Synopsis of Research

Conducted under the 2009-2010 Northern Contaminants Program

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Canada

Synopsis of Research Conducted under the 2009-2010 Northern Contaminants Program

F.P.O.

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Foreword

This report provides a summary of the progress to date of research and monitoring studies on contaminants in northern Canada, and related education, communications and policy activities that were conducted in 2009-2010 under the auspices of the Northern Contaminants Program (NCP). The projects cover all aspects of northern contaminants issues, as outlined in the NCP blueprints, including human health, monitoring the health of Arctic peoples and ecosystems and the effectiveness of international controls (abiotic monitoring and modeling, and biotic monitoring), education and communications, international policy and program management.

These projects were evaluated as proposals, by external peer reviewers, technical review teams, regional contaminants committees, and the NCP Management Committee to ensure that they support the overall Northern Contaminants Program objectives.

Further information about the Northern Contaminants Program is available on the NCP website at http://www.ainc-inac.gc.ca/nth/ct/ncp/index.asp.

Official Languages Disclaimer
These synopsis reports are published in the language chosen by the researchers. The full reports have not been translated. The Abstracts are available in English and French at the beginning of each report. Complete individual project synopses are available in either official language, upon request. Requests for individual reports can be made to: PLCN-NCP@ainc-inac.gc.ca.

Avant-propos

Le présent rapport comporte un résumé des progrès réalisés à ce jour dans le cadre des projets de recherche et des études de contrôle sur les contaminants dans le Nord canadien ainsi que des activités de sensibilisation, de communication et d'orientation menées en 2009-2010 sous l'égide du Programme de lutte contre les contaminants dans le Nord (PLCN). Les projets portent sur tous les aspects du dossier des contaminants dans le Nord, décrits dans les plans directeurs du PLCN, soit la santé humaine, la surveillance de la santé des résidants et des écosystèmes de l'Arctique et de l'efficacité des mécanismes internationaux de contrôle (surveillance abiotique et modélisation; surveillance biotique), l'éducation et les communications, la politique internationale et la gestion de programme.

Des pairs examinateurs de l'extérieur, des équipes d'examen technique, des comités territoriaux sur les contaminants, un comité régional sur les contaminants et le comité de gestion du PLCN ont évalué les propositions de projet, afin de s'assurer de la réalisation des objectifs du programme.

Pour obtenir d'autres renseignements, consultez le site Web du Programme de lutte contre les contaminants dans le Nord, à l'adresse http://www.ainc-inac.gc.ca/nth/ct/ncp/index.asp.

Avertissement lié aux langues officielles
Les chercheurs ont rédigé leurs rapports dans la langue de leur choix. Les rapports n'ont pas été traduits en entier, mais comportent un résumé en anglais et en français, au début. Il est possible d'obtenir sur demande le synopsis d'un projet dans l'une ou l'autre des langues officielles. Pour obtenir un rapport, envoyez un courriel à l'adresse PLCN-NCP@ainc-inac.gc.ca.

Introduction

The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in fish and wildlife species that are important to the traditional diets of northern Aboriginal peoples. Early studies indicated that there was a wide spectrum of substances – persistent organic pollutants, heavy metals, and radionuclides – many of which had no Arctic or Canadian sources, but which were, nevertheless, reaching unexpectedly high levels in the Arctic ecosystem.

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

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

Extensive consultations were conducted in 1997-1998 to find the common elements between the concerns and priorities of northern communities and the scientific needs identified as critical for addressing the issue of contamination in Canada's North. As a result, priorities for current and future research are based on an understanding

Le Programme de lutte contre les contaminants dans le Nord (PLCN) a été créé en 1991, en réaction aux inquiétudes que suscitait l'exposition des humains à des concentrations élevées de contaminants chez les espèces sauvages aquatiques et terrestres constituant une part importante du régime alimentaire traditionnel des populations autochtones du Nord. Les premières études ont mis en évidence une vaste gamme de substances – polluants organiques persistants (POP), métaux lourds et radionucléides –, substances qui dans de nombreux cas n'avaient pas de source dans l'Arctique, ni même au Canada, mais qui se retrouvaient néanmoins à des concentrations anormalement élevées dans l'écosystème de l'Arctique.

Le Programme a comme principal objectif *de travailler à réduire et, dans la mesure du possible, à éliminer les contaminants présents dans les aliments traditionnels, tout en fournissant de l'information pour aider les individus et les collectivités à prendre des décisions éclairées au sujet de leur alimentation*.

Le premier volet du PLCN (PLCN-I) visait principalement à réunir les données nécessaires pour déterminer les concentrations, l'étendue géographique et la source des contaminants dans l'atmosphère, l'environnement et les habitants du Nord ainsi que la durée probable du problème. L'information recueillie a permis de comprendre les tendances spatiotemporelles de la contamination dans le Nord et de confirmer les soupçons à savoir que les principales sources de contaminants se situent à l'étranger. De plus, ces données, qui portaient notamment sur les bienfaits de la consommation régulière de tels aliments, ont servi à évaluer les risques pour la santé humaine de la présence de contaminants dans les aliments traditionnels. Dans le Rapport de l'évaluation des contaminants dans l'Arctique canadien, on présente les résultats obtenus dans le cadre du PLCN-I.

De vastes consultations ont été menées en 1997-1998 en vue de concilier les préoccupations et priorités of the species that are most relevant for human exposure to contaminants in the North, and geographic locations and populations that are most at risk.

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

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

The NCP is directed by a management committee that is chaired by the Indian and Northern Affairs Canada, and which includes representatives from

des collectivités du Nord et les activités scientifiques nécessaires pour traiter la question des contaminants dans le Nord canadien. Ainsi, on a établi, pour les travaux actuels et à venir, des priorités fondées sur la définition des espèces principales par lesquelles les habitants du Nord se trouvent exposés aux contaminants ainsi que des régions et des populations les plus à risque.

Dans le deuxième Rapport de l'évaluation des contaminants dans l'Arctique canadien, on trouve une synthèse des résultats du second volet du Programme (PLCN-II), mis en oeuvre de 1998-1999 à 2002-2003. Les recherches menées au cours de ce volet visaient à déterminer les risques et conséquences pour la santé humaine associés au degré actuel de contamination d'aliments clés dans l'Arctique. Pour que l'évaluation des risques soit juste, on a aussi défini et quantifié les avantages des régimes traditionnels. On a aussi mis l'accent sur les activités de communication dans le cadre du PLCN-II. Sous la conduite des organisations autochtones du Nord, le dialogue entre les habitants de la région et la communauté scientifique, amorcé lors du PLCN-I, a continué d'accroître la sensibilisation aux questions liées aux contaminants et la compréhension de celles-ci et a permis d'améliorer la prise en charge de certains problèmes associés aux contaminants à l'échelle locale. En outre, les efforts déployés dans le cadre du PLCN afin d'assurer l'établissement de mécanismes internationaux de contrôle des contaminants sont demeurés un objectif privilégié du second volet. À l'occasion de la Conférence ministérielle de la Commission économique des Nations Unies pour l'Europe, ayant eu lieu à Aarhus, au Danemark, en juin 1998, trente-quatre pays (dont le Canada) ont signé le protocole sur les POP, ayant force obligatoire, dans le cadre de la Convention sur la pollution atmosphérique transfrontalière à longue distance. Le Canada a ratifié l'entente en décembre 1998. Les négociations visant la conclusion d'un accord global sur les POP, ayant force obligatoire, dans le cadre du Programme des Nations Unies pour l'environnement, ont abouti à la signature de la Convention sur les polluants organiques persistants, à Stockholm, en Suède, le 23 mai 2001, par plus de cent soixante pays. Le Canada a signé et ratifié la Convention. Les efforts concertés déployés dans le cadre des travaux du Conseil de l'Arctique, ce qui comprend le Programme de surveillance et d'évaluation de l'Arctique et le Plan four northern Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapiriit Kanatami, and Inuit Circumpolar Council), the Yukon, Northwest Territories and Nunavut Territorial Governments, Nunavik, and four federal departments (Environment, Fisheries and Oceans, Health, and Indian Affairs and Northern Development). The management committee is responsible for establishing NCP policy and research priorities and for final decisions on the allocation of funds. Three territorial contaminants committees in the Yukon, Northwest Territories and Nunavut, and a regional contaminants committee in Nunavik support this national committee. Funding for the NCP's $4.8 million annual research budget comes from INAC and Health Canada.

The NCP Operational Management Guide, available on the NCP website (www.ainc-inac.gc.ca/ncp), provides a summary of the management structures and review processes used to effectively implement the NCP. The Guide explains the overall management structures currently used, the proposal review process and outlines a protocol to be used to publicly disseminate health and harvest information generated by the NCP. Background information on all NCP committees and review teams is also provided.

In 1998, the NCP Management Committee redesigned the NCP-Phase II for application under the 1999-2000 funding year. The two main initiatives undertaken were: 1) the development of blueprints that represent the long-term vision and strategic direction for NCP-II; and 2) the implementation of a more open and transparent proposal review process. This new management structure is designed to ensure that the NCP remains scientifically defensible and socio-culturally aware, while at the same time, achieving real progress in terms of the Program's broad policy objectives.

Blueprints were developed for each of the three main NCP subprograms: i) Human Health, ii) Monitoring the Health of Arctic People and Ecosystems and the Effectiveness of International Controls, and iii) Education and Communications. The blueprints are used to provide the necessary guidance to project proponents for the development of proposals as well as to peer reviewers, review

d'action du Conseil de l'Arctique, se poursuivent. Les données recueillies dans le cadre du PLCN permettent au Canada de jouer un rôle de premier plan dans ces initiatives.

Le PLCN est dirigé par un comité de gestion, présidé par Affaires indiennes et du Nord Canada (AINC), qui compte des représentants de quatre organisations autochtones du Nord (soit le Conseil des Premières nations du Yukon, la Nation dénée, Inuit Tapiriit Kanatami et la Conseil circumpolaire inuite), des gouvernements du Yukon, des Territoires du Nord-Ouest et du Nunavut, du Nunavik et de quatre ministères fédéraux (Environnement Canada, Pêches et Océans Canada, Santé Canada et Affaires indiennes et du Nord Canada). Le comité de gestion est chargé de l'établissement des priorités du PLCN en matière de politique et de recherche et de la prise des décisions définitives en matière de financement. Trois comités territoriaux sur les contaminants (Yukon, Territoires du Nord-Ouest et Nunavut), et un comité régional sur les contaminants (Nunavik) appuient les travaux du comité national. Les fonds pour le budget annuel de recherche de 4,8 millions de dollars du PLCN-II proviennent d'AINC et de Santé Canada.

Le Guide de gestion des opérations du Programme de lutte contre les contaminants dans le Nord, que l'on peut consulter sur le site Web du Programme (www.ainc-inac.gc.ca/ncp), comprend un résumé des structures de gestion et des processus d'examen utilisés pour assurer la mise en oeuvre efficace du PLCN. On y présente les structures globales de gestion actuelles, le processus d'examen des projets et la marche à suivre pour la diffusion publique d'informations sur la santé et la récolte recueillies dans le cadre du Programme. Le Guide comporte aussi des renseignements généraux sur tous les comités et équipes d'examen du PLCN.

En 1998, le comité de gestion du PLCN a réorienté le second volet du Programme en vue de l'exercice financier 1999-2000. Deux initiatives clés ont été mises en oeuvre, soit : 1) l'élaboration de plans directeurs représentant la vision à long terme et l'orientation stratégique du second volet; 2) la mise en oeuvre d'un processus ouvert et transparent d'examen des propositions. Cette nouvelle structure de gestion visait à assurer le caractère défendable du Programme du point de vue scientifique et la prise en compte des aspects socioculturels, tout en assurant la réalisation de progrès réels en ce qui a trait aux teams and the NCP Management Committee for evaluating proposals. They are evolving documents that are reviewed at least annually.

A revamped proposal review process involves an external peer review process facilitated by review teams. The review of proposals is a two pronged approach involving a scientific review by external peer reviewers, facilitated by technical review teams, and a socio-cultural review facilitated by the Regional Contaminants Committees (RCCs). Both sets of recommendations are considered by the management committee in making final funding decisions. Proposals submitted under the Education and Communications subprogram are evaluated by a technical review team. All peer reviewers, review teams and RCCs use evaluation criteria and the blueprints to review and rate proposals. Written consent from the appropriate northern community authority or national-level Aboriginal organization is required for all projects involving field work in the North and/or analyses of samples as a condition of approval for funding.

This report provides a summary of the progress to date of research and activities funded by the Northern Contaminants Program in 2009-2010. It is a compilation of reports submitted by project teams, emphasizing the results of research and related activities that took place during the 2009-2010 fiscal years. The report is divided into chapters that reflect the broad scope of the NCP: Human Health; Environmental Monitoring and Research, and Education and Communications.

objectifs stratégiques généraux du PLCN. On a créé un plan directeur pour chacun des trois sous-programmes principaux : i) santé humaine; ii) surveillance de la santé des habitants et des écosystèmes de l'Arctique et de l'efficacité des mécanismes internationaux de contrôle; iii) éducation et communications. Ces plans fournissent les directives nécessaires aux promoteurs de projet, pour l'élaboration de leurs propositions, ainsi qu'aux pairs examinateurs, aux équipes d'examen et au comité de gestion du PLCN, pour l'évaluation des projets. Il s'agit de documents évolutifs, examinés au moins une fois par année.

Par suite de changements apportés au processus d'examen, un processus d'examen externe par les pairs, facilité par des équipes d'examen, a remplacé le comité technique du PLCN. L'évaluation des projets se fonde sur une approche à deux volets comprenant un examen scientifique par des pairs examinateurs de l'extérieur (facilité par des équipes d'examen technique) ainsi qu'un examen des aspects socioculturels, mené par les comités sur les contaminants. Le comité de gestion se penche sur les deux types de recommandation en vue de la prise de décisions définitives en matière de financement. Un comité d'examen technique évalue les projets soumis dans le cadre du sous-programme sur l'éducation et les communications. Les pairs examinateurs, les équipes d'examen et les comités sur les contaminants se servent des critères d'évaluation et des plans directeurs pour évaluer et noter les projets. Le consentement écrit d'une autorité compétente de la collectivité nordique ou d'une organisation autochtone nationale est requis pour tous les projets comportant des travaux sur le terrain dans le Nord ou des analyses d'échantillons, comme condition d'approbation du financement.

Le présent rapport comporte un résumé des progrès accomplis à ce jour relativement aux travaux de recherche et aux activités financés par le Programme de lutte contre les contaminants dans le Nord, en 2009-2010. Il s'agit d'une compilation des données provenant des rapports soumis par les équipes de projet. On met l'accent sur les résultats des travaux de recherche et des activités connexes menés au cours de l'exercice 2009-2010. Les chapitres du rapport rendent compte de la portée étendue du programme: soit la santé humaine; les tendances environnementales surveillance et de recherche, et l'éducation et les communications.

Human Health

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Abstract
We have conducted three studies in Nunavik during the last 15 years: monitoring of prenatal exposure based on cord blood sampling, and two effect studies, one with infants up to 12 months of age, and one at preschool age. The proposed study aimed to follow-up these three cohorts of children at 10-11 years of age. The objectives were to document the long-term effects of pre- and postnatal exposure to environmental contaminants and to evaluate the degree to which omega-3 fatty acids and selenium may protect against adverse effects. This 5-year study involves 294 school-age children from the 14 Nunavik communities. Year 2009/2010 was devoted to data collection, data analyses and publications.

Résumé
Nous avons effectué trois études au Nunavik au cours des 15 dernières années : surveillance de l'exposition prénatale par échantillonnage de sang de cordon, ainsi que deux études sur les effets, une sur les nourrissons de 0 à 12 mois et une sur les enfants d'âge préscolaire. L'étude préposée visait à suivre ces trois cohortes d'enfants à l'âge de 10 à 11 ans. Nous voulions ainsi documenter les effets à long terme de l'exposition prénatale et postnatale à des contaminants environnementaux et évaluer la mesure dans laquelle les acides gras oméga 3 et le sélénium protégeaient contre la survenue d'effets indésirables. Cette étude de cinq ans a porté sur 294 enfants d'âge scolaire provenant de 14 communautés du Nunavik. L'année 2009 2010 a été consacrée à la collecte de données, à des analyses de données et à diverses publications.

Key Messages

- The data collection for this study started in October 2005 and ended in February 2010, with 294 Nunavik children successfully tested at 11 years of age.
- Year 2009/2010 was devoted to data collection, updating of the database, data analyses and publications.
- The data collection in completed and all study results will be available in 2010/2011.

Messages clés

- La collecte de données pour cette étude a débuté en octobre 2005 et s'est terminée en février 2010, 294 enfants du Nunavik ayant été testés à l'âge de 11 ans.
- L'année 2009 2010 a été consacrée à la collecte de données, à la mise à jour de la base de données, à des analyses de données et à des publications.
- La collecte de données est terminée et tous les résultats de l'étude seront accessibles en 2010 2011.

Objectives

The **overall objectives** of this prospective study were:

- To document the long-term effects of pre- and postnatal exposure to environmental contaminants such as PCBs, MeHg and lead in multiple domains.
- To evaluate if nutrients, such as polyunsaturated fatty acids (PUFAs) and selenium (Se), can protect against adverse effects of exposure to environmental contaminants.
- To document the impact of lifestyle factors, such as smoking, alcohol and drug use during pregnancy, on multiple domains of child development and behaviour and to document the specific contributions of exposure to environmental contaminants and these other substances to development and behaviour of Inuit children.

Activities in 2009/2010

- One last data collection trip to Puvirnituq to test about 30 children.
- Data coding, data entry and update of the data base with results from children tested in February-March 2009 and children tested during the last data collection trip.
- Data analyses on all available outcomes.
- Development of an innovative statistical approach to test the hypothesis: multilevel modeling.
- Presentation of final results to the NNHC.
- In collaboration with the NNHC, planning and development of communication activities and tools to be used when communicating the study results to the Nunavik population.

The data collection trip, scheduled for spring 2009, was first postponed to fall 2009 and re-postponed to January 2010 due to a serious illness requiring hospitalization of a key member of our Inuit personnel, the person responsible for child testing since the beginning of study. We postponed the field work the longer we could to be able to have this person in our team for the last data collection trip. Unfortunately, she did not recovered enough to be back to work. We hired another Inuit woman who, after training, was able to perform the testing; she successfully tested 18 children. The data collection ended in February 2010, and the following two months were required for coding the instruments and data entry. The updating of the data set is ongoing and the data base will be ready for final statistical analyses on all outcomes at the end of June 2010. Consequently, the presentation of final results to the NNHC was delayed to year 2010-2011, when analyses with the full sample will be completed.

During year 2009/2010, results from previous phases of this prospective study were published in following peer reviewed journals as well as those already presented to the NNHC involving outcomes documented through electrophysiological assessments with 2/3 of sample:

Boucher, O., Bastien, C. H., Muckle, G., Saint-Amour, D., Jacobson, S. W., & Jacobson, J. L. (2010). Behavioural correlates of the P3b event-related potential in 11-year-old children. *International Journal of Psychophysiology*. DOI:10.1016/j.ijpsycho.2010.03.005.

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Farrer D., Poulsen, M., Davoli, D., Bailey, M., Moffett, D., Fowler, D., Welsh, C., Yang, R., Ayotte, P., Verner, M.-A., Muckle, G., Haddad, S. (2010/03). Comparison of estimated PCB-153 concentrations in human milk using various pharmacokinetic models. 49th Annual Meeting and ToxExpo, Salt Lake City, Utah, USA.

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Most significant findings to date could be summarized from the following selected abstracts:

A) Citation from Plusquellec, Muckle et al. 2010.

"Although lead (Pb) exposure has been identified as an important risk factor in child behavioral development, very few is known regarding the relation between child behaviors and exposure to polychlorinated biphenyls (PCBs) and mercury (Hg). Inuit children are particularly exposed to these chemicals and the aim of this study was to investigate the association between prenatal and postnatal exposure to Pb, PCBs, Hg and several aspects of behavioral function in Inuit preschoolers. The sample consisted of 110 five-year old Inuit children from Arctic Quebec. Umbilical cord blood sample was used to document prenatal exposure to Pb, PCBs and Hg. Child's blood samples were collected at testing time to document current exposure to those contaminants. A modified version of Infant Behavior Rating Scale (IBRS) from the Bayley Scales of Infant Development-II was used to assess child behavior through examiners' ratings. Furthermore, attention, activity and emotional outcomes were assessed through behavioral coding of video recordings taken during fine motor testing. Blood Pb concentrations at 5 years of age was associated with examiners ratings of greater impulsivity, irritability and inattention when those behaviors were documented from coding of video recordings. Prenatal exposure to PCB 153 correlated with the examiners ratings of increased state of unhappiness and anxiety during the testing session, which was corroborated from video coding since cord PCB 153 was related to fewer manifestations of positive affects. Hg exposure was not associated with any behavioral outcomes studied here. In conclusion, these results corroborated those from previous Pb cohort studies and underlined an association between prenatal PCBs exposure and emotional outcomes in preschoolers."

B) Citation from Verner, Plusquellec et al. 2010.

"Pre- and postnatal exposure to PCBs can impair behavioural functions in animal models at doses within the range at which humans are commonly exposed. Yet, results from epidemiologic studies are inconsistent with regard to the developmental effects of lactational exposure to these chemicals. This inconsistency may be due to the limitations in the current methodological approaches for assessing postnatal exposure to PCBs. Our study aimed to evaluate the impact of blood PCB levels during specific pre- and postnatal periods as estimated by physiologically-based pharmacokinetic (PBPK) modeling to infant behaviour. A previously validated PBPK model was used to simulate infant blood PCB-153 levels on a month-by-month basis during the first year of life for Inuit infants enrolled in a longitudinal birth cohort. Infant behaviour was assessed using the Behaviour Rating Scales (BRS) of the Bayley Scales of Infant Development (BSID-II) at 11 months of age and video coding of inattention and activity measured during the administration of the BSID-II mental development index. We observed significant increases in infant inattention and activity at 11 months in relation to PCB exposure. Whereas inattention was related to prenatal exposure, activity level, measured by non-elicited activity, was best predicted by postnatal exposure, with the strongest association obtained for simulated PCB levels during the 4th postpartum month. Our findings provide additional evidence of PCB-induced behavioural alteration in attention and activity level. Simulated infant toxicokinetic profiles for the first year of life revealed windows of susceptibility during which PCBs may impair infant attention and activity."

C) Citation from Boucher, Bastien et al. 2010.

"Methylmercury (MeHg) and polychlorinated biphenyls (PCBs) are seafood contaminants known for their adverse effects on neurodevelopment. This study examines the relation of developmental exposure to these contaminants to information processing assessed with event-related potentials (ERPs) in school-aged Inuit children from Nunavik

(Arctic Québec). In a prospective longitudinal study on child development, exposure to contaminants was measured at birth and 11 years of age. An auditory oddball protocol was administered at 11 years to measure ERP components N1 and P3b. Multiple regression analyses were performed to examine the associations of levels of the contaminants to auditory oddball performance and the ERP parameters (latency and amplitude) after control for potential confounding variables. A total of 118 children provided useable ERP data. Prenatal MeHg exposure was associated with slower reaction times and fewer false alarms during the oddball task. Analyses of the ERP parameters revealed that prenatal MeHg exposure was related to greater amplitude and delayed latency of the N1 wave in the target condition but not to the P3b component. MeHg effects on the N1 were stronger after control for seafood nutrients. Prenatal PCB exposure was not related to any endpoint for sample as a whole but was associated with a decrease in P3b amplitude in the subgroup of children who had been breastfed for less than 3 months. Body burdens of MeHg and PCBs at 11 years were not related to any of the behavioural or ERP measures. These data suggest that prenatal MeHg exposure alters attentional mechanisms modulating early processing of sensory information. By contrast, prenatal PCB exposure appears to affect information processing at later stages, when the information is being consciously evaluated. These effects seem to be mitigated in children who are breastfed for a more extended period."

D) Citation from Boucher, Muckle et al. 2010.

"The event-related potential (ERP) P3b, a cognitive electrophysiological measure that has been linked to working memory processing in many experimental paradigms, was measured in Inuit children from Nunavik (Arctic Québec, Canada) to assess lead (Pb) neurotoxicity. Visual and auditory oddball paradigms were administered at 5 (N=104) and 11 (N=201) years of age, respectively, to elicit this ERP component. Pearson correlations and multiple regression analyses were performed to examine the associations between Pb levels and P3b parameters (peak latency and amplitude). Greater prenatal Pb exposure was related to a decrease in P3b amplitude at 5 years of age, and early childhood Pb exposure was associated with delayed P3b latency at 5 years. No significant effect was observed at 11 years. These results, in line with those from previous neurobehavioral studies, suggest that Pb exposure affects cognitive processing in children even though the Pb levels measured in a large majority of our sample were below the recommendations from federal agencies. This study strengthens the arguments for reducing sources of Pb exposure in Nunavik and for lowering the blood Pb concentrations considered "acceptable" in governmental policies."

E) Citation from Jacques et al., under review

"Objective: Findings from several studies indicate that supplementation with omega-3 polyunsaturated fatty acids (n-3 PUFAs) during infancy is beneficial for early development of the visual system. However, little is known about the long-term effect of n-3 PUFA intake during gestation on visual development. Study design: We examined the long-term effects in 136 school-age Inuit children exposed to high levels of n-3 PUFAs during gestation using visual evoked potentials (VEPs). VEP protocols using color and motion stimuli were used to assess parvo- and magnocellular responses. Concentrations of the two major n-3 PUFAs (DHA and EPA) were measured in umbilical cord and child plasma phospholipids, reflecting pre- and postnatal exposure, respectively. Results: After adjustment for confounders, cord plasma DHA was associated with shorter latencies of the N1 and P1 components of the color VEPs. No effects were found for current n-3 PUFA body burden or motion-onset VEPs. This study is the first to demonstrate beneficial effects of DHA intake during gestation on visual system function at school age. Conclusion: The data suggest that DHA is particularly important for the early development and long-term function of the visual parvocellular pathway.

F) Citation from Ethier, Polevoy et al., 2010, under preparation

"The Inuit from Arctic Quebec (Canada) are highly exposed to Hg and PCBs due to their bioaccumulation in fish and marine diet. Exposure to these environmental contaminants has been identified as a risk factor for attention deficits. The present study aimed at assessing the impact of environmental contaminants on spatial attention in a cohort of Inuit children at school age using a Posner cue-target paradigm. Thirty-two Inuit children (mean age = 10.3 years) participated in this follow-up study. Blood concentrations of Hg, lead and PCBs

were measured at birth from cord blood samples and at the time of testing. Children were instructed to detect a pre-cued target that might appear on the left or on the right of the fixation point as quickly as possible. Reaction times (RT) of valid trials (cues and targets on the same side) and invalid trials (cues and targets on different sides) as well as response types (hits, omissions, false alarms and correct withholds) were measured. The association between performances and contaminant levels was obtained using Pearson correlations and multiple regression analyses. Results showed a significant correlation between RT and PCBs at the time of testing ($r = .60$, $p = .006$). As such, high level of PCBs exposure during postnatal development was associated with longer reaction times. In addition, prenatal PCB exposure was significantly associated with a greater number of missing targets ($r = .58$, $p = .003$), suggesting vigilance impairment. Multivariate regression revealed that this prenatal effect remained significant after adjustment for postnatal PCB exposure and other covariates (Std Beta = .67, $p = .012$). This study shows that chronic PCB exposure alters spatial attention and vigilance in school-age children."

Conclusions

During this follow-up we have successfully tested 294 11-year old Nunavik children. Year 2009/2010 was devoted to data collection, data scoring, data entry and statistical analyses. The analyses conducted so far allowed to publish results involving outcomes documented through electrophysiological assessments. During year 2010/2011, study results involving growth, cognitive development, and child behaviours will be presented to the NNHC and a communication plan for presentation of final study results to the Nunavik population will be developed.

Information related to capacity building, communications, and traditional knowledge

Each child was evaluated by four examiners and two of these evaluators were Inuit. For the 5-year duration of the data collection, we trained two Inuit women for child testing; they tested all 294 children seen at age 10-11years. They gained high level training and their involvement on this study makes them very skilled and attractive for work with school and hospital specialists on child psychology, psychiatry, pediatry and learning disabilities. Furthermore, we have always been working with at least one and often two interpreters during the data collection trips. A total of 6-7 interpreters have been trained over the 5-year period to do maternal interviews. The age of our Inuit collaborators ranged from 20 to 60 years and their community of origin were Puvirnituq, Inukjuaq as well as Kuujjuak. Most of them were involved for more than one data collection trip, and our main Inuit collaborator, responsible for the neuropsychological assessment of children worked with us 7 out of the 8 data collection trips.

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

Performance Indicators

Number of northerners engaged in project: 5

Number of meetings/workshops in the North: one 4-weeks trip for data collection

Number of students involved in this work: five PhD students (3 from Laval University and 2 from University of Montreal) and one postdoctoral researcher from Laval University.

Number of citable publications: 14 publications in international peer-reviewed journals and 13 communications in international and national conferences.

Expected Project Completion Date

2010/2011

Assessment of contaminant and dietary nutrient interactions in Inuit Health Survey: Nunavut

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Abstract

The Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey seeks to incorporate contaminants research within the context of a broader health research study conducted in Nunavut, Nunatsiavut and Inuvialuit in 2007 and 2008. This report presented key results obtained from Nunavut in 2007. A total of 1143 adults between 18 to over 60 years old participated in the contaminant study. Concentrations of cadmium, lead, mercury, organochlorines and polybrominated diphenyl ethers in the blood samples of the participants were measured. Dietary exposure to these contaminants was estimated. The risks and benefits associated with the traditional food diet and the relationship between contaminants and health outcomes of the participants are being analyzed. Results of the study are being discussed with the health professionals and policy makers at the territorial, national and international levels in developing environmental health policies and aid Inuit in making informed dietary choices.

Résumé

Cette évaluation des interactions entre les contaminants et les nutriments alimentaires effectuée dans le cadre de l’Enquête sur la santé des Inuits vise à intégrer la recherche sur les contaminants dans le contexte plus large d’une étude scientifique sur la santé menée au Nunavut, au Nunatsiavut et dans l’Inuvialuit en 2007 et 2008. Nous présentons ici les principaux résultats obtenus au Nunavut en 2007. En tout, 1143 adultes âgés de 18 à plus de 60 ans ont participé à l’étude sur les contaminants. Les concentrations de cadmium, de plomb, de mercure, d’organochlorés et d’éthers diphényliques polybromés ont été mesurées dans les échantillons de sang des participants. L’exposition alimentaire à ces contaminants a également été estimée. Les risques et les avantages associés à l’alimentation traditionnelle et la relation entre les contaminants et les effets sur la santé des participants ont été analysés. Nous discutons des résultats de l’étude avec les professionnels de la santé et les responsables

des politiques à l'échelle territoriale, nationale et internationale en vue d'élaborer des politiques d'hygiène du milieu et d'aider les Inuits à faire des choix alimentaires éclairés.

Key Messages

- There were many smokers in Nunavut; 73.1% of participants reported smoking and 21.8% reported as ex-smoker and only 5.2% of participants were non-smokers.
- A percentage of participants had blood level higher than the guideline levels; 14% for cadmium, 8% for lead, 29% for mercury and PCB.
- Lead and mercury levels were similar and cadmium levels were lower when compared to those found in Nunavik.
- The major likely sources for the contaminants were tobacco smoking for cadmium, diet for lead, mercury and PCB, and market food/air pollution for PBDE.

Messages clés

- Le nombre de fumeurs au Nunavut était élevé : 73,1 % des participants ont dit fumer et 21,8 % ont déclaré être des ex fumeurs et seulement 5,2 % des participants étaient des non fumeurs.
- Un pourcentage des participants présentaient des concentrations sanguines supérieures aux niveaux recommandés : 14 % pour le cadmium, 8 % pour le plomb, 29 % pour le mercure et les PCB.
- Les concentrations de plomb et de mercure étaient similaires et les concentrations de cadmium inférieures à celles détectées au Nunavik.
- Les sources les plus probables des contaminants étaient l'usage du tabac pour le cadmium, l'alimentation pour le plomb, le mercure et les PCB, et les aliments du commerce/ la pollution atmosphérique pour les EDP.

Short-term Objectives

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

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

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

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

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

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

Long-term Objectives

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

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

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

Introduction

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

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

Activities in 2009-2010

In 2007 and 2008 the Inuit Health Survey (IHS) visited thirty three costal communities in Nunavut, Nunatsiavut and the Inuvialuit Settlement Region of the Northwest Territories. In 2007 data was collected in 18 communities in Nunavut. In 2008 data was collected in six communities the Kitikmeot Region of Nunavut, and a land-based survey was completed in Baker Lake. For the 2008 survey in the Kitikmeot Region of Nunavut there were 611 participants with 481 samples collected for OCs, 488 collected for metals. At the same time, the IHS also travelled to four coastal Inuvialuit communities aboard the CCGS Amundsen, as well as completing land-based surveys in Inuvik and Aklavik. The participation target was reached for all regions. For the 2008 Inuvialuit Settlement Region portion of the survey there were 291 ship based participants with a total of 280 samples collected for OCs, 281 samples for metals. In October of 2008, the IHS travelled to five Inuit communities in the Nunatsiavut Region aboard the CCGS Amundsen. There were a total of 265 participants in Nunatsiavut with 263 samples collected for OCs, 264 samples collected for metals.

During 2009-2010 data analysis of the 2007 Nunavut results continued and laboratory analysis of the 2008 samples began. Country food samples for the Inuvialuit Settlement Region were collected and analyzed for OCs and Metals. In March and November of 2009 preliminary Inuit Health Survey and contaminant results based on the 2007 Nunavut data were delivered to the Inuit Health Survey Research Regional Committees in Montreal. Consultation and planning for results delivery continued throughout 2009-2010 with members of the Inuit Health Survey Research Committees and Inuit Partners, including face to face meetings in Yellowknife.

Results

The characteristics of the participants in Nunavut are presented in Table 1. There were more women than men participated (60% vs. 40%). The percentage of young adults was less at 13.6% compared to the other two age groups. There were very few non-smokers at only 5.2%.

Concentrations of cadmium (Cd), lead (Pb), mercury (Hg), organochlorines including PCBs and total PBDE are represented in Table 2 and 3. None of the geometric means of contaminant exceeded the guideline levels established by Health Canada (5.0 μg/L for Cd, 100 μg/L for Pb, 20 μg/L for Hg and 20 μg/L for PCBs). However, when comparing the distribution of the contaminant concentrations to the Health Canada guidelines, it was found that the exceedance was14% for Cd, 8% for Pb, 29% for Hg and PCBs (Figure 1a-d).

Table 1. Gender, age and smoking status e participants of the Inuit Health Survey conducted in Nunavut, 2007 (N=1143).

	N	%
Gender		
Men	454	39.7
Women	689	60.3
Age groups		
18-24	155	13.6
25-44	557	48.7
45-	431	37.7
Smoking habits		
Non smokers	58	5.2
Ex-smokers	244	21.8
Smokers	819	73.1

Table 2 . Metal concentrations in the participants of the Inuit Health Survey conducted in Nunavut, 2007 (μg/L whole blood).

Metal	N	Geometric mean	95% Confidence Interval		Range		95th percentile
			Lower	Upper	Min	Max	
Mercury	1143	10	9.8	11	0.05	130	49
Cadmium	1143	1.9	1.8	2.1	0.08	11	6.4
Lead	1143	38	36	39	5.0	250	130

Table 3. Organochlorine concentrations in the participants of the Inuit Health Survey conducted in Nunavut, 2007 (μg/kg lipid).

Organochlorine	N	Geometric mean	95% Confidence Interval		Range		95th percentile
			Lower	Upper	Min	Max	
Hexachlorobenzene	1140	93.8	87.8	100	2.29	1964	538
Mirex	1141	10.1	9.29	11.0	0.500	734	92.9
Chlordane	1141	267	246	289	2.22	6000	2225
pp'-DDE	1141	428	402	456	8.65	6714	2201
pp'-DDT	1139	12.4	11.7	13.1	2.08	214	65.2
β-HCH	1141	17.1	15.9	18.4	0.633	343	124
Total Toxaphene	1141	50.6	46.9	54.7	0.575	1446	387
Total PBDE	1141	16.2	15.4	17.0	4.17	746	91.3
PCB Acroclor 1260	1141	1334	1236	1441	19.2	37142	9982
ΣPCBs	1141	592	553	633.773	40.4	14467	3888

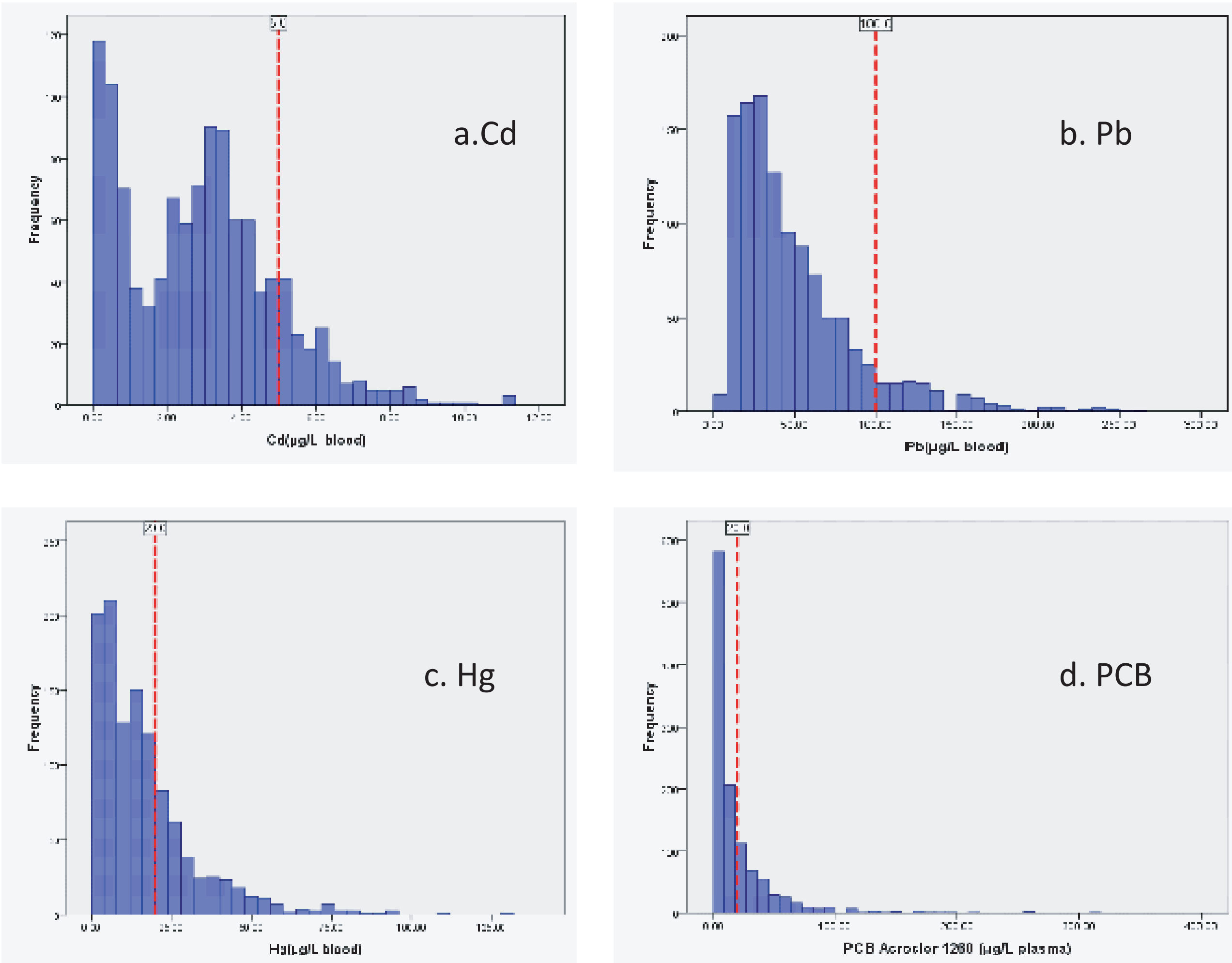

Figure 1. Frequency distribution of contaminant concentrations in the participants of the Inuit Health Survey conducted in Nunavut, 2007 for a). Cd; b). Pb; c). Hg and d). PCB (µg/L plasma). Health Canada blood guideline levels for adult general population are also presented.

Comparing the results collected from Nunavik showed that Hg, Cd and Pb all decreased compared to the data collected in 1992 (Table 4). Hg and Pb levels found in Nunavut was similar to those found in Nunavik in 2004 but Cd levels were significant lower. Blood Cd concentrations were significantly higher among smokers than ex- and non-smokers (Figure 2).

There was a strong correlation between blood Hg, Pb and PCB concentrations (Table 5, r>0.4). The correlation with Cd was much weaker with r equal to around 0.1.

Hg intake from traditional food was estimated using data collected from the food frequency and chemical analysis of food samples collected. There was a strong correlation between blood Hg

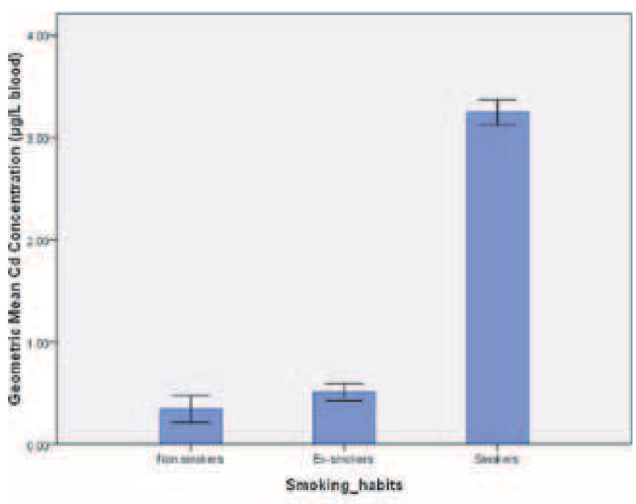

Figure 2. Geometric mean of Blood-Cadmium by smoking habits in the participants of the Inuit Health Survey conducted in Nunavut, 2007. (µg/L whole blood)

Table 4. Comparison of blood mercury, lead and cadmium concentrations in Nunavik (1992, 2004) and Nunavut (2007)

Metal	Region	Year	N	Geometric Mean(µg/l)	95% Confidence Interval	
					Lower	Upper
Mercury	Nunavik	1992	492	15.0	13.9	16.2
	Nunavik	2004	917	10.3	9.6	11.0
	Nunavut	2007	1143	10.4	9.8	11.1
Cadmium	Nunavik	1992	493	3.7	3.5	4.0
	Nunavik	2004	917	2.9	2.7	3.1
	Nunavut	2007	1143	1.9	1.8	2.1
Lead	Nunavik	1992	493	90	83	91
	Nunavik	2004	917	40	37	41
	Nunavut	2007	1143	38	36	39

Table 5. Inter-correlations between trace metals and Total PCBs

	Blood-Mercury (µg/L)	Blood-Cadmium (µg/L)	Blood-Lead (µg/L)	ΣPCBs (µg/L plasma)
Blood-Mercury (µg/L)	1.000	-0.105**	0.481**	0.662**
Blood-Cadmium (µg/L)	-0.105**	1.000	0.093**	-0.103**
Blood-Lead (µg/L)	0.481**	0.093**	1.000	0.597**
ΣPCBs (µg/L plasma)	0.662**	-0.103**	0.597**	1.000

concentrations and the estimated Hg intake (Figure 3, r=0.386, P<0.001). Similar correlation was found for PCBs. In contrast, the correlation between blood PBDE concentrations and dietary intake from traditional food was not significant (r=0.009, p>0.05).

Discussions and Conclusions

Smoking is a major problem for Inuit in Nunavut. The percentage of non-smoker was only 5.2% which was even lower than the 8.9% observed in Nunavik in 2004 (Fontaine et al. 2008). However, the number of smokers were lower that in Nunavik (73.1% vs 77.5%). The main difference is the number of ex-smokers who was higher in Nunavut (21.8%) compared to 13.6% in Nunavik. This relative higher percentage of ex-smokers is encouraging and may likely be the reason for the lower blood Cd concentrations found in Nunavut when compared to Nunavik.

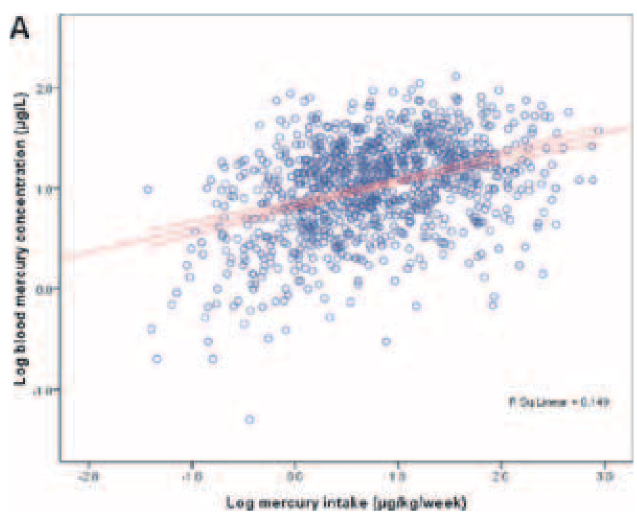

Figure 3. Scatter plot for blood mercury concentrations and daily total mercury intake of Inuit in Nunavut (log-scale). Simple linear regression: r=0.386, P<0.001.

The correlation observed between Pb, Hg and PCB blood concentrations suggest that they are from a similar source whereas as the main source for Cd was apparently from smoking as smokers had much higher concentrations. We estimated the Hg and OCs intake from traditional food using the dietary information and results from the food sample analysis. There was a strong correlation between the blood concentrations and the estimated intake from traditional food. These results suggest traditional food was a major source of Pb, Hg and OCs in Nunavut. PBDE, however, did not show the same correlation suggesting it the source of PBDE was either from market food or from air pollution.

The average concentrations of contaminants were below the guideline levels established by Health Canada suggesting that most of the people do not have a concern for contaminant related adverse health effects. A percentage of high-end traditional food consumers can still be exposed to elevated levels of contaminants. It is good news that blood concentrations of all three metals (Cd, Pb, Hg) showed a significant decreased when compared to the concentrations reported in Nunavik in the early 1990s (Van Oostdam et al. 1999).

Results for participant's profile and health status are being reported back to the communities. Analysis for contaminant in blood samples collected from Nunatsiavut and Inuvialuit in 208 has been delayed but is expected to be completed by July 2010. Biomarkers for neurological effects have been measured. Relationship between contaminants, diet and other health indicators will be analyzed. A communication plan will be developed with the Department of Health and Social Service of Nunavut Government and the NAC followed by the completion of data analysis in partnership with the Inuit Tapiriit Kanatami.

NCP Performance Indicators

The number of Northerners engaged in the project:

Over the life of the Inuit Health Survey, which includes the work of Assessment of Contaminant and Dietary Nutrients in the Inuit Health Survey, over 100 communities members have been engaged in and employed by the projects. Over 2000 participants engaged in the overall project including the contaminant study. The over 20 members of the Region Research Committees continue to engage in the project by participating in processes related to results reporting. The hunter and trapper organizations from each region engaged in collection of country foods samples.

The number of meetings and workshops held in the North:

Two face to face meetings with members of the Nunavut, Inuvialuit, and Nunatsiavut Research Steering Committees took place in Yellowknife NWT in 2009.

The number of students involved in the work:

This project has involved four undergraduate students, three master students, one doctoral student, and three post doctoral fellows.

The number of citable publications related to the work:

In compliance with the community research and ethics agreements for the project, no scientific publications will be produced or released until after all data is return to the regions and communities to the satisfaction of the Regional Research Committees. Results reporting will continue into 2010-2011, it is expected that publications related to Assessment of contaminant and dietary nutrient interactions in the Inuit Health Survey will be produced and publish in 2011-2012 after the reporting requirements have been met.

Expected Project Completion Day

The entire project is expected to be completed by March 31 2012.

