes in Nunavut, Canada. Science of the Total Environment 678:801-812.

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

Muir, D., R. Bossi, P. Carlsson, M. Evans, A. De Silva, C. Halsall, C. Rauert, D. Herzke, H. Hung, R. Letcher, F. Rigét, and A. Roos. 2019. Levels and trends of poly- and perfluoroalkyl substances in the Arctic environment – An update. Emerging Contaminants 5:240-271.

Muir, D. C. G., P. Kurt-Karakas, and J. Stow. 2013. Canadian Arctic Contaminants Assessment Report on Persistent Organic Pollutants. Ottawa.

Rawson, D. S. 1951. Studies of the fish of Great Slave Lake. J. Fish. Res. Board Can. 8:207-240.

Rigét, F., A. Bignert, B. Braune, M. Dam, R. Dietz, M. Evans, N. Green, H. Gunnlaugsdóttir, K. S. Hoydal, J. Kucklick, R. Letcher, D. Muir, S. Schuur, C. Sonne, G. Stern, G. Tomy, K. Vorkamp, and S. Wilson. 2019. Temporal trends of persistent organic pollutants in Arctic marine and freshwater biota. Science of the Total Environment 649:99-110.

Rigét, F., A. Bignert, B. Braune, J. Stow, and S. Wilson. 2010. Temporal trends of legacy POPs in Arctic biota, an update. Science of the Total Environment 408:2874-2884.

Scott, W. B., and E. J. Crossman. 1998. Freshwater Fishes of Canada. Galt House, Oakville, ON.

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 (T.N.-O.)

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Project locations/Emplacements du projet

- Rampart Rapids near Fort Good Hope, NT
- Mackenzie River by the Fort Good Hope Renewable Resources Council (FGH RRC), NT

Abstract

Partnering with the Fort Good Hope Renewable Resources Council, we acquired 40 burbot from the Mackenzie River (Rampart Rapids) in early 2018. Our goals were to analyze the concentrations of mercury and other contaminants from this country food (e.g. persistent organic pollutants), analyze the data with historical time-series concentrations (spanning 32 years in total) and other attributes of the fish, and report information to relevant end users in the Sahtú region

Résumé

En partenariat avec le Conseil des ressources renouvelables et les membres de la collectivité de Fort Good Hope, nous avons obtenu 40 lottes du fleuve Mackenzie (rapides Rampart) au début de 2018. Nos objectifs consistaient à mesurer les concentrations de mercure et d’autres contaminants (p. ex., des polluants organiques persistants) dans cet aliment traditionnel, à analyser les données en fonction de séries chronologiques historiques de concentrations (couvrant une période

and the Northwest Territories. The project's contaminants knowledge is shared 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 (Lockhart et al. 1989). This seems to support local Indigenous Knowledge that dark livers are "unhealthy". Average annual mercury concentrations have increased over the last decades (Carrie et al. 2010), and thus there is a definite need to continue this environmental monitoring.

totale de 32 ans) et d'autres attributs du poisson et à communiquer l'information aux consommateurs dans la région de Sahtú et les Territoires du NordOuest. Les connaissances sur les contaminants obtenues dans le cadre du projet sont diffusées afin de promouvoir des directives de consommation sûre et des régimes de gestion durable des ressources renouvelables. Selon les résultats préliminaires, les concentrations moyennes de mercure dans ces poissons (tissus du foie et tissus musculaires) demeurent inférieures aux recommandations de consommation. La taille et l'âge du poisson ne semblent pas avoir d'incidence sur les concentrations de mercure, bien que certaines années, les concentrations étaient plus élevées dans le foie des femelles. Les lottes qui avaient 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 (faibles réserves lipidiques), ce qui explique la plus forte concentration de mercure dans ces foies (Lockhart et coll. 1989). Selon le savoir autochtone locale, les foies de couleur foncée ne sont pas « sains »; cette constatation semble le confirmer. Les concentrations annuelles moyennes de mercure ont augmenté au cours des dernières décennies (Carrie et coll. 2010), et il est donc absolument nécessaire de poursuivre cette surveillance environnementale.

Key messages

- Mean concentrations of mercury in muscle and liver over the entire data sets were 0.366 ± 0.145 (n = 762) and 0.101 ± 0.088 (n = 757) 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 contaminants are likely bio-concentrating in these tissues.
- Length and age did not influence mercury concentrations.

Messages clés

- Les concentrations moyennes de mercure dans les muscles et le foie pour l'ensemble des ensembles de données étaient respectivement de 0,366 ± 0,145 (n = 762) et 0,101 ± 0,088 (n = 757) g/g en poids humide.
- 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 ($t = 2{,}596$, $p = 0{,}013$) comparativement aux lottes qui avaient un foie blanc. 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.

- Average annual mercury concentrations have increased over the last three decades, and thus there is a definite need to continue this environmental monitoring.

- La taille et l'âge du poisson n'ont pas d'incidence sur les concentrations de mercure.
- 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 it is an important country food and, as such, contaminants from these fish can be transferred; a health risk to the people that consume them. In light of climate change and variability, as well as natural resource extraction (e.g. within the Mackenzie River watershed), these types of long-term datasets are pivotal towards observing and understanding possible associated contaminant changes in northern, freshwater species.

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 by 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 2018-2019 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 2018-2019

Sample collections and lab analyses

Twenty whole fish were collected by Fort Good Hope recreational fishers in December 2018, stored frozen and shipped by FGH RRC, and received in Winnipeg in January 2019. 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.

Burbot samples were processed (e.g. body length, weight, liver weight), sexed, and otoliths were removed for aging in March 2019. 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 Shiva Lashkari on sub-samples of liver and muscle on August 28th, 2019. Analysis, and, thus, the submission of this report was significantly delayed due to staff turnover and major repairs required by our Hydra II mercury analyser. 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 completed by December 2019.

Ten liver samples will be processed and sent to Liisa Jantunen's and Tom Harner's labs at Environment and Climate Change Canada in Toronto for analysis of FOCs and PBDEs. We anticipate this to be completed by December 2019.

Community engagement

In our 2017-2018 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. This, unfortunately, did not happen, as Ashley Gaden left her position with CEOS for another job opportunity. We are hoping that Paloma will be able to visit the community sometime in the spring 2020.

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 & 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 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 3-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 NWT RCC before submission to the FGH RRC and SRRB.

Figure 1. Visual contrast between white "healthy" livers (left) and dark "unhealthy" livers (right) of burbot.

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). Furthermore, we explored statistical relationships between this data and the total mercury data.

Results and outputs/deliverables

Results from 2018-2019

Of the 20 burbot collected, 9 were male, 10 were female and 1 was 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). 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.

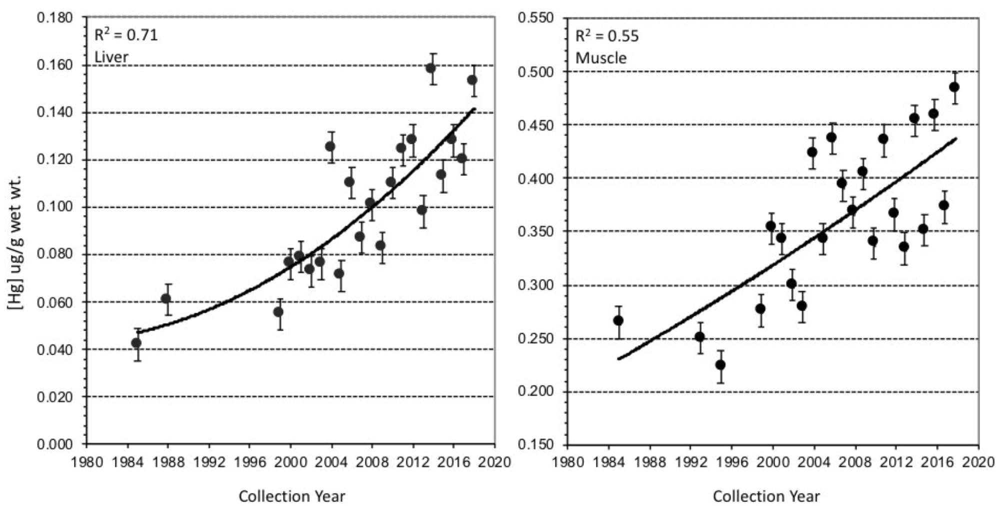
Based on coloration alone, student t-tests revealed dark livers had statistically higher total mercury concentrations in liver ($t=3.819$, $p<0.001$) and muscle ($t=2.596$, $p=0.013$) compared to white livers. Although it would appear burbot with proportionally very small, dark livers appear to have 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.

Table 1. Length, weight, and total mercury (THg, wet weight) of Fort Good Hope burbot collected in December 2018 for the 2018-2019 NCP funding year. SD is short for standard deviation (n=20)

Variable	Average (SD)	Minimum	Maximum
Length	730 (144) mm	440 mm	970 mm
Weight	2456 (1218) g	516 g	4605 g
Liver weight	81 (57) g	14.6 g	203.4 g
THg in muscle	0.364 (0.145) mg/g	0.191 mg/g	0.767 mg/g
THg in liver	0.101 (0.088) mg/g	0.063 mg/g	0.534 mg/g

Figure 2. Average total mercury concentrations (with standard error bars) in liver (left) and muscle (right) from Fort Good Hope burbot, 1985-2018.



Results from the entire time series

Time trend data from Fort Good Hope burbot tissues cover 33 years and 24 time points (1985, 1988, 1993, 1995, 1999-2018) (Figure 2). Mean concentrations in muscle and liver over the entire data sets 0.366 ± 0.145 (n = 762) and 0.101 ± 0.088 (n = 757) mg/g wet weight, respectively. No significant correlation between length (or age) and mercury concentration was observed with muscle or liver for either sex.

Discussion and conclusions

Although average mercury levels in Fort Good Hope burbot 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 2- and 3-fold in muscle and liver, respectively, since the mid-1980s (Figure 2). These increasing trends are gradual, exhibit inter-annual variability, but are significant nonetheless.

Expected project completion date

Temporal trend studies are long-term propositions, and thus annual sampling is projected into the foreseeable future.

Project website

n/a

Acknowledgments

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References

Canadian Food Inspection Agency. 2014. Canadian Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products. Retrieved from http://www.inspection.gc.ca/DAM/DAM-food-aliments/STAGING/text-texte/fish_man_standardsmethods_appendix3_1406403090196_eng.pdf

Carrie, J., F. Wang, H. Sanei, R.W., Macdonald, P.M. Outridge and G.A. Stern. 2010. Increasing contaminant burdens in an Arctic fish, burbot (*Lota lota*), in a warming climate. *Environ. Sci. Technol.* 44: 316-322.

Cott, P.A., B.A. Zajdlik, M.J. Palmer and M.D. McPherson. 2016. Arsenic and mercury in lake whitefish and burbot near the abandoned Giant Mine on Great Slave Lake. *J Great Lakes Res.* 42: 223-232.

Evans, M.S. and D. Muir. 2016. Spatial and long-term trends in persistent organic contaminants and metals in lake trout and burbot from the Northwest Territories. In: S. Kalhok (ed.), *Synopsis of Research Conducted under the 2015-2016 Northern Contaminants Program, Supporting Information.* Ottawa: Indigenous and Northern Affairs Canada. pp. 258-269.

Health Canada. 2004. *Mercury: Your Health and the Environment. A Resource Tool.* Ottawa: Health Canada. 54 pp.

Lockhart, W.L., D.A. Metner, D.A.J. Murray, R.W. Danell, B.N. Billeck, C.L., Baron, D.C.G. Muir and K. Chang-Kue. 1989. *Studies to Determine Whether the Condition of Fish from the Lower Mackenzie River is Related to Hydrocarbon Exposure.* Environmental Studies No. 61. Ottawa: Indian Affairs and Northern Development, 84 pp

Temporal trends of contaminants in Yukon lake trout

Tendances temporelles des contaminants dans le touladi du Yukon

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Project locations/Emplacements du projet

- Lake Laberge, YK
- Kusawa Lake, YK

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 2018 and early winter of 2019, 15 lake trout were collected from Kusawa Lake and 21 from Lake Laberge. Otoliths were aged and liver and muscle samples from these fish are currently being analyzed for a suite of elements, new contaminants (fluorinated and brominated compounds) and older organochlorine pesticides. Previous data from this project are being gathered and curated prior to being analyzed and reported. Mercury levels in muscle from lake trout from Lake Laberge and Kusawa Lake averaged 0.25 and 0.24 $mg{\cdot}g^{-1}$ respectively, about half the recommended guideline level of 0.50 $mg{\cdot}g^{-1}$ for commercial sale. Mercury is declining over time in lake trout from both lakes, although there is considerable annual variation. Arsenic concentrations in lake trout muscle decreased

Résumé

Ce projet consiste à surveiller les contaminants chez le touladi de deux lacs du Yukon, soit les lacs Laberge et Kusawa, depuis 1993, et annuellement depuis 2001. À l'automne 2018 et au début de l'hiver 2019, 15 touladis ont été recueillis dans le lac Kusawa, et 21 touladis l'ont été 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 pour détecter une série d'éléments, de nouveaux contaminants (composés fluorés et bromés) et d'anciens pesticides organochlorés. 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. Les concentrations de mercure dans les muscles du touladi des lacs Laberge et Kusawa étaient en moyenne de 0,25 et 0,24 $g{\cdot}g^{-1}$ respectivement, soit environ la moitié du niveau recommandé de 0,50 $mg{\cdot}g^{-1}$ pour les poissons de pêche commerciale. La teneur en mercure du touladi des deux lacs diminue au fil

over time in Lake Laberge but not in Kusawa Lake, while selenium increased over time in Kusawa Lake but not in Lake Laberge. Both changes were small and likely of little biological significance. Outreach programs were conducted with the Yukon Fisheries Field Assistant Program and the Yukon Fisheries Management Program at Yukon College in Whitehorse, YT. The first group was able to use the recently acquired Direct Mercury Analyzer to measure mercury in their fish. 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 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.

du temps, bien qu'il y ait une variation annuelle considérable. Les concentrations d'arsenic dans les muscles du touladi ont diminué avec le temps dans le lac Laberge, mais pas dans le lac Kusawa, tandis que le sélénium a augmenté avec le temps dans le lac Kusawa, mais pas dans le lac Laberge. Ces deux changements étaient faibles et probablement de faible importance biologique. Des programmes de sensibilisation ont été menés avec le programme d'agent des pêches adjoint sur le terrain au Yukon et le Programme de gestion des pêches du Yukon au Collège du Yukon à Whitehorse (Yukon). Le premier groupe a pu utiliser l'analyseur direct de mercure récemment acheté pour mesurer le mercure dans leurs poissons. Le conseil des Ta'an Kwach'an et les Premières Nations de Champagne et d'Aishihik participent pleinement au prélèvement de poissons pour ce projet et à l'amélioration continue de la communication des résultats. Nous perfectionnons nos capacités de communication et le Comité des contaminants du Yukon, le ministère de l'Environnement du Yukon (pêches) et la Première Nation de Kwanlin Dun prennent part aux discussions. À mesure que nous progressons avec cette approche de collaboration, nous nous attendons à ce que des occasions nombreuses et nouvelles d'activités de consultation et de communication à valeur ajoutée se présentent.

Key messages

- Mercury is declining over time in lake trout from Lake Laberge and Kusawa Lake, although there is considerable annual variation.
- In 2018 mercury levels in muscle from lake trout from Lake Laberge and Kusawa Lake averaged 0.25 and 0.24 mg·g^{-1}, about half the recommended guideline level of 0.50 mg·g^{-1} for commercial sale (note that this represents only one fish from Lake Laberge).
- Arsenic concentrations in lake trout muscle decreased over time in Lake Laberge but not in Kusawa Lake, while selenium increased over time in Kusawa Lake but not in Lake

Messages clés

- Le mercure diminue avec le temps dans les touladis des lacs Laberge et Kusawa, bien qu'il y ait une variation annuelle considérable.
- En 2018, les concentrations de mercure dans les muscles du touladi des lacs Laberge et Kusawa étaient en moyenne de 0,25 et 0,24 mg·g^{-1}, soit environ la moitié du niveau recommandé de 0,50 mg·g^{-1} pour les poissons destinés à la vente commerciale (à noter que cela ne représente qu'un seul poisson du lac Laberge).
- Les concentrations d'arsenic dans les muscles du touladi ont diminué avec le temps dans le lac Laberge, mais pas dans

Laberge. Both changes were small and likely of little biological significance.

- Newer contaminants (PFASs and PBDEs) as well as older organochlorine pesticides are currently being measured in samples collected in 2018.

le lac Kusawa, tandis que le sélénium a augmenté avec le temps dans le lac Kusawa, mais pas dans le lac Laberge. Ces deux changements étaient faibles et probablement de faible importance biologique.

- Des contaminants plus récents (PFAS et PBDE) ainsi que des pesticides organochlorés plus anciens sont actuellement mesurés dans des échantillons prélevés en 2018.

Objectives

This project aims to monitor contaminant levels in lake trout from two Yukon lakes (Kusawa and Laberge) in order to assess:

- potential 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. Arsenic, mercury and selenium were measured in most years since 1993, and starting in 2006, fish muscle has been measured for brominated flame retardants and fish liver for fluorinated organic compounds which have become contaminants of concern in the Canadian Arctic. The decline in many organochlorines (PCBs, DDT, toxaphene) in these fish has been an encouraging note and a testament to the effectiveness of international controls. Although mercury concentrations are also declining over the long term in both lakes, there is high annual variability, rendering it imperative to continue the monitoring of this important food resource for many Yukon residents. This project is conducted in close collaboration with the three First Nations whose traditional territories include Lake Laberge and/or Kusawa Lake: Champagne and Aishihik First Nations (CAFN), Ta'an Kwach'an Council (TKC) and Kwanlin Dun First Nation (KDFN).

Activities in 2018-2019

Mary Gamberg and a CAFN Elder (Ron Chambers) collected 15 lake trout from Kusawa Lake in August 2018. Although plans were made for Mary Gamberg to participate in a fish camp with TKC in the summer of 2018, the timing was not ideal, and samples were only taken from one fish during that camp. A TKC citizen provided an additional 20 fish in February of 2019. Discussions were held with KDFN regarding their involvement in the project and plans were made for them to share in the sampling efforts in 2019 and to request additional sampling of Fish Lake in 2019.

Tissue samples were sent to the National Laboratory for Environmental Testing (Burlington, ON) for analysis: muscle for stable isotopes, polybrominated biphenyls (PBDEs) and a suite of 38 elements; liver for per- and polyfluorinated alkyl substances (PFASs). Otoliths were aged by North/South Consultants, Winnipeg, MB. After sampling, the trout fillets were returned to the relevant community for distribution (CAFN for Kusawa; TKC for Laberge).

Element concentrations in muscle tissue collected in 2017 and the fall of 2018 are presented in this report in the context of past element data (arsenic, mercury and selenium only). Samples collected in February of 2019 are still being analyzed for element concentrations. PFASs and PBDEs are currently being measured in the 2017 and 2018 lake trout samples and PCBs and organochlorines (OCs) are being measured in the 2018 samples. Previous PFAS, PBDE and OC data from this project are still being gathered and curated prior to being analyzed and reported. All data should be in hand by March 2020.

Community engagement

Discussions were held with TKC, CAFN and KDFN to develop 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 2019. Discussions were also held with the Fisheries section of Yukon Environment on how best to share resources and data. Fish were collected by citizens of TKC and CAFN (with Mary Gamberg) for this project, and after fish were sampled, remaining fillets were returned to the communities for distribution.

Capacity building and training

Mary Gamberg spent a full day in May 2018 with the Yukon Fisheries Technician 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 (purchased from a local fish hatchery) and teaching the students correct contaminant sampling techniques, record-keeping and techniques for taking morphometric measurements and the removal of otoliths (ear bones) for aging. Samples were then taken over to the Yukon Research Centre where the students learned to use the Direct Mercury Analyzer (DMA) to measure mercury in their fish. This was an excellent opportunity for hands-on learning and the immediacy of discovering the mercury content of the fish they had just dissected cannot be overstated. Fish fillets from the dissections were taken home by the students.

Mary Gamberg spent a half day in October 2018 with the Yukon Fisheries Management Program at Yukon College in Whitehorse, YT. This was a shortened version of the previous capacity-building exercise, without the DMA training, as the limited time did not allow this portion to be included. In addition to the Yukon College students, two land guardians from CAFN attended this training session.

Communications and outreach

Mary Gamberg updated the fish contaminants section of the Yukon State of the Environment Report for Yukon Environment. Assistance was given to CAFN (Megan Grabowski) interpreting mercury levels in fish in another lake (Aihihik Lake) in their traditional area. This work was done as part of a relicensing requirement for a dam on the river. General results of this project were discussed during training sessions with land guardians of the Taku River Tlinget First Nation in Atlin, BC and the Nacho Nyak Dun First Nation in Mayo, as part of two NCP-funded community-based projects in 2018. Results were also discussed with land guardians from CAFN as they assisted with sampling of burbot for the NCP-funded ‘Mercury in Yukon Fish’ project in November 2018. Plain language summaries will be updated with conclusions from the 2018 data once they are all received.

Indigenous Knowledge

All the fish collected for this project were caught using Indigenous Knowledge of fishing and fish habitat. The opportunity for Mary Gamberg and a CAFN Elder to spend three days fishing on Kusawa Lake together was invaluable in terms of the sharing of knowledge. This knowledge will continue to be used as we move forward in the project to plan fish collections and interpret data. Ongoing collaborations with CAFN, TKC and KDFN will ensure that Indigenous Knowledge will continue to be used in a respectful and relevant way in this project.

Results

Historically, samples for this project were taken from the tail portion of the fish. The current standard location for sampling is the dorsal area, above the midline and anterior to the dorsal fin. In 2017, we took samples from both locations in each fish to compare, to ensure comparability with past data. There were no significant differences in arsenic, mercury or selenium concentrations between sampling locations.

Normally in this project, fish are collected during the summer months. In 2017, only three trout were collected in the summer (July) from Lake Laberge. A further five trout were collected in October and another five in January 2018. Element concentrations in muscle were compared among these three sampling periods. Of the 38 elements tested, only tin showed a significant difference, with concentrations being lower in January than July and October.

Arsenic, mercury and selenium results are presented in Table 1 with past years for context. Mercury concentrations in lake trout muscle tissue were significantly and positively affected by fish length, age and weight. Length was chosen as the most convenient (and standard) way to adjust the data for further analyses. Mercury levels did not differ between the two lakes while arsenic and selenium were both higher in Kusawa than Laberge. Both differences were small and likely of little biological significance.

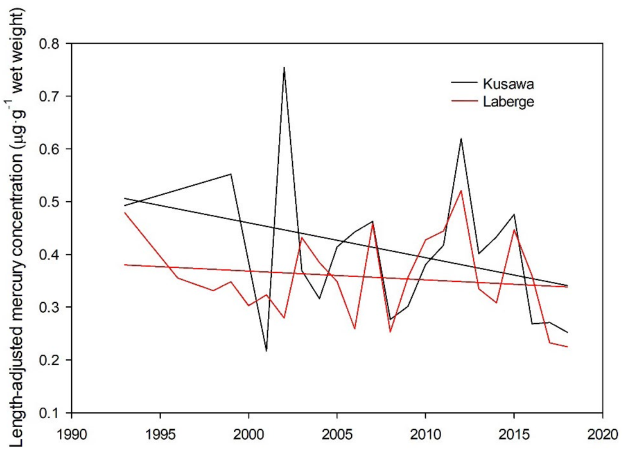
Mercury concentrations in lake trout muscle are declining over time in both Lake Laberge and Kusawa Lake, although less rapidly in the former ($p=0.0425$ and $p<0.0001$, respectively). Figure 1 shows length-adjusted means (length=500 mm) of temporal trends in both lakes. Arsenic concentrations in lake trout muscle decreased over time in Lake Laberge but not in Kusawa Lake, while selenium increased over time in Kusawa Lake but not in Lake Laberge. Both changes were small and likely of little biological significance. Other elements measured in 2017 were not able to be included in the temporal trend analysis, as they have not been analyzed in the past.

Table 1. Concentrations ($mg \cdot g^{-1}$ wet weight) of arsenic, mercury and selenium in lake trout muscle from Kusawa Lake and Lake Laberge, Yukon.

	n		Arsenic				Mercury				Selenium			
Year	Kusawa	Laberge	Kusawa		Laberge		Kusawa		Laberge		Kusawa		Laberge	
			Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
1993	15	13	0.04	(0.05)	0.15	(0.04)	0.84	(0.63)	0.44	(0.13)	0.53	(0.11)	0.45	(0.08)
1996		18			0.11	(0.06)			0.32	(0.10)			0.32	(0.12)
1998*		7			0.18	(0.11)			0.53	(0.24)			0.40	(0.06)
1999	14	1	0.05	(0.05)	0.10		0.57	(0.39)	0.40		0.36	(0.18)	0.41	
2000		6			0.13	(0.04)			0.43	(0.21)			0.66	(0.14)
2001	9	22	0.03	(0.02)	0.10	(0.04)	0.29	(0.11)	0.52	(0.25)	0.52	(0.09)	0.57	(0.13)
2002	10	5	0.02	(0.01)	0.11	(0.05)	0.29	(0.10)	0.38	(0.15)	0.55	(0.07)	0.61	(0.12)
2003	10	8	0.03	(0.02)	0.10	(0.03)	0.35	(0.13)	0.56	(0.25)	0.35	(0.25)	0.47	(0.10)
2004	9	5	0.03	(0.01)	0.08	(0.04)	0.39	(0.13)	0.54	(0.23)	0.48	(0.13)	0.38	(0.03)
2005	10	10	0.01	(0.01)	0.06	(0.03)	0.43	(0.31)	0.50	(0.19)	0.60	(0.11)	0.47	(0.09)
2006**	10	1	0.02	(0.02)	0.08		0.57	(0.36)	0.68		0.58	(0.16)	0.49	(0.06)
2007	9	9	0.02	(0.01)	0.08	(0.03)	0.39	(0.23)	0.70	(0.27)	0.56	(0.08)	0.42	(0.06)
2008	10	10	0.02	(0.01)	0.06	(0.02)	0.24	(0.07)	0.37	(0.19)	0.54	(0.08)	0.43	(0.07)
2009	10	10	0.02	(0.00)	0.06	(0.02)	0.23	(0.08)	0.41	(0.18)	0.56	(0.08)	0.41	(0.03)
2010	10	10	0.04	(0.03)	0.08	(0.03)	0.31	(0.19)	0.49	(0.19)	0.47	(0.09)	0.45	(0.07)
2011	10	10	0.02	(0.01)	0.08	(0.04)	0.32	(0.06)	0.52	(0.29)	0.51	(0.07)	0.41	(0.09)
2012	10	10	0.04	(0.03)	0.07	(0.02)	0.53	(0.13)	0.63	(0.24)	0.54	(0.06)	0.46	(0.06)
2013							0.29	(0.08)	0.33	(0.13)				
2014							0.31	(0.10)	0.40	(0.11)				
2015							0.37	(0.11)	0.55	(0.15)				
2016	10	20	0.19	(0.10)	0.08	(0.07)	0.34	(0.10)	0.29	(0.16)	0.45	(0.07)	0.55	(0.12)
2017	7	13	0.02	(0.01)	0.16	(0.10)	0.29	(0.18)	0.33	(0.17)	0.67	(0.10)	0.41	(0.02)
2018	15	1	0.02	(0.01)	0.12		0.24	(0.11)	0.25		0.57	(0.08)	0.36	

*n=7 for arsenic in Laberge
**n=2 for selenium in Laberge

Figure 1. Temporal trends in length-adjusted (length=500mm) mercury concentrations in muscle tissue from lake trout collected from Lake Laberge and Kusawa Lake, Yukon Territory.



Discussion and conclusions

Given that there were no significant differences in arsenic, mercury or selenium between the dorsal and tail portions of lake trout muscle, we feel confident moving ahead with the new, standardized protocol of sampling the dorsal area. Using this updated sampling method, we are confident that we can maintain the ability to compare new data with old from Lake Laberge and Kusawa Lake. Also, given that none of the 38 elements (except tin) differed among sampling periods (July, October and January), we feel confident in grouping all sampling periods within one year for temporal trend analyses.

Temporal trend analysis indicates that, over the long term, mercury is decreasing in both lakes (Figure 1) and concentrations in 2018 were among the lowest levels that we have seen in this lake. This is encouraging, but we must consider that, first, these data only include one fish from Lake Laberge for 2018 (the others are currently being analysed) and second, there is a high degree of annual variability, which may be somewhat cyclical in nature. We could be at the bottom of the aforementioned cycles. The similarity between lakes in the length-adjusted trends in mercury in lake trout shown in Figure 1 strongly suggests environmental drivers of this annual variability. This is a phenomenon that is currently being explored with respect to Yukon caribou (Porcupine herd) under the NCP-funded 'Contaminants in Arctic Caribou'.

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, CAFN, TKC and KDFN 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.

Acknowledgments

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Arctic Caribou Contaminant Monitoring Program

Programme de surveillance des contaminants dans le caribou de l’Arctique

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Project locations/Emplacements du projet

- Kivalliq region, NU (Qamanirjuaq and Lorillard herds)
- Western Yukon (Forty-Mile herd)
- Northern Yukon (Porqupine herd)
- Sanikiluaq, NU
- Eastern Northwest Territories

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 2018/2019 samples were collected from 16 Qamanirjuaq, 4 Lorillard and 18 Forty-Mile caribou and 11 Sanikiluaq reindeer. Twenty kidneys from the Bathurst caribou were also included in the analysis. Sample analyses for these collections had not been completed at the time this report was prepared. Porcupine, Qamanirjuaq and Forty-Mile caribou samples collected in the 2017/2018 year have been analyzed, and results are presented in this report. Toxic elements tended to be higher in cows than bulls. This difference is likely due to the relatively higher

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 concentrations de contaminants), si cette ressource alimentaire importante continue d’être saine et sécuritaire pour la population du Nord, et si les concentrations de contaminants évoluent au fil du temps. En 2018-2019, des échantillons ont été prélevés sur 16 caribous de Qamanirjuaq, 4 de Lorillard et 18 de Forty-Mile, ainsi que sur 11 caribous de Sanikiluaq. Vingt reins de caribous de Bathurst ont également été inclus dans l’analyse. Leur analyse n’était pas terminée au moment où le présent rapport a été rédigé. Les échantillons de caribous de la Porcupine, de Qamanirjuaq et de Forty-Mile prélevés en 2017-2018 ont été analysés et les résultats sont présentés dans ce rapport. Les

volume of food intake (and hence toxic element intake) by cows due to their smaller size and higher energetic requirements from parturition and lactation. Cadmium and zinc increased with age while mercury decreased with age in Porcupine caribou bulls. Lead continues to decline in both herds. Overall, mercury, selenium and zinc are increasing in the Qamanirjuaq caribou, although increases are slight and may be better described by a cyclic pattern, similar to that seen in the Porcupine caribou, which is not experiencing an overall increase in any of those elements. Toxic elements were present at very low concentrations in marrow from Porcupine caribou, much lower than those found in kidneys.

Perfluorinated sulfonic acids are declining over time in caribou liver (largely due to PFOS, which has been banned). Per- and polyfluorinated alkyl substances and polybrominated diphenyl ethers were present at very low levels in caribou liver. 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 that caribou meat remains a healthy food choice. There have been no health advisories issued for caribou in NWT or Nunavut.

éléments toxiques avaient tendance à être plus élevés chez les femelles que chez les mâles. Cette différence est probablement due au volume relativement plus élevé d'aliments consommés (et donc d'éléments toxiques) par les femelles, de leur plus petite taille et des besoins énergétiques plus importants en raison de la mise bas et de la lactation. Les concentrations de cadmium et de zinc augmentaient avec l'âge, tandis que le mercure diminuait avec l'âge chez les caribous mâles de la Porcupine. Le plomb continue à diminuer dans les deux troupeaux. Dans l'ensemble, le mercure, le sélénium et le zinc augmentent chez le caribou de Qamanirjuaq, bien que les augmentations soient légères et puissent être mieux décrites par un schéma cyclique, similaire à celui observé chez le caribou de la Porcupine, qui ne connaît pas d'augmentation globale de l'un de ces éléments. Les éléments toxiques étaient présents à de très faibles concentrations dans la moelle du caribou de la Porcupine, beaucoup plus faibles que celles trouvées dans les reins.

Les acides sulfoniques perfluorés diminuent avec le temps dans le foie des caribous (en grande partie à cause du SPFO, qui a été interdit). Les substances per-polyfluoroalkylées et les polybromodiphényléthers étaient présents à des concentrations très faibles dans le foie de caribou. La concentration de la plupart des contaminants mesurés dans les reins des caribous ne constituait pas une préoccupation sur le plan toxicologique, bien que les concentrations de mercure et de cadmium dans les reins puissent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. Le ministère de la Santé du Yukon a conseillé aux citoyens de limiter la quantité de rognons et de foie provenant de caribous du Yukon qu'ils consomment; la quantité maximale recommandée varie selon la harde (p. ex., au maximum 25 rognons de caribous de la harde de la Porcupine par année). L'avis sanitaire confirme que les métaux lourds sont très peu présents dans la viande (muscle) du caribou et que celle-ci demeure un choix alimentaire 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 high enough to be 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, therefore, is a healthy food choice.
- Mercury concentrations in the Porcupine and Qamanirjuaq caribou are stable over the long term, although there is considerable annual variation.
- Concentrations of PFASs and PBDEs are low with respect to potential toxicity to caribou or those consuming caribou.
- This program will continue to monitor the Porcupine and Qamanirjuaq caribou herds annually to maintain hunter confidence in this traditional food and to better understand the dynamics of contaminants within this ecosystem (particularly mercury).

Messages clés

- Les concentrations de la plupart des contaminants mesurés dans les tissus du caribou ne sont pas suffisamment élevées pour être préoccupantes, bien que les concentrations de mercure et de cadmium dans les reins puissent l'être pour la santé humaine en fonction de la quantité d'organes consommés. La viande de caribou (muscle) n'accumule pas de concentrations élevées de contaminants, et constitue donc un choix alimentaire sain.
- Les concentrations de mercure dans le caribou de la Porcupine et de Qamanirjuaq sont stables à long terme, bien qu'il y ait une variation annuelle considérable.
- Les concentrations de PFAS et de PBDE sont faibles par rapport à la toxicité potentielle pour les caribous ou les personnes qui en consomment.
- Dans le cadre de ce programme, on continuera de surveiller les hardes de caribous de la Porcupine et de Qamanirjuaq sur une base annuelle, pour maintenir la confiance des chasseurs à l'égard de cette source alimentaire traditionnelle et mieux comprendre la dynamique des contaminants dans l'écosystème (en particulier le mercure).

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. This includes providing information for health assessments and/or advisories as required; and
- wildlife managers can assess possible health effects of contaminants on Arctic caribou populations.
- further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

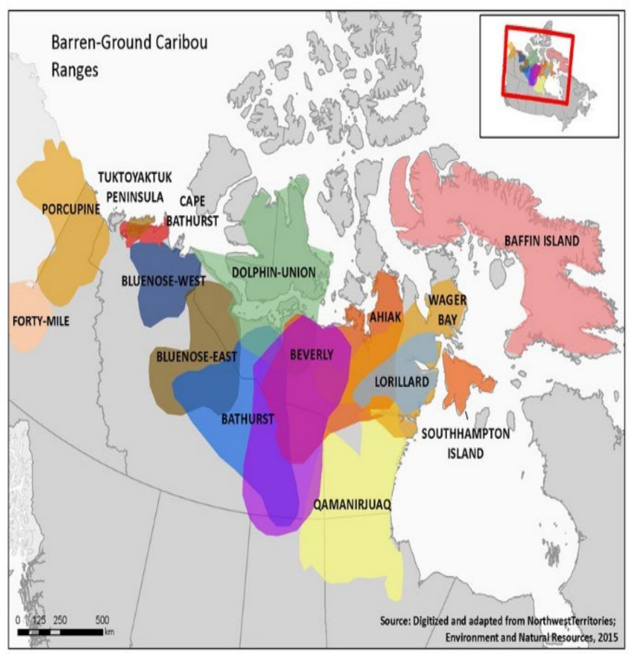
Introduction

Caribou provide an important food resource for Northerners across the Arctic, and the Porcupine and Qamanirjuaq caribou herds have been designated in the NCP blueprint for annual monitoring of mercury, inorganic elements, PBDEs (polybrominated diphenyl ethers) and PFASs (per- and polyfluoroalkyl substances). In addition, the blueprint specifies that one or two other herds will be monitored each year for the same list of contaminants. This year, those herds were the Lorillard caribou (Baker Lake, NU) and Sanikiluaq reindeer (Sanikiluaq, NU).

Activities in 2018/2019

In the fall of 2018, samples were collected from 16 Qamanirjuaq caribou by local hunters in Arviat, NU and from 4 Lorillard caribou with the assistance of the Baker Lake Hunters and Trappers Organization (HTO). Samples were collected from 12 Sanikiluaq reindeer with the assistance of the Sanikiluaq HTO in January/February 2019. No samples were taken from the Porcupine caribou as their migration route did not take them through our sampling location in Old Crow, YT. Attempts were made to solicit samples from Alaskan harvesters, but these were unsuccessful. Shortfalls in sample numbers were completed with 18 samples from the Forty-Mile caribou herd, collected opportunistically by Yukon Environment in the fall of 2018. An additional 20 kidneys from the Bathurst herd collected in August 2011 by the Government of Northwest Territories (Brett Elkin) were included in the analysis. 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.



Current-year kidney samples are being analyzed for a suite of 34 elements using ICP-MS by NLET, Environment Canada, Burlington. Ten liver samples from each of the Forty-Mile and Qamanirjuaq herds and four from the Lorillard herd are being analyzed for PBDEs (including deca-BDE) and PFASs by a private laboratory

(ALS Global). Liver and muscle samples will be archived at the National Wildlife Research Centre (Environment Canada). Incisors were used to analyze age of the animal using the cementum technique with the assistance of Environment Yukon (Angela Milani).

As methylmercury is the more toxic form of this element and we normally measure total mercury in caribou, we took advantage of the room in the analytical budget to analyze methylmercury in livers and kidneys from ten caribou from each of the Forty-Mile and Qamanirjuaq herds, four caribou from the Lorillard herd and in ten kidneys from the Bathurst herd (no livers were available from this collection).

Capacity building

In September 2018, the principal investigator (PI), 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 as well as in caribou. This workshop will be offered again in September 2019.

In October 2018, the PI participated in a Wildlife Contaminants Workshop – building contaminants research capacity in Nunavut, in Arviat NU along with a team of ten other researchers. The workshop was designed to integrate experiences from past workshops, open houses and events that incorporate contaminants, wildlife ecology, physical processes in the Arctic, and climate change. The workshop was delivered to a range of community members in Arviat. An open house and evening gathering were held in Arviat in October 2018. This open house featured hands-on activities and presentations on three important wildlife species in the community: polar bears, seals and caribou, and featured NCP scientists from each project. About 75 community members (mostly students) attended the open house while about 150 participated in the evening gathering. An Inuit Qaujimajatuqangit (IQ) workshop was given to the visiting researchers by the Aqqiummarvik Society of Arviat, providing insight into new ways of developing research protocols in northern communities that will increasingly align with Inuit values and IQ principles and ensuring that northern research is carried out in a collaborative, respectful and effective manner.

Communications

Results of this project were communicated in the following ways:

May/June 2018

In May plain language summaries of contaminants in the Porcupine, Bluenose West, Ahiak, Qamanirjuaq and Dolphin & Union caribou were distributed widely (the latter four were provided both in English and Inuktitut). Mary Gamberg attended a two-day meeting of the Porcupine Caribou Herd Technical Committee to discuss contaminants in Porcupine caribou; Mary Gamberg provided Eva Kruemmel with data (PFHxS) to be included in a risk profile for potential inclusion of this contaminant under the Stockholm Convention. In June the PI included a discussion of contaminants in caribou in a radio interview with CBC.

August/September 2018

In August the PI provided an update on contaminants in caribou to the State of the Environment Report (Environment Yukon). In September the PI presented results to 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.

October 2018

The PI participated in: the Wildlife Contaminants Workshop in Arviat (described in more detail in the Capacity building section); a public caribou event at the Museum of Nature, Ottawa as part of the North American Caribou Workshop (brought displays of caribou clothing, toys made from caribou, caribou tissue processing for contaminant analysis and caribou tooth aging); and met with territorial MLAs on Parliament Hill to discuss contaminants in the North.

December/January 2018/2019

The PI attended two-day AMAP meeting in Ottawa to contribute perspective on contaminants in caribou. In January the PI attended a two-day caribou meeting with the Athabascan Denesuline in Wollaston Lake, SK to discuss contaminants in caribou.

February 2019

Plain language summaries of contaminants in the Porcupine, Bluenose West, Ahiak, Qamanirjuaq and Dolphin & Union caribou were updated with most recent data (including outstanding PBDE and PFAS data) and distributed widely (the latter four were provided both in English and Inuktitut). Community visits to Taloyoak, Cambridge Bay and Kugluktuk, NU are planned for April 22-28, 2019. The Caribou Contaminant Facebook page is being used regularly to communicate results to a wider audience. A first draft of a manuscript entitled 'Perfluoroalkyl acids in Arctic Caribou and Reindeer' has been prepared by Anna Roos of the Swedish Museum of Natural History. Manuscripts are also being prepared on element profiles and differences among herds by Isabeau Pratte and Jennifer Provencher of the Canadian Wildlife Service and on environmental drivers of mercury in Arctic caribou by Jeremy Brammer of the National Wildlife Research Centre.

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 the PI 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. When discussing the results of the sub-project to investigate whether mercury is precluding caribou from becoming pregnant, local hunters pointed out that the year we did that work was the second of two years that the caribou were in peak condition, as a result of windy summers that meant decreased insect harassment. This has provided an important insight into the interpretation of those results.

Results and discussion

Elements

Element concentrations are presented for samples collected in the fall of 2017 (Porcupine, Qamanirjuaq and Forty-Mile herds) and for marrow collected from the Porcupine caribou in 2016 (Table 1a,b). Although kidneys and marrow were analyzed for 34 elements, only results for 7 elements of concern were statistically analyzed in detail (arsenic [As], cadmium [Cd], copper [Cu], lead [Pb], mercury [Hg], selenium [Se] and zinc [Zn]). Porcupine and Qamanirjuaq results were analyzed for temporal trends.

Element concentrations in marrow from the Porcupine herd collected in 2016 were compared to those from the Qamanirjuaq herd collected in 2014. Most elements of concern (As, Cd, Cu, Se and Zn) were higher in the Qamanirjuaq caribou than the Porcupine caribou. However, concentrations of toxic elements were very low in both herds, much lower than levels found in kidneys.

Element concentrations in kidneys collected in 2017 were compared among the Porcupine, Qamanirjuaq and Forty-Mile caribou. The Qamanirjuaq caribou had higher levels of Pb and Hg than the other two herds, while the other elements of concern (As, Cd, Cu, Se, Zn) did not differ among herds. Differences in element concentrations between sexes and trends over time and with age were analyzed using the Qamanirjuaq (2006-2017) and Porcupine (1990-2017) caribou datasets. Cows had higher concentrations of As, Cd, Pb and Hg in both herds than bulls. Cd and Zn increased with age while Hg decreased with age in Porcupine caribou bulls. Pb continues to decline in both herds. Overall, Hg, Se and Zn are increasing in the Qamanirjuaq caribou, although increases are slight and may be better described by a cyclic pattern, similar to that seen in the Porcupine caribou, which is not experiencing an overall increase in any of those elements (Figure 2).

Figure 2. Renal concentrations of mercury (A), selenium (B) and zinc (C) in Porcupine and Qamanirjuaq caribou.

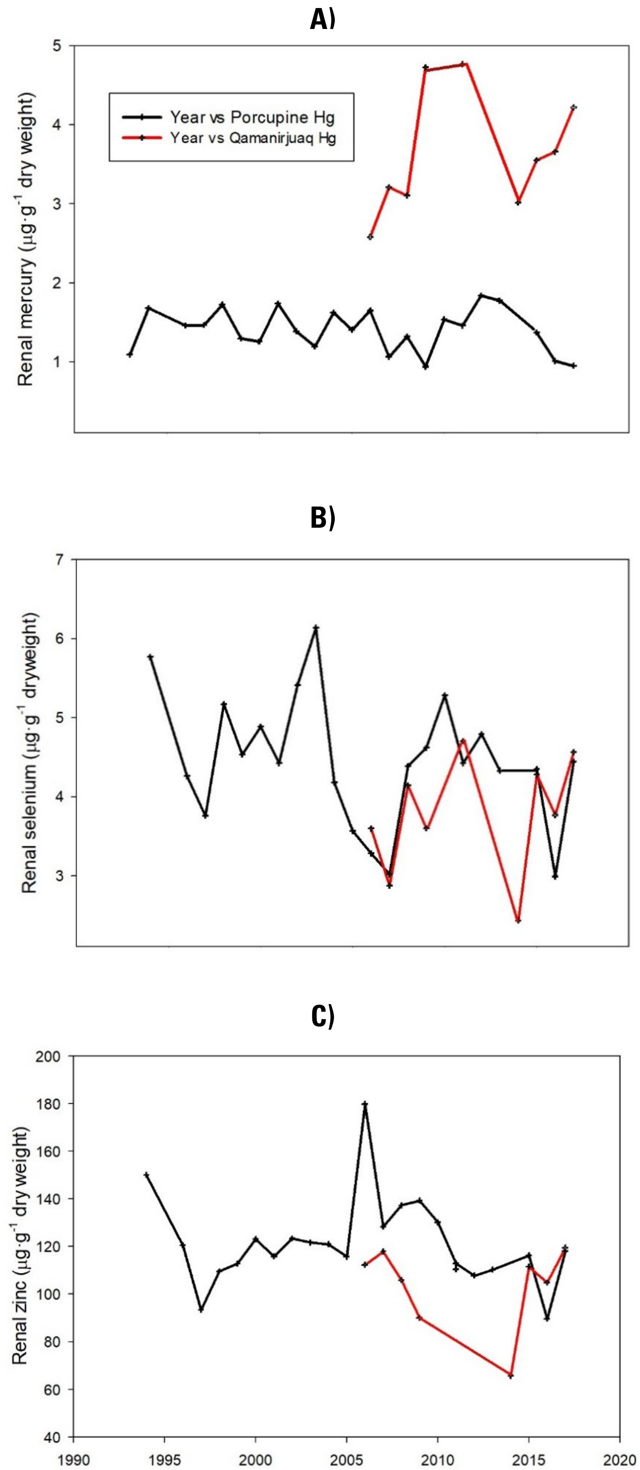


Table 1a. Renal element concentrations (X ± SD; mg·g^{-1} dry weight).

Year	N	Age	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Zinc
Porcupine herd Kidneys; Fall-collected Males									
1997	14	4.1	0.42 ± 0.32	23.2 ± 12.1	21.2 ± 2.1	0.17 ± 0.11	1.47 ± 0.32	3.8 ± 0.6	93.4 ± 11.8
1998	14	4.7	0.19 ± 0.05	26.9 ± 21.0	25.6 ± 3.7	0.25 ± 0.28	1.76 ± 0.72	5.2 ± 1.2	108.4 ± 16.6
1999	11	4.7	0.08 ± 0.04	36.0 ± 25.9	23.5 ± 6.4	0.18 ± 0.09	1.23 ± 0.63	4.6 ± 0.8	113.5 ± 16.3
2000	8	4.8	0.30 ± 0.11	37.4 ± 17.6	25.1 ± 4.3	0.25 ± 0.39	1.23 ± 0.18	4.9 ± 1.0	121.6 ± 21.5
2001	12	5.1	0.36 ± 0.12	29.8 ± 11.9	22.5 ± 2.6	0.17 ± 0.15	1.74 ± 0.78	4.4 ± 1.1	115.8 ± 27.2
2002	9	5.6	0.18 ± 0.04	26.8 ± 8.4	25.1 ± 3.4	0.13 ± 0.05	1.39 ± 0.27	5.4 ± 0.6	123.3 ± 14.1
2003	23	5.8	0.25 ± 0.06	37.5 ± 18.1	25.4 ± 3.4	0.16 ± 0.18	1.19 ± 0.25	6.1 ± 0.7	121.6 ± 15.4
2004	16	4.9	0.05 ± 0.01	24.2 ± 13.8	22.8 ± 3.0	0.14 ± 0.04	1.62 ± 0.59	4.2 ± 0.6	121.0 ± 15.9
2005	14	3.5	0.05 ± 0.04	23.1 ± 14.8	23.1 ± 2.4	0.15 ± 0.04	1.81 ± 0.33	4.5 ± 0.6	121.9 ± 18.0
2006	9	5.1	0.07 ± 0.02	41.6 ± 23.7	24.9 ± 3.0	0.10 ± 0.02	2.18 ± 0.51	5.1 ± 0.6	130.6 ± 14.5
2007	12	4.7	0.04 ± 0.01	28.3 ± 12.2	24.5 ± 4.6	0.12 ± 0.08	1.58 ± 0.45	4.4 ± 0.7	120.0 ± 27.5
2008	20	6.1	0.03 ± 0.02	27.3 ± 16.8	26.7 ± 7.1	0.18 ± 0.38	1.34 ± 0.60	4.3 ± 0.5	138.4 ± 33.7
2009	21	6.3	0.05 ± 0.04	38.1 ± 16.6	24.6 ± 5.2	0.10 ± 0.06	0.98 ± 0.43	4.6 ± 0.7	139.5 ± 39.5
2010	4	6.8	0.07 ± 0.01	26.6 ± 9.9	21.3 ± 1.6	0.11 ± 0.03	1.53 ± 0.51	5.3 ± 0.8	130.1 ± 17.8
2011	11	4.9	0.05 ± 0.04	23.0 ± 12.7	22.8 ± 2.3	0.07 ± 0.03	1.42 ± 0.45	4.5 ± 0.6	112.8 ± 8.0
2012	20	6.2	0.11 ± 0.11	34.7 ± 21.9	22.8 ± 2.1	0.09 ± 0.03	1.84 ± 0.70	4.8 ± 0.5	107.8 ± 9.3
2013	22	5.3	0.04 ± 0.02	21.2 ± 9.2	24.3 ± 2.6	0.07 ± 0.02	1.79 ± 0.50	4.3 ± 0.5	109.4 ± 6.5
2015	15	5.2	0.04 ± 0.04	23.0 ± 10.6	24.6 ± 2.9	0.08 ± 0.03	1.37 ± 0.40	4.3 ± 0.4	116.2 ± 10.1
2016	23	6.6	0.05 ± 0.01	26.6 ± 9.4	25.6 ± 5.3	0.14 ± 0.14	1.53 ± 0.34	4.5 ± 0.4	135.0 ± 22.8
2017	5	7.4	0.045 ± 0.007	17.0 ± 2.7	23.6 ± 0.77	0.05 ± 0.00	0.95 ± 0.05	4.4 ± 0.0	118.1 ± 52.8
Porcupine herd Marrow; Fall-collected Males									
2016	12	6.7	<0.001 ± 0.00	0.003 ± 0.000	0.39 ± 0.05	0.00 ± 0.00	0.01 ± 0.00	0.1 ± 0.0	2.8 ± 0.8

Table 1b. Renal element concentrations (X ± SD; mg·g^{-1} dry weight).

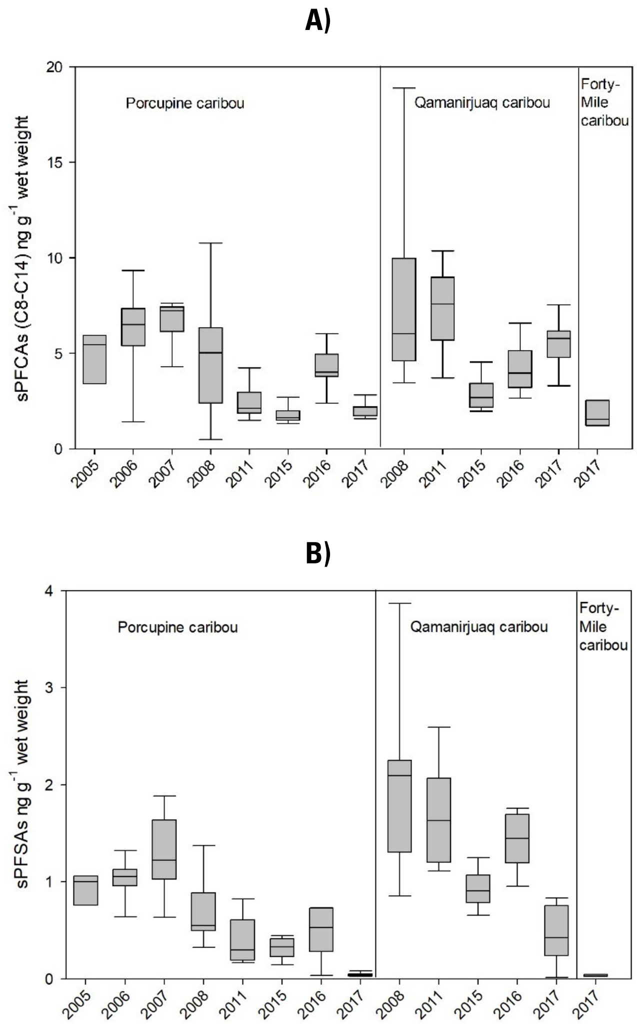
Year	N	Age	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Zinc
Qamanirjuaq caribou Kidneys; Fall-collected									
Females									
2006	7	7.3	0.032 ± 0.007	18.7 ± 5.3	26.3 ± 0.76	0.58 ± 0.31	3.37 ± 0.36	3.6 ± 0.2	104.1 ± 3.2
2007	10	5.1	0.036 ± 0.003	24.0 ± 5.0	25.1 ± 2.8	0.44 ± 0.05	5.57 ± 0.74	4.1 ± 0.4	110.1 ± 9.6
2008	10	8.1	0.041 ± 0.005	29.7 ± 3.7	24.4 ± 1.28	0.36 ± 0.02	4.99 ± 0.50	4.0 ± 0.2	105.7 ± 5.1
2009	4	0.5	0.044 ± 0.009	19.8 ± 7.4	21.1 ± 1.71	0.25 ± 0.03	5.32 ± 1.08	3.5 ± 0.1	94.7 ± 5.6
2010	1		0.051	21.5	18.9	0.49	6.69	3.8	96.5
2011	17	6.0	0.04 ± 0.005	21.0 ± 6.0	22.0 ± 0.69	0.30 ± 0.03	5.04 ± 0.46	4.2 ± 0.1	107.9 ± 2.6
2013	4	5.5	0.034 ± 0.004	31.1 ± 17.6	27.2 ± 0.9	0.26 ± 0.05	3.96 ± 0.36	4.4 ± 0.1	120.5 ± 7.9
2014	10	10.0	0.035 ± 0.004	28.6 ± 4.4	19.9 ± 2.07	0.27 ± 0.07	5.45 ± 0.55	3.5 ± 0.3	98.2 ± 11.0
2015	9	7.1	0.03 ± 0.011	26.2 ± 9.8	25.8 ± 2.5	0.16 ± 0.03	5.22 ± 1.39	4.5 ± 0.4	117.7 ± 4.4
2016	8	7.6	0.02 ± 0.007	25.8 ± 14.8	27.6 ± 1.9	0.16 ± 0.04	6.79 ± 2.84	3.68 ± 0.5	117.0 ± 10.9
2017	7	5.6	0.044 ± 0.002	29.8 ± 7.3	25.2 ± 0.89	0.20 ± 0.04	5.86 ± 0.89	4.7 ± 0.2	122.7 ± 46.4
Males									
2006	14	5.8	0.014 ± 0.003	14.0 ± 2.4	25.8 ± 0.49	0.34 ± 0.07	2.58 ± 0.23	3.6 ± 0.1	112.3 ± 3.7
2007	8	4.0	0.033 ± 0.004	11.5 ± 2.9	20.8 ± 0.89	0.39 ± 0.08	4.23 ± 0.57	3.6 ± 0.2	94.2 ± 3.6
2008	11	5.0	0.028 ± 0.003	16.8 ± 2.8	24.4 ± 1.25	0.27 ± 0.03	3.10 ± 0.47	4.1 ± 0.1	105.8 ± 2.6
2009	1		0.040	3.8	22.4	0.36	4.72	3.6	90.0
2011	2	5.5	0.033 ± 0.014	15.3 ± 2.9	22.9 ± 1.28	0.25 ± 0.09	4.77 ± 1.94	4.7 ± 0.5	110.5 ± 2.6
2014	10	6.9	0.041 ± 0.004	19.2 ± 3.9	23.0 ± 3.11	0.18 ± 0.02	5.42 ± 0.68	4.1 ± 0.3	99.9 ± 3.5
2015	9	6.8	0.03 ± 0.011	17.1 ± 7.0	23.9 ± 2.5	0.15 ± 0.07	3.55 ± 1.18	4.3 ± 0.3	114.4 ± 6.2
2016	10	5.6	0.03 ± 0.01	8.0 ± 3.3	25.0 ± 2.3	0.14 ± 0.03	3.66 ± 1.43	3.8 ± 0.4	104.8 ± 9.9
2017	10	4.2	0.043 ± 0.003	17.9 ± 4.0	24.9 ± 1.31	0.24 ± 0.07	4.22 ± 0.49	4.6 ± 0.2	119.5 ± 37.8
Forty-Mile Kidneys; Fall Collected 2017									
Females	2		0.042 ± 0.014	43.9 ± 3.8	28.8 ± 4.14	0.06 ± 0.00	0.61 ± 0.05	3.8 ± 0.4	137.5 ± 97.3
Males	8		0.058 ± 0.009	26.4 ± 4.2	26.2 ± 1.22	0.06 ± 0.01	0.76 ± 0.11	3.7 ± 0.2	119.1 ± 42.1

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, with the recommended maximum varying depending on herd (e.g. a maximum of 25 Porcupine caribou kidneys/year). Heavy metals are very low in the marrow and meat (muscle) from caribou.

Fluorinated compounds

Hepatic concentrations of PFASs are presented for the 2017 collections of the Porcupine, Qamanirjuaq and Forty-Mile herds, along with data from past years (Figure 3). Results for the short-chain PFCAs (perfluorinated carboxylic acids) (C4-C7) are not reported as they are currently being reanalyzed. Concentrations of total long-chain PFCAs (C8-14) have increased steadily from 2015 through 2017 in the Qamanirjuaq caribou in contrast to the Porcupine caribou which experienced a decline in 2017. These trends are driven by C9-11 which, together, make up just over 90% of the long-chain PFCAs. Concentrations of PFSAs (perfluorinated sulfonic acids) are generally declining in both herds, likely due to the implementation of international controls. The Forty-Mile herd had low concentrations of all PFASs as compared with the other two herds. Concentrations of all PFASs are low with respect to potential toxicity to caribou or those consuming caribou.

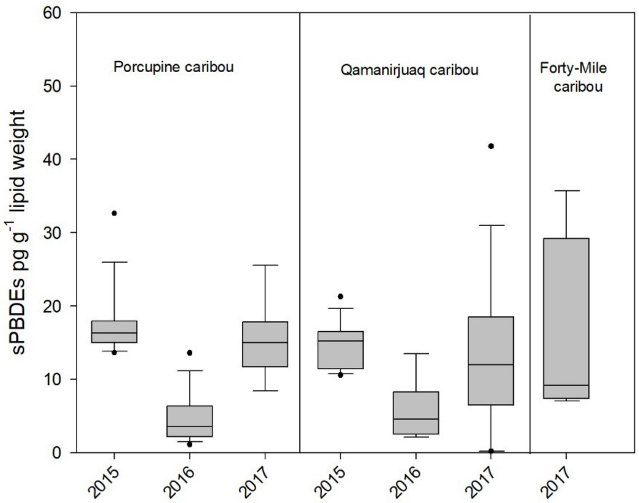
Figure 3. PFCAs (A) and PFSAs (B) in Arctic caribou liver. Error bars represent the 5th and 95th percentile.



Brominated compounds

PBDE results are presented for the 2017 collections of the Porcupine, Qamanirjuaq and Forty-Mile herds, along with data from past years (Figure 4). There is no clear trend in total PBDEs over time in the Porcupine or Qamanirjuaq herds, but with only three years of data, any trend would be difficult to discern. The Forty-Mile caribou had concentrations of PBDEs similar to the other two herds. Concentrations of PBDEs are low with respect to potential toxicity to caribou or those consuming caribou.

Figure 4. PBDEs in Arctic caribou liver. Error bars represent the 5th and 95th percentile.



Data collected from this program continue to provide baseline data for contaminants in Arctic caribou as well as a valuable tissue archive for legacy and emerging contaminants. The ongoing nature of this program provides security and confidence for Northerners using caribou as a food source and acts as an early warning system for wildlife managers. The length and consistency of this program also provides a valuable database for exploring the dynamics of contaminants of concern (e.g. Hg) within the terrestrial ecosystem. This program will continue to collect and analyze samples from the Porcupine and Qamanirjuaq caribou herds (20 animals from each) as well as two additional herds in the coming fiscal year.

Expected project completion date

This program is ongoing.

Acknowledgements

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Community based seawater monitoring for organic contaminants and mercury in the Canadian Arctic

Surveillance communautaire de l'eau de mer à des fins de détection des contaminants organiques et du mercure dans l'Arctique canadien

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Project locations/Emplacements 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)
- Antalâk Fiord in Labrador Sea near Nain, NL (56.4481, -62.0045)

Abstract

This project examines levels and time trends of contaminants in marine waters of Arctic Canada. The project started in May 2014 and built on previous work in Barrow Strait near Resolute in 2011 and 2012, thus presenting the only long-term seawater sampling program in the Arctic, comprising 9 years of data. Seawater samples for mercury, organophosphate ester flame retardants (OPE), and perfluoroalkyl substances (PFAS), were successfully collected from Barrow Strait near Resolute Bay under ice covered conditions (May-June 2018), Cambridge Bay in open water (July to August 2018), and Labrador Sea near Nain (Sept 2018) using Niskin samplers to obtain 1 L samples at various depths. While this method of active sampling is suitable for certain contaminants, passive samplers are used to determine persistent organic pollutants (POPs), specifically polybrominated diphenyl ether flame retardants (PBDEs), polyaromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). The passive samplers are comprised of thin plastic films and were deployed in two locations within Barrow Strait, Allen Bay in May-June 2018 and in Resolute Passage from November 2017 to May 2018 (192 days). Similarly, passive samplers were deployed in Wellington Bay (near Cambridge Bay) in August 2017 and retrieved in August 2018, for sampling over a full year. Two sites were unsuccessful for passive sampler retrieval. The passive sampler deployed in August 2018 in Antalâk Fiord near Nain was discovered to have been removed prior to the intended retrieval date in September 2018. Poor weather and ice conditions prohibited our ability to deploy a sampler in Sachs Harbour (Beaufort Sea) where we typically conduct 30-40 days of sampling in August.