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The project participants in Inuvialuit, Nunavut, and Nunatsiavut

The Government of the Northwest Territories

Inuvialuit Settlement Region

Inuvialuit Development Corporation

The Government of Nunavut

The Government of Nunatsiavut

Nunavut Association of Municipalities

Nunavut Tunngavik Inc.

Nunavut Research Institute

The Aurora Institute

Inuit Tapiriit Kanatami (ITK) and the Inuit Knowledge Centre

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Dr. Eric Sobol, Dr. Eric Dewailley

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Long-term effects of background exposure to environmental contaminants on activity, attention and emotionality in 10-year-old Inuit children

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Abstract

Traditional Inuit diet is contaminated by environmental pollutants such as organochlorines (Ocs), methylmercury (MeHg), and lead (Pb). Prenatal exposure to such contaminants has been linked to developmental and cognitive effects in many epidemiological studies but behavioural effects have not been extensively studied. So far, our results have shown that low-level prenatal Pb exposure is related to subtle change in attention level in 11 month-old Inuit children. This prenatal effect does not persist later on in 5 year-old

Résumé

Les aliments inuits traditionnels sont contaminés par des polluants environnementaux comme les organochlorés (OC), le méthylmercure (MeHg) et le plomb (Pb). L'exposition prénatale à ces contaminants a été associée à des effets sur le développement et les facultés cognitives dans de nombreuses études épidémiologiques, mais les effets sur le comportement n'ont pas été étudiés de façon approfondie. Jusqu'à présent, nos résultats ont montré qu'une faible exposition prénatale au Pb est liée à des changements subtils du niveau d'attention chez

Inuit children, but postnatal exposure to Pb has been related to other subtle behavioural change in the domains of impulsivity, irritability and inattention. Furthermore, background exposure to PCBs in utero was found to be related to subtle behavioural changes targeting emotional outcomes in 5 year-old Inuit children. All those behavioural changes are sub-clinical and the study we proposed aimed at finding whether exposure to environmental contaminants still have an impact on behaviour in 10 year-old Inuit children, and whether those effects have an impact on children's day-to-day functioning. We have collected data from video recordings taken in 2008, 2009 and 2010, and next step will be to statistically analyze these data in order to document the long term behavioural effects of pre- and postnatal exposure to environmental contaminants.

les enfants inuits âgés de 11 mois. Cet effet prénatal ne persiste pas plus tard à l'âge de 5 ans, mais l'exposition postnatale au Pb a été associée à d'autres modifications comportementales subtiles dans les domaines de l'impulsivité, de l'irritabilité et de l'inattention. En outre, des liens ont été établis entre l'exposition naturelle aux PCB *in utero* et des modifications comportementales subtiles au niveau des réactions émotives chez des enfants inuits de 5 ans. Tous ces changements de comportement sont observés au niveau infraclinique, et l'étude que nous avons proposée visait à déterminer si l'exposition à des contaminants environnementaux a toujours un impact sur le comportement des enfants de 10 ans et si ces effets influent sur le fonctionnement quotidien des enfants. Nous avons recueilli des données à partir d'enregistrements vidéo effectués en 2008, 2009 et 2010; la prochaine étape consistera à effectuer des analyses statistiques de ces données afin de documenter les effets comportementaux à long terme de l'exposition prénatale et postnatale aux contaminants environnementaux.

Key messages

- Associations found between environmental contaminants and behavioural development are subclinical. It means that it does not impact the day to day functioning of Inuit children, but it impairs the Inuit population to express its full potential in the field of behavioural development.
- Lead has been related to slight impairment in infants attention levels, and preschoolers impulsivity, irritability and attention levels
- Exposure to PCBs during pregnancy has been related to subtle changes in preschoolers' emotional outcomes.

Messages clés

- Les associations observées entre les contaminants environnementaux et le développement comportemental sont d'ordre infraclinique. Autrement dit, elles n'influent pas sur le fonctionnement quotidien des enfants inuits, mais elles empêchent la population inuite de réaliser son plein potentiel dans le domaine du développement comportemental.
- Le plomb a été associé à une légère diminution des niveaux d'attention chez les nourrissons, à l'impulsivité, à l'irritabilité et à des baisses du niveau d'attention chez les enfants d'âge préscolaire.
- L'exposition aux PCB durant la grossesse a été associée à des changements subtils dans les réactions affectives des enfants d'âge préscolaire.

Objectives

a. to complete behavioural coding of video recordings already collected (102 blood test situations and 145 cognitive test situations) in October 2007 and October 2008

b. to collect new video recordings (n=19) in 10 year-old children (travel initially planned in October 2009, but postponed in February 2010)

c. to complete the behavioural coding of these new video recordings

Introduction

In the United States, learning and developmental disabilities (LDD) appear to affect 5 to 15 percent of all children under the age of 18 years (Boyle et al., 1994). LDD include physical impairments, deficits in cognitive abilities such as memory and IQ, and also behavioural problems. A recent statement by experts in the field of environmental toxicology indicated that environmental contaminants can be reliably added to the list of risk factors associated with LDD (Gilbert, 2008). Indeed, many prospective studies of children have addressed the relationship between background exposure to environmental contaminants and child development during the last several decades. These studies mainly focused on lead (Pb), polychlorinated biphenyls (PCBs) and mercury (Hg). Main outcomes studied with regard to prenatal exposure were growth, neuromotor development, cognitive development (for example, (Boucher et al., 2009; Korrick and Sagiv, 2008)).

As to behavioural development per se, effects of Pb exposure have been more widely studied than those associated with other environmental contaminants. For example, Pb exposure during infancy was significantly associated with increased hyperactivity and distractibility (Mendelsohn et al., 1998) and increased antisocial behaviours (Wasserman et al., 1998). In older children, the effects of Pb exposure during childhood were also documented on various aspects of behaviour, such as symptoms of hyperactivity, inattention and withdrawn behaviours (Chiodo et al., 2004; Davis et al., 2004). As to PCBs, prenatal exposure to PCBs was related to decreased activity level at 4 years of age (Jacobson et al., 1990)and to higher impulsivity at age 11 year (Jacobson et al., 2003) in the Michigan study. In the North Carolina cohort, prenatal PCBs were associated with lower activity at birth (Rogan et al., 1986). In the Oswego study, prenatal PCBs exposure were related to response inhibition at 4.5 years of age, which is crucial to the ongoing regulation of behaviour (Stewart et al., 2003), and to impulsivity at 8 years of age (Stewart et al., 2005).

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

Using this methodology in previous study, we have already found significant associations between lead exposure and infant behavioural development (Plusquellec et al., 2007), but also between lead, PCBs and preschoolers behavioural development (Plusquellec et al., 2010). However, the association between prenatal lead exposure and behavioural development we observed in infancy seems not to endure in preschoolers. Yet, this project was conducted in order to collect data needed to measure behavioural development in 10 years of age Inuit, and to answer the question of long-term effects of environmental contaminants.

Activities in 2009-2010

In direct relations with the objectives of the current project, video recordings have been done in February 2010 in Puvirnituq with the help of Audreay-Anne Ethier (graduate student in Psychology), Jocelyne Gagnon (PhD, research Professional), and the team responsible of the data collection in Nunavik.

From Previous recordings and these new video recordings, Anne Avril and Virginie Audet-Croteau (undergraduate students in Psychology) have collected behavioural data.

Data analyzed in the previous cohort (5 year-old Inuits) and presented to the Nunavik Nutrition Health Committee (Fall 2008) have been published in an international scientific peer-review journal (Plusquellec et al., 2010).

Pierrich Plusquellec (Principal investigator of the current project) has presented main results of the cohort studies in Ottawa, for the 2009 NCP Workshop.

Behavioural results of the previous cohort studies have been presented in an international conference by Pierrich Plusquellec (Neurobehavioral Teratology Society, June 2009).

Results

Behavioural results of the previous cohort studies (1 year and 5 years of age) have been previously described. Behavioural results of the 10 year-olds are not yet available since they will be statistically analyzed in 2010/2011, and presented to the NNHC and to the NCP results workshop, before a scientific publication will be done.

Discussion and conclusions

The current project has provided additional video recordings, and thus additional behavioural data needed to analyze the association between environmental contaminants (lead, and PCBs) and behavioural development in 10 year-old Inuit children. Because travel to Nunavik has been postponed due to logistic problems, these new data will be analyzed during the next year.

Considering that subtle effects have been detect in 1 year and 5 year-old children, these results are particularly important since we will be able to answer the question of long-term effects of early exposure in Inuit children, at least on behavioural development.

Statistical analysis will be conducted during the summer 2010, and results will be presented during the fall/winter 2010 to the NNHC and the NCP, while scientific publication will be prepared and submitted during the spring 2011.

NCP performance indicators

Northerners are not directly engaged in the current project. But video recordings have been done during Gina Muckle's data collection which involved northerners.

No meeting/workshop has been held in the North during the 2009/2010 period, but a communication plan will be established in accordance with Gina Muckle communication plan in order to transfer knowledge to Inuit communities through the NNHC.

Three students (1 graduate and 2 undergraduate) have been involved in the current NCP work,

Two citable publications in relation with the NCP work have been released during the year 2009/2010:

Plusquellec, P., Muckle, G., Dewailly, E., Ayotte, P. Prenatal Exposure to Environmental Contaminants is Related to Sub-Clinical Behavioral Impairment in Inuit Children in Arctic Quebec. The Teratology Society, Puerto Rico, Rio Grande (2009)

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

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

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Contaminant Nutrient Interaction Issues as part of a Public Health Intervention Study of Inuit Children in Nunavik: fourth year of data collection

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Abstract

Children vulnerability to toxic substances is increased due to their immature physiology and sometimes poor nutritional status. Various nutrients and diet components can protect against or attenuate the adverse effects of contaminants on health. The present study has been conducted since 2006 as part of the Nutrition Program in Nunavik Childcare Centres which aims to provide healthy meals rich in iron and containing traditional foods and selected market foods. Blood contaminant levels, dietary intakes and nutritional status are measured at recruitment and twelve months later for participating children. Lead, PCB 153, PBDE 47, PFOS and PFOA were detected in all samples collected at recruitment. Heavy metals and legacy contaminants were less detected in these preschool children than in other Nunavimmiut populations while the rate of detection of some brominated flame retardants, a class of emerging contaminants, was similar (PBDE 153) or more elevated (PBDE 47, 99 and

Résumé

Les enfants sont plus vulnérables aux substances toxiques à cause de leur immaturité physiologique et, parfois, de leur piètre état nutritionnel. Divers nutriments et composants alimentaires peuvent les protéger contre les effets indésirables des contaminants sur la santé ou atténuer ces effets. La présente étude a été amorcée en 2006 dans le cadre du Programme de nutrition dans les Centres de la petite enfance du Nunavik qui visait à fournir des repas sains riches en fer et contenant des aliments traditionnels et certains aliments du commerce. Les concentrations sanguines de contaminants, les apports alimentaires et l'état nutritionnel ont été mesurés au moment du recrutement et douze mois plus tard chez les enfants participants. La présence de plomb, de PCB 153, d'EDP 47, de PFOS et de PFOA a été détectée dans tous les échantillons prélevés au moment du recrutement. Les métaux lourds et les contaminants hérités du passé ont été moins souvent détectés chez ces enfants d'âge préscolaire que dans d'autres populations du

100) than in adults. Blood concentrations of mercury, lead and some legacy contaminants (PCB 153, PCB 180, trans-Nonachlor and p,p'-DDE) were positively correlated with the frequency of traditional food consumption. On the contrary, an inverse relationship was observed between these blood contaminants and some market foods such as fruits, vegetables and milk. These results suggest that some foods could have a protective effect against contaminant toxicity. Multivariate analysis will be necessary to further understand these relationships. For Nunavimmiut parents and authorities, this study will provide useful information about the use of traditional foods among preschool children.

Nunavimmiut, alors que le taux de détection de certains ignifuges bromés, une classe de contaminants en émergence, était similaire (EDP 153) ou plus élevé (EDP 47, 99 et 100) que chez les adultes. Les concentrations sanguines de mercure, de plomb et de certains contaminants du passé (PCB 153, PCB 180, de trans Nonachlor et de p, p' DDE) étaient corrélées positivement avec la fréquence de consommation d'aliments traditionnels. Par contre, une relation inverse a été observée entre ces contaminants sanguins et certains aliments du commerce comme les fruits, les légumes et le lait. Ces résultats semblent indiquer que certains aliments pourraient jouer un rôle protecteur contre les effets toxiques des contaminants. Une analyse multidimensionnelle devra être effectuée si l'on veut mieux comprendre ces relations. La présente étude fournira aux parents et aux autorités du Nunavimmiut des renseignements utiles sur l'usage d'aliments traditionnels chez les enfants d'âge préscolaire.

Key Messages

- Since 2006, 209 Nunavimmiut children have been recruited from both coasts of which 80 of them seen a second time one year later (3 out of 4 cohorts have been completed so far). The last data collection will take place in the fall of 2010 and children recruited in 2009 will be seen for a follow-up visit and new children will be recruited.
- Heavy metals and legacy POPs were less detected in these Inuit preschool children than in other Nunavimmiut populations while the rate of detection of some brominated flame retardants, a class of emerging contaminants, was higher.
- Blood concentrations of some heavy metals and legacy contaminants were positively correlated with the frequency of traditional food consumption.
- Some market foods such as fruits, vegetables and milk were negatively correlated with blood contaminant levels which suggest that these foods could have a protective effect against contaminant exposure. Multivariate analysis is needed to further elucidate these relationships.

Messages clés

- Depuis 2006, 209 enfants du Nunavimmiut ont été recrutés sur les deux côtes, et 80 d'entre eux ont été revus un an après leur recrutement (travail sur 3 des 4 cohortes mené à bien jusqu'à maintenant). La dernière collecte de données aura lieu à l'automne 2010, et les enfants recrutés en 2009 feront l'objet d'un suivi et de nouveaux enfants seront recrutés.
- Les métaux lourds et les POP hérités du passé ont été moins souvent détectés chez les enfants inuits d'âge préscolaire que dans d'autres populations du Nunavimmiut, alors que le taux de détection de certains ignifuges bromés, une classe de contaminants en émergence, était plus élevé.
- Les concentrations sanguines de certains métaux lourds et contaminants du passé étaient corrélées positivement avec la fréquence de consommation d'aliments traditionnels.
- Certains aliments du commerce comme les fruits, les légumes et le lait étaient corrélés négativement avec les concentrations sanguines de contaminants, ce qui donne à penser que ces aliments pourraient jouer un rôle protecteur contre l'exposition à des contaminants. Une analyse multidimensionnelle doit être effectuée pour élucider ces relations.

Objectives

The overall objectives of the present study are:

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

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

The **specific objectives** of this report are (1) to describe blood contaminant levels of young Inuit children attending Nunavik childcare centres and (2) to explore the relationship between consumption frequencies of traditionnal and market foods and, blood contaminant levels, based on data collected during the first three years of the project.

Introduction

Traditional foods are extremely important to ensure adequacy of nutrient intakes for the Canadian Arctic Indigenous Peoples. It was shown that consumption of one or more servings of traditional food significantly increased the levels of proteins and many vitamins and minerals (Kuhnlein and Receveur 2007). However, the multiple nutritional and socioeconomic benefits of traditional foods must be weighed against the detrimental aspects of contaminants that are bioamplified in Arctic food webs (Dewailly 2006).

Heavy metals (methyl mercury [MeHg], lead [Pb]) are associated with poorer neurodevelopment in infants and school-age children (Centers for Disease Control and Prevention (CDC) 2009; Herbstman et al. 2010;World Health Organization 2007). Alterations of visual information processing (Saint-Amour et al., 2006) and, higher action tremor amplitude during pointing movements (Després *et al.*, 2005) have been related to MeHg exposure. Also, despite an abundant literature on MeHg and existing blood guidance values for different countries including Canada (Legrand et al. 2010), the threshold dose for neurotoxic effects is still unclear, in particular when it comes to subtle effects on neurobehaviour (Castoldi et al. 2008).

Higher blood Pb concentrations are also associated with decreased performance on several dimensions of neuromotor function (Després et al., 2005) and behavioural indicators (Plusquellec et al., 2010). Studies indicate that Pb is harmful even at levels below the threshold value used in guidelines for children (Canfield et al. 2003;Chiodo et al. 2004). In preschool Nunavik children, deficits in several fine motor tasks have been observed at blood Pb concentrations below the threshold (Després et al. 2005).

Exposure to persistent organic pollutants [POPs] has also been associated with negative health effects, such as an impaired neurodevelopment and altered levels of thyroid hormones that are essential for normal brain development (Asawasinsopon et al. 2006;Chevrier et al. 2007;Darnerud et al. 2010;Maervoet et al. 2007;Sandau et al. 2002). Early-life exposure to POPs is also associated with alterations in immune function (Nagayama et al. 2007;Nagayama et al. 1998;ten Tusscher et al. 2003;Weisglas-Kuperus et al. 2000). In this regard, two studies carried out in Nunavik indicated that the risk of otitis media, and respiratory and gastrointestinal tract infections increased with prenatal exposure to POPs (PCBs, DDE) (Dallaire et al. 2004;Dallaire et al. 2006).

Mercury and POPs are the major environmental contaminants related to food consumption (Van Oostdam et al. 2005). In Nunavimmiut children, the food items more strongly associated with blood Hg levels are marine mammal meat and fat, arctic char and goose, while consumption of goose and eggs from game birds, although not frequent, are the food items related to higher blood Pb concentrations (Muckle et al. 2001). An increasing number of human studies are devoted to the possible role of nutritional factors in altering susceptibility to heavy metals. It has been suggested that a low micronutrient diet might predispose to toxicity from metals (Peraza et al. 1998;Schell et al. 2004). For example, significant inverse relationships were reported between blood Pb level and dietary intakes of zinc, iron, and calcium in infants (Schell et al. 2004), whereas a poor iron status was associated with higher blood Pb levels (Ahamed et al. 2007;Willows and Gray-Donald 2002)). Strong evidence also exists that fruit consumption provides a protective effect against Hg exposure (Passos et al. 2003;Passos et al. 2007). Moreover, studies carried out in different parts of the globe have shown different Hg toxicities in populations exposed to relatively similar doses of MeHg and these inconsistencies in MeHg toxicity are often attributed to the possible effects of dietary modulation (Passos et al. 2003). To our knowledge, the impact of nutritional factors on heavy metals and POPs toxicity has not been studied in Nunavimmiut children. Thus, while there is clearly a need to reduce the exposure of Inuit to contaminants (Dewailly 2006), there is also an urgent need to determine the impact of diet components and nutritional status on contaminant exposure.

Activities for 2009-2010

Data collection
The fourth data collection took place in the fall of 2009 in 9 communities: Kangiqsualujjuaq, Kuujjuaq, Quaqtaq, Kangiqsujuaq, Ivujivik, Akulivik, Inukjuak, Umiujaq and Kuujjuarapik. Data collected in 2009 were computed and blood samples were analyzed. All blood samples from 2006 to 2009 were analyzed for POPs as part of the 2009-2010 grant.

Statistical analysis
In 2009-2010, statistical analyses on data collected from 2006-2008 included:

- Descriptive analyses on all data related to the socio-demographic characteristics of the children and their family, children's feeding practices in early-life, as well as data from the food frequency questionnaires, the 24-hour dietary recalls and blood contaminant measurements.
- Spearman's correlations between consumption frequencies of traditional and market foods and blood contaminant levels.
- Several exploratory analyses were performed to select among the potential confounding variables those that will be included in regression analysis and analysis of covariance. Responses variables of interest are blood contaminant levels while consumption of traditional and market foods are the main explanatory variables.

Capacity building

- Our team works closely with Inuit people and organizations to ensure the success and continuation of the Nutrition Program. In doing so, we learn more about the Inuit culture and their ways of living which helps us to ensure that our work is appropriate and relevant for Nunavimmiut. We also participated, along with an Inuk consultant from the KRG Childcare Department and two instructors from Kativik School Board, in the training of Inuit field workers (link agents, interpreters, cooks' instructors), and daycare directors, cooks and educators. The Inuk consultant from KRG was also encouraged to be involved in the coordination of the intervention component of the Nutrition Program during the past year. Among others, she participated in the planning and development of every training session.

Communications
Preliminary results were published in the Synopsis of Research conducted under the 2008-2009 Northern Contaminant Program and presented to the NCP meeting in Ottawa in September 2009 (see also NCP Performance indicators). We are currently working on scientific articles to be published in peer reviewed journals and addressing blood contaminant levels in association with food patterns, nutrient intakes and/or nutritional status.

Also, results of the complete blood count were sent to local clinics so children who had abnormal results could be treated. Nunavik health authorities were also informed about children's blood mercury and lead levels.

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

Results

Children recruited in 2006-2008 were aged between 11.6 and 53.8 months (mean ± SD: 25.9 ± 9.6) and 51% were male. About 54% of the children lived on the Hudson coast.

Percentages of detection and plasma concentrations of heavy metals and POPs are presented in **Table 1**. Lead, PCB 153, PBDE 47, PFOS and PFOA were detected in all samples. Toxaphen congeners and perfluorinated compounds were detected in at least half of the participants.

Table 1. Plasma concentrations of 2 heavy metals and 26 persistent organic pollutants (ng/L)[1]

	N	Detection limit	% Detected	Geometric mean	95% CI	Range
Heavy metals						
Mercury (nmol/L)	129	0.5	96.9	8.9	7.1-11.3	0.2 - 164.5
Lead (µmol/L)	129	0.005	100.0	0.08	0.07-0.09	0.02 - 0.48
PCB (IUPAC #)						
Aroclor 1260	126	100	97.6	929	716-1203	<LOD - 61000
118	126	10	88.1	31	25-39	<LOD - 470
138	126	10	95.2	61	47-78	<LOD - 3000
146	126	10	54.8	18	14-23	<LOD - 1400
153	126	10	100.0	118	91-153	10 - 8700
163	126	10	60.3	20	16-27	<LOD - 1900
170	126	10	68.3	21	17-26	<LOD - 2000
180	126	10	89.7	51	39-67	<LOD - 6500
183	126	10	50.8	11	9-13	<LOD - 350
187	126	10	66.7	23	18-30	<LOD - 1900
194	126	10	50.0	12	10-14	<LOD - 890
∑PCBs [2]	126			614	504-747	175 - 30376
Chlorinated pesticides						
p.p'-DDE	126	90	89.7	424	326-551	<LOD - 11000
-HCH	126	10	54.8	15	12-18	<LOD - 250
Hexachlorobenzene	126	40	54.8	65	52-82	<LOD - 1500
cis-Nonachlor	126	5	71.4	15	11-20	<LOD - 470
Trans-Nonachlor	126	10	92.9	86	64-115	<LOD - 3000
Oxychlordane	126	5	95.2	51	38-68	<LOD - 2500
Toxaphen						
Parlar #26	126	5	61.9	12	9-16	<LOD - 400
Parlar #50	126	5	77.8	18	14-24	<LOD - 710
Brominated flame retardants						
PBDE IUPAC # 47	126	30	100.0	184	160-212	40 - 1900
PBDE IUPAC # 99	126	20	94.4	55	47-63	<LOD - 520
PBDE IUPAC # 100	126	20	73.0	32	27-38	<LOD - 1100

	N	Detection limit	% Detected	Geometric mean	95% CI	Range
PBDE IUPAC # 153	109	20	67.9	29	24-35	<LOD - 1600
∑PBDEs [3]	109			320	275-373	70 - 5040
Perfluorinated compounds						
Perfluorooctanesulfonate (PFOS)	86	30	100.0	3369	2798-4056	910 - 31000
Perfluorooctane (PFOA)	86	30	100.0	1617	1412-1852	460 - 11000
Perfluorohexanesulfonate (PFHxS)	86	30	50.0	331	272-403	<LOD - 4400

LOD: Limit of detection.

[1] The following contaminants were detected in less than half of the blood samples: PCB 28, 52, 66, 74, 99, 101, 105, 128, 156, 167, 178, 201, 203, 206, p,p'-DDT, gamma-HCH, mirex, PBB 153, PBDE 25and PBDE 28. The following were not detected in the samples: PCB 52, aldrin, alpha-chlordane, gamma-chlordane, PBDE 15, PBDE 17 and PBDE 33.

[2] Total PCBs includes all PCBs congeners.

[3] ∑PBDEs includes PBDE congeners 47, 99, 100 and 153.

Most of the other legacy POPs and brominated flame retardants were detected in less than 50 % of the participants (data not shown).

Consumption frequencies of traditional and market foods are presented in **Table 2a** and **Table 2b** respectively. For traditional foods, seasonal consumption frequencies were added to obtain annual consumption frequencies. For both, country and market foods, consumption frequencies at home and at the daycare were added to obtain the annual consumption frequency. When a frequency was missing for one food (during any season, at home or at the daycare), the annual consumption frequency for this specific food was considered as a missing value.

Most children consumed country foods during the year prior to the interview. Caribou meat and arctic char were consumed by the highest proportion of children (99.2 % and 97.4 % respectively) and the median consumption was respectively 49.8 and 27.9 times per year respectively (**Table 2a**).

As shown in **Table 2b**, beef and chicken meat were consumed by all children during the month prior to the interview. The other market foods were consumed by more than 75% of the children except for tomato/vegetable juice and tea that were consumed by 38.8 % and 26.6 % of the participants respectively. Food items that were most frequently consumed were milk (as a beverage), real fruit juices and water, with a median consumption frequency of at least once a day (median: 83.8, 51.0 and 31.4 times during the previous month). Eighty four percent of the children drank milk but all children put milk on their cereal. Beef (all sorts of beef), potatoes, ground beef, margarine, chicken meat and whole wheat bread were consumed at least twice a week which is representative of the daycare menu.

The maximum consumption frequencies of some country foods are high but similar to those published for school-aged children from Nunavik (Muckle et al. 2008).

Table 2a. Consumption frequencies of selected traditional foods during the year prior to the interview[1]

Traditional foods	N	% of consumers	Mean (SD)		Median	Range
Marine mammals						
Dried beluga	120	28.3	3.5	(13.7)	0	0 - 117
Beluga misirak/blubber	90	32.2	10.8	(37.3)	0	0 - 234
Beluga muktuk	118	51.7	3.7	(7.9)	1	0 - 52
Seal meat	117	88.0	8.5	(11.0)	5.0	0 - 63
Marine mammal meat*	110	90.0	17.5	(28.4)	8.0	0 - 188
Seal liver	99	17.2	0.9	(3.9)	0	0 - 26
Fish						
Arctic char	115	97.4	40.3	(38.4)	27.9	0 - 209
Other trout and salmon	108	91.7	14.1	(17.0)	11	0 - 108
Game animals and birds						
Caribou meat**	120	99.2	72.1	(73.3)	49.8	0 - 436
Ptarmigan	68	73.5	8.0	(9.8)	4	0 - 41
Goose	98	88.8	16.8	(26.1)	7.0	0 - 142
Duck	122	12.3	0.8	(4.0)	0	0 - 39

[1]Frequencies have been adjusted for the duration of daycare attendance.
* Marine mammal meat includes dried beluga, beluga meat, beluga skin, seal meat and walrus.
** Fresh, cooked or frozen

Table 2b. Consumption frequencies of selected market foods during the month prior to the interview[1]

Market foods	N	% of consumers	Mean (SD)		Median	Range
Meat and alternatives						
Ground beef	121	100.0	10.5	(7.0)	9.3	3 - 66.7
Beef *	102	100.0	15.1	(6.9)	14.2	3.5 - 37.5
Chicken meat	118	100.0	9.1	(3.8)	8.4	1 - 19.2
Grain products						
Whole grain bread	124	96.8	10.3	(7.6)	8.3	0 - 43.8
Fruits and vegetables						
Oranges	123	99.2	15.8	(10.8)	12.9	0 - 64
Real fruit juice	120	95.8	51.0	(44.6)	31.4	0 - 188.6
Potatoes	119	97.5	12.3	(9.2)	11	0 - 64
Tomatoes	116	87.1	6.7	(5.8)	4.3	0 - 28.2
Sweet peppers	113	79.6	7.2	(6.1)	6	0 - 29.2
Turnip	75	77.3	3.8	(3.3)	3	0 - 11.3
Tomato/vegetable juice	116	38.8	2.1	(3.2)	0	0 - 11

Market foods	N	% of consumers	Mean (SD)		Median	Range
Milk and alternatives						
Milk as beverage	121	84.3	91.5	(67.0)	83.8	0 - 257.5
Other foods and beverages						
Margarine	120	97.5	11.0	(8.3)	8.6	0 - 64
Water	117	85.5	44.6	(44.5)	30	0 - 191
Tea	124	26.6	4.1	(15.0)	0	0 - 135

[1]Frequencies have been adjusted by the attendance at daycare duration.
* Beef includes: ground beef, beef steak and beef canned, stewed or corned.

As shown in **Table 3**, consumption frequencies of marine mammals and duck during the year prior to the interview were positively correlated with blood levels of heavy metals and legacy POPs whereas fish, caribou meat and birds were only correlated with mercury concentrations. However, the consumption of seal meat was not associated with blood Pb level. The consumption of traditional foods was not significantly associated with PBDE 99, PFOA and PFOS, with the exception of seal liver and duck that were positively associated with PFOS.

We observed many negative associations between consumption frequencies of market foods during the previous month and blood contaminant levels (see **Table 3**). Milk was negatively correlated to seven of the nine contaminants presented in **Table 3**, with the exception of Hg and PBDE 99. In addition, consumption of some market foods, such as whole wheat bread, tomato/vegetable juice, and margarine, were negatively associated with three to five contaminants. On the contrary, real fruit juices were positively associated with Hg and Pb levels while tea was positively correlated to Hg, Pb and legacy POPs.

Table 3. Correlation between consumption frequencies of selected traditional and market foods, and blood contaminants

	Hg [1]	Pb [1]	PCB 153 [2]	PCB 180 [2]	trans-Nonachlor[2]	p,p'-DDE [2]	PBDE 99[2]	PFOA[3]	PFOS [3]
Marine mammals									
Dried beluga	0.27 **	0.26 **	0.23 *	0.20 *	0.25 **	0.25 **			
Beluga misirak/ blubber	0.38 ***	0.19 ‡	0.26 *	0.22 *	0.33 **	0.25 *			0.25 ‡
Beluga skin	0.45 ****	0.30 **	0.22 *	0.16 ‡	0.26 **	0.22 *			
Seal meat	0.49 ****		0.23 *	0.22 *	0.31 **	0.20 *			
Marine mammal meat	0.52 ****	0.21 *	0.23 *	0.20 *	0.31 **	0.22 *			
Seal liver	0.27 *	0.29 *	0.43 ****	0.42 ****	0.42 ***	0.42 ****			0.27 *
Fish									
Arctic char	0.38 ****								

	Hg [1]	Pb [1]	PCB 153 [2]	PCB 180 [2]	trans-Nonachlor [2]	p,p'-DDE [2]	PBDE 99 [2]	PFOA [3]	PFOS [3]
Trout and salmon	0.42 ****								
Game animals and birds									
Caribou meat	0.20 *								
Ptarmigan	0.34 *								
Goose	0.44 ****								
Duck	0.31 ***	0.16 ‡	0.24 *	0.23 *	0.21 *	0.17 ‡			0.25 *
Meat and alternatives									
Ground beef	- 0.27 **	- 0.17 ‡			- 0.19 ‡				
Beef	- 0.34 ***						0.28 **	0.20 ‡	
Chicken meat	- 0.31 ***								
Grain products									
Whole grain bread	- 0.34 ***			- 0.16 ‡	- 0.20 *			0.22 ‡	
Fruits and vegetables									
Oranges	- 0.17 ‡								
Real fruit juices	0.24 *	0.42 ****							
Potatoes	- 0.23 *				- 0.17 ‡				
Sweet peppers	- 0.26 **								
Tomatoes	- 0.23 *				- 0.18 ‡				
Turnip	- 0.31 *							0.35 *	
Tomato/ vegetable juice	- 0.41 ****		- 0.25 *	- 0.26 **	- 0.27 **	- 0.23 *	0.21 *		
Milk and alternatives									
Milk as beverage		- 0.29 **	- 0.20 *	- 0.20 *	- 0.20 *	- 0.22 *		- 0.30 **	- 0.26 *
Other foods and beverages									
Margarine	- 0.25 **		- 0.18 ‡	- 0.20 *	- 0.21 *	- 0.19 *	0.17 ‡		
Water	0.29 **							- 0.21 ‡	
Tea	0.21 *	0.18 ‡	0.23 *	0.24 *	0.22 *	0.21 *			

Spearman correlation coefficient: * < 0.05, ** < 0.01, *** < 0.001, **** < 0.0001, ‡ < 0.10.
[1] N ranged from 64 to 114.
[2] N ranged from 44 to 108.
[3] Fresh, cooked or frozen.

Discussion and conclusions

Legacy POPs were generally detected in a smaller proportion of these preschool children and at lower levels than what was previously observed in Nunavik children (Després et al. 2005;Muckle et al. 2001). These results are consistent with the decreasing trend observed in Nunavik infants and adults for legacy POPs (Dallaire et al. 2003;Dewailly et al. 2007b).

Some emerging POPs, especially PBDE 47, 99 and 100, were detected in a larger proportion of children and at higher levels than in Nunavimmiut adults (Dewailly et al. 2007a). PBDE 153 was less detected in our study but we observed higher levels of this congener than in Nunavimmiut adults (Dewailly et al. 2007b). Nonetheless, the higher limit of detection used in the present study should be taken into account when interpreting this result. PFOS was detected in all participants of the Nunavik Inuit Health Survey (Dewailly et al. 2007b) and in our study, but lower levels were observed in our participants compared to Nunavimmiut adults.

In general, market foods were consumed by a higher proportion of children and more frequently than traditional foods. These results confirm the transition from a traditional diet to a westernised diet observed in the Canadian Arctic (Kuhnlein et al. 2004). Nevertheless, the consumption of traditional foods was widespread among these preschool Inuit children and the important consumption of foods promoted in the daycare centres may indicate that the nutrition program is well established.

In agreement with other studies (Dewailly et al. 2007b;Muckle et al. 2008), we observed several positive associations between traditional foods and blood contaminant levels. On the contrary, several negative associations were observed with many market foods. Multiple regression analyses are being performed to further elucidate these inverse relationships. Children consuming more milk, fruits and vegetables could also eat less country foods and thus, be less exposed to contaminants. However, traditional foods are unique foods with exceptional nutrient quality. Data from the Canadian Arctic indicate that on days when traditional food was consumed, there was significantly more protein, vitamins and minerals in the diet (Kuhnlein et al. 2004), thus improving the nutritional status of individuals. The role of an adequate nutritional status and the protecting effect of many nutrients and food components against contaminant toxicity have been recognized during most of this century. For example, a number of different nutrients including calcium, zinc, iron and various vitamins influence susceptibility to lead toxicity (Mahaffey 1990). Evidence also exists that fruit consumption provides a protective effect against Hg exposure (Passos et al. 2003;Passos et al. 2007).

In conclusion, these results are in agreement with studies indicating that Hg, Pb and legacy POPs follow a negative trend over time (Dewailly et al. 2007a;Dewailly et al. 2007b). However, the rate of detection of some brominated flame retardants was more elevated in these children than in other Nunavimmiut adult populations (Dewailly et al. 2007b). Emerging contaminants have been found in the Arctic more recently and are of growing concern. Traditional foods are associated with a higher contaminant exposure but they also provide many essential nutrients. Some healthy market foods also appear to have a protective effect against contaminant. This study is of particular interest for Nunavimmiut parents and the Nunavik Public Health since it might lead to a better understanding of the benefits/risks of traditional/country foods and the protecting effect of a healthy diet. As part of 2010-2011 grant, we will complete our last data collection and, continue statistical analysis and communication of our results to various authorities.

NCP Performance indicators

Number of northerners engaged in our project:
Six Inuit were hired during the 2009 data collection, mainly as interpreter. As part of the nutrition intervention, we are working in close collaboration with many Inuit and organisations, including among others Board of Directors and staff members (directors, cooks, educators) of Nunavik childcare centres.

Number of meetings/workshops we held in the North:
Several formal and informal meetings took place while our team members traveled to the North. Our team visited Nunavik at least six times in

2009-2010 and each time we visited at least two communities. Some of these meetings were organized for research purposes (e.g. data collection, results communication) and others for the nutrition intervention (e.g. cooks' training, support to daycare staff members, meetings with daycare boards of directors).

Number of students involved in our NCP work:
Two students worked for us on data entry at Université Laval in 2009-1010. Also, through a partnership with the NRBHSS, two nutrition students did an internship in Nunavik.

Number of citable publications:
In 2009-2010 we worked on four citable publications:

Gagné D, Vézina C, Lauzière J et al. (in preparation). Evaluation of blood mercury and lead concentrations in preschool children attending daycare centres in Nunavik. To be submitted to *Environmental Health*.

Turgeon O'Brien H, with the collaboration of Gagné D, Vézina C, Vinet-Lanouette C, Lauzière J, Hamelin AM et al. (2009). Contaminant Nutrient Interaction Issues as Part of a Public Health Intervention Study of Inuit Children in Nunavik: Third Year of Data Collection. *17th Annual Northern Contaminants Program Results Workshop*. Ottawa; September 29-30 2009.

Turgeon O'Brien H, Gagné D, Vézina C et al. (2009). Contaminant nutrient interaction issues as part of a public health intervention study of Inuit children in Nunavik: third year of data collection. In: *Synopsis of Research Conducted under the 2008-2009 Northern Contaminants Program*. Ottawa: Department of Indian Affairs and Northern Development, p.14-23.

Turgeon O'Brien H, Gagné D, Vézina C et al. (in preparation). Exposure to persistent organic pollutants in preschool children attending daycare centres in Nunavik. To be submitted to *Environmental Research*.

Expected Project Completion Date

The expected project completion is 2011. The last data collection will be done in the fall of 2010. Communication of the final results will be done in 2011-2012.

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Interactions between contaminant exposure and genetic variation in relation to health outcomes in Inuit from Nunavik

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Abstract

The Inuit from Nunavik are exposed to a wide range of environmental contaminants including legacy persistent organic pollutants (POPs), emerging POPs and toxic metals. There is substantial evidence from epidemiological studies that prenatal and postnatal exposure to POPs and heavy metals are associated to growth and developmental effects in children. Similarly, exposure

Résumé

Les Inuits du Nunavik sont exposés à une vaste gamme de contaminants environnementaux, notamment à des polluants organiques persistants (POP) hérités du passé, à des POP émergents et à des métaux toxiques. Un important corpus de données tirées d'études épidémiologiques montre que l'exposition prénatale et postnatale aux POP et aux métaux lourds est associée à des effets sur la croissance et le

to POPs and metals seems to play a critical role in the pathology of cardiovascular diseases or diabetes. However, it is well known that those health conditions are not determined only by exposure to such contaminants or by life style factors but also by genetic risk factors. Hence, we are interested in identifying some gene variants present in Inuit people that may impact on their risk to develop such conditions when exposed to specific contaminants through their food. This will allow us to better evaluate contaminant-health relationships that are sometimes difficult to establish or to more precisely assess those for which clear evidences exist. More specifically, this project aims at investigating if some genetic variations (i.e. polymorphisms) that are frequent in the Inuit population may modify the relationship between contaminants (e.g. POPs and heavy metals) and cardiovascular diseases risk factors in adults or developmental and behavioral related traits in children. To do so, we propose to use two ongoing epidemiological studies conducted among adults and 11 years-old children from Nunavik.

Key Message

Adults Cohort

1. Communications with local stakeholders took time considering the complex matter of gene-environment interaction but ends up with a better understanding of what genetic susceptibility is and how it might be useful for health research as well as public health intervention.
2. As a result, and with the communication material developed, the tour to visit each individual who participated to the initial Qanuippitaa survey was a success with a participation rate of 80% for the genetic testing.
3. The section of gene polymorphism was done according to the literature on both specific exposure of Inuit (e.g. contaminants) and specific health outcomes of interest (e.g. cardio vascular diseases).

développement des enfants. De même, l'exposition aux POP et aux métaux semble jouer un rôle critique dans la pathologie des maladies cardiovasculaires ou du diabète. On sait bien toutefois que ces problèmes de santé ne résultent pas uniquement de l'exposition à ces contaminants ou de facteurs liés au mode de vie mais sont également associés à des facteurs de risque génétiques. Nous cherchons donc à identifier certains des variants génétiques présents chez les Inuits qui peuvent influer sur leur risque de développer ces problèmes de santé lorsqu'ils sont exposés à certains contaminants par voie alimentaire. Nous pourrons ainsi mieux évaluer les relations entre les contaminants et la santé qui sont parfois difficiles à établir ou pourrons déterminer de façon plus précise les relations pour lesquelles il existe des données probantes. Plus particulièrement, ce projet vise à examiner si certaines variations génétiques (ou polymorphismes) qui sont fréquentes dans la population inuite peuvent modifier la relation entre les contaminants (p. ex. POP et métaux lourds) et les facteurs de risque cardiovasculaires chez les adultes ou des caractéristiques développementales et comportementales chez les enfants. Pour ce faire, nous prévoyons utiliser deux études épidémiologiques en cours menées chez des adultes et des enfants de 11 ans du Nunavik.

Messages clés

Cohorte d'adultes

1. Le travail de communication avec les intervenants locaux a pris du temps, compte tenu de la complexité de l'interaction gène-environnement, mais nous a permis de mieux comprendre la susceptibilité génétique et l'utilité potentielle de cette dernière dans les recherches sur la santé de même que dans les interventions en santé publique.
2. Par la suite, une fois le matériel de communication élaboré, nous avons rendu visite à chaque participant à l'enquête initiale Qanuippitaa; cette tournée a été un grand succès, le taux de participation pour les tests génétiques atteignant 80 %.
3. La partie sur les polymorphismes génétiques a été effectuée en tenant compte des études publiées sur l'exposition particulière des Inuits

4. Descriptive analyses show that Inuit have a very specific genetic pattern.
5. Preliminary analyses show that the simple effect of mercury on PON1 activity (associated with cardio vascular risk) was not found in our study population. However, when the genetic components were added to the model in addition to their interaction with mercury, the association was almost significant.
6. Statistical analyses will continue and joint analyses will be performed with the Greenlandic component of the cohort.

Child cohort

7. The testing of 11 year-old children ended, which allowed to send blood samples collected to the CHUQ laboratory for genetic analyses.
8. The literature review allowed identifying 32 genes of interest as well as the polymorphisms to be measure for each of those genes.
9. Laboratory analyses were completed at the "Plateforme de génotypage du CHUQ" in Quebec City, and allowed to characterize 104 polymorphisms on 290 blood samples.
10. Descriptive statistical analyses will start to document the prevalence of the targeted polymorphisms in the study sample, and to identify which of them are frequent enough be taken into account in confirmatory analyses
11. Confirmatory statistical analyses will start to document whether the effects of exposure to POPs or heavy metals on child outcomes are mediated by genetic variants assessed so far.

(p. ex. contaminants) et des effets spécifiques sur la santé qui nous intéressaient (p. ex. maladies cardiovasculaires).

4. Des analyses descriptives montrent que les Inuits possèdent un profil génétique très particulier.
5. Les analyses préliminaires montrent que le simple effet du mercure sur l'activité du gène PON1 (associée à un risque cardiovasculaire) n'était pas visible dans la population de notre étude. Toutefois, lorsque les composantes génétiques ont été ajoutées au modèle en plus de leur interaction avec le mercure, l'association était presque significative.
6. Les analyses statistiques se poursuivent et des analyses conjointes seront effectuées avec la partie groenlandaise de la cohorte.

Cohorte d'enfants

7. Les tests chez les enfants de 11 ans sont terminés, et les échantillons de sang prélevés ont pu être transmis au laboratoire du CHUQ pour des analyses génétiques.
8. La recension des écrits a permis d'identifier 32 gènes d'intérêt de même que les polymorphismes à évaluer pour chacun de ces gènes.
9. Les analyses en laboratoire ont été effectuées à la « Plate-forme de génotypage du CHUQ » à Québec et ont permis de caractériser 104 polymorphismes dans 290 échantillons de sang.
10. Au moyen d'analyses statistiques descriptives, nous commencerons à compiler l'information sur la prévalence des polymorphismes ciblés dans l'échantillon étudié et à déterminer lesquels sont assez fréquents pour être pris en compte dans les analyses de confirmation.
11. Au moyen d'analyses statistiques de confirmation, nous commencerons à compiler l'information en vue de déterminer si les effets de l'exposition aux POP ou aux métaux lourds sur la santé des enfants sont médiés par les variants génétiques étudiés jusqu'à présent.

Objectives

The main aim of this project is to better understand the effect of contaminants on the development of specific health outcomes in Inuit from Nunavik by investigating gene-environment interactions.

Two main objectives are set: 1) To explore genetic variations that are frequent in the Inuit population (i.e. polymorphisms) that could modify the relationship between specific environmental exposures (i.e. contaminants) and cardiovascular diseases related conditions in Inuit adults from Nunavik. 2) To identify genetic variation that could modify the relationship between exposure to contaminants (prenatal and postnatal) and the development of school-aged children from Nunavik. 3) To perform the statistical analyses aimed to test the following specific hypotheses of the proposed project:

a. Specific genes involved in xenobiotic metabolism or directly associated with health outcomes of interest interact with mercury exposure to decrease heart rate variability and blood pressure in adults of the Inuit population from Nunavik.

b. Dioxin-like compounds exposure is associated with elevated blood pressure in adults even after controlling for major confounders and this association is modified by gene variants gene variants frequent in the Inuit population.

c. POPs and Hg are prooxidant and are then associated with oxidized cholesterol measurements and intima-media thickness traits in adults but those relationships are influenced by gene variants.

d. Exposure to POPs cause an elevation in level of serum lipids and this relationship is modified by the presence of some gene variants.

e. POPs are related to a greater risk of developing diabetes and obesity but those relations depend on the presence or absence of some gene variants.

f. Relationships between POPs (e.g. PCBs) or heavy metals (e.g. Hg, lead) are related to growth, cognition and to affective and behavioral endpoints including hyperactivity, ability to interpret interpersonal emotional cues, and psychopathology. These relations are influenced by the presence or absence of some key gene variants.

g. Emerging contaminants of potential concerns such as PFOS and PBDEs have some deleterious effects on the growth and neurobehavioral development and they interact with some polymorphisms.

Introduction

It has been recognized that genetic variability may affect the susceptibility of individuals or populations to the effects of pollutants in the environment. In this sense, the study of gene-environment interactions is important for improving accuracy and precision in the assessment of both genetic and environmental influences. Since few genetic studies have been conducted in the Arctic, and considering that Inuit people have their own genetic background, the impact of genetic variation that could potentially modify their susceptibility to contaminants should be evaluated.

Basic principles of association studies

Genetic factors that modulate the individual susceptibility to complex diseases are most probably common polymorphisms (i.e. genetic variants that appear in at least 1% of a population) having modest effects at the individual level, but that may be associated with a significant population-attributable risk because of their high allele frequencies (1). Genetic association studies aim to test whether a gene variant is associated with a disease or trait: if association is present, a particular allele (i.e. an alternative form of a gene) will be seen more often than expected by chance in participants with the health condition than in healthy individuals. The most commonly used molecular markers for genetic association studies are variations in DNA at which one of the four nucleotides is substituted for another. These polymorphisms are the most frequent in the genome and are called SNPs (i.e. single nucleotide polymorphisms). They constitute 90% of the total human genetic variation while the remaining 10% contains genetic variants resulting mainly from deletions, insertions, duplication or translocations of DNA sequences. These polymorphic sites occur every 100 to 300 base pairs (bp) along the human genome of 3.2 billion bp (2). They can occur in both coding and non-coding regions of the genome and many of them have no effect on cell function, while others may predispose people to disease or influence their response to environmental exposure. Different ethnic groups may have particular gene variants that are not seen in other populations or they can share the same genetic variants with other groups but with different frequencies.

Gene-environment interactions in complex diseases

The great majority of diseases or health related conditions are induced by multiple environmental and genetic factors as well as by interactions between them. Evidence for gene-environment interaction can consist of the observation that exposure to an environmental pathogen has different health effects in people with different genotypes. From a mechanistic viewpoint, interaction suggests that the gene product and the by-product of the environmental insult operate together through the same causal pathway. From a statistical viewpoint, it implies that in combination, the risk associated with the environmental factor and a specific genetic background is higher than the sum of the separate risks. A simple and reliable statistical way to analyze this for a quantitative trait is to use analysis of covariance with the genotype and the environmental factor entered as main effects and with an interaction term between the genotypic and the environmental factors (**3**).

Gene-environment interaction has a long scientific history (**4**). However, many conventional epidemiological studies still restricted their analysis to the environmental causes of diseases without obtaining information about genetic risk factors. Similarly, many health studies focused only on the genetic causes of diseases. But, if we only evaluate the separate contributions of genes and environment to a disease without considering their interactions, we will incorrectly estimate the proportion of the disease that is explained by both factors and their joint effect. In fact, accounting for gene-environment interactions might increase the power to detect environmental factor with small marginal effects (in the population as a whole) especially if the data show a stronger effect in a genetically susceptible subgroup of the population (**5**),(**6, 7**). In the same way, gene-environment interactions studies can shed light on some associations between environmental factors and disease outcomes that only exist in a specific genetic context. In this perspective, identifying genetic variations that modify the relationship between contaminants exposure and cardiovascular-related or development-related traits will help us to better understand the impact of such contaminants on these health conditions.

Contaminants, cardiovascular disease and metabolic syndrome related conditions

Organochlorides (OCs) form a class of persistent organic pollutants (POPs) including polychlorinated dibenzo *p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and various chlorinated pesticides or industrial products. Toxic metals of concern include lead (Pb) and mercury (Hg), mostly under the form of methyl mercury (MeHg). Exposure to POPs and heavy metals can play a critical role in the pathology of cardiovascular diseases (**8**). For instance, a study suggested that residing in and around sites contaminated with POPs, such as PCBs, is associated with increased rates of hospitalization for coronary heart disease and acute myocardial infarction (**9**). Oxidative stress seems to be a hallmark of PCB toxicity and related adverse outcomes. Indeed, it is proposed that certain PCBs can compromise normal functions of vascular endothelial cells by activating oxidative stress-sensitive signaling pathways and subsequent proinflammatory events critical in the pathology of atherosclerosis and cardiovascular disease (**10, 11**). In addition to inducing inflammatory events, POPs seems to contribute to cardiovascular diseases by increasing atherogenic plasma lipids (**12**). It is also possible that POPs exposure may be involved in the development of the metabolic syndrome through endocrine disruption affecting glucose and lipid metabolism (**13-15**), even if they are not the main determinant of this condition. Supporting this, there is a growing body of recent literature reporting that exposure to POPs, especially dioxins, is related to a greater risk of developing diabetes (**16-19**).

In addition to certain POPs, blood lead and cadmium, and urinary cadmium levels were associated with increased incidents of peripheral arterial diseases; but, underlying mechanisms of these effects have not been determined (**20, 21**). However, most studies on the relationship between toxic metals and the risk for clinical cardiovascular disease has been on mercury exposure. The first studies reporting a relationship between MeHg exposure and carotid intima-media thickness (IMT) came from Finland (**22**). Since that report, several other studies have been published, offering support to varying degrees. The same study group in a follow-up study showed that a high content of mercury in hair may be a risk factor for acute coronary events and cardiovascular disease (CVD), coronary heart disease (CHD), and all-cause mortality in middle-aged eastern Finnish men and that mercury also may attenuate the protective effects of fish on cardiovascular health **(23)**. Other studies have reported an association between mercury and elevated blood pressure **(24, 25)** and reduced heart rate variability (HRV) **(24, 26, 27)**.

Contaminants and development

Environmental exposures to POPs have been suspected to disrupt endocrine functions **(15)**. Indeed, several experimental studies have shown that POPs are able to interact with steroid hormones receptors **(28, 29)**, as well as with thyroid hormones receptors and transporters **(30)**, and epidemiological studies have reported effects in exposed populations corresponding to these mechanisms of toxicity **(31-33)**. Most epidemiological and experimental studies on health effects related to toxic metals (Pb, Hg) and OC exposure (mainly PCBs) suggest that prenatal life is the most susceptible period for induction of adverse effects on growth and neurobehavioral development. Indeed, several studies have reported different developmental, immune and/or cognitive deficits in newborns from different parts of the world exposed to OCs during prenatal and/or postnatal development, with some of these deficits persisting in later childhood **(31, 34-40)**. Regarding metals, prenatal exposure to MeHg has also been linked to developmental and cognitive deficits in infancy and childhood **(41-43)**, and the detrimental effects of pre- and postnatal exposure to lead on cognitive and motor development have already been extensively documented **(44-48)**.

Gene-environment interactions in relation to cardiovascular disease and its common risk factors

There are an important number of publications addressing gene-environment interactions in the area of metabolic traits and cardiovascular diseases but most of the emphasis has been placed on gene-diet interactions. Those studies that include both observational and interventional designs have focused on the traditional lipid candidate genes **(49-51)**. Several other studies have also focused on gene-behavioural interactions. The best known and characterized behavioural factors (i.e. smoking, physical activity and alcohol consumption) that may modify cardiovascular disease risk or its intermediate risk factors have received most attention **(52)**. As an example, a prospective study investigated whether the effect of smoking on coronary heart disease risk was affected by apolipoprotein E (APOE) genotype. They found that smoking increases the risk of coronary heart disease (CHD) in men of all genotypes but particularly in men carrying the ε4 allele **(53)**. The same has been demonstrated among men from the Framingham Offspring Study **(54)**. In recent years, coffee drinking has also attracted attention regarding the study of interactions with genes in relation to cardiovascular disease risk **(55)**.

Gene-environment interactions in relation to development

As of yet, the field of gene-environment interaction as a whole has been much more explored in the areas of cancer research and cardiovascular disease than in the area of development-related health outcomes. However, there is a growing awareness of the importance of considering such interactions in teratogenic research studies. For example, few studies reported the modifying effects of frequent polymorphisms included in the cytochrome P450 (CYP) and gluthatione S-tranferase gene families (e.g. CYP1A1, CYP1B1, GSTM1, GSTT1) on the relationship between maternal smoking and neonatal birth weight **(56-58)**. Other studies have reported significant interactions between polymorphisms lying in genes for the dopamine metabolic enzymes, including the dopamine transporter gene (DAT1) **(59, 60)** and dopamine receptor genes (DRD2 and DRD4) **(61, 62)**, and maternal smoking in relation to different behavioural phenotypes in children.

The psychiatric literature contains few examples of gene-environment interactions also related to heavy metals exposures. For example, recent studies of dental professionals suggest that polymorphisms for brain-derived neurotrophic factor **(63, 64)** and the coproporphyrinogen oxidase gene **(65)** modify the adverse effects of elemental mercury exposure on neurobehaviour and mood. Several polymorphisms thought to affect lead metabolism have been investigated as risk modifiers, including δ-aminolevulinic acid dehydratase (ALAD) **(66-68)**, apolipoprotein E (ApoE) **(69, 70)**, the dopamine receptor D4 **(71)** and the HFE protein **(72, 73)**.

Genetics of isolated populations

Genetic factors involved in complex disorders are neither necessary nor sufficient for the disease expression. However, they increase the risk of developing the disease, often with relatively modest individual effects, and through interaction with other genetic or environmental factors. Identification of such genetic effects in complex disorders may be easier to identify in isolated populations than in large outbred populations (74, 75). Indeed environmental risk factors are generally more uniform in the former and they are also expected to show greater genetic homogeneity because of the limited number of founders and the absence of migration. . This potentially leads to less alleles variants but which are at a higher frequency in the population, increases the power to detect association. Finally, linkage disequilibrium (the non-random association of alleles at two or more loci) may extend over larger regions than in outbred populations, increasing the power of association study for gene detection (76).

Inuit and other New World people experienced a severe population bottleneck when ancient populations migrated from Asia into the Americas (77). Because of this episode and the fact that circumpolar populations have been living in an almost genetic isolation for more than 5,000 years (78), we can expect that the contribution of the founders in the contemporary genetic pool is high, decreasing the risk of spurious genetic associations due to genetic stratification (population admixture). Therefore, the Inuit population from Nunavik is a population of choice for conducting genetic association investigations since it can increase the power to detect such an association between a particular gene variant and a phenotype of interest (discrete or continuous trait).

Genetics and contaminants

Metabolic pathways that minimize the effects of biological toxins are present in all human beings, but the presence of some variations in genes involved in these pathways may give some individuals an advantage or a disadvantage in the detoxification process. An individual's genetic makeup thus influences his risk of developing a disease as a result of exposure to toxins and also explains why some individuals and ethnic groups have higher prevalence and mortality rates of certain disorders (79). **Considering that Aboriginal peoples have their own genetic background and considering the fact that few genetic association studies have been conducted in Inuit populations, it is important to investigate the impact of genetic variation that are involved in xenobiotic metabolism and toxicity in the Arctic.**

In this perspective, genes of drug metabolizing enzymes (DMEs) are of major interest because they act at the interface of environmental exposures to inactivate, detoxify, or eliminate xenobiotic substances. Importantly, sequence variation in the coding sequences of theses genes has already been shown to impact function (80). This is the case for most of the genes of the P450 (CYPs) superfamily (81) that metabolized around 56% of existing pharmaceuticals (82). Therefore, it seems likely that genetic differences that may alter protein activity level of such genes could be key factors responsible for susceptibility to toxicity caused by environmental pollutants (83).

Choice of candidate genes

Carefully Selected candidate genes for hypothesis-driven gene-environment studies could be those that have been consistently associated with the health outcome of interest. However, the absence of such an association does not disqualify a gene. Indeed, if the relationship between a gene and a disorder is conditional on the environment, it will consequently be more difficult for researchers to detect a direct association. Therefore, a second logical basis for selecting a candidate gene for gene-environment interaction study is evidence that the gene product and exposure interact in the same biological pathway (5, 84). Beside physiological plausibility, the choice of candidate genes should be driven by the presence of polymorphic variants that are relatively common in the population. Indeed, from a practical viewpoint, it is important to investigate polymorphic genes with frequent variants since it confers advantages of statistical power when testing interaction effect (84). In addition, publicly available database such as HapMap that defines haplotype blocks of genes further allows selecting the SNPs (i.e. tagSNPs) in order to capture a high degree of genetic diversity for haplotype analyses.

Genetic analyses
Basic principle
Since the Blueprint mentions that most human genomics research is beyond the scope of the NCP, we have opted for a candidate-gene-based genetic association study strategy using the high-quality population-based sample from Nunavik to identify gene variants involved in metabolism on the above-mentioned outcomes of interests in adults and children. Also, despite a constant declining in cost, genome scan approaches are still very expensive. We have thus chosen a hypothesis-driven approach that is more in line with the classical epidemiological tradition than hypothesis-free genome scan studies. We will take advantage of the already genotyped gene polymorphisms of interest identified from literature data, combined with the selection of tagSNPs (to be genotyped) using haplotype blocks from the HapMap database, to better capture genetic diversity of the study population, which will further refine our genetic association study than genome scan approaches.

Activities in 2009-2010

This project is based on the following epidemiological studies:

- **The Nunavik Health Survey** was conducted in fall 2004. 929 participants accepted to enter the cohort study (follow up) and be re-contacted for further analyses and follow up.
  - A food frequency questionnaire and a 24h-recall in 1000 participants have been used to calculate various macro and micro nutrients intake.
  - Legacy and emerging POPs, CALUX (dioxin like activity), mercury
  - Oxidative parameters (LDL-Ox), paraxonase-1 (PON1) activity and concentration
  - Holter (HRV), carotid ultrasound (IMT), blood pressure and confounders
  - BMI, sitting BMI and diabetes parameters (insulin and blood glucose).
  - Red blood cell (n=1000) and plasma (n=500) fatty acids available.
  - All medical files have been scanned and interpreted.
  - Ethical and financial support received for phase 1 (Consent of individuals).
- **The Child development cohort.** 300 11 years-old children examined between 2005 and 2010.
  - Legacy POPs, emerging POPs and heavy metals in cord blood, at 6 months of age and at 11 years old (child blood).
  - Fatty acids profile in cord and child blood.
  - Growth parameters: BMI, brachial perimeter, triceps and subscapular skinfold at 11 years.
  - Child Cohort Dietary Questionnaires: Mothers were interviewed about their children's diet. The same questionnaires used in the Nunavik Health Survey are used (FFQ and 24h-recall) for this follow-up study.
  - Medical files. All child medical files (n=300) have been scanned, cleaned-up and medical information about chronic health conditions have been extracted and interpreted.
  - Neurobehavioral development documented through many tests and procedures.
  - Coding and entry of all data will end early 2010.

We have met the Nunavik Nutrition and Health committee (NNHC) in March 2008 in Kuujjuaq to present the rationale of the proposed project regarding gene-environment investigations. After one day of discussion with members of the committee about our specific objectives, the board gave its consent to the continuation of the project **(see Appendix 1 and 2)**. For the adult cohort exclusively, that consent from the NNHC implied that we would re-contact participants in order to get their authorization for doing genetic analyses on blood samples they already gave to us. This field work will take place in February 2009 and will be mainly financed from other sources (INCHR Team). For the school-aged children, the participants already gave their consents allowing us to conduct genetic analyses without having to re-contact participants (**see Appendix 3 and 4 for the consent forms**). Both projects have also been approved by the Laval University research ethical committee (CERUL) (**see Appendix 5 and 6**).

Summary of what has been done up to now (2009-2010) for the Genetic Component of the International Inuit Cohort Study.

- The International Inuit Cohort participants from the Qanuippitaa Nunavik Health Survey in 2004 were revisited in the winter (January-March 2009) and asked to participate in a genetic component:
    - ♦ Consents have been obtained for this genetic component.
    - ♦ A family tree questionnaire was administered to link family members (parents) that were already in the 2004 database
- **DNA extraction and genotyping :**
  DNA extraction was done by Ariane Dubé-Linteau between April 27 and May 4th, 2009. DNA was sent to McGill University genotyping service on July 8th. The genotyping results for 35 Single Nucleotide Polymorphisms (SNPs) were received on July 24th, 2009.
- **Selection of independent individuals for genetic analysis.**
  In 2004, participants from the Inuit Cohort study were sampled on the basis of their household. Hence, participants inside a same house are more likely to have familial relationships between them. In genetic association studies that consider familial relationships, we need to know the parents' identity of all individuals in order to use this information in statistical analysis. In genetic association study that uses a representative population sample; all individuals in the study must have no known familial relationship between them. That's why, in order to get the information about familial relationship, the family tree questionnaire was administered. With the information taken from this family tree questionnaire, each participant was assigned a «father study number» and a «mother study number» depending on whether the participant's parents were already in the Inuit Cohort Study or not. Then, based on the individual's parents' study numbers, only independent individuals were selected for the first part of the analysis: 455 independent individuals were selected.
- **Statistical analysis up to now.**
  First, with the Allele Procedure in SAS, version 9.2, allele and genotype frequencies, Hardy-Weinberg equilibrium and other measures were obtained for the 35 SPNs. Linkage disequilibrium measures and statistics between two loci were also obtained with this procedure. Then, descriptive statistics (mean, variance, percentiles, correlations, etc.) were measured in SAS for the 35 SNPs and their associated phenotypes. These associated phenotypes had been obtained earlier in a literature search made by Ariane Dubé-Linteau. To start, an analysis of variance (ANOVA) was made, without any adjustment, to see if there were differences in the means of the associated phenotypes between the genotype groups for each of the 35 SNPs. Then, a research was done to see which variables should be used to adjust the comparison of the group means in an analysis of covariance (ANCOVA). For now, the ANCOVA models are still being worked on and all statistical hypotheses for these models will be checked thoroughly.

Summary of what has been done up to now (2009-2010) for the genetic component of the Child development study.

The genetic analyses were schedule to be performed when the data collection of the Child development cohort will be completed in order to send to the relevant laboratories the blood specimens from all participants. This was delayed to February 2010 since the last data collection trip, scheduled for spring 2009, was first postponed to fall 2009 and re-postponed to January 2010 due to the illness of a key member of our Inuit personnel, the person responsible for child testing since the beginning of study. She has been hospitalized in Montreal from May to December 2009 and we postponed the field work the longer we could to be able to have this person in our team for the last data collection trip. Unfortunately, she did not recovered enough to be back to work. We hired another Inuit woman who, after training, was able to perform the testing; she successfully tested 13 children so far. The data collection will end February 5 2010, and the blood specimens will be send during the following days to laboratories for analyses of 70 polymorphisms located in 37 candidate genes (see Appendix 8). The database will be update with results (such as contaminant exposure, outcomes and potential confounders) from the last 25 participants during the months of February and March. Consequently, the statistical analyses aimed to address the gene-interaction hypothesis will be accomplished during year 2010-2011.

Results

Preliminary data: Study of PON1 activity in relation with mercury

We wanted to know if three SNPs located on PON1 gene (rs662, rs854560 and rs854572) could modify a relation that is well known between mercury that affects PON1 activity. However, as it can be seen in table 1 (model 1), the simple effect of mercury on PON1 activity was not found in our study population. However, when the SNPs were added to the model in addition to their interaction with mercury, an interaction was very close to being significant at the 5% threshold ($\alpha = 0.05$). Indeed, as shown in table 1 (model 4), the SNP rs854572 almost modify the relationship between mercury and PON1 activity when the SNP is put in two categories with and interaction term that is significant at the 10% threshold (p-value = 0.0844). The two categories of the SNP are the frequent homozygous and the regrouping of rare homozygous and heterozygous together.

A final model was also tested (model 5) to verify the simultaneous effect of these three SNPs. As can be seen in table 1, all three SNPs do have an effect on PON1 activity but the interaction term between the rs854572 SNP and mercury is no longer significant at the 10% threshold. It should be noted that the gender variable was added to this model because it was found significant in previous models.

Table 1 – Multiple linear regression with PON1 activity as the outcome variable (Y)[1]

Model number	Exogenous variables in the model	df	p-value of each variable (Pr > F)	Global p-value (Pr >F)	R^2 of the model
1	mercury	1	0.6622	0.6622	0.000426
2	mercury	1	0.3037	< 0.0001	0.067527
	rs662	2	0.0011**		
	mercury*rs662	2	0.4031		
3	mercury	1	0.7110	0.0406	0.018408
	rs854560	1	0.2440		
	mercury* rs854560	1	0.6947		
4	mercury	1	0.4748	< 0.0001	0.093349
	rs854572	1	< 0.0001**		
	mercury* rs854572	1	0.0844*		
5	mercury	1	0.8953	< 0.0001	0.189097
	rs662	2	< 0.0001**		
	rs854560	1	0.0083**		
	rs854572	1	< 0.0001**		
	mercury* rs854572	1	0.2239		
	gender	1	0.0283		

[1] : PON1 activity was log transformed to respect the model hypothesis (ex: normality)
This model used 451 (model 1), 448 (model 2), 449 (model 3) and 451 (model 4) participants in the analyses
** : Significant exogenous variables to the 5% threshold
* : Significant exogenous variables to the 10% threshold

Methylmercury and cardiovascular diseases (CVD)
In a recent review of the literature examining the evidence of cardiovascular effects induced by exposure to methylmercury, Stern concluded that realistic exposure to MeHg from fish consumption could be associated with heart diseases, in particular myocardial infarction (85). The main evidence supporting this conclusion was provided by Finnish studies conducted among non-fatty fish eaters (86). As different populations consume different species of fish and in some cases marine mammals, the risk of cardiovascular effects may not be a related simply to MeHg exposure, but also to nutrients such as omega-3 polyunsaturated fatty acids (n-3 PUFAs) and selenium that are high in some marine foods. There have been changes in the diet of Aboriginal populations in Canada over the last decades and the abandonment of some aspects of their lifestyle and diet has been associated with increased with of CVD. In particular a decrease in food items that are high in n-3 PUFAs or selenium (sea mammal fat and skin) could exacerbate the toxic effects of MeHg on the cardiovascular system.

Human paraoxonase activity and CVD
Human paraoxonase (PON1) is an enzyme associated with the high-density lipoprotein (HDL) particle that inhibits low-density lipoprotein (LDL)-oxidation and HDL-oxidation through hydrolysis of lipid peroxides (87, 88). Knockout mice lacking the gene for PON1 develop atherosclerosis more rapidly than wild-type mice (89). Hence, it has been suggested that PON1 inhibits the atherosclerotic process by preventing LDL-oxidation in the arterial wall. This theory is further supported by the fact that decreased PON1 activity is associated with an increased prevalence of atherosclerosis (90, 91) and incidence of CVD (92).

Methylmercury and PON1 activity
An intriguing possibility is that methylmercury could inhibit the activity of PON1, leading to an increase in oxidized LDL, which is at the root of the atherosclerotic process. *In vitro* experiments revealed that copper and mercurials were potent inhibitors of paraoxonase activity in human liver microsomes (93). Similar results were obtained in other *in vitro* experiments conducted with pooled human serum of subjects with the $PON1_{Q192}$ genotype (an isozyme with a glutamine at position 192); Mn^{2+}, Co^{2+}, Cd^{2+} and Ni^{2+} also inhibited paraoxonase activity in these experiments (94). More recent experiments have shown that cadmium, iron, zinc and mercury are the most potent inhibitors of another isozyme of paraoxonase, $PON1_{R192}$ (arginine at position 192), with concentrations as low as 100 nM causing a greater than 80% inhibition (95, 96). Despite this robust inhibition of PON1 *in vitro*, treatment of mice with cadmium, methylmercury or dietary iron, leading to metal serum concentrations of greater than 1 M, did not alter PON1 activity in the serum or the liver (95). This is the only *in vivo* dataset available and no data are available regarding the possible inhibitory action of mercury or other metals on serum PON1 activity in humans. In this research proposal, we will investigate the effect of mercury and various metals on PON1 plasma activity in Inuit living in Nunavik who are highly exposed to methylmercury through fish consumption.

NCP Performance Indicators

In the context of the field work that aimed at getting the individual consents of the adult participants only, Inuit research assistants have participated in the translation of the consent form in Inuktitut and in the recording of the voice that go with a DVD that will be presented to participants (**see Appendix 9**). Other Inuit interpreters and field staff will also help nurses in the visit of the 14 communities in February 2009. However, there will be little opportunities to involve Inuit in the proposed phase of the project since it will mostly consist in data analyses and publication of results.

Number of Northerners involved:
650 Northerners were met at home and engaged in the project

Number of meeting in the North:
two in Kuujuuaq

Number of students:
veronique Boiteau (MSc) , PY Tremblay (MSc),

Publications/Communications:
one by Veronique Boiteau at the department of statistics, Laval University in April 2010.

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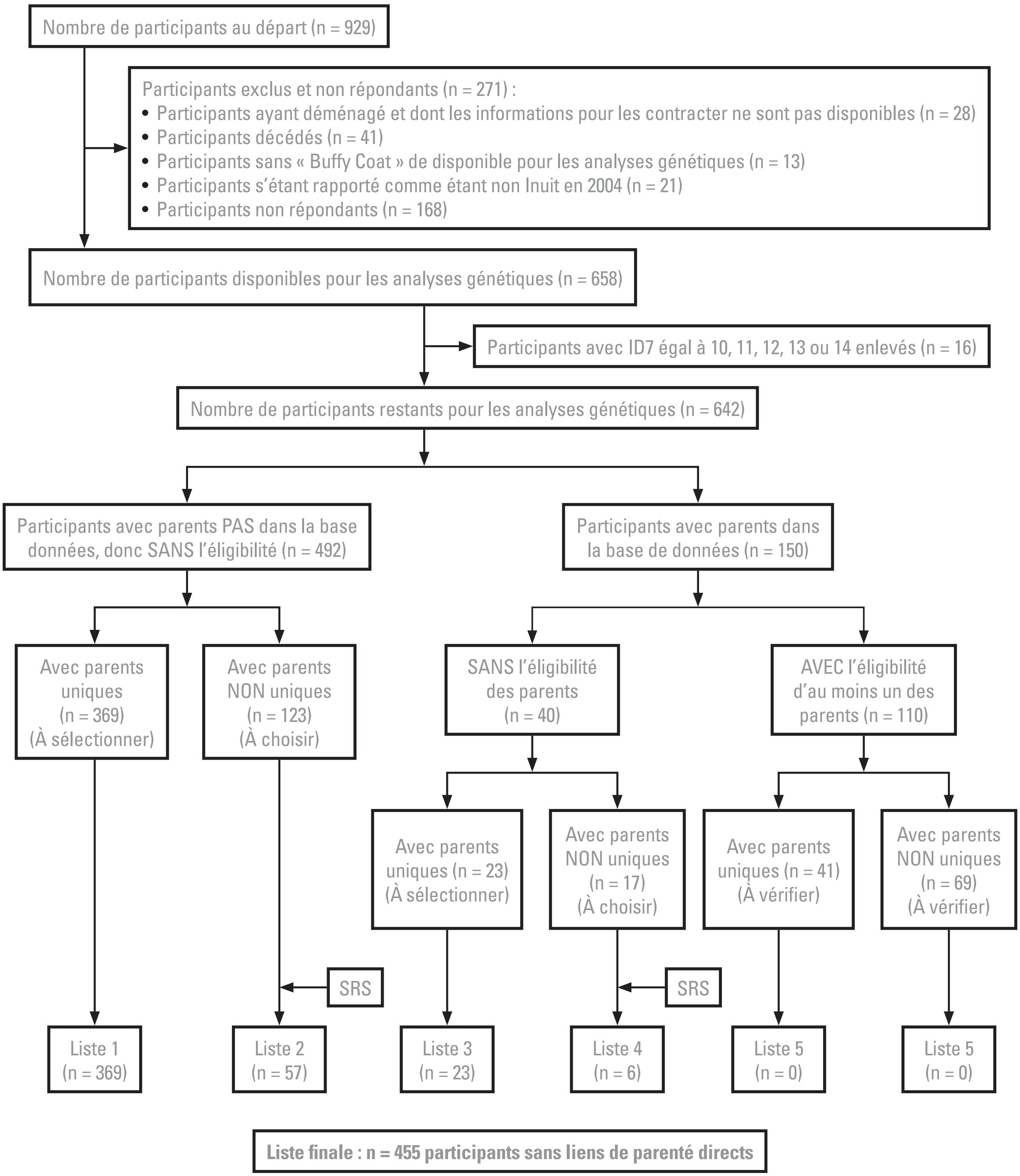
Selection process for genetic analyses in the Nunavik Cohort Study



Note : SRS = « Simple Random Sampling »

In vitro Screening and Identification of Northern Contaminant Mixtures for Their Effects on Insulin Action and Endothelial Function under Conditions Typifying Specific Diets and Lifestyles of Northern Populations: *implication for identification and assessment of the metabolic and cardiovascular health risk of Northern populations*

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Abstract

Emerging evidence from epidemiological studies suggests that exposure to persistent organic pollutants (POPs) and heavy metals may increase the risk of cardiovascular and metabolic diseases, although

Résumé

Des données récentes tirées d'études épidémiologiques semblent indiquer que l'exposition aux polluants organiques persistants (POP) et aux métaux lourds peut accroître le risque de maladies cardiovasculaires

the mechanisms involved remain unclear. A recent study in Nunavik found that blood mercury level was significantly and positively correlated with systolic and diastolic blood pressure after adjusting for confounding factors. Northern populations are exposed to a mixture of a wide range of contaminants, rather than a single one. The health effects of an individual chemical may be altered by the presence of other chemicals, as well as dietary factors and lifestyles. It remains unclear if contaminant mixtures such as those detected in the human blood of Northerners affect metabolic and cardiovascular health, and if the high fat/sugar diet of Western culture, as well as heavy alcohol use, alter the effects of these contaminants. We therefore examined the effects of a number of Northern contaminant mixtures (NCM) on markers of cell integrity, endothelial function, and insulin signalling, which are known to play an important role in the development of cardiovascular and metabolic diseases, in cultured human coronary artery endothelial cells (HCAEC) under conditions typifying a high fat plus high sugar or a normal nutritional diet, and in the presence or absence of a toxic dose of alcohol. Our preliminary data suggest that NCMs at levels relevant to human blood concentrations may cause structural and functional changes in cultured HCAEC. High fat/sugar diet by itself may cause structural and functional changes in HCAEC, in addition to modulating the response of these cells to NCMs. Experiments are underway to confirm and extend these findings.

et métaboliques, bien que les mécanismes en cause n'aient pas encore été élucidés. Une étude récente menée au Nunavik a montré que la concentration de mercure dans le sang était corrélée significativement et positivement avec la pression sanguine systolique et diastolique après correction pour tenir compte des facteurs de confusion. Les populations nordiques sont exposées à un mélange de contaminants très variés, plutôt qu'à un seul contaminant. Les effets sur la santé d'une substance chimique unique peuvent être altérés par la présence d'autres produits chimiques, de même que par les facteurs alimentaires et les modes de vie. On ignore encore si les mélanges de contaminants tels que ceux détectés dans le sang humain dans le Nord influent sur la santé métabolique et cardiovasculaire et si l'alimentation riche en lipides et en sucres de la culture occidentale de même que la consommation d'alcool modifient les effets de ces contaminants. Nous avons donc examiné les effets d'un certain nombre de mélanges de contaminants nordiques (MCN) sur des marqueurs de l'intégrité cellulaire, de la fonction endothéliale et de la signalisation insulinique, qui jouent un rôle important dans le développement des maladies cardiovasculaires et métaboliques, en utilisant des cellules endothéliales coronaires humaines (CECH) mises en culture dans des conditions caractéristiques d'une alimentation riche en lipides et en sucres ou d'une alimentation normale, ainsi qu'en présence ou en l'absence d'une dose toxique d'alcool. Nos données préliminaires indiquent que les MCN à des concentrations en rapport avec les concentrations dans le sang humain peuvent causer des changements structuraux et fonctionnels dans les CECH cultivées. Une alimentation riche en lipides et en sucres peut en elle-même entraîner des changements structuraux et fonctionnels dans les CECH en plus de moduler la réponse de ces cellules aux MCN. Des expériences sont en cours pour confirmer et élargir ces observations.

Key Messages

1. Some Northern contaminant mixtures at the levels found in the Northerners' blood may alter the structure and functions of endothelial cells, therefore impinging on cardiovascular health.

Messages clés

1. Aux concentrations observées dans le sang de résidents du Nord, certains mélanges de contaminants nordiques peuvent modifier la structure et la fonction des cellules endothéliale et, partant, altérer la santé cardiovasculaire.

2. Fat and sugar, when present at high concentrations in human blood, may affect the structure and function of endothelial cells, a single layer of cells lining the interior surface of blood vessels.
3. Fat and sugar, when present at high concentrations in human blood, may alter the toxicity of contaminant mixtures to endothelial cells by changing the forms and/or availability of contaminants, or the response of endothelial cells to contaminants.
4. The toxicity of some Northern contaminant mixtures to human endothelial cells may be changed by the presence of other contaminants in the blood.

2. Lorsqu'ils sont présents en fortes concentrations dans le sang humain, les lipides et les sucres peuvent altérer la structure et la fonction des cellules endothéliales, couche simple de cellules tapissant l'intérieur des vaisseaux sanguins.
3. Lorsqu'ils sont présents en fortes concentrations dans le sang humain, les lipides et les sucres peuvent altérer les effets toxiques des mélanges de contaminants sur les cellules endothéliales en modifiant la forme ou la disponibilité des contaminants ou la réponse des cellules endothéliales aux contaminants.
4. Les effets toxiques de certains mélanges de contaminants nordiques sur les cellules endothéliales humaines peuvent être modifiés par la présence d'autres contaminants dans le sang.

Key Words

Northern contaminant mixtures, human endothelial cells, cardiovascular disease, high fat and high sugar diet, life style, alcohol

Objectives

Short-Term: To screen and identify NCMs prioritized in the 2009 NCP Blueprint for their adverse effects on insulin action and endothelial function under conditions symbolizing different diets and lifestyles of Northerners, so as to identify NCMs as risk factors for metabolic and cardiovascular diseases in the Northern populations.

Long-Term: To a) enhance the understanding of the potential adverse health effects of NCMs and their interplay with specific diets and lifestyles of Northerners, b) provide more biomarker tools for monitoring and assessing the health risk of Northern populations, and c) provide scientific basis for the Canadian Government to institute and implement more effective strategies for contaminant control and heath promotion in the Canadian North

Introduction

There has been a surprising emergence of major circulatory illnesses as a leading cause of death in some Northern populations. Rapid changes in lifestyle and the departure from traditional diets have been considered as important contributing factors. However, increasing evidence suggests that chronic exposure to contaminants may also play a role in the pathogenesis of obesity, diabetes, and cardiovascular disease in the Northern populations.

Although a declining trend was observed for POPs in the Arctic biota, levels of human exposure are still close to the level of concern (Dewailly et al. 2006). Total mercury concentrations in the Arctic environment and biota have remained constant during the last decade. Total mercury levels in beluga, narwhal, and even walrus liver remain higher than the 0.5 μg/g Health Canada guideline for the commercial sale of fish. MeHg concentrations have been predicted to rise with the warming climate. Dewailly et al. (2006) conducted a Nunavik Health Survey in 2004 and 2005, and detected numerous contaminants in the blood samples of Inuit between the age of 17 and 74 years. The impact of these contaminants upon Inuit health remains unclear. The first and second phase of the NCP study assessed contaminant exposures in Northerners, and showed that the main intakes of mercury, PCBs, toxaphene, and chlordane are somewhat above the provisional tolerable daily intakes recommended by Health Canada (NCP 2006). Polybrominated diphenyl ethers (PBDEs) and perfluorooctanesulfonate (PFOS) are emerging contaminants of potential concerns due to their rapidly increasing levels found in the Northern wildlife, and their presence in Northern populations. Their impact on human cardiovascular and metabolic health warrants immediate investigation.

Increasing evidence suggests that exposure to POPs may contribute to the development of cardiovascular diseases (Ha et al. 2007). Baker et al. (1980) first reported that workers exposed to PCBs showed a significant direct relation between serum PCB levels and triglyceride levels. Kreiss et al. (1981) determined serum lipids and PCB levels in 458 individuals over 12 years of age in Triana, Alabama, which had significant PCB contamination, primarily through eating contaminated fish. They found that serum PCB levels ranged from 3.2 to 157.9 ppb, and was positively correlated with serum cholesterol level and blood pressure. Segreev and Carpenter (2005) studied coronary heart disease and myocardial infarction in a subpopulation of New York State residents living along the Hudson River within the 200 miles of a National Priority Site highly contaminated with PCBs. Despite a higher socio-economic status and healthier life style, this population had over 30% higher rate of coronary heart disease and myocardial infarction than other populations. Goncharov et al. (2007) investigated the relationships among the concentrations of total serum PCBs, mirex, DDE, and hexachlorobenzene (HCB), and total serum lipids in a Native American population. They found that high serum levels of PCBs were associated with elevated serum levels of lipids and cardiovascular disease, and concluded that PCBs are directly responsible for increased serum cholesterol and triglycerides. The National Health and Nutrition Examination Survey 1999-2002 conducted in U.S. revealed a positive association between serum levels of PCBs and organochlorine pesticides and prevalence of self-reported cardiovascular diseases among female adults over 40 years of age, as well as a positive correlation between polychlorinated dibenzo dioxins (PCDDs) and prevalence of cardiovascular disease in both males and females (Ha et al. 2007).

Emerging evidence from epidemiological studies in Finland and the Brazilian Amazon suggests that MeHg exposure may increase the risk of cardiovascular disease (Stern 2005, Fillion et al. 2006), although the mechanisms involved remain unclear. In a birth cohort study conducted in Faroe Island, prenatal exposure to increasing mercury concentrations was found to be associated with increased diastolic and systolic blood pressure, and decreased heart rate variability in children at 7 years of age, and the effect of mercury was stronger in children with lower birth weight (Sorensen et al. 1999). A recent study in Nunavik found that blood mercury level was significantly and positively correlated with systolic and diastolic blood pressure after adjusting for confounding factors (Valera et al. 2008, NCP 2009).

Northern populations are exposed to a mixture of a wide range of contaminants, rather than a single one. The health effects of an individual chemical may be altered by the presence of other chemicals, as well as dietary factors and lifestyles. It remains unclear if contaminant mixtures such as those detected in the human blood of Northerners affect metabolic and cardiovascular health, and if the high fat/sugar diet of Western culture, as well as heavy alcohol use of Northern culture, modulate the effects of these contaminants. In this study, we examined the effects of a number of NCMs on markers of endothelial function and insulin signalling, which are known key players in the development of cardiovascular and metabolic diseases, in cultured HCAEC under conditions typifying a high fat plus high sugar diet or a normal nutritional diet, and in the presence or absence of a toxic dose of alcohol.

Activities in 2009-2010

Due to the late arrival of research funding from NCP, the project could not start until Sept. 2009. During 09/2009-04/2010, our research activities included three phases: 1) preparing 5 chemical mixtures, 2) testing and setting up concentrations of LDL, VLDL, glucose, and alcohol, 3) conduct dosing experiments, and 4) perform sample analyses. The chemical mixtures used in the study were listed in Table 1, including 22 inorganic and organic contaminants that were frequently detected at high concentrations in the Inuit blood samples. These chemicals were chosen based on the report of Dewailly et al. (2006) on a Nunavik Health Survey conducted in 2004-2005. Three dose groups were used in this study, a) vehicle solvent (VS) (5 mM Na_2CO_3 or DMSO), b) 1X NCM (the mean levels of contaminants detected in Inuit blood in Nunavik), and c) 100X NCM (a 100 times of

Table 1: NCMs and their concentrations used for treating endothelial cells.

Chemical Treatment Group				Contaminants found in human blood (% detected mean level in Inuit plasma samples) (Dewailly et al. 2006)		NCM concentrations in culture	
Grand Mixture	Combined Mixture	Mixture		Chemicals	ng/L	1X (ng/L)	100X (µg/L)
NCM5	**NCM4**			**Vehicle control**			
		VS1		5 mM Na_2CO_3 (vehicle for metal mixture) in H_2O	1%	1%	1%
		VS2		DMSO (vehicle for organic mixtures)	1%	1%	1%
		NCM1		**Heavy Metals**			
				Cadmium (100%)	3035	3035	303.5
				Mercury (methylmercury) (100%)	10997	10997	1099.7
				Lead (100%)	39368	39368	3936.8
		Total concentrations of contaminants			53400	53400	5340
		NCM2		**PCBs**			
				99 (98%)	170	170	17.0
				138 (100%)	534	534	53.4
				146 (97%)	180	180	18.0
				153 (100%)	1333	1333	133.3
				163 (98%)	221	221	22.1
				170 (99%)	216	216	21.6
				180 (100%)	813	813	81.3
				187 (100%)	287	287	28.7
				194 (95%)	182	182	18.2
				201 (97%)	167	167	16.7
				203 (92%)	105	105	10.5
			Total concentrations of contaminants		13977	13977	1397.7
				Organochlorine			
				Oxychlordane (100%)	431	431	43.1
				p,p'-DDE (100%)	3232	3232	323.2
				Trans-nonachlor (100%)	725	725	72.5
				Pentachlorophenol (100%)	914	914	91.4
			Total concentrations of contaminants		5302	5302	530.2
		Total concentrations of contaminants			19279	19279	1927.92
	NCM3			**Toxaphene**			
				Parlar # 50	142	142	14.2
			Total concentrations of contaminants		142	142	14.2
				Brominated flame retardants			
				PBDE IUPAC #47 (55%)	72	72	7.2
				2,3,4,6-tetrabromophenol (63%)	36	36	3.6
			Total concentrations of contaminants		108	108	10.8
				Perfluorinated compounds			
				PFOS (100%) (Kubwabo et al. 2004)	29000		
			Total concentrations of contaminants		29000	29000	2900.0
	Total concentrations of contaminants				29250	29250	2925.0
Total concentrations of contaminants					**101929**	**101929**	**10192.9**

Table 2. Treatment groups, chemical components, and dose levels.

Group	1	2	3	4	5	6	7	8	9	10	11	12
LVG	–	–	–	–	–	–	+	+	+	+	+	+
EOH	–	–	–	+	+	+	–	–	–	+	+	+
NCM	VS	1X	100X	VS	1X	100X	VS	1X	100X	VS	1X	100X

1X NCM). The 1X NCM represents an average exposure level, while the 100X NCM represents an accumulated or extreme exposure level of the Northern populations.

HCAEC (passages 2-6) were cultured in complete medium containing 10% fetal bovine serum to a 70% confluence. Cells were trypinized and reseeded at 40000 cells/ml in 6, 12, or 96 well plates. After over night culturing at 37°C and 5% CO_2, cells were treated with one of the 5 NCMs dissolved in vehicle solvent(s) for 24h, in the presence or absence of LDL (1.5 mg/ml) plus VLDL (1.0 mg/ml) and glucose (10 mmol/L) (LVG), reflecting high fat and sugar diet, and in the presence or absence of alcohol (EOH) (0.1% v/v) representing heavy alcohol use. Treatment groups were illustrated in Table 2.

Cell morphology was examined under microscope with a 10X objective. Images were taken and compared.

Cytotoxicity of NCMs was quantified using a MultiTox assay kit from Promega (Cat. G9201). The assay simultaneously measures cell viability and cytotoxicity by detecting two distinct protease activities. The live-cell protease activity is restricted to intact viable cells and is measured using a fluorogenic, cell-permeant peptide substrate. The substrate enters intact cells where it is cleaved to generate a fluorescent signal proportional to the number of living cells. This live-cell protease activity marker becomes inactive upon loss of membrane integrity and leakage into the surrounding culture medium. A second, cell-impermeant, peptide substrate, becoming luminescent upon cleavage, is used to measure dead-cell protease activity that has been released from cells that have lost membrane integrity.

Apoptosis/necrosis is being examined using Annexin V-Fluos and propidium iodine staining and fluorescent imaging.

Oxidative stress is being studied in live cells using a fluorescent dye 6-carboxy 2', 7'-dichlorodihydrofluorescein diacetate from Invitrogen (Cat.2938), and in cell lysate obtained by sonication using HNE-his adduct ELISA kit (Cat. STA-334) from Cell Biolabs, Inc..

Endothelial function was examined by measuring endothelin-1 (ET-1) (Cat. 900-020A, from Assay Design), 6-keto prostaglandin-F1α (6KPF) (Cat. 515211, from Cayman Chemical Company), plasminogen activator inhibitor (PAI) (Cat. DSE100, from R&D Systems), and nitric oxide in supernatants, and endothelial NO synthase (eNOS) in cell lysate (Cat. DEN00, from R&D Systems) by ELISA and LDL receptor (anti-LDLR, Cat. H00003949-M01 from Abnova) in cell protein extract by Western blot.

Insulin signalling is being studied by measuring activation of insulin receptor substrate-1 (IRS1) (Cat. 7347 and Cat. 7332) and Akt2 (Cat. 7048) using ELISA kits from Cell Signalling.

All assays were and are performed according to manufactures' instruction. Three or two way ANOVA was performed to determine main effects of and interactions between factors: LVG, alcohol and NCMs. Pearson Product Moment Correlation or Spearman Rank Order Correlation was employed to identify correlations between markers.

Results

Cell Morphology

Effects of LVG: HCAEC grown in medium containing LVG were generally elongated as compared to those grown in medium without LVG (Fig. 1 and Fig. 2).

Effects of Alcohol: EOH slightly increased the number of larger cells at the light microscopic level (Fig. 1 and Fig. 2).

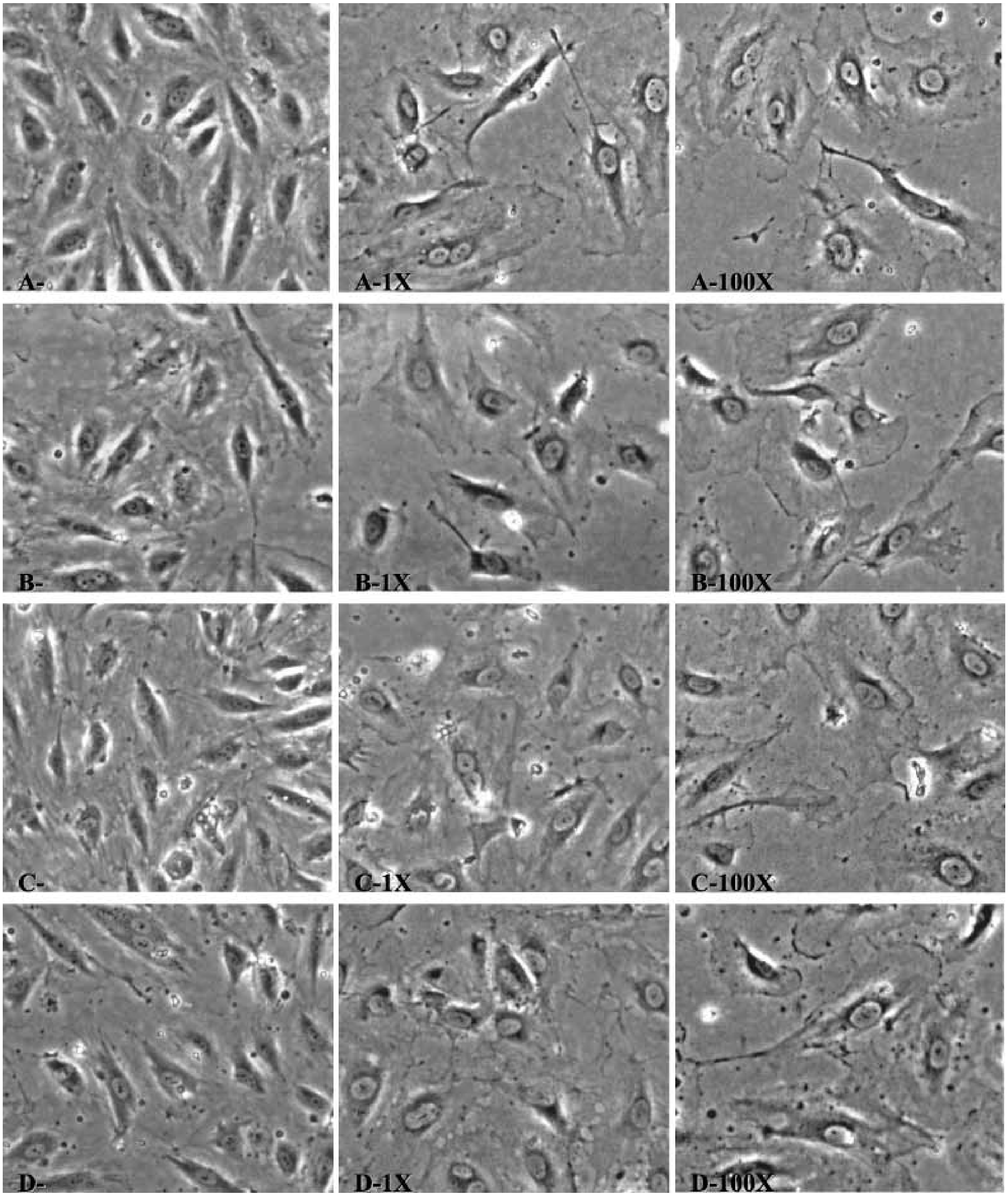

Figure 1. HCAEC cultured in complete medium with (+) or without (–) LVG, in the presence or absence of EOH, and treated with a vehicle solvent (VS) or NCM3 at 1X or 100X concentration. Images were obtained under light microscope with a 10X objective. A) –LVG–EOH; B) –LVG+EOH; C) +LVG–EOH; D) +LVG+EOH.