The major findings are that perfluorooctane sulfonate (PFOS) has declined to non-quantifiable levels since the mid-2000s in Barrow Strait. Other PFAS such as perfluorooctanoate (PFOA) have not changed between 2014 and 2018. Total PFAS concentrations are similar between Barrow Strait, Labrador Sea and Cambridge Bay. Akin to PFAS, OPE concentrations were fairly uniform between the three locations with the sum of OPEs ranging

Résumé

Ce projet examine les concentrations et les tendances temporelles des contaminants dans les eaux marines de l'Arctique canadien. Le projet a commencé en mai 2014 et s'appuyait sur des travaux antérieurs dans le détroit de Barrow près de Resolute en 2011 et 2012, constituant ainsi le seul programme d'échantillonnage d'eau de mer à long terme dans l'Arctique, avec 9 années de données. Des échantillons d'eau de mer pour le mercure, les produits ignifuges à base d'esters d'organophospate (EOP) et les substances perfluoroalkylées (PFAS) ont été prélevés avec succès dans le détroit de Barrow près de Resolute Bay dans des conditions de couverture de glace (mai-juin 2018), à Cambridge Bay en eau libre (juillet à août 2018) et dans la mer du Labrador près de Nain (septembre 2018) à l'aide d'échantillonneurs Niskin pour obtenir des échantillons de 1 L à différentes profondeurs. Si cette méthode d'échantillonnage actif convient pour certains contaminants, les échantillonneurs passifs sont utilisés pour déterminer les polluants organiques persistants (POP), en particulier les produits ignifuges à base de polybromodiphényléthers (PBDE), les hydrocarbures aromatiques polycycliques (HAP) et les biphényles polychlorés (BPC). Les échantillonneurs passifs sont composés de films plastiques minces et ont été installés à deux endroits dans le détroit de Barrow, dans la baie Allen en mai-juin 2018 et dans le passage de Resolute de novembre 2017 à mai 2018 (192 jours). De même, des échantillonneurs passifs ont été placés dans la baie de Wellington (près de Cambridge Bay) en août 2017 et récupérés en août 2018, pour un échantillonnage sur une année complète. Nous avons été incapables de récupérer des échantillonneurs passifs à deux sites. Nous avons constaté que l'échantillonneur passif installé en août 2018 dans le fjord d'Antalâk près de Nain avait été retiré avant la date de récupération prévue en septembre 2018. Le mauvais temps et les conditions de glace nous ont empêchés d'installer un échantillonneur à Sachs Harbour (mer de Beaufort) où nous effectuons généralement 30 à 40 jours d'échantillonnage en août.

from 5 to 9 ng/L, however, ongoing sampling is required to evaluate the temporal trend. Mercury concentrations in Barrow Strait (2014-2018) remain unchanged compared to 10 years earlier (2004-2005). This project is continuing in 2019-2020 so that a long-term temporal data set can be developed. This data can be used to predict and better understand the impacts of changing ice, permafrost, and snow on contaminant levels in seawater.

Les principales conclusions sont que le perfluorooctanesulfonate (SPFO) a diminué à des concentrations non quantifiables depuis le milieu des années 2000 dans le détroit de Barrow. D'autres PFAS comme l'acide perfluorooctanoïque (PFOA) n'ont pas varié entre 2014 et 2018. Les concentrations totales de PFAS sont similaires dans le détroit de Barrow, la mer du Labrador et la baie Cambridge. Comme pour le PFAS, les concentrations d'EOP étaient assez uniformes entre les trois endroits, la somme des concentrations d'EOP variant de 5 à 9 ng/L. Cependant, un échantillonnage continu est nécessaire pour évaluer la tendance temporelle. Les concentrations de mercure dans le détroit de Barrow (2014-2018) demeurent inchangées par rapport à il y a 10 ans (2004-2005). Ce projet se poursuit en 2019-2020 afin d'obtenir un ensemble de données temporelles à long terme. Ces données peuvent être utilisées 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 2018; 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.
- Mercury/methylmercury concentrations at Barrow Strait (2014-2018) remain unchanged compared to 10 years earlier (2004-2005).

Messages clés

- Nous avons mesuré les concentrations de nombreux polluants organiques persistants (POP) hérités, 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 plastifiants et produits ignifuges à base d'EOP se sont avérées quasi identiques aux concentrations des produits ignifuges bromés.
- Les concentrations de la plupart des substances perfluoroalkylées (PFAS) analysées n'indiquent aucune tendance temporelle entre 2005 et 2018. Toutefois, les concentrations de SPFO, qui étaient utilisées dans les mousses à formation de pellicule aqueuse pour la lutte contre les incendies, ont diminué au cours de cette période, possiblement en raison des restrictions

- Methylmercury concentrations in seawater build up during the ice-covered period but decrease during the ice-free conditions, likely due to photodemethylation.
- Polycyclic aromatic hydrocarbons (PAHs) are much higher in concentration in the Arctic Archipelago and Labrador Sea (2.4 to 25 $ng \cdot L^{-1}$) compared to earlier reports in the northwestern Arctic and Chukchi Sea (0.030 to 0.090 $ng \cdot L^{-1}$).

internationales en matière de production et d'utilisation.

- Les concentrations de mercure et de méthylmercure dans le détroit de Barrow (2014-2018) demeurent inchangées par rapport à il y a 10 ans (2004-2005).
- Les concentrations de 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.
- Les hydrocarbures aromatiques polycycliques (HAP) sont beaucoup plus concentrés dans l'archipel arctique et la mer du Labrador (2,4 à 25 $ng \cdot L^{-1}$) que dans le nord-ouest de l'Arctique et la mer des Tchouktches (0,030 à 0,090 $ng \cdot L^{-1}$).

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 2018-2019:
- During early melt (May -June), and
- 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/ methylmercury using Niskin samplers in 2018-2019: (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, OPE, and mercury/ methylmercury in order to establish temporal trends in high central Canadian Arctic seawater; and
- finalize 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/methylmercury in Arctic seawater. Seawater samples are collected by community members at Barrow Strait/Lancaster Sound and other Arctic locations (such as Anaktalak Fiord near Nain) using passive samplers, active high volume samplers, and Niskin samplers from both under ice covered conditions (May-June) and 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. Juntunen 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. (2017) 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 2018-2019

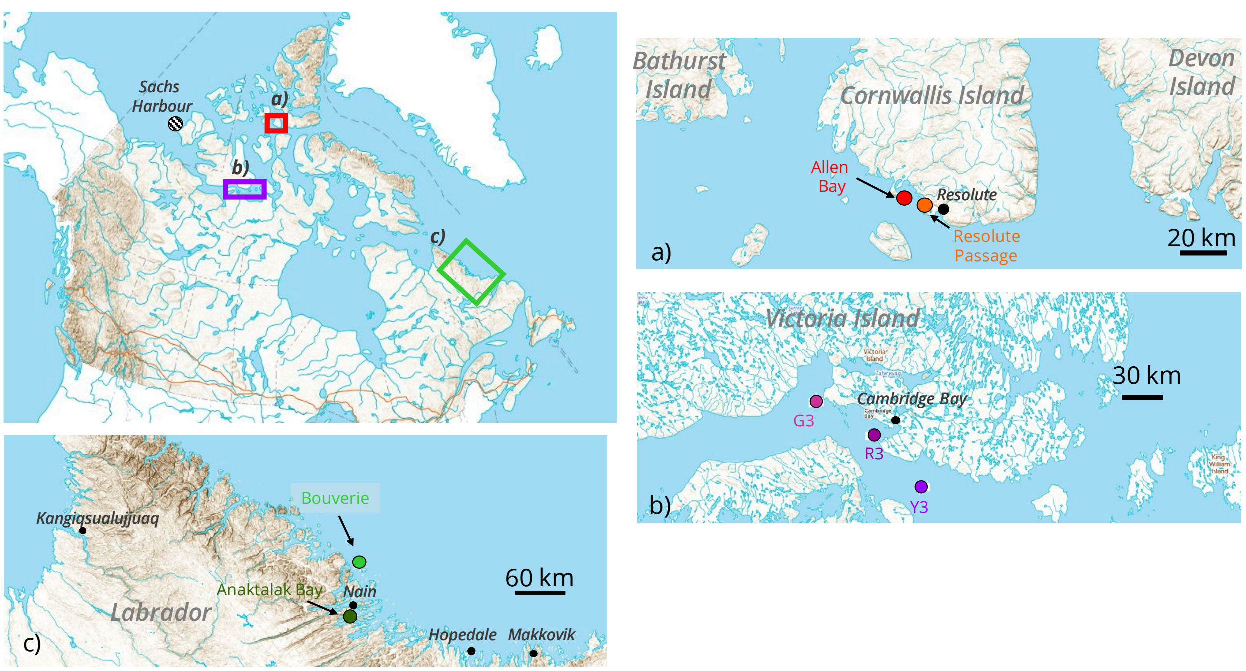
Field work

Seawater samples through active and passive sampling were successfully collected from four locations this year (Table 1, Figure 1). Active sampling using Niskin samplers were used to collect 1 L samples from Barrow Strait near Resolute Bay under ice covered conditions (May-June 2018), Cambridge Bay in open water (July to August 2018), and Labrador Sea near Nain (Sept 2018). This year a depth profile was collected at all of the locations.

Table 1. Sampling activities achieved in 2018.

Location	Coordinates	Depths (m)	2018 date	Analytes
Active sampling				
Cambridge Bay, R3	68.9705°, -105.4714°	2 to 80	July 31	Hg, PFAS, OPE
Cambridge Bay, G3	69.1244°, -106.6102°	2 to 62	August 3	Hg, PFAS, OPE
Cambridge Bay, Y3	68.6893°, -104.4275°	2 to 64	August 7	Hg, PFAS, OPE
Antalâk Bay (Nain)	56.4498°; -61.9878°	2 to 50	Sept 26	Hg, PFAS, OPE
Resolute Passage in Barrow Strait	74.612°, -95.026°	0 to 100	May 29-June 11	Hg, PFAS, OPE
Passive sampling deployment and retrieval: 2 passive samplers per location				
Cambridge Bay, G3 (Wellington Bay)	69.2368°, -106.4468°	4	August 4 deployment for 365 day sampling; Retrieval of 2017 sampler at same time; 365 days	POPs
Nain (Antalâk Bay)	56.4498°, -61.9878°	4	August 16 but were not retrievable 35 days later due to vandalism	POPs
Resolute Passage in Barrow Strait	74.7036°, -95.1216°	4	Deployed Nov 2017 and retrieved May 2018; 192 days	POPs
Allen Bay, Barrow Strait	74.7319°, -95.3689°	4	Deployed May 2018 and recovered in June 2018; 35 days	POPs
Beaufort Sea (Sachs Harbor)	71.9327°, -125.3251°	4	Not deployed due to ice conditions and bad weather	POPs

Figure 1. 2018 Sampling map of seawater in a) Resolute Bay area, b) Cambridge Bay, c) Labrador Sea. Note: 2018 passive sampling was not completed at Sachs Harbour or Anaktalak Bay; Active sampling was not conducted at the Bouverie Island area in Labrador.



Polyethylene passive samplers were deployed in two locations within Barrow Strait, Allen Bay and the Resolute Passage in May 2018. The samplers in Resolute Passage were deployed for 7 months and in Allen Bay for 35 days. Similarly, passive samplers were deployed in Wellington Bay (near Cambridge Bay) in August 2018 for sampling over a full year. Two sites were unsuccessful for passive sampler retrieval. The passive sampler deployed in August 2018 in Antalâk Fiord near Nain was discovered to have been removed prior to the intended retrieval date in September 2018. Poor weather prohibited our ability to deploy a sampler in Sachs Harbour (Beaufort Sea) where we typically conduct 30-40 days of sampling in August.

Sampling in Labrador was conducted by Amber Gleason, Nain community member Liz Pijogge (Nunatsiavut government), Liz's son Donovan Pijogge, and Rudy Riedlsperger (Nunatsiavut government) together with a hired boat driver also from the community.

Sampling in Resolute Bay was conducted by community members Peter Amarualik and son Jeffrey Amarualik. Sampling in Cambridge Bay was conducted by Amber Gleason with assistance from Brent Else. 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 2018. The large volume sampling was done by Peter Amarualik.

Chemical analyses

Samples were distributed to various labs in October 2018 and are being analyzed for several contaminant groups. POPs analyses in passive samplers was conducted by Rainer Lohmann's lab, PFAS and OPE analyses in active samples by Amila De Silva's lab, and Hg (total and methylated) by Jane Kirk's lab.

Community engagement

Team leader, Derek Muir visited the Hunters and Trappers Association (HTA) office in Resolute, Nunavut in July 2018 to update and discuss the project. 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 HTA of Resolute. Nain resident and project team member Liz Pijogge utilized the Nain Research Centre's website and social media, including Twitter and Facebook to reach out to her community of Nain. For example, during the seawater sampling at Nain, live tweets of the field season were posted by Pijogge on the Nain Research Centre twitter feed (@NG_Research) as well as by Kirk, Gleason and De Silva on their twitter feeds (@JaneKirkHg, @amilaods, @ECCCAmber). Liz Pijogge also featured in a seawater sampling protocol video made by Amber Gleason, Liz Pijogge, and Amila De Silva in English and translated to Inuktitut, which includes detailed instruction on using a Niskin water sampler. This video is currently on YouTube (https://www.youtube.com/watch?v=pPY4MDh4RI8).

Capacity building and training

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 2018. Peter also sub-contracted a field assistant to help with work so that there were 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. In addition, a sampling protocol video was made by Amber Gleason and Liz Pijogge in English for instruction on using a Niskin water sampler (https://www.youtube.com/watch?v=pPY4MDh4RI8).

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. Results from this project were also presented at major conferences (1 poster; 1 oral) and in 4 peer-reviewed journal articles:

- Muir, D.C., Houde, M., De Silva, A.O., Kirk, J.L., Butt, C.M., Spencer, C., Williamson, M. Comparison of trends of perfluoroalkyl substances (PFASs) in ringed seals and in seawater across the Canadian Arctic. SETAC North America, Sacramento, California, November 4-8th, 2018 (poster).
- Kirk, J.L., De Silva, A., Muir, D., Lehnherr, I., Spencer, C., Gleason, A., Wang, X., Lohmann, R., Cabrerizo, A., Amarualik Sr., P., Pijogge, L., Morris, A. Seawater Monitoring for organic contaminants and mercury in the Canadian Arctic. ASLO Summer Meeting, Vancouver, BC, June 10-15th, 2018 (oral platform).
- Balmer, J., Morris, A., Hung, H., Jantunen, L., Vorkamp, K., Rigét, F., Evans, M., Houde, M., Muir, D. 2019. Levels and trends of current-use pesticides (CUPs) in the arctic: An updated review, 2010–2018. Emerging Contaminants 5, 70-88.
- Muir, D., Bossi, R., Carlsson, P., Evans, M., De Silva, A., Halsall, C., Rauert, C., Herzke, D., Hung, H., Letcher, R., Rigét, R., Roos, A. 2019. Levels and trends of poly- and perfluoroalkyl substances in the Artic environment – an update. Emerging Contaminants, 5, 240-271.
- Ma, Y., Adelman, D., Bauerfeind, E., Cabrerizo, A., McDonough, C., Muir, D., Soltwedel, T., Sun, C., Wagner, C., Sunderland, E., Lohmann, R. 2018. Concentrations and water mass transport of legacy POPs in the Arctic Ocean. Geophys. Res. Lett. 45, doi.org/10.1029/2018GL078759.
- McDonough, C.A., A. O. de Silva, C. Sun, A. Cabrerizo, D. Adelman, T. Soltwedel, E. Bauerfeind, D.C.G. Muir, R. Lohmann. 2018. Dissolved organophosphate esters and PBDEs in remote marine environments: Fram Strait depth profiles and Arctic surface water distributions. Environ. Sci. Technol. 52, 6208-6216.

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 17 PFAS congeners) concentrations ranged from 0.54 to 0.63 ng·L-1 in 2018 Arctic seawater from Barrow Strait/Lancaster Sound, Anaktalak Bay, and Cambridge Bay (Figure 3). As with previous years, PFBA comprises the majority (42-68%) of the PFAS. In the majority of locations, PFOS remains a very minor component of the total PFAS concentration, likely due to its phase out since the early 2000s. Also shown in Figure 1 are October 2018 data for Iqaluit where water was sampled in Frobisher Bay at the boat launch location. Slightly higher concentrations were observed at this site with a significant contribution of PFOS. This may be due to the influence of the local population. Another regional difference is the detection of 0.082 ng/L perfluoroethylcyclohexanesulfonate (PFECHS), which is mainly used in aircraft hydraulic fluids, in Anaktalak. In all other locations, PFECHS was < 0.01 ng/L. These results are consistent with earlier sampling in Anaktalak which had 1.4 ± 0.2 ng/L PFECHS in 2016 and 0.075 ±0.017 ng/L in 2017. Even further, in the Labrador Sea near Bouverie Island, higher concentrations of PFECHS, 0.046

±0.017 ng/L, compared to seawater sampling in the archipelago. The major usage of PFECHS is in aircraft hydraulic fluid.

Organophosphate ester flame retardants and plasticizers (OPEs)

Analyses of 13 OPEs in Arctic seawater sampled in 2018 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. Total OPEs (∑OPEs) ranged from 5.7 ng·L-1 in Cambridge Bay at site Y3 to 9.1 ng·L-1 in Anaktalak. In 2018, we obtained and analyzed water from lakes located on Cornwallis Island (Figure 4b). In contrast to seawater, lakes from southern Cornwallis Island in the community of Resolute Bay/Qausuittuq had much higher OPE concentrations, particularly Resolute Lake, Char Lake and Merretta Lake, ranging from 47-93 ng·L-1 ∑OPE. OPE concentrations were lower in lakes with less direct human input such as North Lake (21 ng·L-1 ∑OPE), Small Lake (5.1 ng·L-1 ∑OPE), and Amituk (22 ng·L-1 ∑OPE).

Figure 3. Concentrations of PFAS and methylmercury (MeHg) in 2018 sampling of Cambridge Bay (open-water Aug.), Resolute Bay (under-ice May) and Anaktalak Bay (open-water Sept). Concentrations shown here represent the mean of depths from 2 to 100 m (approximately 60 m in Cambridge Bay). For comparison, concentrations determined in Frobisher Bay sampled in October 2018 are presented. Labels indicated the total PFAS concentration. Frobisher Bay/Iqaluit PFAS data provided by Zou Zou Kuzyk for comparison purposes.

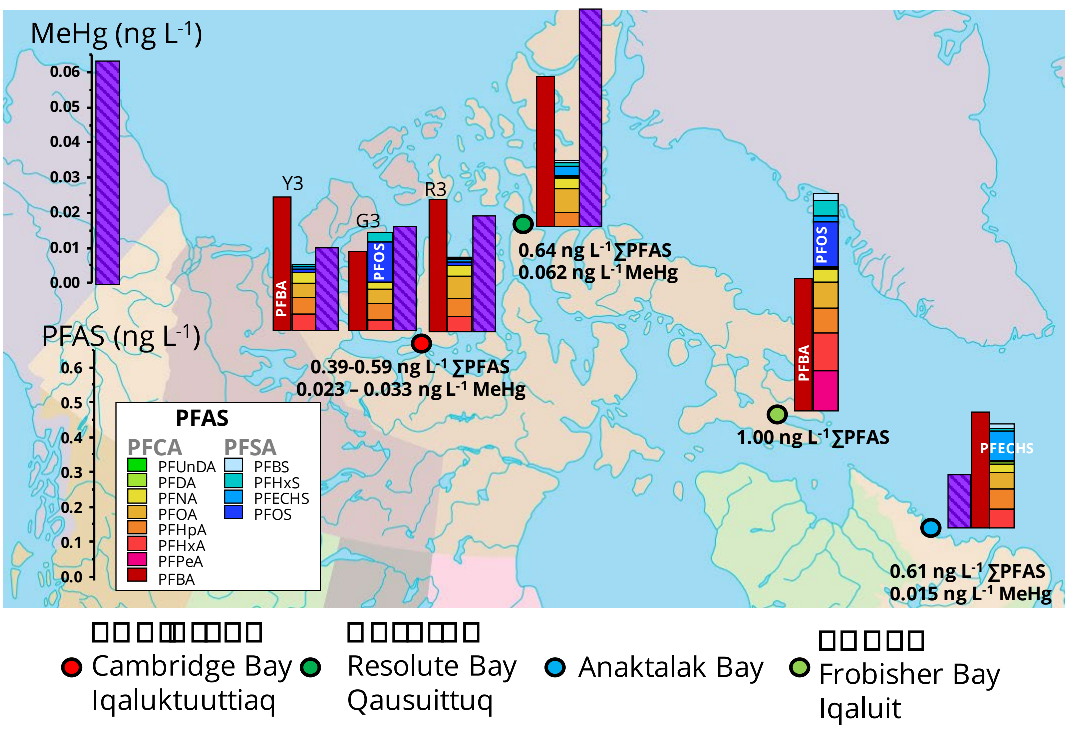
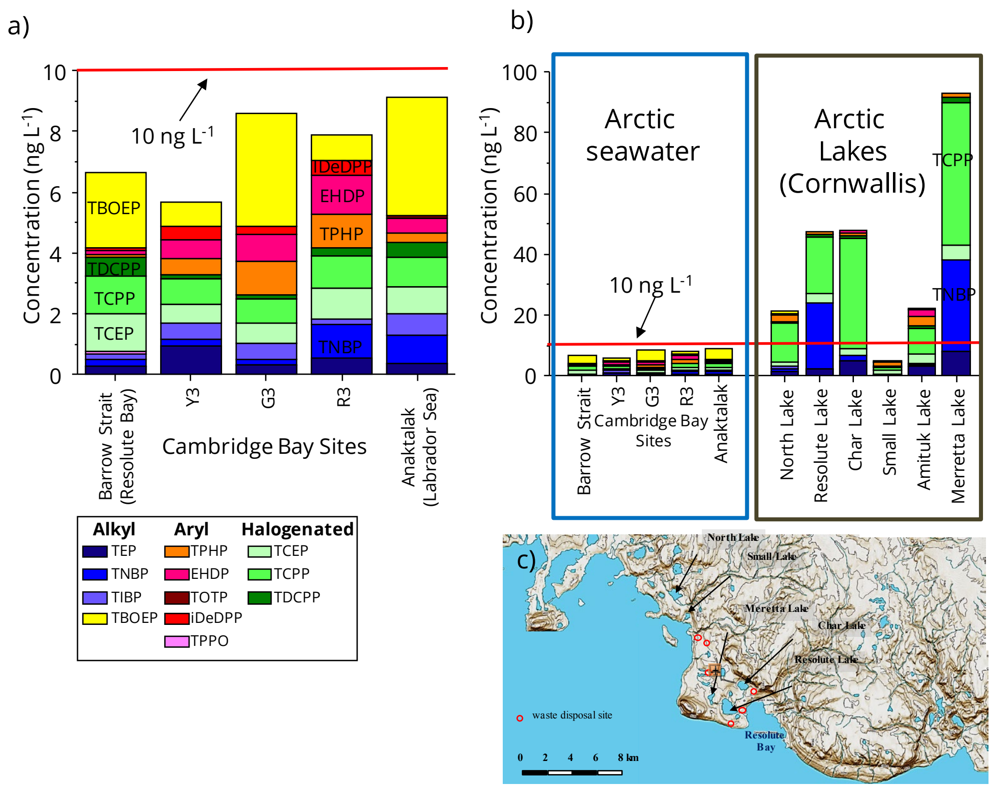


Figure 4. a) Concentrations of OPEs in 2018 sampling of Cambridge Bay (Aug.), Resolute Bay (May) and Anaktalak Bay (Sept). Concentrations shown here represent the mean of depths from 2 to 100 m (approximately 60 m in Cambridge Bay). For comparison, concentrations determined in lakes located on Cornwallis Island sampled in August 2018, are presented in panel b). Map of lake locations on Cornwallis Island are shown in panel c). Data for OPEs in Arctic Lakes were provided by D. Muir.

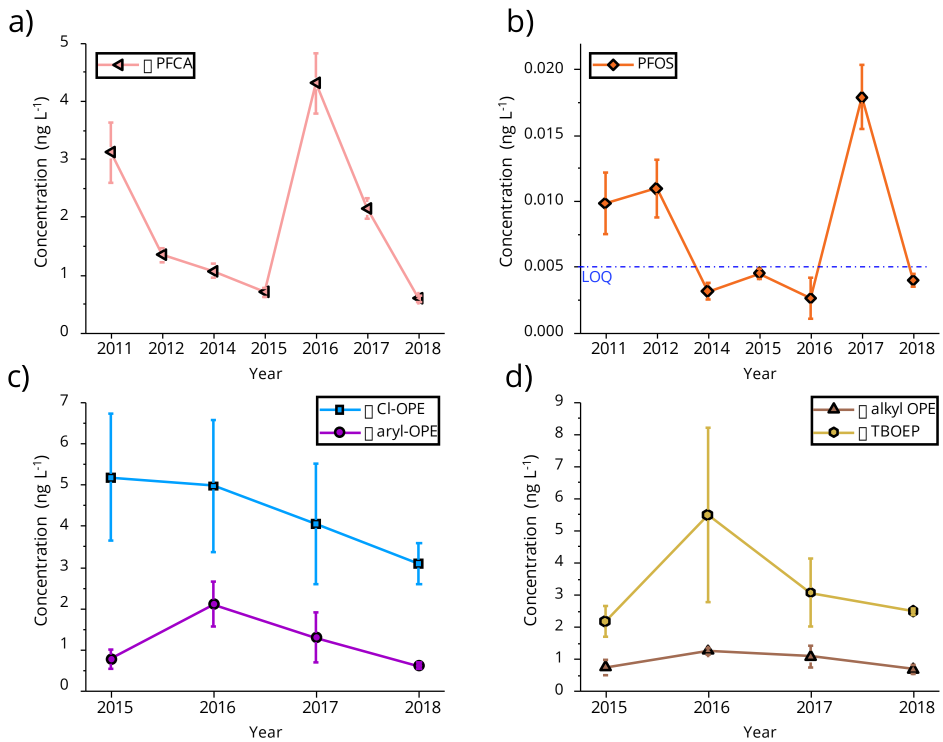


Temporal Trends in PFAS and OPEs

Adding to our growing data set, we continue to conduct temporal trend analysis (Figure 5). In fact, PFOS levels measured in May 2014-2016 corresponded to 0.0036, 0.0046, and 0.0034 ng/L, as did May 2018, 0.0040 ± 0.0005 ng/L. These concentrations are all below the limit of quantitation (0.005 ng/L). An exception is the 2017 sampling period which indicated higher levels of PFOS (0.018 ng/L), which appears to be an anomalous year. On the whole, the decreasing PFOS concentrations could be a result of international restrictions on production and usage of it and its precursors.

Perfluorocarboxylates (PFCAs) are more prevalent than PFOS in Barrow Strait (Figure 4a). The total PFCA (∑PFCA) concentrations in 2018 in Barrow Strait ranged from 0.50 ng/L at 100 m to 0.94 ng/L at the surface in May, and is largely comprised of perfluorobutanoic acid (PFBA). Perfluorooctanoate (PFOA) is lower relative to concentrations in 2011 and 2012 but show little change in the last 4 years. PFOA concentrations corresponded to 0.30 ng/L in 2011, 0.15 ng/L in 2012, 0.036 ng/L in 2014, 0.087 ng/L in 2015, 0.15 ng/L in 2016, 0.057 ng/L in 2017 and 0.067 ng/L in 2018 in under-ice sampling of Barrow Strait. Our previous research on snow and ice in Lake Hazen and Devon Island have shown a high concentration of PFCAs in annual snow accumulation, suggesting on-going inputs of PFAS via atmospheric deposition.

Figure 5. Concentrations of the organic contaminants in Barrow Strait/Lancaster Sound near Resolute Bay from 2011 to 2018. Mean ± standard error concentrations from 2 to 100 m depths sampled under ice in May. Panel a) Concentrations of perfluoroalkyl carboxylates (PFCA) consisting of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA. Panel b) Concentrations of perfluorooctane sulfonate (PFOS). Panel c) Concentration of total chlorinated organophosphate ester (∑Cl-OPE) congeners consisting of TDCPP, TCPP, and TCEP. Also plotted are the sum of aryl organophosphate esters (∑aryl-OPE) comprised of TPPO, IDDPP, TBPDPP, EHDPP, TPPO, and TPHP. Panel d) Concentrations of total alkyl OPEs excluding TBOEP (i.e. TEP, TNBP, TIBP) and TBOEP plotted separately. Full list of acronyms in Table A-1 in the Appendix.



We began analyzing for OPEs in Resolute Bay seawater in 2015. We present temporal data of OPEs from 2015 to 2018 in Figures 4c and 4d. With only 4 years of sampling, it is likely too soon to determine changes in OPE concentrations. However, in 2016, Environment and Climate Change Canada and Health Canada released a draft risk assessment of TDCPP and TCPP (two of the three Cl-OPEs measured in this project) and proposed that TDCPP did not pose an ecological or human health risk, however, TCPP was prioritized for management due to concerns of toxicity and exposure to humans. The proposed measures to reduce TCPP exposure include reducing TCPP to lower levels in consumer products, specifically mattresses and upholstered furniture. Similarly, in 2018, the European Chemicals Agency also proposed restricting TCPP as well as TCEP and TDCP. Thus, continued monitoring of these substances in the Arctic marine environment is a priority in this project.

Mercury (Hg)

Depth profiles of total mercury (total Hg; all forms of Hg in a sample abbreviated THg) 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 2014-2017 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 6). The August depth profile has lower methylated Hg concentrations at the surface (0-10 m) compared to the rest of the water column. For example, in August 2017, the methylated Hg concentrations at 0-10 m corresponded to 33-39 pg/L MeHg whereas at depths 25-100 m, MeHg was 104±24 pg/L. This suggests methylated Hg species build up over the winter under the ice and after ice melt in open waters, photodemethylation occurs.

Concentrations of methylated Hg were much lower in open water conditions in Cambridge Bay and Antalâk Bay near Nain in 2017 and 2018 than at our Barrow Strait location (Figure 3). This data is thus allowing us to begin to assess both temporal and spatial trends in seawater Hg concentrations in the Canadian Archipelago.

Polycyclic aromatic hydrocarbons (PAHs), Polybrominated diphenyl ethers (PBDEs)

Passive sampling in 2017 in Sachs Harbour, Cambridge Bay, Resolute and Nain indicated comparable concentrations of polycyclic aromatic hydrocarbon (PAH) concentrations in the Arctic Archipelago, but concentrations in order of magnitude higher in Antalâk Bay near Nain (Figure 7). Due to vandalism of the passive sampler deployed in 2018, these results in Nain could not be confirmed the following year; however, 2018 passive sampling in Cambridge Bay and Resolute yielded similar results: 2,500 and 1600 pg·L-1 ΣPAHs, respectively. On the whole, the 2017 and 2018 PAC concentrations in this project are much higher than previous reports by Lohmann et al. in the northwestern Arctic, 90±7 pg/L Σ9PAHs, from Norway to Greenland and by Ma et al. in the Chukchi Sea, 31 ± 2 pg/L Σ16PAHs. 2017 and 2018 polybrominated diphenyl ether (PBDE) concentrations were low in all sites: ΣPBDE were 0.094 pg/L in Sachs Harbour, 1.7 pg/L in Cambridge Bay, 1.4 pg/L in Resolute and 0.039 pg·L-1 in Nain. Continued passive sampling in these locations will be necessary to track spatial and temporal trends of POPs in Arctic seawater.

Figure 6. Vertical profiles of total mercury (left) and methylated mercury (right) profiles in Barrow Strait (2014-2016) and comparison with earlier measurements from St Louis et at. 2007 and Kirk et al. 2012.

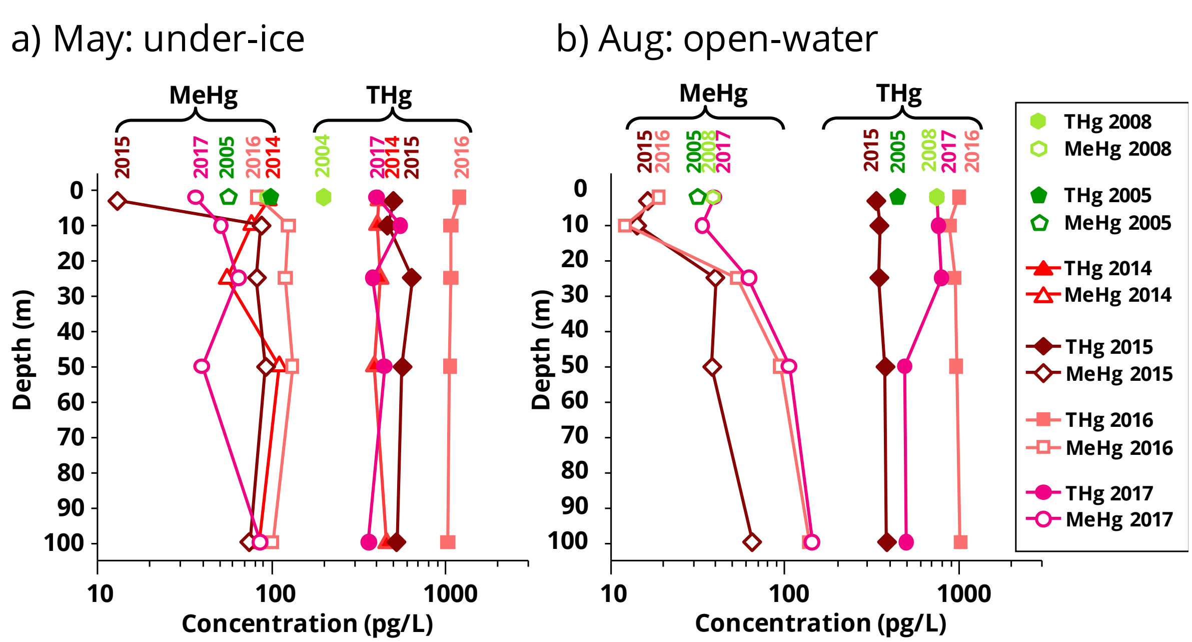
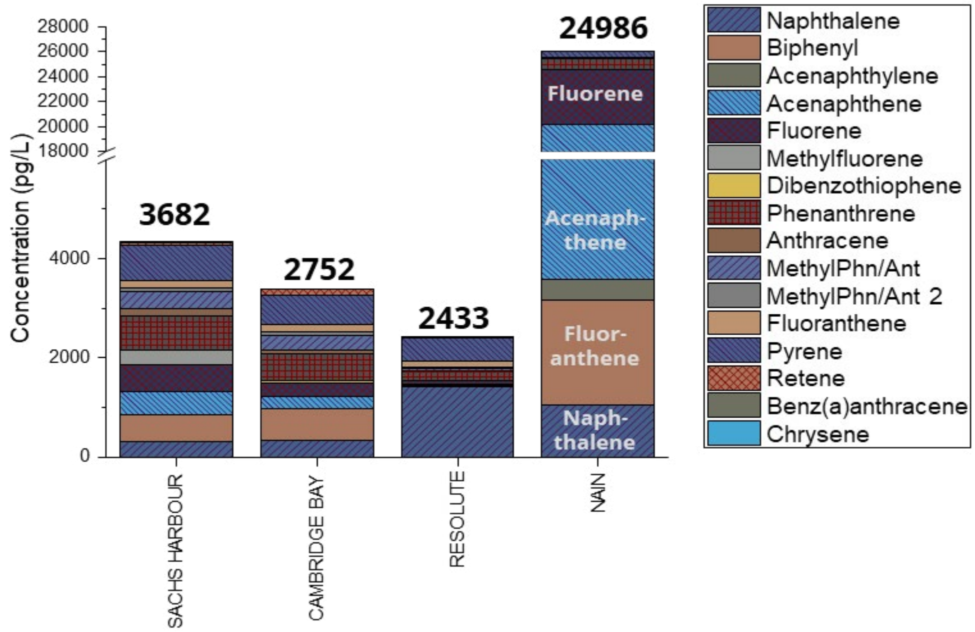


Figure 7. Concentrations (pg/L) of PAC congeners in Sachs Harbour, Cambridge Bay, Resolute and Nain via 2017 passive sampling. Numbers in bold represent total PAH concentration.



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.

References

Baya, P. A., Gosselin, M., Lehnherr, I., St Louis, V.L., and Hintelmann. H. 2014. Determination of monomethylmercury and dimethylmercury in the Arctic marine boundary layer. Environ. Sci. Technol. 49(1):223-32.

Heimbürger, L. E., Sonke, J. E., Cossa, D., Point, D., Lagan, C., Laffont, L., Galfond, B. T., Nicolaus, M., Rabe, B., and M. R. van der Loeff. 2015. Shallow methylmercury production in the marginal sea ice zone of the central Arctic Ocean. *Sci Rep*. 5:10318.

Kirk, J. L., I. Lehnherr, M. Andersson, B. M. Braune, L. Chan, A. P. Dastoor, D. Durnford,

A. L. Gleason, L. L. Loseto, A. Steffen and V. L. St. Louis. 2012. Mercury in Arctic marine ecosystems: Sources, pathways and exposure. *Environ. Res.* 119: 64-87.

Jantunen, L. 2014. Polycyclic Aromatic Compounds, Flame Retardants and Other Persistent organic pollutants in air in the Canadian archipelago. In: *Synopsis of Research Conducted under the 2013–2014 Northern Contaminants Program.* Ottawa: Aboriginal Affairs and Northern Development Canada. 329-339 pp.

Jantunen, L. M., A. Gawor, F. Wong, T. F. Bidleman, F. Wania, G. A. Stern, M. Pucko and H. Hung .2015. Organophosphate Ester Flame Retardants and Plasticizers in the Canadian Arctic. Presented at SETAC North Americaa. Salt Lake City, UT.

Jantunen, L. M., F. Wong, A. Gawor, H. Kylin, P. A. Helm, G. A. Stern, W. M. J. Strachan, D. A. Burniston and T. F. Bidleman. 2015. 20 Years of Air–Water Gas Exchange Observations for Pesticides in the Western Arctic Ocean. *Environ. Sci. Technol.* 49(23): 13844–13852.

Li, J., Xie, Z., Mi, W., Lai, S., Tian, C., Emeis, K-C., Ebinghaus, R. 2017. Organophosphate esters in air, snow, and seawater in the North Atlantic and the Arctic. Environ. Sci. Technol. 51: 6887-6896.

Lohmann, R., et al., *Organochlorine Pesticides and PAHs in the Surface Water and Atmosphere of the North Atlantic and Arctic Ocean.* Environmental Science & Technology, 2009. 43: p. 5633-5639.

Ma, Y., et al., *Deposition of polycyclic aromatic hydrocarbons in the North Pacific and the Arctic.* Journal of Geophysical Research: Atmospheres, 2013. 118(11): p. 5822-5829.

McDonough, C.A., de Silva, A. O., Sun, C., Cabrerizo, A., Adelman, D., Soltwedel, T., Bauerfeind, E., Muir, D.C.G., Lohmann, R. 2018. Dissolved organophosphate esters and PBDEs in remote marine environments: Fram Strait depth profiles and Arctic surface water distributions. *Environ. Sci Technol,* 52, 6208-6216

Morris, A. D., D. C. G. Muir, K. R. S. Solomon, R. J. Letcher, A. T. Fisk, B. McMeans, M. McKinney, C. Teixeira, X. Wang, M. Duric and P. Amarualik. 2018. Distribution of organohalogen flame retardants in seawater and trophic transfer in ringed seal (Pusa hispida) food chains from the Canadian arctic. *In preparation*

Morris, A.D., Muir, D.C.G., Solomon, K.R.S., Letcher, R. J., McKinney, M.A, Fisk, A.T., McMeans, B.C, Teixeira, C., Wang, X., Duric, M. 2016. Current-use pesticides in seawater and their bioaccumulation in polar bear-ringed seal food chains of the Canadian Arctic. *Environ, Toxicol. Chem.* 35(7):1695-707.

St Louis,V. L., Hintelmann, H., Graydon, J. A., Kirk, J. L., Barker J., Dimock, B., Sharp, M. J., Lehnherr, I. 2007. Methylated mercury species in Canadian high Arctic marine surface waters and snowpacks. *Environ. Sci. Technol.* 41(18):6433-41.

St. Pierre, K., St. Louis, V.L., Kirk, J.L., Lehnherr, I., Wang, S., La Farge, C. 2016. The importance of open marine waters to the enrichment of total and monomethylmercury in lichens in the Canadian high Arctic. *Environ. Sci. Technol.* 49: 5930-8.

Sühring, R., Diamond, M.L, Scheringer, M., Wong, F., Pucko, M., Stern, G., Burt, A., Hung, H., Fellin, P., Li, H., Jantunen, L.M. 2016. Organophosphate esters in Canadian Arctic Air: Occurrence, levels and trends. *Environ. Sci. Technol.* 50: 7409–7415.

Yeung, L.W.Y., Dassuncao, C., Mabury, S., Sunderland, E.M., Zhang, X., Lohmann, R. 2017. Vertical profiles, sources, and transport of PFASs in the Arctic Ocean. *Environ. Sci. Technol.* 51: 6735-6744.

Appendix

Table 1. Contaminant classes and acronyms.

Category and acronym	Full name	Uses
1. Perfluoroalkyl substances (PFAS)		
i. Perfluoroalkyl carboxylic acids (PFCAs)		
a. PFBA	Perfluorobutanoic acid	PFAS (i.e. PFCAs and PFSAs) are environmentally persistent surfactants used in paper, textiles, furniture, fluoropolymer manufacturing, fire-fighting foams, metal plating, etc. PFCAs and PFSAs are also degradation products of other fluorochemicals
b. PFPeA	Perfluoropentanoic acid	
c. PFHxA	Perfluorohexanoic acid	
d. PFHpA	Perfluoroheptanoic acid	
e. PFOA	Perfluorooctanoic acid	
f. PFNA	Perfluorononanoic acid	
g. PFDA	Perfluorodecanoic acid	
h. PFUnDA	Perfluoroundecanoic acid	
i. PFDoDA	Perfluorododecanoic acid	
j. PFTrDA	Perfluorotridecanoic acid	
k. PFTeDA	Perfluorotetradecanoic acid	
ii. Perfluoroalkyl sulfonic acids (PFSAs) and related		
a. PFBS	Perfluorobutane sulfonate	
b. PFHxS	Perfluorohexane sulfonate	
c. PFOS	Perfluorooctane sulfonate	
d. PFDS	Perfluorodecane sulfonate	
e. PFECHS	Perfluoro-ethyl-cyclohexane sulfonate	
f. FOSA	Perfluorooctane sulfonamide	
2. Organophosphate ester flame retardants and plasticizers (OPEs)		
i. chlorinated OPEs (Cl-OPE)		OPEs are flame retardants and plasticizers used in building materials, hydraulic fluids, plastics, lubricants, floor polish, lacquers, rubber, textiles.
a. TCPP	tris(2-chloroisopropyl)phosphate	
b. TDCPP	tris(1,3-dichloro-2-propyl)phosphate	
c. TCEP	Tris(2-chloroethyl) phosphate	
ii. aryl OPEs (aryl-OPE)		
a.TPHP	Triphenyl phosphate	
b. IDDPP	Isodecyldiphenyl phosphate	
c. TPPO	Triphenyl phosphine	
d. EHDPP	Ethylhexyldiphenyl phosphate	
e. DTBPPP	Di(tertbutylphenyl)phenyl phosphate	
f. TBPDPP	Tertbutylphenyl(diphenyl) phosphate	
iii. alkyl OPE (alkyl-OPE)		
a. TEP	Triethyl phosphate	
b. TNBP	Tri-n-butyl phosphate	
c. TIBP	Tri-iso-butyl phosphate	
d. TBOEP	Tris-butoxyethyl phosphate	

Assessing persistent organic pollutants (POPs) in Canadian Arctic air and water as an entry point into the Arctic food chain

Évaluation des polluants organiques persistants dans l'air et l'eau de l'Arctique canadien en tant que vecteurs d'entrée dans la chaîne alimentaire de l'Arctique

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Project locations/Emplacements du projet

Sampling took place on board the CCGS Amundsen in Hudson Bay between Churchill and Iqaluit, Leg 2a, see Figure 1; and the Central and Eastern Archipelago Leg 3, see Figure 2. Additionally, samples were taken in the Western Archipelago and Beaufort Sea from on board the CCGS Laurier, see Figure 3.

Abstract

In collaboration with ArcticNet, air, water, sediment and zooplankton samples were collected in the Canadian Archipelago during the summer of 2018. These samples were collected from on board the CCGS Amundsen in Hudson Bay and the central and eastern archipelago. Additional samples were collected in the western archipelago and the Beaufort Sea from on board the CCGS Wilfrid Laurier. These samples were collected to determine the occurrence and levels of persistent organic pollutants and to determine their spatial and

Résumé

En collaboration avec ArcticNet, des échantillons d'air, d'eau, de sédiments et de zooplancton ont été prélevés dans l'archipel canadien au cours de l'été 2018. Ces échantillons ont été prélevés à bord du NGCC Amundsen dans la baie d'Hudson et dans le centre et l'est de l'archipel. D'autres échantillons ont été prélevés dans l'archipel occidental et dans la mer de Beaufort à bord du NGCC Wilfrid Laurier. Ces échantillons ont été prélevés pour déterminer la présence et les concentrations de polluants organiques

temporal trends. The set of compounds that this report focuses on are organophosphate esters. These compounds are flame retardants and plasticizers. They are found in very high levels in Arctic air, water and sediment in comparison to the brominated flame retardants. Samples were also collected to determine the occurrence and levels of microplastics in water, sediment and zooplankton. A northern student from Rankin Inlet who attends Nunavut Arctic College in Iqaluit, was recruited and spent 10 days on board the Amundsen. While on board she learned how samples are collected for both persistent organic pollutants and microplastics. Samples are collected in the following ways:

- the air sampler is run for the entire cruise, where the filters are changed every two days;
- two types of water samples are collected, grab samples and passive samples. Grab samples are taken at the ocean surface and passive samples are taken using passive samplers at a depth attached to moorings that are deployed and left for a year. In 2018, we retrieved and deployed some passive water samplers in the Beaufort Sea, retrieved samplers from Cambridge Bay and Davis Strait and deployed samplers in Hudson Bay;
- sediment was collected with a box corer and the top 0-5cm was kept for analysis; and
- zooplankton samples were collected using Tucker nets, they were sorted and speciated while on the ship.

As part of the engagement and communication aspects of this project I visited Nunavut Arctic College in February 2018, taught a course on air and water sampling for persistent organic pollutants, this included classroom and hands-on sessions. I also visited Cambridge Bay in September 2018 with the Environment Minister, during this trip, I was able to engage and consult with many members of the community including a high school class, the mayor, the heritage society, the youth council and scientists at the CHARS facility.

persistants et pour déterminer leurs tendances spatiales et temporelles. Le présent rapport porte sur le groupe de composés appelés esters d'organophosphate. Ces composés sont des produits ignifuges et des plastifiants. On les trouve en plus grandes quantités dans l'air, l'eau et les sédiments de l'Arctique que les produits ignifuges bromés. Des échantillons ont également été prélevés pour déterminer la présence et les concentrations de microplastiques dans l'eau, les sédiments et le zooplancton. Une étudiante de Rankin Inlet, qui fréquente le Collège de l'Arctique du Nunavut à Iqaluit, a été recrutée et a passé 10 jours à bord de l'Amundsen. À bord, elle a appris comment prélever les échantillons pour les polluants organiques persistants et les microplastiques. Les échantillons sont prélevés de la manière suivante :

- l'échantillonneur d'air est utilisé pendant toute la croisière, et les filtres sont changés tous les deux jours;
- deux types d'échantillons d'eau sont prélevés : des échantillons instantanés et des échantillons passifs. Les échantillons instantanés sont prélevés à la surface de l'océan et les échantillons passifs sont prélevés à l'aide d'échantillonneurs passifs à une profondeur fixée à des amarres qui sont jetées et laissées en place pendant un an. En 2018, nous avons récupéré et jeté quelques échantillonneurs d'eau passifs dans la mer de Beaufort, récupéré des échantillonneurs à Cambridge Bay et dans le détroit de Davis et jeté des échantillonneurs dans la baie d'Hudson;
- les sédiments ont été prélevés à l'aide d'un carottier à boîte et les 0-5 cm supérieurs ont été conservés pour analyse;
- des échantillons de zooplancton ont été prélevés à l'aide de filets Tucker, ils ont été triés et différenciés à bord du navire.

Dans le cadre des activités de mobilisation et de communication pour ce projet, j'ai visité le Collège de l'Arctique du Nunavut en février 2018, j'ai donné un cours sur l'échantillonnage de l'air et de l'eau pour les polluants organiques persistants, qui comprenait des cours en classe et des séances pratiques. J'ai également visité Cambridge Bay en septembre 2018 avec le ministre de l'Environnement. Au cours de ce voyage, j'ai pu mobiliser et consulter de nombreux membres de la collectivité, y compris une classe de l'école secondaire, le maire, la société du patrimoine, le conseil des jeunes et les scientifiques de l'installation CHARS.

Key messages

- Air, water (grab and passive), sediment and zooplankton samples were successfully collected from on board the CCGS Amundsen in the Hudson Bay and Central and Eastern Archipelago during the summer of 2018.
- Air and water (passive and grab) samples were collected from on board the CCGS Wilfrid Laurier in the Beaufort Sea.
- Air, water, sediment and zooplankton samples will be analysed for toxic contaminants including persistent organic pollutant on the Stockholm Convention list and the Chemical Management Plan priority compounds of emerging concern including the organophosphate esters. Additionally, selected water and sediment samples will be analysed for microplastics.
- Data will help establish trends for compounds of emerging Arctic concern, including the organophosphate esters and microplastics, and continues to monitor for trends of banned or restricted compounds.
- Generally, compounds banned under national and international regulations, such as the Stockholm Convention, are declining in Arctic air and water, whereas compounds currently being used are staying the same or in some cases increasing.
- Microplastics were found in all sample media including surface water, zooplankton and sediments in very deep regions of the Canadian Arctic.

Messages clés

- Des échantillons d'air, d'eau (instantanés et passifs), de sédiments et de zooplancton ont été prélevés avec succès à bord du NGCC Amundsen dans la baie d'Hudson et dans l'archipel central et oriental au cours de l'été 2018.
- Des échantillons d'air et d'eau (passifs et instantanés) ont été prélevés à bord du NGCC Wilfrid Laurier dans la mer de Beaufort.
- Les échantillons d'air, d'eau, de sédiments et de zooplancton seront analysés pour détecter les contaminants toxiques, notamment les polluants organiques persistants figurant sur la liste de la Convention de Stockholm et les composés prioritaires du Plan de gestion des produits chimiques, dont les esters d'organophosphate. En outre, des échantillons d'eau et de sédiments sélectionnés seront analysés pour détecter la présence de microplastiques.
- Les données aideront à établir des tendances pour les composés émergents préoccupants dans l'Arctique, notamment les esters d'organophosphate et les microplastiques, et nous continuerons de surveiller les tendances des composés interdits ou limités.
- En général, les composés interdits par la réglementation nationale et internationale, telles que la Convention de Stockholm, diminuent dans l'air et l'eau de l'Arctique, alors que les composés actuellement utilisés restent les mêmes ou, dans certains cas, augmentent.

- Des microplastiques ont été trouvés dans tous les milieux d'échantillonnage, y compris les eaux de surface, le zooplancton et les sédiments dans les régions très éloignées de l'Arctique canadien.

Objectives

The short-term objectives of this project are to:

- measure levels of persistent organic pollutants (POPs) and microplastics in Canadian Arctic air, water, sediment and zooplankton;
- deploy passive water samplers in multiple locations in the Canadian Arctic;
- screen for new and emerging compounds of concern, including microplastics in the Canadian Arctic; and
- provide environmental sampling training to northern students.

Long-term objectives for this project are to:

- develop spatial and temporal trends for POPs and emerging compounds of concern including microplastics in Arctic air, water, sediment and zooplankton; and
- continue the passive water monitoring network on moorings in the Canadian Arctic and to be an on-going site for the AQUA-GAPS a global passive water sampling network.

Introduction

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 controlled chemicals of which Canada is a signatory. Monitoring the levels of compounds in the environment is Canada's contribution to the Stockholm Convention's Global Monitoring Plan. Additionally, many of the emerging target compounds are on Canada's Chemical Management Plan priority compound lists or "up and coming" priority lists, and/or have been identified by the Arctic Monitoring and Assessment Program (AMAP). Microplastics have recently been shown to undergo long-range transport from source regions, although transport pathways are unclear and limited information is available for all media in remote regions, including the Canadian Arctic. Consequently, the Canadian Northern Contaminants Program (NCP) and the Arctic Monitoring and Assessment Programme (AMAP) have added "Marine Plastics and Microplastics" to their list of Chemicals of Emerging Arctic Concern (AMAP, 2017). Canada is addressing this concern regarding plastics by signing the G7 Plastics Charter and initiating the Canada's Plastic Science Agenda (CaPSA).

Activities in 2018-2019

We were very successful at collecting samples in many locations in the Canadian Archipelago for both microplastics and contaminants. Most sampling for this project took place on board Canadian Coast Guard ships, except the passive water sampling in Cambridge Bay. See Figure 1-3 for sampling locations. We were unable to retrieve and redeploy some of the passive water samplers in the Beaufort Sea due to heavy ice cover. During 2018-2019, applications for ArcticNet were renewed and our project was funded for five years starting April 2019.

Figure 1. Sampling locations from on board the CCGS Amundsen, Leg 2a.

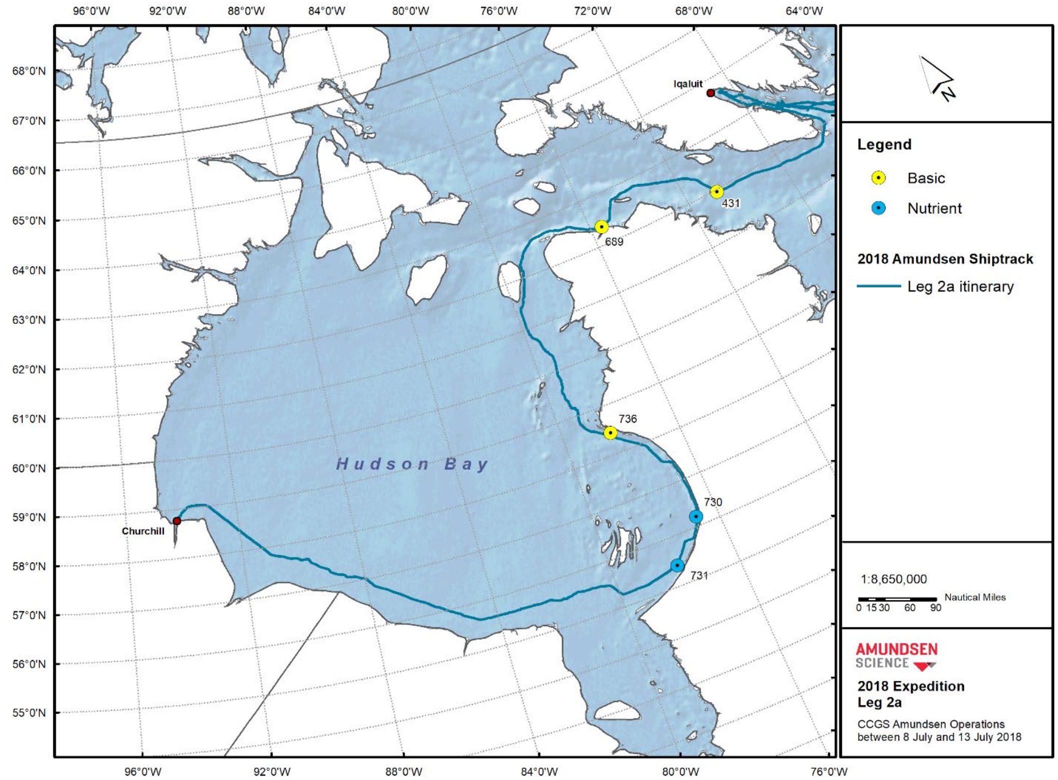


Figure 2. Sampling locations from on board the CCGS Amundsen during Leg 3.

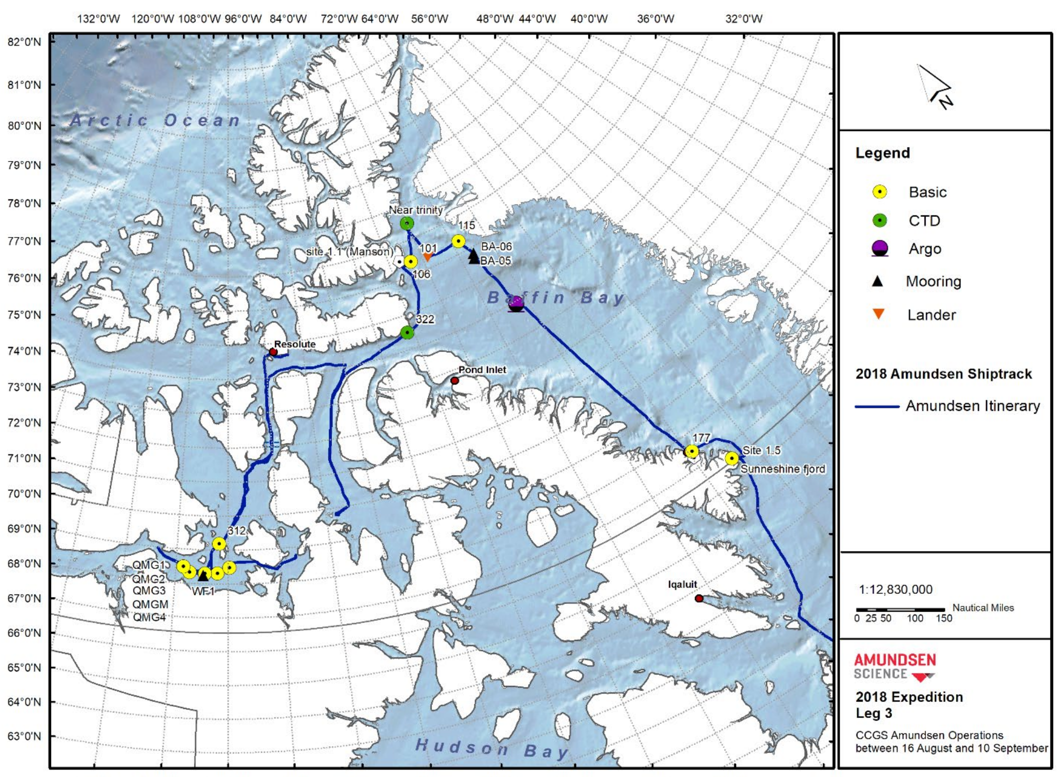
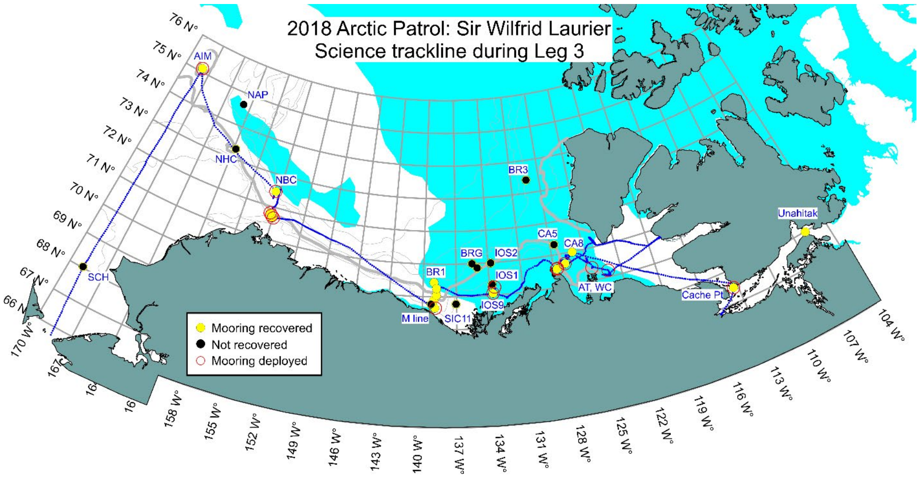


Figure 3. Sampling locations from on board the CCGS Laurier.



Northern engagement, communications, capacity building and Indigenous Knowledge

During 2018-2019, we worked hard to engage Northerners, build capacity and communicate our results to northern communities. We accomplished this by meeting with Northerners and the Regional Contaminants Committees (RCCs) in several communities.

In February 2019, I visited Nunavut Arctic College in Iqaluit, which is a follow up to previous visits in 2014, 2016 and 2017. Along with Hayley Hung and Sandy Steffen, I gave a presentation on my work at Nunavut Arctic College Environmental Technology Class. This presentation included a summary of my results and a hands-on demonstration of how air and water are sampled, processed and analyzed for contaminants and microplastics.

While in Iqaluit, we also met with the NECC to discuss current and projects for the coming year and to get suggestions on how to better engage with communities and incorporate Indigenous Knowledge into our work. I have also stayed in contact with Eric Leonard and more recently, Emma Pike of the NWT-RCC, to keep them informed about the community engagement and capacity building activities I have completed and have planned for the coming year. Eric planned to discuss this project with the NWT-RCC.

During the summer of 2018, Nicole Ymana, a student from Nunavut Arctic College who lives in Rankin Inlet, participated in the ArcticNet cruise. She was trained on air, water, sediment and zooplankton sample collection for contaminants. She was also trained on sample collection of water, sediment and zooplankton for microplastics. Nicole was very engaged with the project. She indicated on a questionnaire that she completed while on the cruise, that she would take the knowledge she gained back to her community. She was offered additional materials to help with this. She has also posted her experience on her personal Facebook site.

I visited Cambridge Bay in September 2018. While there, I spoke to the mayor, town administrator, Elders, leaders of local Inuit organizations, the youth counsel, and a group of high school students. I also attended a Kitikmeot Heritage Society meeting and visited a workplace where the youth are learning a trade. The community expressed concerns about contaminants from the old Distant Early Warning (DEW) line site, the airport, the drinking water quality, the burning of diesel, and the disposal of garbage. The chief scientist of CHARS, Dr. Martin Raillard, indicated that a survey of the community had been done in which 25% of the population responded. The survey asked about concerns in the community. The responses indicated that contaminants were in the top 10. The report is not yet available.

Also while in Cambridge Bay, I asked more general questions about changes that residents observed in the air and snow, e.g., if there was more brown snow? Have you observed changes in the occurrence of brown snow? They responded that they observed brown snow sometimes but the frequency of observations has not changed. I asked if they have observed changes in the air, i.e., was visibility or other characteristics changing over time? The community members did not recall such changes. I was fortunate to be traveling with the Federal Environment Minister, Catherine McKenna and people were eager to speak to this group which is not always the case, even when plans are made well in advance. This trip was made on very short notice due to rescheduling from Gjoa Haven to Cambridge Bay. I attempted to arrange to visit the college but the college students had just begun their fall terms and were out on the field portion of their course. This trip to Cambridge Bay was not funded by NCP but it turned into a really great opportunity to engage with the community.

While on board the CCGS Laurier cruise in the fall of 2018, residents of Ulukhaktok, NWT were invited onboard the ship for a tour and to learn about the science processes that took place on board. My student on board, Sarah Bernstein, provided detailed information on what we were sampling, and the contaminants we were measuring. The demonstration involved walking participants through air and water sampling processes, and a discussion of the contaminants of interest.

We also developed a pamphlet, and had it reviewed by the NECC, NWT-RCC and the NCP management. The pamphlet was translated into four languages and will be distributed in the coming year. While in Inuvik in October 2017, we gave a presentation that was open to the general public. Although there were technical difficulties, part of the presentation is now available at https://youtu.be/ODhV2uZtUsU. I have joined Twitter to communicate results of my work in the Canadian Arctic. I have followed and have followers of individuals and organizations from Arctic regions.

Results and outputs/deliverables

We have been investigating organophosphate esters in Arctic water for some time now, see Figure 4. We have observed higher concentrations of organophosphate esters (OPEs) in some locations in the Canadian Arctic, see Figure 5 and 6. In the summer of 2018, we started investigating these places as potential local sources of OPEs.

Like other semi-volatile organic compounds (SVOCs), OPEs undergo long range transport to the Arctic through the atmosphere, river outflow and ocean currents. OPEs are found to be at high levels in the Arctic compared to other contaminants, including brominated flame retardants and organochlorine pesticides. Water samples were collected from a larger (~30,000 pairs) and older (30+ years) colony of thick-billed murres on Baffin Island. These seabirds are seasonally migratory to northern Labrador.

Levels of OPEs were highest in water adjacent to the colony and decreased with increased distance from the colony, see Figure 7 and 8. Higher levels of TPhP and TEHP+BEHP in water surrounding the seabird colony. TEHP+BEHP is very rarely detected in Arctic water, but was found at higher levels than TCEP and TCPP in water adjacent to the bird colony.

Isopropylated triphenyl phosphates (IPTPs) at a seabird colony

IPTPs (chemical structure displayed in figure 9) were found in surface water adjacent to the bird colony at levels similar to TCEP and TCPP. IPTPs are not detected in open water and air samples from the Arctic but have been detected in melt pond water in Greenland (Jantunen, BFR presentation). IPTPs and TPhP have similar structures and are components of Firemaster 550 (an in-use flame retardant containing chlorinated and brominated compounds, that is used mainly in polyurethane foam to conform to flammability standards). Similar proportions of IPTPs were found in water adjacent to the bird colony, the technical mixture, and Firemaster 550 (Phillips et al., 2017) (figure 10). We hypothesize that seabirds, specifically thick-billed murres, retain this relative proportion, because IPTPs are more poorly metabolized than other OPEs. The birds excrete the OPEs without significant modifications or degradation of these OPEs.

Figure 4. sampling locations for OPEs in water, the star is the large bird colony.

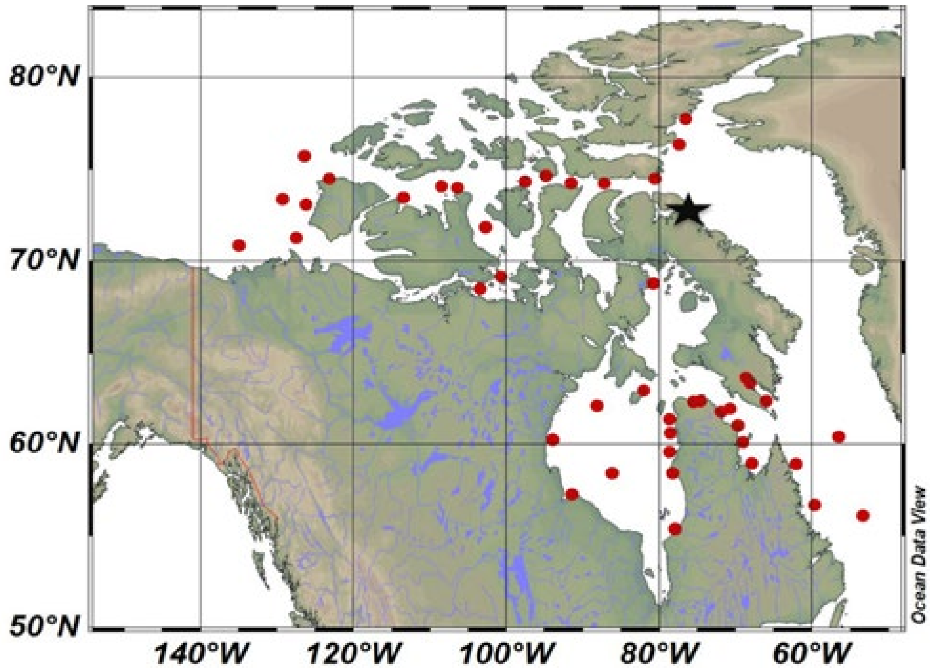


Figure 5. The red bars indicate higher concentration locations for OPEs.

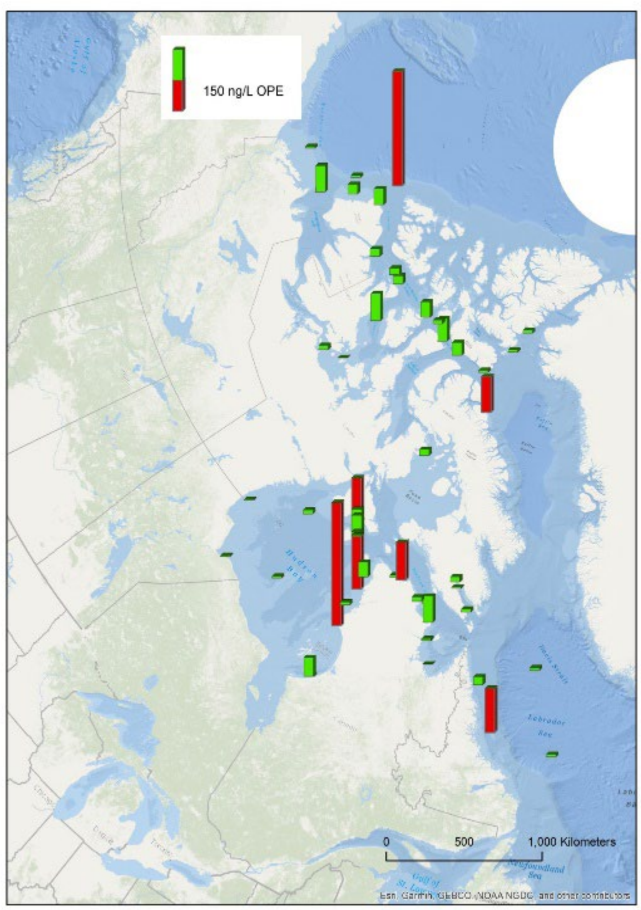


Figure 6. This is the same data presented in Figure 5 but presented as an average of compounds for the green bars (lower concentrations) and the red bars (high concentrations), note the log scale.

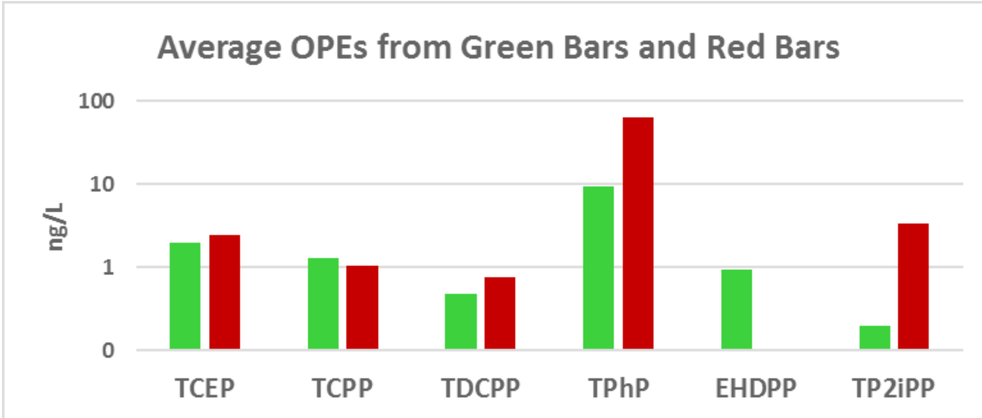


Figure 7. Levels of individual OPEs at an Arctic bird colony, showing enhanced levels of TPhP.

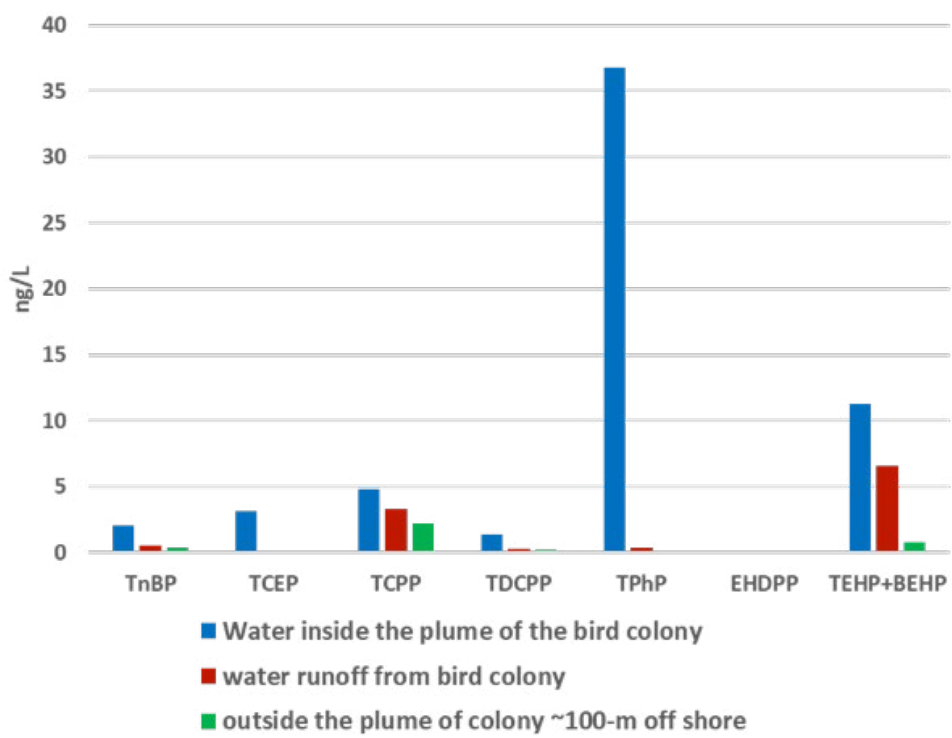


Figure 8. Levels of the sum of OPEs at an Arctic bird colony, showing highest levels of OPEs adjacent to the bird colony.

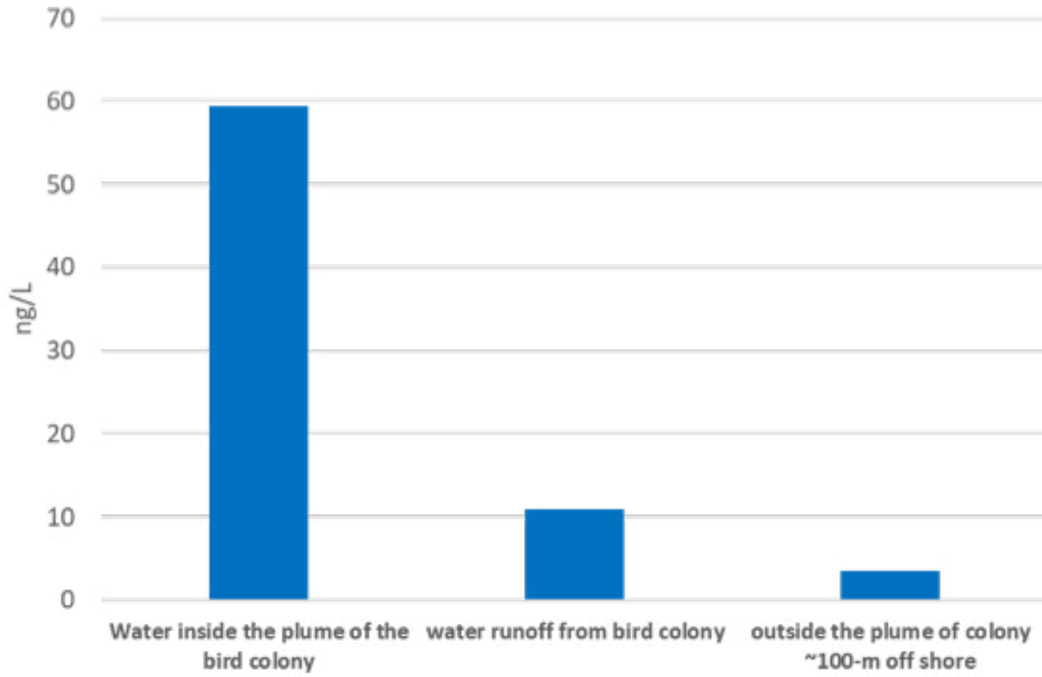


Figure 9. Chemical structures of several IPTPs.

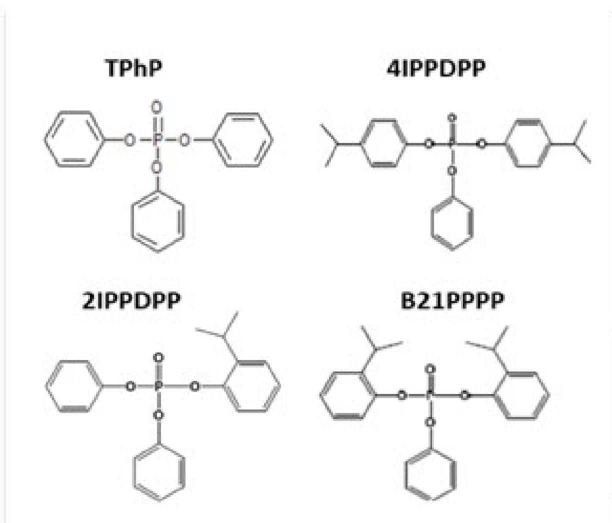
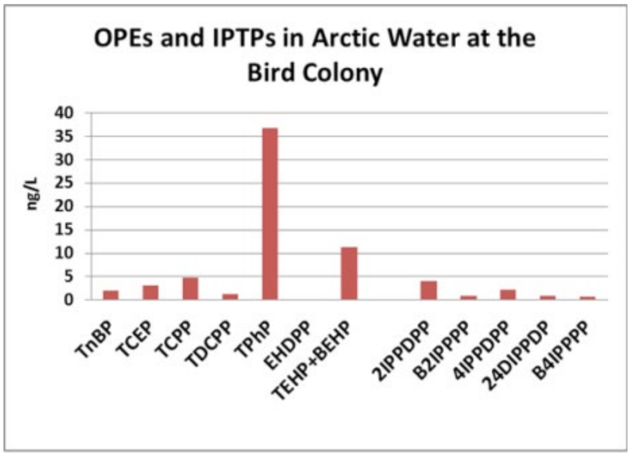
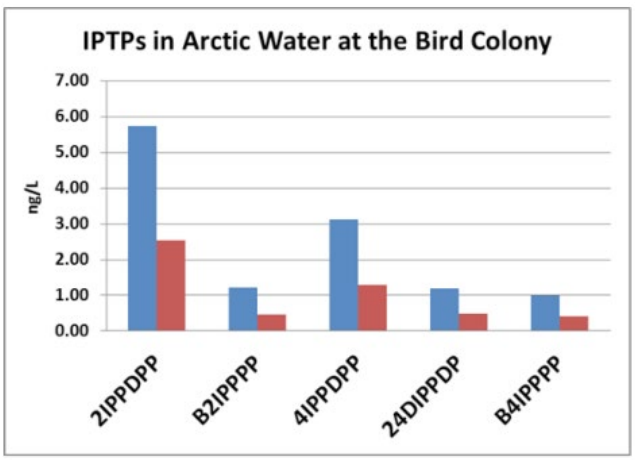


Figure 10. A) Concentration of OPEs at the bird colony showing elevated concentrations of TPhP and TEHP+BEHP. B) IPTPs at the bird colony and C) comparing IPTPs in Firemaster 550 and Technical IPTPs (Philips et al., 2017).

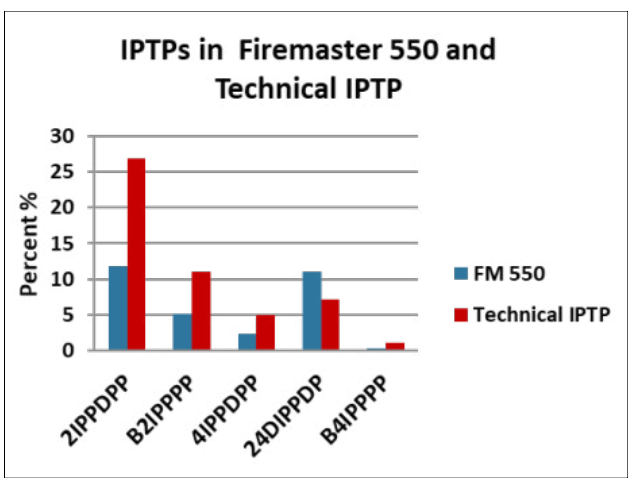
A)



B)



C)



Discussion and conclusions

No spatial (latitude or longitude) or temporal trends were observed for OPEs in Arctic water between 2013-2018. Levels at river outflows do not have elevated OPEs concentrations. At places of evaluated concentrations, TPhP is always elevated and IPTPs are often detected compared to not being detected at other open ocean sites. Levels of OPEs are higher in seawater around a large seabird colony (thick-billed murres), suggesting the seabirds are a source of OPEs including the IPTPs, to this site. IPTPs were found to be more resistant to metabolism than other OPEs in polar bears and seals (Strobel et al., 2018) suggesting they are more likely to bioaccumulate and biomagnify. Sampling will be repeated in 2019-2020 at this bird colony to confirm these results.

Expected project completion date

This project is an on-going core monitoring project, analysis and processing of samples taken this during 2018-2019 will be completed by December 2019.

Acknowledgments

We thank ECCC for its continuing support of this project. We thank ArcticNet for providing travel funding and ship time. We thank the crew and fellow scientist on board the CCGSs Wilfrid Laurier and Amundsen for their help during sampling, additionally we thank Humfrey Melling at DFO for the continuing work on the CCGS Laurier. We thank the community of Cambridge Bay for being so welcoming and inclusive during my visit. We thank the Nunavut Arctic College for welcoming us back again and the very engaged group of students especially the group from Pond Inlet, it was a pleasure hearing about your hometown. We also thank the students who trusted us enough to discuss effects colonialism and residential schools are still having on their communities, it was a powerful experience seeing the students owning their cultural past and turning it into a positive energy for change. We would also like to thank the NCP for their funding and support for this project.

References

AMAP, 2017. AMAP Assessment 2016: Chemicals of Emerging Arctic Concern. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi-353.

Phillips, A.L., Hammel, S.C., Konstantinov, A., Stapleton, H.M. Characterization of Individual Isopropylated and tert-Butylated Triarylphosphate (ITP and TBPP) Isomers in Several Commercial Flame Retardant Mixtures and House Dust Standard Reference Material SRM 2585. Environ Sci. Technol. 2017, 51, 13443-13449.

Strobel, A., Letcher, R.J., Willmore, W.G., Sonne, C., Dietz, R. Structure-Dependent in Vitro Metabolism of Alkyl-Substituted Analogues of Triphenyl Phosphate in East Greenland Polar Bears and Ringed Seals. Environ. Sci. Technol. Lets. 2018, 5, 214-219.

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 aux limites sud de leur aire de répartition

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Project location/Emplacement du projet

Coats Island, NU

Abstract

Pagophilic (ice-associated) Arctic species are facing multiple stressors from climate change and toxic contamination. We investigated whether contaminants compounded the impact of climate change on wildlife by limiting their ability to respond to changes in ice availability. Our current study year (2018) had the latest hatch date on record and provided a strong contrast with 2017 (earliest year on record) and 2016 (average year). 55 thick-billed murres were tracked via GPS-accelerometers (four additional birds received GPS units but data was corrupt), and concentrations of hormones and mercury were measured in the plasma of 59 individuals. We also measured the concentrations of per-/polyfluoroalkyl substances (PFASs) in 21 birds and brominated flame retardants (BFR) in 30 birds. Levels of PFASs and BFRs were low, and

Résumé

Les espèces pagophiles (associées aux glaces) de l'Arctique subissent de multiples facteurs de stress liés aux changements climatiques et aux contaminants toxiques. Nous avons cherché à savoir si les contaminants aggravaient l'impact des changements climatiques sur les espèces sauvages en limitant leur capacité à réagir à la variation de la disponibilité de la glace. L'année d'étude en cours (2018) a connu la date d'éclosion la plus tardive à ce jour et offre un fort contraste avec 2017 (année la plus précoce enregistrée) et 2016 (année moyenne). Un total de 55 guillemots de Brünnich ont été suivis au moyen d'accéléromètres GPS (quatre autres oiseaux ont reçu des unités GPS, mais les données étaient corrompues), et les concentrations d'hormones et de mercure ont été mesurées dans le plasma

unrelated to hormones or behaviour. Mercury levels were also unrelated to hormones or behavior. In contrast to a medium-ice year (2016, positive relationship) and low-ice year (2017, negative relationship), the high-ice year (2018) showed no relationship between T3 and Hg. We found no relationships between hormone levels and foraging behaviour. 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). Based on our 2016-2018 data, we tentatively conclude that mercury may be influencing the ability of thick-billed murres to adjust to variation in ice cover, but only in years when ice leaves unusually early, and we look forward to finalizing our analyses and publishing these results in the coming months.

de 59 individus. Nous avons également mesuré les concentrations de substances per-polyfluoroalkylées (PFAS) chez 21 oiseaux et des produits ignifuges bromés (RFB) chez 30 oiseaux. Les concentrations de PFAS et de RFB étaient faibles et n'avaient aucun lien avec les hormones ou le comportement. Les concentrations de mercure n'étaient pas non plus liées aux hormones ou au comportement. Contrairement à une année de glace moyenne (2016, relation positive) et une année de faible glace (2017, relation négative), l'année de forte glace (2018) n'a montré aucune relation entre l'hormone T3 et Hg. Nous n'avons trouvé aucune relation entre les concentrations d'hormones et le comportement de recherche de nourriture. Les suivis GPS ont permis de constater 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). Sur la base de nos données pour 2016-2018, nous concluons provisoirement que le mercure peut influer sur la capacité des guillemots de Brünnich à s'adapter aux variations de la couverture de glace, mais seulement les années où la glace fond exceptionnellement tôt, et nous attendons avec impatience de finaliser nos analyses et de publier ces résultats dans les prochains mois.

Key messages

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, but only when the ice leaves early. The underlying mechanism appears to vary among years of varying ice concentrations.

Messages clés

Les concentrations de RFB et de PFAS observées étaient plutôt faibles. Cependant, le mercure peut influer sur la capacité des guillemots à s'adapter aux variations de la couverture de glace en raison d'un lien avec les hormones, mais seulement lorsque la glace fond tôt. 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:

- analyze plasma samples from 60 incubating male murres for mercury before and after each GPS deployment to track foraging trips. As we did previously, of those 60 male birds, samples from the 10 birds with the highest mercury levels and the 10 birds with the lowest mercury levels, will also be analyzed for NCP-priority brominated and perfluorinated compounds;
- measure hormones (thyroid hormones, corticosterone) and nutritional biomarkers in plasma samples obtained from the same 60 birds before and after their foraging trip/GPS deployment to examine possible interrelationships among contaminant concentrations and hormones, nutritional status, cardiovascular status, foraging behaviours, and energetics in the same individual birds; and
- measure biomarkers in blood samples from up to 60 birds to characterize their nutritional status, and hence identify possible interrelationships with the reduced ice coverage (notable in the past 2 years), the birds' altered prey selection, increased energy expenditure, and greater time spent diving while foraging for fish.

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 ecosystem 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 to unsustainable levels of energy expenditure (Gaston et al. 2009).

There is growing evidence that contaminant levels currently measured in Arctic wildlife are disrupting endocrine systems and causing altered reproductive behaviours (Appendix 1). Specifically, those individuals with high levels of mercury and/or persistent organic pollutants (POPs) have altered endocrine status. This may compromise the ability of individuals to respond to environmental change, and lead to reduced reproductive success. Because a myriad of factors can impact reproductive success, it is important to establish a strong mechanistic linkage between contamination, the endocrine system, behaviour and reproduction.

To date, contaminant studies have focused on correlations between contaminant concentrations and behaviours, such as nest attentiveness, lay date and chick feeding rates (Appendix 1). The assumption is that high levels of those behaviours are associated with fitness (i.e. reproductive success and survival). However, there is growing awareness that fitness is poorly associated with individual values for any behavior; rather, fitness is associated with plasticity in those traits (Charmantier et al. 2008; Reed et al. 2011). Such flexibility is regulated by hormones that allow the body to respond to variation in food availability. A key insight in this proposed research, then, is to move beyond previous studies (Appendix 1) to examine plasticity in behaviour - which is particularly important in the context of climate change.

A major factor, then, in determining the resilience of Arctic wildlife to climate change is their behavioural plasticity (or flexibility) to accommodate changes in food availability. The overarching hypothesis of this proposal is that toxic contaminants disrupt behavioural plasticity in response to changes in food availability. We specifically test the idea that contaminants disrupt hormones that allow such behavioural plasticity.

Activities in 2018-2019

Sample collection/analysis

Between June 13 and August 6, 2018, Kyle Elliott, along with students Allison Patterson, Redha Tabet, Alyssa Eby, technician Sarah Poole, and local research assistants Josiah Nakoolak (Coral Harbour) and Jupie Angootealuk (Coral Harbour), collected blood samples from 59 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 were collected from 55 individuals (data were corrupt on the additional four birds). The Lab Services Unit at the National Wildlife Research Center (NWRC) analyzed total mercury in the red blood cells of all 59 birds and brominated flame retardants in 30 birds. NWRC Lab Services used 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 21 birds by the Letcher Organic Contaminants Research Laboratory (ORCL). Also, plasma from all 59 birds was analyzed for free and total forms of triiodothyronine and thyroxine (NWRC Lab Services) and corticosterone (Alyssa Eby/Oliver Love). Behavioural analyses from GPS-accelerometers were undertaken by PhD student Allison Patterson and research technician Katelyn Depot.

We successfully achieved our objectives as described in our 2018-2019 NCP proposal. Given the results from 2016-2018, we focused on measuring PFAS and Hg in as many individuals as possible rather than measuring additional legacy POPs 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.

Capacity building

We built substantial capacity in 2018-2019 via the training of seven students at McGill University (Ana Morales, Ashley Hanas, Emile Brisson-

Curadeau, Esteban Gongora, and Allison Patterson), University of Windsor (Alyssa Eby) and University of Toulouse (Redha Tabet). Alyssa, Redha and Allison conducted field research in the North. Ana learned how to conduct corticosterone hormone assays and Ashley learned how to write up such analyses. Allison, Emile, Redha and Ana learned how to analyze GPS-accelerometer data. In addition, Josiah Nakoolak and Jupie Angootealuk acted as research assistants and bear monitors in 2018, and spent time helping to select birds for blood sampling, capturing birds, and handling birds. In addition, Jupie Angootealuk participated in an Inuit Field School at East Bay, where he taught eight members of the Coral Harbour community the basics of avian research and life in a research camp over the course of one week.

Communications

We updated our metadata record and provided our entire data set (2016-2019) for this project in the NCP Polar Data Catalogue. We presented a discussion on climate change and contaminants at the Ecosystem and Wildlife Health Directorate of ECCC. We also attended the Arctic Monitoring and Assessment Program (AMAP) meeting in Stockholm Sweden (April 2019), contributing our findings and expertise in developing the upcoming AMAP report on climate change and contaminants. We also have been accepted to present a platform talk entitled "Climate change, contaminants, ecotoxicology: interactions in Arctic seabirds at their southern range limits" at Society of Environmental Toxicology and Chemistry (SETAC) Europe in Helsinki. We also presented a platform talk entitled "Amino acid and sulfur stable isotopes in thick-billed murre prey: relationships to prey diet and contaminant signatures" at the ArcticNet Annual Scientific Meeting (ASM) in Ottawa. We presented a second platform talk entitled "Is mercury influencing the ability of thick-billed murres to adjust to changing ice conditions in the Canadian Arctic?" at SETAC North America in Sacramento (November 2018). 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 February 2019 to present information on the monitoring and research activities on migratory birds in the region, including the current project. Annual reports of the results to date are made to the NCP each year and results will continue to be published in a peer-reviewed scientific journals project.

Indigenous Knowledge integration

Inuit advice from Josiah and Jupie was solicited as to what birds to sample. We selected individual murres in communication with Josiah and Jupie, who both have extensive experience with murres and other Arctic wildlife.

Results

Objective 1

Total mercury levels averaged 1.99 ± 0.53 µg/g dry weight (0.70 ± 0.18 µg/g wet weight), ranging from 1.03 to 4.38 µg/g dry weight (0.36 to 1.53 µg/g wet weight). Levels of ∑BDE were quite low, averaging 0.13 ± 0.03 ng/g wet weight (maximum = 0.24 ng/g wet weight). Levels of PFAS were uniformly quite low (Table 1). PFUdA, followed by PFOS and 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) in 2018.

Chemical	Average	SD	Maximum	Minimum
PFEtCHxS	0.06	0.10	0.38	0.03
PFBS	0.96	4.48	21.00	0.00
PFHxS	0.05	0.03	0.09	0.03
PFOS	1.81	0.51	2.98	1.12
PFDS	0.54	0.58	2.40	0.26
PFBA	1.44	0.68	1.96	0.60
PFPeA	0.02	0.00	0.02	0.02
PFHxA	0.06	0.04	0.12	0.04
PFHpA	0.04	0.05	0.13	0.01
PFOA	0.14	0.07	0.28	0.10
PFNA	0.53	0.26	1.20	0.06
PFDA	0.60	0.20	0.99	0.34
PFUdA	3.54	0.92	5.49	2.20
PFDoA	0.50	0.17	0.77	0.13
PFTrDA	1.79	0.45	2.82	1.03
PFTeDA	0.18	0.08	0.30	0.02
PFHxDA	0.08	0.05	0.15	0.02
PFODA	0.01	0.01	0.02	0.01

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 $t_{23} = 2.17$, $p < 0.04$) as they had been in previous years (2016, 2017).

Table 2. Hormone levels in thick-billed murre plasma pre- and post- foraging trips in 2018.

Biomarker	Average	SD	Minimum	Maximum
Pre-trip Free T4 (pg/mL)	8.32	2.02	12.10	4.70
Pre-trip Free T3 (pg/mL)	0.94	0.52	2.71	0.15
Pre-trip Total T4 (ng/mL)	17.72	6.93	33.80	7.42
Pre-trip Total T3 (ng/mL)	3.70	2.12	11.10	0.08
Post-trip Free T4 (pg/mL)	8.31	2.74	14.80	3.91
Post-trip Free T3 (pg/mL)	0.73	0.36	1.90	0.18
Post-trip Total T4 (ng/mL)	15.35	6.44	30.80	5.06
Post-trip Total T3 (ng/mL)	3.03	1.61	7.17	0.08
Pre-trip Corticosterone (ng/mL)	0.11	0.16	0.10	0.52
Post-trip Corticosterone (ng/mL)	0.24	0.38	0.10	1.25

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.

Table 3. Foraging parameters for thick-billed murres at Coats Island in 2018.

	Average	SD	Minimum	Maximum
Mean daily time spent flying (minutes)	73	31	22	177
Mean daily time spent swimming (minutes)	488	138	201	883
Mean daily time spent diving (minutes)	131	39	64	209
Mean daily time spent at colony (minutes)	747	148	354	1063
Mean dive duration (minutes)	0.98	0.37	0.48	2.29
Mean surface interval (minutes)	3.83	1.81	1.13	8.78
Mean depth (m)	14	8	36	6
Mean distance (km)	27	14	7	76
Mean daily max depth (m)	45	14	92	15
Mean daily max distance (km)	35	14	10	82
Mean daily energy expenditure (kJ)	2086	307	1436	2985

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 $p > 0.05$). There was also no association between Hg and any biomarker (all $p > 0.05$), or between hormone levels and daily energy expenditure, time spent diving or time spent flying. The overall path analysis indicated no effect in contrast to previous years (2016, 2017).

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 thermo-regulation (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.

In previous years, high mercury levels were associated with low levels of T3, and 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).

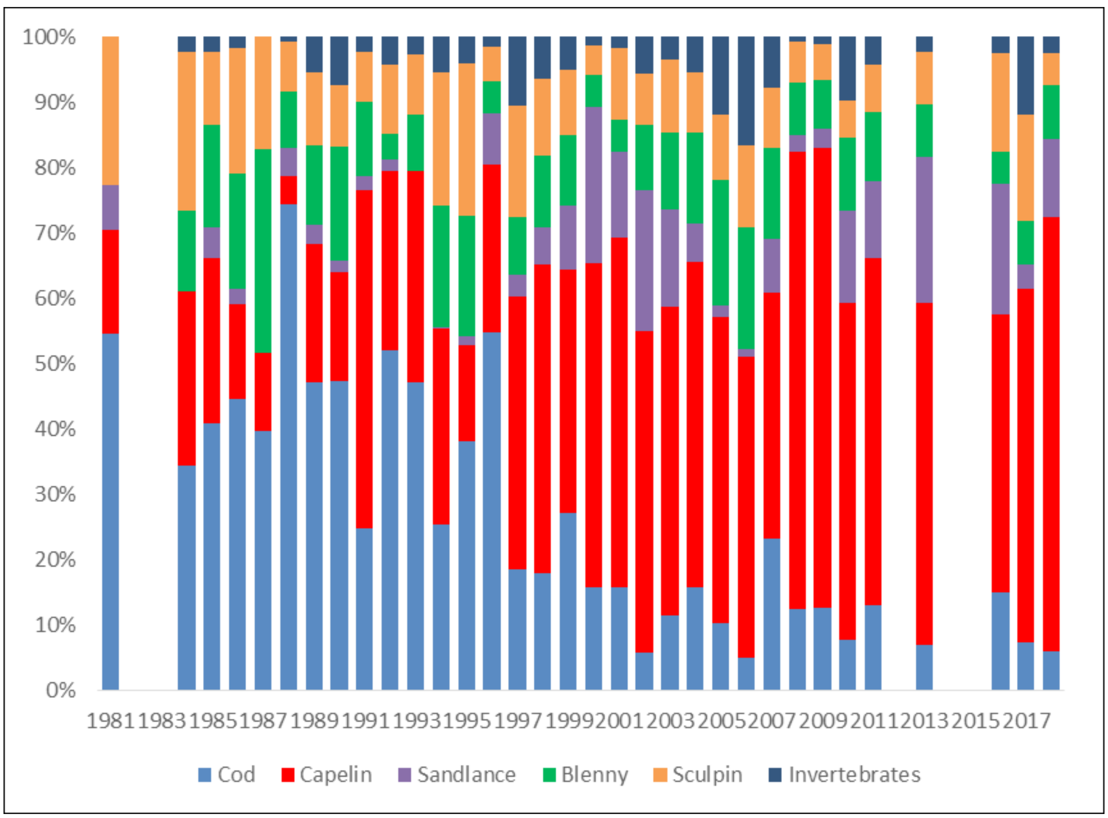
Both 2016 and 2017 were relatively 'early' years, with 2017 being the earliest year on record for breeding murres. In contrast, 2018 was a 'late' year, with median hatch date being tied for latest on record over the past 30 years. We did not find any of the relationships that we recorded in 2016 or 2017 being present in 2018. We conjecture that in late breeding years, when ice disappearance is less of a factor, endocrine disruption may play less of a role.

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 it 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 and BFRs were relatively low in plasma. Not surprisingly, there were no significant relationships between those contaminants and behaviour, in contrast to some previous studies reporting higher levels of contaminants (Appendix, Table 1). The lipid content of plasma is low, notably in comparison to other avian tissues such as eggs. Consequently, low concentrations of lipophilic compounds will occur in tissues with low lipid content (e.g., plasma) compared to high lipid tissues (e.g., eggs).

We were able to increase the capacity of the Coats Island project in 2018-2019, by training six students in field work, hormone analysis, and behavioural analysis. Those students will form the basis for a strong cohort going forward, facilitating work in 2019.

Figure 1. Thick-billed murre chick diet at Coats Island between 1981 and 2017.



Ice conditions in Hudson Bay 2018 were typical (median: 35% coverage in the second week of July was similar to the 1981-2018 average). However, murres bred the latest on record (median hatch date = 1 Aug). This discrepancy likely explains why Arctic cod in the diet was among the lowest on record, even though we conducted no feeding watches late in the season (Figure 1).

Expected project completion date

31 March 2019.

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References

Charmantier, A., R.H. McCleery, L.R. Cole, C. Perrins, L.E. Kruuk and B.C. Sheldon. 2008. Adaptive phenotypic plasticity in response to climate change in a wild bird population. *Science* 320: 800-803.

Elliott, K.H., Hare, J.F., Le Vaillant, M., Gaston, A.J., RopertCoudert, Y. and Anderson, W.G., 2015. Ageing gracefully: physiology but not behaviour declines with age in a diving seabird. *Funct. Ecol.*, 29: 219-228.

Elliott, K.H., Welcker, J., Gaston, A.J., Hatch, S.A., Palace, V., Hare, J.F., Speakman, J.R. and Anderson, W.G. 2013. Thyroid hormones correlate with resting metabolic rate, not daily energy expenditure, in two charadriiform seabirds. *Biology open* 2: 580-586.

Gaston, A.J., H.G. Gilchrist, M. Mallory and P.A. Smith. 2009. Changes in seasonal events, peak food availability, and consequent breeding adjustment in a marine bird: a case of progressive mismatching. *Condor* 111: 111-119.

Laidre, K.L., M.P. Heide-Jorgensen, J. Nyeland, A. Mosbech and D. Boertmann. 2007. Latitudinal gradients in sea ice and primary production determine Arctic seabird colony size in Greenland. *Proc. Roy. Soc. Lond. B* 275: 2695-2702.

Letcher, R.J., J.O. Bustnes, R. Dietz, B.M. Jensen, E.H. Jorgensen, C. Sonne, J. Verreault, M.M. Vijayan and G.W. Gabrielsen. 2010. Exposure and effects assessment of persistent organic pollutants in Arctic wildlife and fish. *Sci. Tot. Environ.* 408: 2995-3043.

McKinney, M.A., S. Pedro, R. Dietz, C. Sonne, A.T. Fisk and R.J. Letcher. 2015. Ecological impacts of global climate change on persistent organic pollutant and mercury pathways and exposures in arctic marine ecosystems: A review of initial findings. *Curr. Zool.* 61: 617-628.

McNabb, F.M. 2007. The hypothalamic-pituitary-thyroid (HPT) axis in birds and its role in bird development and reproduction. *Critical Rev. Toxicol.* 37: 163-193.

Reed, T.E., D.E. Schindler and R.S. Waples (2011) Interacting effects of phenotypic plasticity and evolution on population persistence in a changing climate. *Conserv. Biol.* 25: 56-63.

Welcker, J., Chastel, O., Gabrielsen, G.W., Guillaumin, J., Kitaysky, A.S., Speakman, J.R., Tremblay, Y. and Bech, C. 2013. Thyroid hormones correlate with basal metabolic rate but not field metabolic rate in a wild bird species. *PLoS One* 8:e56229.

Welch, H.E., Bergmann, M.A., Siferd, T.D., Martin, K.A., Curtis, M.F., Crawford, R.E., Conover, R.J. and Hop, H. 1992. Energy flow through the marine ecosystem of the Lancaster Sound region, arctic Canada. *Arctic* 42: 343-357.

Appendix 1

Studies that have investigated the relationships between POPs contaminants, behaviour, reproductive success and the endocrine system in polar seabirds. The table is meant to be representative rather than exhaustive. Contaminants examined included polychlorinated biphenyls (PCBs), organochlorines (OCs), organohalogens (OHs), legacy persistent organic pollutants (Legacy POPs) and polybrominated diphenyl ethers (PBDEs). Species examined included glaucous gulls (*Larus hyperboreus*), great black-backed gulls (*Larus marinus*), black-legged kittiwakes (*Rissa tridactyla*) and snow petrels (*Pagodroma nivea*). Hormones examined include prolactin (PRL), thyroid hormones (THs), corticosterone (CORT) and luteinizing hormone (LH). Because reproductive hormones are often inter-correlated, relationships with one hormone often imply a relationship with other (potentially unmeasured) hormones; it is not necessary to measure all hormone groups.

Species	Contaminant	Effect	
Glaucous gull	PCBs	Decreased nest attentiveness	Bustnes et al. 2001, 2005
Glaucous gull	OCs	Later lay date, reduced second chick size	Bustnes et al. 2003
Great black-backed gull	PCBs	Later lay date, higher predation rate, lower egg size	Helberg et al. 2005
Glaucous gull	PCBs	Lower THs	Verreault et al. 2004
Glaucous gull	PCBs	Higher progesterone in males	Verreault et al. 2006
Glaucous gull	OHs	Tendency for lower PRL	Verreault et al. 2008
Glaucous gull	PCBs	Lower nest temperature	Verboven et al. 2009
Glaucous gull	PCBs/PBDEs	Higher baseline CORT	Verboven et al. 2009
Black-legged kittiwake	PCBs	Higher baseline CORT (pre-laying)	Verboven et al. 2009
Snow petrel	Legacy POPs	Higher baseline CORT	Tartu et al. 2015a
Snow petrel	Hg	Higher baseline PRL	Tartu et al. 2015a
Black-legged kittiwake	Hg	Higher LH and skipped breeding	Tartu et al. 2013
Black-legged kittiwake	Hg	Skipped breeding	Tartu et al. 2013
Black-legged kittiwake	Legacy POPs	Increased CORT	Tartu et al. 2014
Black-legged kittiwake	Hg	Reduced PRL and breeding success	Tartu et al. 2015b

Table References

Bustnes, J.O., V. Bakken, K.E. Erikstad, F. Mehlum and J.U. Skaare. 2001. Patterns of incubation and nest site attentiveness in relation to organochlorine contamination in glaucous gulls. *J. Appl. Ecol.* 38: 791-801.

Bustnes, J.O., Ø. Miland, M. Fjeld, K.E. Erikstad and J.U. Skaare. 2005. Relationships between ecological variables and four organochlorines in an artic glaucous gull population. *Environ. Poll.* 136: 175-185.

Bustnes, J.O., K.E. Erikstad, J.U. Skaare, V. Bakken and F. Mehlum. 2003. Ecological effects of organochlorine pollutants in the Arctic: a study of the glaucous gull. *Ecol. Appl.* 13: 504-515.

Helberg, M., J.O. Bustnes, K.E. Erikstad, K.O. Kristiansen and J.U. Skaare. 2005. Relationships between reproductive performance and organochlorine contaminants in great black-backed gulls. *Environ. Poll.* 134: 475-483.

Tartu, S., F. Angelier, D. Herzke, B. Moe, C. Bech, G.W. Gabrielsen, J.O. Bustnes and O. Chastel. 2014. The stress of being contaminated? Adrenocortical function and reproduction in relation to persistent organic pollutants in female black legged kittiwakes. *Sci. Tot. Environ.* 476: 553-560.

Tartu, S., A. Goutte, P. Bustamante, F. Angelier, B. Moe, C. Clement-Chastel, C. Bech, G.W. Gabrielsen, J.O. Bustnes and O. Chastel. 2013. To breed or not to breed: endocrine response to mercury contamination by an Arctic seabird. *Biol. Lett.* 9: 20130317.

Tartu, S., F. Angelier, J.C. Wingfield, P. Bustamante, P. Labadie, H. Budzinski, H. Weimerskirch, J.O. Bustnes and O. Chastel. 2015a. Corticosterone, prolactin and egg neglect behavior in relation to mercury and legacy POPs in a long-lived Antarctic bird. *Sci. Tot. Environ.* 505: 180-188.

Tartu, S., P. Bustamante, F. Angelier, A.Z. Lendvai, B. Moe, P. Blevin, C. Bech, G.W. Gabrielsen, J.O. Bustnes and O. Chastel. 2015b. Mercury exposure, stress and prolactin secretion in an Arctic seabird: an experimental study. *Funct. Ecol.* 30: 596-604.

Verreault, J., J.U. Skaare, B.M. Jenssen and G.W. Gabrielsen. 2004. Effects of organochlorine contaminants on thyroid hormone levels in Arctic breeding glaucous gulls. *Environ. Health Persp.* 112:532.

Verreault, J., R.J. Letcher, E. Ropstad, E. Dahl and G.W. Gabrielsen. (2006) Organohalogen contaminants and reproductive hormones in incubating glaucous gulls from the Norwegian Arctic. *Environ. Toxicol. Chem.* 25: 2990-2996.

Verreault, J., N. Verboven, G.W. Gabrielsen, R.J. Letcher and O. Chastel. 2008. Changes in prolactin in a highly organohalogen contaminated Arctic top predator, the glaucous gull. *Gen. Comp. Endocrin.* 156: 569-576.

Verboven, N., J. Verreault, R.J. Letcher, G.W. Gabrielsen and N.P. Evans. 2009. Nest temperature and parental behaviour of Arctic-breeding glaucous gulls exposed to POPs. *Anim. Behav.* 77: 411-408.

Verboven, N., J. Verreault, R.J. Letcher, G.W. Gabrielsen and N.P. Evans. 2010. Adrenocortical function of Arctic-breeding glaucous gulls in relation to POPs. *Gen. Comp. Endocrin.* 166: 25-32.

Plastics as a vector of contaminants (benzotriazole UV stabilizers) to Arctic seabird tissues and eggs

Les plastiques comme vecteur de contaminants (stabilisateurs UV au benzotriazole) dans les tissus et les œufs des oiseaux marins de l'Arctique

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Project locations/Emplacements du projet

- Prince Leopold Island, NU
- Labrador Sea, NL

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. Since 2003, the Arctic seabird team has worked to identify which Northern marine bird species are vulnerable to ingesting marine plastic 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. Now in its third phase, this project expands ongoing efforts to assess whether chemical contaminants are associated with ingested plastics, and as a consequence may be

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 que l'on s'interroge sur les répercussions de cette pollution ingérée. Depuis 2003, l'équipe qui étudie les oiseaux de mer de l'Arctique a tenté de répertorier les espèces d'oiseaux de mer du Nord qui sont vulnérables à la pollution des milieux marins par le plastique. Plus important encore, de plus en plus de données probantes montrent qu'une fois que le plastique se trouve 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. Ce projet,

transferred to Arctic marine birds (northern fulmars; *Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*). Beyond the physical impact associated with plastics, there is also increasing awareness of the chemicals associated with marine plastic debris. Plastics are made from a number of chemical components such as UV stabilizers and phthalates. This third project phase examined concentrations of contaminants, known to be associated with plastic, in two species of seabirds. In this case, we targeted benzotriazole UV stabilizers (BZT-UVs), which are added to plastic to prevent colour change. We also targeted substituted diphenylamines (SDPAs) which are industrial antioxidants used in the automotive industry, including as additives to polyurethane foam (PUF). This is the first report of the different distribution patterns of SDPAs & BZT-UVs in seabirds from Canadian Arctic sites. The concentrations of ∑SDPAs in seabird livers (median 336 pg g^{-1}, wet weight (ww)) were significantly higher than the eggs (median 24 pg g^{-1}, ww) and the seal livers (median 38 pg g^{-1}, ww), suggesting liver was a primary tissue of SDPA accumulation in seabirds. 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-derived.

rendu à sa troisième phase, réalisé dans la foulée des efforts en cours, vise à évaluer si les contaminants chimiques sont associés aux plastiques ingérés et, par conséquent, pourraient être transférés aux oiseaux marins de l'Arctique, soit le fulmar boréal (*Fulmarus glacialis*) et à la mouette tridactyle (*Rissa tridactyla*). Au-delà des effets physiques des plastiques, il existe également une sensibilisation croissante aux produits chimiques associés aux débris de plastique marins. Les plastiques sont fabriqués à partir d'un certain nombre de composants chimiques tels que les stabilisateurs UV et les phtalates. La troisième phase du projet a examiné chez deux espèces d'oiseaux marins les concentrations de contaminants, dont on sait qu'ils sont associés au plastique. Dans ce cas, nous avons ciblé les stabilisateurs UV à base de benzotriazole (BZT-UV), qui sont ajoutés au plastique pour empêcher le changement de couleur. Nous avons également ciblé les substances *N*-phénylanilines substituées (NPAS), qui sont des antioxydants industriels utilisés dans l'industrie automobile, notamment comme additifs à la mousse de polyuréthane. Il s'agit du premier rapport sur les différents modèles de distribution des substances NPAS et des BZT-UV chez les oiseaux de mer des sites de l'Arctique canadien. Les concentrations de ∑NPAS dans le foie des oiseaux de mer (médiane 336 pg/g (poids humide)) étaient significativement plus élevées que dans les œufs (médiane 24 pg/g (poids humide)) et le foie des phoques (médiane 38 pg/g (poids humide)), ce qui semble indiquer que le foie était un des principaux tissus où des substances NPAS s'accumulent chez les oiseaux de mer. Ce travail s'appuie sur les travaux antérieurs réalisés dans cette région, et contribuera 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.

Key messages

- This is the first report of SDPAs and BZT-UVs in wildlife from Canadian Arctic sites.
- Seabird tissues showed higher concentrations of SDPAs than BZT-UVs.
- UV329 and UV350 were the predominant BZT-UVs.
- Greater levels of SDPAs were found in seabird livers than in their eggs.
- SDPAs and BZT-UVs are not strong candidate chemicals for long range transport; Their presence in Arctic seabirds may be due to association with small plastic particles.

Messages clés

- Il s'agit du premier rapport sur les substances NPAS et les BZT-UV chez la faune l'Arctique canadien.
- Les tissus des oiseaux de mer présentaient des concentrations plus élevées de substances NPAS que de BZT-UV.
- Les substances UV329 et UV350 étaient les BZT-UV prédominants.
- Les substances NPAS ont été trouvées en concentrations plus grandes dans le foie des oiseaux de mer que dans leurs œufs.
- Les substances NPAS et les BZT-UV ne sont pas de très bons candidats chimiques pour le transport à grande distance; leur présence dans les oiseaux de mer de l'Arctique peut être due à l'association avec de petites particules de plastique.

Objectives

In general, this project aims to:

- explore of the link between macro-contaminants (i.e. plastics) and micro-contaminants (i.e. chemicals) 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.

More specifically, this project aims to:

- explore the concentrations of two plastic-derived contaminants, SDPAs and BZT-UVs, in seabird tissues; and
- investigate if the target plastic-derived contaminants are maternally transferred to seabird eggs

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). The presence of plastic debris in remote environments such as the high Arctic, as detected through seabirds, demonstrates that plastics are persistent and subject to long-range transport (Lusher et al., 2015; Mallory, 2008; Provencher et al., 2009), just as micro-contaminants are.

Beyond the physical impact associated with plastics, there is also increasing awareness of the chemicals associated with marine plastic debris. Plastics are made from a number of chemical components such as UV stabilizers and phthalates (Zhang et al., 2015). Additionally, marine plastic 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), with potential impacts for both wildlife and human health (Hamlin et al., 2015). This work builds on previous sampling efforts to expand our understanding of how plastic-derived chemical contaminants may be plastic-associated and how they accumulate and move through Arctic biota using seabirds as a model species.

Substituted diphenylamine antioxidants (SDPAs) are additives used in many products such as plastics, rubbers, fuels, lubricants, hydraulic fluids and industrial adhesives to prevent materials from undergoing oxidative degradation (Lu et al., 2016a; Environment and Climate Change Canada and Health Canada, 2017, Figure 1a). Benzotriazole UV stabilizers (BZT-UVs) are additives widely used in plastics, paints, coatings, adhesives and personal care products to reduce UV-induced color change or degradation (Lu et al., 2016a, Figure 1a). The high-volume production and widespread use of SDPAs and BZT-UVs have led to studies investigating their occurrence, fate and potential effects in the environment (Lu et al., 2016a). SDPAs and BZT-UVs have been detected in water, sediment, and biota samples from various locations in temperate regions (Kim et al., 2011; Lu et al., 2016a; 2018; 2019; Vimalkumar et al., 2018; Wick et al., 2016), indicating that such industrial additives are ubiquitous in the environment and can bioaccumulate. A recent non-target analysis has identified SDPAs as a major group of organic contaminants in the muscle, gonad, and eggs of European eels (*Anguilla anguilla*) at µg g-1 levels on a wet weight (ww) basis (Sühring et al., 2016). This result indicates that SDPAs is a group of contaminants that were previously overlooked.

Activities in 2018-2019

For this project we utilized tissue samples previously collected from northern fulmars (*Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) at Prince Leopold Island. The samples were collected as part of the core seabird NCP project in 2013, and subsequently stored at the National Wildlife Research Centre in Ottawa. These birds were originally collected to examine the temporal trends of POPs and metals in Arctic seabirds (Mallory and Braune, 2012). These collections were made under the appropriate Government of Nunavut and Canadian Wildlife Service permits required in the region (e.g., NUN-MBS-12-03, NUN-SCI-12-04, WL2013-040), and in consultation with the Sulukvait Area Co-management Committee. Additionally, fulmars were collected from the southern Labrador Sea in the Canadian sub-Arctic by local Inuit hunters in July 2015 (Avery-Gomm et al., 2018). Liver samples from both study regions were collected for chemical analysis during dissections at the Nunavut Arctic College in Iqaluit (Provencher et al., 2013), homogenized, stored at -40 °C, and used in this study. Details of bird collection, euthanasia, storage, and shipping information have been published previously (Avery-Gomm et al., 2018; Provencher et al., 2018).

For this study, bird liver (kittiwake: n=5 from Prince Leopold Island; fulmar: n=9 from Prince Leopold Island, n=10 from Labrador Sea) and egg (kittiwake: n=6 from Prince Leopold Island; fulmar: n=5 from Prince Leopold Island) samples were used for the analysis of SDPAs and BZT-UVs. For this study, a detailed list of the target SDPAs, methods, and quality assurance and quality control procedures can be found in Lu et al. (2019).

Briefly, sample preparation and analysis processes were based on the previously published methods with some modifications (Lu et al., 2016b; 2018). Bird egg homogenate (1 g) with surrogate standards was vortexed with 5 mL of methyl-tert-butyl ether (MTBE) for 1 min in a glass centrifuge tube, followed by 15 min of sonication and 5 min of centrifugation. The extraction was repeated 3 times, and the extracts were combined in a pre-weighed new glass centrifuge tube. The solvent extract was concentrated to dryness under gentle N2. The lipid content was measured gravimetrically. The extract was then dissolved in 1 mL of 1:1 (v: v) hexane: dichloromethane and further cleaned by gel permeation chromatography (GPC) (Express Performance column, 25cm×3.5cm i.d.; packed with 50 g of Bio-Beads S-X3) (J2 scientific; Columbia, MI, USA). The GPC mobile phase was 1:1 hexane: dichloromethane and the flow rate was 5 mL min-1. The fraction corresponding to 7.5 - 22.5 min was collected and concentrated to 5 mL using rotary evaporation. The 5 mL concentrated GPC eluent was further concentrated to dryness using gentle N2 and reconstituted in 1 mL of acetonitrile for instrumental analysis.

The liver homogenate samples (0.5 g, wet weight (ww)) with surrogate standards (UV234-d4, UV328-d4, and UV329-d4) were mixed with 2 g of Na2SO4 in a glass centrifuge tube. A mixture solvent of 5 mL 1:1 (v: v) hexane: dichloromethane was used to extract the sample. The sample was treated with 2 min of the vortex, followed by 15 min of sonication and 5 min of centrifugation. The extraction was repeated 3 times, and the extracts were combined in a pre-weighed new glass centrifuge tube. The solvent extract was concentrated to dryness under gentle N2. The lipid content was measured gravimetrically. The extract was then dissolved in 1 mL of 1:1 (v: v) hexane: dichloromethane and further cleaned by GPC as described above. The eluents were concentrated to dryness and reconstituted in 1 mL of acetonitrile for instrumental analysis.

An ultra-performance liquid chromatography tandem mass spectrometer (UPLC-MS/MS) system was used for sample analysis. The UPLC column was a 50 mm×3.0 mm Gemini-NX 3µm C18 analytical column (Phenomenex, CA, USA). The column temperature was set at 40 °C. Water (A) and acetonitrile (B), each containing 0.1% formic acid, were used as mobile phases. The gradient was initiated at 40:60 (A:B, v:v) and held for 0.5 min before increasing B to 97% in the next 3.5 min. The 97% B was held for 2 min and then increased to 99.5% B at 6.5 min and held for an additional 3 min. At 10 min, the gradient reverted to initial conditions. The flow rate was set at 0.3 mL/min except for 6.5-9.5 min, which was set at 0.5 mL/min. Injection volume was 10 µL. The mass spectrometer was operated in positive electrospray ionization (ESI) mode. Analytes were detected using scheduled multiple reaction monitoring (MRM).

The concentrations of SDPAs and BZT-UVs were reported based on ww, while some data are reported based on lipid weight (lw) in order to make comparisons with literature. Data were analyzed using R 3.4.4 (with RStudio 0.99.903) (Boston, MA, USA) and GraphPad Prism 7.0 (La Jolla, CA, USA) to determine the concentration distribution of SDPAs and BZT-UVs in different samples and the possible differences in target contaminants levels in different species or tissues. Statistics were performed for target analytes with detection frequency ≥ 50%. Data were logarithmically transformed to approximate a normal distribution (Shapiro-Wilk test) before further statistical analysis. Unpaired t-test with Welch's correction, paired t-test or one-way ANOVA followed by Tukey's test were used for data comparisons. The significance level was set as $p<0.05$.

Community engagement

Our team regularly meets with the 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.

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 took place at Prince Leopold Island, NU and 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, 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 J. Provencher, R. Letcher and B. Braune have also been active contributors to the Workshop.

In 2018 and 2019, this project and the associated results were 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. In 2019, the workshop focused on plastics in the Arctic, and the seabird work funded to date by NCP was a major component of the curriculum.

Communications

Our research group regularly meets in person with the HTA board and ACMC in Resolute Bay, NU (usually in the winter and spring months). Results from this study have been incorporated into the presentation that is given to the community and board.

A summary of the results has been incorporated into a series of posters that we 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. These materials are made available in both English and Inuktitut.

Indigenous Knowledge

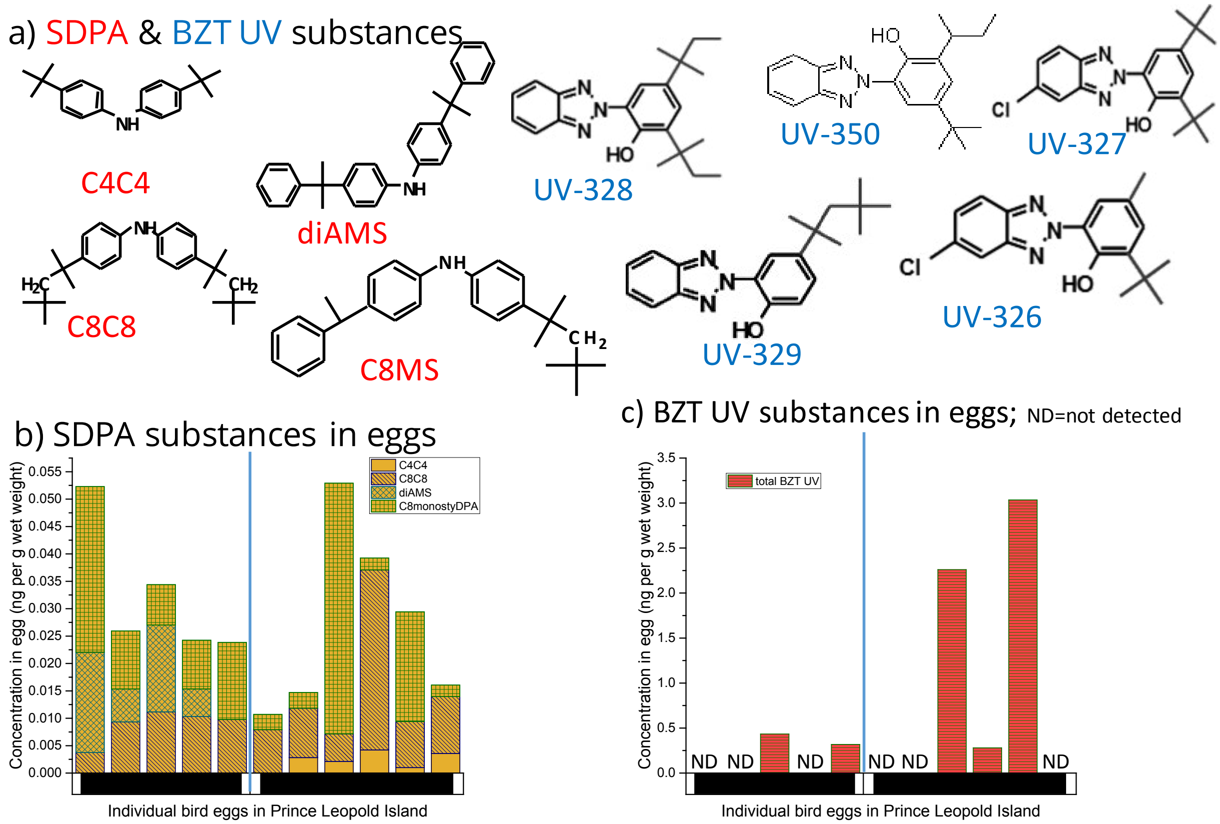
Knowledge from the local community research team members is incorporated when setting up the research camp each year. A local ecological knowledge study on marine birds was conducted in the mid-2000s by Mark Mallory, and the data from that study is still used to interpret our research (e.g., ice-bird relationships, community value of different species). All field work is done in collaboration with the HTA board and the Sulukvait ACMC in Resolute Bay, NU and undertaken with their consultation.

Each year during the Wildlife Contaminants Workshop in community members from the local Hunters and Trappers Association in Iqaluit participate in a session that shared traditional knowledge on wildlife and contaminants. This includes students and Elders speaking about the plastic pollution that they have observed in animals, how this has changed over time, and the concerns hunters have about plastic pollution in the Arctic.