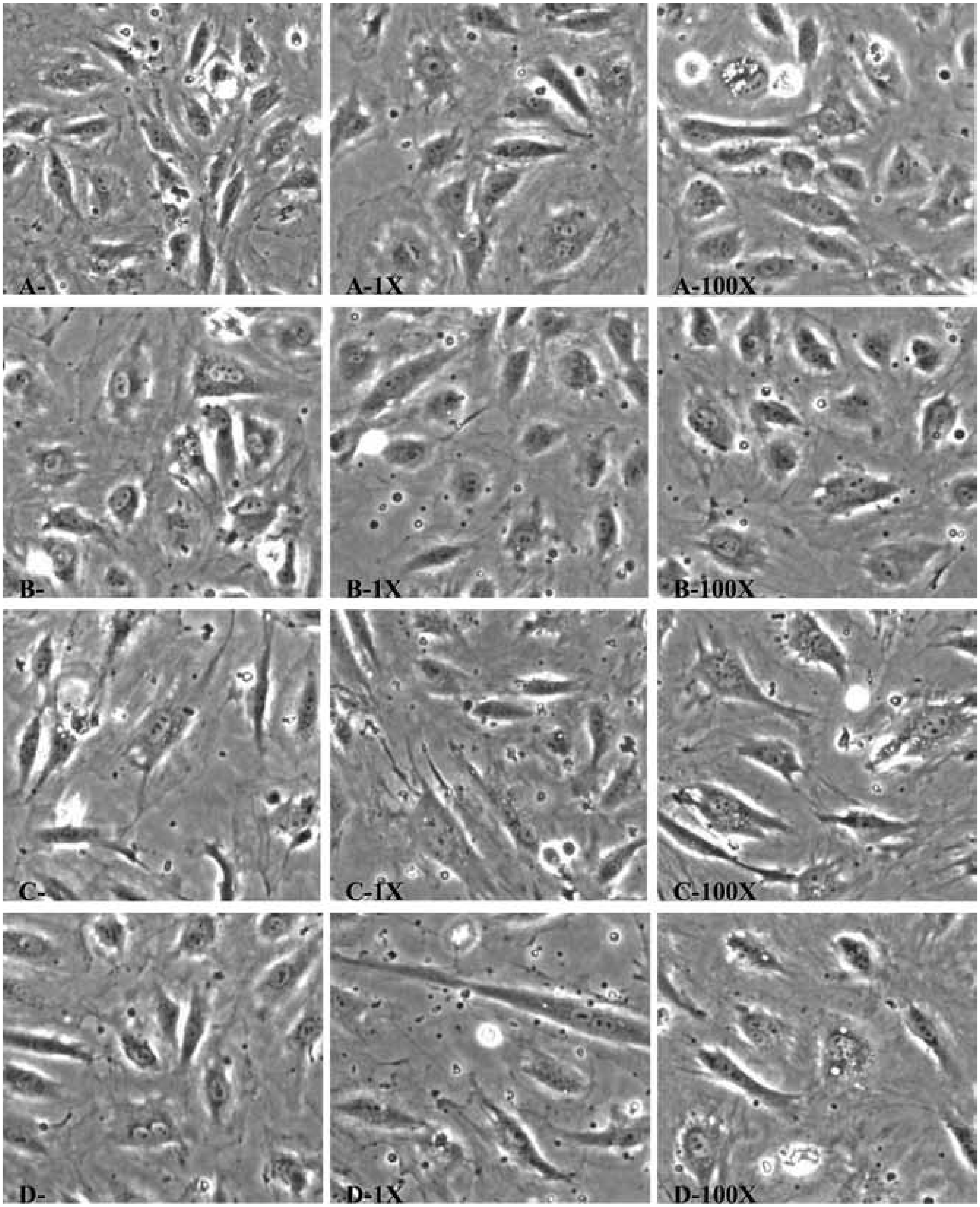

Figure 2. HCAEC cultured in complete medium with (+) or without (–) LVG in the presence or absence of EOH, and treated with a vehicle solvent (VS) or NCM5 at 1X or 100X concentration. Images were obtained under microscope with a 10X objective. A) –LVG–EOH; B) –LVG+EOH; C) +LVG–EOH; D) +LVG+EOH.

Effects of NCMs: Effects of NCM1, NCM 2, and NCM4 on cell morphology are under investigation. Information will be available in the next 3-4 weeks. Effects of NCM3 and NCM5 on cell morphology are illustrated in Fig. 1 and Fig. 2.

In the absence of LVG and EOH, both 1X and 100X NCM3 dramatically enlarged HCAEC, possibly due to changes in cell membrane structure and permeability (Fig. 1). Some of these cells also lost cell-cell connection. In the absence of LVG and presence of EOH, similar effects were seen for NCM3, although to a lesser extent than in the absence of EOH. In the presence of LVG, the effects of 1X NCM3 were less pronounced than, while the effects of 100X NCM3 were similar to, the effects observed in the absence of LVG.

Similar to NCM3, NCM5 at both 1X and 100X doses also caused enlargement of HCAEC, but to a much lesser degree as compared with NCM3 (Fig. 2).

Cytotoxicity

NCM1: Regardless of LVG and EOH, 1X NCM1 did not cause significant changes in live cell protease activity (Fig. 3). In contrast, 100X NCM1 caused dramatic decrease (up to 50%) in live cell protease activity, especially in the absence of LVG, and this effect of NCM1 was unrelated to the presence or absence of EOH. Interestingly, the decreased live cell protease activity by NCM1 corresponded to a 50% increase in dead cell protease activity in the absence, but not presence of LVG, suggesting that in the absence of LVG, the decreased live cell protease activity by NCM1 was very likely due to increased cells death. In the presence of LVG, EOH seemed to intensify the effects of NCM1.

NCM2: No significant changes in live or dead cell protease activity were observed in NCM2-dosed versus vehicle control cells, regardless of LVG and EOH (Fig.4).

NCM3: Regardless of LVG and EOH, both 1X and 100X NCM3 dramatically (up to 70%) decreased live cell protease activity, but had no significant effects on dead cell protease activity (Fig.5). This effect of NCM3 was also observed after 2 hours of dosing (data not shown). This suggests that the decreased live cell protease activity was mainly due to direct or indirect inhibition on protease enzyme rather than cell proliferation by NCM3.

NCM4: Experiments are being performed to determine cytotoxicity of NCM4.

NCM5: A general trend of decrease in live cell protease activity and increase in dead cell protease activity were observed in HCAEC treated with 1X and 100X NCM5, regardless LVG and EOH (Fig.6). However, none of the decreases reached statistical significance as compared with their vehicle controls.

Apoptosis/Necrosis

Experiments are being performed to examine effects of NCMs on apoptosis and necrosis. Results are expected to be available by the end of June, 2010.

Endothelial Function

Supernatants of HCAEC treated with NCM1, NCM2, NCM3, or NCM4 have been collected and are being analyzed for markers of endothelial function. Results will be available by the end of July, 2010.

The effects of NCM5 on endothelial function markers are illustrated in Fig.7-10. A trend of increase in ET-1, a major vasoconstrictor produced by endothelial cells, released into supernatant per cell by 100X NCM5 was observed in cells grown in the absence of LVG and presence of EOH (Fig.7).

In the presence of LVG, HCAEC released into culture supernatants higher amount of 6KPF, a vasodilator produced by endothelial cells, than those grown in the absence of LVG, regardless of EOH (Fig.8). In the presence of LVG, EOH increased 6KPF released per cell. In the absence of LVG, 100X NCM5 increased 6KPF released per cell, especially in the presence of EOH.

Both LVG and NCM5 caused a trend of increase in the levels of PAI released per cell (Fig.9). In the absence of LVG and EOH, 100X NCM5 significantly increased PAI release per cell as compared to the vehicle control.

No significant effects of LVG, EOH and NCM5 on IL-6 release were observed (Fig.10).

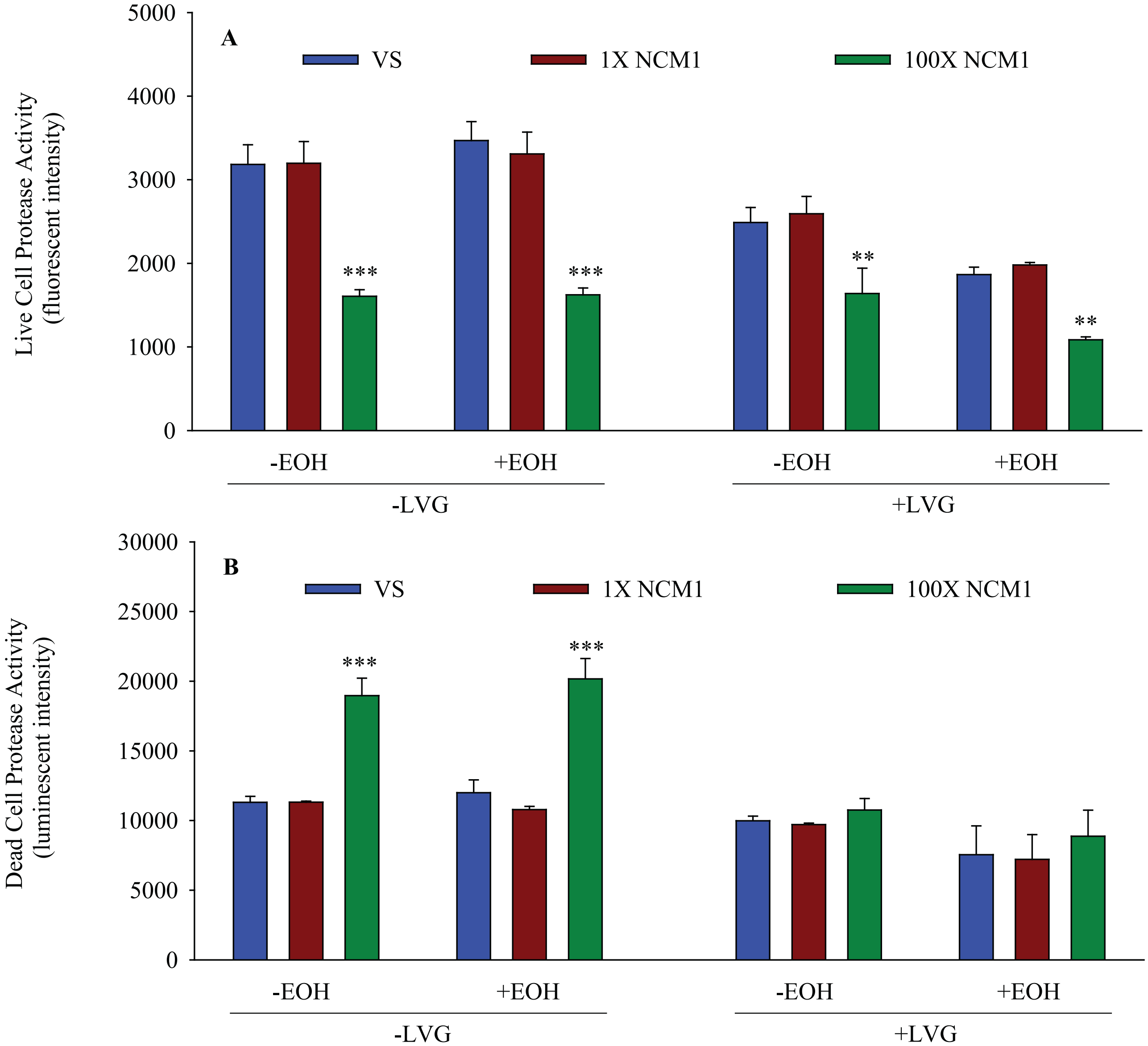

Figure 3. Cytotoxicity of NCM1 determined by live (A) and dead (B) cell protease activity. HCAEC were cultured in complete medium with (+) or without (–) LVG in the presence (+) or absence (–) of EOH and treated with a vehicle solvent (VS) or NCM1 at 1X or 100X concentration for 24h. Vertical bars stand for the mean values of 3 experiments. Error bars are the standard errors of the means. ** and *** indicate significant differences at $p<0.01$ and $p<0.001$, respectively, as compared with their vehicle controls.

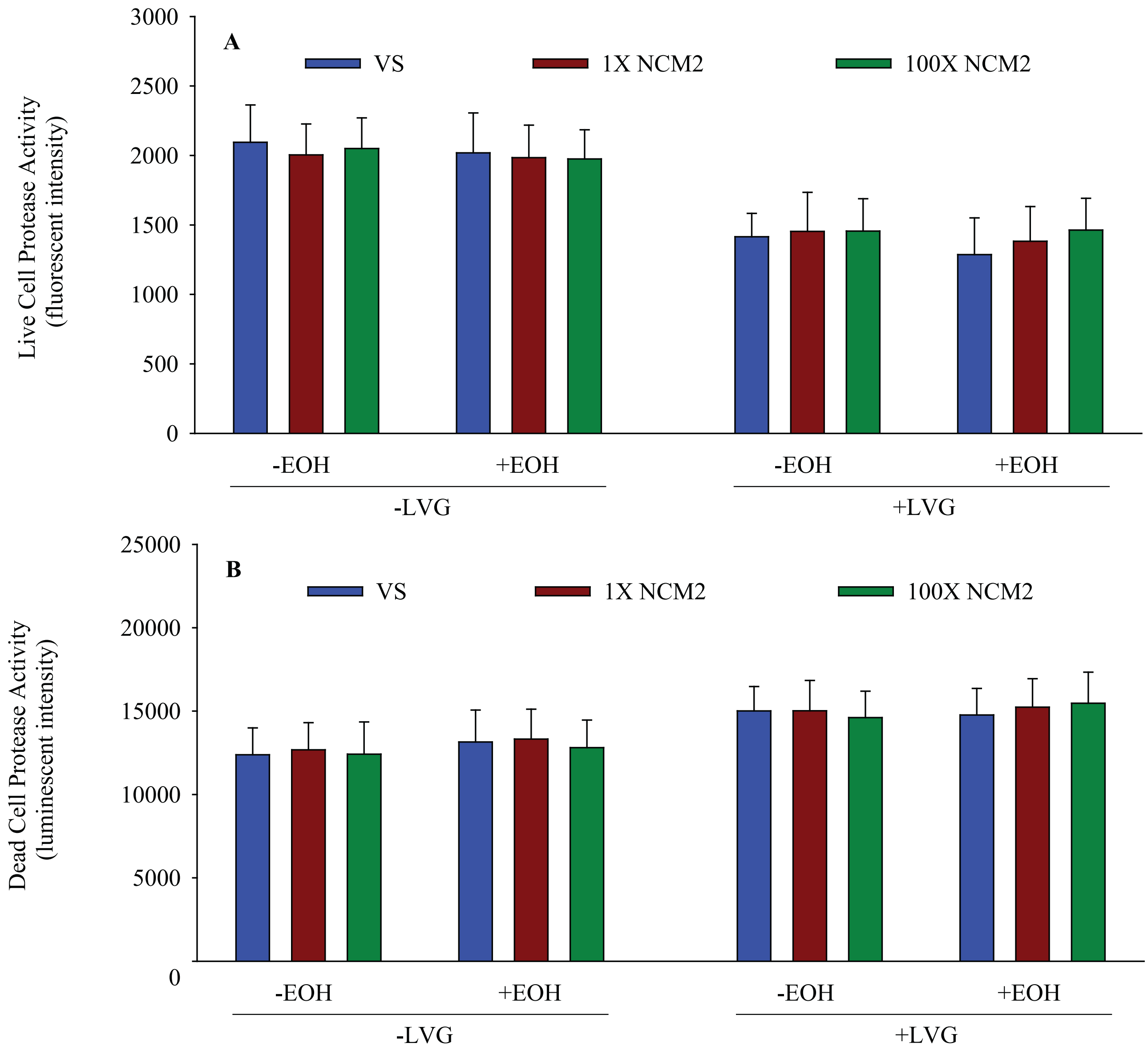

Figure 4. Cytotoxicity of NCM2 determined by live (A) and dead (B) cell protease activity. HCAEC were cultured in complete medium with (+) or without (–) LVG in the presence (+) or absence (–) of EOH and treated with a vehicle solvent (VS) or NCM2 at 1X or 100X concentration for 24h. Vertical bars stand for the mean values of 3 experiments. Error bars are the standard errors of the means.

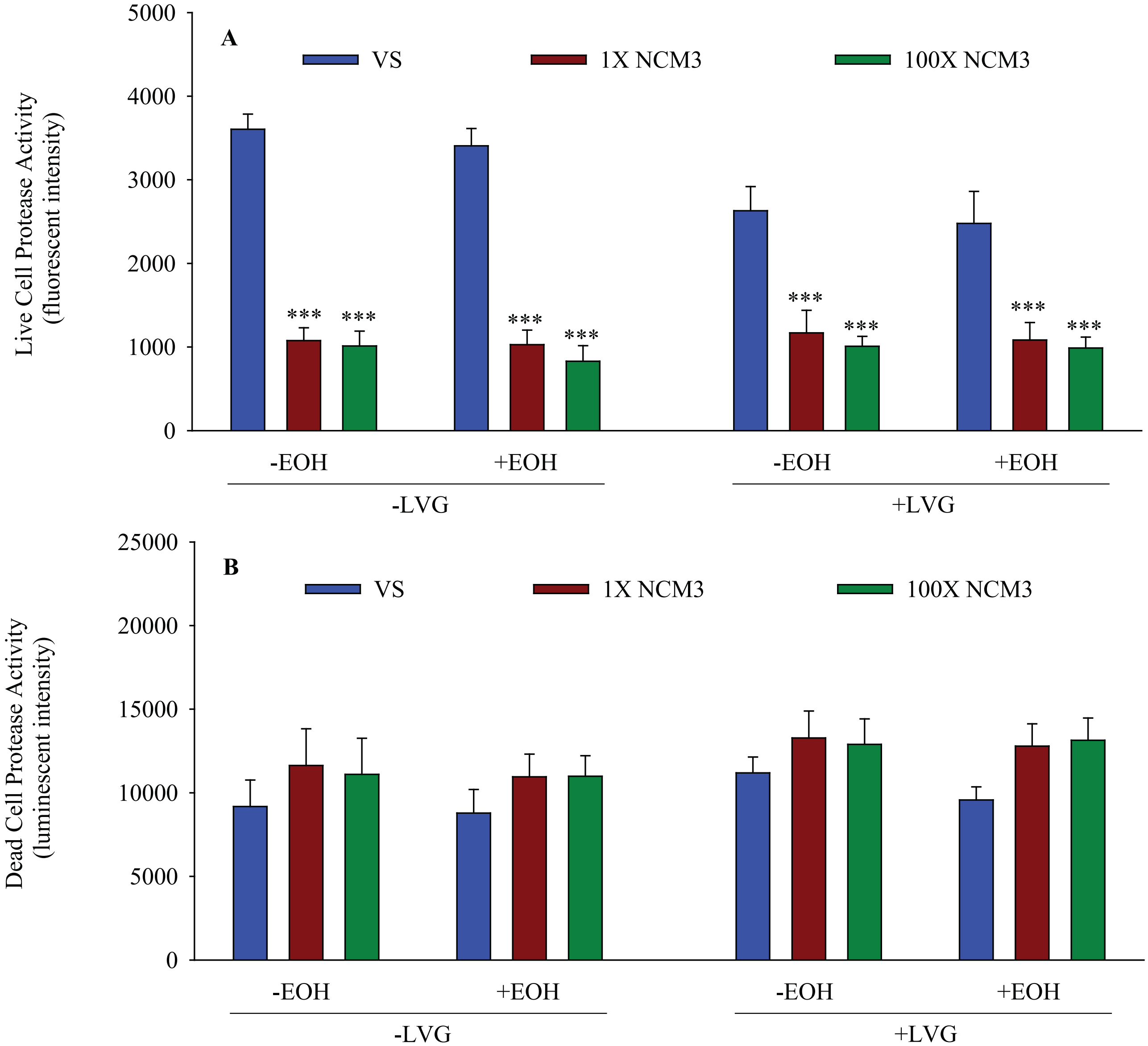

Figure 5. Cytotoxicity of NCM3 determined by live (A) and dead (B) cell protease activity. HCAEC were cultured in complete medium with (+) or without (–) LVG in the presence (+) or absence (–) of EOH and treated with a vehicle solvent (VS) or NCM3 at 1X or 100X concentration for 24h. Vertical bars stand for the mean values of 6 experiments. Error bars are the standard errors of the means. *** indicates a significant difference at p<0.001 as compared with its vehicle control.

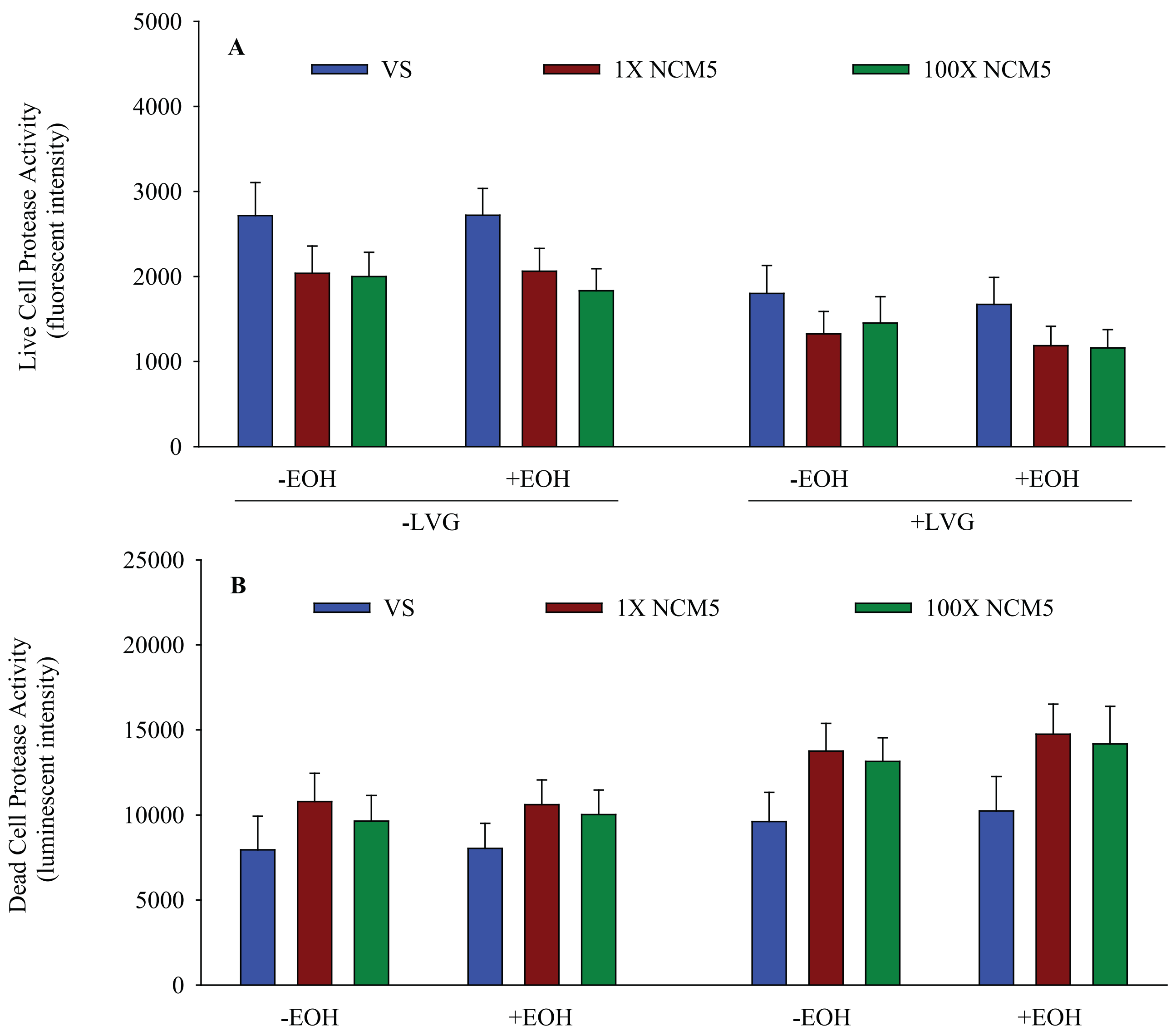

Figure 6. Cytotoxicity of NCM5 determined by live (A) and dead (B) cell protease activity. HCAEC were cultured in complete medium with (+) or without (–) LVG in the presence (+) or absence (–) of EOH and treated with vehicle solvent (VS) or NCM5 at 1X or 100X concentration for 24h. Vertical bars stand for the mean values of 6 experiments. Error bars are the standard errors of the means.

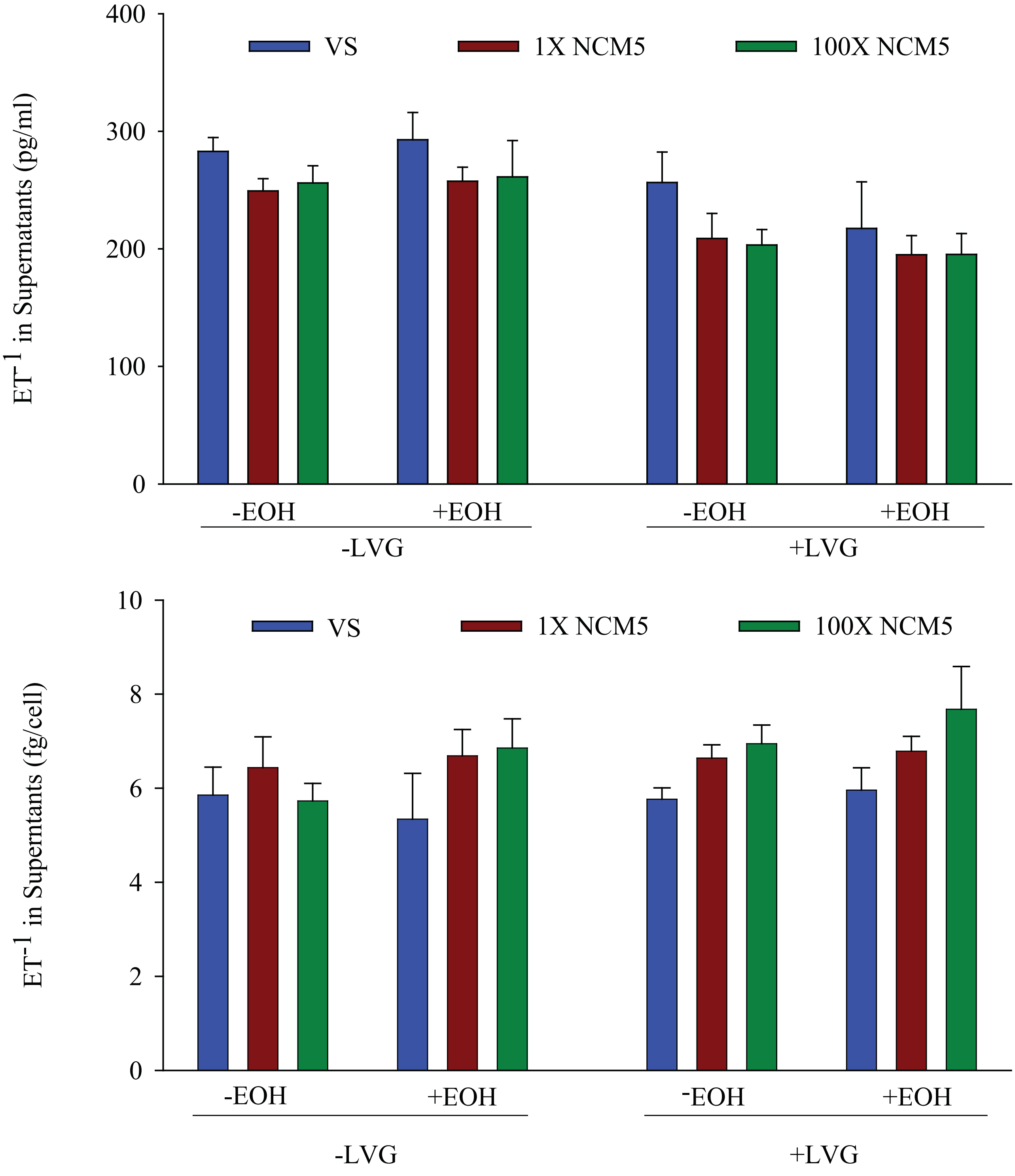

Figure 7. ET-1 levels in the supernatants of HCAEC cultured in complete medium with (+) or without (–) LVG, in the presence (+) or absence (–) of EOH, and treated with a vehicle solvent (VS) or NCM5 at 1X or 100X concentration for 24h. Vertical bars stand for the mean values of 3 experiments. Error bars are the standard errors of the means.

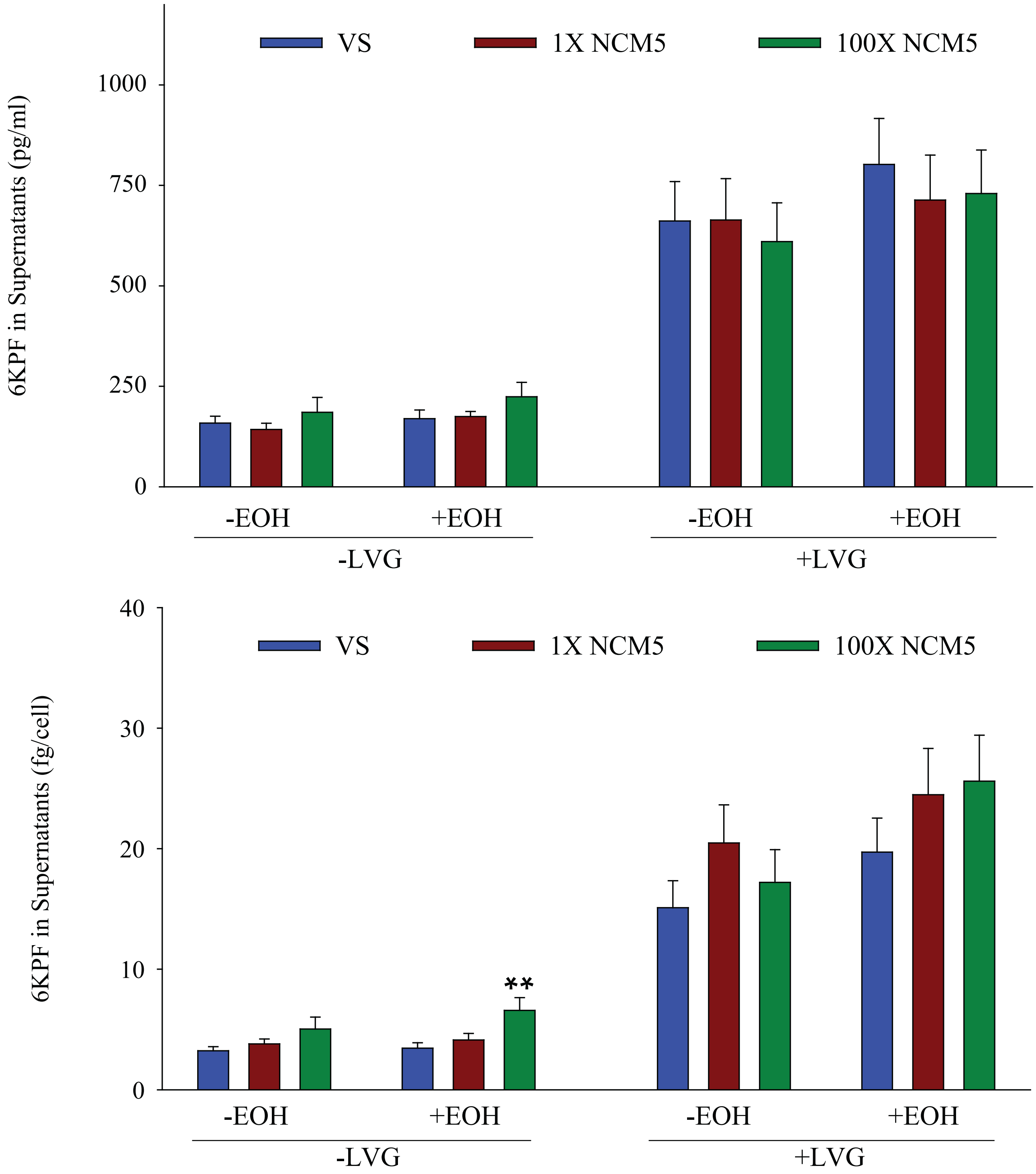

Figure 8. 6KPF levels in the supernatants of HCAEC cultured in complete medium with (+) or without (–) LVG, in the presence (+) or absence (–) of EOH, and treated with a vehicle solvent (VS) or NCM5 at 1X or 100X concentration. Vertical bars stand for the mean values of 3 experiments. Error bars are the standard errors of the means. ** indicates a significant difference at p<0.01 as compared with its vehicle control.

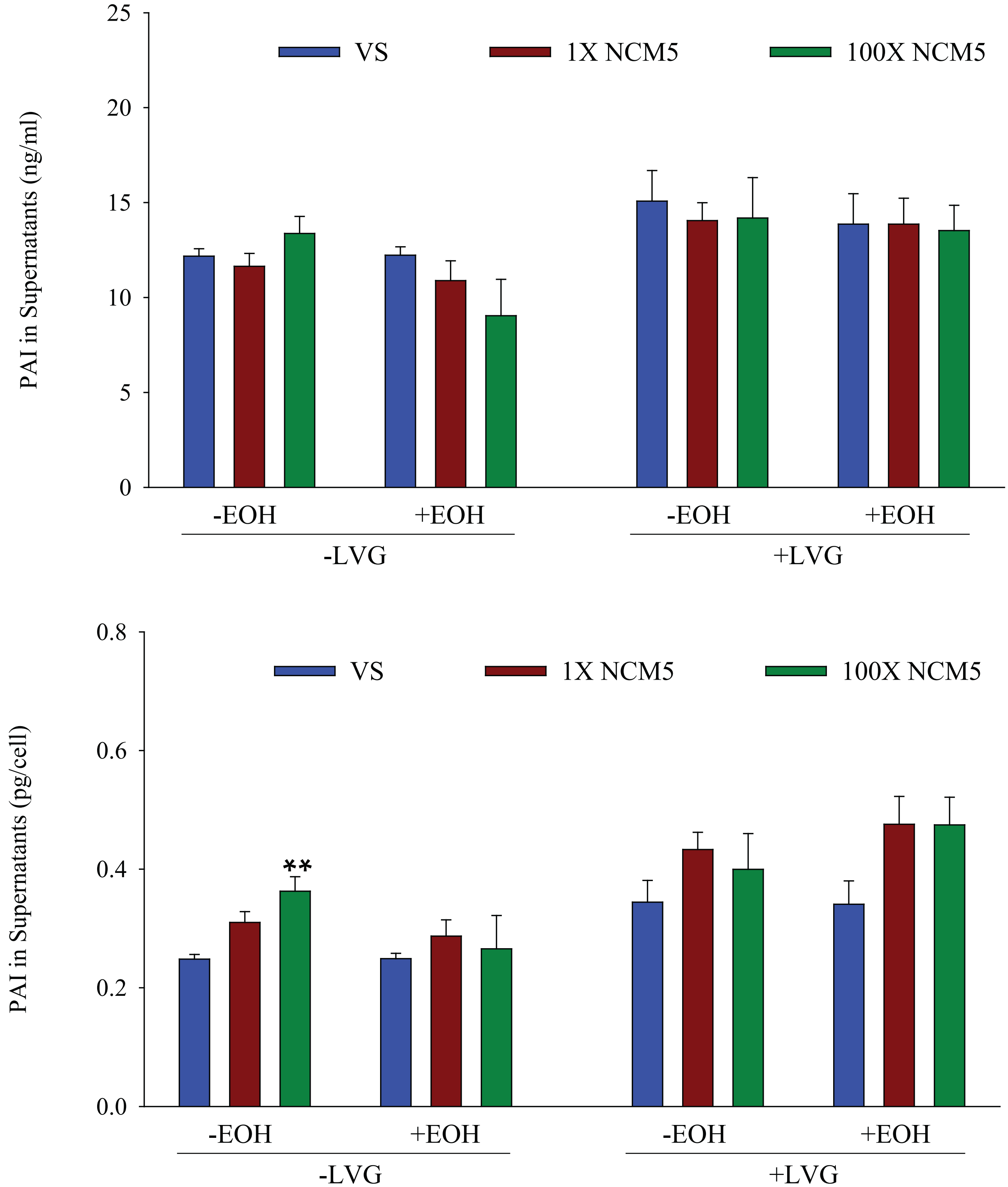

Figure 9. PAI levels in the supernatants of HCAEC cultured in complete medium with (+) or without (–) LVG in the presence (+) or absence (–) of EOH and treated with a vehicle solvent (VS) or NCM5 at 1X or 100X concentration. Vertical bars stand for the mean values of 3 experiments. Error bars are the standard errors of the means. ** indicates a significant difference at $p<0.01$ as compared to its vehicle control.

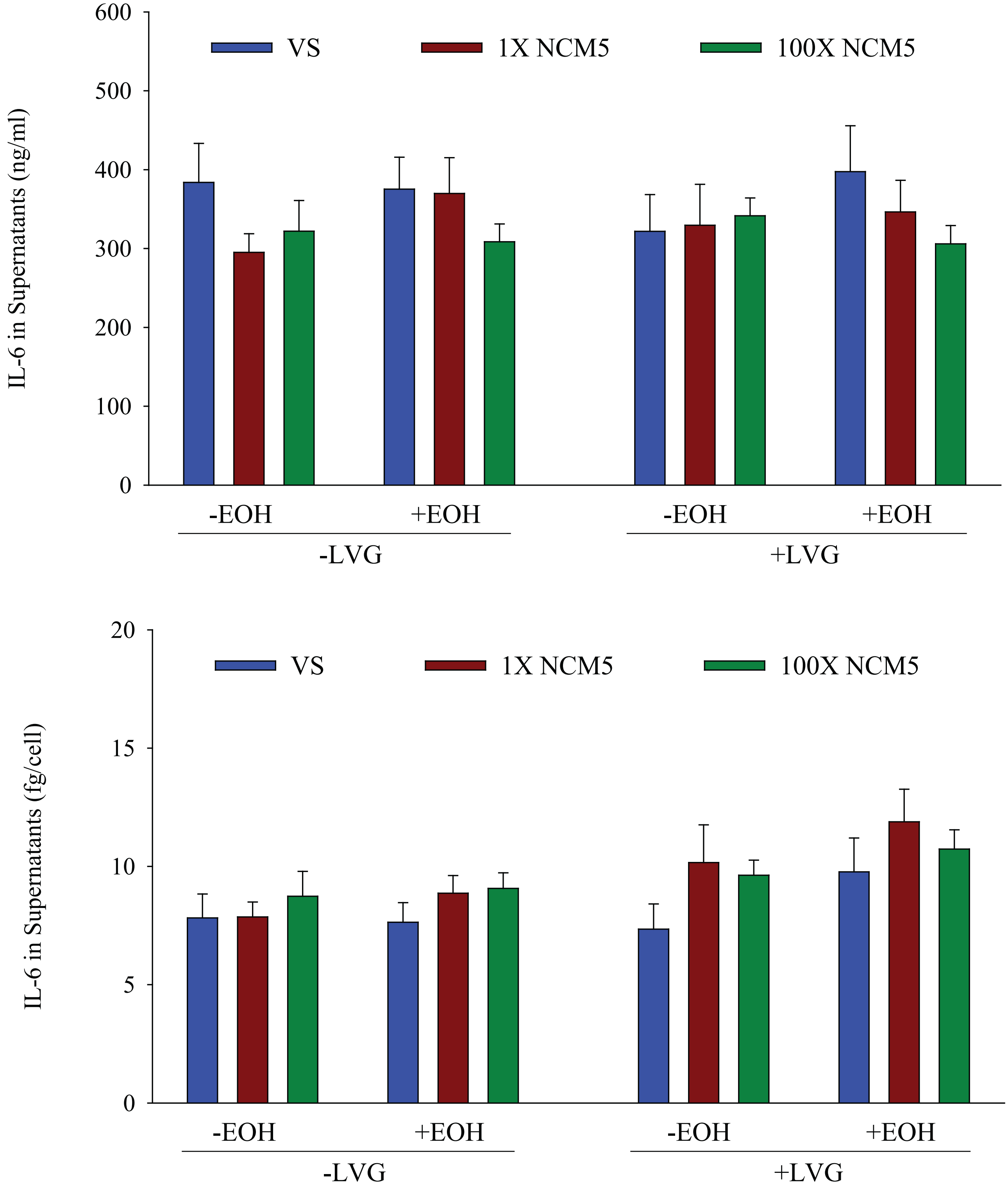

Figure 10. IL-6 levels in the supernatants of HCAEC cultured in complete medium with (+) or without (–) LVG, in the presence (+) or absence (–) of EOH, and treated with a vehicle solvent (VS) or NCM5 at 1X or 100X concentration. Vertical bars stand for the mean.

Insulin Signalling

Experiments are being performed to examine the effects of NCMs on insulin signalling. Results are expected to be available by the end of Aug., 2010.

Discussion and Conclusions

Our data suggested that LVG at the concentration changed HCAEC morphology, which was associated with increased release of endothelial function markers such as 6KPF and PAI. It is surprising that LVG did not increase the sensitivity of HCAEC to NCMs toxicity. Rather, LVG attenuated 100X NCM1 (a heavy metal mixture) induced cell death. This could be explained as that LVG acted as a buffer or storage place for NCMs, therefore decreasing their availability to the HCAEC. We observed greater effects of NCM5 (a total mixture) on endothelial function markers in the absence than the presence of LVG. This may be due to that LVG itself markedly increased the basal levels of these markers (6KPF and PAI), which could not be increased further by NCM5. In the current study, LVG, EOH, and NCMs were added to the cell culture at the same time. Use of sequential dosing will help to minimize the buffering effects of LVG. The increased PAI release by 100X NCM5 in the absence of LVG and EOH suggest a promoting role of NCM5 in atherosclerosis.

It was unexpected that NCM3 (a mixture containing PFOS as major component) at 1X concentration caused dramatic changes in HCAEC at both structural and functional levels. We speculate that PFOS in the mixture might be responsible for the observed effects since PFOS has been shown to cause permeablization of cell membrane. PFOS is known for its surfactant action, and has been shown to increase permeability of cell membrane to hydrophobic ligands and membrane fluidity in fish leukocytes (Hu et al. 2003). This property of PFOS could cause disruption of transmembrane proteins and enzymes leading to decreased live cell protease activity observed in this study. In the current study, we experienced extreme difficulties in trypsinizing NCM3-dosed cells. It is possible that NCM3 also acted as protease (trypsin) inhibitors. The cytotoxicity of NCM5, which contains NCM3, was much lower than that of NCM3, suggesting that the property (solubility) or availability of NCM3 might be altered when mixing with other NCMs, especially heavy metals such as cadmium and lead. Currently, we are conducting experiments to determine the chemical component(s) that is (are) responsible for the observed toxicity in the NCM3-dosed cells.

We have only examined a limited number of end points. Data generated from our future work will provide much clearer pictures for the effects of NCMs on HCAEC, and their roles in the development and progression of cardiovascular disease.

NCP Performance Indicators

a. **The number of northerners engaged in your project:**

   This is a laboratory toxicology study. No northerners were engaged in this project.

b. **The number of meetings/workshops you held in the North:**

   This work was done in a governmental laboratory located in Ottawa. We did not hold meetings/workshops in the North.

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

   One MSc student from Carleton University is currently involved in this project.

d. **The number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc):**

   This project was started in Sept. 2009 and is on-going. We have not produced any citable publications. We will submit abstracts to 2010 NCP Results Workshop, 2010 Health Canada Science Forum and 2010 Annual Meeting of the Society for Free Radical Biology and Medicine.

Expected Project Completion Data

We are actively conducting experiments and samples analysis. We can be expected to complete this study by the end of 2010.

Acknowledgement

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Disruption of thyroxine transport by persistent organic pollutants in Inuit women of childbearing age from Nunavik

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Abstract

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

Résumé

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

several other compounds have been identified as binders of TTR and thyroid binding globulin (TBG), another T4 transport that may be involved in supplying the placenta with T4. The objective of this study is to examine whether plasma levels of these compounds are linked to a decrease in the proportion of circulating T4 bound to TTR and/or TBG in Inuit women of childbearing age. Such a relation would strengthen the biological plausibility of a link between exposure to food chain contaminants and adverse effects on brain development in this population. Major compounds that displace T4 from its transport proteins will also be identified.

barrière hémato-encéphalique jusqu'au cerveau en développement. On a identifié récemment plusieurs autres composés qui sont des agents de liaison de la TTR et de la globuline liant la thyroxine (TBG), une autre molécule de transport de la T4 qui peut approvisionner la placenta en T4. La présente étude visait à examiner si les concentrations plasmatiques de ces composés sont associées à une diminution de la proportion de T4 circulante liée à la TTR et/ou à la TBG chez les femmes inuites en âge de procréer. Une telle relation renforcerait la plausibilité biologique d'un lien entre l'exposition à des contaminants de la chaîne alimentaire et les effets indésirables sur le développement du cerveau dans cette population. Les principaux composés qui perturbent le transport de la T4 seront également identifiés.

Keys messages

- Thyroid hormone transport proteins have been isolated from plasma of Inuit women of reproductive age who participated to the 2004 Nunavik Health Survey.
- Analyses of protein isolates for thyroid hormones and halogenated phenolic compounds are underway.

Messages clés

- Des protéines de transport des hormones thyroïdiennes ont été isolées dans le plasma de femmes inuites en âge de procréer qui ont participé à l'Enquête sur la santé au Nunavik de 2004.
- Des analyses des isolats de protéines sont en cours pour doser les hormones thyroïdiennes et les composés phénoliques halogénés.

Objectives

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

The **specific objectives** are:

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

Introduction

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

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

Activities in 2009-2010

- In August 19, 2009, we submitted our project for review by the *Comité d'éthique de la recherche du CR-CHUQ* and obtained their final approval on October 20, 2009.
- Several experiments were conducted to identify the most appropriate conditions for the isolation of the transport proteins by immunoprecipitation. The isolation of TTR in its native form was attempted using two different antibodies: one directed against TTR itself and the other directed against retinol-binding protein (RBP), which forms a complex with TTR in plasma. Using the TTR-directed antibody, only TTR was found in the immunoprecipitate, whereas both TTR and RBP are isolated when performing immunoprecipitation with the RBP-directed antibody (see the results section).
- We worked on adapting the analytical method already in use at the CTQ for measuring a wide variety of phenolic compounds to include T4 and T3. However, because major changes would have been required to the procedure, especially the derivatisation steps, with subsequent revalidation of all analytes, it was decided to use the existing method for phenolic compounds (GC/MS platform) and to quantify T4 and T3 in immunoprecipitates using LC-MS/MS methods which are currently being adapted in our laboratory.

- **Capacity building:** we specifically advertise a position for an Inuit student (college or University level) in the course of our research project, through our Nasivvik network of contacts. Unfortunately, we did not receive any application for this position. We recently recruited a MSc student (Yannick Audet-Delage) to work on this project. Yannick has completed a BSc in biological sciences at Université Laval.

Results

Figure 1 shows an immunoblot with TTR-directed antibody, in which lane 2 corresponds to an immunoprecipitate obtained from plasma using an RBP-directed antibody. Two bands can be seen for the TTR standard (lane 3): the monomer at 15 kd and the dimer at 30 kd. The presence of a band at 15 kd in lane 2 indicates that TTR was isolated in the immunoprecipitate. A protocol was also set up for the immunoprecipitation of TBG, the second T4 protein transport of interest, but further refinements are needed.

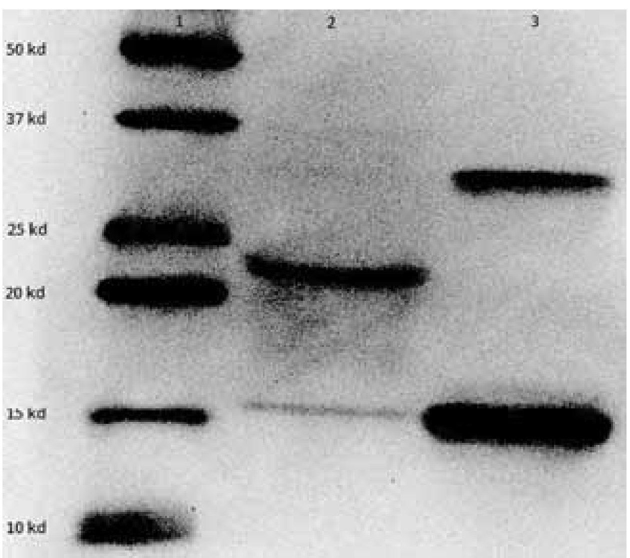

Figure 1. Immunoblot obtained with a TTR-directed antibody. Lane 1 contains markers of different molecular weights; lane 2 corresponds to the immunoprecipitate obtained with a RBP-directed antibody, and lane 3 contains the RBP standard. Note the band in lane 2 that corresponds to the monomeric TTR protein (molecular weight of 15 kda).