Discussion and conclusions

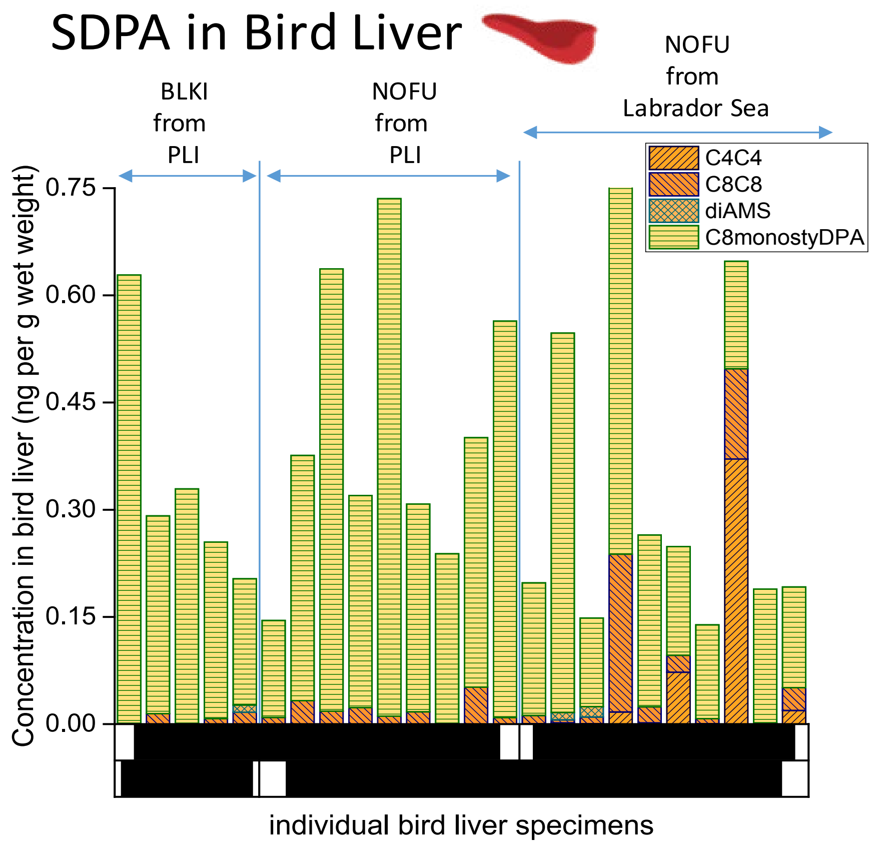
Five SDPAs (C4, C8, C9, C8C8, C8MS-1) and one BZT-UV UV350 were detected in bird eggs from Prince Leopold Island (Figure 1). The concentrations of total SDPAs (∑SDPAs) in bird eggs ranged between 11 and 30 pg. g-1 wet weight (ww) for kittiwake and 12 to 60 pg. g-1 ww for fulmar. There was no significant difference in ∑SDPAs levels between kittiwake and fulmar (Lu et al. 2019). C8C8 (91%) and C8MS-1 (100%) were frequently detected in bird eggs from Prince Leopold Island, indicating the exposure of Arctic seabirds to SDPAs at an early-life stage. C8C8 and C8MS-1 are components of BNST which is primarily used in Canada as an antioxidant in lubricant and vehicle engine oils at levels between 0.20% and 0.25% (Environment Canada and Health Canada, 2009) and are listed in the chemical inventory of many countries, such as the U.S., China, New Zealand, Japan, Australia, Philippines, and South Korea (Asia-Pacific Chemical Inventory Search System). In addition, UV326, UV327, UV328, and UV329 were not detected in any bird eggs in the present study which is consistent with the results of Arctic bird eggs collected from Svalbard, Norway in 2013-2014 (Lucia et al., 2016).

Figure 1. Chemical identity (a) and concentrations of b) SDPAs in black legged kittiwake (BLKI) eggs and northern fulmar (NOFU) eggs and c) benzotriazole UV stabilizers from Prince Leopold Island, NU sampled in 2013. ND = not detected; egg did not have SDPAs above detection limit.



C8, C9, C8C8, C9C9, C8MS-1 and UV328 were detected in the bird livers from Prince Leopold Island. The hepatic concentrations for ∑SDPAs were similar between bird species and ranged from 291 to 697 pg. g-1 (379 ± 81 pg g-1) (ww) for kittiwakes and from 136 to 724 pg g-1 (418 ± 62 pg g-1) (ww) for fulmar. C8MS-1 was the most dominant SDPA in the bird livers (91 ± 3% of ∑SDPAs) and was detected in every sample. The mean concentration of C8MS-1 was 331 ± 78 pg g-1 ww for kittiwakes and 395 ± 65 pg g-1 ww for fulmars, which was ~30 times higher than the levels found in eggs (Figure 2). This result suggests that liver is a major tissue for the accumulation of C8MS-1 and that the biotransformation of this contaminant in Arctic seabirds may be limited. For C8MS-1, the partition coefficients between the paired female liver and egg were similar (1.4 ± 0.09 for kittiwake and 1.7 ± 0.3 for fulmar), indicating similar tissue partitioning and maternal transfer processes in these bird species. In addition, C8C8 was more frequently detected in fulmar livers (56%) than in kittiwake (40%), but the concentrations were not significantly higher compared to the related eggs. For BZT-UVs, only UV328 was detected, and this contaminant was found in a single fulmar liver. UV350 was detected in Prince Leopold Island fulmar eggs but was not found in any Prince Leopold Island bird liver samples.

Figure 2. SDPA concentrations in black legged kittiwake (BLKI) and northern fulmar (NOFU) liver samples from Prince Leopold Island (PLI) and the Labrador Sea.



The factors controlling tissue distribution patterns of SDPAs and BZT-UVs in birds need further investigation; however, these results indicate that sampling both egg and adult bird provide a more holistic understanding of contaminant exposure and accumulation. Diet composition may affect the accumulation of SDPAs and BZT-UVs in seabirds. At the Prince Leopold Island site, kittiwakes generally forage within 100 km of the colony (M. Mallory, unpublished data) and mainly feed on fish (e.g., Arctic cod), while fulmars may forage as far as 500 km away and mainly feed on fish and crustaceans (Frederiksen et al., 2011; Mallory et al., 2008b; 2010). It has been reported that the amount of plastic debris found in the digestive system of fulmar from Prince Leopold Island was about 10 times higher than that of kittiwake from the same habitat (Poon et al., 2017). Such variations of plastic contamination in the two species may contribute to the different detection frequency and composition of these contaminants in seabird tissues (e.g., higher detection frequency of C4, C8, C8C8, UV328 and UV350 in fulmar egg or liver samples than in kittiwake samples), given the potentially high levels of these additives in plastic debris (Lu et al., 2018; Rani et al., 2015; 2017). Further research is underway on the potential relationship between the amount and composition of plastics ingested with the levels of plastic related contaminants including SDPAs and BZT-UVs in Arctic seabirds.

C4C4, C4C8, C8C8, C9C9, diAMS, and C8MS-1 were the SDPAs detected in liver of fulmars from the Labrador Sea (Figure 2). For the six target BZT-UVs, only UV234 was quantifiable in one fulmar liver sample from the Labrador Sea, which is consistent with the low detection of BZT-UVs in fulmar livers from Prince Leopold Island. The concentration of ∑SDPAs ranged from 131 to 2266 pg g-1 (534 ± 203 pg g-1 ww), which was not significantly different from fulmar livers from Prince Leopold Island. The dominant SDPA was C8MS-1 (71 ± 11%

of ∑SDPAs), followed by C4C8 (10 ± 5%) and C8C8 (6 ± 3%). The concentrations of C8MS-1 were significantly higher in the fulmar livers from Prince Leopold Island than those from the Labrador Sea ($p = 0.04$). In contrast, C4C4 (Labrador Sea vs. Prince Leopold Island: 40% vs. 0%) and C4C8 (Labrador Sea vs. Prince Leopold Island: 40% vs. 0%) showed higher detection frequency in fulmar livers from the Labrador Sea than those from Prince Leopold Island, indicating higher exposure risks of seabirds to C4C4 and C4C8 in the Labrador Sea compared to Prince Leopold Island. Different long-range transport potential of target SDPAs is a possible factor affecting their distribution in the Arctic.

Overall, nine SDPAs and BZT-UVs were detected in Arctic and sub-Arctic seabird samples, suggesting the presence of these contaminants in remote regions. Additional research is required to investigate the local sources and possible long-range transport of these contaminants to remote regions and evaluate the toxicokinetics and trophodynamics of SDPAs and BZT-UVs in Arctic food webs.

Expected project completion date

This project was completed in January 2019 with the publication of Lu et al. (2019). Results will continue to be shared, and the data will continue to be used by synthesis projects examining how plastic-derived and plastic-associated contaminants are associated with plastic ingestion.

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References

Avery-Gomm, S., Provencher, J.F., Liboiron, M., Poon, F.E., Smith, P.A., 2017. Plastic pollution in the Labrador Sea: An assessment using the seabird northern fulmar *Fulmarus glacialis* as a biological monitoring species. Mar. Pollut. Bull. doi:10.1016/j.marpolbul.2017.10.001

Avio, C.G., Gorbi, S., Milan, M., Benedetti, M., Fattorini, D., D'Errico, G., Pauletto, M., Bargelloni, L., Regoli, F., 2016. Pollutants bioavailability and toxicological risk from microplastics to marine mussels. Environ. Pollut. 198, 211–222.

Bakir, A., Rowland, S.J., Thompson, R.C., 2014. Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. Environ. Pollut. 185, 16–23.

Endo, S., Takizawa, R., Okuda, K., Takada, H., Chiba, K., Kanehiro, H., Ogi, H., Yamashita, R., Date, T., 2005. Concentration of polychlorinated biphenyls (PCBs) in beached resin pellets: Variability among individual particles and regional differences. Mar. Pollut. Bull. 50, 1103–1114. doi:10.1016/j.marpolbul.2005.04.030

Graca, B., Beldowska, M., Wrzesien, P., Zgrundo, A., 2014. Styrofoam debris as a potential carrier of mercury within ecosystems. Environ. Sci. Pollut. Res. 21, 2263–2271. doi:10.1007/s11356-013-2153-4

Hamlin, H.J., Marciano, K., Downs, C.A., 2015. Migration of nonylphenol from food-grade plastic is toxic to the coral reef fish species *Pseudochromis fridmani*. Chemosphere 139, 223–228. doi:10.1016/j.chemosphere.2015.06.032

Hirai, H., Takada, H., Ogata, Y., Yamashita, R., Mizukawa, K., Saha, M., Kwan, C., Moore, C., Gray, H., Laursen, D., Zettler, E.R., Farrington, J.W., Reddy, C.M., Peacock, E.E., Ward, M.W., Hirari, H., Takada, H., Ogata, Y., Yamashita, R., Mizukawa, K., Saha, M., Kwan, C., Moore, C., Gray, H., Laursen, D., Zettler, E.R., Farrington, J.W., Reddy, C.M., Peacock, E.E., Ward, M.W., 2011. Organic micropollutants in marine plastics debris from the open ocean and remote and urban beaches. Mar. Pollut. Bull. 62, 1683–1692. doi:10.1016/j.marpolbul.2011.06.004Lu, Z., De Silva, A.O., McGoldrick, D., Zhou, W., Peart, T.E., Cook, C.J., Tetreault, G.R., Martin, P., DeSolla, S., 2017a. Implications of terrestrial exposure of Herring Gulls (*Larus argentatus*) to substituted diphenylamine antioxidants in the Great Lakes of North America. Environ. Sci. Technol. Accepted w.

Lu, Z., De Silva, A.O., Peart, T.E., Cook, C.J., Tetreault, G.R., 2017b. Tissue distribution of substituted diphenylamine antioxidants and benzotriazole ultraviolet stabilizers in white sucker (*Catostomus commersonii*) from an urban creek in Canada. Environ. Sci. Technol. Lett. 4, 433–438.

Lu, Z., De Silva, A.O., Peart, T.E., Cook, C.J., Tetreault, G.R., Servos, M., Muir, D.C.G., 2106. Distribution, partitioning, and bioaccumulation of substituted diphenylamine antioxidants and benzotriazole UV stabilizers in an urban creek in Canada. Environ. Sci. Technol. 50, 9089–9097.

Lu, Z., Peart, T.E., Cook, C.J., De Silva, A.O., 2016. Simultaneous determination of substituted diphenylamine antioxidants and benzotriazole UV stabilizters in blood serum, plasma and fish homogenates by ultra-performance liquid chromatography electrospray tandem mass spectrometry. J. Chromatogr. 1461, 51–58.

Lu Z, De Silva, AO, Provencher JF, Mallory ML, Kirk JL, Houde M, Avery-Gomm S, Stewart C, Braune BM, Black A, Muir D. 2019. Accumulation of substituted diphenylamine antioxidants and benzotriazole UV stabilizers in Arctic seabirds and seals. Science of the Total Environment. doi.org/10.1016/j.scitotenv.2019.01.354.

Lusher, A.L., Tirelli, V., O'Connor, I., Officer, R., 2015. Microplastics in Arctic polar waters: the first reported values of particles in surface and sub-surface samples. Sci. Rep. 5. doi:10.1038/srep14947

Mallory, M.L., 2008. Marine plastic debris in northern fulmars from the Canadian high Arctic. Mar. Pollut. Bull. 56, 1501–1504. doi:10.1016/j.marpolbul.2008.04.017

Mallory, M.L., Braune, B., Forbes, M.R., 2006. Breeding and contaminant concentrations in northern fulmars (*Fulmarus glacialis*) from the Canadian high Arctic. Chemosphere 64, 1541–1544.

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., Kaminuma, T., 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. Environ. Sci. Technol. 35, 318–324. doi:10.1021/es0010498

Morrill, A., Provencher, J.F.F., Forbes, M.R.R., 2014. Testing for dual impacts of contaminants and parasites on hosts: the importance of skew. Environ. Rev. 22, 445–456. doi:10.1139/er-2014-0026

Poon, F., Provencher, J.F., Mallory, M.L., Braune, B.M., Smith, P.A., 2017. Plastic accumulation in four Arctic seabird species. Mar. Pollut. Bull. 116, 517–520.

Provencher, J.F., Bond, A.L., Avery-Gomm, S., Borrelle, S.B., Bravo Rebolledo, E.L., Hammer, S., Kühn, S., Lavers, J.L., Mallory, M.L., Trevail, A., Van Franeker, J.A., 2017. Quantifying ingested debris in marine megafauna: A review and recommendations for standardization. Anal. Methods 9. doi:10.1039/c6ay02419j

Provencher, J.F., McEwan, M., Mallory, M.L., Braune, B.M., Carpenter, J., Harms, H.J., Savard, G., Gilchrist, H.G., 2013. How wildlife research can be used to promote wider community participation in the North. Arctic 66, 237–243.

Provencher, J.F.F., Gaston, A.J.J., Mallory, M.L.L., 2009. Evidence for increased ingestion of plastics by northern fulmars (*Fulmarus glacialis*) in the Canadian Arctic. Mar. Pollut. Bull. 58, 1092–1095. doi:10.1016/j.marpolbul.2009.04.002

Provencher, J.F.F., Gaston, A.J.J., Mallory, M.L.L., O'hara, P.D.D., Gilchrist, H.G.G., 2010. Ingested plastic in a diving seabird, the thick-billed murre (*Uria lomvia*), in the eastern Canadian Arctic. Mar. Pollut. Bull. 60, 1406–1411. doi:10.1016/j.marpolbul.2010.05.017

Provencher, J.F.F., Gilchrist, H.G.G., Mallory, M.L.L., Mitchell, G.W.W., Forbes, M.R.R., 2016. Direct and indirect causes of sex differences in mercury concentrations and parasitic infections in a marine bird. Sci. Total Environ. 551–552, 506–512. doi:10.1016/j.scitotenv.2016.02.055

Rani, M., Shim, W.J., Han, G.M., Jang, M., Al-Odaini, N.A., Song, Y.K., Hong, S.H., 2015. Qualitative analysis of additives in plastic marine debris and its new products. Arch. Environ. Contam. Toxicol. 69, 352–366.

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., Watanuki, Y., 2015. Facilitated leaching of additive-derived PBDEs from plastic by seabirds' stomach oil and accumulation in tissues. Environ. Sci. Technol. 49, 11799–11807.

Teuten, E.L., Saquing, J.M., Knappe, D.R.U., Barlaz, M.A., Jonsson, S., Bjorn, A., Rowland, S.J., Thompson, R.C., Galloway, T.S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Pham, H. V, Tana, T.S., Prudente, M., Boonyatumanond, R., Zakaria, M.P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., Takada, H., 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Philos. Trans. R. Soc. B-Biological Sci. 364, 2027–2045. doi:10.1098/rstb.2008.0284

UNEP, 2014. UNEP Year Book 2014 emerging issues update. United Nations Environment Programme, Nairobi, Kenya.

Van Cauwenberghe, L., Janssen, C.R., 2014. Microplastics in bivalves cultured for human consumption. Environ. Pollut. 193, 65–70.

Wang, F., Shih, K.M., Li, X.Y., 2015. The partition behavior of perfluorooctanesulfonate (PFOS) and perfluorooctanesulfonamide (FOSA) on microplastics. Chemosphere 119, 841–847. doi:10.1016/j.chemosphere.2014.08.047

Zhang, W.W., Ma, X.D., Zhang, Z.F., Wang, Y., Wang, J.Y.J., Wang, J.Y.J., Ma, D.Y., 2015. Persistent organic pollutants carried on plastic resin pellets from two beaches in China. Mar. Pollut. Bull. 99, 28–34. doi:10.1016/j.marpolbul.2015.08.002

A comparative assessment of relationships between priority contaminants and metabolomic profiles in polar bears (*Ursus maritimus*) and ringed seal (*Pusa hispida*) prey from Canadian High Arctic and Hudson Bay locations

Évaluation comparative des relations entre les contaminants prioritaires et les profils métabolomiques chez l'ours polaire (*Ursus maritimus*) et sa proie le phoque annelé (*Pusa hispida*), dans l'Extrême-Arctique canadien et la baie d'Hudson

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Project locations/Emplacements du projet

- Polar bears (archived): Rankin Inlet, Whale Cove, Arviat, Chesterfield Inlet, Pond Inlet, Clyde River and Qikiqtarjuaq, NU
- Ringed seals (archived): Arviat and Resolute Bay, NU.

Abstract

Metabolomics measures hundreds of small, natural compounds (metabolites) created by metabolism in an animal or plant (e.g., sugars, amino acids, fatty acids, other lipids). These small compounds are "profiled" in a tissue of an animal and can change in response to differences in diet or health, and with contaminant exposure (among other things). This project expanded on previous investigations of Hudson Bay polar bears by comparing the metabolomic profiles of bears from the Western Hudson Bay (WHB) with those from the High Arctic (Baffin Bay) subpopulations. We also investigated how the metabolite profiles in the liver of polar bears relate to those of their major prey species (ringed seals), which may allow us to more clearly reveal relationships of metabolites with new and legacy persistent organic pollutants (POPs) and mercury, as well as providing information about how diet affects metabolite profiles in the Hudson Bay bears. When complete, this study will help us better understand which legacy and emerging contaminants are related to consistent biological changes, as indicated in the metabolite profiles of polar bears and seals. Our initial assessment has shown that the metabolite levels and patterns of the four groups of animals (High Arctic polar bear and seals, and Western Hudson Bay polar bears and seals) were different enough to be easily identified. This demonstrated that there were measurable differences in the biology between these species, and between the subpopulations within the species. Fat-loving legacy POPs and newer POPs were measured in the liver of polar bears and seals. The results showed distinct differences between the High Arctic and WHB, although the patterns in the bears and seals were the opposite of each other and inconsistent between locations. For example, if a given contaminant was high in concentration in bears from the High Arctic it tended to be low in seals at that location, with the opposite pattern observed in the Hudson Bay. These patterns made identifying the contaminant-metabolite relationships more difficult but the preliminary results are encouraging. Because the differences in POP levels still created unique

Résumé

La métabolomique mesure des centaines de petits composés naturels (métabolites) produits par le métabolisme d'un animal ou d'une plante (p. ex., sucres, acides aminés, acides gras, autres lipides). Ces petits composés forment un « profil » dans un tissu d'un animal et peuvent changer en fonction des différences de régime alimentaire ou de santé, et de l'exposition aux contaminants (entre autres). Ce projet s'est appuyé sur des études antérieures sur les ours polaires de la baie d'Hudson et a permis la comparaison des profils métabolomiques des ours de l'ouest de la baie d'Hudson (OBH) avec ceux des sous-populations du Haut-Arctique (baie de Baffin). Nous avons également étudié la relation entre les profils métaboliques dans le foie des ours polaires et ceux de leurs principales proies (phoques annelés), ce qui pourrait nous permettre de comprendre plus clairement les relations entre des métabolites et les polluants organiques persistants (POP) et le mercure, nouveaux et hérités, et d'obtenir des données sur la façon dont le régime alimentaire influence les profils métaboliques des ours de la baie d'Hudson. Une fois terminée, cette étude nous aidera à mieux connaître les contaminants hérités et nouveaux liés à des changements biologiques constants, comme l'indiquent les profils métaboliques des ours polaires et des phoques. Notre première évaluation a montré que les concentrations et les profils de métabolites des quatre groupes d'animaux (ours polaires et phoques du Haut-Arctique, et ours polaires et phoques de l'ouest de la baie d'Hudson) étaient suffisamment différents pour être facilement identifiés. Nous avons constaté des différences mesurables dans la biologie entre ces espèces, et entre les sous-populations au sein de ces espèces. Les POP hérités lipophiles et les POP plus récents ont été mesurés dans le foie des ours polaires et des phoques. Les résultats ont révélé de nettes différences entre le Haut-Arctique et l'OBH, bien que les tendances chez les ours et les phoques soient opposées et incohérentes d'un endroit à l'autre. Par exemple, si un contaminant donné était fortement concentré chez les ours du Haut-Arctique, il avait tendance à être faible chez les phoques à cet endroit, la tendance opposée

profiles in each group of animals, we were able to use them to investigate how they relate to changes in metabolite profiles. Consistent correlations were seen between the total levels of perfluorinated alkyl substances (PFASs) and fat-related metabolites and amino acids, suggesting that high levels of the PFASs were related to decreases in fat metabolism and increases in protein metabolism. Total mercury levels were also weakly correlated to some fat-related compounds that may be part of the response of the liver to stress or may simply be part of lipid metabolism. Once we have complete profiles of POPs, more specific relationships between POPs and metabolites will be investigated, however, the preliminary results showed some consistent relationships between contaminant exposures and metabolite levels and patterns. To introduce the concept of metabolomics to Northerners a metabolomics “fact sheet” (“Using Metabolomics to Study Contaminants and Diet in Nunavut Wildlife”) was prepared that was developed with input from the Nunavut Environmental Contaminants Committee (NECC) and was later distributed at the NCP Results Workshop in Whitehorse, YT and discussed with those that were interested.

étant observée dans la baie d’Hudson. Ces tendances ont rendu plus difficile notre tâche de déterminer les relations contaminants-métabolites, mais les résultats préliminaires sont encourageants. Comme les différences entre les concentrations de POP créaient encore des profils uniques dans chaque groupe d’animaux, nous avons pu les utiliser pour étudier leur lien avec les changements de profils de métabolites. Des corrélations cohérentes ont été observées entre les concentrations totaux de substances perfluoroalkylées (PFAS) et les métabolites et acides aminés liés aux graisses, ce qui laisse croire que des concentrations élevées de PFAS sont liées à une diminution de la métabolisation des graisses et à une augmentation de la métabolisation des protéines. Les concentrations de mercure total étaient également faiblement corrélées avec certains composés lipidiques qui peuvent faire partie de la réponse hépatique au stress ou peuvent simplement faire partie de la métabolisation des lipides. Une fois que nous disposerons de profils complets des POP, des relations plus spécifiques entre les POP et les métabolites seront étudiées. Cependant, les résultats préliminaires ont montré certaines relations cohérentes entre l’exposition aux contaminants et les concentrations et modèles des métabolites. Afin de présenter le concept de la métabolomique aux habitants du Nord, une « fiche d’information » sur la métabolomique (Utilisation de la métabolomique pour étudier les contaminants et le régime alimentaire des animaux sauvages du Nunavut) a été préparée. Cette fiche a été conçue avec la contribution du Comité des contaminants environnementaux du Nunavut (CCEN). Elle a ensuite été distribuée lors de l’atelier sur les résultats du PLCN à Whitehorse (Yukon), et a fait l’objet de discussions avec les personnes intéressées.

Key messages

- Metabolite profiles of polar bears from the High Arctic, Baffin Bay subpopulation were compared to those from the Western Hudson Bay subpopulation in order to expand on previous observations regarding relationships between metabolites and POPs and mercury from nearby subpopulations

Messages clés

- Les profils métaboliques des ours polaires de la sous-population du Haut-Arctique et de la baie de Baffin ont été comparés à ceux de la sous-population de l’ouest de la baie d’Hudson afin d’améliorer les observations précédentes concernant les relations entre les métabolites et les POP et le mercure des sous-populations voisines ayant un profil with similar exposures (Southern and Western Hudson Bay).

- We performed the same analyses in ringed seals from similar locations in order to assess dietary transfer of metabolites, POPs, and mercury, and to compare the POP-metabolite relationships between two important Arctic species.

- The profiles of metabolites of the four groups (High Arctic polar bear and seals, and Western Hudson Bay polar bears and seals) could be identified from each other using statistics, indicating significant differences between the species and between the populations/locations of bears and seals which were related to differences in the biology and toxicology (contaminant exposures) of the animals.

- In the liver of both species, total mercury (THg) and the åPFAS levels were the highest contaminant concentrations, followed by åCHL and the åPCB and åDDT, with smaller amounts of åHCH, åCBz, and the åPBDE.

- Several groups of legacy POPs were greater in the WHB bears, however, the THg and åPFAS levels were greater in the High Arctic bears, while the opposite pattern was observed in seals. Despite these differences, the levels have created unique exposure groups that can be used to investigate POP/THg-metabolite relationships.

- Final POP/THg profiles remain in process; however, preliminary analyses have found significant correlations between the åPFAS, THg and several major groups of metabolites related to fatty acid and protein metabolism as well as cellular signalling and inflammation responses.

d'exposition similaire (sud et ouest de la baie d'Hudson).

- Nous avons effectué les mêmes analyses sur des phoques annelés provenant d'endroits similaires afin d'évaluer le transfert alimentaire des métabolites, des POP et du mercure, et de comparer les relations entre les POP et les métabolites de deux espèces importantes de l'Arctique.

- Les profils des métabolites des quatre groupes (ours polaires et phoques du Haut-Arctique, et ours polaires et phoques de l'ouest de la baie d'Hudson) ont pu être différenciés statistiquement les uns des autres, et présentaient des différences significatives d'une part entre les espèces, et d'autre part entre les populations/emplacements des ours et des phoques qui étaient liées à des différences biologiques et toxicologiques (exposition aux contaminants) des animaux.

- Dans le foie des deux espèces, les concentrations de mercure total (HgT) et de ∑PFAS étaient les plus élevées, suivies de celles des ∑CHL, ∑BPC et ∑DDT, et les quantités plus faibles concernaient HCH, ∑CBz et ∑PBDE.

- Plusieurs groupes de POP hérités étaient plus importants chez les ours de l'OBH, mais le HgT et les concentrations de ∑PFAS étaient plus élevées chez les ours du Haut-Arctique, tandis qu'on observait l'inverse chez les phoques. Malgré ces différences, les concentrations nous ont permis de créer des groupes d'exposition uniques qui peuvent être utilisés pour étudier les relations entre POP-HgT et métabolites.

- Les profils définitifs POP/HgT sont encore en cours d'élaboration. Toutefois, des analyses préliminaires ont révélé des corrélations significatives entre les ∑PFAS, le HgT et plusieurs grands groupes de métabolites liés à la métabolisation des acides gras et des protéines ainsi qu'avec les réponses de signalisation cellulaire et de l'inflammation.

Objectives

The aims of this project were to:

1. improve the scientific understanding of how natural variation in POP and mercury exposures are related to differences in metabolomic profiles in polar bears and ringed seals;
2. improve the scientific understanding of how diet affects the metabolomic profiles in polar bears from different subpopulations in the Canadian Arctic;
3. establish whether consistent relationships exist as per (1) and (2), which may help identify potential biomarkers indicating differences in diet or POP exposure;
4. improve the usefulness and application of metabolomics in field-based environmental monitoring of POP and mercury exposure and effects; and
5. develop a fact sheet to communicate metabolomics concepts and applications to both Southern and Northern governments and communities.

Introduction

Metabolomics measures low molecular weight metabolites, including sugars, amino acids (AAs), fatty acids (FAs), membrane lipids (mostly phospholipids), neurotransmitters, and other important molecules. The changes in metabolic profiles of tissues or cells can be used as indicators of exposure to contaminants and/or specific metabolites may be biomarkers of exposure to particular contaminants (Bundy et al. 2009). Metabolomics can be used to produce large amounts of information on the metabolites and pathways that are changed in an animal in response to environmental or physiological factors. Changes in metabolite patterns have been observed after seasonal changes (Sadler et al. 2014), pharmaceutical/contaminant exposures (Aliferis and Chrysayi-Tokousbalides 2011; Huang et al. 2016; O'Kane et al. 2013; Samuelsson et al. 2011), temperature stress (Ellis et al. 2014), dietary restriction (van Ginneken et al. 2007), long distance movement/migration (Benskin et al. 2014), infection/disease (Ellis et al. 2014), sex (Størseth et al. 2009), and age (Niemuth and Stoskopf 2014; Størseth et al. 2009).

Only a few metabolomic studies of any species of bear exist in the literature, most of which involve differences such as age, sex and reproductive condition of the animals (Niemuth and Stoskopf 2014; Størseth et al. 2009; Zhang et al. 2015). Recently, our work has shown consistent correlations between organic contaminants and metabolites in field-sampled polar bears from the closely oriented WHB and southern Hudson Bay (SHB) subpopulations (Morris et al. 2019). The strongest relationships were between the perfluorinated alkyl substances (PFASs), some lipophilic persistent organic pollutants (POPs), and components of metabolome that were related to lipid metabolism (FAs, phospholipids, acylcarnitines). Though, there were consistent relationships observed with contaminants. Many of the lipid-based compounds that were responsible for separating the bears were also significantly correlated with dietary indicators (d^{13C} and d15N), suggesting that differences in diet were also important to consider in comparisons like these, and that, dietary differences complicated the relationships with contaminants (Morris et al. 2019). Other recent studies have also shown some consistent relationships between contaminant concentrations and changes in the liver metabolome and the lipidome (fat) of Norwegian polar bears (Tartu et al. 2017). Studies have also shown that changes in the blubber transcriptome were also related to polychlorinated biphenyls (PCB) concentrations in ringed seals from Labrador, Canada (Brown et al. 2017).

The current project is complementary to the ongoing polar bear (Project M-05 -*Temporal and Spatial Trends of Legacy and Emerging Organic and Metal/Elemental Contaminants in Canadian Polar Bears*, PI R.J. Letcher) and ringed seal (Project M-04 - *Temporal trends of persistent organic pollutants and metals in ringed seals from the Canadian Arctic*, co-PI D. Muir, M. Houde) core monitoring programs. The project focussed on two focal ecosystems from the NCP Environmental Monitoring and Research Blueprint, the Barrow Strait/Lancaster Sound and Hudson Bay, as well as the Baffin Bay (BB) region. Our previous studies (Morris et al. 2019; Morris et al. 2018) allowed us to optimize the metabolomic methods and analysis in polar bear muscle and liver tissues and establish that distinct differences were observed in metabolite profiles that were related to contaminant levels, even in the nearby subpopulations of the SHB and WHB. Concentrations of legacy organochlorine contaminants and flame-retardants in the Hudson Bay tend were among the greatest observed in the fat of bears throughout the Canadian Arctic (McKinney et al. 2011a). Including a subpopulation from further north with one from Hudson Bay could help to confirm the relationships we observed in the SHB and WHB, as they should have larger differences in POPs concentrations due to differences in the latitude of their ranges and the greater population density and shipping traffic in the Hudson Bay relative to Baffin Bay. The High Arctic subpopulation of polar bears in BB was selected to compare with the WHB bears because of the spatial separation, but also because samples from BB were readily available from previous NCP collections and were included at minimal cost.

The polar bear diet is undergoing alterations in some subpopulations, but ringed seals are still the major component of most of them (McKinney et al. 2011b). Thus, we included paired ringed seal samples from approximately the same locations that the polar bear samples were taken from, so that we may be able to identify some metabolites that were specific to diet and not heavily affected by contaminant concentrations. The seals also provided a means to investigate the consistency of correlations between concentrations of contaminants and potential effects across two species, and investigate how the predator-prey interaction influences those relationships. To achieve this, we have produced detailed dietary information for both polar bears and ringed seals in the form of stable isotope ratios of carbon (d13C) and nitrogen (d15N) as well as fatty acid profiles. Oxidized FAs called oxylipins, dietary signaling molecules that regulate many fundamental physiological processes such as inflammation and oxidative stress, were also included in the analyses. Even if the dietary relationships with metabolites cannot be compensated for, investigating changes in concentrations of metabolites and contaminants in a predator and a major prey species will be valuable for improving our understanding of the relationships between contaminants and physiological responses at a molecular level. Both polar bears and ringed seals are high priority wildlife from an ecotoxicological perspective and from the human health and culture perspective as they are regularly hunted for subsistence and cultural reasons. This makes understanding their exposure profiles and the combined effects of the mixture of contaminants in them a priority, and using metabolomics and other Omics methods may help us advance those goals.

Activities in 2018-2019

Samples

We used samples from 2015-2016 collections under the NCP core monitoring programs M-04 and M-05 as the sample numbers and timelines of collection between the polar bears and ringed seals were very comparable (Table 1). WHB collections included contributions from hunters from Rankin Inlet, Whale Cove, Arviat, Chesterfield Inlet, and from Arviat for the ringed seals. Baffin Bay polar bears were collected by the hunters from Pond Inlet, Clyde River and Qikiqtarjuaq and Lancaster Sound seals were collected from Resolute Bay (both will be referred to as "High Arctic (HA)" animals). Tissues were excised and stored in the respective tissue banks: polar bears at the Specimen Bank at the National Wildlife Research (ECCC, Ottawa, ON) and ringed seals at the Muir laboratory at the Canada Center for Inland Waters (CCIW, ECCC, Burlington, ON). Stable isotope, PFAS, and THg analyses for seals were all performed as part of the M-04 NCP monitoring program. Analysis of 15 of 30 polar bears for stable isotope, PFAS, and THg were part of the M-05 NCP core monitoring program (those from the WHB), the other 15 samples were analyzed as part of this project under the NCP in 2018-2019. All liver samples for contaminant analyses (from seals and bears), liver samples for metabolomics assessments, as well as fat for supplementary fatty acid analysis and muscle for supplementary stable isotope analyses were subsampled and prepared at the National Wildlife Research Centre (NWRC) when necessary.

Analyses

Analytical details of POPs and THg are available in very recent publications by Letcher et al.(2018) and Morris et al.(2019) respectively. The analytes include the majority of those listed in Annex A, B and C of the Stockholm Convention on POPs as well as several proposed POPs (United Nations Environment Programme 2019). We opted to measure all organic contaminants and mercury in liver, including the lipophilic POPs typically assessed in blubber or fat of marine mammals. Since profiles of contaminants and metabolites were measured in the same tissue, our hypothesis was that this method would strengthen the identification of potential contaminant effect-related relationships. Measuring lipophilic POPs in liver required some optimization of the established NWRC method for extraction and clean up of polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs), and halogenated flame retardants (HFRs) to ensure the quality of the extractions and instrumental determination to generate the quantitative data. The lipophilic POPs included PCBs, OCPs and other organochlorines (OCs), polybrominated diphenyl ethers (PBDEs) and alternative HFRs, as well as perfluorinated alkyl substances (PFASs). Only PFASs are routinely measured in liver. Lipophilic contaminant analyses for bears and seals were all performed at the Letcher / Organic Contaminant Research Laboratory (OCRL) and THg in bears was measured at Laboratory Services (THg) at the NWRC (ECCC, Ottawa, ON) as detailed in NCP project M-05. PFASs and THg in seals were analyzed at the Canada Center for Inland Waters (CCIW, Burlington, ON), as outlined in project M-04.

Metabolomics analysis was carried out by SGS AXYS (Sidney, BC). Methods for metabolomics have been provided elsewhere (Morris et al. 2018). In all, 239 metabolites were analyzed in liver tissues including sugars (hexoses), AAs, biogenic amines (including neurotransmitters), FAs, acylcarnitines, and membrane

Table 1. Summary of the samples collected under NCP core monitoring projects M-04 (ringed seals) and M-05 (polar bears) in 2015-2016 and used for the present investigation. Ages are shown as means ± standard deviations. Stable isotope ratios (‰) are also illustrated in Figure 3.

	Polar bears		Ringed seals	
	WHB	Baffin Bay	WHB	Lancaster Sound
Year	2015	2015	2015	2016
Month	Sept-Oct	Oct-Dec	Oct	May-June
Age	6.5 ± 3.9	In process	6.6 ± 7.1	7.8 ± 7.1
Total n	15	15	15	13
Adult males	6	7	2	5
Adult females	4	1	6	4
Subadults	5	7	7	4
d13C (‰)	-18.9 ± 0.739	-17.9 ± 0.398	-21.1 ± 1.16	-19.2 ± 0.683
d15N (‰)	18.9 ± 1.82	20.2 ± 0.605	16.3 ± 0.471	17.6 ± 0.677

lipids including phosphatidylcholines, lysophosphatidylcholines, and sphingomyelins as well as a suite of metabolites from the glycolytic and citric acid cycles. Stable isotope ratios were measured for d13C and d15N in muscle tissue at The Great Lakes Institute for Environmental Research (GLIER) (University of Windsor, Windsor, ON) and the University of Waterloo (Waterloo, ON) for bear and seals respectively, and FA signatures were measured by Laboratory Services (NWRC, Ottawa, ON). Oxylipins were measured in Dr. Amy Rand's laboratory in the Department of Chemistry at Carleton University (Ottawa, ON).

Statistical analyses

Multivariate statistical analyses of metabolites alone or metabolites with dietary tracers and contaminants were performed using partial least squares discriminant analysis (PLS-DA) through the online bioinformatics platform Metaboanalyst 4.0 (www.metaboanalyst.ca), pathway analyses will be also be carried out on that platform. Other statistical comparisons (ANOVA, *t*-tests, correlations) were performed using a combination of SYSTAT v.12 and Sigmaplot v.11 (SYSTAT Software Inc). Data were filtered so only metabolites detected in > 80 % of samples were included, unless they were distinctly different between groups and could be related to specific physiological processes. A principal component analysis (PCA) was performed, the variance explained by the loadings (loading value squared) across the first three components was summed, and the least influential 25 % of the variables were eliminated. PLS-DA analysis combined with variable importance in projection (VIP) methods were used to identify the metabolites that distinguish the groups of bears from each other and from the seals (VIP scores greater than one indicate influential compounds). For exploratory purposes, only the four-group PLS-DA analysis is shown. However, a series of two group comparisons were also used to help clarify what metabolites and contaminants that drove the differences between and within species (results pending).

Capacity building, communications and Indigenous knowledge (IK) integration

Because samples were collected under other NCP programs with their own well-developed communication plans, there was no extensive consultation with the communities involved with sample collection in terms of capacity building or IK integration, though these are integral to collections under M-05 and M-04. We prepared a metabolomics "fact sheet" that was redeveloped after feedback from the the Nunavut Environmental Contaminants Committeee (NECC) before being translated to Inuktitut and disseminated at the 2019 NCP Results Workshop (English and Inuktitut versions are provided in Appendix A). We focussed on the nutritional aspects of metabolomics methods, as the majority of the compounds involved are related to the metabolism of proteins (amino acids), carbohydrates (sugars), and fats (fatty acids, cell membrane lipids, and related compounds). Because the metabolomics profiles are affected by diet, we highlighted this as an example, and offered one non-specific example of how contaminants might affect patterns of metabolites in wildlife. After feedback and editing as per comments from the NECC, we included this fact sheet with communication materials provided to the communities as part of M-05 and M-04. These NCP core projects provide annual results to participating communities, with PIs Letcher and Houde also participating in regional workshops. The fact sheet was also included with this year's contaminant results, with a summary of the major metabolomics results included in the communications package the following year (once approved by the NECC). Any suggestions from the NECC or other contributors regarding communications or integration of IK are welcome.

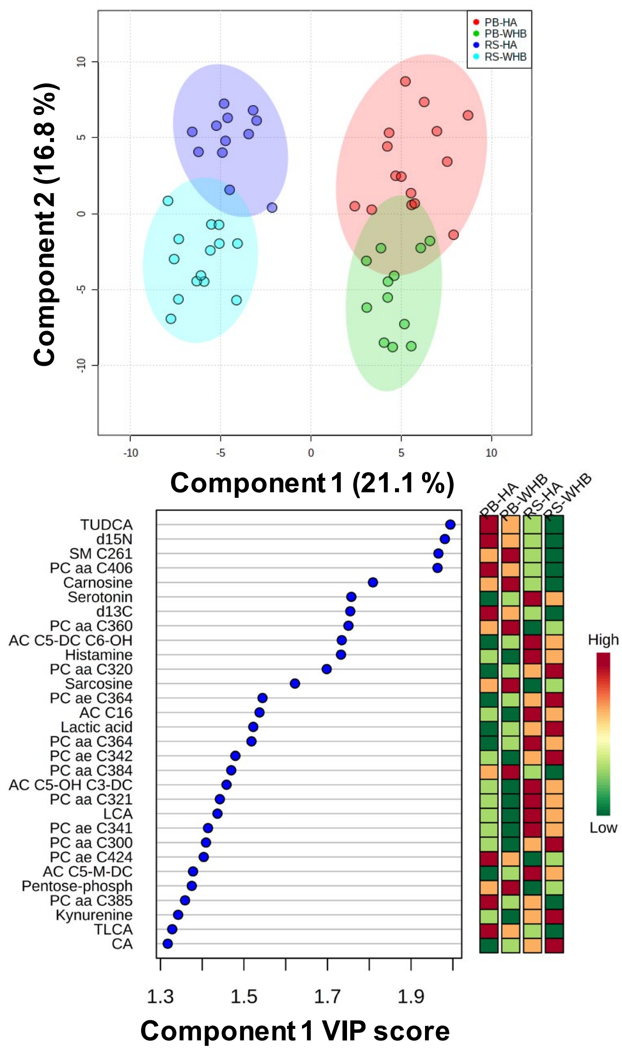
Results and outputs/deliverables

Metabolomics profiles

Initial exploratory analyses showed that the metabolite profiles produced relatively well resolved clustering of the four groups: High

Arctic seals (Resolute Bay), High Arctic bears (Baffin Bay), WHB seals, and WHB bears (Figure 1). There were three outlying samples in the WHB bears, one WHB seal and one HA seal identified in the PCA score plots, which were eliminated for the current analyses but will be reassessed once the contaminants are added to the dataset as the variation in the model will change.

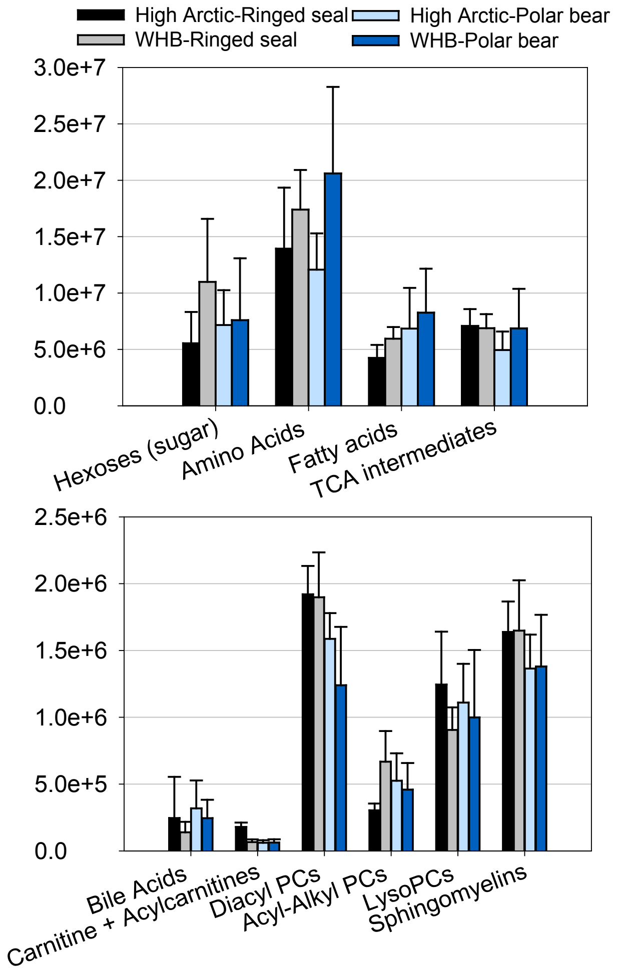
Figure 1. Partial least squares discriminant analysis (PLS-DA) score plot (top panel), with the associated variable importance in projection (VIP) plot to variables of importance to the model (bottom panel). The data were glog transformed (general logarithmic transformation) and autoscaled for PCA and PLS-DA analyses. PB = polar bear, RS = ringed seal, HA = High Arctic, WHB = western Hudson Bay. Three WHB polar bear outliers were removed, as were outliers from each seal population.



The model was composed of three components that explained 46.8% of the variance (Figure 1). The bears and seals separated clearly along component 1 in the PLS-DA model, which the loadings values and VIP scores indicated were driven by stable isotope values of both d13C and d15N, some biogenic amine-based compounds (histamine, kynurenine, sarcosine), several bile acids, a number of compounds related to lipid metabolism and b-oxidation (acylcarnitines, phospholipids), lactic acid, serotonin and symmetric dimethyl arginine (SDMA). Clustering of scores along the second component seemed to be most relevant to the separation of the different subpopulations of the same species, though these did also vary along component 1 to a lesser degree. Separation on component 2 had large influences from a few membrane lipids involved in lipid storage, metabolism and cellular signalling, (phosphatidylcholines, sphingomyelins) and a number of AAs including glutamine, glutamate, lysine, threonine and others suggesting that differences in protein synthesis largely drive the separation on component 2. These exploratory statistics showed that even without the addition of contaminants and fatty acid signatures to the models and with only minimal filtering of the data, the four groups of animals had unique metabolomic signatures that were distinguishable from each other.

The total (å) concentrations of the metabolites are shown in Figure 2. Free FAs and bile acids were greater in bears over seals, likely due to the lipid rich diet of the bears (seal blubber) compared to the diet of fish and invertebrates in seals. Greater concentrations of AAs in polar bears from WHB compared to BB bears may indicate a greater proportion of protein in the diet of these bears. Ringed seals from Hudson Bay also had greater AAs than their HA counterparts, which may also be related to different nutrient inputs in to the Bay relative to the HA, localized differences in diet, or possibly similar physiological responses to stressors such as contaminants.

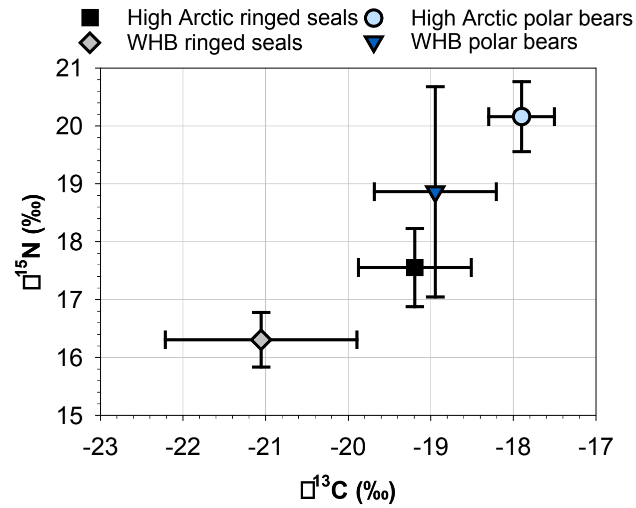
Figure 2. Total (å) concentrations (ng·g-1 wet weight) of major metabolite classes in the four groups investigated in this project. PC = phosphatidylcholines, lysoPC = lysophosphatidylcholines, TCA = tricarboxylic acid cycle.



Stable isotope ratios

Stable isotope plots showed greater variation in both carbon and nitrogen isotopes in the WHB polar bears than in the HA polar bears which may indicate a more consistent diet in the more northern population (Figure 3). Like the WHB bears, the seals in WHB had broader d13C values than the HA seals, which may again be related to differences in dietary sources, or possibly nutrient dynamics in the large catchment area of the Hudson Bay.

Figure 3. Stable isotope ratios (‰) of carbon (d13C = 13C/12C) and nitrogen (d15N = 15N/14N) in ringed seals from Lancaster Sound (High Arctic) and western Hudson Bay, and polar bears from the Western Hudson Bay and Baffin Bay (High Arctic) subpopulations.



Fatty acid and oxylipin profiles

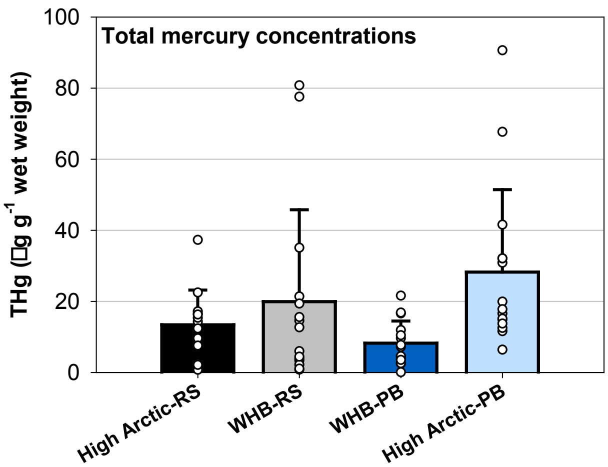
Fatty acid profiles have been received, but have not yet been analyzed statistically. Oxylipin methods have been optimized for the new conditions in Dr. Rand's laboratory and analyses are currently underway.

Contaminant concentrations

Mercury

Total mercury (THg) concentrations in liver of seals and bears varied differently by species, but only the HA polar bears and WHB bears were significantly different (ANOVA on Ranks with Dunn's Test, $p < 0.05$) (Figure 1). The opposite trend in concentrations were observed in the seals, with the WHB animals having greater and more variable concentrations of THg than HA seals, however, these were not statistically different. Biomagnification of mercury was apparent in the HA bears compared to seals (biomagnification factors (BMF) = 2.1 ± 2.3) but not in the WHB animals (BMF = 0.41 ± 0.62). However, given the high variability in both measurements, results were not definitive in terms of dietary magnification of THg.

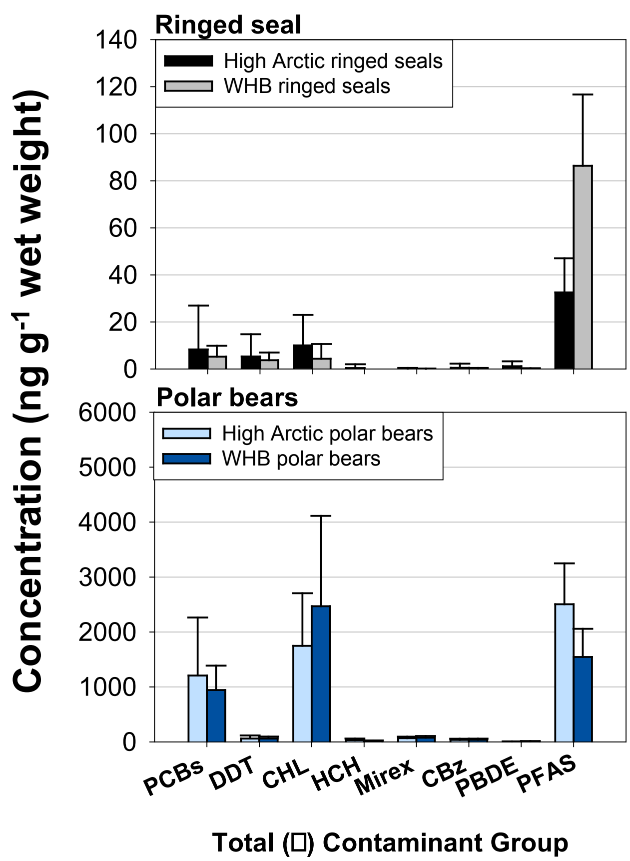
Figure 4. Concentrations (means ± SDs) of total mercury (µg·g-1 wet weight) in the liver of ringed seals (RS) from Lancaster Sound (High Arctic) and the western Hudson Bay (WHB), and polar bears (PB) from the Western Hudson Bay and Baffin Bay (High Arctic) subpopulations. Hollow circles are concentrations in individual animals.



Organic contaminants

Lipophilic POPs were determined in liver tissue rather than fat/blubber tissue, which is normally the tissue of analysis in polar bear and ringed seal studies. As indicated, the ringed seal dataset is partially incomplete, so these data were not tested statistically at this point. The greatest legacy POPs in the four groups were the åchlordanes (CHL), the åPCB and the åDDT, followed by much lower concentrations of åchlorobenzenes (CBz), åmirex, and åHCH (Figure 5). The majority of the åCHL is the metabolite oxychlordane, which typically had the greatest individual concentrations for all of the contaminants, exceeding those of the recalcitrant PCB congeners such as PCB-153. Very few HFRs were detected in the liver of either species. Of the 45 HFRs (24 PBDEs, 2 PBBs, and 19 alternative HFRs) only BDE-47, BDE-99 and BDE-153 were detected at reasonable frequencies, and only BDE-47 was detected at acceptable frequencies for future multivariate analyses (> 80 % detections in all samples). The mean åPBDE concentrations exceeded those of the lesser OCs (CBz, HCH, mirex) in seals, but were lower than all of the legacy POPs in polar bears. In general, the concentrations in the polar bears were 1-2 orders of magnitude greater than those in ringed seals (note scale difference in Figure 5). Though the seal dataset for the lipophilic POPs is preliminary, the HA seals had greater concentrations of the PCBs and OCs than the WHB seals, though most of the differences were relatively small. In the bears, the differences in contaminant concentrations were not consistent with the seals–the åPCB and åHCH were ~28 % and 100 % greater in the HA bears while the åCHL and the åPBDE were ~41 % and 76 % greater in WHB over the HA polar bears. The remaining lipophilic compounds had very small differences between polar bear subpopulations.

Figure 5. Concentrations of major organic contaminant groups (ng·g-1 wet weight) in polar bears and ringed seals from the High Arctic and western Hudson Bay. Note the scale differences between the seals and polar bears and that the PCB, OCP and PBDE data are preliminary and should be interpreted cautiously.



Like the lipophilic POPs, the pattern of PFAS accumulation in seals differed regionally from those in polar bears. The åPFAS was 165 % greater in the WHB over HA seals, but the opposite was true in bears, with the HA bears having 62 % greater concentrations than those of the WHB bears (Figure 5). At both locations, the concentrations of the åPFAS were also 1-2 orders of magnitude greater in bears than seals. The biomagnification factors (BMFs) in bears indicated a greater degree of biomagnification of PFASs in the HA bears (åPFAS BMF = 77 ± 41) than in the WHB (BMF = 18 ± 8.6) (Table 2).

Table 2. Biomagnification factors (BMFs; liver:liver comparisons) of total PFASs (ng·g-1 wet weight) and total mercury (THg, µg·g-1 wet weight) calculated from mean contaminant concentrations in liver of polar bears compared to those in liver of ringed seals. High Arctic comparisons were between Baffin Bay polar bears and Lancaster Sound seals. BMFs are means ± standard deviations. åPFAS = total perfluorinated alkyl substances, åPFCA = total perfluorocarboxylic acids, åPFSA = total perfluorosulfonic acids.

Contaminant	Hudson Bay BMF	High Arctic BMF
Total mercury (THg)	0.41 ± 0.62	2.1 ± 2.3
åPFAS	18 ± 8.6	77 ± 41
åPFCA	14 ± 6.5	43 ± 24
åPFSA	22 ± 11	126 ± 71

Discussion and conclusions

Metabolite profiles were well resolved between the four groups of animals investigated here, even when the contaminants were not included in the profiles for analyses. This indicates that the metabolite profiles and related physiological processes vary significantly both within and between species. The addition of other significant covariates, such as contaminants and oxylipins along with further filtering of uninfluential variables, will strengthen the multivariate models for final interpretations. Pairwise comparisons of species from each location, as well as between predator-prey, bears and seals at each location, along with the incorporation of other detailed dietary tracer analysis (fatty acids) will help us identify the metabolites strongly related to dietary differences and those that covary with contaminants (with or without dietary influence) and that may be indicative of effects of chronic exposures.

In terms of the stable isotope signatures, the diet-tissue discrimination factors for d15N (D15N) between the polar bears and seals were both consistent at 2.6 ‰, while the diet-tissue discrimination factors for d13C (D13C) were 1.3 ‰ and 2.1 ‰ for the HA and WHB comparison respectively. The expected diet-tissue discrimination factors for predator-prey interactions in the Arctic range from 3–5 ‰ for D15N (Jardine et al. 2006), and » 1.3 ‰ for D13C (McKinney et al. 2012). The measured values here were within reasonable range of the expected values, though the larger than expected D13C does indicate that there is greater dietary variation in the WHB bears than those in the HA. Likewise, the slightly lower than anticipated D15N values for the bear:seal relationship may be indicative of dietary components of a lower trophic level such as other species of open water seal for example (McKinney et al. 2011b). However, the ringed seals do remain important and are the most abundant component of the polar bear diet (McKinney et al. 2011b).

It appears that our exposure groups (high versus low) for the metabolomic assessment will be contaminant-class and species-specific due to the differences between HA and WHB animals, which were also inconsistent between the bears and seals. The majority of the legacy POPs were very low and variable in concentration and may not have a significant impact on the multivariate models, though the chlordanes, PCBs, DDT and PBDEs varied the most between groups. The greatest differences were observed for the known hepatotoxic PFAS compounds and THg, which were both greater in the HA bears and conversely in the WHB seals.

Because the dataset was incomplete, we did not test correlations between lipophilic POPs and the metabolites,however, correlations between THg and the total (å) metabolite groups showed that THg was positively, but weakly correlated to the åLysoPC ($r2 = 0.079$, $p = 0.033$, $n = 58$). LysoPCs function in the alteration of plasma membrane phospholipid composition, FA metabolism and are released during lipoprotein formation. Lysophospholipids are also ligands for G-protein receptors and can affect gene expression, development, immune and inflammatory responses, as well as nervous system and cardiovascular functions (Meyer zu Heringdorf and Jakobs 2007). The åPFAS and åPFCA were strongly, negatively correlated with fatty acids and bile acids ($r2 = 0.43–0.45$, $p < 0.0001$, $n = 58$), and more weakly, inversely correlated to acylcarnitines (b-oxidation intermediates) and acyl-alkyl phosphatidylcholines (membrane lipids) as well as some tricarboxylic acid (TCA) cycle intermediates ($r2 = 0.14–0.17$, $p = 0.0011–0.0038$, $n = 58$). The åPFAS and åPFCA were also related to increasing concentrations of amino acids ($r2 = 0.15$, $p = 0.003$, $n = 58$).

Together, these preliminary observations indicate differences in lipid metabolism and regulation as well as protein synthesis, and were partially consistent with previous lab studies (Ding et al. 2009; Yu et al. 2016) and our observations in the WHB and SHB (Morris et al. 2019). The physiological and dietary differences between the bears and seals makes their comparison in the four-group model interesting, however, regional comparisons between bears alone and seals alone, as well as the trophic interaction between the bears and seals, may be more informative in terms of the contaminant-related effects.

Expected project completion date

Analytical and related activities are nearly complete, with only the oxylipin analyses and some contaminant quality assurance/quality control remaining in process. We expect these results in the early summer 2019 and will begin in-depth statistical analyses and preparations for publication. Expected publication dates for manuscripts are between Dec 2019–March 2020.

Acknowledgments

We extend our sincere gratitude to the NCP for funding this exploratory research project and to the NCP Review Team, Management Committee and the Nunavut Environmental Contaminants Committee for their support of the project. We look forward to further interactions and communications with communities. We also thank any and all contributors to consultations and tissue collections under projects M-04 (ringed seals) and M-05 (polar bears) including Hunters and Trappers Associations, Nunavut Department of Environment (NDE), conservation officers, Hamlet officials, local hunters and guides, field biologists, and students, among others. We also thank all of the technicians at the National Wildlife Research Center (Ottawa, ON) and the Canada Centre for Inland Waters (Burlington, ON) who contributed to sample processing and analyses.

References

Aliferis, K.A., Chrysayi-Tokousbalidesm, M. 2011. Metabolomics in pesticide research and development: review and future perspectives. *Metabolomics* 7: 35-53.

Benskin, J.P., Ikonomou, M.G., Liu, J., Veldhoen, N., Dubetz, C., Helbing, C.C., Cosgrove, J.R. 2014. Distinctive metabolite profiles in in-migrating sockeye salmon suggest sex-linked endocrine perturbation. *Environ Sci Technol.* 48:11670-11678.

Brown, T.M., Hammond, S.A., Behsaz, B., Veldhoen, N., Birol, I., Helbing, CC. 2017. *De novo* assembly of the ringed seal (*Pusa hispida*) blubber transcriptome: A tool that enables identification of molecular health indicators associated with PCB exposure. *Aquat Toxicol.* 185: 48-57.

Bundy, J.G., Davey, M.P., Viant, M.R. 2009. Environmental metabolomics: a critical review and future perspectives. *Metabolomics.* 5:3-21.

Ding, L., Hao, F., Shi, Z., Wang, Y., Zhang, H., Tang, H., Dai, J. 2009. Systems biological responses to chronic perfluorododecanoic acid exposure by integrated metabonomic and transcriptomic studies. *J Proteome Res.* 8(6): 2882-2891.

Ellis, R.P., Spicer, J.I., Byrne, J.J., Sommer, U., Viant, M.R., White, D.A., Widdicombe,S. 2014. 1H NMR metabolomics reveals contrasting response by male and female mussels exposed to reduced seawater pH, increased temperature, and a pathogen. *Environ Sci Technol.* 48: 7044-7052.

Huang, S.S., Benskin, J.P., Chandramouli, B., Butler, H., Helbing, C.C., Cosgrove, J.R. 2016. Xenobiotics Produce Distinct Metabolomic Responses in Zebrafish Larvae (*Danio rerio*). *Environ Sci Technol.* 50: 6526-6535.

Jardine, T.D., Kidd, K.A., Fisk, A.T. 2006. Applications, considerations, and sources of uncertainty when using stable isotope analysis in ecotoxicology. *Environ Sci Technol.* 40:7501-7511.

Letcher, R.J., Morris, A.D., Dyck, M., Sverko, E., Reiner, E.J., Blair, D.A.D., Chu, S.G., Shen, L. 2018. Legacy and new halogenated persistent organic pollutants in polar bears from a contamination hotspot in the Arctic, Hudson Bay Canada. *Sci Tot Environ* 610-611: 121-136.

McKinney, M.A., Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Gabrielson, G.W., Peacock, E., Sonne, C. 2011a. Flame retardants and legacy contaminants in polar bears from Alaska, Canada, East Greenland and Svalbard, 2005-2008. *Environ Int.* 37: 365-374.

McKinney, M.A. Letcher, R.J., Aars, J., Born, E.W., Branigan, M., Dietz, R., Evans, T.J., Gabrielsen, G.W., Muir, D.C., Peacock, E., Sonne, C. 2011b. Regional contamination versus regional dietary differences: understanding geographic variation in brominated and chlorinated contaminant levels in polar bears. *Environ Sci Technol.* 45(3): 896-902.

McKinney, M.A., McMeans, B.C., Tomy, G.T., Rosenberg, B., Ferguson, S.H., Morris, A., Muir, D.C., Fisk, A.T. 2012. Trophic transfer of contaminants in a changing arctic marine food web: Cumberland Sound, Nunavut, Canada. *Environ Sci Technol.* 46(18): 9914-9922.

Meyer zu Heringdorf, D., Jakobs, K.H. 2007. Lysophospholipid receptors: signalling, pharmacology and regulation by lysophospholipid metabolism. *Biochim Biophys Act.* 68(4): 923-940.

Morris, A.D., Letcher, R.J., Dyck, M.G., Chandramouli, B., Cosgrove, J.R. 2018. Multivariate statistical analysis of metabolomics profiles in tissues of polar bears (*Ursus maritimus*) from the Southern and Western Hudson Bay subpopulations. *Polar Biol.* 41: 433-449.

Morris, A.D., Letcher, R.J., Dyck, M., Chandramouli, B., Cosgrove, J. 2019. Concentrations of legacy and new contaminants are related to metabolite profiles in Hudson Bay polar bears. *Environ Res.* 168: 364-374.

Niemuth, J.N., Stoskopf, M.K. 2014. Hepatic Metabolomic Investigation of the North American Black Bear (*Ursus americanus*) Using 1H-NMR Spectroscopy. *Wildlife Biol in Practice.* 10: 14-23.

O'Kane, A.A., Chevallier, O.P., Graham, S.F., Elliot, C.T., Mooney, M.H. 2013. Metabolomic profiling of *in vivo* plasma responses to dioxin-associated dietary contaminant exposure in rats: implications for identification of sources of animal and human exposure. *Environ Sci Technol.* 47: 5409-5418.

Sadler, T., Kuster, C., von Elert, E. 2014. Seasonal dynamics of chemotypes in a freshwater phytoplankton community - A metabolomic approach. *Harmful algae.* 39: 102-111.

Samuelsson, L.M., Bjorlenius, B., Forlin, L., Larsson, D.G.J. 2011. Reproducible 1H NMR-based metabolomic responses in fish exposed to different sewage effluents in two separate studies. *Environ Sci Technol.* 45: 1703-1710.

Størseth, T.R., Bytingsvik, J., Standal, I.B., Hansen, B.H., Jenssen, B.M. Gender differences in the metabolic profiles of blood plasma from polar bear (*Ursus maritimus*) analyzed by 1H-NMR metabolomics. 5th International Conference of the Metabolomics Society, Edmonton, AB, 2009.

Tartu, S. Lille-Langøy, R., Størseth, T.R., Bourgeon, S., Brunsvik, A., Aars, J., Goksøyr, A., Jenssen, B.M., Polder, A., Thiemann, G.W., Torget, V., Routti, H. 2017. Multiple-stressor effects in an apex predator: combined influence of pollutants and sea ice decline on lipid metabolism in polar bears. *Sci Rep.* 7: 16487.

United Nations Environment Programme. (2019, April 10). Stockholm Convention on Persistent Organic Pollutants. Retrieved from: http://chm.pops.int/. Accessed April 28, 2019 2019

van Ginneken, V., Verhey, E., Poelmann, R., Ramakers, R., van Dijk, K.W., Ham, L., Voshol, P., Havekes, L., Van Eck, M., van der Greef, J. 2007. Metabolomics (liver and blood profiling) in a mouse model in response to fasting: a study of hepatic steatosis. *Biochim Biophys Acta.* 1771: 1263-1270.

Yu, N., Wei, S., Li, M., Yang, J., Li, K., Jin, L., Xie, Y., Giesy, J.P., Zhang, X., Yu, H-X. 2016. Effects of perfluorooctanoic acid on metabolic profiles in brain and liver of mouse revealed by a high-throughput targeted metabolomics approach. *Sci Rep.* 6: 23963.

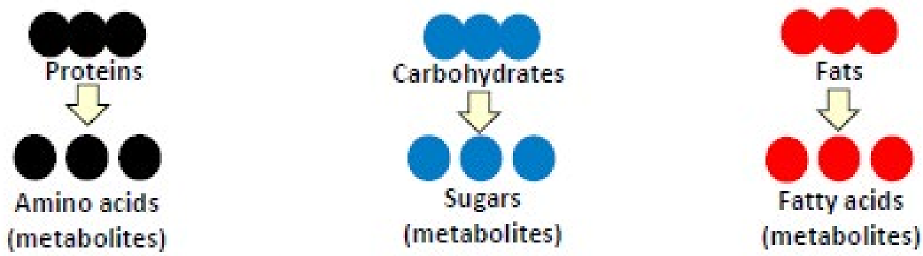
Zhang, D., Zhang, R.,, Zhang, L., Zhang, Z., Hou, R., Wang, H., Loeffler, I.K., Watson, D.G., Kennedy, M.W. 2015. Changes in the milk metabolome of the giant panda (*Ailuropoda melanoleuca*) with time after birth - three phases in early lactation and progressive individual differences. *PLoS One.* 10: e0143417.

Appendix A – Metabolomics Fact Sheet

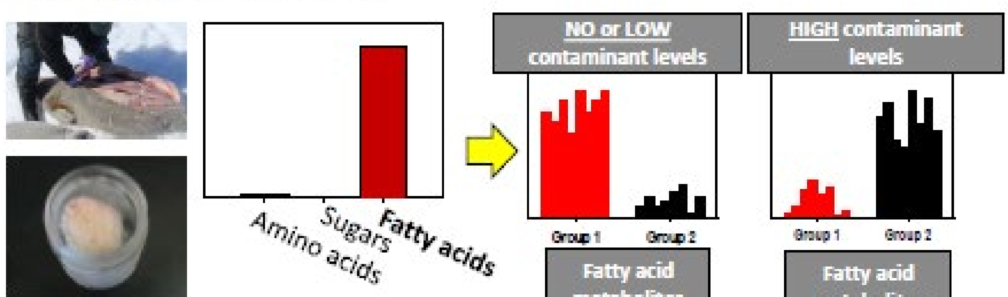
Using Metabolomics to Study
Effects of Contaminant and Diet Change in Nunavut Wildlife

Food contains nutrients like proteins, fats and carbohydrates.
Metabolism breaks down food into more nutrients.

Metabolism also breaks down nutrients into metabolites.
Metabolites are used to make energy or to make other nutrients.



Example: Ringed seal blubber



Different foods have different nutrients in them, and when the animal's diet changes so will the pattern of metabolites in their bodies.

Contaminants also act like some metabolites and "confuse" the body. Changes in patterns of metabolites can teach us more about the effects of contaminants on the animal and why they may or may not be harmful.

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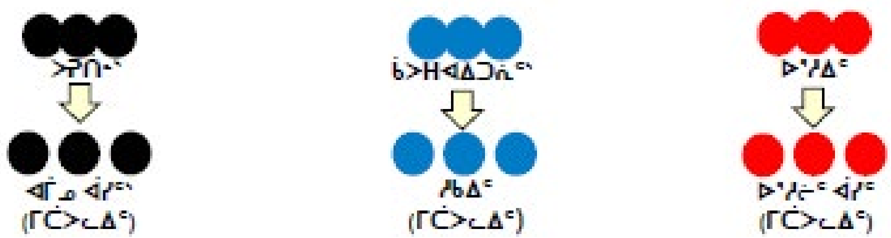

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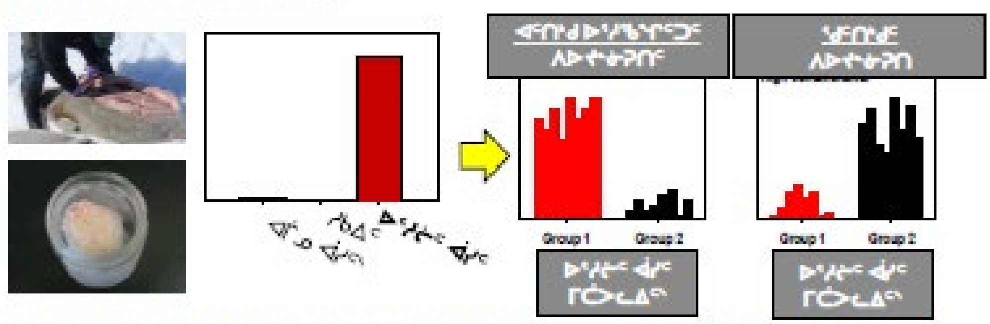

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Seabirds as a vector and concentrators of microplastics in Arctic ecosystems

Les oiseaux de mer en tant que vecteur et concentrateurs de microplastiques dans les écosystèmes de l'Arctique

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Project location/Emplacement du projet

Qaqulluit National Wildlife Area, NU

Abstract

Plastic debris is now recognized as a common contaminant affecting marine ecosystems. Since 2003 the Arctic seabird team has worked to assess which northern marine bird species are vulnerable to ingesting marine plastic pollution. To date, a number of marine bird species have been shown to ingest plastics. Through these studies it has also been recently demonstrated that seabirds may shed ingested plastics in the form of microplastics in their guano. This suggests that seabirds may act as a vector for microplastic movement in the marine environment, and potentially to the terrestrial environment. To test if seabird

Résumé

Il est maintenant connu que les débris de plastique sont des contaminants fréquents ayant des répercussions sur les écosystèmes marins. Depuis 2003, l'équipe qui étudie les oiseaux de mer de l'Arctique s'efforce d'évaluer les espèces d'oiseaux de mer du Nord qui sont vulnérables à l'ingestion de plastique polluant les milieux marins. À ce jour, il a été démontré qu'un certain nombre d'espèces d'oiseaux marins ingèrent du plastique. De plus, ces études ont récemment permis de montrer que les oiseaux marins peuvent se débarrasser des plastiques ingérés sous forme de microplastiques dans leur guano. Cela semble indiquer que les oiseaux de

excretion of microplastics is contributing to the accumulation of microplastics around seabird colonies, we worked with local Inuit hunters in Qikiqtarjuaq, Nunavut to collect biotic and environmental samples from around two seabird colonies known to have birds with high plastic ingestion rates. Seabird, air, water, sediment, and blue mussel samples were collected below the cliff-side colonies, and at increasing distances from the colony edges. This work builds on past work in the region and will further identify how microplastics are distributed and move through Arctic ecosystems. Preliminary data has shown that microplastics are present in air, water, sediment and blue mussel samples. The seabird samples have not yet been processed. As we continue to process and analyze these samples, we will look for significant trends in microplastic concentrations as it relates to the distance from seabird colonies.

mer peuvent agir comme vecteur de transport des microplastiques dans le milieu marin, et potentiellement dans le milieu terrestre. Pour vérifier si l'excrétion de microplastiques par les oiseaux de mer contribue à l'accumulation de microplastiques à proximité des colonies d'oiseaux de mer, nous avons travaillé avec des chasseurs inuits locaux à Qikiqtarjuaq (Nunavut) pour prélever des échantillons biotiques et environnementaux autour de deux colonies d'oiseaux de mer dont on sait que les oiseaux présentent un taux élevé d'ingestion de plastique. Des échantillons d'oiseaux de mer, d'air, d'eau, de sédiments et de moules bleues ont été prélevés sous les colonies situées au bord des falaises et à des distances croissantes du bord des colonies. Ces travaux s'appuient sur des travaux antérieurs effectués dans la région; ils permettront de mieux déterminer comment les microplastiques sont distribués et se déplacent dans les écosystèmes de l'Arctique. Les données préliminaires ont montré que des microplastiques sont présents dans l'air, l'eau, les sédiments et les échantillons de moules bleues. Les échantillons d'oiseaux de mer n'ont pas encore été traités. Nous continuerons de traiter et d'analyser ces échantillons, afin de rechercher des tendances significatives dans les concentrations de microplastiques par rapport à la distance par rapport aux colonies d'oiseaux de mer.

Key messages

- This is the first report of microplastics in the environment directly around seabird colonies in the Canadian Arctic sites.
- Preliminary data has shown that microplastics are present in air, water, sediment and blue mussel samples.
- This data will help examine if seabirds are acting as concentrators of microplastics in the coastal environment.

Messages clés

- Il s'agit du premier rapport sur la présence de microplastiques dans le milieu situé directement à proximité des colonies d'oiseaux marins dans les sites de l'Arctique canadien.
- Les données préliminaires ont montré que des microplastiques sont présents dans l'air, l'eau, les sédiments et les échantillons de moules bleues.
- Ces données permettront d'examiner si les oiseaux de mer agissent comme concentrateurs de microplastiques dans l'environnement côtier.

Objectives

The general aims of this project are to determine the distribution of both plastics and microplastics in Arctic ecosystems, and how seabirds may act as vectors and accumulators of plastic pollution.

More specifically, the aims of this project are to answer three main questions:

1. What is the distribution of microplastics in air, water, and sediments and how does microplastic concentration relate to proximity to large seabird colonies?
2. How are microplastics distributed in a benthic indicator species (blue mussels) in relation to their proximity from large seabird colonies?
3. How has the type and quantity of plastics accumulated by two seabird species in the Qikiqtarjuaq area changed since it was last quantified in 2007/2008?

Introduction

Marine plastic pollution is an emerging environmental issue identified by both the United Nations Environment Program, and the Arctic Monitoring and Assessment Program and Northern Contaminants Program (AMAP, 2017; UNEP, 2014). Previous work supported by Northern Contaminants Program (NCP) helped identify and understand the distribution of plastics and microplastics in Arctic seabirds, and how plastics may act as a vector for contaminants in Arctic food webs (project M-21 titled *Plastics as a vector of contaminants (benzotriazole UV stabilizers) to Arctic seabird tissues and eggs* led by Mark Mallory and Jennifer Provencher in 2016/2017 and 2017/2018). While the analytical and reporting work for plastics as a vector of contaminants in Arctic seabirds is ongoing, we propose a new phase of NCP supported work that will capitalize on this previous work. This project builds on existing knowledge achieved through NCP support and examines how seabirds may act as vectors for plastics, and potentially concentrate microplastics around their colonies.

To date, most of the work assessing plastics in the Canadian Arctic has focused on seabirds. Seabirds from Arctic Canada have been shown to ingest both industrial plastics (nurdles or pellets) and user plastics (pieces from consumer goods). This includes recent work conducted under a project funded by the Marine and Environmental Observation and Prediction Response Network (MEOPAR); a Networks of Centres of Excellence (NCE) under which the PIs (Mark Mallory and Jennifer Provencher) of this proposed project (along with others) have received funding to analyze ingested plastic levels in northern fulmars from the Labrador Sea. The Arctic seabird research team has also taken advantage of collections done under the NCP and the International Polar Year (IPY) to examine plastics across the eastern Canadian Arctic. Within these studies, ~85% of the northern fulmars in Arctic Canada have ingested plastics, and ~10% of thick-billed murres have ingested plastics (Poon et al., 2017; Provencher et al., 2010, 2009). More recent work has shown that in addition to accumulating plastics in their guts, northern fulmars were also shedding microplastics in their guano (Provencher et al., 2018; van Franeker, 2011). In the Arctic, where seabirds can congregate in large numbers (e.g. tens of thousands), this shedding of microplastics may have implications for Arctic ecosystems surrounding seabird colonies.

Seabird colonies, and the guano that accumulates beneath them, have been shown to both contribute nutrients and contaminants to the local environment (Blais et al., 2005; Michelutti et al., 2009). Through the decomposition of bird guano near seabird colonies, it has also been shown that seabirds are important contributors of nutrients to terrestrial ecosystems (Anderson and Polis, 1999). This often results in the green halo of biota around seabird colonies. Unfortunately, when seabirds are exposed to high levels of contaminants, this same guano can result in increased levels of chemicals in the regions around seabird colonies (Blais et al., 2005). Given recent findings that seabirds are also excreting microplastics (Provencher et al., 2018), this suggests that seabird colonies may also be influencing the distribution of microplastics in and around their colonies.

This project explores how seabird colonies may be influencing the fate and abundance of microplastics in Arctic ecosystems. If seabirds are contributing microplastics to the environment through their guano, we would expect to see decreasing levels of plastics in air, water, sediments, and mussels as one moves away from the colony.

Activities in 2018-2019

Community engagement, capacity building, communication and Indigenous Knowledge

A meeting with the Qikiqtarjuaq Hunters and Trappers Organization (HTO) occurred in November 2017 to introduce the project to the community and discuss the logistics of hiring local guides with boats. The Sululiit Area Co-Management Committee (ACMC) was also consulted prior to the approval of the project and recommended two members that we hired to take part in the field trip and witness the sampling activities. Three local guides recommended by the HTO, and their assistant, were also hired with their boat for the field trip in August 2018. The participation of local guides and HTO and ACMC members was crucial to the implementation of the project not only in the field, but also at each step of the process. To follow up with the community, a field report has been sent to the HTO, and two members from the research team will visit Qikiqtarjuaq in May 2019 to get feedback and discuss the work done in more details.

During the boat-based surveys conducted at the Qaqulluit colony, the team was able to collect critical samples such as:

- surface water, air, and sediments at 11 sites surrounding the Qaqulluit colony to assess how microplastics are distributed around seabird colonies;
- blue mussel specimens for analysis investigating oil-related contaminants and microplastics distribution around seabird colonies; and
- northern fulmar and thick-billed murre specimens to look at changes in marine plastic pollution ingestion in these birds in the region.

During the Wildlife Contaminants Workshop (WCW) in September 2018 all the birds collected by the hunters in Qikiqtarjuaq, NU in August 2018 were dissected by the Environmental Technology Students at the Nunavut Arctic College. This formed a major training component for the WCW this past year, with plastic pollution being a major theme. Currently, the air, water, sediment and blue mussel samples are being processed. Methodologies and initial results are presented below but represent a small proportion of the total samples.

Results

Preliminary data has shown that microplastics are present in sediment, water, blue mussel and air samples. The majority of the microplastics in the water appear to be chips of boat bottom paint of various colours (and different from the boats used for sampling). Most of the microplastics in the mussels were fibers, while air deposition and sediment samples contained both fragments and fibers (Figure 3). As we continue to process and analyze these samples, we will look for significant trends in microplastic concentration as it relates to the distance from seabird colonies. These results will also be compared with samples in these matrices taken from various locations in Northern Canada in order to better understand the benefits and limitations of different sampling regimes used for microplastics.

Figure 1. Sampling sites around Qaqulluit National Wildlife Area where air, water, sediment and blue mussels were sampled in August 2018.

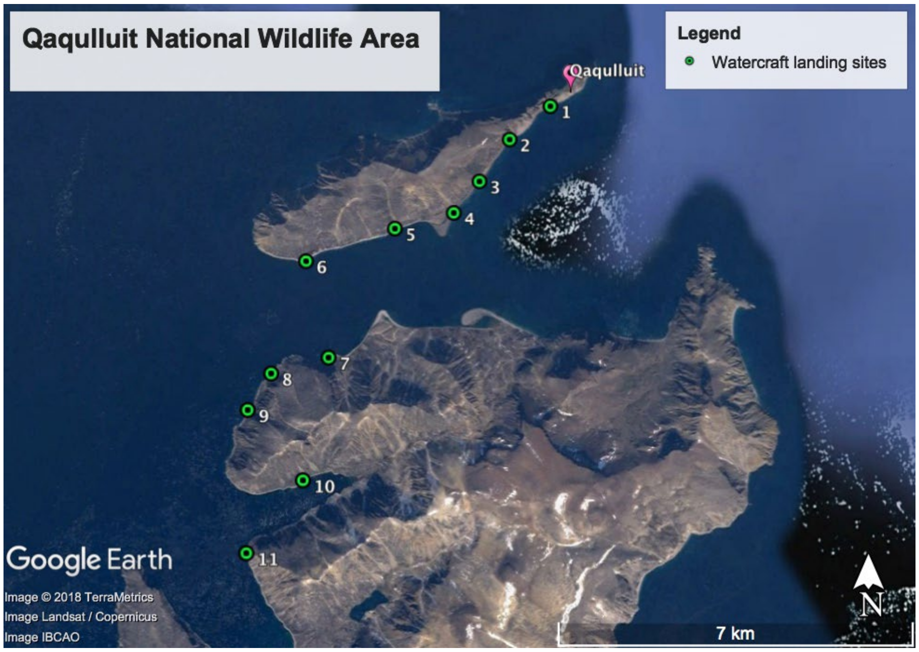
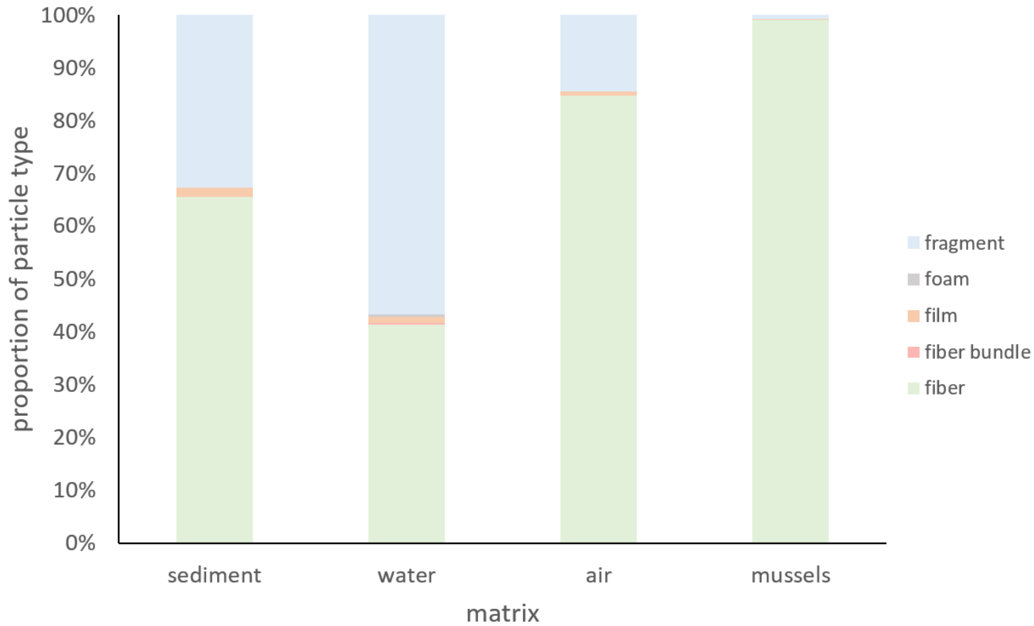


Figure 2. Capturing air particles around the colony; filtering surface water to retain possible microplastic particles; dissecting a blue mussel for contaminant analysis.

Figure 3. Proportion of microplastic types found across four environmental compartments sampled in the Qaqulluit National Wildlife Area, Nunavut.



Discussion and conclusions

This project aims to take a more comprehensive approach to microplastics in the Arctic environment than many previous projects in the region. There are several other additional benefits this work will provide. First, this research will both update our data on ingested plastics in two indicator species in the Arctic (northern fulmar and thick-billed murre). These two species represent our longest-term dataset on microplastics in the Arctic, and the fulmar represents the only species where international comparisons can be made via standardized protocols (Provencher et al., 2017). This is a critical piece of knowledge in addressing how microplastic pollution may be changing in the Arctic. Second, the collection of air, water, sediment and mussels form a pilot project with community members of Qikiqtarjuaq who are interested in establishing a community-based monitoring program for plastics that can be implemented within nearby protected areas.

Preliminary data has shown that microplastics are present in both blue mussel and air samples. As we continue to process and analyze these samples, we will look for significant trends in microplastic concentration as it relates to the distance from seabird colonies. Plastic pieces include both fibers and fragments. While the concentrations of plastic pieces have not been compared yet to the location of the seabird colony, these initial results indicate that there are microplastics in the environment surrounding the colonies. 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). Additionally, AMAP has recently formed a Litter and Microplastics Expert Group that will be undertaking a project in the next 2 years to examine monitoring tools that can be employed by researchers and communities to track microplastics in the environment.

Expected project completion date

The seabirds (northern fulmars and thick-billed murres) will be processed in the fall of 2019 for ingested plastics pollution and this new data will be compared with data from previous collections of seabirds at this site. We expect the final report on the seabirds to be completed in mid 2020. Once the seabird data is confirmed, there will be an overall comparison of the microplastics in the abiotic and biotic compartments around the colony will be completed in late 2020.

Acknowledgments

We would like to thank all those that supported the collection, analysis and preparation of this manuscript. This project was funded by the Northern Contaminants Program and took advantage of samples and results from other programs including ECCC. The Nunavut Wildlife Management Board supported the field component of this project. Many thanks to the Nattivak Hunter and Trapper Organisation and the Sululiit Area Co-management Committee for their support of this project.

References

AMAP, 2017. Chemicals of emerging Arctic concern, summary for policy-makers. Oslo, Norway.

Anderson, W.B., Polis, G.A., 1999. Nutrient fluxes from water to land: seabirds affect plant nutrient status on Gulf of California islands. Oecologia 118, 324–332. doi:10.1007/s004420050733

Blais, J.M., Kimpe, L.E., McMahon, D., Keatley, B.E., Mallory, M.L., Douglas, M.S. V, Smol, J.P., 2005. Arctic seabirds transport marine-derived contaminants. Science (80-.). 309, 445.

Michelutti, N., Keatley, B.E., Brimble, S., Blais, J.M., Liu, H.J., Douglas, M.S. V, Mallory, M.L., Macdonald, R.W., Smol, J.P., 2009. Seabird-driven shifts in Arctic pond ecosystems. Proc. R. Soc. B-Biological Sci. 276, 591–596.

Poon, F., Provencher, J.F., Mallory, M.L., Braune, B.M., Smith, P.A., 2017. Plastic accumulation in four Arctic seabird species. Mar. Pollut. Bull. 116, 517–520.

Provencher, J.F., McEwan, M., Mallory, M.L., Braune, B.M., Carpenter, J., Harms, H.J., Savard, G., Gilchrist, H.G., 2013. How wildlife research can be used to promote wider community participation in the North. Arctic 66, 237–243.

Provencher, J.F., Vermaire, J.C., Avery-Gomm, S., Braune, B.M., Mallory, M.L. 2018. Garbage in guano: seabird faeces as a tool to monitor a pervasive environmental pollutant. Science of the Total Environment.

Provencher, J.F.F., Gaston, A.J.J., Mallory, M.L.L., 2009. Evidence for increased ingestion of plastics by northern fulmars (Fulmarus glacialis) in the Canadian Arctic. Mar. Pollut. Bull. 58, 1092–1095. doi:10.1016/j.marpolbul.2009.04.002

Provencher, J.F.F., Gaston, A.J.J., Mallory, M.L.L., O'hara, P.D.D., Gilchrist, H.G.G., 2010. Ingested plastic in a diving seabird, the thick-billed murre (Uria lomvia), in the eastern Canadian Arctic. Mar. Pollut. Bull. 60, 1406–1411. doi:10.1016/j.marpolbul.2010.05.017

Provencher, J.F.F., Gaston, A.J.J., O'Hara, P.D.D., Gilchrist, H.G.G., 2012. Seabird diet indicates changing Arctic marine communities in eastern Canada. Mar. Ecol. Ser. 454, 171–182. doi:10.3354/meps09299

UNEP, 2014. UNEP Year Book 2014 emerging issues update. United Nations Environment Programme, Nairobi, Kenya.

van Franeker, J.A., 2011. Reshape and relocate: seabirds as transformers and transporters of microplastics, in: Fifth International Marine Debris Conference. Honolulu, Hawaii.

Snowpack mercury mass balance over the spring melt period, Iqaluit, Nunavut

Bilan massique du mercure dans le manteau de neige à la fonte printanière, à Iqaluit (Nunavut)

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- **Project location/Emplacement du projet**
  Iqaluit, NU

Abstract

The purpose of this two-year project is to improve understanding and predictive modelling of the fate of mercury in end-of-winter Arctic snowpack through intensive monitoring of the surface to air exchanges of mercury prior to and throughout the spring melt period. The study was 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 not yet been reported on Baffin Island. Two spring field-seasons were conducted in 2017 and 2018. The 2017 field season was initiated in late spring after the onset of snowmelt, and results demonstrated very low snowpack emissions, apart from a single short-lived emission peak immediately following a snowfall event. In 2018, approximately two months of flux data

Résumé

Le but de ce projet de deux ans est d'améliorer la compréhension et la modélisation prédictive du devenir du mercure dans le manteau neigeux de l'Arctique en fin d'hiver grâce à une surveillance intensive des échanges de mercure entre la surface du manteau et l'air avant et pendant la période de fonte printanière. L'étude a été 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. Deux saisons de travail sur le terrain ont été menées au printemps de 2017 et 2018. La saison de 2017 a débuté à la fin du printemps, après le début de la fonte des neiges, et les résultats ont montré que les émissions du manteau neigeux étaient très faibles, à l'exception d'un seul pic

were collected, beginning in late April, well in advance of the snowmelt period. Results from the 2018 field season corroborated initial findings from 2017, demonstrating that snow-air emissions of gaseous elemental mercury at this coastal marine study site are primarily associated with re-emission of freshly deposited Hg in snow. Over the two-month monitoring period, 100% of the mercury deposited via wet deposition was re-emitted via gaseous elemental mercury (GEM) efflux, with no further net-loss from the snowpack.

d'émission de courte durée immédiatement après une chute de neige. En 2018, nous avons recueilli environ deux mois de données sur les flux, à partir de la fin avril, bien avant la période de fonte des neiges. Les résultats de la saison de 2018 ont corroboré les résultats initiaux de 2017, indiquant que les émissions neige-air de mercure élémentaire gazeux sur ce site marin côtier sont principalement associées à la réémission de Hg fraîchement déposé dans la neige. Au cours de la période de surveillance de deux mois, 100 % du mercure déposé par voie humide a été réémis par l'efflux de mercure élémentaire gazeux (MEG), sans autres pertes nettes par le manteau neigeux.

Key messages

- During the 2017 and 2018 study periods, significant snowpack-air efflux of GEM from Arctic spring snowpack were observed following wet (snowfall) mercury (Hg) deposition events.
- In 2018, snow-air exchanges of GEM resulted in a net loss of mercury from the snowpack surface during the pre-melt period, and a net gain of mercury from the atmosphere during the melt period, implying that the onset of snowmelt causes the surface to air efflux of GEM to cease.
- Over the two-month monitoring period in 2018 the total snowpack surface to air efflux of Hg was equal to the total inputs of Hg via snow and rain, causing no net change in the mass balance of the snowpack associated with surface-air exchanges.
- Inputs of Hg via rainfall and wet snowfall in late June 2018 substantially offset cumulative snowpack Hg losses via GEM efflÅux over the entire monitoring period and were not associated with re-emission events typical of May and early June when air and snow surface temperatures were below 0°C.

Messages clés

- Au cours des périodes d'étude de 2017 et 2018, un important efflux de mercure élémentaire gazeux (MEG) dans l'air du manteau neigeux du printemps de l'Arctique a été observé à la suite d'épisodes de dépôts humides (chutes de neige) de mercure (Hg).
- En 2018, les échanges neige-air de MEG ont entraîné une perte nette de mercure à la surface du manteau neigeux pendant la période précédant la fonte, et un gain net de mercure dans l'atmosphère pendant la période de fonte, ce qui semble indiquer que le début de la fonte des neiges fait cesser l'efflux de MEG de la surface du manteau vers l'air.
- Au cours de la période de surveillance de deux mois en 2018, le flux total de Hg de la surface du manteau neigeux vers l'air était égal aux apports totaux de Hg par la neige et la pluie, ce qui n'a entraîné aucune variation nette dans le bilan massique du manteau neigeux associé aux échanges surface-air.
- Les apports de Hg par la pluie et la neige humide à la fin du mois de juin 2018 ont largement compensé les pertes cumulées de Hg par l'efflux de MEG depuis le manteau neigeux pendant toute la période de surveillance et n'ont pas été associés aux réémissions typiques de mai et du début juin, lorsque les températures de l'air et de la surface de la neige étaient inférieures à 0 °C.

Objectives

The overarching 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 to be addressed in this study is: "How do short-term variations in weather conditions (e.g. over periods of days to weeks) during Arctic spring affect surface to air emissions and 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 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 (Hg0 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 before the spring melt period from AMDEs. There are, however, substantial 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 was to measure and model the snowpack Hg mass balance melt period to quantify the fate of snowpack 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. In this report, only results on the snow surface mass balance are presented (objective 1). 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 2018-2019

Field activities

Field activities were conducted between June 10th and July 5th, 2017 and between April 24 and June 30th, 2018. A Tekran 2537 ambient air mercury analyzer was deployed to sample GEM fluxes over snow using the dynamic flux chamber (DFC) technique (Figure 1). In 2017, the DFC was placed over a late-lying snowpack with a starting depth of approximately 50 cm. Snow temperatures were isothermal throughout the study period, with active melt happening during daytime periods. Snowpack relative density was consistently near 0.3 (i.e. 30% water equivalent). Towards the end the 2017 study period, more than half of initial snowpack area had ablated, and the DFC was placed over recently exposed soil for 12 days until July 5th.

In 2018, the field season began much earlier, nearly 6 weeks prior to the onset of snowmelt. Two DFCs were used to test for spatial variability of snow-surface GEM exchanges. The starting snowpack depths at the two DFCs were 90 cm and 130 cm. Data from both chambers were subsequently merged into a single time series after determination of no statistically significant difference in fluxes between the two DFCs. In contrast to the 2017 melt season, which initiated early and ended quickly, the 2018 season was much more protracted, allowing for early season sampling during the pre-melt period as well as sampling at the onset and throughout the early stages of the melt period.

Prior to and throughout the measurement periods in both seasons, the snowpack was sampled for major ion chemistry and total mercury (THg) concentrations. In 2018, surface snow was collected, including fresh snowfall whenever possible, for chemical analysis. DFCs were re-positioned frequently, including over fresh snow whenever possible, particularly following larger snowfall events exceeding 1 cm accumulation. Towards the end of the field season, rainfall was collected directly into multiple glass jars and composited into a single sample to achieve adequate sample volumes.

Over the course the 2017 and 2018 monitoring periods, approximately 8 days and 21 days of sampling, respectively, were missed due to

Figure 1. Photos from the spring 2017 field season including the Teflon DFC place over the late-lying spring snowpack (left) and project team member Chris Eckley checking the data stream of the Tekran 2537 (right).

equipment malfunction or other logistical challenges. Gap-filling was conducted using Random Forest regression. Details of this procedure are documented in our 2017 Synopsis Report. An advantage of this modelling procedure is that it allows for a robust analysis of the meteorological variables driving snowpack Hg emissions through variable importance scores.

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 workshop in Yellowknife.

Capacity building

Murray Richardson and team member Keegan Smith have provided training in snow hydrology to Nunavut Arctic College Environmental Technology Program (NAC ETP) students since 2015, in collaboration with ETP instructors Daniel Martin and Jason Carpenter. This has typically involved 3-4 days of field activities during late April and early May after the term is ended. Participating students receive training as well as a daily stipend. These activities continued successfully during the 2017 and 2018 field seasons associated with this NCP project. In 2018, 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, some of whom participated in snow surveying activities.

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 and the aforementioned annual snow surveying activities. 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 two study periods are shown in Figure 2 (2017) and Figure 3 (2018). In 2017, 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 hr1 on the following day at approximately the same time.

In 2018, surface-air fluxes also increased following recent snowfall events (Figure 3). Maximum GEM emissions (13 ng m-2 hr-1) were observed following a significant snowfall at the end of May. This event registered approximately 12 mm of water equivalent at the airport gauge over the course of several days. However, on-the-ground measurements indicated 20 cm of fresh snow, or 20 mm of water accumulation at the DFC site, so the total was adjusted to reflect the local conditions for proper gap-filling and mass balance calculations.

Snow ripening and surface melting initiated around June 10th and from this point onwards, surface-air emissions were suppressed and even became negative (deposition) compared to the pre-melt period between April 28th and June 10th. During this period, fresh snowfall and rainfall were found to have THg concentrations ranging from approximately 5-20 ng L-1, higher than snowfall concentrations prior to the melt period which ranged from approximately 3 to 6 ng L-1 (THg concentration data in precipitation not shown).

We concurrently measured meteorological conditions including, air temperature, snow temperature (2018 only), net radiation, incoming shortwave radiation (2018 only), relative humidity, and windspeed at the GEM monitoring site. Hourly precipitation was extracted from the Iqaluit airport where it is measured by an Ott Pluvio all-weather precipitation gauge. This data record was used to extract 3-day antecedent precipitation (cumulative precipitation received over the past 72 hours at Iqaluit airport). For snowfall events exceeding 1 cm of total accumulation, estimates of site-specific snow accumulation were made and used to augment the airport snowfall record, since distance to the airport gauge and site-specific factors causing snow redistribution resulted in some differences in local accumulation.

Meteorological and snow temperature data were used to empirically model fluctuations in GEM fluxes using Random Forest regression analysis (Breiman 2001). Specific details of this approach are provided in our 2017 Synopsis Report (Richardson 2017). Over the relatively short study period in 2017, modelling results indicated net radiation to be the best predictor of GEM flux. In 2018, three variables were found to be important: 3-day antecedent precipitation, snow surface temperature and incoming shortwave radiation (Figure 4). Of these three variables, antecedent precipitation was the single-most-important predictor, followed closely by snow temperature, with incoming short-wave radiation contributing only a minor effect (Figure 4). The difference in the identified predictor variables between 2017 and 2018 reflects two factors: (1) The 2018 period spanned the pre-and post-melt period during which snow surface temperatures and conditions (water content and texture) changed considerably; and (2) modelling of the 2017 data excluded the early snow accumulation period since there were insufficient records impacted by precipitation for the remainder of the study to test the effect of this variable. Overall, the diel variability in GEM flux (seen clearly in the 2017 data, bottom panel of Figure 2) is small relative to the large increases in GEM flux associated with fresh snowfall.

Figure 2. Time series of GEM fluxes over snow and freshly exposed bare soil during the 2017 study period. In the bottom time series, the y-axis is reduced to illustrate lower, diel emission peaks throughout the monitoring period. Dashed vertical lines indicate timing of fresh snow fall and the transition from snow to soil, as indicated.

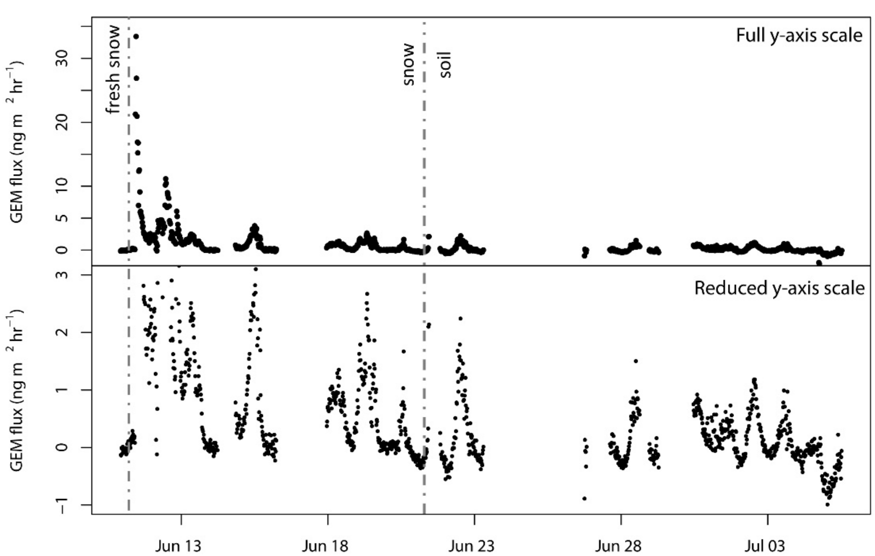
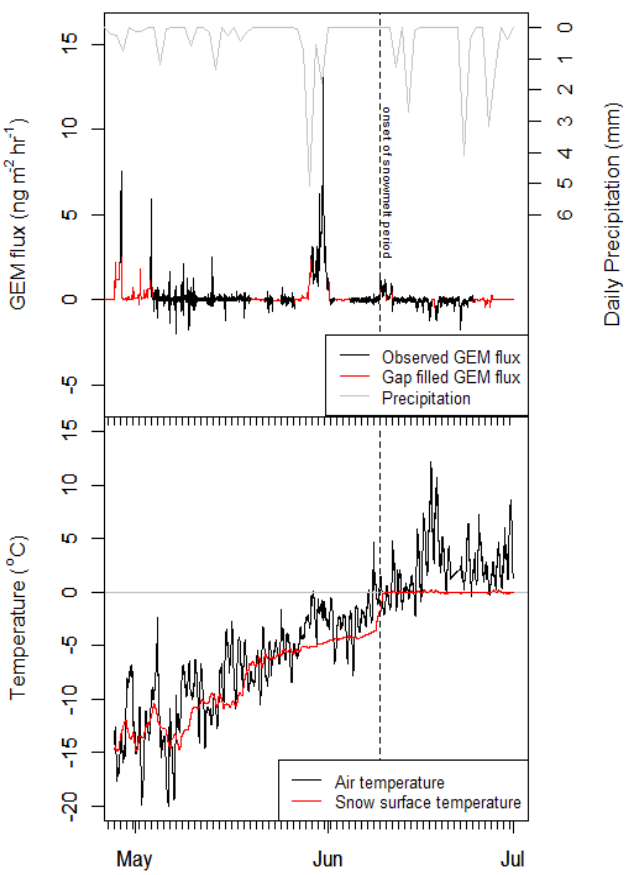


Figure 3. ***Top*: Time series of GEM emissions from snowpack and temporal associations with precipitation events over a 2-month period in 2018. Gap-filled periods using Random Forest regression are shown in red. *Bottom*: Air and snow surface temperatures over the corresponding time period, showing the onset of snowpack surface ripening/melting (when snow surface temperatures reached 0oC).**



During the snowmelt period in 2018 (from June 10th onwards), GEM fluxes were net-negative (Figure 3 and Table 1). Moreover, in contrast to the pre-melt period, GEM re-emission following wet-deposition events was not observed during the melt period. As a result, the snowpack surface mass balance associated with GEM fluxes and wet deposition was slightly net-positive during the melt period, which is seen in the cumulative mass-balance fluxes shown in Figure 5. Importantly, the overall mass balance shows that total outputs via GEM surface-air emission equaled the total-inputs via wet-deposition, resulting in no net change in the surface mass balance associated with GEM fluxes or wet deposition inputs. However, Figure 5 shows that during the pre-melt period, there was a small net loss of Hg from the snowpack surface via GEM emissions, despite the large wet-deposition event at the end of May. Following the onset of melt, however, there was a more substantial net gain in Hg to the snowpack surface associated with wet-deposition, which fully offset the cumulative losses that occurred prior to the onset of snowmelt.

As in 2017, Random Forest regression proved to be a practical statistical approach for gap filling and for identifying key variables affecting GEM fluxes in the 2018 dataset. Using a randomly-selected subset comprising 50% of the observations, cross-validated statistics were generated and demonstrate a high correspondence between observed *vs* predicted values (R2=0.89 and root mean square error or RMSE=0.35 ng m-2 hr-1 and a negligible bias of -0.02 ng m-2 hr-1) (Figure 5).

Table 1. Statistical summary of GEM surface-air fluxes over snow and soil during the 2017 and 2018 study periods.

Season	Period and Surface Condition	Mean (and median) GEM flux (ng m-2 hr-1)	Range GEM flux (ng m-2 hr-1)
2017	Entire period (snow and soil fluxes)	0.68 (0.1)	-2.13 to 37.19
	Snow fluxes only (melt period)	1.11 (0.21)	-0.63 to 37.19
	Soil fluxes only	0.1 (0.01)	-2.13 to 2.24
2018	Whole period	0.19 (0.005)	-2.04 to 13.5
	Pre-melt period only	0.3 (0.03)	-2.04 to 13.5
	Melt period only	-0.08 (-0.02)	-1.75 to 0.92

Figure 4. ***Top***: **Results of Random Forest regression variable importance plots (higher values of variable importance indicate greater contribution to explained variance in the observed GEM fluxes). Variable name key: 3-day Precip = total precipitation accumulated in past 72 hours, Snow Temp= Snow surface temperature at approximately 5 cm below surface. Rad=incoming shortwave radiation in W m-2 hr-1.** ***Bottom***: **Plot of observed vs predicted snow surface GEM fluxes and associated accuracy metrics, derived using a 50% independent subset of emissions data for the 2018 study.**

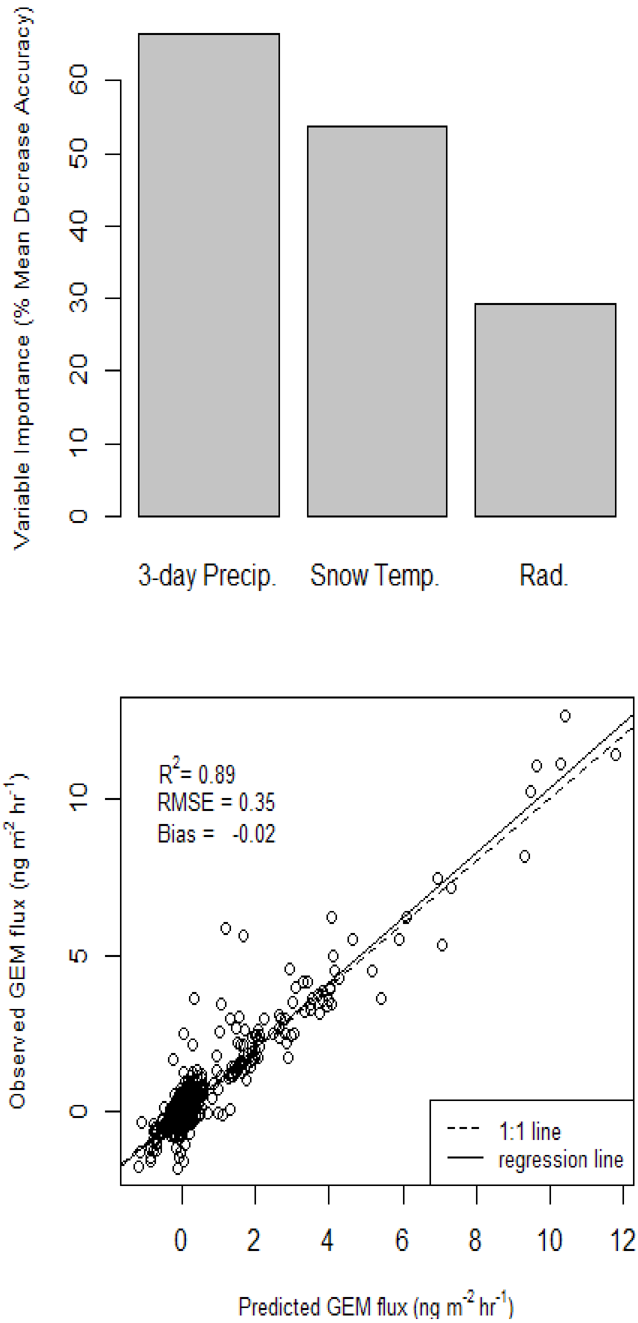
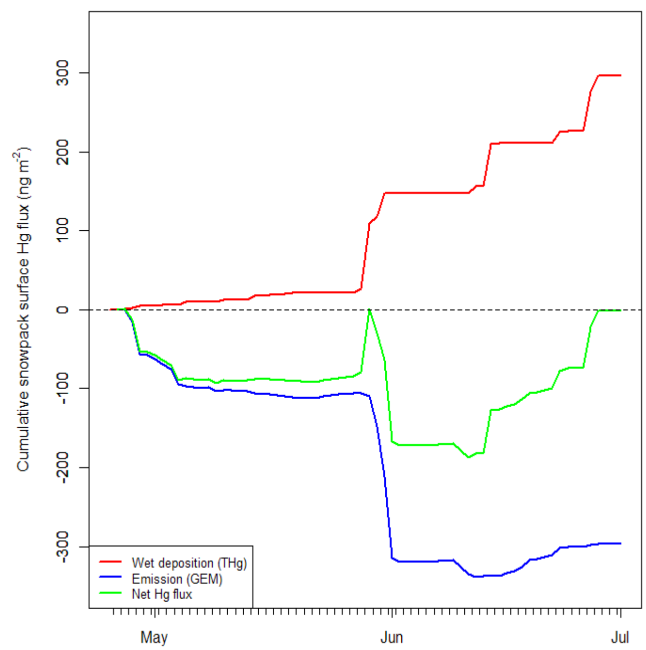


Figure 5. Cumulative net surface-air Hg flux (green line) over the two-month study period in 2018. Inputs from wet deposition (red line) are based on THg concentrations of sampled snowfall and rainfall and observed precipitation amounts, and are expressed as positive fluxes. Emissions (blue) are derived from continuous (gap-filled) GEM flux estimates seen in Figure 3 and are expressed as negative fluxes. The cumulative net surface-air Hg flux in green is the sum of wet deposition and emission fluxes.



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 snowpacks measured using the DFC approach used in our study also vary widely, ranging from 0 to 70 ng m-2 hr-1 in the reported literature (Poulain et al. 2004, Ferrari et al. 2005, Sommar et al. 2007, Mann et al. 2014). Even within individual studies, fluxes can vary over similarly large ranges, typically peaking during mid-day periods due to photo-chemically mediated production of GEM within the near-surface of 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 Figures 1 and 2 and Table 1 are consistent with these findings.

Over the course of 12 days of snow surface monitoring in 2017, we found flux rates from the snowpack to be relatively 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. Similarly, in 2018, high emissions fluxes were observed almost exclusively following snowfall events after moving the DFCs over fresh snow. 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 may be problematic to assume that these fluxes represent a net loss of snowpack Hg over the study period. In 2018, however, there were very few emission peaks that were not associated with precipitation events. Combined with regular snow surface sampling, we did not detect any significant dry-deposition inputs associated with AMDEs.

Modelling of snowpack GEM fluxes is not commonly reported in the literature. We used Random Forest regression as an approach to fill observations gaps, which can be used to satisfy data requirements for snowpack mass balance analysis provided adequate model performance. Additionally, such modelling can help identity environmental variables associated with surface-air Hg exchanges. Preliminary modelling efforts were reported in 2017 (Richardson 2017) and demonstrated net radiation and wind speed to be the most important environmental predictors of GEM flux. This modelling was repeated in 2018 using the longer time series record and additional input variables including antecedent precipitation, snow surface temperature and incoming shortwave radiation. All three of these new variables proved to be strong predictors of GEM flux and the only input variables required to achieve good predictive modelling results.

Random Forest regression is an effective method for gap-filling of GEM flux time series observed using the DFC method. Unlike linear modelling methods such as multiple linear regression, the Random Forest approach captures non-linearities and interactions among variables that appear to be important determinants of GEM production in the snowpack surface. One limitation of the method, as with most empirical approaches, is that it will not produce reliable predictions outside of the range of observed GEM fluxes. For example, applying our fitted model from 2018 would not work well for the 2017 time-series because the peak GEM fluxes in 2017 substantially exceeded those in 2018. In the future, a more mechanistic approach to modelling snow surface GEM fluxes as a function of snow surface Hg concentration, snow surface condition (temperature) and shortwave radiation would provide a more generalizable modelling approach. Importantly, however, our results show that empirical prediction of snowpack GEM emissions peaks is only possible when recent snowfall is accounted for.

In summary, our analysis of surface to air exchanges of GEM over the 2017 and 2018 spring snowpack near Iqaluit, NU demonstrates that the surface Hg budget is dominated Hg deposition and re-emission events, consistent with previously published studies on this topic. Subsequent analysis of our 2018 dataset will incorporate snowpack outputs of water and Hg throughout the remainder of the melt period. Since the melt period was very late and protracted in 2018, we were unable to continue to monitor GEM emissions until snowpack disappearance. In the final phase of this study, a complete snowpack Hg mass balance will be conducted using our empirical modelling approach with Random Forest, in combination with snowpack Hg concentration profiles, a simple snowmelt model, and measurements of Hg in precipitation and snowpack meltwater that were collected by local field assistants in early July 2018.

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. The 2018 field season could not have proceeded successful without the generous volunteer contribution and tireless effort of Murray Lackie during the months of April, May and early June. We would also like to thank all of the ETP students who helped with field activities and/or played other important supporting roles in 2017 and 2018 including Jeremy Fraser, Daniel Taukie, Dylan Qappik, Jenny Mosesie, Natalie Jean, Nicole Ymana, Mick Appaqaq, Jonah Qittusuk, Karen Nungaq. Thank you finally to 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.

References

Breiman, L. (2001). Random forests. *Machine learning* 45(1): 5-32.

Kamp, J., H. Skov, B. Jensen and L. L. Sørensen (2018). Fluxes of gaseous elemental mercury (GEM) in the High Arctic during atmospheric mercury depletion events (AMDEs). *Atmospheric Chemistry and Physics* 18(9): 6923-6938.

Mann, E., S. Ziegler, M. Mallory and N. O'Driscoll (2014). Mercury photochemistry in snow and implications for Arctic ecosystems. *Environmental reviews* 22(4): 331-345.

Poulain, A. J., J. D. Lalonde, M. Amyot, J. A. Shead, F. Raofie and P. A. Ariya (2004). Redox transformations of mercury in an Arctic snowpack at springtime. *Atmospheric Environment* 38(39): 6763-6774.

Sommar, J., I. Wängberg, T. Berg, K. Gårdfeldt, J. Munthe, A. Richter, A. Urba, F. Wittrock and W. Schroeder (2007). Circumpolar transport and air-surface exchange of atmospheric mercury at Ny-Ålesund (79 N), Svalbard, spring 2002. *Atmospheric Chemistry and Physics* 7(1): 151-166.

Ferrari, C. P., P.-A. Gauchard, K. Aspmo, A. Dommergue, O. Magand, E. Bahlmann, S. Nagorski, C. Temme, R. Ebinghaus and A. Steffen (2005). Snow-to-air exchanges of mercury in an Arctic seasonal snow pack in Ny-Ålesund, Svalbard. *Atmospheric Environment* 39(39): 7633-7645.

Steffen, A., T. Douglas, M. Amyot, P. Ariya, K. Aspmo, T. Berg, J. Bottenheim, S. Brooks, F. Cobbett and A. Dastoor (2008). A synthesis of atmospheric mercury depletion event chemistry in the atmosphere and snow. *Atmospheric Chemistry and Physics* 8(6): 1445-1482.

Temporal trends of emerging pollutant and mercury deposition through ice and sediment core sampling

Tendances temporelles des dépôts de polluants émergents et de mercure mesurées par le prélèvement de carottes de glace et de sédiments

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Project locations/Emplacements du projet

Mount Oxford Plateau, Ellesmere Island, NU (82.179°N, 72.956°W)
Lake Hazen, Ellesmere Island, NU (81.783°N, 71.011°W)

Abstract

Contaminants produced and emitted in southern regions can travel through the atmosphere and deposit in the Arctic. Remote Arctic ice caps preserve these chemicals and allow us to understand trends in transport and deposition. This project collected ice cores from the Mount Oxford icefield on Ellesmere Island in the Canadian High Arctic, as well as sediment

Résumé

Les contaminants produits et émis dans les régions du Sud peuvent voyager dans l'atmosphère et se déposer dans l'Arctique. Les calottes glaciaires des régions éloignées de l'Arctique préservent ces produits chimiques et nous permettent de connaître les tendances relatives au transport atmosphérique et au dépôt des contaminants. Ce projet a permis de

cores from Lake Hazen located downstream of the ice field. Mercury and emerging pollutants were measured in ice and sediment cores. We observed that perfluoroalkyl substances (PFAS) were deposited to the Oxford icefield in all years from 1967 to 2014. Most PFAS increased from the mid-1980s to present. The organophosphate ester flame retardants/plasticizers (OPEs) were lower in concentration at the Oxford icefield compared to our earlier findings in the Devon Ice Cap. Furthermore, OPEs had varying temporal trends with some OPEs showing no trend while others indicated an increasing deposition. The chlorinated OPEs increased until the mid-2000s and then decreased. Future work will focus on relating temporal trends in contaminants to changes in production/emissions as well as climate change variables.

recueillir des carottes de glace dans le champ de glace du mont Oxford sur l'île d'Ellesmere dans le Haut-Arctique canadien, ainsi que des carottes de sédiments du lac Hazen situé en aval du champ de glace. Le mercure et les polluants émergents ont été mesurés dans les carottes de glace et de sédiments. Nous avons observé que des substances perfluoroalkylées (PFAS) se sont déposées sur le champ de glace d'Oxford à chaque année, de 1967 à 2014. La plupart des PFAS ont augmenté depuis le milieu des années 1980 jusqu'à aujourd'hui. Les produits ignifuges et les plastifiants à base d'esters d'organophosphate (EOP) étaient moins concentrés sur le champ de glace d'Oxford que dans la calotte glaciaire de Devon. En outre, les EOP présentaient des tendances temporelles variables, certains EOP ne montrant aucune tendance tandis que d'autres indiquaient un dépôt croissant. Les EOP chlorés ont augmenté jusqu'au milieu des années 2000, puis ont diminué. Les travaux futurs se concentreront sur les liens entre les tendances temporelles des contaminants et l'évolution de la production et des émissions, ainsi que sur les variables des changements climatiques.

Key messages

- Perfluoroalkyl substances (PFAS) and organophosphate ester flame retardants (OPE) were measured in ice cores from the Mount Oxford icefield on Ellesmere Island
- Perfluoroalkyl sulfonic acids are declining in Mount Oxford since 1990 whereas perfluoroalkyl carboxylic acids are increasing since 1985
- Chlorinated OPE displayed a parabolic trend in deposition flux to Mt. Oxford, increasing from the early 2000s with peak fluxes occurring in ~ 2010, followed by a decline
- Increased mercury accumulation in Lake Hazen sediment through increased glacial melt and runoff.

Messages clés

- Les substances perfluoroalkylées (PFAS) et les produits ignifuges à base d'esters d'organophosphate (EOP) ont été mesurés dans des carottes de glace provenant du champ de glace du mont Oxford sur l'île d'Ellesmere;
- Les acides perfluoroalcanesulfoniques sont en baisse au mont Oxford depuis 1990 alors que les acides perfluoroalcanecarboxyliques sont en hausse depuis 1985;
- Les EOP chlorés ont présenté une tendance parabolique dans le flux de dépôt sur le mont Oxford, augmentant à partir du début des années 2000 avec des pics de flux se produisant vers 2010, suivis d'un déclin;
- L'accumulation de mercure est croissante dans les sédiments du lac Hazen en raison de l'augmentation de la fonte des glaciers et du ruissellement.

Objectives

The aim of this project is to:

- analyze ice and sediment cores for trace contaminants mercury (Hg), organophosphate esters (OPEs), and perfluoroalkyl substances (PFASs);
- examine temporal trends of atmospheric deposition of Hg, OPEs and PFASs determined from the ice core analysis and relate their respective concentrations to long-range transport, sources, and production trends;
- examine accumulation rates of Hg, OPEs and PFASs determined from lake sediment core analysis in comparison to ice core data to quantify fate and delivery of contaminants from the ice cap into downstream aquatic ecosystems; and
- provide the new information to local communities and the Nunavut Environmental Contaminants Committee.

Introduction

Assessing temporal trends pathways for mercury and emerging contaminants is a valuable tool in understanding long-range transport pathways to the Arctic. Measurement of trends into the future can be effectively captured by continued or new atmospheric monitoring, while past temporal trends can be understood through deposition records, such as ice or sediment cores. Ice core samples provide a preserved record of atmospheric deposition (e.g. Zhang et al. (2013)). Sediment cores are also useful archives of contaminant deposition (Muir et al., 2009), but incorporate both direct atmospheric deposition and catchment inputs. Measurements in ice and sediment cores can be compared to known changes in production and emission of these contaminants to better understand transport pathways. 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. Due to climatic warming, Arctic glaciers including those in the Lake Hazen watershed, are melting which may lead to the remobilization of contaminants trapped within glacial ice and/or within the catchment due to increased erosion and greater hydrological transport. Thus, our data will elucidate whether climate change may delay the benefits expected from reduced emissions of certain contaminants. 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.

In this project, we collected ice core samples from the Mount Oxford icefield and sediment cores from Lake Hazen for analysis of mercury and emerging contaminants.

Activities in 2018-2019

Chemical analyses of ice and sediment core samples for mercury and contaminants was undertaken. Samples were collected in the 2017-2018 season for ice and sediment cores from the Mount Oxford Plateau and Lake Hazen, respectively. Perfluoroalkyl substances (PFAS) and organophosphate esters (OPEs) were measured in ice cores. Mercury was measured in sediment cores. All chemical analyses took place in Southern Canada.

Community engagement

The project involved solely chemical analysis and did not require any northern work. When samples were collected during the 2017-2018 season, Co-PI Criscitiello engaged with students and educators in Resolute Bay.

Capacity building and training

The project involved solely chemical analysis and did not require any northern work. Thus, there was no on-site involvement of communities or hunting and trapping organizations in this project.

Communications and outreach

We are in the process of putting together a video describing the sampling process. Photos and videos from the ice core collection to the final data will be included. The video will be made publicly available in English and Inuktitut, expected to be released in spring 2020.

Photos and videos of ice core collection and sectioning have been disseminated by team members on social media (e.g. Twitter posts by Co-PIs De Silva @amilaods and Young @ SVOCora). Preliminary results have been presented at the ArcticNet meeting in 2018 and at the Society of Environmental Chemistry and Toxicology North American meeting in Toronto, Ontario in fall of 2019.

Indigenous Knowledge

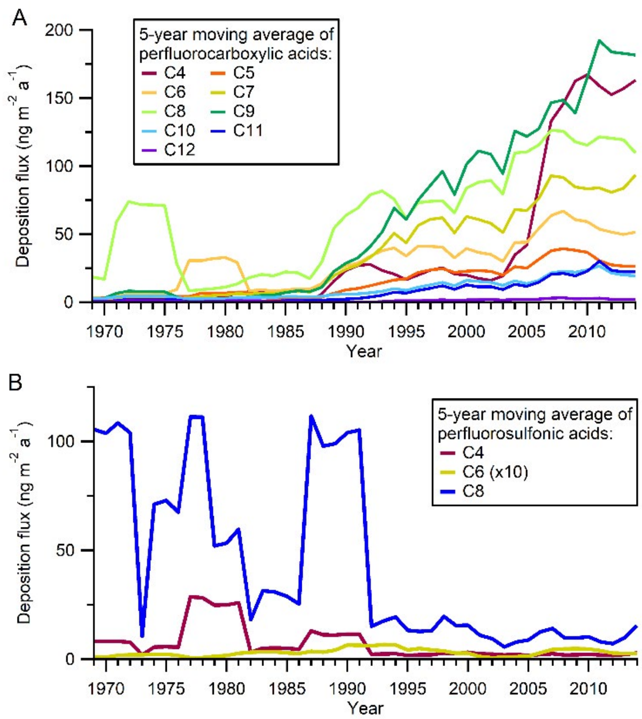
Indigenous knowledge of prevailing winds and ocean/ice behaviour throughout the year will be used to understand the temporal trends of pollutants and mercury derived from the ice and sediment cores. This Indigenous knowledge will be derived primarily from the 2001 Elder's Conference on Climate Change summary document (https://www.tunngavik.com/publication_categories/climate-change/).

Results and outputs/deliverables

PFAS in Mount Oxford ice core

The ice core used for the measurement of PFAS preserved deposition from 1967 to 2016. Target analytes included perfluorocarboxylic acids (PFCAs) from two to twelve carbons, perfluorosulfonic acids (PFSAs) with four, six, and eight carbons, as well as the volatile PFSA analogue, perfluorosulfonamide (FOSA). Detectable concentrations of PFAS were found in all samples, representing deposition in all years. Concentrations range from sub-pg/L to over 100 ng/L. Deposition flux is a more useful reporting metric for ice cores than concentration, because it takes into account precipitation variability. Concentrations were converted to deposition fluxes for all measured PFAS compounds. Deposition fluxes for PFCAs generally increased as a function of time from 1967 to 2016 (Figure 1A). In contrast, deposition fluxes of PFSAs did not exhibit a clear trend with time, although they have decreased in recent years (Figure 1B). The variation in PFSAs with time is not understood at this time.

Figure 1. Deposition fluxes of perfluoroalkyl substances in an ice core collected from the Mount Oxford Ice Field for perfluoroalkyl carboxylic acids (A) and perfluoroalkyl sulfonic acids (B) shown as a 5-year moving average to account for errors associated with dating and ice core melt.