Discussion and Conclusions

Results regarding the immunoprecipitation of TTR using an RBP-directed antibody are similar to those recently reported by Frey et al. (2009). The fact that the RBP-TTR complex is isolated when using an RPB-directed antibody suggests that the native form of TTR is preserved under these immunoprecipitation conditions. Preserving the native TTR conformation is crucial in oprder to be able to measure compounds that bind TTR and co-precipitated during TTR isolation.

We have now started isolating the RBP-TTR complex for the 300 women of reproductive age enrolled in the Nunavik Health Survey. In the course of this survey, biological samples were collected and questionnaires administered to document socio-demographic, lifestyle and dietary habits in a large sample of the Nunavik population (900 randomly selected adults, men and women). Subjects with a history of cardiovascular diseases, diabetes or cancer were excluded at baseline. Participants were invited onboard the Amundsen research vessel for interview, biological sample collection and various clinical measurements including free T4, total T3, TSH, and TBG. The additional analyses mentioned in the present project are conducted using archived plasma samples from 300 childbearing age women who were enrolled in the survey. The samples were stored frozen at -80°C since the time of collection.

In 2010/2011, the following work will be performed:

- Complete the isolation of RPB-TTR and TBG from plasma samples by immunoprecipitation.
- Measure TBG and TTR in immunoprecipitates by ELISA assays.
- Measure thyroid hormones (T4, T3) in immuno-precipitates using isotope dilution LC-MS/MS (Thienpont et al., 1999; Van Uytfanghe et al., 2004).
- Measure phenolic compounds in immuno-precipitates using a method that includes derivatisation followed by GC-MS analysis (Dumas et al., 2006). The method covers 32 HO-PCBs, 16 halogenated phenolic compounds and 2 HO-PBDEs.

- If none of the suspected chemicals are found in the supernatant, additional exploratory analyses using GC-time-of-flight MS and additional instrumental techniques will be conducted to initiate the identification of compounds interfering with T4 binding to TTR and TBG in this population.
- Statistical analyses of the data, including correlation analyses between the dependent variables (T4 bound to TTR or TBG expressed as molar ratio) and independent variables (plasma concentrations of the various thyroid transport disrupting chemicals). Subsequently, predictive multiple linear models will be constructed to explain the variance in transport protein-bound T4 in relation to plasma concentrations of total T4, total T3, TTR and TBG as well as those of thyroid transport disrupting xenobiotics.

NCP Performance Indicators

Number of northerners engaged in the project: none

Number of meeting/workshops held in the North: none

Number of students involved in the NCP work: 1

Number of publication: none

Expected Project Completion Date

This project will be completed in March 2011.

Acknowledgments

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Environmental Monitoring and Research

Northern Contaminants Air Monitoring for Organic Pollutants and Data Interpretation

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Abstract

Air monitoring of organic pollutants has been continuously conducted at Alert, Nunavut, Canada since 1992. A novel flow-through air sampler (FTAS) designed for use under cold environment, which does not require electricity to operate but can potentially capture a relatively large volume of air over a short time period (over several weeks), was deployed at Alert since October 2007 to compare its performance under Arctic conditions in parallel with the high volume air sampler for routine measurements. Comparable results were obtained for several organochlorine pesticides (OCPs), indicating the feasibility of the FTAS under extreme conditions. Air samples collected at Alert were also screened for polybrominated diphenyl ethers (PBDEs) and other flame retardants (FRs). Measured results are compared to those observed at a remote station on the Tibetan Plateau using a FTAS. PBDE concentrations at Alert are slightly higher than those at the Tibetan site. Distinctive seasonality was observed at Alert while no such variation was seen at the Tibetan location indicating that the

Résumé

Les polluants organiques dans l'atmosphère sont surveillés de façon continue à Alert, au Nunavut (Canada), depuis 1992. En octobre 2007, on a installé à Alert un nouvel échantillonneur d'air à flux continu (EAFC) conçu pour être utilisé en milieu froid, fonctionnant sans électricité et pouvant capturer un volume relativement important d'air sur une courte période de temps (plusieurs semaines). Le but était de comparer ses performances dans des conditions arctiques en parallèle avec un échantillonneur d'air à volume élevé pour les mesures courantes. Des résultats comparables ont été obtenus pour plusieurs pesticides organochlorés (POC), ce qui démontre l'utilité de l'EAFC dans des conditions extrêmes. Des échantillons d'air prélevés à Alert ont également été analysés pour détecter des polybromodiphényléthers (PBDE) et autres ignifugeants. Les résultats mesurés sont comparés à ceux qui sont obtenus également à l'aide d'un EAFC par une station éloignée, sur le plateau tibétain. Les concentrations de PBDE à Alert sont légèrement plus élevées qu'à la station tibétaine. Un effet saisonnier net a été observé à Alert, alors qu'une telle variation n'a pas été observée à la station

latter do not have regional sources. No significant temperature dependence was observed for new BFRs at either site.

tibétaine, ce qui indique qu'il n'y a pas de source de ces substances dans cette région. Aucune dépendance significative par rapport à la température n'a été observée pour les nouveaux ignifugeants bromés aux deux stations.

Key Messages

1. The reliability of FTAS as a quantitative sampling technique under Arctic environment was tested. The observed results were comparable with those measured using the active sampling method.
2. The atmospheric concentrations of PBDE-substitute "new" FRs at 2 remote sites have reached similar levels as those of PBDEs. Further toxicology and environmental fate studies regarding these compounds are needed to assess risks.

Messages clés

1. La fiabilité de l'EAFC comme technique d'échantillonnage quantitatif dans l'environnement arctique a été testée. Les résultats observés sont comparables à ceux obtenus avec la méthode d'échantillonnage actif.
2. Les concentrations atmosphériques des « nouveaux » ignifugeants remplaçant les PBDE ont été mesurées dans deux endroits éloignés et elles étaient similaires à celles des PBDE. Des études supplémentaires sur la toxicologie et le devenir environnemental de ces composés sont nécessaires pour évaluer les risques.

Objectives

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

Introduction

Atmospheric measurements of organic pollutants, including polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and polycyclic aromatic hydrocarbons (PAHs), have been conducted at Alert, Nunavut, since 1992. In 2004-2005, a FTAS which does not require a power supply to operate and suitable for use under cold environments was developed. This sampler was deployed at Alert in September 2007 to compare its performance in parallel with the conventional super-high-volume air sampler (superhivol). In this report, the air concentrations of organochlorine pesticides (OCPs) measured by the FTAS was compared with those by the superhivol to assess its feasibility for deployment under Arctic conditions.

The atmosphere is considered the major and fastest route of transport for many priority pollutants to the remote Arctic. New and emerging chemicals that are detected in Arctic air may indicate long-range transport potential which is one of the criteria for classifying chemicals as persistent organic pollutants (POPs) that may be considered for control. Flame retardants (FRs) polybrominated diphenyl ethers (PBDEs) were included in Arctic air measurements at Alert since 2002. With the listing of PBDEs as POPs subjected to global restrictions under the Stockholm Convention on POPs in May 2009, non-PBDE new FRs which are used as replacement compounds become potential chemicals of concern. Samples collected with the superhivol at Alert were screened for 15 new FRs and the results were compared to those measured at another remote station located on the Tibetan Plateau.

Activities in 2009–2010

Field and laboratory studies

1. Regular atmospheric measurements of OCPs, PAHs, PCBs and PBDEs continued at Alert on a weekly basis, which include field sampling, solvent extraction, clean-up, instrumental analysis, and data archive.
2. Testing work was initiated at Alert in December 2005 for the atmospheric sampling of emerging chemicals, including currently used pesticides (CUPs) and perfluorinated compounds (PFCs). Sampling generally occurred once per month from October to February and once every other week from March to September. Fifty-two air samples were collected at Alert between August 2006 and March 2009 for the screening of 21 CUPs and 7 PFCs. Preliminary blank-corrected results revealed that 8 out of the 21 CUPs were detected in over 50 % of the 52 samples. Six out of the 7 PFCs were found in 92–98 % of the 52 air samples. Screening for 15 new FRs [syn- and anti-dechlorane plus (DP) plus 13 brominated FRs (BFRs)] was performed in superhivol samples collected in 2007. Early data assessment has shown that 7 new FRs were frequently detectable in Alert air. Continuous measurements are required to examine the relative concentrations of these compounds during different seasons and what factors influence their transport to the Arctic. This information will inform national and international control initiatives of the long-range transport ability of these chemicals for potential consideration for control.
3. A FTAS has been deployed at Alert since October 2007 to test the use of this type of sampler under Arctic conditions. Monthly air samples have been taken with the FTAS to compare with results obtained using the superhivol (see results presented below).

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

4. The Little Fox Lake station in Yukon has been restarted in August 2007 and sampling ended October 2009.
5. Two Research Affiliate Program (RAP) students, John Norman Westgate of the University of Toronto and Uwayemi Sofowote of McMaster University, have participated in two intensive air sampling excursions in August 2007 and again in September 2008 at Little Fox Lake. During these trips, 24-hour air samples were taken continuously for 14 days. Air samples were also taken simultaneously at Wudalianchi (48.6°N, 126.2°E), China, during the sampling period in August 2007. During the September 2008 sampling period, 24-hour air sampling occurred simultaneously at Fairbanks and Dillingham, Alaska. Four sampling stations in Asia, including Wudalianchi, Waliguan GAW and Xuencheng in China and Ba Vi in Vietnam, have started 24-hour continuous monitoring one week in advance and continued for 2 weeks. This potentially provides data with regard to pollutant transport across the Pacific.
6. As an in-kind contribution from Environment Canada, in July/August 2007, Prof. Frank Wania, a collaborator of IPY INCATPA, and RAP student, John Norman Westgate, collected soil samples along the Chilkoot Trail crossing Yukon and Alaska. Also, under an NSERC Strategic Grant, Mr. Westgate is performing passive air sampling for POPs on four mountains in B. C. at various heights on both the windward side and the leeside to assess differences in atmospheric POPs. Results of these studies will be combined with the NCP and IPY air measurement results to assess the transport and deposition of organic pollutants to the western Canadian Arctic and sub-Arctic.

7. Samples from items 5 and 6 are being analyzed at NLET and at the University of Toronto, respectively. Analysis has been completed for most samples and data are currently being analyzed.

Data interpretation

8. An article which compares brominated FR air concentrations measured at Alert and at the Tibetan station of Nam Co is currently under preparation. Although both sites are extremely remote, different temporal patterns and chemical profiles of PBDEs and new flame retardants, e.g. BTBPE, EHTeBB and BEHTBP, were observed at the two stations. A 4-page short paper has been submitted to the Brominated Flame Retardant (BFR) Symposium held in Kyoto, Japan in April 2010.

9. A paper which compares the air concentrations of OCPs at Alert measured by the FTAS and those by the routine super-high volume air sampler is currently in preparation. Some results are presented below.

10. A paper titled "Sources and Pathways of Polycyclic Aromatic Hydrocarbons Transported to Alert, the Canadian High Arctic" [Wang et al., Environ. Sci. Technol., 2010, 44 (3), pp 1017–1022] has been published. Our team worked with a Ph.D. student Rong Wang and his supervisor Prof. Tao Shu (Peking University) on this paper to examine sources and atmospheric pathways of PAHs to Alert using a probabilistic function (integrated source contribution function, ISCF) based on air mass back trajectories. By incorporating emission intensities at the sources and the major processes of partitioning, indirect photolysis and deposition occurring on the way to the Arctic, this study found that PAHs observed at Alert are mostly from East Asia (including Russia Far East), North Europe (including European Russia), and North America. These sources account for 25, 45, and 27% of PAHs atmospheric level at Alert, respectively. The major sources to Alert shifted from Russia and Europe in the winter to northern Canada in the summer.

11. The air monitoring dataset for POPs at Alert and those collected for all satellite stations (namely Tagish, Little Fox Lake, Kinngait, Valkarkai, Amderma and Dunai) and NCP/NOAA collaborative station at Barrow, Alaska, and those from the AMAP/EMEP (Arctic Monitoring and Assessment Programme/European Monitoring and Evaluation Programme) stations of Pallas (Finland), Storhofdi (Iceland) and Zeppelin (Svalbard/Norway) have been included in a status review article for air monitoring of organic pollutants under AMAP. The paper has been published online as "Hung et al. Atmospheric monitoring of organic pollutants in the Arctic under the Arctic Monitoring and Assessment Programme (AMAP): 1993–2006, Sci Total Environ (2009), doi:10.1016/j.scitotenv.2009.10.044". This article has formed the basis for the atmospheric measurements provided in the AMAP report of Arctic Pollution published in 2009.

12. In the previous year, IPY INCATPA has conducted an interlaboratory QA/QC study on atmospheric POPs which covers the NCP atmospheric laboratories. The final report is now available. A paper detailing the results of this interlaboratory QA/QC study has been submitted to *Environmental Pollution* for consideration of publication. The INCATPA team is currently collaborating with Dr. Wenche Aas at the Norwegian Institute for Air Research (NILU) and the Ontario Ministry of the Environment team that are coordinating the NCP Phase III interlaboratory comparison to operate an AMAP/EMEP/NCP interlaboratory comparison specifically designed for atmospheric samples.

Capacity Building

13. Through the Council of Yukon First Nations (CYFN), an NCP/IPY INCATPA assistant, Ms. Tonya Makletzoff, was hired with IPY INCATPA funding to assist with outreach and communication activities in the Yukon region. Through this employment, Ms. Makletzoff learnt about the science of contaminants in the North and generated an outreach package suitable for use in the North (see below item 16).

Outreach and Communication Activities

14. ***March 5, 2009*** – Yukon IPY Celebration Event, Whitehorse, Yukon

    Hayley Hung attended this event at the Yukon College to present activities conducted under NCP and IPY INCATPA to the general public in Yukon. A communication poster about INCATPA activities in the Yukon was also presented.

15. ***March 6, 2009*** – Ms. Infiniti Conference, Whitehorse, Yukon

    The purpose of this conference is to invite grade 9–10 girls to explore the infinite possibilities of careers in math and the sciences. Hayley Hung was the keynote speaker of this event organized by the Yukon Women in Trades and Technology to talk about her research in the North and activities under NCP and INCATPA.

16. ***June–August, 2009*** – Multiple Yukon community outreach presentations and production of outreach material on contaminants

    In order to make the science information and research on contaminants accessible and relevant for communities in the Yukon, our team collaborated with the CYFN to supervise a northern student, Ms. Tonya Makletzoff, who conducted outreach to communities in the Yukon. Ms. Makletzoff worked with the NCP and INCATPA teams to produce outreach materials suitable for the Yukon communities, including an IPY INCATPA/NCP Storyboard, a Powerpoint presentation, a brochure, a poster and a coloring book. Ms. Makletzoff has conducted outreach on behalf of the NCP/IPY INCATPA teams between June and September 2009 at summer events such as aboriginal gatherings, science camps and various First Nations (FN) General Assemblies (GA).

17. ***October 2–5, 2009*** – 9th Association of Canadian Universities for Northern Studies (ACUNS) International Students Conference on Northern Studies and Polar Regions

    Ms. Makletzoff represented IPY INCATPA and NCP in the presentation of a poster at this conference held in the Yukon College, Whitehorse, Yukon.

18. ***October 5, 2009*** – October Polar Week presentation

    During the October Polar Week of 2009, Hayley Hung spoke to the Natural Studies Club of the Marc Garneau Collegiate Institute in Toronto about NCP/ IPY INCATPA and contaminants in the north. The audience includes more than 30 students from Grades 9 to 12.

Traditional Knowledge

19. At this time, Traditional Knowledge is only indirectly related to this project. When on board the Amundsen Icebreaker as one of her IPY activities, Hayley Hung participated in a Traditional Knowledge Workshop. She has gained insight on how potentially open sea ice could contribute to the movement of organic pollutants between the air, in which they are carried to the Arctic, and the open seawater. This information was used in interpreting rising atmospheric trends of hexachlorobenzene and some lighter PCBs at Zeppelin (a Norweigian AMAP station) after 2006 which may be attributable to the enhanced volatilization of these substances from the Arctic Ocean on the west coast of Spitsbergen, where Zeppelin is located, due to ice-free winters from 2003-2006 (Hung et al. Sci Total Environ (2009), doi:10.1016/j.scitotenv.2009.10.044).

Results

A FTAS was deployed at Alert in September 2007 and monthly samples have been collected using this sampler with air volumes ranging from 2360 to about 14000 m^3 per month. Detail description of this sampler was given in Xiao et al. (2007). Weekly-integrated air samples were also collected with the superhivol at Alert which included one glass fiber filter (GFF) and two polyurethane foam plugs (PUFs), trapping the particle and gas phase compounds, respectively. OCP concentrations measured with the two types of samplers are compared in Figure 1.

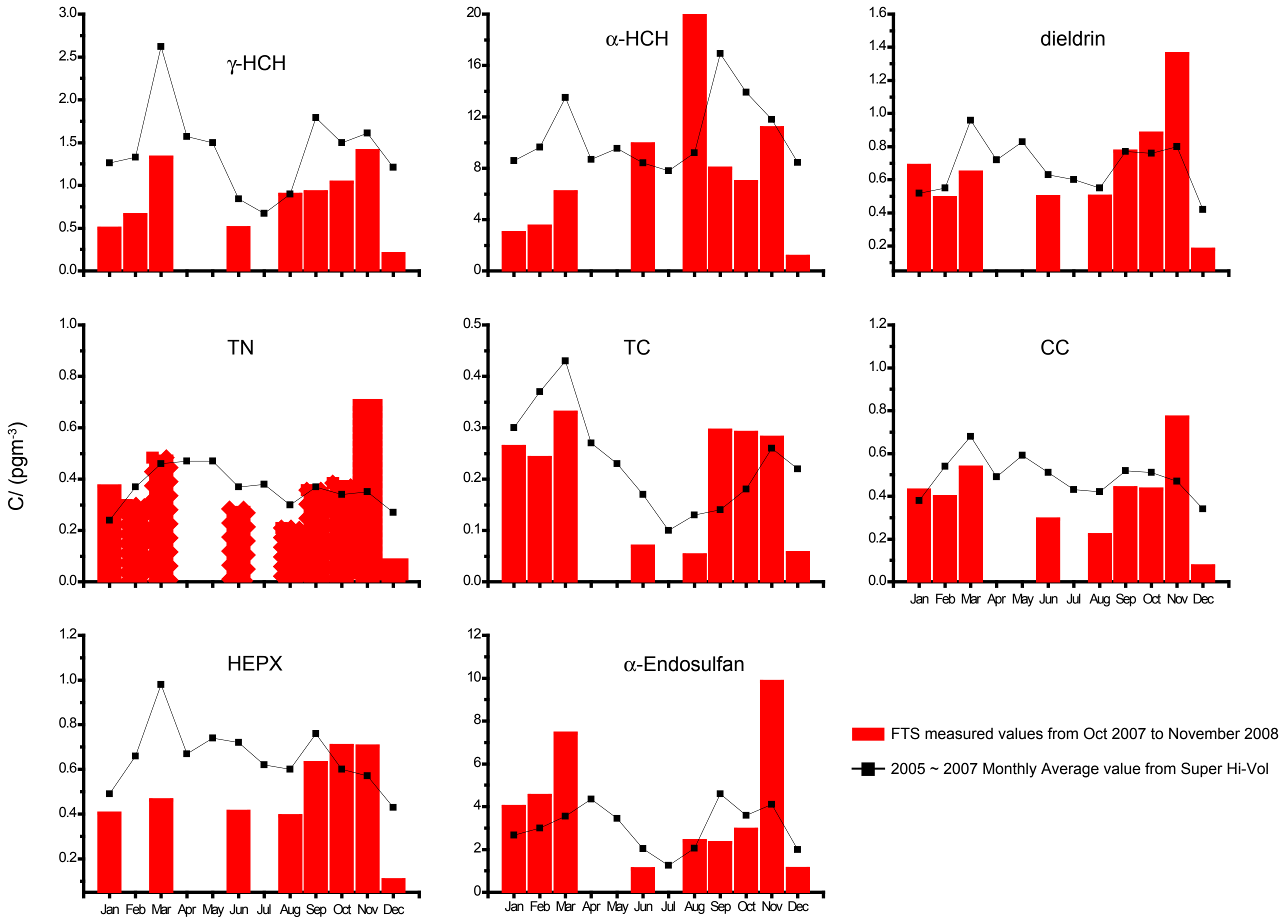

Figure 1. Comparison of major OCP atmospheric concentrations detected at Alert using the superhivol and FTAS. The superhivol measurements are the monthly average values from the previous three years.

Air samples collected using the superhivol at Alert in 2007 were screened for 2 dechlorane plus (DP) (syn- and anti-dechlorane plus) and 13 non-PBDE BFRs (Allyl 2,4,6-triBromophenyl Ether (ATE), Pentabromotolune (PBT), 2-Bromoallyl-2,4,6-tribromophenyl Ether (BATE), PentabromoBenzene (PBBe), Hexabromobenzene (HBB), 1,2-Bis(2,4,6-tribromophenoxy)ethane (BTBPE), Tetrabromo-o-chlorotoluene (TBCT), 2,3-dibromopropyl--2,4,6-tribromophenyl Ether (DPTE), 2,2',4,5,5'-Pentabromobiphenyl (BB-101), Pentabromobenzyl Acrylate (PBBA), 2-Ethylhexyl-2,3,4,5-tetrabromobenzoate (EHTeBB), bis(2-ethyl-1-hexyl)-tetrabromophthalate (BEHTBP) and Octabromotrimethylphenylindane (OBIND)). Analytical methods are given in Xiao et al. (BFR 2010 short paper, Kyoto, Japan).

A FTAS was deployed at a remote research station located close to Nam Co Lake on the Tibetan Plateau (30° 46.44' N, 90° 59.31' E, 4730 m asl) between October 2006 and February 2008. Fifteen consecutive one month-long samples, with air volumes ranging from 4,500 to 16,000 m^3. Twenty-six PBDE congeners (BDE-30, 17, 28, 49, 71, 47, 66, 100, 119, 99, 154, 153, 139, 140, 138, 156/169, 184, 183, 204/197, 203, 196, 205, 207, 208, 206 and 209) and three BFRs (BTBPE, EHTeBB and BEHTBP) were quantified used GC-HRMS. PBDEs and other BFRs measured at these two stations are shown on Figure 2 and 3.

Discussions and Conclusions

Comparison of FTAS OCP Measurements with Super-high-volume Air Sampler Results

Air concentration data collected with the superhivol from the same time periods are currently still undergoing quality assurance/quality control

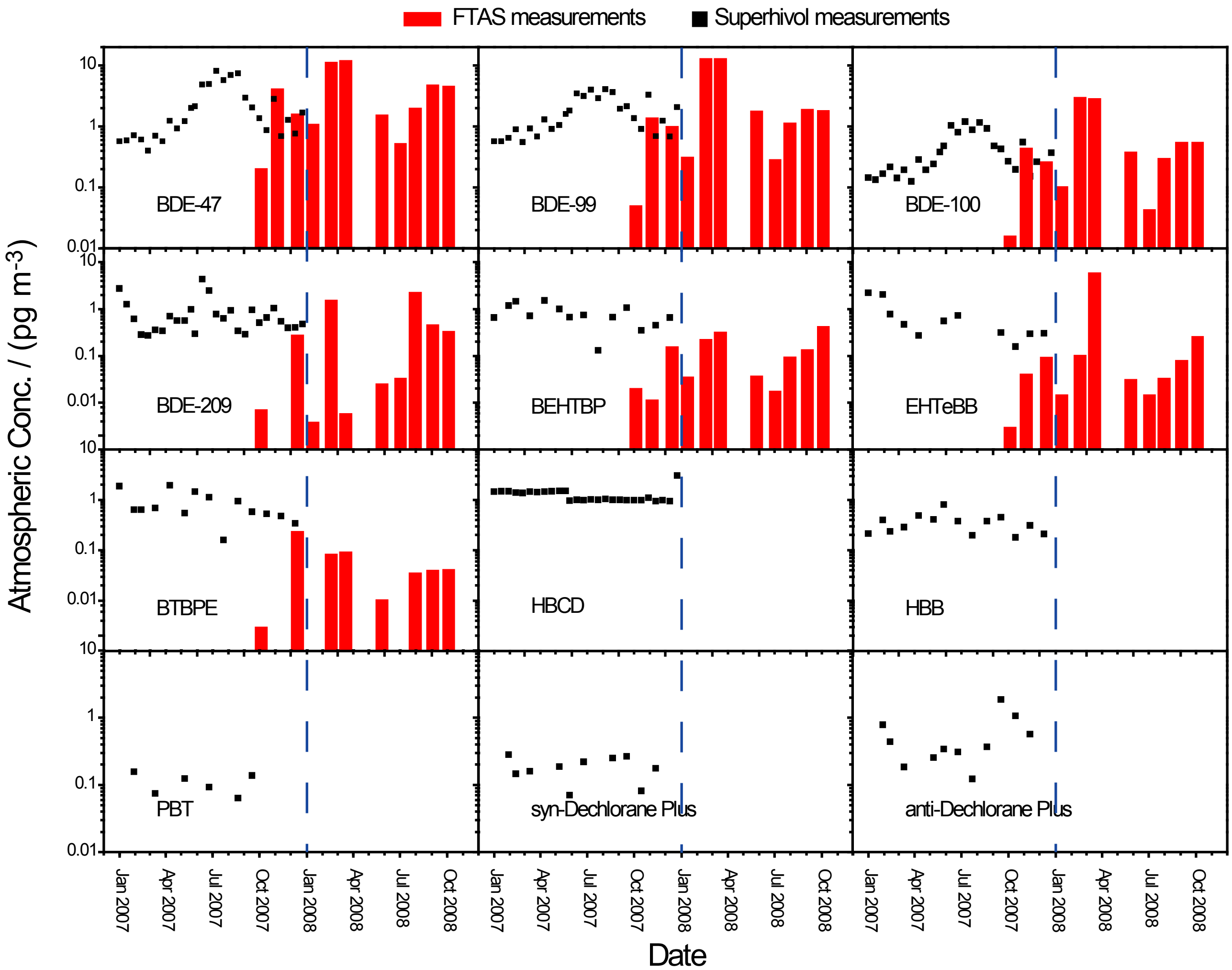

Figure 2. Seasonal variations of the atmospheric concentrations of PBDEs and other FRs at Alert observed using the two different techniques.

(QA/QC) procedures. Here, the FTAS data were compared with the monthly average superhivol results for the previous three years. For the dominant OCPs in the Arctic atmosphere (Figure 1), these two techniques not only give similar absolute values, but also similar seasonal trends. For more volatile compounds like HCHs, the breakthrough-corrected FTAS values for 2007-2008 were slightly lower than the active sampling results from the previous three years, especially for the winter months. This may reflect declining HCH air concentrations over time. The superhivol measurement results for the same sampling periods are needed to further confirm whether the slightly declining trends for the HCH atmospheric concentrations are true or not.

The Atmospheric Concentrations of Brominated Flame Retardants at Extreme Remote Locations: The Canadian High Arctic Station of Alert and the Tibetan Plateau

Figure 2 and 3 present the seasonal variation of the atmospheric concentrations of these commonly detectable compounds at Alert and Nam Co, respectively. The atmospheric FR levels in both remote sites were general very low, normally below a few pg m^{-3}, with the PBDE concentrations at Alert are slightly higher than those at Nam Co. The dominant PBDE congeners were always BDE-47, 99 and 209, while other congeners, such as BDE-100, 183, 153 and 196 were also frequently detected. BTBPE, EHTeBB and BEHTBP were

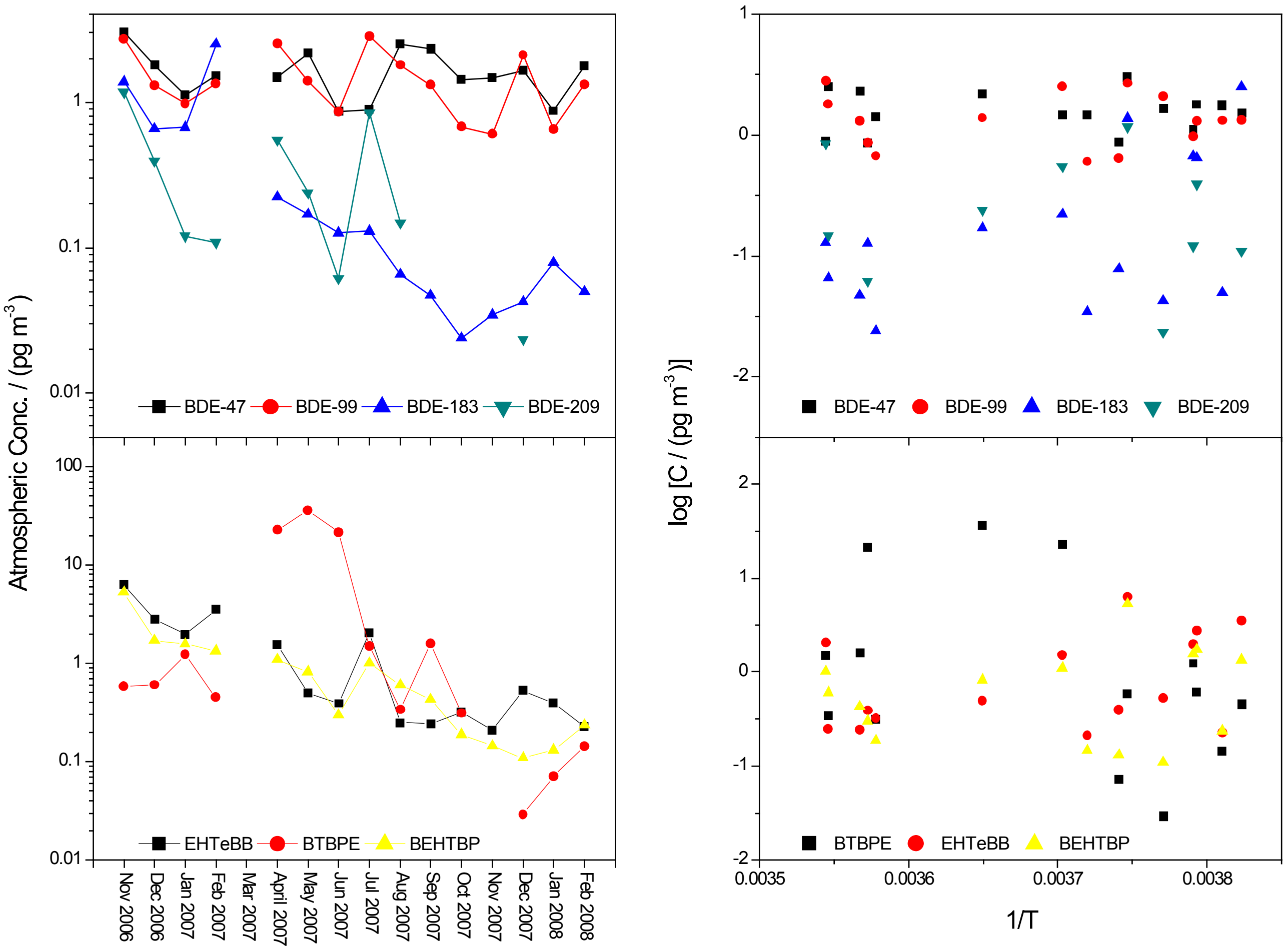

Figure 3. Seasonal variations and temperature dependence of the atmospheric concentrations of PBDEs and other BFRs at Nam Co (from Xiao et al. BFR2010 short paper).

generally detected at both sites as well with concentrations similar to those of the dominant BDE congeners. PBT, HBB and HBCD were sometimes detectable in the Alert atmosphere. For PBDEs, significant seasonal variations and temperature dependence were apparent for the Alert superhivol samples, which is consistent with previous results (Su et al. 2007); but such trends are much less obvious in the monthly FTAS results. The PBDE concentrations at Nam Co lack seasonal variability, which may suggest no significant regional sources in Tibet. A BFR detected in the Tibetan atmosphere thus should be regarded as having a very high potential for long range atmospheric transport, which may reflect the truly global background contamination (Xiao et al. BFR 2010, Kyoto, Japan).

In contrast to PBDEs, no significant temperature dependence of the new BFR air concentrations was found at either site. Considering that air concentrations of new BFRs are similar to those of the PBDEs at both remote sites, studies of the toxicology and risks of PBDE-substitutes are called for.

NCP Performance Indicators

The following performance indicators reflect the combined effort of both NCP and IPY INCATPA which are related projects:

The number of northerners engaged in your project: Northern students 1, northern participants 7

The number of meetings/workshops you held in the North: Event presentations 3, Community presentations 11

The number of students (both northern and southern) involved in your NCP work: NCP 2, IPY INCATPA 4

The number of citable: Journal 6, Presentations 6

Expected Project Completion Date

On-going

Acknowledgements

We would like to acknowledge the Northern Contaminants Program (NCP) for funding the atmospheric measurements at Alert and the FTAS deployment at Alert. Also, thanks to NCP and NSERC for supporting the development of the FTAS and NSERC for its deployment at Nam Co, Tibet. We would also like to thank Li Shen for BFRs analysis. We would like to thank Len Barrie and Derek Muir for initiating the air monitoring program of organic pollutants under NCP and their continuous support.

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Mercury Measurements at Alert and Little Fox Lake

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Abstract

Mercury (Hg) is a global priority pollutant and continues to be of concern in Arctic regions. The longest Arctic record of atmospheric mercury concentrations have been collected in the Canadian high Arctic at Alert, Nunavut. This time series shows distinct repeatable seasonal and annual patterns in the gaseous elemental mercury (GEM). Further analysis into the time trend of this data set has been undertaken and has revealed a decreasing annual trend in GEM. Collection of measurements continued in order to understand the processes of atmospheric mercury conversion and deposition in the springtime to the Arctic by collecting atmospheric mercury species including Reactive Gaseous Mercury (RGM) and Particle Associated Mercury (PHg) and observing the behaviour of them over time. In addition, a time trend analysis by month showed that the spring minimum in GEM has been shifting to earlier in the spring. Analysis of the springtime data showed a strong

Résumé

Le mercure (Hg) est un polluant prioritaire mondial et continue d’être préoccupant dans les régions arctiques. La plus longue série de données sur le mercure dans l’atmosphère de l’Arctique a été recueillie dans le Grand Nord canadien à Alert (Nunavut). Cette série chronologique présente des tendances périodiques saisonnières et annuelles dans le mercure élémentaire gazeux (MEG). Une analyse plus approfondie des tendances temporelles dans cet ensemble de données a été entreprise et a révélé une tendance à la baisse annuelle du MEG. La collecte des mesures s’est poursuivie afin de comprendre les processus de conversion et de dépôt du mercure atmosphérique au printemps dans l’Arctique, et à cette fin on a recueilli des échantillons de différentes espèces de mercure dans l’atmosphère, y compris le mercure gazeux réactif (MGR) et le mercure associé aux particules (HgP) et on a observé leur comportement au fil du temps. En outre, une analyse des tendances temporelles sur une base

relationship between air temperature and the occurrence of AMDEs. GEM measurements continued to be collected in the Yukon at Little Fox Lake and the progress on those measurements will be reported.

mensuelle a montré que le minimum printanier pour le MEG survenait plus tôt au printemps. L'analyse des données printanières a montré une forte relation entre la température de l'air et l'occurrence des baisses du mercure atmosphérique. Les mesures de MEG ont continué au Yukon, à Little Fox Lake, et l'état de ces travaux sera communiqué.

Key Messages

- Fifteen years of atmospheric mercury measurements have been made at Alert, Nunavut. This data has been, and will continue to be, used to establish trends of atmospheric mercury in the Canadian high Arctic
- Three years of atmospheric mercury measurements have been collected at Little Fox Lake, Yukon to establish baseline levels and the impact of long range transport from the Pacific Rim to this area.
- In collaboration with IPY efforts, intensive studies of mercury depletion/deposition episodes and their impact on the Arctic environment were undertaken
- While studies continue to further understand the processes driving mercury depletion events, the cause, effects and implications of these events are still pending.

Messages clés

- Le mercure atmosphérique a été mesuré pendant quinze ans à Alert (Nunavut). Ces données ont été et continueront d'être utilisées pour établir les tendances du mercure atmosphérique dans l'Extrême-Arctique canadien.
- Le mercure atmosphérique a été mesuré pendant trois ans à Little Fox Lake (Yukon) pour établir les niveaux de base et mesurer l'impact du transport à longue distance depuis la côte du Pacifique jusqu'à cette région.
- De concert avec les activités de l'API, on a entrepris des études approfondies des épisodes d'appauvrissement et de dépôt du mercure et de leur impact sur l'environnement arctique.
- Bien que les études se poursuivent pour mieux comprendre les mécanismes de l'appauvrissement du mercure, les causes, les effets et les conséquences de ces épisodes sont encore nébuleux.

Objectives

The objectives of this project are to establish long term baseline concentrations of mercury in the Arctic atmosphere and to study the behaviour of mercury in the Canadian high Arctic. By collecting this information on concentrations of atmospheric mercury, temporal variability, transport events and trends can be established. This information will be crucial in the development of Canadian strategies for national and international pollution control objectives. For instance, this data will be part of Canada's strategy on the current UNEP global negotiations on a legally binding agreement for mercury. Through the NCP, the transport of atmospheric mercury to the Arctic, the cycling of mercury in the atmosphere and the subsequent deposition of mercury from the atmosphere to the arctic environment has been studied at Alert since 1995. This long term record is advantageous to elucidate changes to and properties of the chemical and physical aspects of atmospheric mercury depletion events (AMDEs) after polar sunrise and the resulting potential link to enhanced Hg concentrations in the Arctic environment. Understanding these processes will help us to predict the effects that a rapidly changing Arctic climate will have on mercury deposition. More recently, the impact of mercury emissions from areas in the Pacific Rim to the Canadian western Arctic have become a concern. To address this, measurements have begun in the Yukon to measure the transport of mercury to this area.

Introduction

Mercury (Hg) continues to be a priority pollutant of concern in Arctic regions. This project, within the NCP, provides long term data on the temporal trends and contributes to understanding the spatial variability of mercury in the High Arctic air as well as information concerning the behaviour of Hg that may impact the pristine Arctic. The change of the global atmospheric pool of Hg over time and the resulting concentration levels in particular regions are poorly defined. Thus, areas like the Arctic are a good place to assess such changes. Further, with global climate change expected to occur at a rapid pace in Arctic regions, the atmospheric dynamics and the impacts of pollutants such as Hg to this environment have to be well understood. Pollution of Hg in the Arctic has mainly occurred after industrialisation (Steffen, Douglas et al. 2008). While European and North American emissions of gaseous elemental mercury (GEM) have decreased since 1995, emissions in other regions such as Asia and Africa have increased (Pacyna, Pacyna et al. 2006). Circulation patterns show that air masses originating in Asia can enter the Canadian Arctic (Dastoor and Larocque 2004) and thus the increase in Asian emissions is particularly important to the Canadian north. It has been established by modellers that the Little Fox Lake site in the Yukon is an ideal location to measure such input from these sources (Dastoor and Durnford 2008).

Annual time series of GEM have been produced and show repetitive distinct seasonal cycling of this pollutant. Through analysis of this annual cycling, it was discovered that a substantial amount of reactive mercury is present in the air and on particles during the spring time when levels of GEM in the air are very low (Schroeder, Anlauf et al. 1998; Steffen, Schroeder et al. 2003). This shift in mercury species in the air is called an atmospheric mercury depletion event (AMDE). A portion of these reactive mercury species remain in the air while a large amount is deposited onto the snow and ice surfaces (Ariya, Dastoor et al. 2004). It is likely that this conversion of mercury (and subsequent deposition) after polar sunrise may provide a pathway by which these more reactive and potentially bio-available mercury species are introduced into the Arctic environment (Lu, Schroeder et al. 2001). These data (Canadian and other) will provide important information on the atmospheric transport, transformation and deposition processes of this priority pollutant throughout the Polar Regions.

As the International Polar Year (IPY) activities wind down and the analysis of collected data begin, the three Canadian IPY funded programs (Steffen 2009) that we have undertaken to understand the transport, transformation and deposition of mercury in the Arctic will be linked with this ongoing NCP mercury research.

Activities in 2009/2010

Research activities

Ground-based continuous atmospheric measurements of GEM, Reactive Gaseous Mercury (RGM) and Particulate Mercury (PHg) continued at Alert. RGM and PHg concentrations were collected and the data has been quality assured. The GEM data from Alert and Little Fox Lake for 2009 have been collected and initial quality control processing has been completed. However, the GEM data from Alert for 2008 and 2009 are currently being reviewed for final quality assurance. This year, a robust statistical analysis of long-term trends in GEM at Alert up to 2007 and an analysis of the long-term relationship between GEM and meteorological parameters were (Cole and Steffen 2010). Snow samples continued to be collected on weekly samples (ground) and on a per event basis (table). Due to ongoing lab construction, the samples collected in 2008 and 2009 have not yet been analysed and thus we have no new data to report this FY. Three IPY projects (INCATPA, OASIS-Canada and CFL) that directly relate to this NCP program have completed the collection of data and are now in the analysis Stage.

Capacity Building

In keeping with past years, the NCP-funded air research projects for POPs and Mercury have combined communication and consultation activities because they are so closely related in terms of facilities and technical support. Further, because there is significant integration between these NCP projects and the IPY INCATPA program, we have combined several of our communication and capacity-building activities.

Through the Council of Yukon First Nations (CYFN), an NCP/IPY INCATPA student, Tonya Makletzoff, was hired with IPY INCATPA funding to assist with outreach and communication activities in the Yukon region. Through this employment, Ms. Makletzoff learnt about the science of contaminants in the North and generated an outreach package suitable for use in the North.

As part of capacity building around the Toronto area, Sandy Steffen participated in the Government of Canada's Science and Technology Week at the Ontario Science Centre (OSC). A booth was set up with Arctic gear, photos and a video. Students were welcome to stop by and learn about the work undertaken by NCP and IPY in the high Arctic.

Communications

The Alert outreach brochure has been finished. The goal of this brochure is to inform the "more" local population (those in closest vicinity of Alert) of the work occurring at the Alert Global Atmospheric Watch (GAW) Station including the NCP-funded contaminants work. The brochure was sent for consultation to the NAC (through Erika Solski), ITK (Eric Loring), NCP (Jason Stow and Russell Shearer), NCP researchers (Hung and Steffen) and GAW program researchers (Marjorie Sheppard, Andrew Platt and Sangeeta Sharma). The brochure has been published by Environment Canada and has been translated into French and Inuktitut. Once printed, it will be distributed to all parties.

Sandy Steffen participated in an Aboriginal Peoples Network Children's Show "This is Turtle Island" and was interviewed on camera speaking about the work she does in the Arctic and how to engage youth in such careers. The show was aired on TV.

As part of the OASIS- Canada IPY research project, Sandy Steffen gave a Saturday seminar talk in Barrow, Alaska discussing the IPY program on mercury and the OASIS-Canada program in which she was participating in March 2009. Sandy was the outreach coordinator for the OASIS- Barrow 2009 project and coordinated with the local community to introduce the science to the community but to also introduce the community to the scientists. Arrangements were made to participate in local community activities such as dog sledding, seal skin boat making, local festivals and meet and greet nights with northerners.

Through the IPY, Canadian Geographic Magazine issued a special issue for IPY research and the investigation of mercury in the arctic was featured prominently in the issue. "The Case of the Missing Mercury" is the article and it discusses the research results that have come from long term NCP work and the ongoing IPY studies.

Tonya Makletzoff, the NCP/IPY INCATPA student, worked with the NCP and INCATPA teams to produce outreach materials suitable for the Yukon communities, including a storyboard, a Powerpoint presentation, a brochure, a poster and a coloring book. Ms. Makletzoff conducted outreach on behalf of the NCP/IPY INCATPA teams between June and September 2009 at summer events such as aboriginal gatherings, science camps and various First Nations (FN) General Assemblies (GA).

Ms. Makletzoff represented IPY INCATPA and NCP in the presentation of a poster at the 9th Association of Canadian Universities for Northern Studies (ACUNS) International Students Conference on Northern Studies and Polar Regions, held at Yukon College, Whitehorse, YT.

As part of the IPY Film Festival, Sandy Steffen and Hayley Hung worked at the Environment Canada booth to discuss with people attending the festival about the research we undertake through the NCP and IPY programs. Further, a film that was produced during the OASIS-Canada IPY project that discussed the mercury work in the Arctic was accepted into the Oslo IPY Science Conference film competition.

Traditional Knowledge

At this time, TK is only indirectly related to this NCP project. As part of an IPY project, OASIS-Canada, we undertook field studies in Barrow, local guides/hunters/ice observers from the town of Barrow were hired to help us with the project on the ice. Through their extensive knowledge of the ice and the lead, they provided us information that led to the success of the project. This knowledge was coupled with our measurements and improved our understanding of the springtime chemistry of mercury and ozone depletions in this area.

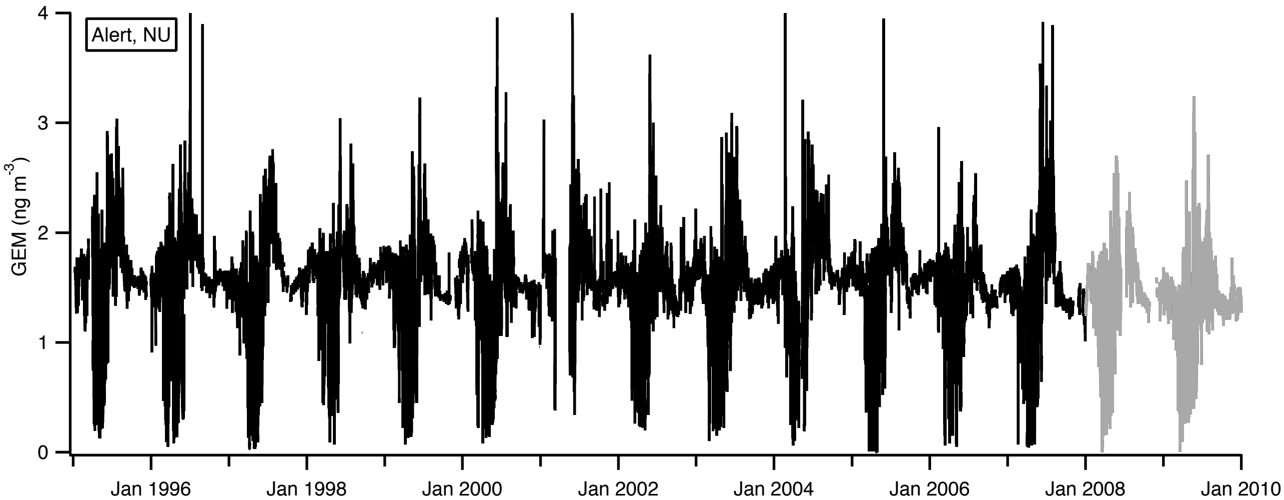

Figure 1.

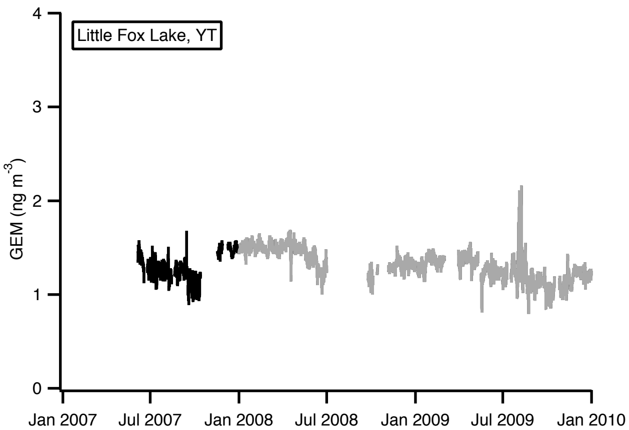

Figure 2.