OPEs in Mount Oxford ice core

In the ice sections representing the last decade, 2010 – 2017, in the Mt. Oxford Ice Field, the major OPEs based on concentration were the chlorinated OPEs, 40-42% TCPP (58 ±10 ng L^{-1}), 4-5% TCEP (7.8 ±1.9 ng L-1), 2-4% TDCPP (5.1 ±0.8 ng L-1), the aryl OPE, 4-27% TBEP (39 ±7 ng L-1), and the alkyl OPE, 4-18% TEP (5.1 ± 1.0 ng L-1) (Figure 2). The linear tributyl OPE isomer TnBP was less prevalent in Oxford (5.2 ±1.6 ng L-1) compared to our earlier study in the Devon Ice Cap (29 ±3 ng L-1), as was TPP (3.7 ±0.7 ng L-1 in Oxford vs 155 ±79 ng L-1 in Devon). Conversely, the isopropyl butyl OPE isomer, TiBP, was more prevalent in the Mt. Oxford Ice Field (14 ±2 ng L-1 in Mt. Oxford and 1.2 ±0.1 ng L-1 in Devon).

Figure 2. OPE fluxes (ng/m2/y) in Devon Ice Cap and Mt. Oxford icefield. Fluxes are presented as a 3-year moving average (solid line, filled symbols, "smooth") and as measured values (dashed line, open symbols, "obs").

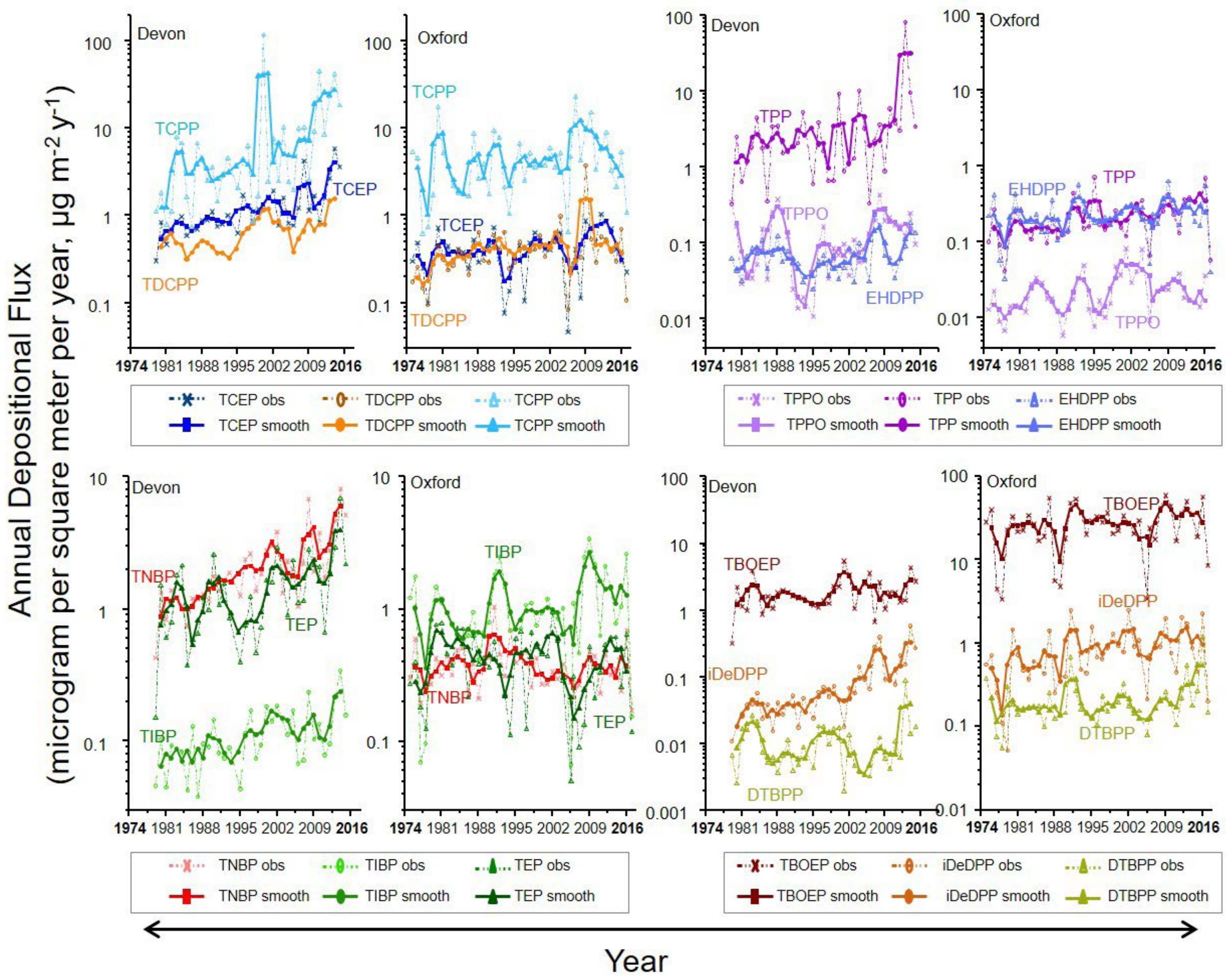
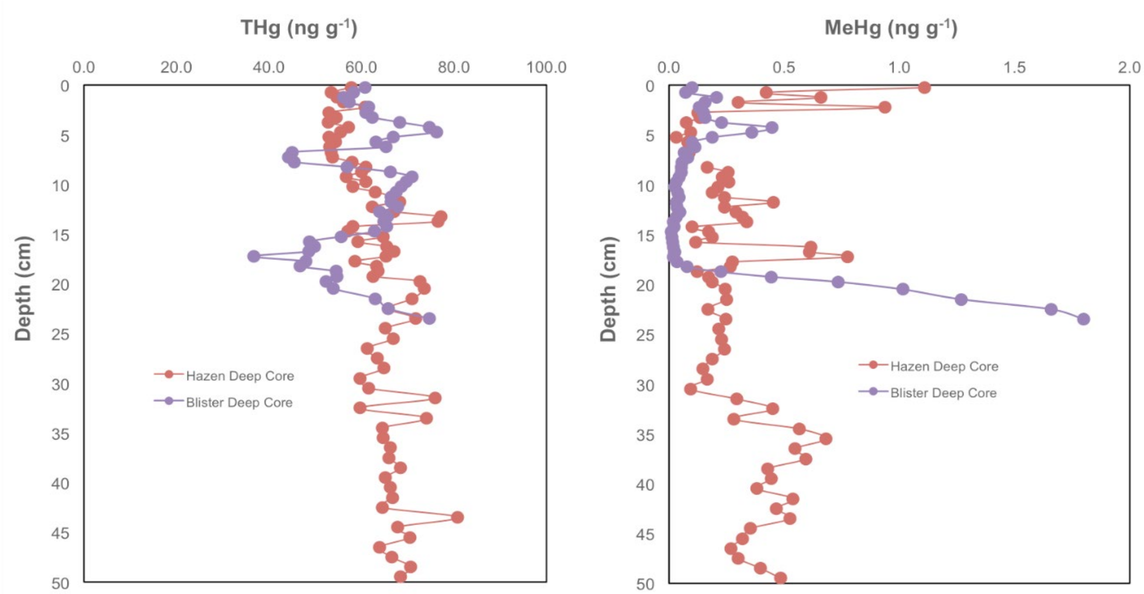


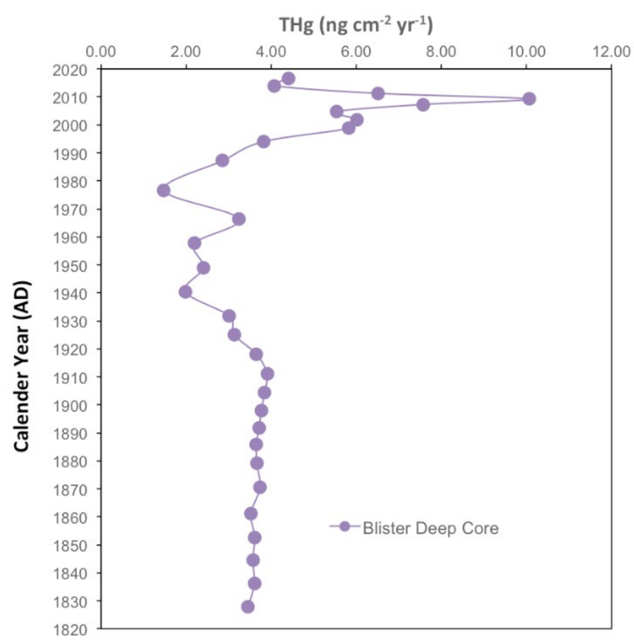
Figure 3. Concentrations of (a) total mercury (THg; ng g-1) and (b) methylmercury (MeHg; ng g-1) in Lake Hazen sediment cores. Both sediment cores were collected from ~260 m depth, but at two different sites along the lake's deep trench: Hazen Deep core (81.825 °N, 70.715 °W) and Blister Deep Core (81.792 °N, –71.469 °W).



Hg in Lake Hazen sediment core

Lake sediments are also useful archives for examining past trends in contaminant deposition and delivery. The Lake Hazen sediment cores reflect atmospheric deposition (similar to the ice cores) but also inputs from the catchment. Concentrations of total Hg (THg) in both sediment cores collected from Lake Hazen show some variability with depth (mean 62 ng g-1, range 37-81 ng g-1) (Figure 3). However, the THg profile in the sediment cores do not exhibit any consistent increasing or decreasing trend over time. In order to better understand temporal trends in THg deposition, we have transformed these concentrations into accumulation rates with units ng cm-2 y-1 by incorporating the sedimentation rate (Figure 4). The annual accumulation of THg in Lake Hazen sediments have increased significantly over time.

Figure 4. Accumulation rate of total mercury (THg; ng cm-2 y-1) over the past ~200 years in Lake Hazen sediments.



Discussion and conclusions

PFAS in Mount Oxford ice core

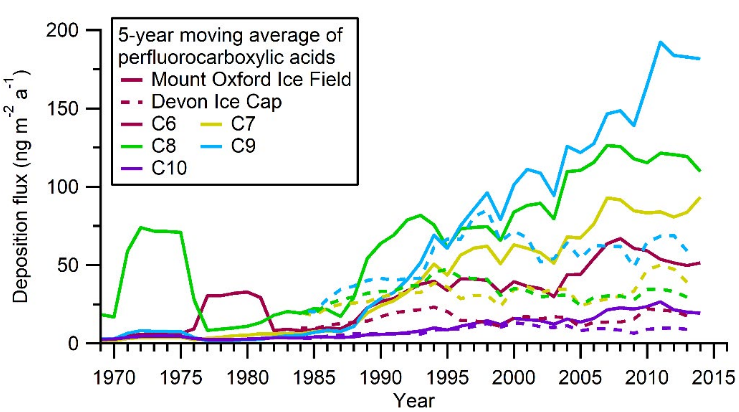
The 48-year record of PFAS deposition determined from the Mount Oxford icefield ice core represents the longest temporal trend for PFAS in the Canadian Arctic. Similar to our previous work in the Devon Ice Cap, the carboxylate PFAS (i.e. PFCA, Figure 1A) are more prevalent than the sulfonate PFAS (i.e. PFSA, Figure 1B). Furthermore, our data indicate that all PFSA including PFOS have declined since the 1990s. We observed the deposition of most PFCA homologues was very low prior to approximately 1985, after which levels begin to increase to present day (Figure 1A). A similar, although shorter, ice core was collected from Devon Ice Cap in the Canadian Arctic in 2015, which recorded deposition from 1977 to 2014 (NCP M-26 2015-2016 - *Temporal trends of emerging pollutant deposition through ice core sampling on the Devon Ice Cap*). In recent years, deposition to the Mount Oxford icefield is higher than deposition to the Devon Ice Cap for many PFAS homologues (Figure 5). These two ice cores are known to represent different sources, as Mount Oxford icefield (Ellesmere Island) receives pollution primarily from Eurasia, while the Devon Ice Cap receives pollution primarily from North America (Goto-Azuma and Koerner, 2001). These different source regions may contribute to the observed differences in fluxes.

OPEs in Mount Oxford ice core

In our earlier Devon Ice Cap project, the majority of the OPEs had exponentially increasing flux from the 1980s to 2015. Using the slope from the natural log transformed flux versus time, doubling times were between 10 and 35 years for the majority of OPEs. In the Mt. Oxford icefield, temporal trends in OPE fluxes were varied with some OPEs showing no statistically significant trend such as TEP, TnBP, and TBEP. Other OPEs had a zero-order increasing flux with slopes corresponding to 4.9 ± 0.8 ng m-2 y-1 for TPP, 1.9 ± 0.4 ng m-2 y-1 for iDeDPP, 1.8 ± 0.2 ng m-2 y-1 for TEHP, 1.1 ± 0.2 ng m-2 y-1 for TBDPP, and 0.59 ± 0.01 ng m-2 y-1 DIPI. The chlorinated OPEs each had a parabolic trend in flux with increasing flux from the early 2000s and peak fluxes occurring in 2008 for TCPP, 2009 for TDCPP, and 2013 for TCEP, followed by a decline.

Contrasts in the OPE composition of the Devon Ice Cap compared to the Mt. Oxford icefield can likely be attributed to differences in air mass source delivery to the two sites. In the eastern Canadian Arctic where Devon Island is situated, back trajectory analysis has shown contributions from both European and North American air masses (Pickard et al., 2018). Long term back-trajectory analyses shows western Russia and central Siberia are major source regions for aerosols to northern Ellesmere Island and Greenland (Freud et al., 2017). Earlier research indicates that northern Ellesmere Island receives fewer Arctic haze events compared to research

Figure 5. Deposition of perfluoroalkyl carboxylic acid congeners with 6-10 carbons to Mount Oxford icefield and Devon Ice Cap. Devon Ice Cap data from Pickard et al. (2018).



stations in Utqiagvik (previously known as Barrow), Alaska, Station Nord, Greenland, Tiksi in Russia, and Zeppelin in Svalbard due to katabatic winds from the high mountain range.

Hg in Lake Hazen sediment core

Sediment THg fluxes increased above baseline values beginning at the turn of the century (~1998 CE), rising up to 10 ng cm-2 y-1 (post 1998 mean: 6.1 ng cm-2 y-1), compared to a pre-1998 baseline mean of 3.1 ng cm-2 y-1. The timing of this increase coincides with the onset of other known climate-driven changes in the watershed, such as declining lake ice cover and increasing delivery of sediment and organic carbon into the lake (Lehnherr et al., 2018). In fact, the highest THg flux values occurred between 2007 and 2011, a period of time during which total annual glacial runoff in the watershed increased rapidly, reaching the highest values in the 70 years for which this data is available (beginning in 1948) (Lehnherr et al., 2018). Therefore, one of the impacts of climate warming in the Lake Hazen watershed has been to increase the delivery of Hg into the lake through the mechanism of increased glacial melt and runoff facilitating erosion and subsequent transport of sediment, including particulate-bound Hg. Thus, it appears that the recent increase in Hg accumulation in Lake Hazen sediments is caused by the remobilization of Hg within the catchment, rather than from increased atmospheric Hg deposition associated with changing anthropogenic Hg emissions. On-going measurements of Hg accumulation rates in the Mt. Oxford ice core, which directly reflect atmospheric Hg deposition, will be used to test whether this hypothesis is correct.

Expected project completion date

We anticipate that all analysis will be completed by March 2020.

Acknowledgments

Polar Continental Shelf Program for in-kind logistical support. ArcticNet and NSERC (Discovery and Northern Research Supplement Programs), W. Garfield Weston Foundation, Kenneth M. Molson Foundation and the Northern Contaminants Program for funding.

References

Freud, E., Krejci, R., Tunved, P., Leaitch, R., Nguyen, Q., Massling, A., Skov, H. and Barrie, L.: Pan-Arctic aerosol number size distributions: seasonality and transport patterns, Atmos Chem Phys, 17, 8101–8128, 2017.

Goto-Azuma, K. and Koerner, R. M.: Ice core studies of anthropogenic sulfate and nitrate trends in the Arctic, J Geophys Res, 106(D5), 4959–4969, 2001.

Lehnherr, I., St. Louis, V. L., Sharp, M., Garnder, A., Smol, J., Schiff, S., Muir, D., Mortimer, C., Michelutti, N., Tarnocai, C., St. Pierre, K., Emmerton, C., Wiklund, J., Kock, G., Lamoureux, S. and Talbot, C.: The world's largest High Arctic lake succumbs to climate warming, Nat Commun, Accepted, 2018.

Muir, D. C. G., Wang, X., Yang, F., Nguyen, N., Jackson, T. A., Evans, M. S., Douglas, M., Köck, G., Lamoureux, S., Pienitz, R., Smol, J. P., Vincent, W. F. and Dastoor, A.: Spatial trends and historical deposition of mercury in eastern and northern Canada inferred from lake sediment cores, Environ Sci Technol, 43(13), 4802–4809, doi:10.1021/es8035412, 2009.

Pickard, H., Criscitiello, A., Spencer, C., Sharp, M. J., Muir, D. C. G., De Silva, A. O. and Young, C. J.: Continuous non-marine inputs of per- and polyfluoroalkyl substances to the High Arctic: A multi-decadal depositional record, Atmos Chem Phys, 18(7), 5045–5058, doi:10.5194/acp-2017-1009, 2018.

Zhang, X., Meyer, T., Muir, D. C. G., Teixeira, C., Wang, X. and Wania, F.: Atmospheric deposition of current use pesticides in the Arctic: Snow core records from the Devon Island Ice Cap, Nunavut, Canada, Environ Sci Process Impacts, 15, 2304–2311, 2013.

Communications, Capacity, and Outreach

Communications, capacités et sensibilisation

Yukon Contaminants Committee (YCC) CIRNAC Yukon Regional Office Coordination

Coordination du Comité des contaminants du Yukon et des bureaux régionaux de RCAANC, région du Yukon

Project leader/Chef de projet
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Project team/Équipe de projet
Yukon Contaminants Committee (YCC) including: Ellen Sedlack, CIRNAC (Chair), James MacDonald, Council of Yukon First Nations (Co-Chair), Dr. Mary Vanderkop, Yukon Government, Sabrina Kinsella, Yukon Government, Dr. Brendan Hanley, Yukon Government; Mary Gamberg, independent consultant and researcher.

Project location/Emplacement du projet
Whitehorse, YK

Abstract

The YCC has operated since 1991 and continues to keep residents of the Yukon informed of the Northern Contaminants Program's initiatives. In 2018-2019 the YCC continued to work with Yukon Health authorities and researchers on contaminants in traditional food sources and continued to support three Yukon communities (White River First Nation, the First Nation of Nacho Nyäk Dun and Taku River Tlingit First Nation) involved in research of long-range contaminants in wildlife in their Traditional Territories.

Résumé

Le CCY, qui existe depuis 1991, continue d'informer la population du Yukon sur les initiatives exécutées dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN). En 2018-2019, le CCY a continué sa collaboration avec les autorités sanitaires et les chercheurs du Yukon sur les contaminants dans les sources d'alimentation traditionnelles et a continué de soutenir trois collectivités du Yukon (la Première Nation de White River, la Première Nation des Nacho Nyäk Dun et la Première Nation des Tlingits de Taku River) qui participent à la recherche sur les contaminants transportés à grande distance et qui se retrouvent dans la faune de leurs territoires traditionnels.

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 YCC has spent the past 26 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.
- 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

- La consommation des aliments traditionnels ou régionaux est sûre.
- 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.
- Au cours des 26 dernières années, le CCY a communiqué les résultats du Programme de lutte contre les contaminants dans le Nord à la population du Yukon et a contribué à des publications nationales et internationales.
- Le CCY est considéré comme la ressource pour les questions touchant les contaminants transportés à grande distance au Yukon.
- Les travaux liés au PLCN sont toujours pertinents à l'échelle 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 of information 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 over 26 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 2018/2019

Communications and outreach

- In 2018-2019 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, YCC members discussed NCP initiatives with participants, and described how to apply for funding.

Community engagement

- The YCC continued to support and engage with three Yukon First Nation communities (White River First Nation, the First Nation of Nacho Nyäk Dun and Taku River Tlingit First Nation) with their NCP research to see how long-range contaminants are affecting traditional foods in their Traditional Territories.

Capacity building and training

- The YCC met several times over the course of the year 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 these projects through a social/cultural review and made recommendations to the NCP Secretariat and later to the NCP Management Committee.

Results and outputs/deliverables

The YCC reviewed Yukon Territory project proposals and made comments in writing to the NCP in preparation for the April 2019 Management Committee meeting in Ottawa, Ontario.

Discussion and conclusion

The regional office will continue to coordinate contaminants projects in the Yukon, including fiscal agreements where required, as well as assist National and International NCP initiatives. The regional office will work with the YCC to review all proposals relevant to the Yukon for socio-cultural content. The YCC also completed a second strategic planning session for the committee to understand roles/responsibilities and how to further NCP initiatives in the Territory. This planning session built 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 and Mary Gamberg for their contributions to assisting CIRNAC, Yukon region and the YCC with their involvement, collaboration and connection with the Yukon First Nation in the Territory.

Northwest Territories Regional Contaminants Committee (NWTRCC)

Comité régional des contaminants des Territoires du Nord-Ouest (CRCTNO)

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Project location/Emplacement du projet

Northwest Territories, Canada

Abstract

In the 2018-2019 year, the Northwest Territories Regional Contaminants Committee (NWTRCC) continued to fulfill its mandate of assisting in communicating results of research to NWT residents and providing input on proposed research projects from a social and cultural lens. The NWTRCC held a number of in-person and teleconference meetings to meet its objectives. Members also worked independently in the communities they

Résumé

En 2018-2019, 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 et de leur fournir des perspectives sur des projets de recherche d'un point de vue social et culturel. Le CRCTNO a organisé un certain nombre de réunions par conférence téléphonique en vue de respecter

represent to share research and where possible identify community research priorities with regards to long-range contaminants.

ses objectifs. Les membres ont aussi travaillé indépendamment dans les collectivités qu'ils représentent pour diffuser leurs recherches et, dans la mesure du possible, déterminer les priorités de recherche communautaires concernant les contaminants transportés sur de longues distances.

Key messages

- Through its social-cultural review of all NWT-based Northern Contaminant Program (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 in a culturally-appropriate way.
- The NWTRCC continues to highlight the need to integrate Traditional 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.

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 d'une manière culturellement appropriée.
- Le CRCTNO continue de souligner la nécessité d'intégrer les connaissances traditionnelles à tous les stades des projets de recherche afin que ceux-ci contribuent à répondre aux préoccupations de la collectivité concernant la salubrité de l'eau et des aliments traditionnels.

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 as many of the NWTRCC members sit on the various committees and boards, or are involved in complimentary programs, 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;
- review and advise researchers on NCP NWT proposals for social/cultural criteria; discussions are held at the NWTRCC Social/Cultural Review and submitted to the NCP Management Committee for consideration when approving proposals;

- 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 complimentary programs 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 other complimentary committees and boards, such as the Cumulative Impact Monitoring Program (CIMP) committee, Protected Areas Strategy, Mackenzie River Basin Board and the 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 NCP Management Committee

Activities in 2018-2019

The NWTRCC continued to assist in communicating 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 teleconferences and in person meetings in order to ensure effective communication among all members and determine priorities of the NWTRCC for the year. 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 members. The NWTRCC Co-Chairs are also members of the overall NCP Management Committee and participated in their in-person meetings and overall decision-making as well. 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. For example, several members attended the CIMP Results Workshop held December 5-6, 2018 in Yellowknife (CIRNAC, Northwest Territory Métis Nation (NWTMN), Dehcho First Nations (DCFN), Tłı̨chǫ Government (TG). Several members also attended the ArcticNet Annual Scientific Meeting held December 10-14, 2018 in Ottawa (CIRNAC, IRC, TG). CIRNAC NWT & NU also co-hosted a session on Contaminants in the North with the Inuit Circumpolar Council (ICC).

Community engagement

Various members of the committee engaged with the communities they represent.

The North Slave Métis Alliance (NSMA) representative held meetings with leadership and general membership to update them on NCP initiatives. Issues related to long-range contaminants were communicated to members via the NSMA lands newsletter which circulates to 136 registered recipients.

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.

The Gwich'in Tribal Council is piloting a new approach to evaluate prospective research projects, which involves working with communities to establish their research priorities, communicating those priorities to researchers, and then supporting projects that cater to those priorities over others, such as by charging a lower rate for services.

Capacity building and training

The structure of the RCC was reformed in order to ensure that the committee's leadership representation is better reflective of the diversity of Indigenous groups in the NWT. The committee will be chaired by a Métis and Inuvialuit representative, with the Dene Nation as an Indigenous Partner.

The committee discussed the importance of involving youth/early-career members, in the interest of establishing long-term capacity. It was decided that wherever possible, an early-career member should have the opportunity to attend the Management Committee meeting, and all members are welcome to bring an early-career observer to RCC meetings.

Communications and outreach

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.

The NWT Métis Nation member reported to the NWTMN Annual General Assembly on NCP activities, and had the opportunity to hear from members on issues of concern, such as the impacts of climate change and permafrost degradation on contaminants and the environment more broadly.

Akaitcho Territory Government assisted NCP researchers Marlene Evans and Hailey Hung with project updates and results dissemination to the Lutsel K'e Dene and Deninu K'ue First Nations.

On June 15, 2018, CIRNAC participated in Rivers to Oceans Day, hosted by the Government of the Northwest Territories and Ecology North. At our booth, students from Yellowknife learned about long-range contaminants and how they magnify as they go up the food chain. (See Figure 1).

Figure 1. Rivers to Oceans Day, June 15, 2018. Children were chosen to be either invertebrates, fish or bears. The invertebrates "foraged" for food and unknowingly ingested contaminants (red beans). Once eaten by fish and then by bears (and taking their beans), they saw how contaminants could biomagnify up the food chain.

Indigenous Knowledge

RCC Members regularly incorporate or provide support for traditional knowledge in their engagement work, and when reviewing proposals from a Social/Cultural lens ensure the incorporation of traditional knowledge into NCP projects is being done in a culturally sensitive, relevant and appropriate manner.

This year was the first year that an Indigenous caucus meeting was held, where all Indigenous members of the NWT Regional Contaminants Committee met. This provided the Indigenous members an opportunity to discuss the governance structure of the RCC as well as program priorities, and whether the RCC is administering the program according to Indigenous priorities. This then led into discussions on governance and a shifting of the Terms of Reference to get rid of the annual elections for Chair, which had been the source of conflicts in the RCC.

Discussion and conclusions

The NWTRCC continues to provide a regional network that helps ensure NCP research is culturally appropriate and helps to build capacity, with the goal of greater self-determination in research in the NWT. The change to the governance of the committee this past year will also help to create more consensus and greater focus on the program objectives.

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 sur les contaminants environnementaux du Nunavut (CCEN)

Project leaders/Chefs de projet

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Project location/Emplacement 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 information on long-range contaminants in Nunavut.

The NECC attended the in-person NCP Management Committee (MC) meetings in Nain, Labrador in April 2018; in Ottawa, Ontario in November 2018; Ottawa, Ontario in March 2019 as well as in the meeting via teleconference on October 11, 2018. The

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 de la population 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 distances présents au Nunavut.

Le CCEN a participé aux réunions en personne du Comité de gestion (CG) du PLCN à Nain, au Labrador, en avril 2018, à Ottawa, en Ontario,

NECC hosted a productive in-person meeting in Iqaluit, NU in October 2018 for the review of the mid-year reports and hosted another face-to-face meeting for the social-cultural review of NCP proposals in Iqaluit, NU in February 2019.

The NECC participated in the NCP-funded Wildlife Contaminants Workshop (*Wildlife Contaminants Workshop – building contaminants research capacity in Nunavut*) in Iqaluit, NU (September 2018) and in the NCP-funded Arviat Workshop (*Learning about ringed seal health from contaminants science and Inuit Qaujimajatuqangit: an educational workshop in Arviat, Nunavut, and Regional NCP Workshop in Arviat*) in October 2018.

The NECC provided feedback to NCP-funded researchers on communications, met face-to-face with NCP-funded researchers to discuss their respective proposals/projects, and attended seminars/workshop held by NCP-funded researchers.

en novembre 2018 et en mars 2019, ainsi qu'à la réunion par téléconférence du 11 octobre 2018. Le CCEN a organisé une réunion productive en personne à Iqaluit (Nunavut) en octobre 2018 pour l'examen des rapports semestriels et a organisé une autre réunion en personne pour l'examen socioculturel des propositions du PLCN à Iqaluit (Nunavut) en février 2019.

Le CCEN a participé à l'atelier sur les contaminants de la faune financé par le PLCN (*Atelier sur les contaminants des espèces sauvages – Accroître la capacité en matière de recherche sur les contaminants au Nunavut*) à Iqaluit (Nunavut) (septembre 2018) et à l'atelier d'Arviat financé par le PLCN (*En apprendre davantage sur la santé du phoque annelé grâce à la science sur les contaminants et au savoir traditionnel des Inuits (Inuit Qaujimajatuqangit)* : atelier éducatif à Arviat au Nunavut, et atelier régional du PLCN à Arviat) en octobre 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.

Key messages

- The NECC has spent the past 20 years assisting researchers to communicate results of the NCP funded research 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

Messages clés

- Depuis 20 ans, le CCEN communique les résultats des recherches financées par le 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 et présents au Nunavut.

in two capacity-building activities funded by NCP, and met or corresponded with numerous NCP-funded researchers to provide feedback on projects and communication materials.

- Cette année, le CCEN a participé à plusieurs réunions internes et externes et à deux 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:

- ensure that the interests of Nunavummiut are being addressed during research activities through its social-cultural review of all Nunavut-based NCP proposals. This process ensures the following:
  - local or northern training and capacity building opportunities are pursued by Principal Investigators (PI) whenever possible;
  - Inuit Qaujimajatuqangit (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 media that is understood by Nunavummiut;
- assist and advise NCP-funded researchers on the relevant methods and distribution of communication materials to communities;
- by way of GN-DOH representatives on the committee, provide relevant NCP-funded contaminant research results to the Chief Medical Officer of Health (CMOH) for Nunavut;
- work in partnership with communities, researchers, governments, and Inuit organizations when undertaking community outreach related to communicating NCP research results;
- when requested by the GN, provide support to the CMOH who will work in collaboration with 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 was struck in May 2000 and since its inception, the annual social-cultural review of NCP proposals has been the committee's primary focus. Through its review of all Nunavut-based proposals, the committee ensures northern and Inuit interests are being served by scientific research conducted in Nunavut.

Activities in 2018-2019

Meetings and teleconferences

The NECC:

- attended the NCP Management Committee meeting in Nain, Labrador in April 2018 (CIRNAC and 2 GN-DOH representatives);
- hosted a face-to-face NECC meeting in Iqaluit on October 15, 2018 to provide an update on the NCP MC meeting and funding decisions and to review mid-year reports, NCP Blueprints and Call for Proposals;
- attended the NCP Management Committee meeting in Ottawa, ON in November 2018 (NTI, CIRNAC, GN-DOH and Government of Nunavut - Department of Environment [GN-DOE]);
- hosted a face-to-face NECC social-cultural review meeting on February 5-7, 2019 in Iqaluit to review 26 Nunavut-based NCP proposals. A total of 13 members (out of 15), 2 community members (Pitsiula Kilabuk from Pangnirtung; Barnie Aggark from Chesterfield Inlet participated through teleconference); and 7 Environmental Technology Program students and their instructor participated in the proposal review. Co-chairs provided detailed feedback in a summary report to the NCP Secretariat in March 2019;
- met with Hayley Hung, Liisa Jantunen, 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]; Investigating the Abundance, types and Potential Sources of Microplastics in the Arctic – Unfunded[M-26]) on February 4, 2018; and
- attended the NCP Management Committee meeting in Ottawa, Ontario in March 2019 (CIRNAC, NTI, GN-DOE, and 2 GN-DOH representatives).

Capacity building and training

The NECC:

- participated in the Arviat Workshop (Learning about ringed seal and Arctic wildlife health from contaminants science and Inuit Knowledge through educational workshops in Resolute Bay, Sachs Harbour and Arviat [C-12]), and Regional NCP Workshop in Arviat) hosted by Jennifer Provencher, Dominique Henri, Magali Houde, and Amie Black in Arviat, NU in October, 2018 (GN-DOE and GN-DOH); and
- supported one Nunavut Arctic College Environmental Technology Program (NAC ETP) student's travel to Sachs Harbour, NT to participate in an NCP-funded ringed seal health workshop (C-12) on January 28 to February 3, 2018.

Communications and outreach

The NECC:

- participated in the Wildlife Contaminants Workshop hosted by Jamal Shirley, Mary Gamberg, and Jennifer Provencher (Wildlife Contaminants Workshop – building contaminants research capacity in Nunavut) at Nunavut Arctic College in Iqaluit on September 24-27, 2018. Amy Caughey presented at this workshop on nutrition and country food, in particular, in the context of risk-benefit communication about food safety and country food. Jean Allen was planning on introducing the NECC and the NCP at the workshop but unfortunately became ill and could not give the presentation as scheduled;
- attended the ArcticNet Scientific Meeting in Ottawa, ON in December 10-14, 2018 (CIRNAC, NTI, GN-DOH). This was not funded by NCP but we participated in NCP-related activities (co-chaired the contaminant session, presentations on NCP-funded research, meetings with NCP researchers, and NCP side-meetings, etc.);

- 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, and draft proposals;
- corresponded with many other NCP-funded researchers, including Magali Houde, Birgit Braune, Derek Muir, Marlene Evans, Robert Letcher, Jane Kirk, Mary Gamberg, Joel Heath, Lisa Losetto, Kyle Elliot, James Simonee, Dominique Henri, and Virginia Walker; and
- created an information poster in plain language translated in Inuktitut, Inuinnaqtun and French to disseminate information on NECC mandate in Nunavut's communities.

Results

- The NECC provided feedback to some researchers on communications materials prior to their publication or distribution (i.e., plain language summaries, reports, posters).
- The NECC submitted the 2018-2019 NECC Mid-Year Report Review Summary Report to the NCP Secretariat (October 2018).
- The NECC provided feedback to the NCP Secretariat on Blueprints for 2019-2020 Call for Proposals.
- The NECC submitted the 2019-2020 NECC Social-Cultural Review Summary Report to the NCP Secretariat (March 2019)
- Information posters were developed to re-introduce the NECC to Nunavummiut. The posters were translated in four languages for distribution in Nunavut (March 2019). report

Discussion and conclusions

The work of the NECC is on-going and will continue into 2019-2020. The NECC saw many changes: Taha Tabish joined the committee in September 2018; Angela Young (GN-DOE, Fisheries & Sealing) returned from maternity leave in January 2019; Jason is no longer with the NCP Secretariat but Chase Morrison from the NCP Secretariat participated in NECC activities since October 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 results 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 submitted by researchers; 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.

Acknowledgments

The NECC would like to acknowledge all NECC and NCPMC-NU members, the Nunavut Arctic College, ETP instructors and ETP students and community members that have contributed to NCP and NECC activities in Nunavut. The NECC would also like to acknowledge the NCP Secretariat, ITK, and ICC for their continued support.

Nunavik Nutrition and Health Committee (NNHC): coordinating and learning from contaminants research in Nunavik

Comité de la nutrition et de la santé du Nunavik (CNSN) : Coordonner la recherche sur les contaminants au Nunavik et en tirer des leçons

Project leaders/Chefs de projet

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Project location/Emplacement du projet

Nunavik, QC

Abstract

The Nunavik Nutrition and Health Committee (NNHC) is a long-standing committee that has evolved and adapted over the years. Since its creation in 1989, the regional committee has broadened its perspective toward a more holistic approach to contaminants, nutrition and health issues, and has linked to the Northern Contaminant Program. Today, the NNHC acts as an advisory committee to the director of Public Health on issues related to

Résumé

Le Comité de la nutrition et de la santé du Nunavik (CNSN) est un comité de longue date qui a évolué et s'est adapté au fil des ans. Depuis sa création en 1989, le comité régional a élargi son champ d'action, a adopté une approche plus globale au sujet des contaminants, la nutrition et la santé, et a établi des liens avec le PLCN. De nos jours, le CNSN agit à titre de comité consultatif auprès du directeur de la santé publique en ce qui concerne ses domaines

its areas of expertise. The committee provides guidance, establishes liaisons with research groups and communities, and orients research work on regional priority issues. Moreover, the committee facilitates and, when pertinent, undertakes research-communications activities on contaminants, nutrition, and health. Making research relevant to *Nunavimmiut* needs and interests as well as protecting and promoting public health in Nunavik are among the main NNHC priorities. This year, with the Northern Contaminants Program's (NCP) support, the NNHC and the region were able to play a central role in the interpretation and outcomes of the Qanuilirpitaa? 2017 Health Survey (Qanuilirpitaa?) results related to contaminants, nutrition, and health. Extensive regional efforts to mitigate lead and mercury exposure were also pursued this year. These efforts aim to protect the subgroups of the population which are more at risk, including pregnant women and their unborn babies as well as children.

Key messages

- The NNHC is the key regional committee for health and environment issues in Nunavik.
- The NNHC advises the Nunavik Director of Public Health about educating the public on food, nutrition and health issues, including the benefits and risks (such as contaminants) associated to country food consumption.
- The NNHC 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.*

d'expertise. Le comité offre des conseils, assure la liaison avec les collectivités et les groupes de recherche et oriente les travaux de recherche sur les questions prioritaires régionales. De plus, le comité soutient les activités de recherche et de communication sur les contaminants, la nutrition et la santé et entreprend de telles recherches lorsqu'elles sont pertinentes. Faire en sorte que la recherche réponde aux besoins et aux intérêts des Nunavimmiuts ainsi que protéger et promouvoir la santé publique au Nunavik figurent parmi les principales priorités du CNSN. Cette année, grâce au soutien du PLCN, le CNSN et la région ont pu jouer un rôle central dans l'interprétation et les résultats de l'enquête de santé Qanuilirpitaa? de 2017 (Qanuilirpitaa?) en matière de contaminants, de nutrition et de santé. D'importants efforts régionaux visant à atténuer l'exposition au plomb et au mercure ont également été poursuivis cette année. Ces efforts visent à protéger les sous-groupes de la population les plus exposés, notamment les femmes enceintes et leurs enfants à naître ainsi que les enfants.

Messages clés

- Le CNSN est le principal comité régional pour les questions de santé et d'environnement au Nunavik.
- Le CNSN conseille le directeur de la santé publique du Nunavik sur l'éducation du public en matière d'alimentation, de nutrition et de santé, y compris les avantages et les risques (notamment les contaminants) associés à la consommation d'aliments traditionnels.
- Le CNSN continue de participer activement au Programme de lutte contre les contaminants dans le Nord : il examine et soutient 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 health. The NNHC aims to:

- interact and establish liaison with the NCP and other researchers working on contaminants, nutrition, and health to guide, support, and ensure the relevancy of research for Nunavik communities;
- compile elements of public concern, identify regional and community research priorities and information gaps related to contaminants, nutrition, and health, and address these priorities by sharing them with 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 projects and inform public-health interventions related to country food, nutrition, and health;
- encourage and support NCP researchers and other researchers researching contaminants, nutrition and environmental health to build northern capacity within research projects;
- provide comprehensive and valuable information on contaminants, nutrition and health in appropriate format to Nunavimmiut and regional organizations;
- build and implement communication campaigns and mobilization activities to reduce lead and mercury exposure in close collaboration with the various partners; and
- discuss, interpret and communicate the Qanuilirpitaa? results on nutrition, contaminants, and health with regional partners.

Introduction

In Nunavik, a group of representatives from different regional organizations concerned with health, the environment and nutrition issues has formed to address these matters. The group communicates with and educates the public so that it can make more informed decisions on these issues. The group, the Nunavik Nutrition and Health Committee (NNHC), 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 with an increased focus on benefits. Its mandate addresses the full range of nutritional issues that affects the health of *Nunavimmiut* in the region.

The committee, through its long-term existence as well as the complementary expertise and background of its members, plays an important role in the region in addressing the complex topics of contaminants, nutrition, and health on an ongoing basis. The NNHC is the recognized and authorized body for the region on contaminants, nutrition, and health issues. 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. The committee ensures that research conducted in Nunavik is relevant to population needs and concerns, with the health and well-being of *Nunavimmiut* as a central goal.

An important volume of new information is continually generated by research on contaminants, nutrition and environmental health. Foods from the land, which contain differing amounts of contaminants, are central to *Nunavimmiut* health, way of life, identity, and food security. The NNHC aims to address this issue and ensure that *Nunavimmiut* concretely benefit from knowledge produced by northern research. The work realized directly responds to NCP Blueprint priorities under the Communications, Capacity and Outreach subprogram.

Activities in 2018-2019

The NNHC continued to review, guide, coordinate and promote research, interventions and communication activities in Nunavik related to contaminants, nutrition and health. In order to properly fulfill its mandate, the NNHC met three times in person in 2018-2019 and corresponded with researchers on different occasions. The committee and the Department of Public Health produced and disseminated communication material as part of the regional efforts to mitigate *Nunavimmiut* exposure to contaminants.

NNHC May 2018 meeting in Kuujjuaq

The first meeting was in Kuujjuaq on May 15-16 allowed for discussion and information sharing on several topics related to contaminants, nutrition, and health. At this meeting, the NCP management-committee (NCPMC) members gave an update regarding the April 2019 NCPMC meeting and summarized the funding decisions for the 2018-2019 projects for NNHC members. Presentations and discussions on the following were also held:

- preliminary Qanuilirpitaa contaminants results available to date (HH-02 - Exposure to food chain contaminants in Nunavik: biomonitoring in adult and youth cohorts of the Qanuilirpitaa survey) (Pierre Ayotte, in person);
- follow-up to the Chemical-MADO (maladies à déclaration obligatoire - reportable diseases of chemical origin) concerning lead, mercury, and cadmium generated by Qanuilirpitaa? and consultation on the content and format of the tools developed;
- NQN-Pregnancy Wellness with Country Foods project (HH-03 - Exposure to food chain contaminants in Nunavik: evaluating spatial and time trends among pregnant women & implementing effective health communication for healthy pregnancies and children), more specifically, the analysis entitled "Exposure to mercury and consumption of country foods in Nunavik: Geographical and temporal trends among pregnant women" (Mariana Pontual, in person, Mélanie Lemire by telephone);
- lead-reduction efforts (i.e., spring 2018 communication campaign and letter to the Environment Minister) (Nunavik Hunting, Fishing and Trapping Association (NHFTA) board member took part in this discussion);
- housing, health & well-being project (Mylène Riva in person); and
- Qanuilirpitaa? community component (Mylène Riva in person).

NNHC October 2018 meeting in Kuujjuaq

The second meeting of 2018-2019 was held on October 10 in Kuujjuaq. At this meeting, the committee undertook the review of the mid-year reports for 2018-2019 NCP projects and addressed the following topics:

- Qanuilirpitaa? contaminants results (HH-02) (Mélanie Lemire, by telephone);
- update on the NQN-Pregnancy Wellness with Country Food project (HH-03) (Mélanie Lemire and Chris Furgal, by telephone);
- lead-reduction efforts (i.e., presentation for consultation purposes of the real-footage video produced; the regional Hunter Support Program (KRG) coordinator joined for this topic);
- risk-communication articles for consultation (Chris Furgal, by telephone);
- selenoneine, beluga sampling and food preferences/cultural practices interviews in collaboration with NHFTA & Nunavik

Marine Regional Wildlife Board (NMRWB) (Matthew Little, by telephone); and

- NNHC work plan for the coming year.

NNHC February 2019 meeting

The last meeting of the year took place in February 2019 and focussed mainly on the socio-cultural review of the 2019-2020 NCP proposals for the region. The committee invited the researchers who submitted proposals to the NCP to make themselves available for committee questions. Committee members first reviewed each proposal among themselves, determined a provisional rating and identified questions for the project leaders. Then the committee met with the project leaders (by telephone). They were invited to summarize their proposal and, when needed, to answer previously raised questions. The last step was to go over all proposals to provide a final socio-cultural rating and evaluate whether the committee wanted to modify the provisional rating based on the clarification provided. The committee finds that this way of functioning results in a more extensive comprehension of the work proposed and gives the committee a better sense of the researchers' engagement and approach. The committee reviewed ten proposals this year.

Other topics were also covered at that meeting. Matthew Little presented an update of his work on the Selenoneine-beluga project, including preliminary results for the fieldwork done in Quaqtaq, in the fall of 2018. Mélanie Lemire updated the committee on the BriGHT (Bridging Global Change, Inuit Health and the Transforming Arctic Ocean) project as well as the 'Must-read papers' project. Accompanied by Jean-Sébastien Moore, she also presented a new research project on Arctic char for which a proposal was submitted to Genome Canada (FISHES: Fostering Indigenous Small-scale fisheries for Health, Economy, and food Security). Finally, the NNHC was consulted regarding the Nunavik priorities for the National Inuit Health Survey, as part of the region consultation process.

Qanuilirpitaa? 2017 Health Survey

The Qanuilirpitaa? health survey generates a quantity of new, updated and valuable information on aspects such as contaminants exposure, nutrition status, country-food and store-bought-food consumption, food security, socio-demographic status, lifestyle, ammunition use, etc. The data collected from the survey now has to be carefully analyzed and interpreted to make this information as valuable and meaningful as possible for *Nunavimmiut*. The expertise of the NNHC is key in the interpretation of survey analyses related to contaminants, nutrition and environmental health as well as in relevant communication of these results and their significance in terms of public health. Throughout the execution of this work, the NNHC collaborates with the Qanuilirpitaa? Data Management Committee (DMC). The Qanuilirpitaa? DMC oversees the management of all Qanuilirpitaa? data to ensure that the access to, and use of, the data respect the OCAP® principles and the policy on the management of databases and biological samples.

In 2018-2019, the NNHC reviewed and commented on the analyses plans for the contaminants and zoonosis Qanuilirpitaa? thematic reports to be published in the 2019-2020. Preliminary results on contaminants exposure were also presented and discussed with the NNHC during this year's meetings. The committee will continue to work closely with the researchers to adequately interpret and communicate to the population the results and their public-health implications. To contribute to the achievement of these goals, sub-regional workshops will be held. It was not possible to hold the first workshop in 2018-2019 as initially planned, but the sub-regional workshops are in the work plan for 2019-2020 and 2020-2021. These workshops are a shared project between the research team, the Nunavik Department of Public Health, the NNHC and the Nunavik Regional Working Group on Food Security (NRWGFS). They will be an occasion to:

- present and discuss Qanuilirpitaa? findings and other NCP projects results;

- allow co-learning and knowledge exchange;
- fuel and support the current efforts to mitigate contaminants exposure; and
- assess research and information needs as well as identify relevant actions and initiatives on the topic of contaminants, nutrition and food security.

Lead exposure-reduction efforts

Lead is an important public-health issue in the region and a global approach is needed to tackle this issue. The prevalence of lead blood levels of concern remains significant in Nunavik. Lead ammunition, which has been identified as the main source of lead, is currently used on a regular basis. The regional interest and mobilization on lead exposure have recently been revitalized and there is a need to pursue and reinforce efforts while there is regional momentum. The NNHC and the Department of Public Health has continued to work with relevant partners to convey communication activities and support mobilization to identify, implement and/or advocate for measures and incentives to make lead-free ammunition more available and affordable.

A real-footage video was developed this year. It featured a well-respected hunter, who is member of the NHFTA board of directors, a ballistics expert and a knowledgeable physician. The latest has spent much time in Nunavik and was involved in the voluntary lead ammunition ban in 1999. The goal of this documentary-type video (of approximately 10 minutes) is to raise awareness, generate discussion and support mobilization against the use of lead ammunitions. A preliminary version of the video was presented for consultation to the NNHC (at the October 2018 NNHC meeting), the NHFTA (at the November 2018 Annual General Meeting (AGM)) and the Hunter Support Program (at the December 2018 AGM). Following that step a final version has be produced.

In addition to the broadcast of the video, Public Health representatives made presentations on the lead issue at the NHFTA AGM and at the Hunter Support Program local coordinators' AGM. These presentations aimed to present the issue of lead (including health impacts, sources of exposure, and latest data on *Nunavimmiut* blood lead levels) with emphasis on potential actions to be undertaken to address the issue. The responses from both groups were very positive, and tangible actions on ammunition availability, access to funding and training needs, as well as political actions, were identified by the groups and will be worked on in the coming years.

In the spring of 2018, Environment and Climate Change Canada (ECCC) released two studies on lead for public consultation, one on lead ammunition and non-lead alternatives and one on lead in fishing sinkers and jigs and non-lead alternatives. In April 2018, an open letter was sent to Environment Minister Catherine McKenna calling for the elimination of the use of lead in ammunition and fishing tackle. This letter was co-signed by the NHFTA, the NRBHSS, the Cree Board of Health and Social Services of James Bay, the Cree Trappers Association of James Bay, the RightOnCanada advocacy group, and the Canadian Environmental Law Association on behalf of numerous groups including the NNHC. The letter was also supported by a number of scientists, health professionals, and environmentalists. The group is asking for governmental action, based on compelling scientific evidence, as voluntary approaches have proven ineffective; the lead making it into the environment and food from these sources is causing serious harm in hunting and fishing communities that rely on subsistence hunting, especially among infants and children.

Mercury exposure-reduction efforts

Mercury exposure is a major issue in Nunavik and in the North, especially prenatal exposure as harmful effects of mercury on brain development are well documented. Mercury represents a more complex challenge compared to lead, as the mercury that influence blood levels is not introduce in the food at the time of hunting or fishing; rather, mercury is present in some country foods through transfer from the environment and the food chain. These same country foods, that have significant health benefits, are exceptionally nutritious, wholly unprocessed and very much central to Inuit cultural identity and community well-being.

In the context of the Qanuilirpitaa? health survey, many people were diagnosed with high blood mercury levels, which translated into an increased workload for the Department of Public Health. With the guidance of the NNHC, the Department of Public Health produced tools to support the clinical interventions among persons with high blood mercury levels. Sylvie Ricard, a Public Health Officer, presented these tools and their development process in detail at the NCP Beluga Working Group meeting in Ottawa on March 18, 2019. The current public-health recommendation released in 2011 concerning mercury was also presented at that meeting.

Throughout the year, additional information needed to revise the current Public Health recommendation was documented, including the work done by Mariana Pontual and Mélanie Lemire: identification of the main source of mercury found in the diet, based on more recent data and the up-to-date and detailed profile of *Nunavimmiut* exposure to mercury generated by the Qanuilirpitaa? health survey.

For 2019-2020, the inclusion of activities related to clinical contaminants as part of pregnancy follow-up was identified as a promising approach and consultation activities are currently being conducted in the region (under the NCP HH-03 project led by Mélanie Lemire).

Review of research products before publication or dissemination

As part of its role in guiding and ensuring that research outcomes properly reflect the *Nunavimmiut* perspective, the committee asks researchers to submit all research products that fall under the NNHC's expertise to the committee prior to submission for publication. Consequently, in 2018-2019, the NNHC reviewed and commented on a number of research products. Draft scientific manuscripts revised in 2018-2019 included:

- "Determinants of selenoneine concentration in red blood cells of Inuit from Nunavik" (Little Matthew, Université Laval);
- "Selenoneine is a major selenium species in beluga skin and red blood cells of Inuit from Nunavik" (Achouba Adel, Université Laval);
- "Social housing construction in the Canadian Arctic: Improvements in housing outcomes in Nunavik and Nunavut" (Riva Mylène, McGill University);
- "Moving to a new house in the Arctic: Significant improvements in psychosocial health for Inuit adults" (Riva Mylène, McGill University);
- "Assessment of naturally acquired neutralizing antibodies against rabies Lyssavirus in a subset of Nunavik's Inuit population considered most at risk of being exposed to rabid animals" (Ducrocq Julie, Université Laval);
- "Twenty 'must-read' research article for primary care providers in Nunavik: selective literature review and development of an information tool" (Paquin Vincent, Université Laval);
- "The unique contribution of a local intervention group in the field investigation and management of a trichinellosis outbreak in Nunavik" (Ducrocq Julie, Université Laval);
- "Toward a better understanding of the benefits and risk of country food consumption using the case of walrus in Nunavik" (Martinez-Levasseur Laura M., Trent University);
- "Assessing a Participatory Approach to Risk Communication: The Case of Contaminants and Inuit Health" (Furgal Chris/Boyd Amanda, Trent University);
- "Exploring the Role of Trust in Health Risk Communication in Nunavik" (Furgal Chris/ Boyd Amanda, Trent University); and

- "Exposure to POP and mercury, and glucose metabolism in two Canadian indigenous populations" (Corder S., Université Laval and Univ. Rennes).

In addition to scientific articles, the NNHC also reviewed fact sheets and public communication materials generated by research projects. This material included:

- the draft versions of the newsletters related to the "must-read papers" project (http://en.nasivvik.chaire.ulaval.ca/must-read-papers-on-inuit-health.html) of the Nasivvik Research Chair;
- a fact sheet on the selenoneine work for Makivik magazine; and
- a fact sheet from the passive air sampler monitoring project titled Passive Air Sampling Network for Organic Pollutants and Mercury - NCP.

Community engagement

Through the nature of its work, the committee ensures the region's meaningful engagement in the NCP's research activities. Details included above in the subsections of the Activities in 2018-2019 section.

Capacity building and training

The interactions of researchers, public-health officials, wildlife and environment representatives, and Inuit community representatives are viewed as a process in capacity building for all involved. The exchange of ideas and views and the application of various types of expertise to the issues being faced by the committee are processes of mutual learning and capacity development among all members.

Communications and outreach

A number of communication activities on the topics of contaminants, nutrition and environmental health are necessary again in 2019-2020. The communication activities are described in further detail throughout the present report, as one of the main objectives in the current project on the Communications, Capacity and Outreach subprogram is to address regional coordination and communication needs related to research and interventions on contaminants, nutrition and environmental health.

Indigenous Knowledge

Inuit knowledge is central to all activities and decisions related to country food, nutrition and health. Inuit committee members contribute their Inuit perspective and knowledge constantly.

Discussion and conclusions

There is a great need to pursue the inter-organizational collaboration and communication through the NNHC's work on the important issues of food, contaminants, nutrition, and health. The committee will maintain 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, and the contaminants and nutrition component of the Qanuilirpitaa? 2017 Health Survey. The NNHC's main priorities will be to use and communicate the Qanuilirpitaa? 2017 Health Survey results as well as to pursue the development and implementation of strategies to reduce contaminants exposure, specifically to lead and mercury, while promoting and preserving the consumption of country food.

Expected project completion date

Not applicable

Project website

https://nrbhss.ca/en/departments/public-health

https://nrbhss.ca/en/lead-ammunition

Acknowledgments

The committee would like to thank all *Nunavimmiut* for their ongoing participation and support in contaminants, health, and environment research. Furthermore, the NNHC is grateful to the Northern Contaminants Program (NCP) for its essential support and to the researchers for their important work. The NNHC also acknowledges the contribution of the regional organizations in terms of ongoing support and funding of its activities related to health, contaminants and nutrition in the region.

Chercheur spécialiste des contaminants dans le Nord, Nunatsiavut

Project leader/Chef de projet

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Project location/Emplacement du projet

Nain, NL

Abstract

The Northern Contaminants Researcher (NCR) is a core component of the Nunatsiavut Government. Based at the newly renamed Nunatsiavut 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 proposal is a

Résumé

Le chercheur spécialiste des contaminants dans le Nord est une composante fondamentale du gouvernement du Nunatsiavut. Affecté au Centre de recherche du Nunatsiavut, nouvellement renommé et qui relève de 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), afin d'aider les Inuits du Nunatsiavut à mieux comprendre les enjeux liés aux 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 Nunatsiavut, le

prescribed priority activity within the NCP and builds on the capacity that has been developed in the region to facilitate an even greater level of management and ownership of research in Nunatsiavut. This funding ensures the continuation of both the NCR position as well as the NGRAC and complements other NCP research programs ongoing or previously implemented in the region, including water, air, ringed seal, Arctic char, and Micro/Marine Plastics monitoring. All of our monitoring programs include a Traditional 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 of our NCP research programs and meetings are coordinated through the NCR at the Nunatsiavut Research Centre on an annual basis. Most importantly, this position 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.

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 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. Le financement assure le maintien du poste de chercheur spécialiste des contaminants dans le Nord et du CCRN, en plus de compléter d'autres programmes de recherche du PLCN antérieurs ou en cours dans la région, dont des projets de surveillance de l'eau, de l'air, du phoque annelé, de l'omble chevalier et des microplastiques et des plastiques marins. Tous nos programmes de surveillance comprennent une composante relative au savoir traditionnel, car celles-ci sont essentielles pour bien comprendre les tendances et les enjeux et constituent le meilleur véhicule pour consigner l'information historique de toute notre région.

Tous les programmes de recherche et les réunions du PLCN sont coordonnés chaque année par l'intermédiaire du chercheur spécialiste des contaminants dans le Nord au Centre de recherche du Nunatsiavut. Surtout, ce poste permet de s'assurer qu'il existe une personne-ressource fiable 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

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 manifeste un intérêt pour la question des 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.

Sangilivalliannatuk), traditional hunting, and through collaboration with educators in the communities.

- 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 continue de renforcer les capacités grâce au congélateur communautaire et au Programme de jeunesse Aullak sangilivallianginnatuk (Partir pour grandir), à la chasse traditionnelle et à la collaboration avec des éducateurs de la collectivité.
- 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 from caribou to other country foods;
- continue to foster a relationship built on trust with Inuit in Nunatsiavut with regards to sharing information on contaminants;
- continue to increase ownership of contaminant-related research by collaborating with partners that support capacity building in Nunatsiavut;
- work with schools and educators to engage youth in contaminant-related research;
- manage the contaminants section of our Nunatsiavut 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 these results 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 traditional 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 Climate Change Liaison 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 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 continuing to be generally below guideline levels of concern; and
- 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 outcomes 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 2018-2019

Community engagement

In collaboration with the Inuit Research Advisor and the Community Climate Change Liaison and several volunteers, we have held a couple of 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 working together, building capacity, providing training and job opportunities, and thus, enhancing research in Nunatsiavut. The NCR continues to build connections by 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 how to hunt for Inuit traditional food, they 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 safely survive off the land. With these skills, they will be able to provide for their families and teach future generations.

Communications and outreach

A research tour was held in four communities on the coast of Nunatsiavut. From March 11-15, 2019 , five members of NGRAC traveled to Rigolet, Makkovik, Postville and Hopedale to do presentations on research that will and has happened in Nunatsiavut and to hear any concerns or to hear what kind of research each community would like to see happened in their towns. NGRAC had a lot of positive feedback about research that happens in Nunatsiavut.

Indigenous Knowledge

All research projects and Nunatsiavut Government associated programs are designed and based on Traditional 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 traditional knowledge (TK), including verification, 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.

Discussion

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.

The NCR traveled to communities to discuss ongoing projects. The NCR also hosted 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

www.nainresearchcentre.com

www.facebook.com/nainresearchcentre/?ref=aymt_homepage_panel

Acknowledgments

The Northern Contaminants Researcher acknowledges the NCP for their funding support in 2018-2019.

Coordination, participation and communication: evolving Inuit Research Advisor responsibilities in Nunatsiavut for the benefit of Inuit and their communities

Coordination, participation et communication : évolution des responsabilités du conseiller en recherche inuite du Nunatsiavut, au bénéfice des Inuits et de leurs collectivités

Project leader/Chef de projet

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Project location/Emplacement du projet

Nunatsiavut, NL

Abstract

The Inuit Research Advisor for Nunatsiavut continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science and represents a new way of knowledge sharing and engagement of Inuit in Arctic science. The Nunatsiavut Government (NG) encourages researchers to consult with Inuit Community Governments in the five Nunatsiavut communities, Rigolet, Makkovik, Postville, Hopedale, and Nain, as well as NG departments in developing more community-based research proposals. Comprehensive reviews of proposals involve NG departments and Inuit Community Government(s)/Corporation(s).

Together with IRAs in the other Inuit regions of Canada, the Nunatsiavut IRA works towards achieving a new way of knowledge sharing

Résumé

Le conseiller en recherche inuite du Nunatsiavut poursuit son mandat, constituant la première étape d'une approche coordonnée en matière de participation et de coordination communautaires dans le domaine des sciences de l'Arctique. Il propose un nouveau moyen de diffuser les connaissances et de mobiliser les Inuits en ce qui concerne les sciences de l'Arctique. Le gouvernement du Nunatsiavut incite les chercheurs à consulter les gouvernements des cinq collectivités inuites du Nunatsiavut (Rigolet, Makkovik, Postville, Hopedale et Nain) ainsi que ses ministères en vue d'élaborer de nouvelles propositions de recherche basées sur la collectivité. Les ministères du gouvernement du Nunatsiavut et les gouvernements et entreprises des collectivités inuites prennent part à l'examen complet des propositions.

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.

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.

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 71 researchers from 1st April 2018 to 31st March 2019. This year the IRA has chaired 12 NGRAC meetings, one of which was a face to face meeting in Nain.
- The IRA served as liaison, contact, and assistant to research projects taking place in Nunatsiavut. This assistance ranged from linking the researchers with appropriate individuals and/or organizations such as NG departments and Inuit Community Governments in Nunatsiavut, 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.

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 71 chercheurs du 1er avril 2018 au 31 mars 2019. 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 aussi joué le rôle d'agent de liaison, de contact et d'assistant pour ce qui est des projets de recherche menés au Nunatsiavut. Entre autres, il a mis les chercheurs en contact avec les personnes ou organisations pertinentes, p. ex., les ministères du GN et l'administration 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), l'administration des collectivités inuites et les sociétés communautaires inuites du Nunatsiavut, des chercheurs, des étudiants et divers organismes.

Objectives

The aim of the IRA is to:

- improve the coordination and operation of the Nunatsiavut Research Center;
- continue developing and managing 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 other funders 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. The Nunatsiavut Research Centre is a hub for community and regionally owned research in Nunatsiavut, including contaminants related research, and requires operational coordination. Efficient coordination will result in enhanced benefits for community members with respect to research. The Inuit Research Advisor will also focus on internal capacity building by participating more directly and actively in regionally led research initiatives. Finally, as research in the region increases, including research related to contaminants, publication of the annual 'Nunatsiavut research compendium' will result in greater awareness of research, a better understanding of research results generally, and of contaminants related issues specifically.

Activities in 2018-2019

In 2018-2019 the IRA:

- managed the Nunatsiavut Research Centre 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 IRAs in the other regions, 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 two face-to-face meeting in Ottawa;
- reviewed NCP proposals along with members of NGRAC for Nunatsiavut;
- attended ArcticNet's, annual scientific meeting in Ottawa; and
- participated as a member of the Nuantsiavut Climate Change committee.

Community engagement

The IRA gave numerous local presentations to a variety of audiences including community public meetings, meetings with organizations such as Inuit Community Governments, and with Food Security Network NL.

Capacity building

The IRA 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. The IRA also assisted researchers with hiring of local research assistants, school visits, and holding open houses.

Communications and outreach

The IRA visited the five Inuit communities in Nunatsiavut during the Research Tour in March 2019 and met with local Inuit Community Governments, individuals, and schools.

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 traditional knowledge holders, and to integrate traditional 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 will focus on Inuit Knowledge and Inuit relationships, and values associated with the environment. The Inuit Research Advisor will be heavily involved in the on-the-ground implementation of these new research initiatives This involves gathering Inuit Knowledge and values as well as focusing on ways in which the Knowledge and values can be 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.

Acknowledgments

The IRA would like to acknowledge the continued support of the NCP.