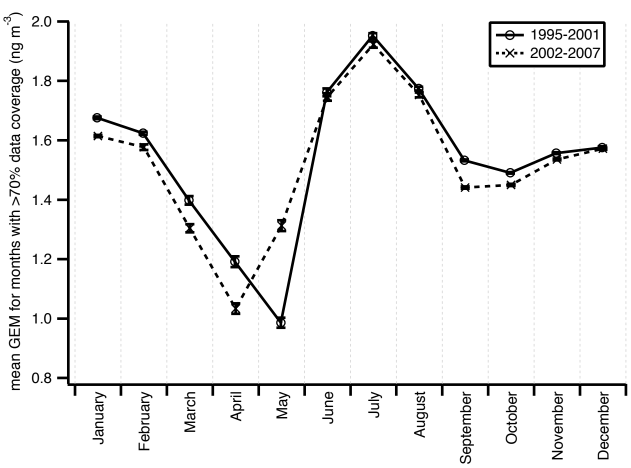

Figure 3.

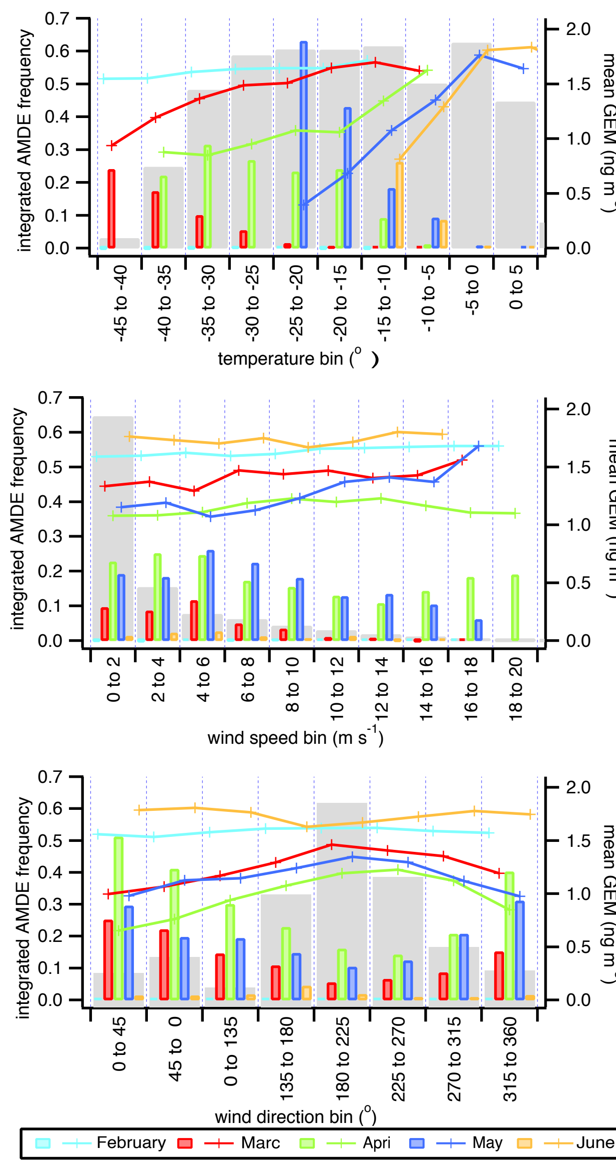

Figure 4.

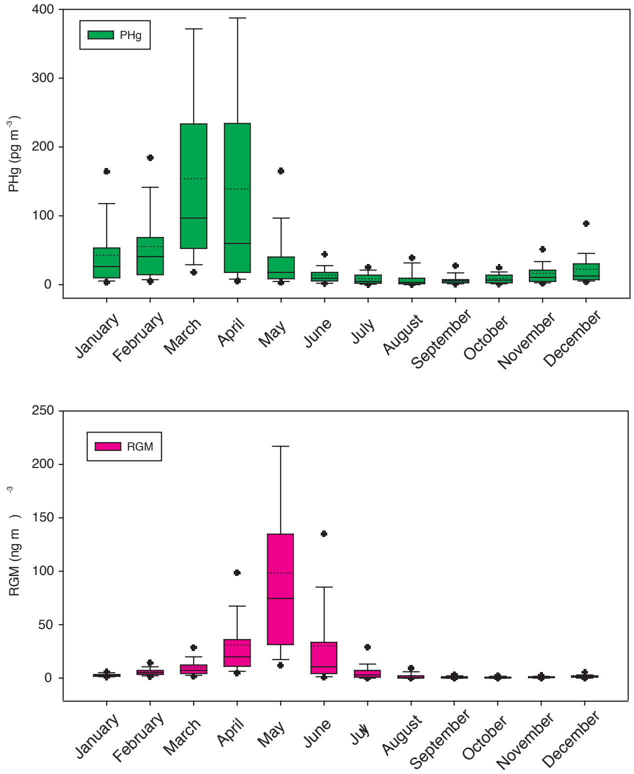

Figure 5a.

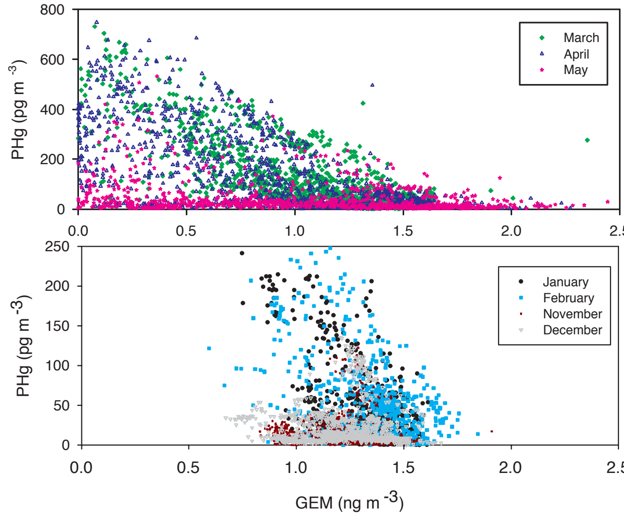

Figure 5b.

Results

Figures 1 and 2 show the preliminary GEM measurements at Alert from 1995 to 2009 and Little Fox Lake from 2007 to 2009. Trend analysis on 13 years of GEM data from Alert was completed and revealed (a) a shift in the spring minimum GEM concentration from May to April, shown in Figure 3, and (b) a decreasing annual trend of -0.0086 ng m^{-3} yr^{-1} (-0.6% yr^{-1}). A further detailed analysis of the chemistry and dynamics of atmospheric mercury depletion events (AMDEs) was undertaken. Correlations between AMDEs and meteorological parameters are shown in Figure 4. Figure 5a shows box and whisker plots of the monthly PHg and RGM concentrations from Alert from 2002 to 2008 and Figure 5b show the relationship between gaseous elemental mercury (GEM) and mercury associated to particles (PHg) during different months over the same time period.

Discussion and Conclusions

Atmospheric mercury trends:

Fifteen years of GEM concentration data from Alert have now been collected. This is an impressive record of long term atmospheric mercury in the Arctic. Previous analyses of the data have shown no trends in the annual data set (Steffen et al., 2003; Temme et al., 2007). However, this data exhibits such seasonal fluctuations that a more robust investigation of the data needed to be undertaken in order to assess any true changes with time. Thus, a statistical test called the seasonal Kendall test was performed for the data from 1995-2007 and was used to calculate the changes in GEM concentration for each month and annually. The results, as seen in Figure 3, show a decrease in the GEM concentration for every month except May. This observation is in agreement with findings reported last year that show that the frequency of AMDEs has shifted to earlier in the season (Steffen 2009). Additionally, for the first time a small, yet statistically significant, decrease in the overall annual mean GEM concentration was observed from 1995 to 2007 with a slope of -0.0086 ng m^{-3} yr^{-1} (Cole and Steffen 2010). This result is a valuable contribution to our understanding of global and regional mercury budgets and illustrates the importance of this ongoing monitoring.

Measurements at Little Fox Lake were initiated in 2006 to monitor the concentration levels of atmospheric Hg at an Arctic background inland location in the Yukon. The data, shown in Figure 2, indicate that the atmospheric mercury concentration levels fall within what is expected for a remote location and the data also shows minimal seasonal variability including no distinct springtime chemistry. However, this data set will be used to assess long range transport of mercury into the Canadian Arctic and to define background levels of GEM in the air in the Yukon. The addition of 2009 data, once they have cleared the complete QA/QC process, will provide enough data to begin analysis to investigate the contribution of mercury from long-range transport to the Yukon.

Atmospheric mercury processes:
The chemical transformation of mercury in the Arctic environment is still not fully understood and is a crucial part of predicting future inputs of mercury to the ecosystem. Thus, continuous measurements of RGM and PHg at Alert were extended through 2009. The monthly data from 2002 to 2008 is shown in Figure 5a. This plot shows that the most significant concentrations occur in March and April and April and May for PHg and RGM, respectively. This is not surprising given the information reported from the past several synopsis reports. It is interesting to note the elevated concentrations in PHg from November to February (in general higher concentrations than those reported in temperate regions). These months do not include significant input from AMDEs and thus indicate that there are other potential sources of PHg at Alert than atmospheric springtime chemistry. Plot 5b shows the relationship between GEM and PHg for these 2 time periods and that there is a correlation between elevated levels of PHg and low levels of GEM in the springtime but this relationship does not hold true for November – February when elevated levels of PHg are not well correlated with GEM. In contrast, RGM appears to only be recorded at Alert during the springtime when AMDE chemistry dominates the atmospheric mercury concentrations.

NCP Performance Indicators

Number of northerners engaged: 0 (excluding IPY)

Number of meetings/workshops held in the North: 0 (excluding IPY)

Number of students involved in project: 2

Number of citable publications: 1 (Cole and Steffen, 2010)

Expected Project Completion Date

ongoing

Acknowledgements

The project team would like to thank the Global Atmospheric Watch program at Alert for supplying facilities, assistance and personnel. We would like to thank Christian Wile and Adrienne Glover for collecting the 2008/2009 GEM data at Alert. Much appreciation to Greg Skelton for the ongoing work on compiling this large data set! Thanks to NCP and Environment Canada for financial support of this program.

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

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Abstract

Trends in concentrations of mercury, chlorinated naphthalenes and legacy persistent organic pollutants (POPs) such as PCBs, DDT, and hexachlorocyclohexanes (HCHs) were studied in ringed seals. Samples were collected by local hunters in 2009 at 5 communities and combined with results from previous years to examine the trends. Average mercury concentrations in seal muscle from Arviat, Resolute and Sachs Harbour were unchanged over the period 2005 to 2009. DDT and one component of HCH (α–HCH) continued to decline in seals from all communities

Résumé

Les tendances dans les concentrations de mercure, de naphtalènes chlorés et de polluants organiques persistants (POP) hérités du passé comme que les BPC, le DDT et les hexachlorocyclohexanes (HCH) ont été étudiées chez le phoque annelé. Les échantillons ont été recueillis par les chasseurs locaux en 2009 dans 5 communautés, et les résultats ont été combinés avec ceux des années précédentes afin de déceler les tendances. Les concentrations moyennes de mercure dans les muscles de phoques provenant d'Arviat, de Resolute et de Sachs Harbour n'ont pas changé entre 2005 et 2009. La concentration de

while PCBs, hexachlorbenzene and DDT and chlordane declined only in Hudson Bay. This regional difference may be due to the influence of Pacific Ocean waters traversing the archipelago which influences the contaminants accumulated by ringed seals in the Beaufort Sea and Lancaster Sound. Chlorinated naphthalenes were present at very low concentrations in seal blubber compared to most POPs and have declined in concentration since the 1990s.

DDT et de l'un des composants des HCH (αHCH) a continué de baisser chez les phoques dans toutes les communautés, tandis que les BPC, l'hexachlorobenzène, le DDT et le chlordane ont diminué seulement dans la baie d'Hudson. Cette différence régionale peut être due à l'influence des eaux du Pacifique qui traversent l'archipel, ce qui influe sur les contaminants accumulés dans les phoques annelés dans la mer de Beaufort et le détroit de Lancaster. Les naphtalènes chlorés sont présents en très faibles teneurs dans le petit lard de phoque par rapport à la plupart des polluants organiques persistants et leur concentration a diminué depuis les années 1990.

Key project messages

- Temporal trends of POPs and mercury were examined in ringed seals from 3 regions (Beaufort Sea, Lancaster Sound and Hudson Bay) by combining new results from samples collected in 2009 with previous results from communities in these regions.
- Chlorinated naphthalenes were detected at low concentrations in all seals but concentrations were lower than in samples from 1970s and 1990s
- Mercury concentrations in seal muscle remained more or less constant over the period 2005 to 2009 at Arviat, Resolute, and Sachs Harbour.

Messages clés du projet

- Les tendances temporelles des concentrations de polluants organiques persistants et de mercure ont été examinées dans les phoques annelés de 3 régions (mer de Beaufort, détroit de Lancaster, baie d'Hudson) en combinant les résultats des nouveaux échantillons prélevés en 2009 avec les résultats antérieurs provenant des collectivités dans ces régions.
- Les naphtalènes chlorés ont été détectés à des concentrations faibles dans tous les phoques, et celles-ci étaient toutes inférieures aux concentrations trouvées dans les échantillons au cours des années 1970 à 1990.
- Les concentrations de mercure dans les muscles de phoque sont demeurées plus ou moins constantes entre 2005 et 2009 à Arviat, Resolute et Sachs Harbour.

Objectives

1. Determine temporal trends of persistent organic pollutants (POPs) and new organic chemicals of potential concern, as well as mercury and other metals in ringed seals using annual collections at 3 communities
2. Determine temporal trends of POPs and mercury at 10 other locations on a 5 year cycle using previous data from the 1970s, 1980s and 1990s as well as archived samples if available.
3. Identify and prioritize other new contaminants that are entering the Arctic environment and contribute information to Canadian and International assessments of new candidate POPs.
4. Provide the information on levels and temporal trends of these contaminants to each participating community and to the Territorial contaminants committees.

Introduction

The ringed seal is the most abundant Arctic pinniped with a circumpolar distribution and has been a key biomonitoring animal for examining spatial and temporal trends of persistent organic pollutants (POPs) and mercury in the Arctic since the 1970s. This project began in April 2004 under NCP Phase III and follows up earlier projects on ringed seals (Muir and Lockhart 1994; Muir 1996; Muir 1997; Muir et al. 1999; Muir et al. 2001; Muir et al. 2003). Results for POPs and heavy metals including mercury in the form of the original raw data are available going back to the 1980s, and earlier in some cases. This ringed seal contaminants project now has a very large database consisting of results for about 680 samples for PCBs and organochlorine pesticides (OCPs). Biological data including age and carbon and nitrogen stable isotope data are available for about 550 individual seals collected in the past 10 years.

Because ringed seals are an important species harvested by hunters each year in almost all communities in Nunavut, Nunavik, and the Inuvialuit Settlement Region, this project provides an opportunity to involve the communities in the scientific program of the NCP. Participation of hunters in each community has been consistent and the quality of the hunter based collection has generally been high. For example, in 2008 and 2009 requested information on gender, girth, length, blubber thickness was provided for 92% and 95%, respectively, of the animals sampled which is good considering the logistical challenges the hunters face in having to harvest and dissect the animals.

In these synopsis reports we try to focus on a different aspect of the data each year given limited space and the large size of the dataset. Our 2008-09 report focused levels and trends of PBDEs and endosulfan as well on spatial trends of mercury in muscle (Muir et al. 2009). In 2007-08 we reported on trends of mercury (Hg) in seal liver, perfluorinated compounds and on trends of toxaphene (Muir et al. 2007). This report for fiscal year 2009-10 presents new information on temporal trends of "legacy POPs" and a first detailed report on polychlorinated naphthalenes (PCNs) in seal blubber, as well as trends of mercury in muscle.

Activities in 2009-10

Sample collection

In 2009-10 ringed seal samples were successfully collected with the help of hunters in the communities of Arviat (N=25), Arctic Bay (N=19), Resolute Bay (N=22), Pond Inlet (16), and Gjoa Haven (15). No samples could be collected at Sachs Harbour because the HTA office was closed from May to October and reopened too late for fall sampling.

Collections consisted of blubber, liver, muscle, kidney, tooth/lower jaw (for aging). Essential data on length, girth, blubber thickness at the sternum, and sex was provided for almost all animals for all locations. Samples were stored at -20°C and then shipped frozen to NvRC in Kuujjuaq or to Burlington for processing. Large subsamples of all tissues were archived in walk-in freezers at -20 to -35°C in sealed plastic bags (double bagged).

In 2009 all tooth aging was conducted by Matson Labs (Milltown, MT). Muscle samples were sent to Wildlife Genetics International (Nelson BC) for gender confirmation using a DNA marker and to the University of Waterloo (Environmental Isotope Lab) for C and N stable isotope analysis.

Short reports (in English and Inuktitut) on the results of the study to date were faxed to the Hunters and Trappers committee offices of each community in April/May 2010 as part of communication and consultations. In August 2009, Marlene Evans presented these short reports to the HTA office managers in Pond Inlet, Pangnirtung and Iqaluit when visiting as part of her searun char project. In March 2010, project summaries were also sent to the Chairs and Inuit Research Advisors of the Nunavut Niqiit Avatitinni Committee and the NWT Environmental Contaminants Committee.

Chemical analyses

Organochlorine pesticides (OCPs), PCBs and polybrominated diphenyl ethers (PBDEs), in seal blubber were determined as described by Muir et al. (2005) with minor modifications. Samples were extracted with dichloromethane (DCM) using either pressurized fluid extraction (ASE 300, Dionex Instruments) or a Soxhlet apparatus, and lipid was removed by gel permeation chromatography. The extracts were then fractionated on a small activated silica column into non-polar (hexane) and polar (hexane:DCM 1:1) fractions. These fractions were concentrated, vialed and then analysed by gas chromatography with electron-capture detection (GC-ECD). Separation was accomplished on a HP 6890 GC using a 30m DB-5 column with H_2 carrier gas. Only samples from females or juvenile males were analysed.

All organic analyses except for SCCPs and PFAs were conducted by the National Laboratory for Environmental Testing (NLET) Organics Analysis Laboratory using established protocols (NLET 2007a; NLET 2007b). This lab is certified by Canadian Standards Association and has participated in the NCP Interlab comparison since 1998 as well as in international intercomparisons (e.g. QUASIMEME).

PCNs and coplanar PCBs were determined in the hexane fraction from the silica column fractions. The sample was applied to a ENVITM –Carb SPE Tube using 7.5% DCM/Cyclohexane. Two fractions were collected (1) 7.5% DCM/Cyclohexane containing co-planar PCBs and (2) toluene which contained the PCNs (NLET 2007b). PCNs and co-planars were subsequently analysed by GC-MS in electron-ionization mode.

Seal liver samples were analysed for perfluorinated alkyl acids as described by Butt et al.(2008). Instrumental analysis was performed by LC-MS/MS following previously described conditions (Butt et al. 2008).

Seal muscle was analysed for total mercury using a Direct Mercury Analyser (DMA; Milestone Instruments).

Quality assurance and statistical analysis

QA steps included the analysis of reference materials for heavy metals and organochlorines and reagent blanks. All results were blank subtracted. Under clean room conditions used for 2007 and 2008 sample extractions blank values for PCBs were <1% of typical values and <10% of BDE47, 99 and 100 values. Under regular NLET lab conditions (1998-2006 and 2009 samples) blank results were typically <1% of individual PCBs except for CB31, 28 and 52 where they were 10-30% of measured values in seal blubber. Similarly PBDEs congeners BDE 47, 99 and 100 were 30-50% of the values of these congeners in seal blubber under non-clean room conditions.

Basic statistics, correlations and frequency distributions were determined using Systat Version 12 (Systat Software Inc, Chicago IL). Organohalogen concentrations in ringed seals were normalized to 100% lipid. For temporal trend comparisons results for both mercury and organohalogens were first tested for normality 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. Temporal trends of PCBs and OCPs in the data for female ringed seals were analysed using the statistical program PIA (Bignert 2007).

Capacity Building

The Project works directly with HTA offices in each community, and in some cases directly with hunters, e.g. in Sachs Harbour we hired a local person at the recommendation of project team member Lois Harwood because he had worked with her previously in the collection of samples. The Nunavik Research Centre employs local people in Kuujjuaq in the laboratory who are trained by and work with Michael Kwan. Heavy metals analysis for this project and most of the aging of seals has been done in Kuujjuaq.

Communications

A short progress report on the project in English and Inuktitut is sent to each participating HTA each year. In August 2009, Marlene Evans visited Pond Inlet and Pangnirtung as part of her arctic char collection and was able to discuss the ringed seal project with the HTA managers. Derek Muir will visited the HTA office in Resolute in July 2009 to discuss the project with the office manager and HTA officers as part of his annual trip to that community. Tara Bortoluzzi and Magaly Chambellant of DFO Winnipeg visited the HTA in Arviat to discuss the organization of their seal sampling program. A draft of the fax and report to the HTAs will be sent in early February to the Nunavut Niqiit Avatitinni Committee for review and comment.

Traditional Knowledge

Collection of samples is being carried out exclusively by hunters in Nunavut and Inuvialuit communities. They decide when, where and how to hunt and provide information of gender and size of the animals. This project relies heavily on the knowledge and experience of these hunters and for the ecological information on behavior, condition and population numbers they provide to us and indirectly to DFO biologists and Natural Resource officers.

Results and Discussion

Temporal trends of mercury in seal muscle

Geometric mean concentrations of mercury in ringed seal muscle from Arviat, Sachs Harbour and Resolute are shown in Figure 1A. The average results for $\delta^{15}N$, which is an indicator of the trophic level of the seals, and seal body length are presented in Figure 1B. Results for animals <1 yr old were excluded from the time trend comparison. Results for both males and female ringed seals were combined because there was no influence of gender of the animals on mercury muscle concentrations. Average mercury concentrations in muscle were unchanged at all 3 locations over the period 2005 to 2009. Concentrations in earlier years were higher, however, this was not due to differences in the trophic status or the size/age of the seals (Figure 1B) which remained relatively constant at Arviat and Resolute. The average size of the seals sampled at Sachs Harbour in 2007 was shorter because it was comprised of more juveniles, but this had no effect on mean concentrations of mercury or the $\delta^{15}N$ values.

Temporal trends of PCBs and OCPs

To assess temporal trends we combined the results from Sachs Harbour and Ulukhaktok ("Beaufort"), Resolute, Grise Fiord and Arctic Bay ("Lancaster"), and Arviat and Inukjuaq ("Hudson Bay") in order to strengthen the statistical power of the data. Statistical analysis showed that most PCB/OCs concentrations were similar for nearby communities while differing significantly among regions. The trends for α-HCH, β-HCH, HCB, Σ10PCB (sum of 10 major congeners), ΣDDT and ΣCHL are shown in Table 1. Overall, there are declining trends with the relative magnitude of ΣDDT> α-HCH>Σ10PCB>ΣCHL similar to that found by Riget et al. (2010) for all time series in arctic marine mammals in general. However, the declines in the Canadian arctic e.g. HCB, Σ10PCB, ΣCHL in the Beaufort and Lancaster regions, are not statistically significant despite the relatively large numbers of sampling years now available, suggesting continued inputs. The importance of ocean

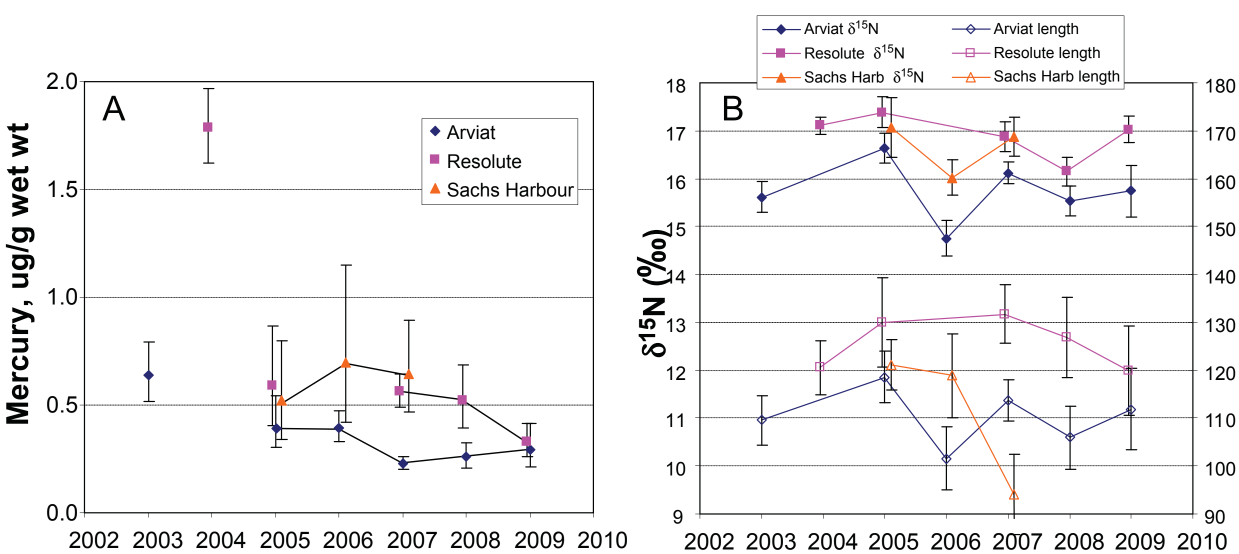

Figure 1. Trends in concentrations of mercury in muscle of ringed seals from Arviat, Resolute and Sachs Harbour. A. Geometric mean concentrations (symbols) and 95% confidence limits (vertical lines). B. Average values for nitrogen stable isotope ratio, $\delta^{15}N$ in seal muscle and length of the animals analysed for mercury. Vertical lines are the 95% confidence intervals.

Table 1. Results of analysis of time trends of the ringed seal data using the PIA program

Region		years		α-HCH	β-HCH	HCB	Σ10PCB	ΣDDT	ΣCHL
Beaufort[1] Sea	1972–2007	6	% decline or increase	-1.2%	5.8%	-0.63%	-0.34%	-2.6%	0.67%
			95% CI	1.6	2.4	1.3	1.9	1.3	4.3
			r^2	0.16	0.92	0.33	0.03	0.47	0.04
			P	0.443	0.003	0.23	0.738	0.134	0.687
			LDC (%) @ 'Power 80%	49%	26%	13%	31%	48%	53%
			yrs required to detect 5%	21	15	10	16	21	22
Hudson[2] Bay	1986–2009	11	% decline or increase	-9.7%	-4.9%	-4.4%	-4.8%	-7.4%	-8.3%
			95% CI	4.7	4.6	2.2	4.5	4.4	4.8
			r^2	0.73	0.23	0.73	0.45	0.65	0.66
			P	0.002	0.156	0.002	0.033	0.005	0.004
			LDC (%) @ 'Power 80%	19%	30%	8.3%	17%	18%	19%
			yrs required to detect 5%	22	29	14	21	21	22
Lancaster Sound[3]	1972–2009	14	% decline or increase	-3.9%	4.9%	-0.27%	-1.3%	-3.0%	0.13%
			95% CI	2.4	2.3	1.0	0.90	1.5	1.90
			r^2	0.55	0.66	0.01	0.20	0.63	0.01
			P	<0.004	<0.001	0.708	0.12	<0.001	0.868
			LDC (%) @ 'Power 80%	9.8%	9.6%	6.3%	7.0%	6.2%	9.0%
			yrs required to detect 5%	20	20	15	16	15	19

1 Sachs Harbour + Ulukhaktok (2001 & 2006)
2 Arviat + Inukjuaq

water moving through the Arctic archipelago is illustrated by the trend of β-HCH which has increased significantly at Sachs Harbour/Ulukhaktok and Resolute but not in Hudson Bay. In general, the greatest declines for all PCB/OCs were in Hudson Bay which may indicate the importance of the ocean transport route from the Pacific for other POPs as well. Addison et al. (2009) showed that β-HCH was continuing to increase at Ulukhaktok while α-HCH and γ-HCH showed no change over the period 1978-2006. The samples from 2006 in that study were also part of the "Beaufort" dataset used here.

Temporal trends of chlorinated naphthalenes
Concentrations of PCNs in ringed seal blubber from Arviat, Resolute and Sachs Harbour are shown in Figure 2. The results from Resolute for 1972 are from 5 seal blubber samples in the Environment Canada specimen bank provided by Rob Letcher. The PCN concentrations are relatively low compared to legacy POPs and PBDEs (Muir et al. 2008) and appear to have declined at Resolute, where samples from 1972 and 1993 were analysed, and at Arviat based on samples from 1998. Results for Pangnirtung for samples from 2002, previously reported in Muir et al. (2004) and from 1993 reported by Helm et al. (2002) are also shown. The results from Pangnirtung for 2002 were adjusted so that they are based on the same number of congeners as analysed by NLET in this current study. Agreement between the previous PCN results, which were determined by Paul Helm while at DFO Winnipeg, with current results was checked by reanalysing 9 samples from Sachs Harbour from 2001. Mean concentrations were within 15%.

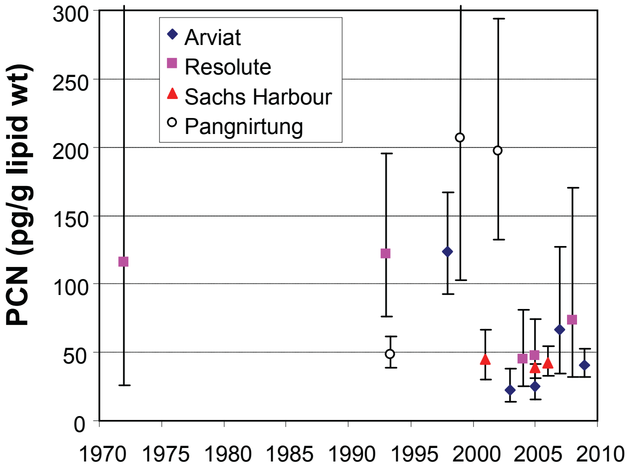

Figure 2. Temporal trends of chlorinated naphthalenes in ringed seal blubber (females and juvenile males only) from 4 communities. Results from Pangnirtung are from Muir et al. (2004) and Helm et al. (2002). Symbols represent geometric mean concentrations and vertical lines are 95% confidence intervals.

However the higher concentrations at Pangnirtung reported in Muir et al. (2004) are not in good agreement with other locations nor with the results for the 1993 and may need to be reinvestigated.

Discussion and Conclusions

This study has provided new information on the temporal trends of mercury, PCNs and legacy POPs in three regions. For mercury, we are adding substantially to the information on time trends in seal muscle, which was previous limited to the study by Gaden et al. (2009) at Ulukhaktok. While levels and trends of muscle mercury are similar at Arviat, Sachs Harbour and Resolute, there is significant regional variation according to our previous results for other communities where we have only single sampling years (Muir et al. 2008). Thus further studies of time trends in other locations e.g. Pangnirtung where there are samples available from a number of sampling times, should be pursued.

The statistical power of trends for legacy POPs in ringed seals is getting stronger with Hudson and Lancaster Sound regions reaching N=11 and 14 as of 2009. We are approaching the NCP goal of having a dataset capable of detecting a 5% annual change over a 10-15 year period with a power of 80% and confidence level of 95% for HCB and ΣDDT. The lack of decline of PCBs, and the increase in β-HCH, in the Beaufort and Lancaster region samples implies continued inputs from the same source which is presumably the influence of Pacific Ocean waters traversing the archipelago.

The regional variation in time trends for legacy POPs and PCNs illustrate a potential pitfall of NCPs 2010-11 Blueprint which reduced the seal project to just 3 locations/regions (Beaufort, Lancaster, Hudson Bay) and omitted the eastern arctic entirely.

NCP Performance Indicators

Number of northerners engaged in the project: 5 (includes HTA office managers

Number of meetings/workshops held in the North by the project: 0

Number of students (both northern and southern) involved in the project in 2009-10: 1

Number of peer reviewed publications in 2009-10: 1

Expected project completion date

The project is ongoing with annual sampling at 3 locations planned under the NCP 2010-11 "Blueprint".

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Temporal and Spatial Trends of Legacy and Emerging Organic and Metal Contaminants in Canadian Polar Bears

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Abstract

Polar bears (using liver, fat or muscle tissue samples) from seven Canadian management zones (i.e., Gulf of Boothia/Foxe Basin (GB), western Hudson Bay (WHB), southern Hudson Bay (SHB), Lancaster Sound/Jones Sound (LJS), Davis Strait (DS), Baffin Bay (BB), and Beaufort Sea (BS)) in the Canadian arctic have been monitored for persistent organic pollutant (POP) contaminants and health assessments since 1989. With the exception of WHB, sampling is standardized to short annual periods for every five year cycle. Every five years, contaminant monitoring in polar bears was primarily to assess the geographical trends for Canadian subpopulations for these management zones, but also to monitor temporal changes by comparing contaminant data between five-year cycles. For WHB bears, longer-term monitoring has been on an annual basis where possible. The contaminant monitoring focus has shifted to bear subpopulations were the impact of arctic warming on e.g. marine food web structure and thus polar bear diet, has been documented as being more substantial over time and in particular in Hudson Bay.

In the present 2007-2008 assessment, regarding geographic (spatial) trends in Canadian bears for legacy POPs, PCB levels were higher relative to emerging contaminants as well as other legacy contaminants (e.g., DDTs), and increased in subpopulation bears going west to east. Chlordane (CHL) pesticide levels were highest among legacy organochlorine pesticides (OCPs) and relatively

Résumé

Depuis 1989, les ours polaires sont suivis pour mesurer les polluants organiques persistants (POP) et évaluer leur santé (par des prélèvements dans le foie, les tissus adipeux et musculaires) dans sept zones de gestion de l'Arctique canadien : le golfe de Boothia/bassin de Foxe (GBBF), l'ouest de la baie d'Hudson (OBH), le sud de la baie d'Hudson (SBH), le détroit de Lancaster/détroit de Jones (DLDJ), le détroit de Davis (DD), la baie de Baffin (BB) et la mer de Beaufort (MB). Sauf dans la zone OBH, l'échantillonnage est normalisé pour couvrir de courtes périodes annuelles pour chaque cycle de cinq ans. Tous les cinq ans, la surveillance des contaminants dans les ours polaires visait principalement à évaluer les tendances géographiques dans les sous-populations canadiennes de ces zones de gestion, mais cherchait aussi à suivre l'évolution temporelle en comparant les données sur les contaminants entre les cycles de cinq ans. Pour les ours OBH, le suivi à long terme s'est fait sur une base annuelle autant que possible. L'objectif de la surveillance des contaminants a changé, et le projet cible maintenant les sous-populations d'ours là où l'impact du réchauffement de l'Arctique (p. ex., sur la structure du réseau trophique marin et donc sur l'alimentation des ours polaires) a été le plus important au fil des ans, en particulier dans la baie d'Hudson.

Dans la présente évaluation (2007-2008) des tendances géographiques (spatiales) dans les concentrations de POP hérités chez les ours du Canada,

spatially uniform, whereas DDT levels were relatively low and spatially variable. Among the emerging contaminants, PBDE flame retardants were highest in bears from WHB and SHB. Hexabromocyclododecane (HBCD) levels were lower than PBDE levels in bears from all subpopulations. Emerging perfluorinated compound (PFC) levels were highest in bears from SHB, and lower but comparable among bears from other subpopulations. Among PFCs, in the liver perfluorooctane sulfonate (PFOS) was the most concentrated, and levels similar in all bears except for SHB where they were higher. PFOS was consistently comprised of ~99% of the linear PFOS isomer. Furthermore, total PFOS levels in Canadian bear ranged from about 400-1000 ng/g wet weight, and were higher than fat levels of e.g. *p,p*'-DDE and CHL levels on a lipid weight basis. Comparing to earlier Canadian polar bear spatial studies (2001-2002), PBDE, PFOS, HBCD, DDT and CHL levels were consistently lower, whereas other legacy contaminant levels were not. Total Hg levels were highest for BS bears, intermediate for central arctic (Nunavut) subpopulations, and lowest in SHB and WHB bears. For WHB bears, longer-term temporal studies (1991-2007), shifts in diet as a function of changing ice conditions led to greater rates of apparent chlorinated and brominated POP level increases over time (e.g., PBDEs and some legacy OCPs), and an apparent decreasing trend to increasing trend for PCBs, compared to trends assuming a constant diet. Continued monitoring of contaminants in polar bears is warranted given the continued temporal changes and spatial differences of priority POPs among bears from different geographic subpopulations, and the influence of shifting diets on POP trends. Thus, POP exposure continues to change in time and space as do the possible health concerns to bear, and by extension to humans (northerners).

les teneurs en BPC étaient plus élevées par rapport aux contaminants émergents et aux autres contaminants hérités (p. ex., le DDT), et ils augmentaient chez les sous-populations d'ours d'ouest en est. Parmi les pesticides organochlorés (POC) hérités, les concentrations du pesticide chlordane (CHL) étaient plus élevées et relativement homogènes dans l'espace, tandis que les concentrations de DDT étaient relativement faibles et variables dans l'espace. Parmi les contaminants émergents, les ignifugeants à base de PBDE étaient plus présents chez les ours OBH et SBH. Les concentrations d'hexabromocyclododécane (HBCD) étaient inférieures à celles de PBDE dans toutes les sous-populations d'ours. Les concentrations de composés perfluorés (CPF) émergents étaient plus élevées chez les ours SBH, et plus faibles, mais comparables dans les autres sous-populations d'ours. Parmi les CPF, le sulfonate de perfluorooctane (SPFO) dans le foie était le plus concentré, et les concentrations étaient similaires dans tous les ours, sauf ceux de la zone SBH, où elles étaient plus élevées. Le SPFO était constamment constitué à environ 99 % de l'isomère SPFO linéaire. En outre, les concentrations de SPFO total dans les ours du Canada variaient d'environ 400 à 1 000 ng/g poids humide, et étaient plus élevées que la teneur, entre autres, de *p,p*'-DDE et de CHL dans les tissus adipeux sur une base de masse lipidique. Par rapport aux études spatiales précédentes sur les ours polaires du Canada (2001-2002), les concentrations de PBDE, de SPFO, de HBCD, de DDT de CHL étaient systématiquement inférieures, alors que celles des autres contaminants hérités ne l'étaient pas. Les concentrations de mercure total étaient plus élevées pour les ours MB, intermédiaires pour les sous-populations de l'Arctique central (Nunavut) et plus faible pour les ours SBH et OBH. Dans le cas des études temporelles à long terme (1991-2007) des ours OBH, les changements dans le régime alimentaire, en raison de l'évolution des conditions des glaces, ont entraîné une accélération de l'augmentation apparente des concentrations de POP chlorés et bromés au fil du temps (p. ex., les PBDE et certains POC hérités), et la teneur en BPC, qui était à la baisse, est maintenant à la hausse dans l'hypothèse d'un régime alimentaire constant. La surveillance continue des contaminants chez les ours polaires est justifiée, car les concentrations de POP prioritaires continuent de présenter des changements temporels et des différences spatiales dans les différentes sous-populations géographiques d'ours, et la modification des régimes alimentaires influe sur les tendances des concentrations de POP. Ainsi, l'exposition aux POP continue d'évoluer dans le temps et l'espace, tout comme les problèmes de santé possibles pour les ours et, par extension, pour les habitants du Nord.

Key Messages

- Spatial trends in Canadian bears for legacy contaminants showed that PCB levels were higher relative to emerging contaminants as well as other legacy contaminants, and increased in subpopulation bears going west to east.
- CHL pesticide levels were highest among legacy OCPs and relatively spatially uniform, whereas DDT levels were relatively low and spatially variable.
- PBDE levels were highest in bears from WHB and SHB. HBCD levels were lower than PBDE levels in bears from all subpopulations.
- PFC levels were highest in bears from SHB, and lower but comparable among bears from other subpopulations. Among PFCs, PFOS was the most concentrated, and levels similar in all bears except for SHB where they were higher. PFOS was consistently comprised of ~99% of the linear PFOS isomer. Total PFOS levels on a wet weight basis were higher than fat levels of e.g. *p,p'*-DDE and CHL levels on a lipid weight basis.
- Comparing to earlier Canadian polar bear spatial studies (2001-2002), PBDE, PFOS, HBCD, DDT and CHL levels were consistently lower among subpopulations, whereas other legacy contaminant levels were not.
- Total Hg levels were highest for BS bears, intermediate for central arctic (Nunavut) subpopulations, and lowest in SHB and WHB bears.

Messages clés

- Les tendances spatiales des concentrations des contaminants hérités chez les ours canadiens montrent que la teneur en BPC était plus élevée par rapport aux contaminants émergents et aux autres contaminants hérités, et augmentait chez les sous-populations d'ours d'ouest en est.
- Parmi les POC hérités, le CHL présentait la teneur la plus élevée et relativement homogène dans l'espace, tandis que les concentrations de DDT étaient relativement faibles et variables dans l'espace.
- Les concentrations de PBDE étaient plus élevées chez les ours OBH et SBH. Les concentrations de HBCD étaient plus faibles que celles de PBDE dans les ours de toutes les sous-populations.
- Les concentrations de CPF étaient plus élevées chez les ours SBH, et plus faibles, mais comparables chez les ours des autres sous-populations. Parmi les CPF, le SPFO était le plus concentré, et les teneurs étaient similaires chez tous les ours, sauf dans la région SBH où elles étaient plus élevées. Le SPFO était constamment constitué à environ 99 % de l'isomère SPFO linéaire. Les concentrations de SPFO total étaient plus élevées que la teneur, entre autres, de *p,p'*-DDE et de CHL dans les tissus adipeux sur une base de masse lipidique.
- Par rapport aux études spatiales précédentes sur les ours polaires du Canada (2001-2002), les concentrations de PBDE, de SPFO, de HBCD, de DDT de CHL étaient systématiquement inférieures, alors que celles des autres contaminants hérités ne l'étaient pas.
- Les concentrations de mercure total étaient plus élevées pour les ours MB, intermédiaires pour les sous-populations de l'Arctique central (Nunavut) et plus faible pour les ours SBH et OBH.

Project Objectives

Overall

To determine and monitor the spatial and temporal trends (e.g., concentrations and congener patterns), bioavailability, fate, and toxicokinetics (e.g., biotransformation and tissue distribution) of legacy and emerging POPs (chlorinated, brominated and fluorinated), their persistent degradation products, precursors and isomers, as well metal and other elements, in polar bears from seven Canadian arctic management zones.

Specific and shorter term

- To determine the spatial (2010) and comparative temporal changes of priority, legacy and emerging POPs (e.g., PBDEs, HBCD and PFCs) and degradation products, precursors and/or isomers, and metals/elements (e.g., Hg) in polar bears using the appropriate tissues collected in communities within the management zones in the Canadian arctic.
- To determine annual, longer-term temporal trends of legacy and emerging POPs specifically in polar bears from (western) Hudson Bay.
- To use carbon and nitrogen SIs and FAs as ecological tracers of trophic levels and diet, and determined in polar bear tissues (muscle or fat) from selected management locations (assessed in (1) and (2)) to examine the influence of diet and trophic level as confounding factors on POP spatial and temporal trends, in addition other influential factors such as sex, age, time of collection, and lipid content.
- Ongoing characterization and identification of emerging chlorinated, brominated and fluorinated POPs that may persist in the tissues of polar bears, are not necessarily listed as a NCP, LRTAP or Stockholm Convention priority POPs, and ideally with minimal analytical method modifications and development.

Introduction

The polar bear (*Ursus maritimus*) is the apex predator of the arctic marine ecosystem. Due to its position at the top of the marine food web, levels of POPs (halogenated organics and metals/elements) in polar bears are among the highest observed in the Arctic. Like humans, polar bears are distributed throughout the circumpolar region, and thus are an ideal sentinel/monitoring species for contaminants in the Arctic. Through the process of biomagnification the polar bear achieves some of the highest POP and metal concentrations of any arctic species or any species on the planet (Letcher et al. 2009a, 2009b, 2010; Muir et al. 2006, 2009; Rush et al. 2008; Smithwick et al. 2005; Verreault et al. 2005a), with potential effect ramifications in exposed bears and the human consumers who eat them or their prey items such as ringed seals (Letcher et al. 2010; Fisk et al. 2005; Sonne et al. 2009).

Although the Arctic is far from large urban and industrial areas, it has relatively high levels of previously used, or "legacy" POPs including PCBs and OCPs, such as DDTs and CHLs. Recent and currently used POPs including brominated flame retardant (BFR) materials such as PBDEs, are used in furniture and electronics, and have also found their way into polar bears and their arctic food chain. Also there are other emerging POPs being found in polar bears and other arctic wildlife including per- and poly-fluorinated compounds (PFCs), which are used in water-repellent coatings such as on carpets and furniture coverings as well as in non-stick coating for pots and pans.

The emergence of PFCs as ubiquitous environmental contaminants is recent (Butt et al. 2010; Houde et al. 2006). We showed in the last monitoring cycle that several emerging POPs such as PFCs (e.g., PFOS and perfluorooctanoic acid (PFOA)) accumulated in the liver of bears of subpopulations spanning the Canadian arctic (Smithwick et al. 2005). However, there is only one known report on the temporal trends of PFCs in polar bears for any North American bear population. In liver samples of bears collected in six years between 1972 and 2002 from one Canadian regional location (Northern Baffin Island) and Barrow, Alaska, had concentrations of PFOS and perfluorinated carboxylic acids (PFCAs) with carbon chain lengths from C_9 to C_{11}, to be exponentially increasing at both locations (Smithwick et al. 2006). Very recently a temporal trend study (1972-2006) on PFCs was completed for East Greenland polar bears. The 2006 levels of, e.g. PFOS, showed continued exponential increases over time (Dietz et al. 2008). PFC changes over time have been reported in Canadian arctic ringed seals, but showing decreases in recent years (Butt et al. 2007; Muir et al. 2009). However, to date there has been a pan-Canadian spatial assessment of bioaccumulative PFCAs and PFSAs for only one collective time period for polar bears (1999-2001).

Based on various configurations of the C_8 hydrocarbon chain, eighty-nine structural isomers of PFOS are theoretically possible. Polar bears from the Canadian, Alaskan, Svalbard and East Greenland arctic have been shown to have high PFOS levels in liver relative to other PFCs and POPs (Butt et al. 2010; Letcher et al. 2010; Smithwick et al. 2006), although as yet nothing has been reported about PFOS isomer levels and patterns in polar bears or their marine mammal prey.

PBDEs have been reported in arctic biota with increasing frequency (de Wit et al. 2010; Letcher et al. 2010) including in circumpolar polar bears (Dietz et al. 2007; Gebbink et al. 2008a, 2008b; Letcher et al. 2009b; Muir et al. 2006; Sørmo et al. 2006); however, the focus has generally been on Br_4 to Br_8 PBDE congeners, which largely comprise the PentaBDE and OctaBDE technical mixtures, and continue to be phased out from commercial use. Much less is known about in arctic biota, including polar bears, about higher brominated PBDEs, and especially BDE-209, which is the major constituent of the DecaBDE technical mixture (de Wit et al. 2010). Up until the present study, other important and bioaccumulative BFRs such as HBCD (total and not isomer-specific) have yet to be determined in Canadian polar bears (Letcher et al. 2009a, 2009b, 2010). In fat samples collected in 2001-2002 (one time point period) we did report on total-HBCD in Alaskan, East Greenland and Svalbard bears, and not Canadian sub-population bears, and levels for East Greenland and Svalbard bears were high and comparable to ΣPBDE concentrations (Muir et al. 2006).

The last study that examined spatial trends of metals and elements in Canadian polar bears was carried out on 2001-2002 collected samples (Rush et al. 2008). These studies showed that the levels of many metals, and especially the major metal contaminants Cd, Hg and Se varied between different regions of the Canadian arctic. For example, polar bears collected from the western Canadian arctic had lower concentrations of Cd but higher concentrations of Hg and Se than those collected from other regions. In light of the evidence of increasing Hg concentrations in arctic biota and the lack of temporal trend metal data for polar bears there is a need to assess the current levels of metals.

Previous spatial assessments of contaminant trends in polar bears have not determined the influence of diet due to difficulties in quantifying diets of individual bears. Nitrogen and carbon stable isotope (SI) ratios ($\delta^{15}N$, $\delta^{13}C$) and fatty acid (FA) composition; however, are increasingly used as chemical tracers of food web pathways and structure. Recently, these tracers have provided inferences regarding the time-integrated diets of individual bears (Bentzen et al. 2007; Thiemann et al. 2008a). Relative trophic positions of species within food webs have been estimated using $\delta^{15}N$, whereas $\delta^{13}C$ has differentiated nearshore/offshore, benthic/pelagic, sympagic (ice-associated)/pelagic, freshwater/marine, terrestrial/freshwater and terrestrial/marine feeding strategies (Hebert et al. 2008; Hobson and Welch 1992; Post 2002; Smith et al. 1996). FA signatures have also proven useful in distinguishing feeding strategies. Distinct FA signatures in several arctic marine mammal species were recently used to estimate prey species composition in diets of Canadian polar bear subpopulations (Thiemann et al. 2007, 2008a, 2008b).

Activities in 2009-2010

This is an ongoing multi-year NCP project, and the current phase on 2007-2008 collected samples began in 2006-2007. As mentioned in a previous NCP report (Letcher et al. 2009a), all necessary fat, liver and muscle samples from polar bears from the seven management zones in the Canadian arctic were collected in 2007-2008 in collaboration with HTAs and governments in Nunavut and NWT. These sample numbers complete or exceed the minimum number of individual samples per management zone that are necessary for robust statistical assessments of the data. New studies for 2009-2010 on isomer-specific PFOS and metal determinations, required no new samples, but rather made use of existing 2007 and 2008 collected samples that have been archived (EC-NWRC) and were available. Blubber of ringed seals (2004-2006) from Canadian populations complementary to the present polar bears were obtained via Dr. D.C.G. Muir for FA profiling (and SIs) as ecological tracers of diet in comparison to that of polar bears.

The collection of polar bear tissues in NWT had been carried out by the Department of Resources, Wildlife and Economic Development, Government of the Northwest Territories. Nunavut Wildlife Research Permits were obtained and approved for 2009 and 2010 for ongoing polar bear sample collections (liver, fat and muscle) from all participating communities, and in particular Hudson Bay and Baffin Bay regions. Thus, community approval was granted by the Inuvialuit Game Council and appropriate Hunters and Trappers Committees. Furthermore, as of March 2010 a formal, multi-year collaborative agreement on research on contaminants in polar bears was completed, approved and signed between the Wildlife Research Group of the Government of Nunavut, as represented by the polar bear biologist (Dr. S. Atkinson), and the Ecotoxicology and Wildlife Health Division, Environment Canada, as represented by Dr. Letcher. The formal agreement specifies the collection of tissue samples from bears legally harvested in selected polar bear management zones (subpopulations) within Nunavut over a period of up to 5 years (covering the 2009-2010 to 2013-2014 hunting seasons). Regardless, collection of existing and new samples was carried out exclusively by hunters in the NWT and Nunavut communities. The project therefore relies heavily on the knowledge and experience of these hunters for its samples and for the ecological information on behavior, condition and population numbers they provide to wildlife officers and biologists.

Prior to 2009-2010 and as we reported to NCP last year (Letcher et al. 2009a), age determinations for all bears for which a tooth had been collected have been completed for NWT and Nunavut bears. Furthermore, all available 2007-2008 fat samples had been analyzed and completed for a large suite of legacy PCB and OCP POPs. For all polar bears fat samples, in-house (NWRC) FA analysis (by M.A. McKinney) had been completed (i.e., for a suite of 37 saturated and polyunsaturated, C_6-C_{24} fatty acids). Finally, for all available muscle samples for 2007-2008 bears, carbon and nitrogen SI analysis had been completed by the Environmental Isotope Lab (University of Waterloo). As detailed in the NCP Performance Indicators Section, all of the previously obtained legacy PCB and OCP, emerging BFR, SI and FA data sets have been utilized in papers on new POP characterization, and spatial and trend assessments, and either been published or have been submitted from publication in 2009-2010. In subsequent activities sub-sections we detail new analysis of polar bear samples that were carried out in 2009-2010.

PFCs and isomer-specific PFOS

In 2009-2010 we completed the analysis of all remaining (2008 collected) polar bears samples for PFCs (C_4, C_6, C_8 and C_{10} PFSAs, C_6-C_{15} PFCAs, PFOSA, 3 fluorotelomer alcohols (FTOHs) and 3 fluorotelomer unsaturated acids (FTUCAs)). Furthermore, we recently developed a GC/MS based method to separate and determine eleven, linear and branched (mono(trifluoro)methyl and bis(trifluoro)methyl) PFOS isomers in PFOS technical products, as well as demonstrate successful application to environmental biological samples such as polar bear liver and plasma (Chu and Letcher 2009). Using our new method (Chu and Letcher 2009), we completed the analysis and determination for all eleven linear and branched structural isomers of PFOS, known to be present in technical mixtures, in all available polar bear liver samples from 2007 and 2008 collections (as well as for a broader spatial study including bears from Alaska and East Greenland)

Metals/elements

As described in the 2009-2010 NCP proposal and based on the findings of Rush et al. (2008) in assessments of metals and elements in polar bear (liver) from Canadian bears collected in 2001-2002, via NWRC-EWHD Lab Services we completed that analysis of all 2007 and 2008 collected polar bear liver samples for fifteen metals, i.e., Ag, As, Ba, Cd, Cu, Ga, Mn, Mo, Pb, Rb, Se, Sr, V and Zn by ICP-MS (NWRC) and total Hg by atomic absorption spectrometry (AAS) (EC-NWRC) according to established methods (Rush et al. 2008).

Quality assurance of chemical analysis and data analysis

NWRC-EWHD (Lab Services and Organics Research Group) labs have participated in the NCP III Phase I, 2, 3 and the recent Phase 4 QA/QC round (results submitted in June 2010) for PCBs, OCPs, PBDEs, PFCs and metals/elements, as well as for FAs. Statistical analysis of the all POP data (including degradation products, precursors and isomers) has and will take into account such confounding factors as location, age, sex, diet and trophic level and other available information on the bears.

Capacity Building

As noted in the 2009-2010 and 2010-2011 NCP blueprint guidelines for responsible research, for all parties to benefit from research, efforts should be made, where practical, to employ and train local (especially Aboriginal) researchers and assistants. In 2009-2010 this core monitoring project adhered where possible to this guideline, and continues to help build expertise in scientific sampling among wildlife officers and hunters in each community. The PI and project team members continue to work with key partners in the Wildlife Research Group of the Government of Nunavut, and/or when necessary directly with wildlife COs in each community, who in turn interact directly with Nunavut hunters, in the collection of samples. As we previously described, we have formalized this integrated working relationship with northerners as of March 2010 a formal, five-year collaborative agreement on research on contaminants in polar bears, which was approved and signed between the Wildlife Research Group of the Government of Nunavut, as represented by the polar bear biologist (Dr. S. Atkinson), and the Ecotoxicology and Wildlife Health Division, Environment Canada, as represented by Dr. Letcher.

As detailed in an approved 2010 Nunavut Wildlife Research Permit, and in cooperation with the Dr. Stephen Atkinson (formerly with Dr. Elizabeth Peacock) the lead polar bear biologist with the Government of Nunavut in Igloolik, Dr. Letcher and students arranged and sent directly to the COs in each community a cooler complete with a suitable number of sampling kits that coincides with the number of bears required for these management zones and within the allowable hunting quota for that community. For the hunters in each community, each cooler contained simple and easy to read sampling instructions in both English and Inuktitut. Therefore, when the COs distributed the kits to the hunters, it was as easy as possible for them to sample correctly. As part of these regional sample collections in Nunavut, the participating project team members in the Nunavut Department of the Environment provided via COs training to members of the HTAs that were involved. The Government of Nunavut and Dr. Letcher (NWRC) compensate the hunters directly for the sampling and thus their involvement in the project.

Communications

As detailed in the section on NCP Performance Indicators, in 2009-2010 the complied and interpreted OCP, PCB and BFR data, and in relation to the dietary tracer data among Canadian (and circumpolar) bears has been communicated to the scientific community via several papers that have been published or submitted for publication to peer-reviewed scientific journals. Also, results and findings have been presented substantially in 2009-2010 at relevant scientific conferences, Arctic workshops and meetings with northern/Arctic stakeholders and communities. Spatial and limited temporal trend data had been reported to NCP last year (Letcher et al. 2009a). Temporal POP studies in beat from western Hudson Bay (1991-2007) was communicated in a 2008-2009 Canadian IPY report (Peacock et al. 2009), as well as at a recent Canada IPY Early Results Workshop held in Ottawa in February 2010.

Letcher (and PhD student, M.A. McKinney) had intended to travel to at least one Nunavut community (e.g., Coral Harbour or Igloolik) to interface with our central Nunavut research partner (E. Peacock) and individuals in her Nunavut government department, and also to communicate the study findings and discussion with community and HTA representatives (see NCP Performance Indicator Section). Regardless, in 2009-2010 via the project leaders and team members, the final analysis of the contaminant data generated in this project, when possible, has been made available and communicated to each Inuit community and RCCs that has participated in the study. Detailed as well as more general interpretations and conclusions made from the data generated were made available in the form of a bi-lingual (English and Inuktitut) poster that was presented at the Nunavut Wildlife Symposium, March 19-20, 2009, that was held in Rankin Inlet, Nunavut. In 2009-2010 the PI has responded to any inquires or concerns of the participating communities and team members.

The PI has made sincere efforts and attempts to communicate in person with the RCC representatives and COs and hunters in each participating community. The PI and team understand the role of the RCCs to be an interfacial and local body in translating into laypersons terms what is most often complex scientific information (contaminants and contaminant-related effects in exposed organisms). The PI views his role in assisting the RCCs in effectively communicating new scientific information, and the impacts they (potentially) have on the health of their communities and the wildlife, including polar bears, on which their present and traditional way of life depends.

Regular communications were made with Dr. Peacock as well as with Dr. S. Atkinson who, since late summer 2009 has been the interim polar bear biologist replacement (Government of Nunavut) for Dr. Peacock who relocated to the USGS in Alaska. Also, and because NWT could be involved in polar bear sampling in future years of this project, Ms. M. Branigan (NWT), Ms. L. Skinner (NWT RCC) and Ms. S. O'Hara (NWT, Inuit Research Advisor) have been updated on the project with copies of publications, presentations and reports that were generated in 2009-2010. INAC has also been regularly informed as well as others associated with participating departments, and including (where possible) community COs (and by extension hunters).

All publications that result from NCP research, education and communication projects are being reported to pscowen@ucalgary.ca for inclusion in the NCP Publications Database.

Traditional Knowledge

As already mentioned, as in past sampling for this core monitoring project, the 2009-2010 collection of samples was carried out exclusively by hunters in participating Nunavut communities and in coordination with E. Peacock, S. Atkinson and A. Coxon in the Wildlife Research Group in the Government of Nunavut. This project is working under the direct guidelines of the allowable hunting quotas for each of the HTAs and communities. The project therefore relies heavily on the knowledge and experience of these hunters for the sampling and for the ecological information on behaviour, condition and population numbers they provide to wildlife COs and biologists. The traditional knowledge of polar bear and their food web will be enhanced by this research initiative. A better understanding of changes in the types and levels of established and emerging chemicals that are in polar bear will benefit the traditional knowledge of what and how much can be consumed of prey animals that humans have in common with polar bears, e.g., seals.

Results

PFC and PFOS isomers

Regardless of the Canadian subpopulation, as we reported in the 2008-2009 NCP synopsis report (Letcher et al. 2009a), ΣPFSA concentrations were comprised of >99% PFOS. Furthermore, the ΣPFCA concentrations were comprised largely of C_9 (PFNA), C_{10} (PFDA) and C_{11} (PFUdA), with much lesser amounts of C_8 (PFOA), C_{12} (PFDoA) and C_{13} (PFTrA), and very low or non-detectable C_6 (PFHxA), C_7 (PFHpA), C_{14} (PFTeDA) and C_{15} (PFPA). Of all the Nunavut and NWT samples, the 10:2 FTUCA (FDUEA) was barely quantifiable in all but one NWT bear. FTOHs were not detectable in any bear sample, and levels of FOSA were in the low ng/g (wet weight) range but quantifiable with very high frequency in samples. The spatial trends for the 2007-2008 samples showed that PFOS and ΣPFCA levels were highest in bears from SHB, and lower but comparable bears from the other six Canadian population management zones. For a sub-set of individuals where remaining liver tissue was available, an examination of PFOS isomers in polar bears was possible. As shown in Figure 1, regardless of bear or subpopulation L-PFOS was highly enriched (~99% of the total PFOS concentration) in polar bear liver, whereas mono(trifluoromethyl)-branched PFOS isomers were <1% and bis(trifluoromethyl)-branched isomers were not detectable.

Spatiotemporal trends of dietary tracers and chlorinated and brominated contaminants

Although 37 PBDEs, total-(α)-HBCD, 2 polybrominated biphenyls (PBBs), pentabromotoluene, pentabromoethylbenzene, hexabromobenzene, 1,2-*bis*(2,4,6-tribromophenoxy(ethane) and decabromodiphenyl ethane were screened, only 4 PBDEs, total-(α)-HBCD and BB153 were consistently found in bear fat samples. Geometric mean ΣPBDE (4.6-78.4 ng/g lipid weight (lw)) and BB153 (2.5-81.1 ng/g lw) levels were highest in East Greenland (43.2 and 39.2 ng/g lipid weight (lw), respectively), Svalbard (44.4 and 20.9 ng/g lw)

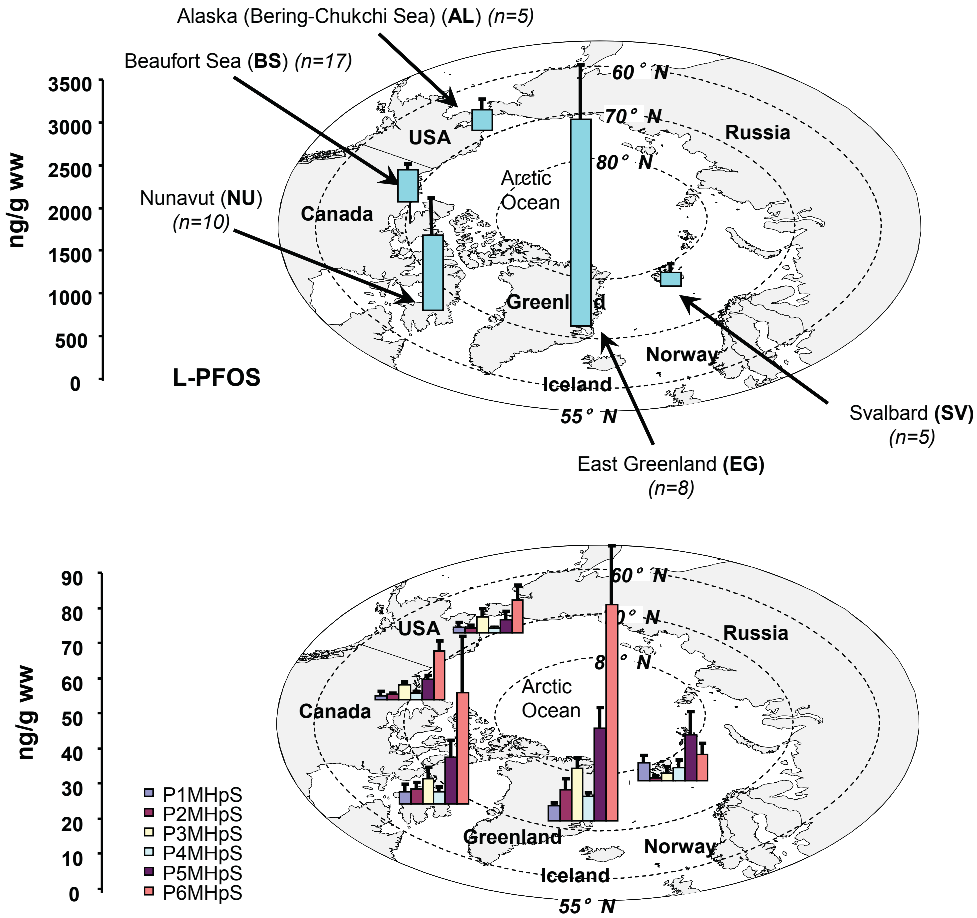

Figure 1. Geometric mean concentrations (± 95% CI) (ng/g lipid weight) of linear (top) and six mono(trifluoromethyl)-branched (bottom) isomers of PFOS in polar bears from Canadian management zones (2007 and 2008 collections). Due to low availability of residual liver samples from some bears collected from Nunavut, the mean concentrations for all Nunavut (NU) bears was determined.

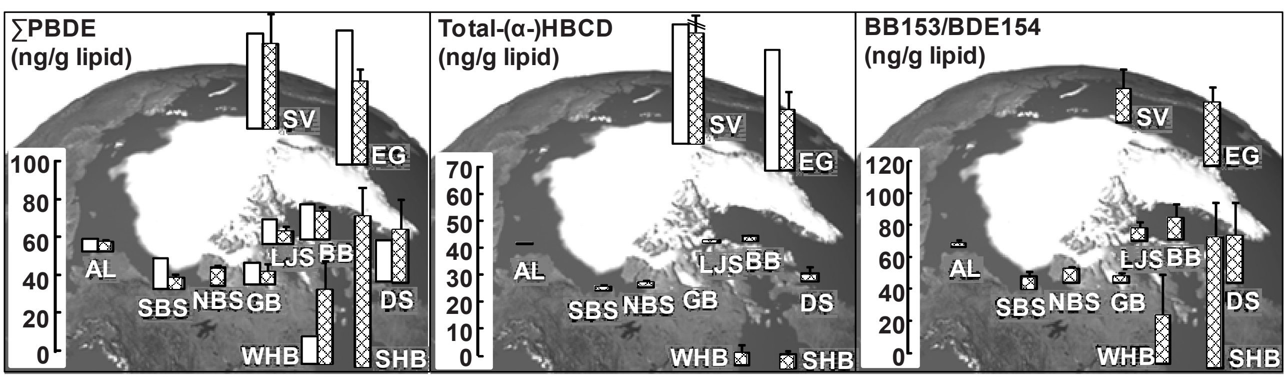

Figure 2. Spatiotemporal patterns in geometric mean (±95% confidence interval) levels of major brominated flame retardants in adipose of polar bears from 11 subpopulations (BS bears split into north and south BS, NBS and SBS, respectively) collected from 1996-2002 (white bars; from Muir et al. 2006) and from 2005-2008 (crosshatched bars; present study). The 1996-2002 study did not report BB153/BDE154, and 1996-2002 SBS data shown was from NBS and SBS. Satellite map adapted from www.nasa.gov.

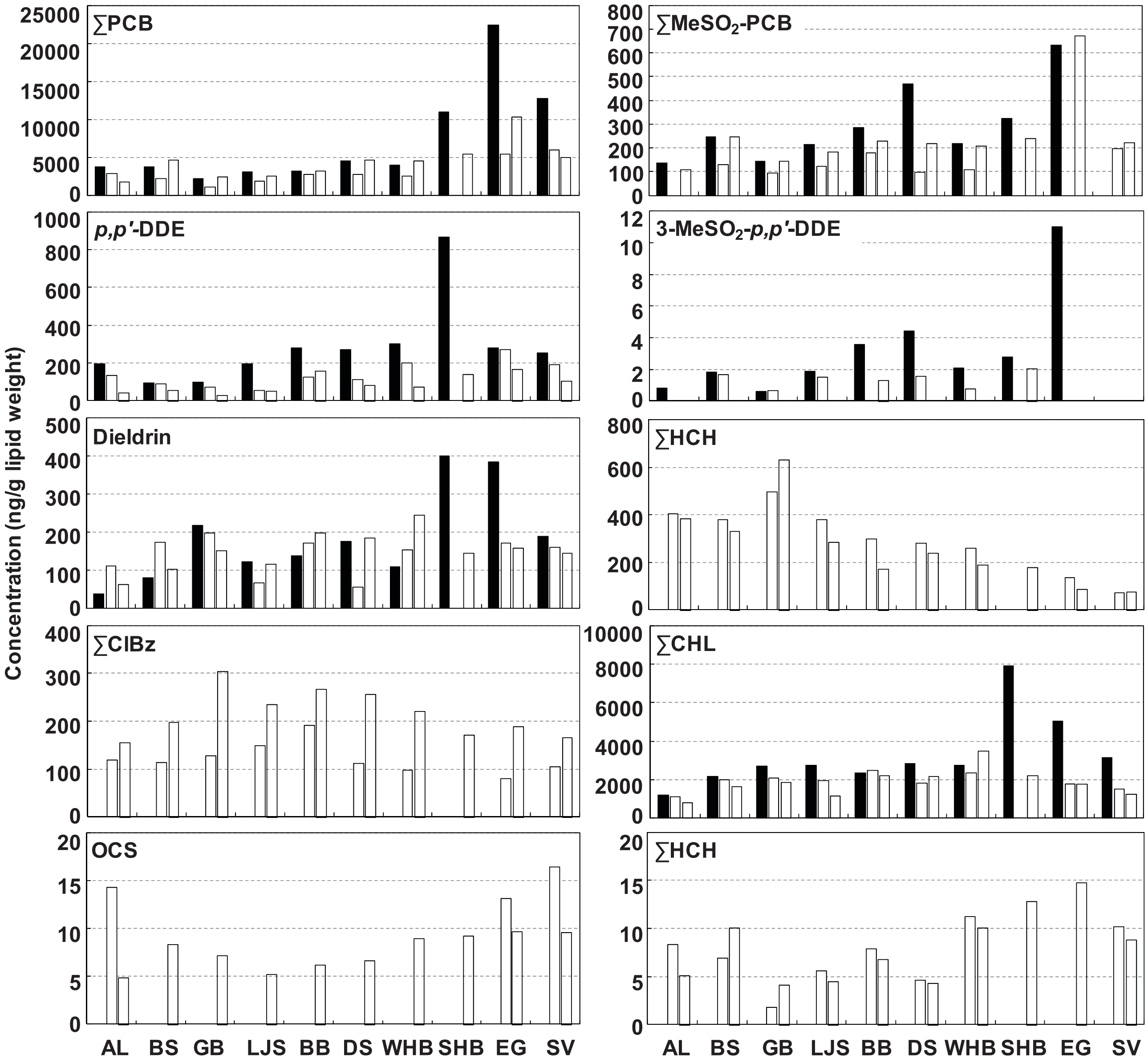

Figure 3. Temporal comparisons of legacy contaminants in 10 polar bear subpopulations (SBS and NBS reported together as BS) collected in 1989-1993 (black bars; from Letcher et al. 1995; Norstrom et al. 1998), 1996-2002 (white bars; from Verreault et al. 2005) and 2005-2008 (crosshatched bars; current study). Blank values indicated a contaminant that was not analyzed from the location/time point, with the following exceptions in which the contaminant was below the MLOQ for a majority of samples: OCS in 1996-2002 in BS, GB, LJS, BB, DS, WHB; mirex in 1996-2002 in EG; 3-MeSO$_2$-*p,p'*-DDE in 1996-2002 in BB, SV and in 2005-2008 in all except BB and SHB.

and WHB (38.6 and 30.1 ng/g lw) and SHB (78.4 and 81.1 ng/g lw) (Figure 2). Total-(α)-HBCD levels (<0.3-41.1 ng/g lw) were lower than ΣPBDE levels in all subpopulations except in Svalbard (Figure 2). ΣPCB levels were high relative to flame retardants as well as other legacy contaminants and increased from west to east (1797-10537 ng/g lw) (Figure 3). ΣCHL levels were highest among legacy organochlorine pesticides and relatively spatially uniform (765-3477 ng/g lw). ΣDDT levels were relatively low and spatially variable (31.5-206 ng/g lw). However, elevated proportions of *p,p'*-DDT to ΣDDT in BS relative to other subpopulations. Comparing earlier circumpolar polar bear studies, generally, ΣPBDE, total-(α)-HBCD, *p,p'*-DDE and ΣCHL levels were consistently lower, whereas other legacy contaminant levels were not (Figures 2 and 3).

With respect to dietary tracers, WHB and SHB signatures were characterized by depleted $\delta^{15}N$ and $\delta^{13}C$, lower proportions of C_{20} and C_{22} monounsaturated FAs and higher proportions of C_{18} and longer chain polyunsaturated FAs. East Greenland and Svalbard tracer signatures were reversed relative to bears from Hudson Bay. Alaskan and Canadian high arctic bear signatures were intermediate. Among the various chlorinated and brominated contaminants under study, variations in diet signatures significantly explained the regional differences in adipose PCB (18-21%) and PBDE (14-15%) levels in bears from all subpopulations. However, diet influence was contaminant class-specific, since diet only explained lower amounts of variation in OCP levels. Hudson Bay diet signatures and dietary adjustment were associated with lower PCB and PBDE levels, whereas East Greenland and Svalbard dietary adjustment were associated with higher levels (Figure 4).

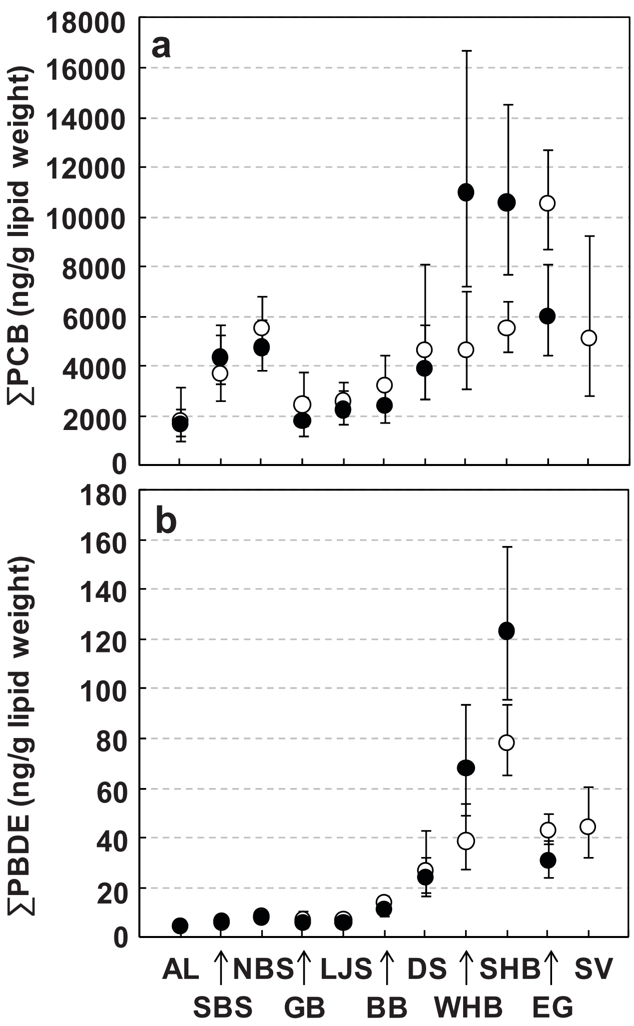

Figure 4. Mean (±95% CI) (a) ΣPCB and (b) ΣPBDE levels before (●) and after (○) adjusting for the influence of Diet-Index in 11 polar bear subpopulations from Alaska east to Svalbard. Adjusted levels were not available for SV.

Spatial trends in metals

Preliminary interpretation of the metals data in the liver of Canadian bear subpopulations indicates that among the metals and for all subpopulations the highest metal concentrations were Zn (164 to 224 μg/g dry wt.), Cu (132 to 220 μg/g dry wt.) and total Hg (21 to 229 μg/g dry wt.). In contrast the lowest metal concentrations were Pb, Cd and As, in the low to sub-μg/g dry wt. range among all subpopulations. Preliminary interpretation of the spatial trends of the metals data in the liver of Canadian bear subpopulations indicates that the highest total Hg levels were for SBS (228±158 μg/g dry wt.) and NBS (161±112 μg/g dry wt.), intermediate for central arctic subpopulations (e.g., LJS (103±48 μg/g dry wt.)), and lowest in Hudson Bay (SHB (21±12 μg/g dry wt.) and WHB (24±16 μg/g dry wt.)).

Discussion and Conclusions

The present PFOS results for the 2007-2008 collected samples are highly consistent with the spatial trends results reported previously for Canadian bears collected in 2001-2002 (Smithwick et al. 2005). That is, PFCs were highly dominated by PFOS, and with lesser but substantial levels of PFNA, PFDA and PFUdA), and with much lesser amounts of PFOA, PFDoA, PFTrA and PFOSA. Spatial trends for the 2007-2008 samples indicate that ΣPFSA (PFOS), ΣPFCA and FOSA levels are highest in bears from SHB, and lower but comparable among the BS, GB, LJS, DS and BB collected samples. Given the very high PFOS to FOSA concentration ratios, and that FOSA is a known precursor of PFOS, in 2009-2010 and in a separate NCP supported research project, we examined the hepatic *in vitro* depletion (metabolism) capacity of polar bears to metabolically degrade FOSA and *N*-Et-FOSA to PFOS. Compared with 2001-2002 results (Smithwick et al. 2005), the present 2007-2008 results showed that PFOS levels in all subpopulations bear have decreased somewhat, with the exception of SHB were levels have increased. The present results of bears from Canadian high arctic subpopulations showing some decrease over the last eight years appear to be consistent with results from other studies. Dietz et al. (2009) reported that PFOS in East Greenland bears showed continued exponential increases over time beginning in the late 1990s and up to 2006. In may be that PFOS levels in East Greenland bears only started decreasing post-2006. PFOS in Canadian arctic ringed seals have shown earlier decreasing trends beginning in years in first half of this decade (Butt et al. 2007).

In preliminary sample application assessments of our novel, PFOS isomer-specific determination method (Chu and Letcher 2009), we reported earlier that for a sub-set of 2007-2008 collected liver samples from LJS polar bears that linear PFOS (L-PFOS) was enriched whereas branched PFOS isomers were either reduced in proportion or non-detectable relative to PFOS technical products. The present, more expansive study on PFOS isomers in polar bears was consistent with these preliminary findings, where regardless of the bear or subpopulation (AL, BS, NU (a collection of all available liver samples of bears from Nunavut) as well as East Greenland and Svalbard, L-PFOS is highly enriched (~99% of the total PFOS concentration) in polar bear liver (Figure 1) relative to technical PFOS products were L-PFOS has been shown to constitute ~65% of the total PFOS concentration (Chu and Letcher, 2009). Furthermore, the six mono(trifluoromethyl)-branched PFOS isomers were <1% of the total PFOS concentration, and none of the four bis(trifluoromethyl)-branched isomers were detectable (Figure 1). The branched isomers were thus depleted as it has been reported that in PFOS technical mixture mono(trifluoromethyl)-branched and bis(trifluoromethyl)-branched PFOS isomers constituted `33% and ~2%, respectively, of the total PFOS concentration (Chu and Letcher 2009).

In spatial studies, mean ΣPBDE and BB153 levels were highest in EG, SV, WHB and SHB (Figure 2). Total-(α)-HBCD levels were lower than ΣPBDE levels in all subpopulations except in SV (McKinney et al. 2010b unpublished data), consistent with greater European HBCD use versus North American pentaBDE product use (de Wit et al. 2010). ΣPCB levels were high relative to flame retardants as well as other legacy contaminants and increased from west to east (Figure 3). ΣCHL levels were highest among legacy OCPs and relatively spatially uniform. ΣDDT levels were relatively low and spatially variable. However, elevated proportions of *p,p'*-DDT to ΣDDT in BS relative to other subpopulations suggested fresh inputs from vector control use in Asia and/or Africa. Comparing earlier circumpolar polar bear studies, generally, ΣPBDE, total-(α)-HBCD, *p,p'*-DDE and ΣCHL levels were consistently lower, whereas other legacy contaminant levels were not (Figures 2 and 3). Despite international regulations, high levels of certain historic pollutants and a complex mixture of "new" chemicals are predicted to remain a concern in arctic marine ecosystems in years to come.

The relative contribution of regional contamination versus diet differences to geographic variation in polar bear contaminant levels is presently unknown. Diet variation between Alaska, Canada, East Greenland and Svalbard subpopulations was assessed by muscle $\delta^{15}N$ and, $\delta^{13}C$ and adipose FA signatures relative to their main prey (ringed seals) (McKinney et al. 2010c unpublished data). WHB and SHB signatures were characterized by depleted $\delta^{15}N$ and $\delta^{13}C$, lower proportions of C_{20} and C_{22} monounsaturated FAs and higher proportions of C_{18} and longer chain polyunsaturated FAs. East Greenland and Svalbard tracer signatures were reversed relative to Hudson Bay. Alaskan and Canadian arctic signatures were intermediate. The results suggested regional diet differences predominated over inter-annual, seasonal or demographic variation. Among the various chlorinated and brominated contaminants under study, variations in diet signatures significantly explained the regional differences in adipose PCB (18-21%) and PBDE (14-15%) levels in bears from all subpopulations (McKinney et al. 2010c unpublished data). However, diet influence was contaminant class-specific, since diet only explained lower amounts of variation in OCP levels. Hudson Bay diet signatures were associated with lower PCB and PBDE levels, whereas East Greenland and Svalbard signatures were associated with higher levels (Figure 4). Understanding diet and possible food web differences is important to interpreting contaminant trends, perhaps more so in a changing Arctic.

Longer term temporal trends of halogenated contaminants in WHB bears

In a very recent study, we assessed the temporal trends of POP levels and congener pattern (e.g., PCBs) in WHB bears over the period of 1991-2007, and in relation to dietary shift and sea-ice conditions (McKinney et al. 2009, 2010c unpublished data). Concentrations of ΣDDT (and *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT) decreased (-8.4%/yr). Concentrations of α-HCH also decreased (-11%/yr), but β-HCH concentrations increased (+8.3%/yr). ΣPCB and ΣCHL, which were the highest concentration organochlorines in all years (> 1 ppm), showed no distinct trends, even in comparison to previous data in this subpopulation dating back to 1968. Recent FA research has demonstrated that the WHB bear diet consists of two ice-associated prey, ringed and bearded seal (*Erignathus barbatus*), and two open water-associated prey, harbour (*Phoca vitulina*) and harp seal (*Phoca groenlandica*) (Thiemann et al. 2008a, 2008b, 2008c).

With respect to POP (congener) pattern in WHB bear, we have shown that some of the less persistent PCB congeners significantly decreased, whereas CB153 levels tended to increase (+3.3%/yr) (McKinney et al. 2010c unpublished data). Parent CHLs (*c*-nonachlor and *t*-nonachlor) declined, whereas non-monotonic trends were detected for metabolites (heptachlor epoxide and oxychlordane). Lack of significant change was also observed for ΣCBz, OCS, Σmirex and for $\Sigma MeSO_2$-PCB and dieldrin. Increasing levels of ΣPBDE (+13%/yr) matched increases in the four consistently detected congeners, BDE47, BDE99, BDE100 and BDE153. Although no trend was observed, total-(α)-HBCD was detected in 2001-2007, but not 1991-1995. Levels of the highest concentration brominated contaminant, BB153, showed no directional change. WHB polar bear organochlorine trends varied with respect to those measured in other northern wildlife, and as already mentioned, we have previously found that rates were influenced by sea ice-associated diet changes (McKinney et al. 2009). To our knowledge, this is the first examination for any arctic species that has shown a link in the temporal variation of sea ice and/or diet to altered POP trends and exposure. These results suggest that although some of the effects of climate change will be direct, others may also involve interaction with different stressors such as anthropogenic contaminants, which may exacerbate the decline in health and survivability of already sensitive populations and species.

This is an ongoing core monitoring project, and assessments will continue into 2010-2011 and beyond. In 2010-2011, all spatial and 2-point temporal trends of metals and total Hg in polar bears will be written up and submitted for publication in 2010-2011. For example, for metals data are being fully interpreted and are in the process of being written-up as journal publications for submission in 2010 (Routti et al. 2010a unpublished data, 2010b unpublished data). All PFC, PFOS isomer, and endosulfan and metabolite (via D. Muir and his PhD student A. Morris) data will be interpreted, including examination of the role of diet on spatial trends, and will be written up and published in three journal papers. In 2010-2011, and as detailed in the formal, five-year Government of Nunavut-Environment Canada agreement on polar bears contaminants research, a renewed (2011) Nunavut Wildlife Research Permit will be obtained for sampling (liver, fat and muscle) of harvested bears from communities in WHB and SHB as well as in Baffin Bay.

NCP Performance Indicators

The number of northerners engaged in this project: The number of northerners (directly and indirectly) involved in or engaged in this project is large, including:

NWT and Nunavut team members: 4 (Peacock, Atkinson, Coxon, Branigan)

Community Conservation officers: 14 (at least one for each of the 14 participating Nunavut communities)

HTA representatives: 14 (at least one for each of the 14 participating Nunavut communities)

Community hunters: 14 (at least one for each of the 14 participating Nunavut communities)

The number of meetings/workshops for this project held in the North: The PI had intended to travel to at least one Nunavut community (e.g., Coral Harbour, Iqaluit or Igloolik) in 2009-2010. In the case of Igloolik the intention was to interface with the major Nunavut government research partner (E. Peacock), and individuals in her Nunavut government department, as well as the CO at the time (Mr. Theo Ikummaq) and community representatives to communicate the study findings and discussions. In 2009 Dr. Peacock moved from here position with the government of Nunavut to the USGS in Anchorage, Alaska.

As with Igloolik, in 2009 Dr. Letcher was in discussion in arranging a visit and field trip to Iqaluit with the community CO, a Mr. Alden Williams. Part of the planned trip involved a specialized, polar bear sample collection component (for a 2009-2010 NCP-supported research project), as described in an approved 2009 Nunavut Wildlife Research Permit, and would have involved a PhD student of Dr. Letcher's, a Ms. Melissa McKinney. However, difficulties were encountered in reaching an agreement of cooperation with the involved hunter(s), and the trip had to be cancelled. Similarly, in late 2009 the PI was in communication with the CO in Coral Harbour, a Mr. Kyle Wood, with respect to visitation and similar polar bear sampling as described above but in late 2009/early 2010. However, in early November 2009 the Coral Harbour HTA held an AGM and made the rapid decision to open their polar bear hunt beginning November 17th, with only 3 days for each hunter to hunt. Therefore, the PI had only one week in which to prepare for travel and field work, which rendered it impossible to travel.

Despite the difficulties for northern community travel experienced by PI in 2009-2010, he is committed to traveling north in 2010-2011. Since early 2010, Dr. Letcher has been in communication with the interim polar bear biologist in the government of Nunavut, Dr. Stephen Atkinson, as to the possibility of arranging a meeting and information exchange on 2010-2011. If fact, such details have been enshrined in a new 5-year MOU between Dr. Letcher (Environment Canada) and Dr. Atkinson (Government of Nunavut).

The number of students (both northern and southern) involved in this NCP project: The students involved in this project in 2009-2010 have been southerners or international, and are presently listed:

- Ms. Melissa McKinney: PhD candidate, Carleton University, Dr. Letcher as supervisor
- Mr. Adam Morris: PhD candidate, University of Guelph, Dr. Derek Muir and Dr. Keith Solomon as supervisors (Dr. Letcher, PhD thesis committee member)
- Dr. Heli Routti: Postdoctoral Fellow, via Carleton University, Dr. Letcher as supervisor.

The number of citable publications:

a. Domestic/international journals, book chapters, etc.

The number of citable publications, book chapters, etc. from or related to this project as of 2009-2010 is currently 19 (Gebbink et al., 2008a, 2008b; Letcher et al. 2009a, 2009b, 2010; Letcher and Chu, 2009; McKinney et al. 2010a unpublished data, 2010b unpublished data, 2010c unpublished data; Muir et al. 2006; Peacock et al;. 2009; Pilsner et al. 2010; Routti et al. 2010a unpublished data, 2010b unpublished data; Rush et al. 2008; Smithwick et al. 2005; Sonne et al. 2009; Verreault et al. 2005, 2008).

b. Conference and workshop presentations

The number of conference and workshop presentations made in 2009-2010 that were related to this project is presently 10, and are listed below:

- McKinney, M.A., E. Peacock, M. Branigan, T.J. Evans, G.W. Gabrielsen , R. Dietz, C. Sonne, F.F. Rigét and R.J. Letcher. 2009. Chemical contaminants in polar bears can be influenced by location, time and the diet they eat. Nunavut Wildlife Symposium, March 19-20, Rankin Inlet, Nunavut.
- McKinney, M.A., E. Peacock, M. Branigan, T.J. Evans, G.W. Gabrielsen, R. Dietz, C. Sonne and R.J. Letcher. 2009. Regional Differences and Temporal Patterns of Brominated Flame Retardants in Polar Bears from Alaska, Canada, Greenland and Svalbard. 11th Workshop on Brominated Flame Retardants (BFR'2009), May 19-20, Ottawa, ON, Canada.
- Letcher, R.J., M.A. McKinney, E. Peacock, M. Branigan and D.C.G. Muir. 2009. Core monitoring of spatial and temporal trends of legacy and emerging contaminants in polar bears from Canadian populations. 17th Annual Results Workshop of the Northern Contaminant Program (NCP),

Canadian Arctic Contaminants Assessment Symposium, Sept. 29-30, Ottawa, ON, Canada.

- Letcher, R.J. 2009. Analytical challenges and environmental relevance of branched and linear isomers of perfluorooctane sulfonate and related fluorinated compounds in biota. QUASIMEME Workshop, Analysis of Perfluorinated Compounds", Oct. 14-15, Amsterdam, the Netherlands.
- Letcher, R.J. and S.G. Chu. 2009. Branched and linear perfluorooctane sulfonate isomers in technical products and liver from various wildlife and fish from the Arctic and Great Lakes. 30th Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 19-23, New Orleans, LA, U.S.A.
- Letcher, R.J. 2010. Contaminants and trends over two decades in polar bears from western Hudson Bay: Climate change, sea ice conditions and diet shifts. Environment Canada, Science and Technology Branch, National Capital Region Science Forum, Jan. 26-27, Gatineau, QC, Canada.
- Letcher, R.J., M.A. McKinney, I. Stirling, E. Peacock, N.J Lunn and D. Andriashek. 2010. Organohalogen contaminant trends in polar bears from western Hudson Bay are influenced by temporal changes in climate, sea ice conditions and diet. IPY Canada Early Results Workshop, Feb. 16-18, Ottawa, ON, Canada.
- Jenssen, B.M., G.D. Villanger, E.I. Smette, R.J. Letcher, C. Sonne, R. Dietz. 2010. Identification of testosterone disrupting organohalogenated compounds in polar bears (Ursus maritimus). 3rd Norwegian Environmental Toxicology Symposium, April 14-16, Bergen, Norway.
- Sonne, C., R.J. Letcher, JO. Bustnes, R. Dietz, B.M. Jenssen, E.H. Jørgensen, J. Verreault, M.M. Vijayan, G.W. Gabrielsen, E.W. Born and N. Basu. 2010. An overview of the potential health effects from long-range transported pollutants in Arctic wildlife and fish. International Polar Year-Oslo Science Conference. June 8-12, Oslo, Norway.
- McKinney, M.A., D. Andriashek, E.W. Born, M. Branigan, R. Dietz, T.J. Evans, G.W. Gabrielsen, N. Lunn, E. Peacock, C. Sonne, I. Stirling and R.J. Letcher. 2010. Regional differences, temporal trends and the influence of diet in organohalogen contaminants in polar bears. International Polar Year-Oslo Science Conference. June 8-12, Oslo, Norway.

Expected Project Completion Date

All aspects of the pan-Canadian spatial trends phase of this project and based on the 2007 and 2008 pan-Canadian/circumpolar sample collections (e.g., data generation, data compilation and interpretation, data interpretation and writing of papers) are expected to be fully completed by July 2011. The new phase of this core contaminant monitoring project began in 2009-2010 with the collection of new polar bear (fat, liver and muscle) samples from individuals for longer-term and annual temporal trends assessments of bear in priority subpopulation regions, i.e. Hudson Bay (as well as Baffin Bay), and as identified in the revised 2010-2011 NCP core monitoring blueprint.

Acknowledgments

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Mercury In Beluga, Narwhal and Walrus from the Canadian Arctic: Status In 2010

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Abstract

Mercury levels in organs of beluga and walrus have been determined and added to a growing database on concentrations of these elements in arctic animals. The data on these animals offer opportunities to test for changes that may be driven by several environmental variables (time, location, climate) as well as to compare among organs of a species and among species. Tests for changes that relate to time or other variables will become increasingly rigorous as future collections supply additional data. Mercury content varies from organ to organ within an animal and from animal to animal from a given site and time of collection. Of the organs analyzed in this study, usually the liver has the highest concentrations of mercury, followed by kidney, muscle and muktuk. Estimation of temporal change is complicated by the fact that mercury accumulates with age so that older animals usually have higher levels than younger ones from the same location. The role of age was complicated for beluga when it was learned that these whales

Résumé

Cette étude en cours vise à maintenir les données actuelles sur les concentrations de contaminants dans les mammifères marins et à continuer à évaluer les tendances temporelles des composés organiques halogénés (COH). Cela nous permettra de déterminer si les concentrations de ces composés dans les mammifères marins, et donc l'exposition des habitants de l'Arctique qui les consomment dans leur alimentation traditionnelle, changent avec le temps. Ces résultats contribueront également à tester l'efficacité des contrôles internationaux et, de concert avec divers projets comme l'étude du système de chenaux de séparation circumpolaires (projet CFL de l'API et du CRSNG) et ArcticNet, permettront de comprendre les effets possibles des variations climatiques sur les concentrations de ces contaminants.

form one growth layer group per year in their teeth, not two as had been assumed previously (Stewart et al, 2006). Previously reported ages have been doubled and recent data use one layer per year. Since the basis of comparison of mercury levels among different groups of beluga requires an adjustment for differing ages, age data are critical. Usually the chemical analyses are completed prior to the age determinations and so there is a lag in the interpretations. Mercury and selenium in liver are related statistically and this is hypothesized to be the result of the formation of HgSe in biological tissues as a means to detoxify mercury.

Key Messages

- New collections of beluga and walrus were obtained in 2009 from several communities: Hendrickson Island 27 beluga, 5 beluga from Pangnirtung, 18 beluga from Sanikiluaq, 3 walrus from Grise Fiord, 21 walrus from Hall Beach and 8 walrus from Igloolik.
- Average levels of total mercury in beluga liver kidney and muscle from all collections remained above 0.5 $\mu g \cdot g^{-1}$. Levels of mercury in walrus organs were lower than those in beluga but almost all samples of liver exceeded 0.5 $\mu g \cdot g^{-1}$ while almost all samples of kidney fell below $\mu g \cdot g^{-1}$.
- Beluga from the Hendrickson Island had mean levels of mercury in liver higher than those in beluga from Sanikiluaq or Pangnirtung although levels in kidney were similar.
- The question of temporal change in levels of mercury is of interest but it is complicated by a relationship between mercury in liver and age of beluga and walrus. We lack age data for some collections reported and so we are limited in attempts to describe any temporal change. As more age data become available, rigorous statistical examination for temporal trends will become possible.

Messages clés

- Aucune tendance n'a été observée pour les groupes de composés organiques dans le béluga de l'ouest de l'Arctique. En particulier, les concentrations de HCH ne présentent pas la baisse observée dans l'atmosphère et l'océan Arctique depuis l'interdiction de l'utilisation du mélange technique par la Chine en 1983 et l'Inde en 1990.
- Depuis 2006, en moyenne, seulement quatre bélugas ont été recueillis et analysés chaque année à partir de Pangnirtung. Un échantillon d'aussi petite taille rend hautement improbable toute interprétation des résultats. En revanche, grâce au financement du CGRFN et du MPO, nous avons réussi à accumuler une excellente série d'échantillons depuis Sanikiluaq (1994, 1995, 1998, 2003, 2004, 2005, 2006, 2007, 2008, 2009). Par conséquent, nous proposons que le Programme de lutte contre les contaminants dans le Nord (PLCN) envisage de déménager à Sanikiluaq notre station de surveillance temporelle du béluga dans l'Arctique de l'Est. Toutefois, cela nécessitera une analyse rétrospective et des coûts supplémentaires pour le Programme de lutte contre les contaminants dans le Nord (PLCN).
- La réponse de Hall Beach pour les échantillons de morse s'est nettement améliorée en 2009. Nous disposons maintenant d'une série chronologique pour trois années consécutives (voir le tableau 4).