Inuit Research Advisor for the Inuvialuit Settlement Region

Conseiller en recherche inuite pour la région désignée des Inuvialuits

Project leader/Chef de projet

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Project team/Équipe de projet

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Project location/Emplacement du projet

Inuvik, NT

Abstract

By virtue of grant funding from ArcticNet and a tri-party funding contribution agreement between the Northern Contaminants Program (NCP), the Indigenous Community Based Climate Monitoring Program (ICBCMP), and Environment and Climate Change Canada (ECCC), the proposed regional and national activities for the Inuit Research Advisor (IRA) were completed as planned in 2018-2019. These activities included completing annual IRA duties specified by the NCP and ArcticNet. The IRA also undertook membership duties on various Inuit/Indigenous Committee's, including the IRC Research Committee (IRC RC), NWT Regional Contaminants Committee (NWT RCC), Inuit Tapiriit Kanatami's (ITK) Inuit Qaujisarvingat National Committee (IQNC), and ArcticNet's Inuit Advisory Committee (AN IAC). New Committee memberships/participations in 2018-2019 include the IRA being recently appointed to

Résumé

Grâce à une subvention d'ArcticNet et à un accord de contribution tripartite de financement entre le Programme de lutte contre les contaminants dans le Nord (PLCN), le Programme de surveillance du climat dans les collectivités autochtones (PSCCA) et Environnement et changement climatique Canada (ECCC), les activités régionales et nationales proposées pour le conseiller régional en recherche inuite (CRI) ont été menées à bien comme prévu en 2018-2019. Ces activités comprenaient l'accomplissement des tâches annuelles du CRI spécifiées par le PLCN et ArcticNet. Le CRI a également assumé diverses fonctions dans divers comités inuits et autochtones, notamment le comité de recherche des CRI (CR de la Société régionale inuvialuite), le Comité régional des contaminants des T.N.-O. (CRCTNO), le comité national de l'Inuit Qaujisarvingat (IQNC) de l'Inuit Tapiriit Kanatami (ITK) et le comité

ArcticNet's Research Management Committee (AN RMC) in April 2018, the NWT Climate Change Committee (NWT CCC) in June 2018, and the NCP Management Committee (NCP MC) in March 2019, by the Chair and CEO of IRC. Most recently, the IRA joined the new NCP Beluga Sub-Committee in December 2018. In addition to IRA and Committee work, the IRA led internal IRC regional research initiatives, including coordinating the Research Committee, and working to resolve governance issues within the NCP and ArcticNet. The resolution of these governance issues has resulted in more equitable committee representation for Inuvialuit in both programs, a new regional review processes under development for both programs, as well as national level coordination between ITK and Inuit Nunangat in the coming fiscal year.

consultatif inuit d'ArcticNet (CCI AN). Les nouveaux membres/participants aux comités en 2018-2019 comprennent le CRI récemment nommé au Comité de gestion de la recherche d'ArcticNet (CGR AN) en avril 2018, au Comité sur le changement climatique des T.N.-O. en juin 2018, et au Comité de gestion du PLCN (CG PLCN) en mars 2019, par le président et le directeur général de la Société régionale inuvialuite. Plus récemment, le CRI a rejoint le nouveau sous-comité du PLCN sur les bélugas en décembre 2018. En plus de son travail de CRI et dans les comités, le CRI a mené des initiatives de recherche régionales internes à la Société régionale inuvialuite, notamment en coordonnant le comité de recherche et en travaillant à la résolution des problèmes de gouvernance au sein du PLCN et d'ArcticNet. La résolution de ces questions de gouvernance a permis une représentation plus équitable des Inuvialuit au sein des comités dans les deux programmes, un nouveau processus d'examen régional en cours d'élaboration pour les deux programmes, ainsi qu'une coordination au niveau national entre ITK et l'Inuit Nunangat au cours du prochain exercice financier.

Key messages

- The IRA continues to participate and serve as a representative of the IRC in key NCP activities. (i.e. NWT Regional Contaminants Committee teleconferences and in person meetings, mid-year reviews, and other events such as this year's risk management workshop.
- The IRA served as liaison, contact, and assistant to research projects taking place in Inuvialuit Settlement Region.
- The NWT RCC has changed the Committee's Terms of Reference to remove the election and appointment process for the Chair and Vice-Chair. This process only allowed two Indigenous members to represent all Indigenous members of the Committee, including Dene Nation, who has a seat on the Committee. The new governance structure includes the Dene Nation, Metis Nation, and the Inuvialuit

Messages clés

- Le CRI continue de participer et de représenter la Société régionale inuvialuite dans les principales activités du PLCN. 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.
- Le CRCTNO a modifié le mandat du comité afin de supprimer le processus d'élection et de nomination du président et du vice-président. Ce processus ne permettait qu'à deux membres autochtones de représenter tous les membres autochtones du Comité,

regions Co-chairing and equally representing their regions on the NWT RCC and the NCP Management Committee.

- The IRC will hold a regional Inuit NCP workshop, as well as develop a regional review process for proposals received by the IRC Research Committee

y compris la Nation dénée, qui dispose d'un siège au sein du Comité. La nouvelle structure de gouvernance comprend la nation dénée, la nation métisse et les régions inuvialuites qui coprésident et représentent à parts égales leurs régions au sein du CRCTNO et du comité de gestion du PLCN.

- La Société régionale inuvialuite organisera un atelier régional du PLCN pour les Inuits, et mettra en place un processus d'examen régional des propositions reçues par le comité de recherche de la Société régionale inuvialuite.

Objectives

Northern Contaminants Program/ArcticNet

The IRA aims to:

- complete the review of the 2017-2018 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; and
- advise NCP and ArcticNet researchers in establishing appropriate community connections and potential partners in ISR.

Inuvialuit Regional Corporation

The IRA aims to:

- identify Inuvialuit research priorities and share those with research programs;
- coordinate and integrate research activities with researchers and Inuvialuit institutions through coordination of the IRC Research Committee;
- consult and communicate with community members and leadership on research activities; and
- undertake regionally appointed Committee membership duties on IQNC, NWT CCC etc. on behalf of IRC.

Indigenous Community Based Climate Monitoring Program /Environment and Climate Change Canada

The IRA aims to:

- support Inuvialuit communities who want to monitor the effects of climate change in their communities by promoting climate change programs and assisting regional communities to access them through the call for proposal process; and
- undertake membership duties as a Inuvialuit member of the Northwest Territories Climate Change Committee.

Activities in 2018-2019

The following activities were completed as part of the IRA's duties to the NCP program:

- attended monthly or bimonthly NWT RCC teleconferences to review proposals, review public health advisories or to deal with an issue specific to the Committee;
- maintained regular correspondence and communication with NCP researchers with work based in the ISR during peak reporting times (September, March, April, and July);
- submitted midyear report and communicate with researchers and NWT RCC (September 2018). Participated in the NCP Beluga Sub Committee to create guidelines for health messages and advisories (December 2018). The Sub-Committee is Chaired by Jason Stow of Fisheries and Oceans Canada and made up of Indigenous organizations, researchers, and territorial, provincial and federal health authorities;
- attended NWT RCC mid-year review (fall 2018);
- attended NWT RCC social and cultural review meeting (February 2019);
- attended NCP Management Committee meeting (March 2019); and
- submitted end of year Synopsis report (April 2019).

Results and outputs/deliverables:

- Submitted mid-year report (September 18, 2018)
- Submitted 2019-2020 proposal (December 18, 2019
- Submitted end of year Synopsis report (May 4, 2019)
- Submitted final financial report (May 4, 2019)
- Will submit final financial statement (July 29, 2019)

Discussion and conclusions

At the regional level, the IRA led a few IRC research initiatives, including coordinating the IRC RC, the submission of a successful SSHRC Grant for an Inuvialuit Research Self-Determination workshop in 2019.
As a long-standing regional member and contributor to the Inuit Qaujisarvingat National Committee (IQNC), the IRA was also pleased when ITK released the National Inuit Strategy on Research (NISR) in March 2018, and the accompanying Implementation Plan in October 2018, which the four region Committee co-developed. At the NWT RCC, the Committee resolved to change their Terms of Reference and is now operating under a 3-co-chair governance model in the NWT, with the Dene, Metis Nation, and Inuvialuit having equal representation at regional and national NCP meetings. The regions not represented by the Inuvialuit and Metis Nation fall under or support the Dene Nation representing them as a National Dene organization. These changes were a result of a Committee resolution at a Committee meeting in February 2019.
This ensures improved self-determination of research for all NWT Indigenous regions participating in the Program.

At the national level, additional funding allows for the IRA to host a workshop to identify Inuit regional and national Inuit priorities within the NCP, as well as to provide the IRC with funding to support regional research capacity building initiatives. These capacity building initiatives are currently under development with the IRC Research Committee. These two initiatives will contribute profoundly towards better regional decision making in the Inuvialuit Settlement region and for Inuit Nunangat as a whole.

Expected project completion date

March 31, 2019

Acknowledgments

Inuit Research Advisor for the Inuvialuit Settlement Region would like to acknowledge the continued funding and support by the Northern Contaminants Program.

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 leaders/Chefs de projet

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Project team/Équipe de projet

Nunavik Nutrition and Health Committee (NNHC); Makivik Corporation; Inuit Tapiriit Kanatami (ITK); ArcticNet

Project location/Emplacement du projet

Nunavik, QC

Abstract

The Nunavik Inuit Research Advisor (IRA) is essential in continuing to coordinate and enhance community involvement with Arctic science in Nunavik. The Renewable Resources, Environment, Lands and Parks Department of the Kativik Regional Government (KRG) houses the IRA position. The IRA works in close collaboration 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. Facilitating research, at the project level, by assisting researchers from the Northern Contaminants Program (NCP) and

Résumé

Le conseiller en recherche inuite (CRI) au Nunavik est essentiel pour continuer à coordonner et à renforcer la participation de la collectivité aux sciences de l’Arctique au Nunavik. Le Service des ressources renouvelables, de l’environnement, du territoire et des parcs, Administration régionale Kativik (ARK) héberge le poste du CRI. Le CRI travaille en étroite collaboration avec le Comité de nutrition et de santé du Nunavik (CNSN), la Régie de la santé et des services sociaux du Nunavik (RSSSSN), la Commission scolaire Kativik (CSK) et le Centre de recherche Makivik. Le CRI facilite la recherche au niveau des

ArcticNet, and by updating communities in advance of upcoming research. The Nunavik IRA, like the other IRAs in Inuit regions of Canada, strive to share knowledge and engage Inuit in Arctic science and research. NCP and ArcticNet co-funds the Nunavik IRA position.

projets en aidant les chercheurs du PLCN et d'ArcticNet, et en informant les collectivités au sujet des recherches à venir. Comme les autres CRI des régions inuites du Canada, le CRI du Nunavik s'efforce de partager les connaissances et de mobiliser les Inuits dans la science et la recherche arctiques. Le PLCN et ArcticNet cofinancent le poste du CRI au Nunavik.

Key messages

The Nunavik Inuit Research Advisor (IRA) is essential in linking the Nunavik residents and the Arctic Nunavik scientific research members. Enhancing and benefiting both parties through this coordinated approach ensuring the perspectives and needs of Nunavummiut are prioritized and respected.

Messages clés

Le conseiller en recherche inuite (CRI) au Nunavik est essentiel pour établir un lien entre les habitants du Nunavik et les membres de la recherche scientifique du Nunavik arctique. Cette approche coordonnée, avantageuse pour les deux parties, garantit que les perspectives et les besoins des Nunavummiut sont prioritaires et respectés.

Objectives

The Nunavik IRA aims to:

- make research more specific to Nunavummiut needs and interests;
- offer input and direction, from a Nunavummiut perspective, on proposals and research to the NCP;
- coordinate, share information and assist researchers and Nunavik communities;
- ensure the IRA and the NNHC (Nunavik Nutrition and Health Committee) are the first points of contact for NCP researchers working in Nunavik;
- represent the Nunavik voice during the NCP proposal process and communication of NCP information to members the Nunavik Nutrition and Health Committee and Nunavik communities; and
- advise community governments and members as well as researchers to ensure research objectives needs are being met and Nunavummiut needs respected.

Introduction

The Nunavik Health and Nutrition Committee was formed when representatives from different regional organizations became concerned about contaminants. These regional organizations also understood that proper communication was needed to ensure Nunavummiut made informed decisions on their consumption of traditional and store-bought foods. This committee focused on health, the environment, education, and nutritional issues as well as on NCP research. Guidance and recommendations are given by the Inuit Research Advisor related to Inuit needs, priorities, policy development, and research to NNHC in which is then transmitted to the NCP, ArcticNet, Inuit Tapiriit Kanatami (ITK) and Inuit Circumpolar Conference (ICC).

Coordination, active engagement, and communication are key aspects to the responsibilities of the Inuit Research Advisor that are constantly evolving. The NNHC continues to be the focal point for researchers and community members with concerns related to contaminants research. Communicating with researchers and concerned community members requires operational coordination to ensure consistent and accurate messaging. Efficient coordination of the communication of research results provides enhanced benefits for community members with respect to research. The Inuit Research Advisor also plans to focus on internal capacity building by direct and active involvement in regionally-led research initiatives. This engagement with the NNHC and NCP on issues related to contaminants, food and health in the region makes the role of the IRA an important one.

Many researchers and research activities are funded by ArcticNet and the NCP annually and these programs inform researchers about the IRAs and encourage regular contact with them. It is beneficial for the funding programs to know which researchers has been in contact with the Nunavik IRA. A list will be received at the beginning of each fiscal year from the two funding programs outlining the research activities scheduled in Nunavik.

Activities for 2018-2019

The IRA is involved in many activities at KRG that include attending workshops and meetings to collaborate and network with researchers and community members.

For the period of April 2018 to February 2019, Monica Nashak, KRG Environmental Technician, was available to respond to the needs of researchers and communities. Other KRG employees in the Renewable Resources, Environment Lands and Parks Department made themselves available when needed. Lucy Grey was hired as the Nunavik Inuit Research Advisor in March 2019.

During the year, the Inuit Research Advisors and department staff participated regularly with the Nunavik Nutrition and Health Committee. Specifically, there was a two day meeting held in Kuujjuaq on May 14-15, 2018 which focused on the review of the 2018-2019 NCP proposals. Another meeting in June 2018 addressed the preliminary results *of the Qanuilirpitaa 2017 Health Survey*, lead found in ammunition, and the Nutaratsaliit Qanuingisiarningit Niqituinnanut (NQN) Pregnancy Wellness with Country Food project. Additionally, NCP research proposals were reviewed in February 2019.

Monica participated in the NCP Results Workshop held in Nain, Nunatsiavut on April 10-13, 2018. Other NCP activities included a NCP Management Committee meeting attended by both Monica and Lucy on March 19-21, 2019 in Ottawa.

ArcticNet activities throughout the year included a meeting with the Inuit Advisory Committee on June 11, 2018 in Ottawa and on the Research Management Committee reviewing research proposals on June 24-25, 2018. A regional review for funding proposals for ArcticNet Research also took place in March 2019.

Communications and outreach

Giving reports to KRG Regional Council meetings, participating in NNHC activities, and attending workshops and meetings continue to be important components when it comes to communications and outreach. Communicating and many other outreach engagements concerning Nunavik community needs remains essential for providing, assisting, coordinating or engaging with researchers and colleagues.

Capacity building and training

In collaboration with the NNHC, training and education is given to the researchers when commenting, reviewing and making recommendation on research programs with Nunavik Inuit realities and perspectives. However, it has been a challenge to arrange training opportunities for the IRAs throughout the Inuit Nunangat regions. Promoting

Northern capacity building is always a priority when reviewing research proposals. Improvements are always needed throughout the Arctic research field.

Indigenous Knowledge and consultation

Conveying information to the public and scientists as well as decision making based on the Nunavik Inuit perspective is central to the IRA position. Inuit knowledge is always at the forefront when any engagement is made. A workshop called Knowledge Sharing, organized by Institute Nordique in Ouje-Bougoumou, was planned for April 2019. The goal of the workshop was to bring the aboriginal groups in the Quebec Plan Nord region together to share the importance and relevance of Indigenous Knowledge in the context of scientific research. The workshop highlighted the need to fuse the two knowledges (Indigenous Knowledge and Scientific Knowledge) together for the benefit of both groups of knowledge holders. Similar workshops should be promoted and organized in the future.

Consultations and communications occurred when needed with the Kativik 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 and the residents of Nunavik.

Discussion and conclusions

The Nunavummiut perspective is emphasized throughout all undertakings with the Arctic scientific researchers when it comes to their health, the environment, education and nutritional issues. It is important to have this voice and point of view highlighted when giving guidance and recommendations to researchers and policy makers. More capacity building initiatives must also be carried out to enhance the work completed by residents of Nunavik and the scientific researchers conducting research in Nunavik.

Expected project completion date

This project is ongoing.

Acknowledgements

Acknowledgments to all Nunavik members, NNHC members, NRBHSS, Makivik Corporation, Nunavik Research Centre, ITK, ICC, KRG Council Members and especially to the KRG employees in the Renewable Resources, Environment Lands and Parks Department.

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

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Project location/Emplacement du projet

Iqaluit, NU

Abstract

We held the Wildlife Contaminants Workshop (WCW) for students of Nunavut Arctic College's Environmental Technology Program (ETP) in Iqaluit, Nunavut in the fall of 2018. 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

Résumé

L'atelier sur les contaminants de la faune a eu lieu à l'automne 2018 à Iqaluit, au Nunavut, à l'intention des étudiants du Programme des technologies environnementales (PTE) du Collège de l'Arctique du Nunavut. L'ACES est un modèle de formation fondée sur l'expérience qui mise sur une panoplie de méthodes interactives pratiques adaptées pour sensibiliser, favoriser le développement des connaissances, des compétences et des habiletés au sein de ce groupe fondamental

research, communication, and assessment within the broader context of ecosystem, public, and wildlife health, and in relation to Inuit knowledge, practices and values. In 2018, the WCW again combined lectures, interactive lab activities, and group discussions around wildlife contaminants monitoring, risk communication and human health. The main focus of the 2018 workshop was on one contaminant that has a long history of monitoring in Canada (mercury) and one emerging contaminant (plastic pollution). The long-term goal of the WCW is to build capacity among this group of Nunavut's future environmental managers and decision makers. The workshops enable attendees to effectively interpret and evaluate contaminants information and to convey that information to community members.

de spécialistes de l'environnement de première ligne. L'ACES enseigne les aspects fondamentaux de la recherche sur les contaminants environnementaux, de la communication et de l'évaluation dans le contexte plus général de l'écosystème, de la santé de la population et des espèces sauvages et en lien avec les connaissances, les pratiques et les valeurs des Inuits. En 2018, l'atelier a de nouveau offert ders conférences, des activités interactives en laboratoire et des discussions de groupe sur la surveillance des contaminants de la faune, la communication des risques et la santé humaine. L'atelier de 2018 a porté principalement sur un contaminant (le mercure) qui fait l'objet d'une surveillance de longue date au Canada, et un contaminant émergent (les matières plastiques polluantes). L'objectif à long terme de l'ACES est de renforcer les capacités de ce groupe de futurs gestionnaires et décideurs environnementaux du Nunavut. Les ateliers permettent aux participants d'interpréter et d'évaluer efficacement les données sur les contaminants et de transmettre ces informations aux membres de la collectivité.

Key messages

- The Wildlife Contaminants Workshop is a collaborative program that aims to teach future workers in Nunavut about environmental contaminants and develop skills to communicate those ideas.
- The foci of the 2018 workshop were on one contaminant that has a long history of monitoring in Canada (mercury) and one emerging contaminant (plastic pollution).

Messages clés

- L'Atelier sur les contaminants des espèces sauvages (ACES) est un programme collaboratif qui vise à faire connaître aux futurs travailleurs du Nunavut les contaminants environnementaux et à développer les compétences nécessaires pour communiquer ces idées.
- L'atelier de 2018 était axé sur un contaminant qui fait l'objet d'une surveillance de longue date au Canada (le mercure) et sur un contaminant émergent (les plastiques).

Objectives

The main objective of this project is to build capacity among students of the Environmental Technology Program (ETP) of Nunavut Arctic College (NAC) with regards to northern contaminants research. More specifically, a combination of lecture material and hands-on training provided NAC students with:

- background knowledge about contaminant research in the Arctic, resulting in an increased capacity to understand the Northern Contaminants Program (NCP) and contextualize information on contaminants and individual project results into the broader health and environment sphere;
- hands-on training with two applied science projects, demonstrating how research projects in the North are used to study wildlife health and the safety of country foods, allowing an increased capacity to engage with contaminants research in the future;
- the opportunity to interact and learn directly from NCP researchers working on projects in the region;
- the opportunity to interact and learn directly from community members and holders of local and traditional knowledge;
- support and facilitate the communication of NCP research activities and results in a forum where students are able to actively participate in contaminants research through skill-building dissections, shoreline monitoring, and discussions that will increase their participation in the research community; and
- provide an opportunity for NCP researchers to present their work in a Northern context.

Introduction

The NCP has identified the 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 allow 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 and communication with northern community members is most effective when presented within the context of other relevant information and concerns. With these goals in mind, the WCW delivers 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 Wildlife Contaminants Workshop (WCW) held each year at the NAC builds on the experiences from past workshops with the goal of further building contaminants communication skills for frontline workers through direct interactions with NCP researchers. In 2018-2019 the WCW focused on one legacy contaminant (mercury) and one emerging contaminant (plastic pollution). During the workshop students learn about mercury and microplastics and then are given the opportunity to apply this knowledge in a laboratory setting and while speaking with Elders.

Figure 1. Environmental Technology Program Students at the Nunavut Arctic College in Iqaluit work with Environment and Climate Change biologists to dissect seabirds collected in Qikiqtarjuaq, Nunavut and examine them for plastic pollution.

Figure 2. Environmental Technology Program Students at the Nunavut Arctic College in Iqaluit conduct a beach survey for plastic pollution.

Activities in 2018-2019

2018 workshop schedule

Monday – Monday morning started with some introductory material about contaminants and an overview of NCP which helped prepare the students for the analytical work they would be doing in the following days. We started off by discussing what contaminants are, where they come from and how they get to the Arctic and continued with an exploration of persistence and degradation of particular contaminants using DDT as a case study. In the afternoon we talked about the toxicity of particular contaminants using mercury as a case study and followed that up with an exercise considering contaminants in country food, nutrition and food safety and security, using an AMAP contaminant dataset.

Tuesday – The lectures on the second day focused on the two main themes for the workshop, mercury and plastic pollution. This included a series of activities and lectures delivered by Mary Gamberg, Chelsea Rochman, and Jennifer Provencher. Additionally, Jean Allen delivered a lecture about the Northern Contaminants Program, and how the Wildlife Contaminants Workshop fits into the larger program.

Wednesday and Thursday – On the Wednesday and Thursday the students participated in two different modules, the seabird dissection activity lead by Jennifer Provencher (Figure 1), and the plastic survey activity led by Chelsea Rochman (Figure 2). The classes were divided into two groups which alternated between the two themes on the two days. During the seabird dissection module the students learned about plastic pollution studies in Arctic seabirds. This session included learning skills related to the dissection of seabirds for plastic pollution studies, as well as other contaminants. In total 109 seabirds were dissected by the ETP students. These seabirds were all collected in Qikiqtarjuaq, Nunavut in August 2018 as part of a community-based project with Environment and Climate Change Canada examining a variety of contaminants in seabirds and the coastal environment. Students learned how to take blood, feather, muscle, liver, kidney and bone samples from the birds.

During the plastic pollution activities, the students learned about how plastic pollution is monitored around the globe and why. They also learned about some of the local work that has been conducted on microplastics in the Canadian Arctic. The students then conducted a shoreline survey for plastic pollution using the standardized framework from the Ocean Conservancy's International Shoreline Cleanup. The data collected by the students was graphed and compared to international data collected using the same protocols, and differences in local patterns were discussed. Finally, we discussed solutions at different scales and how some of those may be applied locally.

Friday – The last day of the workshop aims to synthesis many of the ideas that have been covered throughout the week and focus on allowing the students to practice and develop their own contaminant communication skills. In the morning Amy Caughey from the Government of Nunavut delivered a lecture and an activity about communicating contaminants in country foods in Nunavut. The current ringed seal advisory was discussed, as well as the Nunavut Food Guide and the information that can be found in these resources. In the afternoon on Friday the students examined the plastic pollution data that was collected by the students in Iqaluit, and compared this to internationally available data.

Community engagement

Partners at the Nunavut Research Institute, the Nunavut Arctic College and the Nunavut Environmental Contaminants Committee have been integral to the development of this program long term, and in deciding this year's focus. Chelsea Rochman delivered a public lecture at the Nunavut Research Centre on plastic pollution in the Arctic region.

Indigenous Knowledge

This project included Indigenous knowledge in several significant ways. The collection of the seabirds was carried out by Inuit hunters using Indigenous knowledge of the animals and their habitats. As we have done each year since 2014, we invited an Inuit wildlife expert, Joshua Kango, the president of the Amarok Hunters and Trappers Association to come and talk to the students about wildlife health and contaminants from an Inuit perspective. Joshua has participated in the workshop in 2014, 2015 and 2016 (he was unable to attend in 2017), and each year he shares his rich insights and perspectives, including methods Inuit traditionally use to assess animal health, and to determine whether the meat from harvested animals is fit for consumption. Unfortunately, a sudden medical emergency precluded Joshua from attending the workshop.

During the student design of the community based monitoring program for microplastics students were encouraged to incorporate the Indigenous knowledge shared with them by community Elders, and the design of the field work in Qikiqtarjuaq carried out in the summer of 2018 under the related project Seabirds as a vector and concentrators of microplastics in Arctic ecosystems led by Jennifer Provencher and Mark Mallory.

Discussion and conclusions

This project represents the 11th year that the Wildlife Contaminants Workshop has been delivered at the Nunavut Arctic College in one form or another. Over the years a number of different themes have been focused on, and the team continues to explore themes that are of interest to the students, and come up through the group discussions.

The 2018-2019 workshop was the first year that focused on plastic pollution as a theme. The students were very engaged for all of the hands-on activities but showed a particular interest in the plastic themed discussions.

Expected project completion date

This project was completed in October 2018.

Acknowledgments

We would like to thank all those that supported the contaminants workshop, particularly the students and staff of the Nunavut Arctic College. We would also like to thank the NCP for their support.

Learning about ringed seal health from contaminants science and Inuit knowledge: an educational workshop in Arviat, Nunavut

En apprendre davantage sur la santé du phoque annelé grâce à la science sur les contaminants et au savoir traditionnel des Inuits : atelier éducatif à Arviat, au Nunavut

Project leaders/Chefs de projet

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Project locations/Emplacements du projet

- Arviat, NU (2018-2019)
- Sachs Harbour, NT (2017-2018)
- Resolute Bay, NU (2016-2017)

Abstract

This project addressed a shared interest among Nunavummiut and scientific researchers in enhancing communications and community capacity building related to contaminants research on ringed seals. On October 23-24, 2018, we delivered an educational workshop on ringed seals in Arviat, Nunavut, where annual core monitoring of ringed seals takes place under the Northern Contaminants Program

Résumé

Ce projet s'est appuyé sur l'intérêt commun des Nunavummiuts et des chercheurs scientifiques d'améliorer les communications et de renforcer les capacités de la collectivité concernant la recherche menée sur les contaminants chez le phoque annelé. Les 23 et 24 octobre 2018, nous avons organisé un atelier éducatif sur les phoques annelés à Arviat, au Nunavut, où une surveillance annuelle de base des phoques

(NCP). This workshop was held at the Levi Angmak Elementary School and the Qitiqliq Middle School. The objective was to engage 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 Arviammiut and students from the Levi Angmak Elementary School and the Qitiqliq Middle School. It also provided an opportunity for Inuit 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 two-day event employed a combination of short interactive presentations, laboratory activities, group discussions, storytelling, games, and a ringed seal booklet activity. These activities taught 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 Arviat workshop as a way to increase the capacity of northern students and early career scientific researchers to engage meaningfully with northern communities in contaminants research. We evaluated this workshop through a written survey and informal discussions with participants. In doing so, we identified some best practices for communicating contaminants research with Inuit youth. This project will contribute to expanding collaboration and communication between northern residents and researchers working on contaminants in Arviat and Inuit Nunangat, and supporting the development of innovative methods of community engagement around contaminants monitoring in wildlife.

annelés a lieu dans le cadre du PLCN. Cet atelier a eu lieu à l'école primaire Levi Angmak et à l'école intermédiaire Qitiqliq. L'objectif était de faire participer les élèves, les aînés, les chercheurs scientifiques, le personnel de l'école et le Comité local des chasseurs et des trappeurs pour en apprendre davantage sur les phoques annelés, tant du point de vue des connaissances des Inuits que des perspectives scientifiques. L'atelier a permis aux chercheurs du PLCN travaillant sur les contaminants des phoques annelés de partager des informations sur leur travail avec les Arviammiut et les élèves de l'école primaire Levi Angmak et de l'école intermédiaire Qitiqliq. 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 de deux jours a fait appel à une combinaison de courtes présentations interactives, d'activités de laboratoire, de discussions de groupe, de récits, de jeux et d'une activité avec le livret sur les phoques annelés. Ces activités ont permis aux participants d'apprendre les concepts fondamentaux, les questions et les méthodes touchant l'étude et la compréhension de la santé des phoques annelés, tant du point de vue scientifique que du point de vue des Inuits. Un étudiant du Programme des technologies environnementales de l'Arctic College à Iqaluit et un étudiant diplômé de l'Université du Manitoba ont codirigé l'atelier d'Arviat afin d'accroître la capacité des étudiants du Nord et des chercheurs scientifiques en début de carrière à mobiliser de manière notable les collectivités du Nord dans la recherche sur les contaminants. Nous avons évalué cet atelier par une enquête écrite et des discussions informelles avec les participants. Ce faisant, nous avons relevé certaines des meilleures pratiques pour communiquer la recherche sur les contaminants aux jeunes Inuits. Ce projet contribuera à étendre la collaboration et la communication entre les habitants du Nord et les chercheurs travaillant sur les contaminants à Arviat et à Inuit Nunangat, et à soutenir le développement de méthodes innovantes de mobilisation communautaire concernant la surveillance des contaminants dans la faune.

Key messages

- An educational workshop on ringed seals involving students, Inuit Elders, scientific researchers, school personnel, the local Hunters and Trappers Organization was held at the Levi Angmak Elementary School and the Qitiqliq Middle School, Arviat, Nunavut, in October 2018.
- Scientific researchers and Inuit Elders worked together with students, school personnel, and community members to share their knowledge about contaminants in ringed seals and learn from Inuit 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, ringed seal dissection, seal skin preparation, laboratory activities, group discussions, storytelling and games), and school personnel welcomed researcher engagement in the classroom.
- Best practices for sharing information about contaminants research with northern schools through workshops include: (a) planning workshop in collaboration with community partners; (b) having a flexible approach to workshop programming; (c) developing teaching tools that can be easily adapted to various age groups; (d) preparing educational material that can be left with teachers once workshop is over; (e) taking the time to introduce concepts that are new to students (e.g., contaminants, bioaccumulation, biomagnification); and (f) 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 engage meaningfully with northern

Messages clés

- Un atelier éducatif sur les phoques annelés, auquel ont participé des étudiants, des aînés inuits, des chercheurs scientifiques, le personnel scolaire et l'organisation locale des chasseurs et des trappeurs, s'est tenu à l'école primaire Levi Angmak et au collège Qitiqliq d'Arviat, au Nunavut, en octobre 2018.
- Les chercheurs scientifiques et les aînés 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 a accueilli favorablement la participation des chercheurs en classe.
- 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 : (a) la planification des ateliers en collaboration avec les partenaires communautaires; (b) une approche souple pour ce qui est de la programmation des ateliers; (c) des outils d'enseignement qui s'adaptent aisément à divers groupes d'âge; (d) du matériel pédagogique qui peut être laissé aux enseignants après l'atelier; (e) la présentation des concepts nouveaux pour les étudiants (p. ex., les contaminants, la bioaccumulation, la bioamplification); et (f) 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

communities in contaminants research in Inuit Nunangat.

- We developed an illustrated ringed seal booklet that can be shared with northern students to enhance their knowledge of ringed seal ecology and raise their awareness about northern contaminants.

de l'Université du Manitoba 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 collectivités du Nord.

- Nous avons créé un livret illustré sur le phoque annelé qui peut être partagé avec les étudiants du Nord afin d'améliorer leurs connaissances sur l'écologie de cet animal et de les sensibiliser aux contaminants du Nord.

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 Levi Angmak Elementary School and the Qitiqliq Middle School, Arviat, Nunavut, in October 2018.

In the short-term, this workshop pursues the following objectives:

- provide an opportunity for scientists working on contaminants in ringed seals to share information about their work with northern 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 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 Arviat 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 Inuit youth) to engage in and better understand ongoing scientific research on northern contaminants.

Introduction

For over two decades, the NCP has been funding a long-term and ongoing research project on contaminants in ringed seals under the Environmental Monitoring and Research subprogram. Northern residents from the communities of Resolute, Arviat, Sachs Harbour, and Nain have played a pivotal role in the success of this project by collecting ringed seal samples that were tested for contaminants and reporting biological data from harvested animals. Over the years, scientific researchers involved have communicated results from this project 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 by Dominique Henri, Magali Houde, and Jennifer Provencher (Project leaders). Our collaborative project 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. Now in its third year, 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; ITK 2018). Researchers also recognize that meaningful engagement with northern residents can lead to improved research methods and results, as well as enhanced 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 to enhance 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 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.

Since 2016, two ringed seal workshops, financially supported by the NCP, were successfully held in Resolute, Nunavut (2016/2017), and Sachs Harbour, NWT (2017/2018) (please refer to previous synopsis reports for more information). The workshop in Arviat, Nunavut, in 2018/2019 was designed based on lessons learned and feedback received from participants attending the two previous workshops.

Activities in 2018/2019

The ringed seal workshop held in 2018/2019 Arviat, Nunavut, 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 April 2018 to October 2018, workshop program and content were co-developed by scientific researchers, staff from the Levi Angmak Elementary School and the Qitiqliq Middle School, the Arviat Hunters and Trapper Organization (HTO) (Andrea Ishalook and Winona Gibbons), and other project team members. Dominique Henri (Environment and Climate Change Canada - ECCC) oversaw the workshop co-design process, and project reporting activities. The workshop funded by NCP took place on October 23-24, 2018 in Arviat, Nunavut. The scientific team co-leading and present at the workshop was composed of: Magali Houde (ECCC), Jennifer Provencher (ECCC), Dominique Henri (ECCC), Cassandra Debets (University of Manitoba), and Michael Salomonie (Arctic College ETP student). In April 2018, Henri travelled to Arviat to meet with representatives from three local schools (elementary school, middle school, and high school) to introduce the project and initiate project co-design with interested school staff. She also met with representatives from the Arviat HTO board who reiterated their support for the project. Both the Levi Angmak Elementary School (Principal Tony Phinney) and the Qitiqliq Middle School (Principal Doreen Hannak and science teacher Juanita Balhuizen) expressed their interest in hosting a workshop in fall 2018. The John Arnalukjuak High School (Principal Romeo Fournier) was unavailable to host a ringed seal workshop in the fall given their busy school calendar. In early September 2018, Henri contacted representatives from the Arviat HTO, the Levi Angmak Elementary School and the Qitiqliq Middle School via phone and email to finalize workshop programming and arrange logistics. Provencher contacted Amy Caughey (Government of Nunavut) via email to confirm the messaging to be used by workshop instructors related to contaminants and human health. Project co-leaders also worked in with Amie Black (ECCC; project co-leader of NCP funded project entitled *Regional NCP Workshop in Arviat*) to ensure coordination between the ringed seal workshop and the regional NCP workshop that would be held in Arviat during the same week as the ringed seal workshop.

Workshop delivery

On Monday, October 22, upon arrival in Arviat, members of the scientific team (workshop instructors) met with representatives from the Levi Angmak Elementary School and the Qitiqliq Middle School to introduce themselves and discuss workshop logistics and programming. The final workshop schedule (co-designed with school staff) is presented in Tables 1 and 2. The team visited the Arviat HTO to invite HTO board members to the workshop and finalize workshop logistics. The attendance of two local Elders and one interpreter selected by the HTO was confirmed. Henri met in person with Elders Julia Pingushat and Peter Sanertanut prior to the workshop to discuss their roles with the help of Bobby Suluk (interpreter). The scientific team also contacted the Young Hunters Program and the Aqqiumavvik Society (Shirley Tagalik) to invite their members to the workshop.

Table 1. Ringed seal workshop schedule, Levi Angmak Elementary School, Arviat.

Time	Activities for Jamie's class (Grade 5A)	Activities for Joshua's class (Grade 5B)
Period 1	Ringed seal dissection In: DEA area Instructors: Dominique (lead), Elders, Jenn	Seal ecology & contaminants In: Classroom Instructors: Magali (lead), Mike
Period 2	Lab activity on seal diet In: DEA area Instructors: Jenn (lead), Dominique	Inuktitut class on seal anatomy In: Classroom Instructors: Joshua (lead), Elder, Magali, Mike
Period 3	Seal ecology & contaminants In: Classroom Instructors: Jenn (lead), Dominique	Lab activity on plankton In: DEA area Lead: Magali (lead), Mike
Period 4	Inuktitut class on seal anatomy In: Classroom Instructors: Jamie (lead), Elder, Jenn, Dominique	Games about contaminants In: DEA area Lead: Mike (lead), Magali
Lunch		
Period 5	Lab activity on plankton In: Classroom Instructors: Dominique (lead), Mike, Jenn	Ringed seal dissection In: DEA area Instructors: Magali (lead), Elders
Period 6	Country food & human health In: Classroom Lead: Jenn (lead), Dominique, Mike	Lab activity on seal diet In: DEA area Instructors: Magali (lead)
Period 7	Games about contaminants In: DEA area Lead: Mike (lead), Jenn	Country food & human health In: Classroom Instructors: Magali (lead), Dominique

Table 2. Ringed seal workshop schedule, Qitiqliq Middle School, Arviat.

Class/ Period	8:45-9:10	Period 1 9:10-9:50	Period 2 9:50-10:30	Period 3 10:30-11:10	Period 4 11:10-11:55	Period 5 1:10-1:45	Period 6 1:45-2:20	Period 7 2:20-2:55	Period 8 2:55-3:30
Grade 6A (Maggie)	TEACHERS PREPARE STUDENTS FOR THE DAY Please explain to students how the day will work (move around stations) and also prepare some questions that students could ask to the Elders and researchers about seals.	Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Lab activity on plankton In: Juanita's science class Lead: Magali	Seal ecology & contaminants In: Assembly area Lead: Jenn	Country food & human health In: Michelle's class (6B) Lead: Dom	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Lab activity on seal diet In: Art room Lead: Cassandra	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers	Games about contaminants In: Gym Lead: Dom
Grade 6B (Michelle)		Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Lab activity on seal diet In: Art room Lead: Cassandra	Seal ecology & contaminants In: Assembly area Lead: Jenn	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Lab activity on plankton In: Juanita's science class Lead: Magali	Games about contaminants In: Gym Lead: Mike	Country food & human health In: Michelle's class (6B) Lead: Dom	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers
Grade 6C (Daisy)		Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Games about contaminants In: Gym Lead: Dom and Mike	Lab activity on plankton In: Juanita's science class Lead: Magali	Seal ecology & contaminants In: Assembly area Lead: Jenn	Lab activity on seal diet In: Art room Lead: Cassandra	Country food & human health In: Michelle's class (6B) Lead: Dom	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Ringed seal booklet In: Kip's class (7A) Lead: Teachers
Grade 7A (Kip)		Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Country food & human health In: Michelle's class (6B) Lead: Dominique	Seal ecology & contaminants In: Assembly area Lead: Jenn	Games about contaminants In: Gym Lead: Jenn	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers	Lab activity on plankton In: Juanita's science class Lead: Magali	Lab activity on seal diet In: Art room Lead: Cassandra and Mike
Grade 7B		Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers	Games about contaminants In: Gym Lead: Mike	Lab activity on plankton In: Juanita's science class Lead: Magali	Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Seal ecology & contaminants In: Assembly area Lead: Jenn	Lab activity on seal diet In: Art room Lead: Cassandra	Country food & human health In: Assembly area Lead: Jenn
Grade 8A		Lab activity on plankton In: Juanita's science class Lead: Magali	Ringed seal booklet In: Kip's class (7A) Lead: Teachers	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Lab activity on seal diet In: Art room Lead: Cassandra	Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Seal ecology & contaminants In: Assembly area Lead: Jenn	Games about contaminants In: Gym Lead: Dom	Country food & human health In: Assembly area Lead: Jenn
Grade 8B		Lab activity on seal diet In: Art room Lead: Cassandra	Country food & human health In: Assembly area Lead: Jenn	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers	Games about contaminants In: Gym Lead: Mike	Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie	Seal ecology & contaminants In: Assembly area Lead: Jenn	Lab activity on plankton In: Juanita's science class Lead: Magali
Grade 8C		Games about contaminants In: Gym Lead: Jenn	Country food & human health In: Assembly area Lead: Jenn	Lab activity on seal diet In: Art room Lead: Cassandra	Ringed seal booklet In: Maggie's class (6A) Lead: Teachers	Ringed seal dissection In: Assembly area Lead: Dom, Mike & Elders	Lab activity on plankton In: Juanita's science class Lead: Magali	Seal ecology & contaminants In: Assembly area Lead: Jenn	Inuktitut class on seal anatomy In: Daisy's class (6C) Lead: Teachers & Winnie

We delivered our ringed seal workshop over the course of two days and involved approximately 300 students, 25 school staff, and 25 other community members (representatives from the Arviat HTO, the Aqqiumavvik Society, the Young Hunters Program, and other Arviat residents) in workshop activities.

On Tuesday, October 23, the scientific team conducted the workshop at the Qitiqliq Middle School and worked with approximately 180 students from grade 6 to grade 8. Juanita Balhuizen (science teacher) had asked our team to involve as many students as possible in workshop activities. We, therefore, designed a workshop schedule involving all classes in the school throughout the day. Eight different activities were set up in different classrooms and spaces. Classes would follow their teacher and rotate between activities during the day. We structured workshop schedule around eight regular periods and followed the school schedule. Activities proposed to students included:

- two interactive presentations about (a) ringed seal ecology and contaminants (Figure 1), and (b) country food and human health (Figure 2);
- a ringed seal dissection led by Elders;
- two laboratory activities about (a) plankton (i.e., students could observe plankton (Daphnia magna) using a magnifying glass and light table, and had an opportunity to feed daphnids with algae), and (b) ringed seal diet;
- a ringed seal activity booklet;
- an Inuktitut lesson on seal anatomy led by Elders and teachers (Figure 3); and
- games about contaminants at the gym (Figure 4).

Figure 1. ECCC researchers made interactive presentations to students about ringed seal ecology and contaminants; they answered the following key questions: 'What are contaminants?', 'How do they travel to the Arctic?', 'How do they get into animals?'(picture shared with permission).

Figure 2. Students participated in discussions about country food and human health; students wrote and drew about the importance of country food to them and their family.

Figure 3. Students learned about ringed seal body parts in English and Inuktitut using an interactive poster (right); teachers and Elders participated in these activities (picture shared with permission).

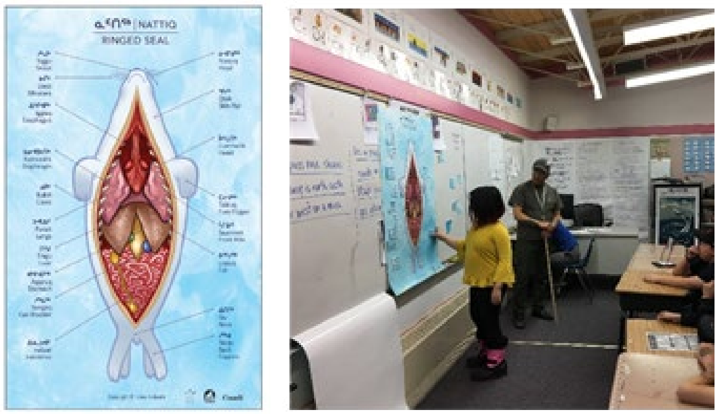


Figure 4. The 'Arctic food chain game' was used to teach students about contaminants biomagnification in Arctic food webs through play (left); Michael Salomonie, an ETP student from Iqaluit, led various games with students during the workshop (right) (pictures shared with permission).

For detailed information about these activities, please consult our project report:

Henri, D., Provencher, J., Debets, C., Appaqaq, M., Debets, C., Giraudo, M., and Houde, M. 2018. *Learning about ringed seal health from contaminants science and Inuit knowledge: educational workshops 2016-2018*. Report prepared by Environment and Climate Change Canada for the Northern Contaminants Program and project partners, 29 pp.

Throughout the day, the scientific team often used short PowerPoint presentation modules or interactive posters to introduce and/or conclude each of the activities. Themes covered by the scientific team during the workshop included: ringed seal ecology, Arctic food chains and food webs, sources and pathways of contaminants, bioaccumulation, biomagnification, and the importance of country food for human health. Elders Julia Pingushat and Paul Sanertanut (Figure 5) led two ringed seal dissections and participated in Inuktitut lessons on seal anatomy. Before each dissection, Julia and Paul shared and stories about seals in Inuktitut (which Bobby Suluk translated for non-Inuktitut speakers), and talked with students about ringed seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game. During the dissections, some students volunteered to help with seal sampling. The science team explained to the group how researchers worked on contaminants; analyzed different ringed seal samples (what we could learn from them); and what we would do with the meat, fat, and skin once the dissection was over. The science team brought some ringed seal meat and blubber to the Elders' centre right after the first dissection in the morning. Meat and blubber was also distributed to students and those present at the workshop after the school day. Ringed seal skins were offered to Elders or people who asked for them. We followed community advice (HTO members, teachers, workshop participants) at every step to make sure all the animals would be used.

On Wednesday, October 24, the scientific team conducted the workshop at the Levi Angmak Elementary School and worked with approximately 60 students from grade 5. Tony Phinney (school principal) had asked our team to involve only the two grade 5 classes in workshop activities (to work with the oldest students at the school). We, therefore, designed a workshop schedule involving these two classes throughout the day. Seven different activities were set up in different classrooms and spaces. Classes would follow their teacher and rotate between activities during the day. We structured workshop schedule around seven regular periods and followed the school schedule. Activities proposed to students were similar to the ones we offered to students from the Qitiqliq Middle School, except for the ringed seal booklet activity. For this activity, we left

Figure 5. Peter Sanertanut (left) and Martha Pingushat (right) from Arviat shared their knowledge about ringed seals with students during the workshop; they were involved in ringed seal dissection and seal skin preparation activities (pictures shared with permission).

copies of the booklet with teachers for students to complete once the workshop was over. In addition, we were able to offer elementary school students a seal skin preparation activity led by Martha Pingushat (who replaced her mother Julia Pingushat on that day) (Figure 5); we could not offer this activity at the middle school due to scheduling constraints. During the day, Elder Paul Sanertanut led two ringed seal dissections and participated in Inuktitut lessons on seal anatomy. It was beneficial this year to repeat the dissection activity four times over the course of the entire workshop; this allowed the Elders involved to feel engaged in the process, and comfortable in their role as their experience with students grew. Similar to what we did during the workshop held at the elementary school, we followed community advice to ensure that ringed seal meat, blubber and skin were distributed according to local preferences and customs. For example, meat and blubber were offered to Arviammiut during a community feast held on Wednesday night, and any seal leftovers were stored in the community freezer.

In the early afternoon, two workshop instructors (Debets and Provencher) attended the regional NCP workshop held at the community hall. They managed a booth where they shared information about ringed seals and contaminants. The booth also included one of our popular laboratory activities focusing on ringed seal diet. For this activity, Debets made a brief presentation about what ringed seals eat and how researchers use ringed seal stomach contents to learn about seal diet. She then invited students to dig through a fake ringed seal stomach (made of Jell-O) to find various types of beads. Each type of bead represented an animal that ringed seals can eat. Older students could record their findings into datasheets. About 60 students (mostly from the high school) and other members of the public visited the booth over the course of the afternoon. In the evening, the scientific team attended public presentations and a community feast hosted by the Arctic College at the community hall, which was part of the regional NCP workshop.

Workshop assessment

At the end of each workshop day, the scientific team left a workshop assessment survey (Appendix A) with school personnel. On Thursday October 25, Henri went back to the two schools to collect the written surveys that were completed by teachers, gather additional feedback through informal discussions, and leave some educational material (posters and additional activity booklets). The educational materials are intended to be used in future classroom activities to consolidate and expand learning that took place during the workshop. Feedback received from school personnel and students was very positive and some suggestions were made for improving the delivery of our activities in future years (e.g., develop a ringed seal activity booklet for students with support from a professional illustrator, and create video capsules for teaching students how contaminants research is done). School personnel, overall, enjoyed the presentations and activities proposed to students and welcomed researchers' engagement in the classroom. 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 Arviammiut – especially youth – to engage in contaminants research. All workshop activities conducted with Arviammiut were described in the 'Community engagement' section above (i.e., delivery of a two-day workshop at the school, involvement of various community partners in workshop planning, and meetings with various community organizations). In addition, Michael Salomonie, 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 Arviat workshop as a way to increase the capacity of northern students and early career scientific researchers to meaningfully engage with northern community members in contaminants research. Lastly, Mick Appaqaq, a former ETP student involved in the workshops conducted in Resolute and Sachs Harbour, was invited to co-present with Henri about the ringed seal workshop project at the 2018 ArcticNet Annual Scientific Meeting held in Ottawa.

Communications and outreach

In addition to communications and outreach activities conducted in collaboration with Arviammiut during the workshop (please refer to 'Community engagement' section above), the following presentations (8) were made about our project in 2018/2019:

- Invited Speaker. Henri, D. Savoirs autochtones et environnement: regards sur la recherche participative. Table interministérielle fédérale sur la question autochtone, Montréal, QC. April 2019. Platform
- Invited Plenary Speaker. Houde, M. Working with Inuit communities to assess trends of contaminants in ringed seals in relation to climate change. Third Northern Research Day. McGill University. January 2019. Platform
- Henri, D.A, J. Provencher, C. Debets, M. Giraudo, M. Appaqaq, L.M. Martinez, A. Black, D. Muir, S. Ferguson, D. Yurkowski, Houde, M. Using educational workshops on ringed seal ecology to engage Inuit youth in contaminants research. ArcticNet Annual Scientific Meeting Ottawa, ON. December 2018. Platform
- Henri, D.A., J. Provencher, C. Debets, M. Appaqaq, L.-M. Martinez, A. Black, D.C.G. Muir, S. Ferguson, D. Yurkowski, and Houde, M. Engaging Inuit youth in research: A ringed seal workshop in Arviat, Nunavut. ArcticNet Annual Scientific Meeting Ottawa, ON. December 2018. Poster.
- Houde, M. and Muir, D.C.G. Mercury and methylmercury in ringed seals from Inuit Nunangat. AMAP Mercury Expert Group meeting, Ottawa, ON. December 2018. Platform
- Henri, D.A., J. Provencher, C. Debets, M. Giraudo, M. Appaqaq, L.M. Martinez, A. Black, D. Muir, S. Ferguson, D. Yurkowski, Houde, M. Engaging Indigenous communities in contaminants research on wildlife: educational workshops on ringed seal health conducted in Inuit Nunangat. 39th SETAC North America meeting, Sacramento, CA. November 2018. Poster.
- Plenary Speaker. Houde, M. Accumulation et effets de contaminants d'intérêt émergent: du Saint-Laurent à l'Arctique. Chapitre Saint-Laurent. Québec City, QC. June 2018. Platform.
- Invited Speaker. Houde, M. Environmental contaminants of emerging concern: from the St. Lawrence to the Canadian Arctic. Green Chemistry Initiative, Department of Chemistry, University of Toronto. Toronto, ON. May 2018. Platform

Indigenous Knowledge

This workshop provided an opportunity for three Arviat residents (Elders Peter Sanertanut and Julia Pingushat; and Martha Pingushat) to share their knowledge of seal ecology and traditional methods for butchering seals, preparing seal skin and identifying abnormalities in harvested game with students and researchers. Please note that in our original proposal, we had planned to document Inuit knowledge about ringed seals through a student-developed hunter survey designed during the 2017 NCP Wildlife Contaminants Workshop (held at the Nunavut Arctic College in Iqaluit). This survey was developed by ETP students for collecting local/traditional 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. However, given the number of students involved in our workshop this year (around

300 students participated over the course of two days), we were unable to carry this survey this year due to capacity constraints within our project team (full workshop schedule, and limited availability of local interpreter).

Results and outputs/deliverables

Approximately 350 Arviat residents participated in workshop activities held at the Levi Angmak Elementary School, the Qitiqliq Middle School and the community hall (see 'community Engagement' section for details). Students, school personnel, Elders and other community members took part in the workshop. Additionally, Arviat HTO manager and board members contributed to workshop planning and attended a meeting during which project information was shared. Our workshop was completed in October 2018. Appendix B includes a poster summarizing the three NCP-supported ringed seal workshops carried by our team since 2016.

Please note that we had planned to produce lesson plans as part of our original 2018/2019 proposal. We cancelled this project component as our school partners suggested that we improve our ringed seal activity booklet for students instead of drafting lesson plans. We followed this advice and produced an illustrated ringed seal activity booklet (with support from a professional illustrator), which is now available in draft format. We intend to share this educational booklet with the NCP, other project partners, and interested individuals/organizations for feedback. Lastly, our team is now in the process writing a peer-reviewed manuscript to share project results more widely within the research community.

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 Inuit 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, ringed seal dissection, seal skin preparation, laboratory activities, group discussions, storytelling, and games) and school personnel welcomed researcher engagement in the classroom;
- Participation of one ETP student, one former 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 developed an illustrated ringed seal activity booklet that can be shared with Northern students to enhance their knowledge of ringed seal ecology and raise their awareness about northern contaminants.

Discussion and conclusion

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 our workshop, which included topics such as ringed seal ecology, Arctic food webs, contaminants, 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:

- involving community partners and collaborators in workshop planning and programming;
- having a flexible approach to workshop programming (being able to make last minute changes depending on the interests and needs of students, teachers, and community partners);
- developing teaching tools that can be easily adapted to various age groups, group sizes, and linguistic preferences;

- preparing additional educational material that can be left with teachers (e.g., activity booklet);
- 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 2019 (pending NCP funding), we propose to carry out a similar workshop in Nain, Nunatsiavut, 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 2018/2019 edition of the ringed seal workshop was completed in August 2019.

Project website

Not applicable.

Acknowledgments

We would like to thank the Levi Angmak Elementary School and the Qitiqliq Middle School for their hard work in planning and hosting the workshop, especially Tony Phinney, Juanita Balhuizen and Doreen Hannak. We are grateful to the Arviat Hunters and Trappers Organization, Andrea Ishalook and Winona Gibbons, who supported and helped carry out the workshop. Thanks to Peter Sanertanut, Julia Pingushat and Martha Pingushat for their enthusiasm in sharing their knowledge about ringed seals with students and researchers. We would also like to thank the NCP for their funding and support.

References

Aurora Research Institute. 1996. Doing research in the Northwest Territories: a guide for researchers applying for a scientific research license. Aurora Research Institute: Inuvik, 67 pp.

Brunet, N.D., G.M. Hickey and M.M. Humphries. 2014. The evolution of local participation and the mode of knowledge production in Arctic research. *Ecology and Society* 19(2): 69.

Furgal, C. 2006. Ways of knowing and understanding: towards the convergence of traditional and scientific Knowledge of climate change in the Canadian North. Ottawa: Minister of Public Works and Government Services Canada: Ottawa.

Gearheard, S. and J. Shirley. 2007. Challenges in community research relationships: learning from natural science in Nunavut. *Arctic* 60(1):62-74.

Gilchrist, H.G., M.J. Mallory and F. Merkel. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society* 10(1): 20.

Henri, D. 2012. Managing nature, producing cultures: Inuit participation, science and policy in wildlife governance in the Nunavut Territory. DPhil thesis. Oxford: OUCE, University of Oxford.

Henri, D., H.G. Gilchrist and E. Peacock. 2010. Understanding and managing wildlife in Hudson Bay under a changing climate: recent contributions from Cree and Inuit ecological knowledge. In: Ferguson, S., M. Mallory and L. Loseto (eds.). A little less Arctic: top predators in the world's largest northern inland sea, Hudson Bay. London: Springer, pp. 267-289.

Inuit Tapiriit Kanatami. 2018. National Inuit Strategy on Research. Ottawa: Inuit Tapiriit Kanatami.

Inuit Tapiriit Kanatami and Nunavut Research Institute. 2007. Negotiating Research Relationships with Inuit Communities: A Guide for Researchers. Scot Nickels, Jamal Shirley, and Gita Laidler (eds.). Ottawa and Iqaluit: Inuit Tapiriit Kanatami and Nunavut Research Institute, 38 pp.

Pearce, T. D., J. D. Ford, G. J. Laidler, B. Smit, F. Duerden, M. Allarut, M. Andrachuk, S. Baryluk, A. Dialla, P. Elee, A. Goose, T. Ikummaq, E. Joamie, F. Kataoyak, E. Loring, S. Meakin, S. Nickels, K. Shappa, J. Shirley, and J. Wandel. 2009. Community collaboration and climate change research in the Canadian Arctic. *Polar Research* 28(1):10-27.

Provencher, J.F., M. McEwan, M.L. Mallory, B.M. Braune, J. Carpenter, N.J. Harms, G. Savard and H.G. Gilchrist. 2013. How wildlife research can be used to promote wider community participation in the North. *Arctic* 66(2): 237-243.

Tondu, J.M.E., A.M. Balasubramaniam, L. Chavarie, N. Gantner, L.A. Knopp, J.A., J.F. Provencher, P.B.Y. Wong, D. Simmons. 2014. Working with northern communities to build collaborative research partnerships. *Arctic* 67(3): 419-429.

Wenzel, G. 1991. Animal rights, human rights: ecology and ideology in the Canadian Arctic. Toronto: University of Toronto Press.

Appendix A – Workshop assessment survey

Evaluation and Feedback Form

Project name: Ringed seal workshop, Arviat, Nunavut

Your feedback is important to us!

We are interested in knowing what you and your students think about the ringed seal workshop that just took place at your school. Your feedback will help us improve our work. It will allow us to share information with other researchers about best practices for engaging and communicating with northern youth as part of wildlife contaminants research.

The information you provide as part of this evaluation process will remain anonymous. It will be used only in reports, presentations and posters associated with this project.

We thank you in advance for your valuable collaboration!

Dominique, Magali, Jennifer, Cassandra and Michael

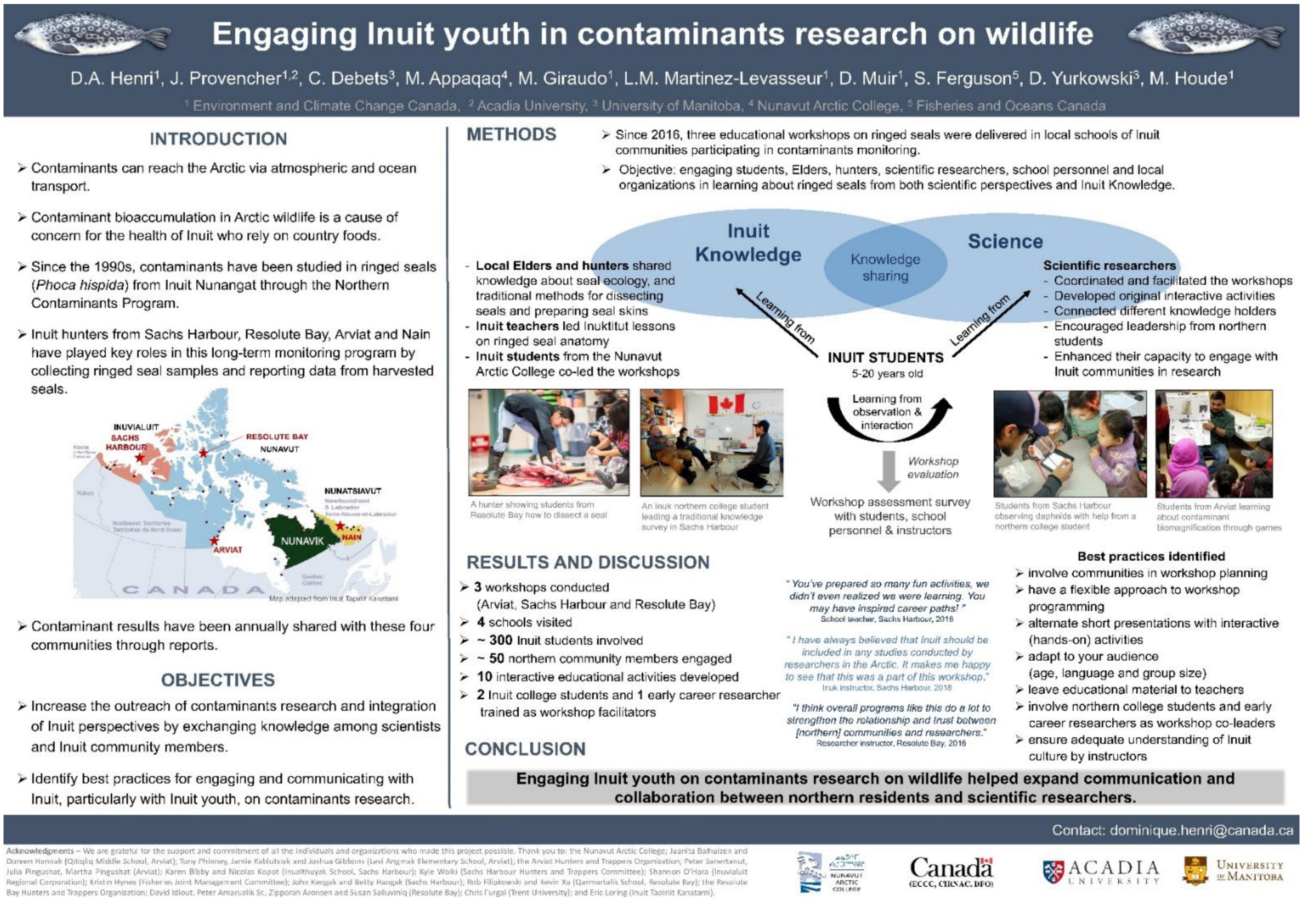
Please take a few minutes to discuss the following questions with your class, ideally the day after the workshop. We suggest that you note down student impressions as well as yours. Dominique will contact you to gather your feedback and comments.

1. What did you learn during the workshop? What do you remember?
2. What activity did you like the most? Why?
3. Is there an activity that you did not like? Which one? Why?
4. What did you think about the researchers who came here to present? Were they interesting? Where they easy to understand?

5. What could researchers do better if they came to visit again?
6. Did you discuss what you learned with your friends or family?

Appendix B

Poster summarizing the three ringed seal workshops funded by the NCP since 2016 (Arviat, Sachs Harbour, Resolute)



Regional NCP Workshop in Arviat

Atelier régional du PLCN à Arviat

Project leaders/Chefs de projet

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Project team/Équipe de projet

Amy Caughey, Government of Nunavut, Iqaluit; Cassandra Debets, University of Manitoba, Winnipeg; Dr. Steve Ferguson, Department of Fisheries and Oceans (DFO), Winnipeg; Mary Gamberg, Gamberg Consulting, Whitehorse; Dr. Dominique Henri, ECCC, Montreal, Dr. Magali Houde, ECCC, Montreal; Dr. Rob Letcher, ECCC, Ottawa; Dr. Lisa Losetto, DFO, Winnipeg; Dr. Derek Muir, ECCC, Burlington; Shirley Tagalik, Aqqiumavvik Society, Arviat

Project location/Emplacement du projet

Arviat, NU

Abstract

The goals of the NCPs Communications, Capacity, and Outreach subprogram is to support and facilitate activities and initiatives that:

a. raise awareness of contaminants in the North from long-range sources and the work that is under way to address the issue;

b. help to support food choice decisions among consumers of traditional/country foods; and

c. build capacity in the North to participate in and/or contribute to addressing these issues.

With these goals in mind, the Arviat Regional Workshop was designed to integrate experiences from past workshops, open houses and events that incorporate a variety of concepts. This includes many themes under the NCP, including contaminants, wildlife ecology, physical processes in the Arctic, and climate

Résumé

Le sous-programme « Communications, renforcement des capacités et sensibilisation » du PLCN a pour but de soutenir et de faciliter les activités et les initiatives qui :

a. font mieux connaître les contaminants dans le Nord provenant de sources à grande distance et les travaux en cours pour résoudre le problème;

b. aident à soutenir les décisions concernant le choix des consommateurs quant aux aliments traditionnels ou régionaux;

c. renforcent la capacité du Nord à participer et/ou à contribuer à la résolution de ces problèmes.

Avec ces objectifs à l'esprit, on a mis sur pied l'atelier régional d'Arviat afin d'intégrer les expériences des ateliers, des journées portes ouvertes et des événements passés qui

change to be delivered to a range of community members in Arviat. An open house and evening gathering were held in Arviat in October 2018, that featured hands-on activities and presentations on three important wildlife species in the community: polar bears, seals, and caribou and featured NCP scientists from each project. About 75 community members (mostly students) came through the open house while about 150 participated in the evening gathering. An Inuit Qaujimajatuqangit (IQ) workshop was given to the visiting researchers by the Aqqiumavvik Society of Arviat, providing insight into new ways of developing research protocols in Northern communities that will increasingly align with Inuit values and IQ principles and ensure that Northern research is carried out in a collaborative, respectful, and effective manner.

offrent une variété de concepts. Cela inclut de nombreux thèmes dans le cadre du PLCN, notamment les contaminants, l'écologie de la faune, les processus physiques dans l'Arctique et le changement climatique, qui seront présentés aux membres de la collectivité d'Arviat. En octobre 2018, une journée portes ouvertes et une soirée ont été organisées à Arviat, avec des activités pratiques et des présentations sur trois espèces sauvages importantes pour la collectivité : les ours polaires, les phoques et les caribous, avec la participation de scientifiques du PLCN pour chaque projet. Environ 75 membres de la collectivité (principalement des étudiants) ont participé à la journée portes ouvertes et environ 150 à la soirée. Un atelier sur l'Inuit Qaujimajatuqangit (IQ, le savoir traditionnel inuit) a été donné aux chercheurs invités par la Société Aqqiumavvik d'Arviat, donnant un aperçu des nouvelles façons de développer des protocoles de recherche dans les collectivités nordiques qui s'aligneront de plus en plus sur les valeurs et les principes de l'IQ et des Inuits et assureront que la recherche nordique est menée de manière collaborative, respectueuse et efficace.

Key messages

- Presenting results of NCP projects in a coordinated fashion in the form of a workshop is an effective way of communicating results to communities in a larger scientific and social context.
- Community engagement is essential to the successful implementation of contaminants research projects in the North.
- Developing awareness of IQ is crucial to ensuring that research protocols are increasingly aligned with Inuit values.

Messages clés

- La présentation des résultats des projets du PLCN de manière coordonnée sous forme d'un atelier est un moyen efficace de communiquer les résultats aux collectivités dans un contexte scientifique et social plus large.
- L'engagement des collectivités est essentiel à la mise en œuvre réussie des projets de recherche sur les contaminants dans le Nord.
- La sensibilisation à l'IQ est essentielle pour garantir que les protocoles de recherche sont de plus en plus conformes aux valeurs des Inuits.

Objectives

The general objectives of this project are to:

- deliver coordinated research overviews and results of NCP projects to Arviat, NU; and
- build community capacity to engage in contaminants research.

The specific objectives of this project are to:

- hold an integrated community event presenting results of three core NCP research projects in a larger context;
- provide community members opportunities for feedback on NCP projects; and
- support northern research and develop coordination capacity through a local coordinator.

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 in a way 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 and that information is best shared with northern community members within the context of other relevant information and concerns. With these goals in mind, the Arviat Regional Workshop was designed to integrate experiences from past workshops, open houses and events that incorporate contaminants science, wildlife ecology, physical processes in the Arctic, and climate change science to be delivered to a range of community members in Arviat. This approach is built on the idea that it takes a community of researchers to communicate science to a community of people. By creating a range of programs (talks, open house booths, school events) featuring a range of researchers (a diverse mix of gender, experience and age), we are better situated, as a research community, to interact and engage with a range of different community members.

Activities in 2018-2019

Through consultation with Shirley Tagalik at the Aqqiumavvik Society in Arviat, Kukkik Baker was hired as a Northern coordinator to help organize the workshop on a local level.

A team of 11 researchers travelled to Arviat, the week of October of 2018. They represented research on polar bears (Rob Letcher, ECCC), caribou (Mary Gamberg, Yukon) and seals (Magali Houde, ECCC; Steve Ferguson, DFO; Brent Young, DFO; Cassandra Debets, University of Manitoba)). The team also included a Science and Indigenous Knowledge Specialist (Dominique Henri, ECCC), a representative of the Nunavut Environmental Contaminant Committee (David Oberg, GN Dept of Environment), a student from the Environmental Technology Program at Arctic College in Iqaluit (Mike Salome) and the project coordinators (Jennifer Provencher, ECCC; Cody Dey, ECCC).

The team spent Monday, October 22, in the middle school and Tuesday, October 23, in the elementary school in Arviat helping deliver the NCP companion project ‘Learning about ringed seal health from contaminants science and Inuit Qaujimajatuqangit: an educational workshop in Arviat’, which was led by Dominique Henri and Magali Houde (Figure 1). The open house and evening gathering were held on Wednesday, October 24, in the Community Hall in Arviat and were organized by Kukkik Baker and Cody Dey.

Figure 1. Michael Salomonie (ETP student) talking with Arviat students about biomagnification in Arctic food webs or Michael Salomonie (ETP student) talking with Arviat students about the Northern Contaminants Program.

Figure 2. A simulation of finding plastics in seal stomach contents (Jell-O) and using a key to identify what type of plastics they represent.

The open house included hands-on activities for three NCP core projects. The polar bear table included posters on tooth aging, polar bear distribution and contaminants in polar bears (sampling and results), as well as a 3-D model of a polychlorinated biphenyl (PCB), a polar bear baculum and jaw and a PowerPoint presentation on contaminants in polar bears.

The seal section included a hands-on activity simulating finding plastics in seal stomach contents (Jell-O) and using a key to identify what type of plastics they represented (Figure 2). This was very popular with the school children. A seal tooth aging station allowed the participants to use a microscope to count the rings in the tooth to age a seal. Images were also used to show community members how infrared technology can be used to detect seals on the ice during aerial surveys. A display of seal bones and fur rounded out this table. Ringed seal workshop booklets were available to take home.

The caribou section included a taste test to see if community members could tell cooked meat from their caribou herd (Qamanirjuaq) from a distant herd (Forty-Mile from the western Arctic). Almost everyone could taste the difference, and a few could identify the origin of the caribou by the look alone. A community member (Angelina Suluk) cooked all the caribou for the open house in the local, traditional way. There was also a display of the quantity of kidney, liver, and muscle that is recommended for consumption from the Porcupine caribou, which people found very interesting. A caribou tooth aging station displayed the teeth, and a microscope with a stained, sectioned tooth enabled participants to try their hand at counting the rings in the tooth to age the caribou (Figure 3). Plain language summaries of the 'Contaminants in Arctic Caribou' were popular with the adult participants, while the younger group found the caribou bone snow goggles and hand game more engaging.

Figure 3. Student using microscope to determine caribou age by counting rings on the teeth.

Figure 4. Community Feast; Drumming.

Participants in the open house were mostly school groups, with about 75 individuals attending. As each person came into the community centre, they were given a questionnaire in English and Inuktitut (Appendix 1) which was designed to help them engage with each of the researchers to answer the questions. Once the questionnaire was completed, they could return it for a prize.

The evening gathering was co-hosted with the Nunavut Arctic College. It started with a feast of caribou, seal, and bannock, which was enjoyed by all (Figure 4). Following the feast, Jennifer Provencher presented an overview of the Northern Contaminants Program, followed by presentations on contaminants in polar bears (Rob Letcher), seals (Steve Ferguson), and caribou (Mary Gamberg). All presentations were translated into Inuktitut by Angelina Suluk for the Elders in the audience. Drumming and dancing were enjoyed by everyone while they finished up the remains of the feast. About 150 community members participated in the evening event.

On Thursday, October 25, Kukkik Baker and Joe Karetak from the Aqqiumavvik Society generously offered an Inuit Qaujimajatuqangit (IQ) workshop for the visiting researchers. The full-day workshop delved into the essential nature of IQ in the Inuit culture and gave each researcher the opportunity to assess how their research could benefit by viewing it through IQ principles. Those principles include:

- working for the common good,
- being respectful of all living things, and
- continually planning for a better future.

Considering northern research in the context of these principles allowed the workshop participants to better understand how their research is viewed by northern communities and resulted in many concrete examples of how research protocols could be improved to better align with IQ principles. One of the highlights of the workshop was the presence of two Elders who entertained questions from the participants (conversation was translated both ways between English and Inuktitut). The workshop was skillfully facilitated by Joe Karetak (a longtime educator) and was greatly appreciated by the participants. The Aqqiumavvik Society plans to produce a video of the workshop in summer 2019, which will be available online and accessible to the public, including all NCP researchers and Northerners.

In addition to the workshop, the project team has completed an analysis of the workshop goals and results in relation to the NCP Blueprint and the Communications, Capacity and Outreach subprogram. This report is intended to inform future NCP activities under this subprogram, both in Arviat as well as in other communities where NCP research takes place.

Indigenous Knowledge

During the workshop all the NCP researchers highlighted how local and Indigenous Knowledge has informed their work, including presenting how Indigenous Knowledge is incorporated directly into their different aspect of their work. Community members had the opportunity to share their knowledge via the direct interactions with researchers, and through the facilitated sessions. The facilitated session in the evening involved posters of the projects outlining sampling locations and data being collected. Community members were invited, through posters and markers, to add questions (in English or Inuktitut) and propose ideas that they would like to see core programs address.

Community engagement

The community was engaged in all aspects of the workshop and events. The evening gathering was co-hosted with the Nunavut Arctic College and lead by local staff from the community. The workshop was co-developed with the Aqqiumavvik Society to ensure that community participation would be maximized. Additionally, Kukkik Baker and Joe Karetak from the Aqqiumavvik Society organized and hosted an Inuit Qaujimajatuqangit (IQ) workshop for the visiting researchers. This community lead component promoted ideas to be shared about how the community would like research to be done with the community.

Discussion and conclusions

Results from three separate NCP core projects were successfully presented to the community of Arviat in a coordinated manner, providing a larger context for understanding contaminants in three important species in the community. Caribou and seals are harvested for food and fur, while polar bears are harvested primarily for their fur. Each of the projects was discussed in detail during the evening session so that everyone was aware of the nature of the ongoing work and the community and researcher participation, cooperation and collaboration required for carrying out these monitoring programs, as well as their common link back to the NCP. During the week of the workshop there were many opportunities for community members to give feedback on existing projects.

Focussing on the requirements for each of the projects helps to build capacity to engage in contaminants research in Arviat, as more hunters will be able to participate in the projects through harvesting, sampling specified tissues and recording data appropriately for each project. Presenting overviews of results also helps to increase interest in, and knowledge of, the projects, particularly in the long-term aspects of whether contaminants are increasing in these important species.

A significant bonus within this project was the addition of the IQ workshop for the visiting researchers. This approach is key to scientists developing research protocols that increasingly align with Inuit values so that projects can be conducted in a collaborative, respectful and effective manner.

Expected project completion date

This project was completed in October 2018.

Acknowledgments

We would like to thank all those that supported the contaminants workshop, particularly Shirley Tagalik (even though she was not in Arviat at the time and could not participate). Thanks to Kukkik Baker for her logistical support and to Kukkik and Joe Karetak for providing the excellent IQ workshop. Thanks also to the cooks of the feast and Angelina Suluk for cooking the caribou for the open house and providing translations during the presentations and the IQ workshop. This project was funded by the Northern Contaminants Program.

Appendix 1. Northern Contaminants Program Scavenger Hunt

Caribou

1. Are contaminants generally higher in caribou cows or bulls?
2. Which has higher levels of contaminants – caribou kidneys or bone marrow?

Seals

1. How many seals are in the aerial survey photo?
2. Name two prey items found in the seal stomach

Polar Bears

1. What species of seal do polar bears like to eat the most?
2. How many subpopulations of polar bears are there in Canada?

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
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Project team/Équipe de projet
Members of the Yukon Contaminants Committee include the following: Mary Vanderkop, Ainslie Ogden, and Dr. Brendan Hanley, Yukon Government; Mary Gamberg, private consultant and researcher; Ellen Sedlack, Government of Canada; and 1 or 2 yet to be identified representatives of a Yukon First Nations.

Project location/Emplacement du projet
Whitehorse, YK

Abstract

The Council of Yukon First Nations (CYFN) continues to be an active member of the Northern Contaminants Program (NCP) Management Committee through responding to requests for information, participating in regional 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.

The CYFN participated in the fall meeting of the NCP Management Committee, along with the regionally hosted Yukon Contaminants Committee meetings. At the CYFN General Assembly in Mayo, Yukon, there was a booth set up displaying the NCP pop-up along with background materials. The CYFN assisted in the review of all proposals wanting to undertake

Résumé

Le Conseil des Premières Nations du Yukon (CPNY) continue de siéger activement au Comité de gestion du Programme de lutte contre les contaminants dans le Nord (PLCN). 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 actuellement à l'œuvre sur le territoire du Yukon.

Le CPNY a participé à la réunion d'automne du comité de gestion du PLCN, ainsi qu'aux réunions du comité des contaminants du Yukon, organisées à l'échelle régionale. Lors de l'assemblée générale du CPNY à Mayo, au Yukon, un kiosque a été installé pour présenter

research in Yukon, and participated in the ongoing strategic planning of the Yukon Contaminants Committee.

la bannière du PLCN ainsi que des documents de référence. Le CPNY a participé à l'examen de toutes les propositions de recherche au Yukon et à la planification stratégique en cours du comité des contaminants 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 Traditional Knowledge.

Messages clés

- Les aliments traditionnels et locaux sont sans danger pour la consommation.
- Les concentrations de contaminants sont généralement faibles sur le territoire du Yukon.
- Il faut continuer la surveillance, car de nouveaux contaminants 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 du PLCN sont toujours pertinents à l'échelle 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 addressing northern community concerns because there is a perception that 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 as it is generally recognized that long-range contamination in Yukon is lower in comparison to other jurisdictions in the North; 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 2018-2019

The CYFN participated in NCP Management Committee meetings held in Ottawa in November 2018 to participate in the mid-year review of all approved 2018-2019 NCP projects and to advise the Program on the Yukon Contaminants Committee's activities and recommendations. Unfortunately, the CYFN did not attend the spring Management Committee meeting in March due to a scheduling conflict. However, the CYFN did participate in the Social and Cultural reviews undertaken by the regional Yukon Contaminants Committee in winter/spring and further assisted the process by filling in the template requested by the NCP in respect of the proposals and the comments stemming from the reviews.

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. The Committee met with researchers, discussed communications on contaminants issues and reviewed proposals submitted by researchers to the NCP who wanted to conduct research in the Yukon Territory. The CYFN worked with researchers to disseminate information, where appropriate, on their research and ensured they engaged with communities in all aspects of their work as much as possible. The Yukon Contaminants Committee reviewed each of the project proposals proposed to take place in or connected to the Yukon, made comments on the proposals, and generally assessed the value of projects through recommendations to the NCP Secretariat and later to the Management Committee.

Merran Smith, the CYFN Climate Change Community Liaison, has signaled an interest in the NCP and will become more involved in the program in the future. Unfortunately, there was no Results Workshop during the 2018-2019 reporting period otherwise Ms. Smith would have attended. Since Derek Cooke of the Ta'an Kwäch'än Council left his position and the Yukon Contaminants Committee, there was also no Yukon First Nation rep to whom the CYFN could provide supplementary funding support to enable their attendance at the annual ArcticNet Conference in December 2018.

James MacDonald attended the CYFN General Assembly in Mayo, Yukon in June 2018 and was available to answer questions about the NCP and its Yukon chapter. This was a good opportunity for community members to learn more about the CYFN's involvement in the NCP.

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 but experienced delays due to staffing turnover. This work is being done with the assistance of Ellen Sedlack and Mary Gamberg of the Yukon Contaminants Committee.

Traditional Knowledge

The CYFN did not participate in traditional 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 2019, with an eye to traditional knowledge components and made comments as appropriate to other members of the Yukon Contaminants Committee and to the NCP Secretariat.

Results and outputs/deliverables

The CYFN:

- attended the November 2018 Management Committee meetings to participate in the mid-year review of all approved NCP projects;
- 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 March 2019 Management Committee meeting in Ottawa, ON;
- 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 Sarah Kalhok as part of the Yukon Contaminants Committee and received an update on NCP activities and transitions;
- met with Environment and Climate Change Canada researcher Hayley Hung about the Little Fox Lake air monitoring site; and
- 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. These concerns have come from Yukon First Nation communities who have a close connection with both barren ground and mountain caribou and stem from observations from Elders and hunters. These interests have led to current projects that test for contaminations and involve those communities in those projects. Long-term data sets are critical to understanding background levels, tracking changes and understanding their relationship with climate change, industrial activity, and other factors. The CYFN serves as a central organization with strong connections to Yukon First Nations and can therefore serve as a liaison between communities and researchers with the aim of supporting both in achieved defined goals and objectives. The CYFN has a good understanding of First Nation values, ethics and interests and relay those as appropriate during the social and cultural project screening meetings and during the meetings of the NCP Management Committee meetings generally.

Expected project completion date

Ongoing

Project website

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. In particular, special thanks go out to Ellen Sedlack for her contribution to assisting the CYFN with maintaining its involvement in the NCP.

Dene Nation participation in the Northern Contaminants Program

Participation de la Nation dénée au Programme de lutte contre les contaminants dans le Nord

- **Project leader/Chef de projet**
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- **Project team/Équipe de projet**
  Trevor Teed, Director Lands & Environment, NT; Aleksandra Taskova, Coordinator, Lands & Environment; NT; Norman Yakeleya, Dene National/AFN Regional Chief (former Dene National Chief Bill Erasmus); NT
- **Project location/Emplacement du projet**
  Dene National Office, Yellowknife, NT

Abstract

This project is working towards building plans to build capacity and knowledge about contaminants within Denendeh through the development of a Dene workshop, and continued participation in the NCP Management Committee and NWT Regional Contaminants Committee (NWTRCC). The Dene National Assemblies and Dene Leadership meetings will engage its members and citizens on contaminant issues. Furthermore, there will be input on the direction that research in Denendeh should take from the Environment Committee and other appropriate bodies that partner with the Dene Nation. All relevant and appropriate information is, and will be, posted on the website to provide awareness of funded activities and the results.

Résumé

Ce projet vise à établir des plans pour renforcer les capacités et les connaissances sur les contaminants au Denendeh par la mise en place d'un atelier déné et la poursuite de la participation au Comité de gestion du PLCN et au Comité régional des contaminants des T.N.-O. (CRCTNO). Les assemblées nationales dénées et les réunions des dirigeants dénés permettront de mobiliser ses membres et les citoyens sur les questions relatives aux contaminants. En outre, le Comité de l'environnement et d'autres organismes appropriés qui travaillent en partenariat avec la Nation dénée apporteront leur contribution à l'orientation que devrait prendre la recherche au Denendeh. Tous les renseignements pertinents et appropriés sont et seront affichés sur le site Web afin de faire connaître les activités financées et leurs résultats.

Key messages

- The NCP is in place to ensure the security of traditional food and water, you can determine what contaminants should be studied, where, when and by whom.
- Dene Nation plans to build capacity and knowledge about contaminants within Denendeh. This will include the preplanning meeting for a future workshop that will involve the Dene Nation Health, Elders and Environment committees as well as Denendeh youth, the Indigenous representatives of the NWTRCC and the staff of the Dene Nation National Office.

Messages clés

- Le PLCN est en place pour assurer la sécurité de l'eau et des aliments traditionnels, et vous pouvez déterminer quels contaminants devraient être étudiés, où, quand et par qui.
- La Nation dénée prévoit renforcer les capacités et les connaissances au sujet des contaminants sur le territoire du Denendeh. Cela comprendra la réunion de planification préalable d'un futur atelier auquel participeront divers comités de la Nation dénée (santé, aînés, environnement), ainsi que les jeunes du Denendeh, les représentants autochtones du CRCTNO et le personnel du bureau national de la Nation dénée.

Objectives

This project aims to:

- develop a workshop on northern contaminants hosted by Dene Nation for Dene based on what the Dene regions want from the NCP;
- develop more community-based projects;
- attend NCP Management Committee meetings (2 meetings each year), NWT Regional Contaminants Committee meetings (2 meetings each year), and attend NWT Regional Contaminants Committee teleconferences (5 meetings each year);
- liaison with other Indigenous organizations in Denendeh including members of the NWTRCC;
- add to the Dene Nation website and the Northern Contaminants Program section of the website and links to other relevant sites;
- provide and reflect the Dene Nation mandate from Dene Nation Leadership meetings and assemblies on all northern contaminant related issues; and
- coordinate activities in other contaminates research and programs in Denendeh so we are aware of all contaminant work in Denendeh.

Introduction

Dene National office has been part of the NCP since its inception in 1991. The original concept of the NCP was to provide funding and support for Indigenous Peoples. This must be supported and reflected as it appears in the articles of the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) which Canada and the Crown fully support.

Concern for Dene health in Denendeh and the integrity of their food warrants focus of contaminants study on high priority harvest areas near their communities. It is also important for Dene to understand where people are being exposed to contaminants that threaten health and to understand what type of contaminants there are and their pathways. Dene Nation must continue to receive up to date scientific information but to participate in the study of heavy metals and all other pollutants and their pathways. It must also relay this information to the regions in language and with terms that the communities understand. Persistent Organic Pollutants (POPS) are not new to Denendeh and are real man-made pollutants. The NCP funding will assist to educate, help prevent contamination, and assist to implement the appropriate legislation, regulations and policies. The Dene Nation wants to promote, engage and advance further contaminates studies funded by the NCP throughout Denendeh.

Activities in 2018-2019

The team attended NCP Management Committee and NWTRCC meetings, participated in teleconference calls, reviewed study proposals and attempted to hold a preplanning meeting with the Dene members of the NWTRCC to determine what would be written into a Dene Nation proposal to host a workshop on northern contaminants.

The Dene Nation attended 3 National Assemblies and presented on NCP funded activities in Denendeh. The Dene Nation also prepared an NCP report for its Denendeh activities for 2 Dene Leadership Meetings and engaged with the NWT Contaminates And Remediation Division (CARD). Finally, in an effort to keep the communities informed of the current NCP funded programs in Denendeh, the Dene Nation communicated with communities in Denendeh by upgrading and enhancing the Dene Nation website and communicating via Social Media (Facebook).

The NCP Secretariat was invited to present to the Dene Leadership meeting in 2017-2018. The NCP Secretariat (Simon Smith) presented to the Dene National Assembly at the Hay River Dene reserve, Denendeh, during July 16 – 21, 2017. The NCP Secretariat was not invited to attend in 2018-2019, however, it we are hopeful to have regular visits by the NCP to the Annual General Assembly or to the Dene Leadership meetings in the future.

Community engagement

The Dene Nation engaged with communities in Denendeh through engagements with Dene Leadership, the Environment Committee, other NWT Indigenous Organizations, NWTRCC, the Dene Nation Health & Social Development Secretariat, the Assembly of First Nations (AFN) and other appropriate organizations and governments.

Capacity building and training

This team worked with the NWTRCC toward hosting a workshop for the Dene Nation by hosting a pre-planning meeting. The team report to the Dene Nation CEO. Lastly, the team informed communities of the NCP Call For Proposals and assisted in submitting community based monitoring research proposals.

Communications and outreach

The Dene Nation and the Dene members to the NWTRCC planned to attend a pre-planning meeting for a future workshop, upgraded its website and posted more frequent on social media using our Facebook platform.

Indigenous Knowledge

Indigenous Knowledge is a tool utilized by relevant entities to improve scientific research and monitoring. At the NWT Regional Contaminants Committee Proposals review, proposals were inspected and reviewed for their use of traditional Knowledge, as reflected in the Paris Treaty Agreement on Climate Change (2015). Indigenous knowledge was incorporated into proposals to improve Dene Nation capacity and communications addressing contaminants. Indigenous Knowledge was used to identify study targets from the local food chains including land and aquatic activities.

Results and outputs/deliverables

The team attended all required meetings and participated in all required teleconference calls. It also acquired an extra $10,000.00 from the NCP secretariat to host a teleconference call (it also reallocated funds from the previous year to assist) and a preplanning meeting with the Dene Members of the NWTRCC. The conference call was held but not the meeting. The meeting will take place in the next fiscal year.

Discussion and conclusions

There was an honest attempt by Dene Nation and some of the NWTRCC Dene members to hold a preplanning meeting to plan the submission of a proposal to hold a northern contaminants workshop. The timing was not there. Dene Nation will submit a reallocation of funds request to try host this meeting during the next fiscal year (2019-2020).

Expected project completion date

This is the second year of a multi-year, ongoing project (3 years) and the end date will be at the end of the third year, 2020 – 2021.

Project website

Denenation.com (a work in progress)

Acknowledgments

The Dene Nation would like to acknowledge the NCP Secretariat for their funding and support, as well as the contributions of Aleksandra Taskova.

Inuit Tapiriit Kanatami national coordination

Coordination nationale d'Inuit Tapiriit Kanatami

Project leader/Chef de projet

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Project team/Équipe de projet

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Project locations/Emplacements 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 (NCP). As the national political voice for Canadian Inuit, ITK continues to play multiple roles within the NCP. For example, ITK provides guidance and direction to Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC) and the other NCP partner's (Health Canada, Department of Fisheries and Oceans Canada, Environment and Climate Change Canada, etc.) bringing Inuit interests to the NCP management and liaison committees of which we are active members. As a result, the NCP can better respond to the needs and concerns of Inuit. In addition, ITK is dedicated to facilitating appropriate, timely communications about

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 du Canada et pour le PLCN. À titre de porte-parole politique des Inuits du Canada, ITK continue de jouer de multiples rôles au sein du PLCN. Par exemple, ITK fournit des conseils et des orientations à Relations Couronne-Autochtones et Affaires du Nord Canada (RCAANC) et aux autres partenaires du PLCN (Santé Canada, Pêches et Océans Canada, Environnement et changement climatique Canada, etc.) en faisant valoir les intérêts des Inuits auprès des comités de gestion et de liaison du PLCN dont nous sommes des membres actifs. En conséquence, le PLCN peut mieux répondre aux besoins et mieux réagir aux préoccupations des Inuits. En outre, ITK s'efforce de faciliter des communications appropriées et opportunes

contaminants in the North. ITK also works with their Inuit partners at the Inuit Circumpolar Council (ICC)-Canada on the international stage to persuade nations to reduce their generation and use of persistent organic pollutants (POPs) and Heavy Metals (Mercury, Lead etc.) that end up in the Inuit diet. Furthermore, ITK works with other research programs to ensure that research on contaminants is conducted in a coordinated approach.

Key messages

- This project wants to provide a voice for Inuit Nunangat during NCP discussions.
- The project team wants to continue to be an active and constructive member of the NCP Management Committee.
- It is important to have a communications structure in place that ensures that contaminants issues, NCP research, and NCP results are communicated to Inuit and that Inuit are represented at key regional, circumpolar, and international meetings and initiatives.
- It is important to contextualize contaminant information in a broader communication process using the Inuit Knowledge Centre and other ITK structure (i.e. National Inuit Committee on Health (NICoH)).
- Support is needed to enable Inuit to develop confidence when making informed decisions about country food use.
- Coordination of contaminants activities with other research programs is crucial.

sur les contaminants dans le Nord. ITK travaille également avec ses partenaires inuits au sein du Conseil circumpolaire inuit (CCI)-Canada à l'international pour persuader les pays de réduire leur production et leur utilisation des polluants organiques persistants (POP) et de métaux lourds (p. ex., le mercure) qui finissent par se retrouver dans les aliments des Inuits. De plus, 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

- Ce projet veut donner une voix à l'Inuit Nunangat lors des discussions du PLCN.
- L'équipe du projet veut continuer à être un membre actif et constructif du comité de gestion du PLCN.
- Il est important de mettre en place une structure de communication qui garantisse que les questions relatives aux contaminants, les recherches et les résultats du PLCN soient communiqués aux Inuits et que ces derniers soient représentés aux principales réunions et initiatives régionales, circumpolaires et internationales.
- Il est important de contextualiser les informations sur les contaminants dans un processus de communication plus large en utilisant le Centre du savoir inuit et d'autres structures d'ITK (p. ex., le Comité inuit national de la santé, CINS).
- Un soutien est nécessaire pour permettre aux Inuits d'acquérir la confiance nécessaire pour prendre des décisions éclairées sur l'utilisation des aliments traditionnels.
- La coordination des activités relatives aux contaminants avec d'autres programmes de recherche est cruciale.

Objectives

Short term objectives

This project aims to:

- participate in the NCP Management Committee and Regional Contaminant Committees;
- participate on NCP review teams and in NCP reports;
- participate in and/or on the ArcticNet Annual General Meeting (AGM), Research Management Committee (RMC), Board of Directors (BOD), and in the review of Integrated Regional Impact Studies (IRISs) reports;
- participate with Inuit Research Advisors through teleconferences and in-person meetings;
- participate in The ITK Inuit Health Survey discussions;
- promote and provide NCP information to regular ITK BOD meetings;
- participate in and provide a voice for NCP at the Public Health Task Group, the National Inuit Committee on Health, at Inuit Early Childhood Development Programs, at the National Inuit Food Security Group, and at Canada's Chemical Management Plan;
- participate in the National Inuit Climate Change Committee and in the National Wildlife Committee meetings;
- provide a voice for NCP in the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC);
- participate in the Inuit Qaujisarvingat National Committee (IQNC) BOD meetings and help with implementation of the ITK National Research Strategy;
- participate in Health Canada and CIRNAC Climate Change Programs;
- help researchers in communicating their research findings back to communities and develop proposal and capacity at the community level.; and
- continue with mentorship and education activities.

Long term objectives

This project 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 on environmental and wildlife issue affecting Inuit; and,
- support the enhancement of Inuit capacity to better address environment and wildlife priorities.

Introduction

The story of contaminants in the Arctic can be one of fear of the unknown. Research carried out under NCP has shown that the contaminants of most concern for Inuit are persistent organic pollutants (POPs) and heavy metals like mercury. The concern of these contaminants comes from the fat-rich country marine foods diet that Inuit depend upon both for nutritious food and sustaining a lively culture. As a result, there are places in the Canadian Arctic where some of the Inuit population is at risk because their dietary intake of contaminants are greater than the levels that are known to be safe (NCP, 2012). Inuit want to know and have the right to know what is happening to their health, and to the health of the Arctic wildlife and environment. With potentially alarming data, it is critical that Inuit be involved throughout the Northern Contaminants Program to effectively provide advice, direction, and information to Inuit.

Activities in 2018-2019

Funding from the NCP to ITK comes from the funding envelop National Coordination which allows ITK to assess information and research generated by the program and to play an informed role in influencing present and future NCP management priorities through the established committees and Inuit governance structures that are in place.

ITK continues to provide advice and direction from Inuit to the NCP, additional federal agencies, the territorial governments, and other partners. We believe firmly that our involvement in the program enables the program to better respond to the needs and wishes of Inuit with respect to the design and delivery of specific projects as well as in defining Canadian positions in international processes.

In addition, we are committed to facilitating the appropriate and timely distribution of information about contaminants and the NCP to Inuit regional organizations and from there to communities. By improving and systemizing 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.

There are many key activities that are happening this year. Firstly, the ITK weekly management meetings are providing updates to the ITK directors and the President on NCP research. This will feed into the ITK Executive speeches, policy forums, and social media. Secondly, we are continuing to work with the Chief Medical Officers to explain the NCP program and research when needed through established ITK committees. Thirdly, we are providing critical updates to other programs such as the Inuit early childhood development and food security program. In addition, with the use of NCP information, we are in the process of developing a Climate Change Strategy. Another one of our main activities is maintaining a close working partnership with the Inuit Knowledge Centre (IKC) and informing their National Committee and NCP research.

We continue to focus on using the NCP as a “model” program for other research program development. Our team also believes that the IKC can assist the NCP in helping guide and direct both the program and researchers, as well as in training Inuit at the community and regional level, enabling them to be more active members on NCP research.

The ITK continues to educate various forums on contaminants. In a yearly Arctic Tour offered to senior government officials ITK provides a quick 101 on Arctic contaminants, also, ITK teaches contaminants 101 course to Inuit students at Nunavut Sivuniksavut which is a unique eight-month college program based in Ottawa. This program is for Inuit youth from Nunavut who want to prepare for the educational, training, and career opportunities being created by the Nunavut Land Claims Agreement (NLCA) and the new Government of Nunavut Our team plans to continue work with Carleton University in teaching Arctic and Inuit contaminant issues to university students (the presentation of this year’s presentation is available).

It is important that ITK can contextualize scientific information and Inuit knowledge to ensure we are communicating information back to the communities and regions in a format that they can make the best use from. To do this, ITK has made connections with various committees and working groups established by ITK like the National Inuit Committee of Health (NICoH) and the Inuit Knowledge Center Committee, and the Amaujaq National Centre for Inuit Education. These are just a few of the committees and working groups that we can utilize to contextualize the contaminant messages into the bigger picture of information going back to the communities.

When issues arise at NCP that may have a potential human health risk, we can utilize ITK Health and Social Economic Development Department and bring concerns to various committees in place like the Inuit Public Health Task Group or the Food Security Working Group. Conversely if there are issues related to wildlife health, we can utilize regional wildlife experts that are part of ITK National Wildlife Committee as well as other Senior Researchers within ITK Department of Environment and Wildlife. An example of this would be that working with NCP polar bear scientist we were able to include NCP data in our polar bear efforts and fact sheet development.

On an international scale we will continue to partner with Inuit Circumpolar Council (ICC) to assist and help in their global efforts related to eliminating the use of mercury on an ad hoc basis. ICC is part of the larger Inuit governance structure to ensure that information is shared with other Inuit groups outside of Canada and to utilize their international status to influence global efforts.

ITK also works with other research programs like ArcticNet, Polar and Climate Change programs. This is key to help communicate information from many programs, to share best practices and to ensure fiscal responsibility. Within ArcticNet ITK plays an important role at the ArcticNet BOD level, the Regional Management Committee, the Inuit Advisory Committee, and the various IRIS assessments. Also, the Inuit Research Advisors play key roles in both the NCP an ArcticNet programs and ITK helps with coordination of activities and training opportunities for the IRA's. ArcticNet also has a very strong Students Association and we are often called upon to present to this groups on how to conduct research in Inuit Nunangat, how best to communicate and build capacity, what priorities do Inuit communities have for research. This student mentorship has made great strides. This is evident when looking at past Inuit Award recipients, who incorporated the NCP, ArcticNet and Inuit communities into their research, like Lisa Loseto and Shawn Donaldson.

Our main body of work continues to focus on the heart of the NCP: The Regional Contaminants Committees. ITK can help provide a long-term perspective to these RCC's that often have a lot of turnover in membership. It also provides a venue for ITK to hear community and regional concerns and to make sure that these are then heard at the NCP management level or included in the NCP blueprints.

ITK participated in all the NCP management meetings, as well as various review committees such as the Human Health review team, the Environment Monitoring team, the Community Based Monitoring and Research team and the Communications, Capacity and Outreach team. Participation on these committees provided a voice for the Inuit of Canada, developed priorities and issues within NCP framework and helped Inuit develop confidence to make informed decisions regarding their food. Furthermore, the opportunity to participate on those specific committees allowed for the coordination of contaminant activities with other research programs, such as ArcticNet and Polar, to ensure that the contaminants were placed in a wider context and to ensure that the research within Inuit Nunangat was conducted responsibly. This is also done with the Inuit Research Advisors (IRA's) that are partially funded by the NCP and are assisted by ITK. The main objective is to provide a coordinated approach towards research and communication, and to provide Inuit with a "voice" and direction at the NCP management table, which will ultimately allow Inuit to have confidence in making informed decisions about their food use.

As well as continuing to actively participate in the above committees and forums, ITK will continue to be available for ad hoc review committees generated by NCP research. A good example of this is the newly formed beluga risk communication committee and, in the past, the Traditional Knowledge working group. ITK will also work to bring Inuit concerns and issues into the development of various NCP communications like the development of video segments and the development of into the NCP Assessment Reports. ITK also helps share NCP information with other federal programs like the Chemical Management Plan).

Long Term goals continue to be fulfilled and successful due to the long-term nature of this research program. Now that there are renewed connections to wildlife and environment organizations in Inuit Nunangat, over the next few years we will determine, identify, and implement environmental and wildlife research and policy priorities within this program for Inuit Nunangat. 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 in regard to matters not only of environment and wildlife research, but also of Inuit health as well. In order to accomplish this goal, 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. Critical to this is the development of the Inuit Health Survey in which NCP has played a major role in. Ongoing work at the community and regional level on the Inuit Health Survey will identify and highlight a future role that NCP research may play in assisting with the Inuit Health Survey.

NCP and Inuit regions have developed a very strong governance network to properly communicate NCP research. ITK will seek regional direction for the purposes of developing departmental strategies and action plans and we will 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

ITK coordination of Inuit participants

In a time of great turnover and changing personnel, ITKs engagement to the NCP committees has been the one constant over the last 20 years. This has provided each of the contaminant's committees with some record of history. This year ITK will work and help each of the four regional committees (Nunatsiavut, Nunavik, Nunavut, and the NWT), engage with the NCP review teams, help with the development of the new Beluga Risk Communication Subcommittee, and participate and help with any issue that NCP might need assistance with. ITK will continue to sit on all contaminant committees (Nunatsiavut, Nunavik, Nunavut and Inuvialuit), and NCP Management, Human Health, Communication and Outreach, and Community Based Monitoring and Environmental Monitoring and Research review teams. Also, ITK will bring information learned from participation with the Inuit Public Health Task Group, Food Security Working Group. National Inuit Climate Change Committee, National Inuit Wildlife Committee. Committee, Mental Wellness committees, Early Childhood Development, ITK research forums, directions from ITK BOD Inuit Health Survey, National Inuit Committee on Health, ArcticNet, FNIB community-based climate change program, and Inuit youth programs. Support from the NCP will allow ITK to participate in all these initiatives and be able to bring a contextualization to the NCP program and to Inuit regions.

Developing partnerships with Northerners

The ITK has been, and will continue to, act as liaison between communities/regions and NCP government partners and researchers to advocate and advise on securing and strengthening these relationships.

Capacity building, employment and training opportunities

ITK has continued to work with the NCP partners and Inuit in the regions to enhance the level of involvement and employment of community members in all NCP activities. Extensive use is made of local capabilities, and a mix of small and large projects has been useful in capacity building and skills bases at the community level as well, local people gain training and employment through working with researchers.

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 to Inuit (the IRA, frontline workers, and community representatives). With the ultimate goal of making research in Inuit Nunangat one that is lead and developed by Inuit, ITK, with support from the NCP, will continue in its process of mentoring, training and fostering Inuit researchers at the national, regional and community level. It's vital that training activities are conducted and viewed at this scale (national, regional, community) because this is the established network that Inuit have organized and developed in order to take information at the community level to inform policy at the national/international level along with taking information 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 like the NCP, ArcticNet, Polar 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 online contaminants course (Inuit Knowledge Website). The project team will also utilize forums at ITK Amaujaq National Centre for Inuit Education and the National Inuit Educational Strategy and how best to relate these activities to the developing curriculum, as well as the National Inuit Committee on Health and the National Inuit Climate Change Committee. As a follow up to a June 2013 meeting of the IRAs in which Inuit Qaujisarvingat presented the NIQIIT Online Contaminants 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 be successful it has been reported from the recent IRA training manual that they need consistent training and support from the national organization (ITK). Since many of the best examples of training, communication and education come from the NCP, it is expected that the Inuit Qaujisarvingat: Inuit Knowledge Centre (IKC) will work with NCP researchers and NCP frontline workers to establish their needs and address any concerns.

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, youth are a targeted audience, and 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 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.

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 were close to 40 projects that are taking place in the Inuit regions. ITK involvement in these projects can range from a minimal advisory role to very intensive project control. ITK has guided researchers in various environmental monitoring programs on how to communicate to communities, translate scientific information, make links to other research programs, and encourage capacity building. ITK will continue to assist both the researchers and the Inuit regions and communities with the conclusion of these projects.

Discussion and conclusions

The potential social and environmental health threats caused by contaminants is serious enough that the Inuit of Canada require essential information about contaminants and their effects be provided and this effort must be well coordinated, consistent, and timely. There is a need for increased and improved information as the problem of exposure to contaminants in Inuit Nunangat continues. This has always required strong partnerships with Inuit, scientists, and government agencies involved with the health and welfare of people living in Inuit Nunangat.

Throughout the year ITK has heard the need for better communication, education, and capacity. Over the past 20 years ITK has heard these concerns raised at all levels from individual to regional organizations. Despite substantial communication outreach there still exists a collective concern that contaminants information needs to communicate to northern residents. ITK will continue to play a key role in making sure that Inuit Nunangat residence are able to access, learn and understand contaminant information being generated by the program.

Contaminants are threatening the Arctic food chain, one of the cornerstones of Inuit culture and identity. Inuit have expressed the importance of having quick and definitive diagnosis of food safety. They are not always satisfied with technical, quantitative information. The more threatening the situation, the greater demand not only for clear, unambiguous information, but also for full disclosure of all available information. Not to do so will only heighten suspicion and mistrust.

Despite the attention drawn to dangers of contaminants it is paramount to repeat a theme often reiterated by all NCP researchers: The known benefits of country foods continue to outweigh any risks. It is of the utmost importance that research findings be interpreted within the broader context of Inuit lifestyle utilizing the knowledge from the population at risk, effective partnerships that the NCP has created will/ can provide a place for Inuit participation in the research. The NCP with ITK has been highly successful in bringing together Inuit with scientist, government agencies, Elders, environmental organizations, and other Indigenous organizations to discuss questions and exchange information about contaminants.

Internally, ITK is building a strong relationship to collectively address the correlation between the health of the environment and the health of Inuit. ITK is bridging the gap between human health and wildlife work together in relaying information on contaminants in country food to Inuit Nunangat. Working with NCP and its partners has allowed ITK to educate Inuit in a culturally sensitive manner to give our communities information necessary to make informed decisions about the benefits and risks related to the consumption of country food.

ITK Department of Environment Wildlife is dedicated to improving its ability to monitor progress on files that impact the environment and wildlife across Inuit Nunangat. We also have increased ability to participate at the national level in the development of policies and practices that ensure a healthy Arctic environment. Our Department will continue to advocate and stimulate research on environmental issues that affect Inuit. Dedication to these activities, in cooperation with Regional Inuit Organizations and ICC (Canada), will guarantee that impacts effecting northern ecosystems and Northerners will be identified and addressed, ensuring that Inuit, through ITK, will help maintain the Arctic environment and its species for future generations to enjoy.

We, the Environment Department at ITK, are proud of the work we have accomplished, the relationships we have forged, the degree to which we have successfully promoted an Inuit specific agenda, and the representation we provide for Canadian Inuit.

Expected project completion date

Ongoing

Acknowledgments

The ITK would like to acknowledge the NCP for their funding and support direction, insight and vision. This program continues to be a flagship program for research in Canada. We would also like to acknowledge all of the NCP researchers who work hard to make sure that Inuit stay healthy and are able to access safe country foods. This program would not be possible without the advice and direction provided by the Regional Contaminants Committees who often volunteer their time and knowledge to the program. I would also like to thank the Inuit Research Advisors who make sure that the researchers are supported and that the communities understand all the research being generated from the program, it’s a tough job and they are unbelievable.

Inuit Circumpolar Council – Canada activities in support of circumpolar and global contaminant instruments and activities 2018-2019

Conseil circumpolaire inuit – Activités du Canada en appui aux activités et aux outils visant les contaminants circumpolaires et mondiaux

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Abstract

This report outlines ICC Canada's activities funded by the Northern Contaminants Program (NCP) in the fiscal year 2018-2019. 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. Internationally, ICC Canada continued its activities related to the United Nations Environment Programme (UNEP). Work on the Stockholm Convention on Persistent Organic Pollutants (POPs) and Minamata Convention on Mercury is ongoing, with ICC Canada attending the 14th POP Review Committee (POPRC) in October 2018, and giving a platform presentation during a

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 2018-2019. 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. À l'échelle internationale, le CCI Canada a poursuivi ses activités se rapportant au Programme des Nations Unies pour l'environnement (PNUE). Les travaux concernant la Convention de Stockholm sur les polluants organiques persistants (POP) et la Convention de Minamata sur le mercure

side event at the second Conference of the Parties of the Minamata Convention. 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).

sont en cours. Le CCI Canada participera à la 14[e] réunion du Comité d'examen des POP en octobre 2018, et fera une présentation de plateforme lors d'un événement parallèle à la deuxième conférence des parties de la Convention de Minamata. 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 Community Based Monitoring technical review committees.
- ICC Canada attended the 14[th] POP Review Committee (POPRC) meeting, provided input in POPRC working group documents, and informed the NCP and AMAP about POPRC work.
- ICC Canada attended the second Conference of the Parties (COP-2) of the Minamata Convention and gave a platform presentation during a side event on monitoring activities 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, de santé humaine et de surveillance s'appuyant sur la collectivité.
- Le CCI Canada a assisté à la 14e 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 PSEA au sujet des travaux du Comité.
- Le CCI Canada a participé à la deuxième Conférence des Parties (COP-2) de la Convention de Minamata et a fait une présentation de plateforme lors d'un événement parallèle sur les activités de surveillance sur la façon dont les Inuits sont touchés par le mercure dans l'Arctique, ainsi que sur les activités de surveillance dans l'Arctique dans le cadre 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 the Mercury Expert group, and is leading a chapter on risk communication for the upcoming AMAP Assessment on Human Health in the Arctic, as well as co-leading a chapter on Indigenous perspectives for the upcoming AMAP Mercury Assessment.

- Le CCI Canada a joué un rôle très actif au sein du groupe d'évaluation de la santé humaine du PSEA et du groupe d'experts sur le mercure, et dirige un chapitre sur la communication des risques pour la prochaine évaluation du PSEA sur la santé humaine dans l'Arctique. Il co-dirige également un chapitre sur les perspectives autochtones pour la prochaine évaluation du mercure par le PSEA.

Objectives

Short-term

The aim of the Inuit Circumpolar Council is to ensure that:

- Inuit are aware of global, circumpolar and national activities and initiatives on contaminants;
- 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
- scientific research in the Arctic is addressing Inuit needs and is done with Inuit support and involvement.

Long-term

The 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 the need to have a united voice to represent them internationally, and to represent circumpolar Inuit in their respective countries. Since then, ICC has been growing into an internationally renowned organization with offices in each of the four countries. ICC is working successfully to address Inuit concerns on matters and overarching issues such as health, the environment, and culture. Among ICC's principle goals are the promotion of Inuit rights and interests on an international level and the development and encouragement of long-term policies that safeguard the Arctic environment.

A very important issue for Inuit is contaminants which undergo long-range transport, bioaccumulate in the Arctic ecosystem and lead to high concentrations in some Inuit populations, potentially impacting their health and well-being. Funding 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, is a Permanent Participant of the Arctic Council and works within the Arctic Monitoring and Assessment Programme (AMAP), and represents Inuit at the United Nations Environment Programme (UNEP) and related meetings.

Activities in 2018-2019

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 2018-2019.

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 Community-based Monitoring technical review teams, and provided comments for the NCP blueprints. ICC Canada attended Management Committee meetings in Nain, Nunatsiavut on April 10 – 12, and in Ottawa November 6 - 8, 2018, as well as the preceding Chemical Management Plan 101 meeting at Health Canada on November 5th, and provided updates about international activities.

The NCP secretariat and ICC Canada developed a contaminant session at the ArcticNet Science Meeting in Ottawa, December 12 – 14, 2018. The session was co-organized and co-chaired by Jean Allen (Nunavut Government/NTI), Emma Pike (CIRNAC Yellowknife), and Eva Kruemmel (representing ICC Canada). During the session, Eva Kruemmel gave a presentation of ICC's international activities on contaminants (presentation is listed under Communications below).

Arctic Monitoring and Assessment Programme (AMAP)

General

ICC Canada participated in the AMAP Working Group meeting on September 25 – 27, 2017, and the Heads of Delegation (HoD) meeting following it on September 28, in Kiruna, Sweden, as well as the AMAP HoDs meeting April 1 – 2, 2019 in Washington DC. ICC reviewed and provided input into AMAP documents before and after the meetings and provided briefings about the meetings and AMAP activities to the NCP Regional Contaminant Committees (RCCs).

ICC Canada was very active in the drafting of AMAP's Strategic Framework 2019+, and ensured that Inuit positions are reflected in the document.

ICC also participated in an AMAP group "mission to United Nations Environment" consisting of the AMAP secretariat (Rolf Rødven, Simon Wilson), Derek Muir (Canada, co-chair of the POPs Expert Group), Timo Seppälä (Finland), and Mikala Klint (Denmark). The group met with several representatives working under the umbrella of UN Environment: Stockholm Convention on Persistent Organic Pollutants (POPs) secretariat, Minamata Convention on Mercury Secretariat, and representatives responsible for the Strategic Approach to International Chemicals Management (SAICM). The meeting was held to brainstorm about approaches on how AMAP and UN Environment can work better together.

Further, ICC Canada continues to pursue the development of a pilot project to advance Indigenous participation and the utilization of Indigenous knowledge in AMAP's work. This is also in alignment with objectives and goals described in AMAP's Strategic Framework 2019+. ICC will continue to work with its partners (Canadian and US governments/ AMAP HoDs, Saami Council, Arctic Athabascan Council) towards the implementation of this pilot project.

Sustaining the Arctic Observing Network (SAON)

Eva Kruemmel represents ICC on the SAON Board, the SAON Executive Committee, and is a member of the organizing committee of the Arctic Observing Summit (AOS), which is a SAON activity. ICC participated in teleconferences of the SAON Executive Committee, SAON Board, task forces, as well as teleconferences of the AOS organizing committee. ICC Canada helped organize the AOS that took place in Davos, Switzerland June 24 – 26, 2018, led one of the working groups, and attended the SAON Board meeting that took place on June 23rd, 2018, before the AOS. ICC tries to ensure that Indigenous knowledge, community-based monitoring and ethical research remain at the center of SAON's activities.

ICC was also engaged in the development of a SAON side-event "Towards a Roadmap for Coordinated Arctic Observing" on 24th October 2018 during the Arctic Science Ministerial Meeting in Berlin, Germany, and invited Ellen Avard (Director of the Nunavik Research Centre) to give a presentation on Nunavik's monitoring activities. Carolina Behe from ICC Alaska presented on ICC's perspective with regards to Indigenous knowledge and community-based monitoring in Arctic observing activities (the presentations are listed below under "Communications").

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 is currently working on a new Human Health assessment. Eva Kruemmel is again leading a chapter on risk communication and has contacted Inuit regions and NCP RCCs for input. This work is funded by Health Canada.

ICC Canada attended the HHAG meeting on February 27 – March 1 in Quebec City, reviewed associated documents and provided comments, and participated in several teleconferences.

POPs Expert Group

ICC Canada reviewed the technical chapters of the Biological Effects of Contaminants on Wildlife and Fish and provided comments. ICC Canada's comments are aimed to provide an Inuit perspective on the assessment content, and included updates related to activities of the Stockholm Convention on POPs and the POP Review Committee.

ICC Canada further developed a section on knowledge gaps (co-authored with ICC Alaska, Saami Council, and Jennifer Provencher of Environment and Climate Change Canada) in the Biological Effects assessment (see References), had several teleconferences on the topic with the AMAP secretariat, assessment lead and co-authors, and made further edits to the contribution.

Mercury Expert Group

ICC Canada attended the kick-off meeting of the Mercury Expert Group's next assessment, which took place December 10-11, 2018 during the ArcticNet Scientific Meeting in Ottawa. Eva Kruemmel represented ICC, and also invited Ennoyaq Sudlovenick to the meeting. Ennoyaq, who is currently finalizing her master's thesis in Iqaluit on mercury in seals, attended part of the meeting, and is interested to contribute to the mercury assessment. ICC Canada is co-leading a chapter on Indigenous activities (together with Magali Houde from Environment and Climate Change Canada), and has contacted Inuit regions and NCP Regional Contaminant Committees to solicit input into the chapter.

United Nation (UN) related activities

Minamata Convention on Mercury

The second Conference of the Parties (COP-2) of the Minamata Convention on Mercury took place November 19 – 23, 2018 in Geneva, Switzerland. Eva Kruemmel represented ICC at the meeting, gave an intervention on the topic of effectiveness evaluation, which highlighted mercury monitoring done under NCP and AMAP, and participated in contact group meetings on Effectiveness Evaluation during COP-2. ICC was further invited to present a talk about mercury monitoring in the Arctic during a monitoring side event, which included activities of the NCP and AMAP (see list of presentations below under "Communications").

Eva Kruemmel represented ICC as an invited observer at the ad-hoc Expert Group on Effectiveness Evaluation of the Minamata Convention meeting on November 18, 2018, in Geneva, Switzerland, participated in teleconferences of the group and continued to provide input into the reports. These reports will be presented to COP-3 of the Minamata Convention in November 2019.

Stockholm Convention on Persistent Organic Pollutants (POPs) – POP Review Committee (POPRC)

NCP funds allowed ICC Canada to participate in activities of the Stockholm Convention's POP Review Committee (POPRC) in 2018. ICC Canada worked in contact groups and intersessionally to provide input on risk profiles of several POP candidates. Eva Kruemmel attended the 14th POPRC meeting, which took place in Rome, Italy, on September 17 – 21, 2018, intervened to highlight Inuit concerns about contaminants under review and pointing out monitoring/research results from AMAP and NCP. ICC Canada further actively participated in contact groups and had discussions at the meeting with government and other representatives to emphasize contaminant levels in the Arctic which are of concern for Inuit.

Other mercury and POPs related work

Eva Kruemmel 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.

Community engagement

ICC is the Inuit organization that represents Inuit internationally, but, due to the structures that Canadian Inuit have created to organize their work, ICC Canada is usually not active on a community level. ICC is connected to Inuit regions and communities through its Board members (comprised of Inuit leaders from all Inuit regions) who oversee ICC's work, as well as the General Assemblies, which take place every four years, and are attended by Inuit delegates from all Inuit regions. During ICC General Assemblies, the ICC leadership is elected, and an ICC declaration is drafted, which guides ICC's activities for the next four years. Additionally, ICC works closely with Canada's national Inuit organization, Inuit Tapiriit Kanatami (ITK), and is an ex-officio member in all ITK Inuit committees relevant to ICC's work. Furthermore, ICC Canada wants to ensure Inuit communities are aware of the international work and connect local/regional Inuit experts to ICC's international activities more directly. For example, ICC Canada asked Liz Pijogge, PI of NCP-funded project CB-10: "*Community Monitoring of Plastic Pollution in Wild Food and Environments in Nunatsiavut*", if she would be willing to be an expert on the newly founded AMAP expert group on Plastics, and she graciously agreed.

Capacity building and training

The lack of capacity in Inuit organizations, regions, and communities is a very big problem. Whenever possible, ICC Canada employs Inuit students, and tries to bring youth or Inuit experts to international fora. As described above, ICC Canada also has engaged in discussions with various partners on how to increase local and regional capacity to be able to have them involved in ICC's international work. These efforts are ongoing.

ICC Canada participated in the ArcticNet Scientific Conference that took place on December 12 - 14, 2018 in Ottawa, as mentioned above. ICC Canada leadership also attended the conference and participated in panel discussions: Lisa Koperqualuk (ICC Canada Vice President) presented how the National Inuit Strategy on Research is implemented internationally through NCP activities, AMAP, Stockholm and Minamata conventions, and other fora.

Other talks on ICC activities given by ICC leadership included a presentation by ICC Canada President Monica Ell-Kanayuk during the Arctic Science Forum in October 24, 2018 (associated with the Arctic Ministerial Meeting) in Berlin, Germany, and Okalik Eegeesiak (ICC Chair until July 2018) during the Arctic Science Summit Week, 19 June 2018 in Davos, Switzerland (please see details in the list below).

ICC Canada has been improving its web presence with a revamped website (http://www.inuitcircumpolar.com) and has Facebook and Twitter accounts, where updates are about ICC's work are regularly posted. 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 2018/2019

- EM Kruemmel, Carolina Behe, Stephanie Meakin, Joanna MacDonald. Presentation "Inuit Circumpolar Council (ICC) – Global Actions on Contaminants" in the "Arctic Contaminants: Emerging Concerns" session, ArcticNet Science Meeting, 12 December 2018, Ottawa, Canada.
- EM Kruemmel. Invited presentation "Arctic Monitoring Activities". Side event "Existing Global Mercury Monitoring Networks and Programs" during the 2nd Conference of Parties (COP-2) of the Minamata Convention on Mercury, 22nd November 2018, Geneva, Switzerland.
- EM Kruemmel. Invited lecture "Arctic Research and International Policy Development on Contaminants" for the University of Ottawa course "Toxicology and Regulation", 1 November 2018, Ottawa, Canada.
- C Behe. Invited presentation: "Indigenous Knowledge, Indigenous Community Based Monitoring and Coordinated Observation Systems" at SAON side event "Towards a Roadmap for Coordinated Arctic Observing" during the Arctic Science Ministerial, 24 October 2018, Berlin, Germany.
- E Avard. Invited presentation: "The Nunavik Research Centre – 40 years of Inuit-Led Research" at SAON side event "Towards a Roadmap for Coordinated Arctic Observing" during the Arctic Science Ministerial, 24 October 2018, Berlin, Germany.
- M Ell-Kanayuk. "Inuit Perspectives on Societal Needs in Arctic Observing". Invited plenary presentation during Arctic Science Forum, 25 October 2018, Berlin, Germany.
- JO Eegeesiak. Invited presentation on the Inuit Circumpolar Council. Open Science Conference during the Arctic Science Summit Week, 19 June 2018, Davos, Switzerland.
- EM Kruemmel. Invited panel contribution on the AACA report for the Canadian Archipelago-Greenland Region. AMAP International Conference on Arctic Science. 24 - 27 April 2017, Reston, Virginia, USA.
- EM Kruemmel, Andrew Gilman, Carolina Behe, James Berner, Michael Brubaker, Alexey Dudarev, Parnuna Egede, Stephanie Meakin, Gina Muckle, Gert Mulvad, Pál Weihe, Shawn Donaldson. Presentation on "Communicating contaminant risk in the circumpolar Arctic and internationally", AMAP International Conference on Arctic Science. 24 - 27 April 2017, Reston, Virginia, USA.

Indigenous Knowledge

The enhanced utilization of Inuit knowledge in all of ICC's work is at the centre of ICC's activities. In ICC's Utqiaġvik Declaration 2018 the section on "Indigenous Knowledge" states:

"Indigenous Knowledge is a systematic way of thinking applied to phenomena across biological, physical, cultural and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observations, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Under this definition, it is recognized that Inuit Knowledge is a way of life. It goes beyond observations, ecological knowledge, and research, offering a unique 'way of knowing'.

Inuit have a right to self-determination in all facets of life, including in the promotion of Indigenous Knowledge and research.

Recognizing the work that ICC has done to advance the understanding and utilization of Indigenous Knowledge is important to continue this work and, furthermore, focus on advocating for Inuit driven research and monitoring, equitable partnerships in all aspects of research, information sovereignty, and working to increase intellectual and political space for Inuit across scales.

To advance self-determination and recognition of Indigenous knowledge the following is needed:

27. Direct ICC to facilitate the development of International Inuit protocols on the equitable and ethical utilization of Indigenous Knowledge and engagement of Inuit communities to provide guidance to international fora, such as the Arctic Council;

28. Instruct ICC to engage appropriate international forums (e.g. Arctic Council, United Nations Framework Convention on Climate Change, Convention on Biological Diversity, Intergovernmental Panel on Climate Change) in all aspects of Arctic science and research to contribute to the advancement of Inuit self-determination by promoting and contributing to activities that achieve partnerships and reflects the utilization of both Inuit Knowledge and science;

29. Direct ICC to continue to educate the international community on what Inuit Knowledge is and to work to make political and intellectual space for Inuit Knowledge holders at international fora by protecting the intellectual property rights of Inuit Knowledge holders;

30. Call for an Inuit review of the consultation process of the Arctic Council Arctic Science Cooperation Agreement, and all appropriate United Nations agencies to identify actions to ensure these legal instruments adhere to the human rights affirmed in the United Nations Declaration."

Therefore, ICC is continuously working to further improve the utilization of Inuit knowledge internationally, for example by working on a framework to enhance Arctic Indigenous Peoples engagement in AMAP's work and creating opportunities for Inuit knowledge holders to be active in AMAP expert groups (as described above) and other work, as is possible.

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-14, 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. The successful outcome of POPRC-14 was that the committee decided to recommend one perfluorinated compound (PFOA) for addition to Annex A of the Stockholm Convention, recommended the elimination of several uses for another already listed perfluorinated compound (PFOS) and advanced a third one (PFHxS) further in the review process. ICC Canada continues to be engaged in the Minamata Convention, gave an intervention during COP-2, and presented during a side event on mercury monitoring activities conducted by NCP and AMAP in the Arctic. At the Arctic Council, ICC Canada attended AMAP-related meetings, contributed to and reviewed AMAP assessments, presented at the AMAP science conference and actively contributed to other related initiatives, such as SAON and the AOS. ICC Canada supported the NCP with contributions to the management structure of the NCP program. 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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References

Chapter 5 Future perspectives: Robert J. Letcher, Rune Dietz, Carolina Behe (Inuit Circumpolar Council, Alaska), Jean-Pierre Desforges, Igor Eulaers, Eva M. Kruemmel (Inuit Circumpolar Council, Canada), Melissa A. McKinney, Jennifer Provencher (Acadia University, Canada), Christian Sonne, Jannie Staffansson (Saami Council, Sweden), Simon Wilson; and

Chapter 6 Synthesis and knowledge gaps: Robert J. Letcher, Rune Dietz, Jean-Pierre Desforges, Igor Eulaers, Eva M. Kruemmel, Melissa A. McKinney, Christian Sonne, Simon Wilson. In AMAP, 2018. **AMAP Assessment 2018: Biological Effects of Contaminants on Arctic Wildlife and Fish**. Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway. vii+84pp