Objectives

To continue to assess levels and long-term trends of mercury in organs of beluga, narwhal and walrus from selected locations in the Canadian Arctic and to maintain a database of this information.

Introduction

The levels of mercury in organs of northern marine mammals generally exceed the guideline of 0.5 $\mu g \cdot g^{-1}$ used to regulate the sale of commercial fish. There is no regulation governing the concentrations in marine mammals for subsistence consumption. However, there is a published recommendation that fish consumed in a subsistence fishery not exceed 0.2 $\mu g \cdot g^{-1}$ (Health and Welfare Canada, 1979) although this recommendation has no legal status. There are three main hypotheses about the source of the mercury to the animals. The first is that the mercury is present naturally in northern habitats and the animals there simply reflect the geology and oceanography of their ranges. The second is that processes associated with climate change have altered the availability of mercury present naturally in the habitat. The third is that mercury from outside the habitat has been imported with movements of air (or water or ice) masses and that some of that mercury has found its way into northern animals. The extent to which these arguments apply is not yet clear. Studies of sediment cores suggest that more mercury has been reaching recent lake sediments than was the case when deeper, older layers of sediment were laid down (Lockhart et al., 1998). Studies of mercury in beluga teeth suggest that most of the mercury in contemporary beluga from the Beaufort Sea has been derived from recent anthropogenic activity (Outridge et al., 2002). However, parallel studies of mercury in teeth of walrus from Igloolik were not elevated over archeological samples suggesting little anthropogenic mercury in those animals (Outridge et al., 2002). Since pervious studies by Outridge et al. (2000) has shown that mercury levels in teeth are correlated with those in liver, kidney, muscle and muktuk, it seems likely that the trends reported in teeth occurred similarly in other organs.

The samples we describe here were all collected since the 1970s and Mercury has increased in air over the North Atlantic (Slemr and Langer, 1992) and mercury has been measured in air and in snow in the Arctic (Lu et al., 2001). While there is little doubt that industrial mercury is deposited in the Arctic, the ultimate fate of that mercury remains in question. Processes within the snow suggest that much of the mercury deposited to Arctic snow may be volatilized back into the air without ever reaching arctic animals. A question of great interest is whether mercury resulting from human activities is sufficient to cause changes in the levels of mercury in arctic animals. Stern and Macdonald (2005) postulated that the apparent increases of mercury in western Arctic beluga since the early 1990's may be attributed to recent changes in ice cover and distribution in the western Arctic Ocean. Gaden et al. (2009) found that levels of mercury in muscle of ringed seals collected from Holman between 1973 and 2007 showed no temporal trend but were related in a curvilinear way to the length of the ice-free season. Gaden and Stern (2010) have found that mercury levels in female beluga from Arviat decreased between the early 1980s and 2008. They used isotopic ratios of $\delta^{15}N$ and $\delta^{13}C$ to show that beluga feeding had changed over the interval. They suggested that this was likely due to the capture of prey from more offshore areas in response to the longer ice-free season over the interval. Loseto et al. (2008) have begun to look at biological variables that reflect food habits (a suite of 40 fatty acids in tissue extracts) in efforts to explain the levels of mercury found in beluga and this is a promising new approach.

A previous study of mercury in northern animals pooled data from different locations in the eastern and western Arctic and reported a trend to higher levels in both regions (Wagemann et al., 1996). With growing recognition that arctic populations of marine mammals are composed of multiple stocks that are hunted separately in different communities, the need is for trend data on a stock-specific basis. A more recent analysis considering locations separately was provided by Lockhart et al., 2005. In view of the changes required in ages of beluga, the calculations published in a number of earlier studies will have to be repeated.

Whales may range long distances from the communities where they are hunted, but the hunting itself is usually relatively close to the communities. Here, mammals are described only by the communities where the samples were obtained. Hence two or more communities may hunt the same stock if those communities are relatively near each other.

The raw data from several investigations are archived in the Freshwater Institute and comprise records of 1143 arctic beluga, 285 walrus, 390 narwhal and 1011 ringed seals. Biologists obtain samples from hunter kills and those samples form the basis of most analyses. The archive grows through the collection and analyses of new samples and also through the analyses of archived samples from past collections. Over time, the accumulated data offer increasingly powerful means to detect changes and relate them to environmental variables. Beluga ages in the archived data have been revised in keeping with the new information on growth layer formation.

Activities in 2009/10

This report covers data available by June, 2009. The collection of samples is done independently of this project and is not described here. The analytical methods have been described in previous reports and have been continued to date. While the project is concerned with mercury, some of the same samples have analyzed for selenium. Liver tissue of most animals was analyzed with smaller numbers of samples of kidney and muscle. The new samples reported were from collections made in 2009. The new data available are listed in Table 1.

Results

Levels of mercury in liver and kidney of beluga and walrus

This report provides the new records available from collections in 2009 (Table 1). New collections of beluga are those from Hendrickson Island, Pangnirtung and Sanikiluaq, New collections of walrus are reported from Hall Beach, Igloolik and Grise Fiord. Ages for collections in 2009 are not available yet; they will be added to the database

Table 1. New data for mercury and selenium in organs of beluga and walrus added to the database during 2010

Species	Location	Year	Organ	Mean Age (yr) and number of samples	Mean Length (cm) and number of samples	Mean Total mercury ($\mu g \cdot g^{-1}$) and number	Std. Dev. Total Hg	Mean selenium ($\mu g \cdot g^{-1}$) and number of samples
Beluga	Pangnirtung	2009	Liver		390.5 (4)	10.6 (5)	15.4	
Beluga	Pangnirtung	2009	Kidney		390.5 (4)	3.83 (5)	2.70	
Beluga	Pangnirtung	2009	Muscle		390.5 (4)	0.91 (4)	0.36	
Beluga	Sanikiluaq	2009	Liver		341.7 (17)	13.7 (18)	11.3	
Beluga	Sanikiluaq	2009	Kidney		341.7 (17)	2.62 (18)	1.40	
Beluga	Sanikiluaq	2009	Muscle		341.7 (17)	0.83 (18)	0.46	
Beluga	Hendrickson I.	2009	Liver		391.9 (27)	22.1 (27)	21.7	6.75 (27)
Beluga	Hendrickson I.	2009	Kidney		391.9 (27)	3.20 (27)	2.28	3.23 (27)
Beluga	Hendrickson I.	2009	Muscle		391.9 (27)	0.94 (27)	0.61	0.36 (27)
Walrus	Hall Beach	2009	Liver		317.8 (20)	2.05 (21)	1.32	
Walrus	Hall Beach	2009	Kidney		317.8 (20)	0.29 (21)	0.12	
Walrus	Igloolik	2009	Liver		300.6 (9)	1.62 (8)	0.62	
Walrus	Igloolik	2009	Kidney		300.6 (9)	0.34 (9)	0.60	
Walrus	Grise Fiord	2009	Liver		346.3 (3)	6.62 (3)	4.26	
Walrus	Grise Fiord	2009	Kidney		346.3 (3)	0.51 (3)	0.07	

when examinations of teeth have been completed. Summary statistics for mercury levels and animal length are listed in Table 1. In addition, each collection in 2009 is compared graphically with earlier collections from the same location with respect to levels of mercury in liver.

Beluga, mercury, Pangnirtung, 2009

Five new samples were obtained from Pangnirtung in 2009 (Table 1), 3 females, 1 male and one not described for gender. Four of these animals were analyzed for mercury in liver and values fell in the range of 0.5 to 6.4 $\mu g \cdot g^{-1}$ for three of the four, and one whale had a very high value of 37.8 μg·g, the second highest level on record for beluga from Pangnirtung. With the small number of samples, the mean of 10.6 μg·g was influenced strongly by the very high value. The median may offer a more representative picture of the samples from 2009 in the context of previous samples from the same location (Figure 1). The mean mercury level in kidney was lower, at 3.83 $\mu g \cdot g^{-1}$ and the four muscle samples were lower yet with a mean of only 0.91 $\mu g \cdot g^{-1}$. Inspection of Figure 1 suggests a possibility that levels of mercury in liver have increased somewhat over levels found in the 1980s but more definitive comparisons can be made after all the ages have been determined.

Beluga, mercury, Sanikiluaq, 2009

The sample of 18 beluga from Sanikiluaq in 2009 consisted of seven females, nine males and two for which no gender data were available. The mean level of mercury in liver for the eighteen samples was 13.7 $\mu g \cdot g^{-1}$. Median values and interquartile ranges are shown in the graph in Figure 2 and there is no obvious suggestion of a systematic increase in levels over the period since 1994. As in other cases, however, this tentative interpretation may change when ages are available. Mean levels of mercury in kidney and muscle are also shown in Table 1, and are lower in these organs than in liver. In spite of the lower values in these organs, means still exceeded 0.5 $\mu g \cdot g^{-1}$, the concentration used to regulate the sale of commercial fish.

Beluga, mercury, Hendrickson Island, 2009

Twenty seven beluga samples of liver were obtained from Hendrickson Island in 2009, 19 from males, 7 from females, and one from an animal of unreported gender. The mean concentration of mercury in liver for all the whales was 22.1 $\mu g \cdot g^{-1}$ while that for kidney was 3.20 $\mu g \cdot g^{-1}$ and muscle 0.91. In spite of this relatively low mean value in muscle, only 3 of the 27 animals had levels below 0.5 $\mu g \cdot g^{-1}$. The results for liver in 2009 are compared with data from earlier collections from the same area as

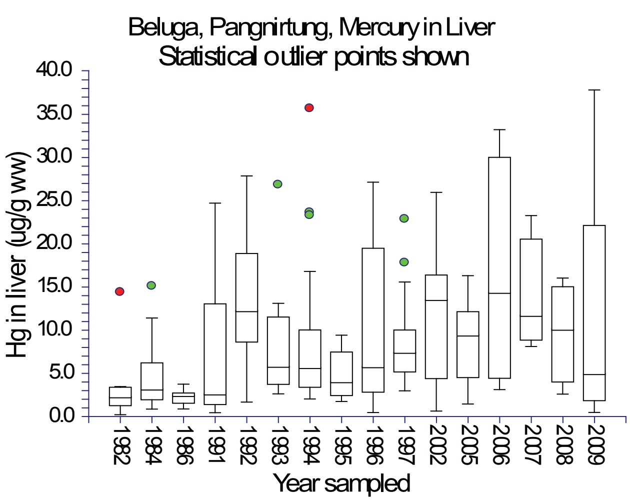

Figure 1. Median concentrations of mercury in liver of beluga whales from Pangnirtung collected at intervals from 1982 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

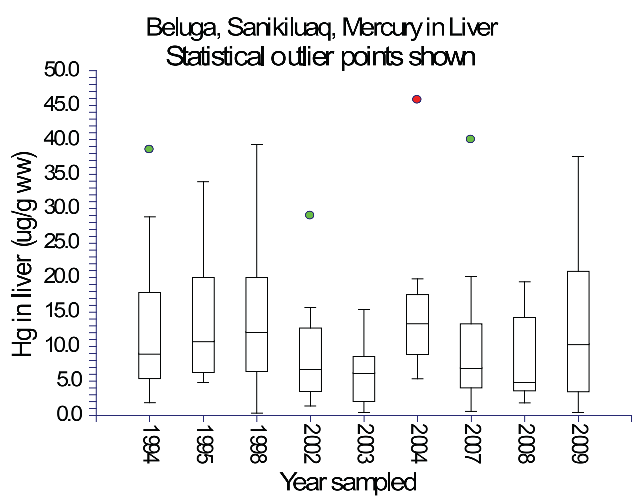

Figure 2. Median concentrations of mercury in liver of beluga whales from Sanikiluaq collected at intervals from 1982 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

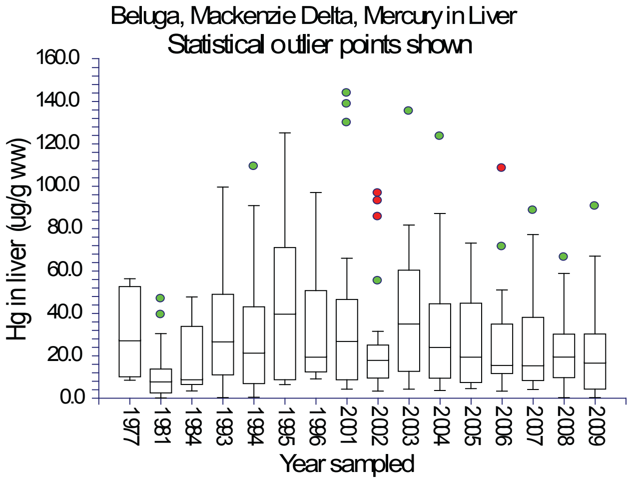

Figure 3. Median concentrations of mercury in liver of beluga whales from the Mackenzie Delta area collected at intervals from 1977 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

medians and interquartile ranges. in the box plots in Figure 3. The figure does not offer a clear indication of a single trend to higher or lower values; more detailed analysis will await age data.

Beluga, selenium, Hendrickson Island, 2009

The only samples analyzed for selenium in 2009 were the beluga from Hendrickson Island. The mean levels found in liver, kidney and muscle were 6.75, 3.23 and 0.36 $\mu g \cdot g^{-1}$ respectively (Table 1). As has reported for previous samples, there were statistical correlations between levels of mercury and selenium in all three organs (Figure 4).

The basis for these correlations is not completely certain but is hypothesized to arise from the storage of mercury in tissues as HgSe as a means to detoxify the mercury.

The levels of selenium in liver of beluga from this location have been determined on several previous occasions since 1991 in a total of 377 individuals. The levels in 2009 are shown with the previous measurements as medians and interquartile ranges in Figure 5. There is no obvious linear trend over the interval.

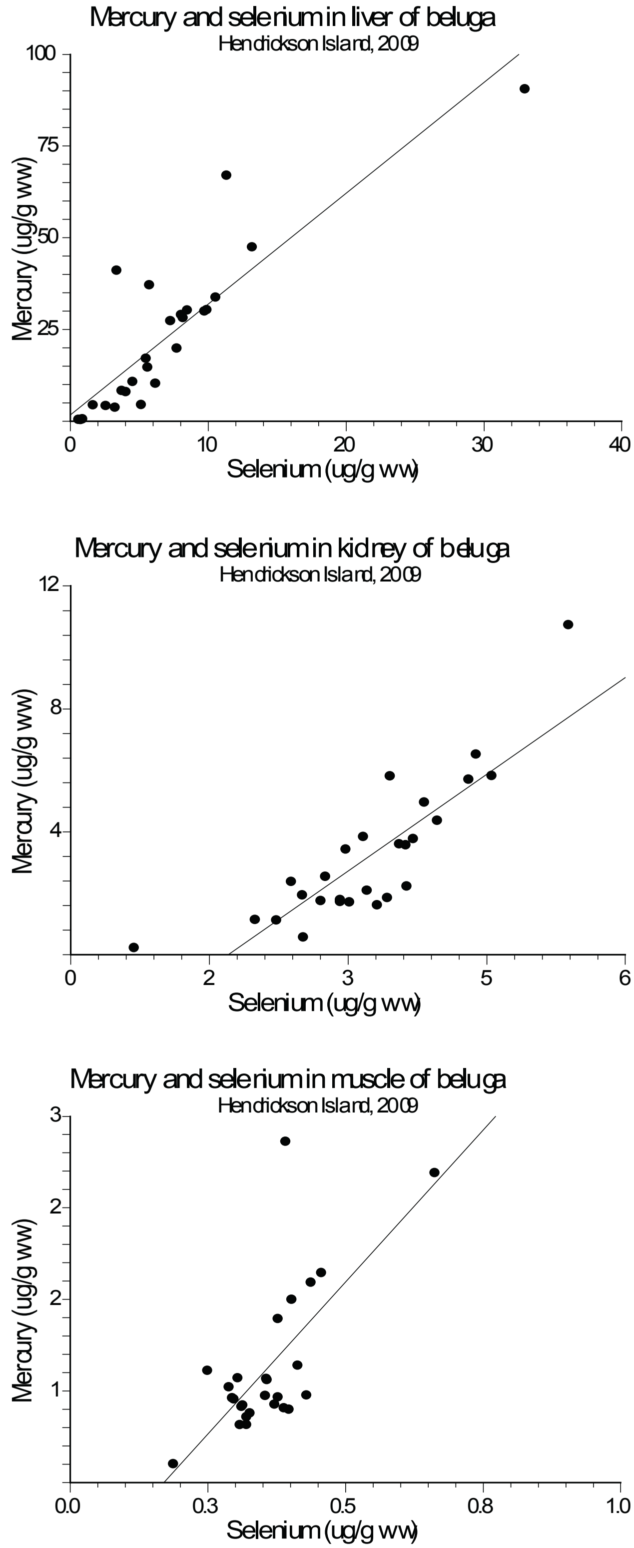

Figure 4. Mercury and selenium in liver (top, r=0.88), kidney (middle, r=0.85) and muscle (bottom, r=0.69) of beluga from Hendrickson Island in 2009.

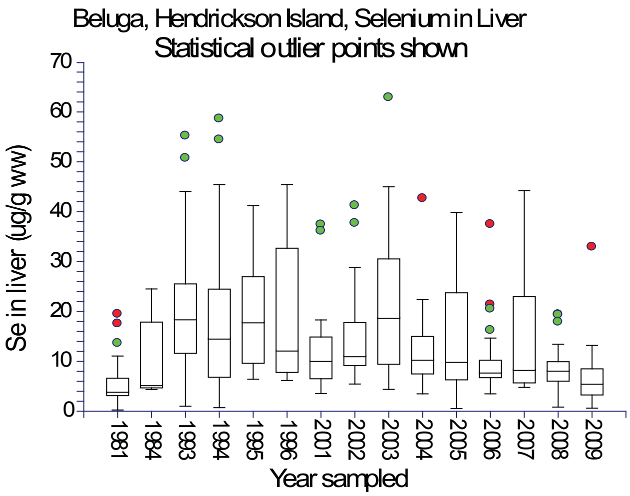

Figure 5. Selenium levels in liver of 377 beluga whales from the Mackenzie Delta area over the period 1991 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

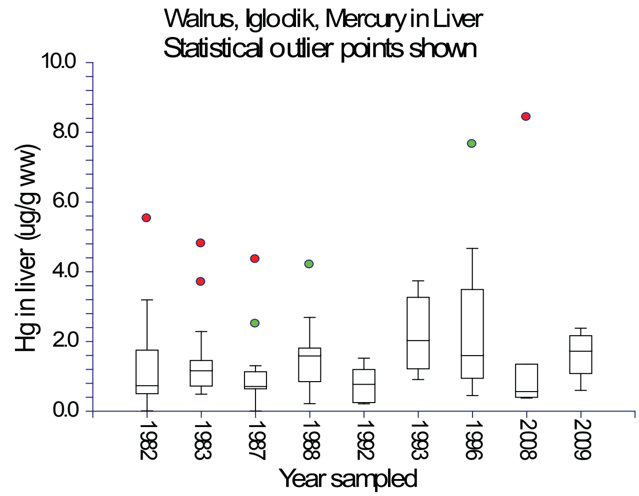

Figure 7. Median concentrations of mercury in liver of walrus from the Igloolik collected at intervals from 1982 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

Walrus, Hall Beach, 2009

Twenty-one walrus were obtained from Hall Beach 2009, consisting of 18 males, 2 females and one of unspecified gender. Mean mercury levels in liver and kidney are shown in Table 1 and were considerably below those found in the beluga organs. Liver mercury ranged from 0.45 to 5.33 $\mu g \cdot g^{-1}$ while kidney values were from 0.06 to 0.62. The box plot (Figure 6) shows the medians and interquartile ranges for 2009 in comparison with previous collections. The database contains liver data on 94 walrus from Hall Beach. Ages are available for those walrus collected in 2004 or earlier and it will become possible to make more rigorous analyses for age-corrected levels of mercury over the interval when remaining ages become available.

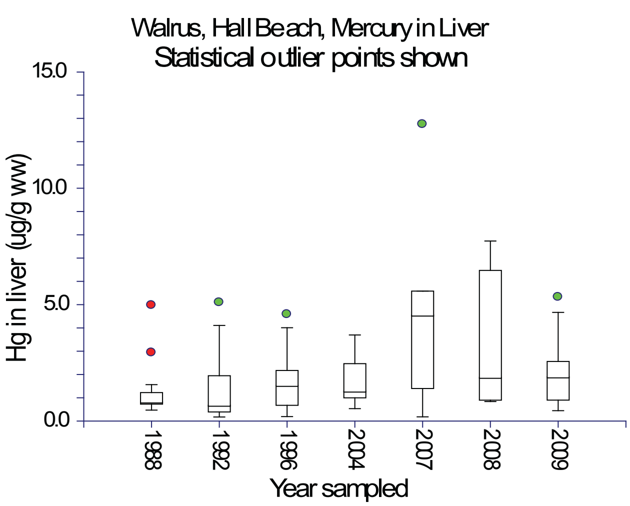

Figure 6. Median concentrations of mercury in liver of walrus from the Hall Beach collected at intervals from 1988 to 2009. The bar across each box is the median and the ends of each box are the 25th and 75th percentiles. Outlier points shown were identified by NCSS software.

Walrus, Igloolik, 2009

The largest number of walrus we have from any community is the series of 128 animals from Igloolik taken between 1982 and 2009. The mean concentrations in liver and kidney in 2009 were 1.62 and 0.34 $\mu g \cdot g^{-1}$ respectively. The comparison of 2009 data with prior collections is shown in Figure 7 with medians and percentile ranges. There is no obvious pattern of change at this level of analysis.

Walrus, Grise Fiord, 2009

We have only five walrus from Grise Fiord, one taken in 2007, one in 2008 and three in 2009 (Table 1). With such low numbers of samples we cannot reach any conclusions about trends. About all that can be said about them is that the values for mercury in liver are high in comparison with walrus from other communities. We do not have ages for any of the walrus from Grise Fiord and they may simply be old individuals. Given the low numbers of samples, no graphical presentation was prepared. We have liver samples of beluga and narwhal from Grise Fiord and the levels of mercury in these species fall in approximately the same ranges as those from other communities. We have no measurements of mercury in muscle of walrus from any of the Arctic communities and it would be desirable to obtain some in view of the apparently high levels in the livers at Grise Fiord. It is hoped that additional samples of walrus from Grise Fiord will be collected in future years and that muscle samples will be included.

Overall, there appears to have been little change in any of the concentrations between 2009 and previous years. Liver was more highly contaminated with mercury than kidney which was more highly contaminated than muscle. Almost all levels of mercury in beluga liver, kidney and muscle exceed the guideline level of 0.5 $\mu g \cdot g^{-1}$ used to regulate sales of commercial fish. Selenium in all three organs of beluga from Hendrickson Island in 2009 correlated statistically with those of mercury, as has been reported for earlier samples. Mercury levels in liver and kidney of walrus from Hall Beach and Igloolik were considerably below levels in beluga from other communities. Levels in liver still mostly exceeded the consumption guideline for fish but levels in most of the samples of kidney fell under 0.5 $\mu g \cdot g^{-1}$. The very small number of samples of walrus from Grise Fiord were unusually high in mercury and further samples are required.

Expected Project Completion Date

Mercury at the levels in these mammals remains a concern with regard to human dietary intakes. The levels also pose legitimate questions regarding the sources of the mercury and the effects on the mammals themselves. In view of the physical changes occurring in the Arctic, it seems likely that some form of this research will have to be continued for as long as marine mammals there are hunted for human consumption.

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Temporal Trends of Contaminants in Arctic Seabird Eggs

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Abstract

Contaminants have been monitored in arctic seabird eggs collected from Prince Leopold Island in the Canadian High Arctic since 1975. In order to examine inter-year variation in the temporal trend data series, annual egg collections have been made since 2005 from each of two species of seabirds from Prince Leopold Island. All of the eggs have been analyzed for the legacy organochlorines (OCs) and mercury (Hg) as well as brominated flame retardants (BFRs) and perfluorinated compounds (PFCs). The annual sampling undertaken in recent years (2005 onwards) for the arctic seabird eggs has greatly improved the power of the time series. It has also shown that there can be considerable inter-annual variation in residue levels which would be missed in the regular sampling regime of every five years.

Résumé

Les contaminants dans les œufs d'oiseaux de mer prélevés à l'île Prince Leopold dans l'Extrême-Arctique canadien font l'objet d'une surveillance depuis 1975. Afin d'examiner la variation annuelle dans les séries chronologiques de données, la cueillette annuelle d'œufs est réalisée depuis 2005 pour chacune des deux espèces d'oiseaux de mer étudiées à l'île Prince Leopold. Tous les œufs ont été analysés pour les composés organochlorés (CO) et le mercure (Hg) hérités, ainsi que les ignifugeants bromés et les composés perfluorés (CPF). L'échantillonnage annuel entrepris ces dernières années (depuis 2005) pour les œufs d'oiseaux de mer de l'Arctique a considérablement amélioré la pertinence de la série chronologique. Il a aussi montré qu'il peut y avoir une variation annuelle considérable des concentrations de résidus qui ne serait pas détectable avec le régime régulier d'échantillonnage aux cinq ans.

Key messages

- Total mercury (Hg) concentrations in eggs of two arctic seabird species, the thick-billed murre and northern fulmar, have increased significantly between 1975 and 2009 at Prince Leopold Island.
- Annual monitoring of the thick-billed murre and northern fulmar eggs has shown that there can be considerable inter-annual variation in

Messages clés

- Les concentrations de mercure (Hg) total dans les œufs de deux espèces d'oiseaux de mer de l'Arctique, les guillemots de Brünnich et le fulmar boréal, ont nettement augmenté entre 1975 et 2009 à l'île Prince Leopold.
- La surveillance annuelle des œufs du guillemot de Brünnich et du fulmar boréal a montré qu'il peut y avoir une variation annuelle considérable

residue levels which would be missed in the regular sampling regime of every five years.

- The annual sampling undertaken in recent years (2005 onwards) for the arctic seabird eggs has greatly improved the power of the time series.

des concentrations de résidus qui ne serait pas détectable avec le régime régulier d'échantillonnage aux cinq ans.

- L'échantillonnage annuel entrepris ces dernières années (depuis 2005) pour les œufs d'oiseaux de mer de l'Arctique a considérablement amélioré la pertinence de la série chronologique.

Objectives

In order to examine annual variation in the temporal trend data series, eggs are to be collected for contaminant analyses from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island annually starting in 2005. For comparative purposes, we also make annual collections of thick-billed murre eggs from Coats Island in northern Hudson Bay (our Low Arctic monitoring colony since 1993) in parallel with the High Arctic collections.

Introduction

Eggs of thick-billed murres (*Uria lomvia*), northern fulmars (*Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) from Prince Leopold Island in the Canadian High Arctic have been monitored for contaminants since 1975 (Braune 2007) to provide an index of contamination of the arctic marine ecosystem and possible implications for seabird health. Past collections of arctic seabird eggs for contaminant analyses have been opportunistic but collections have been standardized to every five years since 1988. Most of the legacy persistent organic pollutants or POPs (e.g. PCBs, DDT) have been declining whereas total mercury (Hg) has been increasing (Braune 2007), as have the perfluorinated carboxylic acids (PFCAs) and, until relatively recently, the polybrominated diphenyl ethers (PBDEs) (Braune 2008).

Interpretation of temporal trend data is often obscured by the "noise" associated with concentration measurements. The probability that a monitoring program will detect a temporal trend in concentrations, in spite of the "noise" in the data, represents its statistical power. Long contaminant monitoring time series show random inter-year variations which are not part of a trend, which demonstrates the risks in using small, scattered sets of data on occasionally collected samples for addressing environmental issues (Bignert et al. 1993, 1994, 1998; Olsson 1995, Hebert and Weseloh 2003).

One of the objectives of the core monitoring component of the NCP Blueprint for Environmental Monitoring and Research is to be able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and confidence level of 95%. In order to examine the inter-year variation in contaminants data, and to improve the statistical power of the temporal trend data series for Canadian Arctic seabirds, we have been collecting eggs from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island annually since 2005. For comparative purposes, we have also been making annual collections of thick-billed murre eggs from Coats Island in northern Hudson Bay (our Low Arctic monitoring colony since 1993) in parallel with the High Arctic collections. Eggs are being analyzed for the normal suite of legacy POPs and total Hg, and the murre and fulmar eggs from Prince Leopold Island are being analyzed for PBDEs, hexabromocyclododecane (HBCD), polychlorinated dibenzo-*p*-dioxins (PCDDs), dibenzofurans (PCDFs), coplanar PCBs, and perfluorinated compounds (PFCs), as well.

Activities in 2009/2010

Sample collection/analysis: Eggs (n=15) were collected on the basis of one egg per nest from each of two species of seabirds (northern fulmar, thick-billed murre) from Prince Leopold Island (74°02'N, 90°05'W) in Lancaster Sound as well as from thick-billed murres on Coats Island (62°30'N, 83°00'W) in northern Hudson Bay. Eggs were analyzed for the normal suite of legacy POPs (e.g. PCBs, DDT, chlordanes, chlorobenzenes, etc.), PBDEs, HBCD, and PFCs in pools of 3 eggs each (15 eggs per collection = 5 pools of 3 eggs each). Murre and fulmar eggs from Prince Leopold Island are also analyzed for for PCDDs, PCDFs and coplanar PCBs in pools of 5 eggs each (15 eggs per collection = 3 pools of 5 eggs each) to conform with previous analyses. All eggs are individually analyzed for total Hg and stable isotopes of nitrogen ($^{15}N/^{14}N$) and carbon ($^{13}C/^{12}C$).

Analytical methods: Analyses of the legacy POPs, PBDEs, HBCD, PFCs and total Hg are carried out at the National Wildlife Research Centre (NWRC) laboratories at Carleton University in Ottawa, Ontario. The legacy POPs are analyzed by gas chromatography using a mass selective detector (GC/MSD) according to NWRC Method No. MET-CHEM-OC-06B. Analyses of the standard 14 PBDE congeners and total-α-HBCD are carried out using GC-low resolution MS also according to NWRC Method No. MET-CHEM-OC-06B. PFCs are analyzed using HPLC/MS/MS in negative electrospray mode (ESI$^-$) according to NWRC Method No. MET-WTD-PFC-01. PFCs analyzed include 10 PFCAs (including PFOA), 4 PFSAs (including PFOS), 3 FTUCAs, PFOSA and 3 FtOHs. Total mercury (Hg) is analyzed using an Advanced Mercury Analyzer (AMA-254) equipped with an ASS-254 autosampler for solid samples according to NWRC Method No. MET-CHEM-AA-03G. The method employs direct combustion of the sample in an oxygen-rich atmosphere. PCDDs, PCDFs and coplanar PCBs are analyzed by the Research and Productivity Council (RPC) in Fredericton, NB, which identify and quantify the compounds by high resolution gas chromatography coupled to a High Resolution Mass Spectrometer (HRGC/HRMS) using internal and external standards. The method is based on EPA Method 1613B in which specific congeners are targeted. Comparability with previous results generated by NWRC is assessed by analysis of two commercial Certified Reference Materials. Quality assurance/quality control (QA/QC) is monitored by NWRC Laboratory Services which is an accredited laboratory through the CALA and has participated in the NCP's QA/QC Program. Stable isotope (C, N) analyses are carried out through the Environment Canada lab at PNWRC in Saskatoon with isotopic measurements made at the Department of Soil Science, University of Saskatchewan, Saskatoon. All samples are archived in the National Wildlife Specimen Bank housed at the NWRC in Ottawa.

Capacity Building: The contaminants monitoring program at Prince Leopold Island in the Canadian High Arctic is part of a long-term, integrated seabird monitoring program which has been investigating seabird population trends and relationships with climate change and contaminants for over 30 years. In 2009, we sent a laboratory technician (Guy Savard) trained in dissection and tissue preparation from NWRC to Iqaluit for the second year in a row to teach students at the Nunavut Arctic College the correct procedures for sampling and storing tissue samples for contaminants analyses. Guy and a graduate student (Jennifer Provencher) worked with Arctic College students in the lab as well as discussing various aspects of seabird ecology. An Inuk assistant (Josiah Nakoolak from Coral Harbour) was hired to help with the field work at Coats Island in 2009, as has been the case for more than 20 years at the site.

Communications: Birgit Braune (Project Lead) offered to meet with the Niqiit Avatittinni Committee (NAC) in Iqaluit to discuss her projects in more detail in June 2009. Mark Mallory (Project Team Member) gives presentations on the work that Environment Canada is doing on arctic birds regularly in Resolute Bay, but a planned meeting with the community in 2009 was cancelled due to the passing of the HTA Chair. Grant Gilchrist (Project Team Member) gives presentations on the work that Environment Canada is doing on arctic birds at the school and elsewhere in Coral Harbour about every two years. Grant gave a presentation on the marine bird research going on at Coats Island, East Bay and other areas in the region in Coral Harbour in April 2009, and in Ivujivik, Quebec, in August 2009.

Traditional Knowledge: It is difficult to incorporate new traditional knowledge annually into an ongoing contaminants monitoring program focussed on established seabird colonies which have been studied for many years. However, in 2009, extensive, community-based interviews relating to observations of bird population trends were conducted in Cape Dorset, Kimmirut, Igloolik, and Coral Harbour. These provide potentially useful information for how to assess whether environmental stressors (e.g. contaminants, climate change) may be affecting northern migratory bird populations. To date, results suggest that Inuit have observed declines in populations of shorebirds and terns, and increases in goose populations, but no trends or obvious differences in other marine bird abundance or distribution.

Results

Although the Hg data have not yet been corrected for possible variations in trophic position over time as indicated by stable nitrogen ratios, trends of total Hg show statistically significant increases in concentrations in eggs of thick-billed murres (n=55, r=0.77, p<0.00001) and northern fulmars (n=56, r=0.45, p<0.0005) between 1975 and 2009 at Prince Leopold Island (Figure 1). The increase in Hg levels seems to be continuing, particularly in thick-billed murres whereas, after 2003, concentrations in the fulmars appear to be levelling off. In contrast, the concentrations of legacy POPs such as ΣPCB and ΣDDT in the Prince Leopold Island murre and fulmar eggs continue to decline (p<0.00001 for ΣPCB and ΣDDT in both murre and fulmar eggs) although the rate of change in recent years is low.

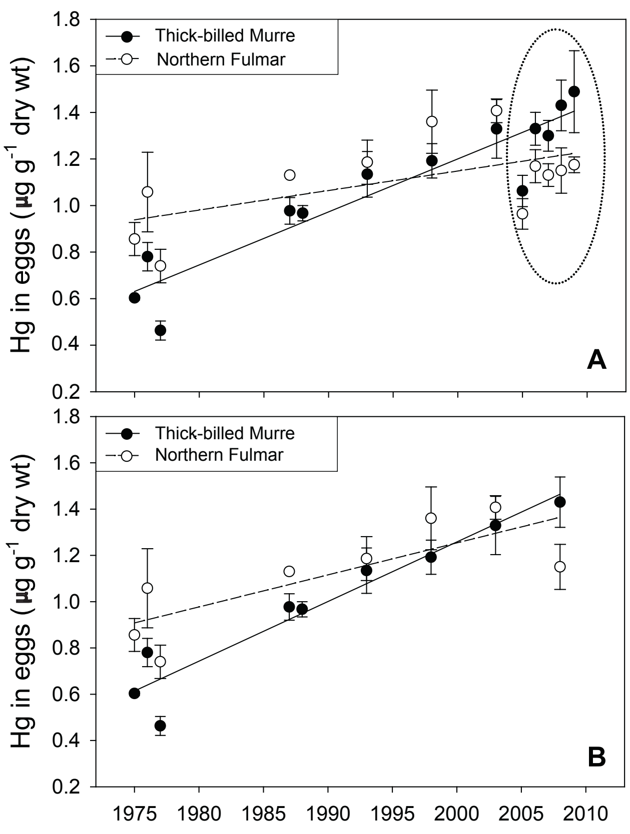

Figure 1. Mean concentrations (± standard error) of total Hg (mg g^{-1} dry wt) in eggs of northern fulmars and thick-billed murres collected from Prince Leopold Island, 1975-2009. A. Data for annual sampling 2005-2009 shown; B. Only data for five-year intervals (e.g. 2003, 2008) shown.

Five years of annual sampling (2005-2009) of murre and fulmar eggs clearly illustrate that there may be considerable inter-year fluctuation in Hg concentrations (Figure 1A); a level of detail would have been missed in the regular schedule of sampling every five years (Figure 1B). An indication of the inter-year variation in Hg concentrations was also evident during the early years, 1975-1977 (Figure 1).

A statistical package (PIA) developed by Anders Bignert of the Swedish Museum of Natural History to analyze trends in time-series datasets was used to compare the time series for seabird eggs including the recent annual sampling results (i.e. 2005 onwards) vs results if sampling had continued on a 5-year cycle. The results show that the recent annual sampling has greatly increased the power of the datasets and has lowered the lowest detectable change (Tables 1 & 2). For example, in the case of the Hg trends (Table 2), the inclusion of the annual data from 2005 to 2009 has reduced the lowest detectable change by 46-50% and increased the power of the time series by 43-56%.

Discussion and Conclusions

Major organochlorines, such as total PCBs (ΣPCB) and DDT metabolites (ΣDDT), in eggs of both thick-billed murres and northern fulmars from Prince Leopold Island have decreased since 1975 but now appear to be levelling off, albeit with some inter-annual fluctuation (Braune 2008). However, total Hg concentrations seem to continue increasing, particularly in the thick-billed murres.

The probability that a monitoring program will detect a temporal trend in concentrations, in spite of the inter-annual fluctuations or "noise" in the data, represents its statistical power. The probability or power of detecting changes in contaminant levels with time depends both on the pattern and magnitude of those changes (Nicholson and Fryer 1992). Implications of ignoring power include collection of insufficient data to make reliable inferences about temporal trends and/or collection of extraneous data (Braune et al. 2003). Hebert and Weseloh (2003) used contaminant levels in Great Lakes herring gull eggs to examine the effect of sampling frequency on the detection of statistically significant trends and illustrated that decreased identification of statistically significant trends was apparent in the sampling regimes where samples were collected less frequently. As shown in Tables 1 and 2 for thick-billed murres and northern fulmars, the annual sampling undertaken in recent years for the arctic seabird eggs has greatly improved the power of the time series. It has also demonstrated that there can be considerable inter-year fluctuation in concentrations, a level of detail which would be missed in the regular regime of sampling every five years.

Table 1. Results from power analysis of ΣDDT and ΣPCB in thick-billed murre and northern fulmar eggs from Prince Leopold Island, 1975-2008, comparing results including annual sampling during 2005-2008 (left-hand column) with results based on five-year sampling regime (right-hand column) for each species.

	Thick-billed Murre		Northern Fulmar	
	Annually 2005-2008	Every 5 years	Annually 2005-2008	Every 5 years
	n=50; #yrs=12	*n*=35; #yrs=9	*n*=51; #yrs=11	*n*=36; #yrs=8
ΣDDT				
# Years required*	15	15	14	15
Lowest detectable change**	7%	11%	6.8%	15%
Power of time series***	52%	24%	54%	17%
ΣPCB				
# Years required*	14	13	13	13
Lowest detectable change**	6%	8.6%	6.3%	11%
Power of time series***	65%	38%	61%	27%

* Number of years required to detect an annual change of 5% with a power of 80%
** Lowest detectable change in current time series
*** Power of current time series to detect a log-linear trend of 5%

Table 2. Results from power analysis of total Hg in thick-billed murre and northern fulmar eggs from Prince Leopold Island, 1975-2009, comparing results including annual sampling during 2005-2009 (left-hand column) with results based on five-year sampling regime (right-hand column) for each species.

	Thick-billed Murre		Northern Fulmar	
	Annually 2005-2009	Every 5 years	Annually 2005-2009	Every 5 years
	n=55; #yrs=13	*n*=35; #yrs=9	*n*=56; #yrs=12	*n*=36; #yrs=8
Total Hg				
# Years required*	12	12	10	10
Lowest detectable change**	4.1%	8.2%	3.7%	6.8%
Power of time series***	94%	41%	97%	55%

* Number of years required to detect an annual change of 5% with a power of 80%
** Lowest detectable change in current time series
*** Power of current time series to detect a log-linear trend of 5%

NCP Performance Indicators

- There have been many students and northerners involved in this monitoring program over the years. Likewise, this project has been discussed at numerous workshops in the North. Previous results have been included in the 1999 and 2001 tours of Arctic communities. Annual consultation with northern communities is integral to the permitting process and thus engages the local HTA's (i.e. Resolute Bay, Coral Harbour).
- In 2009, one southern student and one northerner, who has worked with us for over 20 years, participated in the field work. As well, one graduate student and a NWRC technician trained ~20 northern students from the Nunavut Arctic College in aspects of tissue sampling for contaminant analyses as part of the overall arctic seabird monitoring program (see Capacity Building).
- There were two planned meetings in the North for 2009 which did not occur for various reasons and there were two meetings which did take place (see Communications).
- Over the years, the data have been included in 17 peer-reviewed publications/reviews, 15 departmental reports, three AMAP assessments, 2 NCP assessments, and at least 63 presentations at conferences/workshops/meetings. In 2009, the data were included in 3 review papers published in The Science of the Total Environment as part of the AMAP POPs Assessment, one government report (NCP Synopsis Report), and 7 presentations.

Expected Project Completion Date

March 31, 2015

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Temporal trends and spatial variations in persistent organic pollutants and metals in sea-run char from the Canadian Arctic

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Abstract
Our study is investigating metal and organic contaminant levels in sea-run char as they return from feeding in the ocean. In 2009, sea-run char were collected from Holman, Cambridge Bay, Pond Inlet, Pangnirtung, Iqaluit, and Nain. Mercury concentrations were very low; selenium, which is an essential nutrient and binds with mercury reducing its toxicological effects, occurred in 4-8 times greater concentrations than mercury. Iron and zinc, also essential micronutrients, were even more abundant. There was a statistically significant trend for mercury concentrations to be increasing at Cambridge Bay but not Nain when factors such as fish length and weight also were considered. At Cambridge Bay, most persistent organic pollutants (POPs) occurred in lower concentrations over 2004-2008 than in 1987 with PCBs being the notable exception. In contrast, Pond Inlet, also

Résumé
Notre étude porte sur les concentrations de contaminants organiques et de métaux dans l'omble anadrome quand il revient après s'être nourri en mer. En 2009, des spécimens d'omble anadrome ont été recueillis à partir de Holman, de Cambridge Bay, de Pond Inlet, de Pangnirtung, d'Iqaluit et de Nain. Les concentrations de mercure étaient très faibles; le sélénium, qui est un nutriment essentiel et se lie avec le mercure tout en réduisant ses effets toxicologiques, était présent en concentrations 4 à 8 fois supérieures à celles du mercure. Le fer et le zinc, également des micronutriments essentiels, étaient encore plus abondants. On a constaté une tendance statistiquement significative pour les concentrations de mercure qui augmentaient à Cambridge Bay, mais pas à Nain lorsque l'on prenait en considération certains facteurs comme la longueur et le poids des poissons. À Cambridge Bay, la plupart des polluants

analyzed in 1987, showed no evidence of POPs decline with the exception of HCH and possibly PCBs. For Nain char, first analyzed in 1998, PCBs and, to a lesser extent, DDT and HCH concentrations, were lower in 2007 and 2008 than in 1998. PBDEs occurred in low concentrations with concentrations possibly higher in 2006 and 2007 than earlier and later periods. Community visits and consultations went well with brief presentations given in Pond Inlet, Pangnirtung and Iqaluit.

organiques persistants (POP) étaient en concentrations plus faibles entre 2004-2008 qu'en 1987, seuls les BPC faisant exception. En revanche, à Pond Inlet, où des analyses avaient aussi eu lieu en 1987, on n'a constaté aucun signe de diminution des POP, sauf les HCH et probablement les BPC. Dans les spécimens d'omble prélevés à Nain, et analysés pour la première fois en 1998, les concentrations de BPC et, dans une moindre mesure, de DDT et de HCH étaient plus faibles en 2007 et 2008 qu'en 1998. Les PBDE étaient présents en faibles concentrations avec des concentrations potentiellement plus élevées en 2006 et 2007 que dans les périodes antérieures et postérieures. Les visites et les consultations dans les collectivités se sont bien déroulées, et de brefs exposés ont été présentés à Pond Inlet, Pangnirtung et Iqaluit.

Key messages

- Mercury concentrations were very low in sea-run char caught in 2009, i.e., well below the 0.5 μg/g guideline for the commercial sale of fish.
- There was a trend of mercury increase at Cambridge Bay when comparisons were based on commercial fish data collected in 1977, 1992, and 1993 and NCP data in 2004 and 2006-2009. No trend was evident at Nain where the temporal record is shorter.
- Concentrations of legacy contaminants (PCBs, DDT, CBz, HCH, and chlordane) were low with trends of decline most evident at Cambridge Bay.
- Fish appear healthy with only a few instances of disease and/or parasites noted in the majority of collections.

Messages clés

- Les concentrations de mercure étaient très faibles dans l'omble anadrome cueilli en 2009, bien en deçà de la ligne directrice de 0,5 μg/g pour le poisson destiné à la vente commerciale.
- Le mercure présentait une tendance à la hausse à Cambridge Bay d'après la comparaison des données pour le poisson commercial prélevé en 1977, 1992 et 1993 et des données du PLCN en 2004 et 2006-2009. Aucune tendance ne ressortait dans les données de Nain, où la série chronologique est plus courte.
- Les concentrations de contaminants hérités (BPC, DDT, CBz, HCH et chlordane) sont faibles, et les tendances à la baisse sont les plus manifestes à Cambridge Bay.
- Les poissons semblent en bonne santé avec seulement quelques cas de maladie ou de parasites constatés dans la majorité des prélèvements.

Objectives

1. Determine levels of persistent organic pollutants (POPs) and metals (including mercury) as well as "new" POPs from sea-run char which are harvested by Arctic communities.
2. Investigate the role of factors such as fish age, trophic feeding, climate, and location in affecting contaminant body burdens and trends.
3. Contribute to AMAP's assessment of long-term trends in metals and POPs in the Arctic and subarctic and the factors affecting such trends.

4. Provide and explain data to Arctic environmental contaminant committees, health committees, and local communities in a timely manner so that appropriate advice can be given on consuming sea-run char, a country food which is particularly low in contaminant concentration.

Introduction

The addition of sea-run Arctic char (*Salvelinus alpinus*) to the NCP annual monitoring program is recent, beginning in 2004. The relatively late addition of sea-run char to the core monitoring program is based in part on the fact that early exploratory studies of mercury and persistent organochlorine contaminant concentrations in sea-run char determined that levels were substantially lower than in marine mammals and landlocked char (Muir et al. 1990; 1999; Jensen et al. 1997; Braune et al. 1999; Fisk et al. 2003). However, because contaminant levels are relatively low in sea-run char, they are a highly recommended country food for consumption for those seeking to minimize their contaminant update while enjoying a traditional diet and fulfilling cultural values. Thus, sea-run char were added to the NCP monitoring program in order to provide a stronger data base to support the general recommendation that sea-run char are an excellent food choice through being particularly low in contaminant concentrations.

Sea-run Arctic char are related to lake trout (*Salvelinus namaycush*) with a more northern range, inhabiting primarily Arctic and subarctic waters. The majority of their life is spent in freshwater, generally lakes, although some occupy river reaches. Some sea-run char migrate to the sea in late spring, spending a few weeks feeding on benthos and small forage fish, before migrating inland in late summer (Scott and Crossman 1998). Such char are commonly collected by coastal communities during their migrations, but also are caught while feeding in the sea. Sea-run char are sufficiently abundant in some areas to be harvested commercially (e.g., Cambridge Bay, Pangnirtung and Nain) and also are important to the growing sports fishery. The most extensive contaminant data for char are based on mercury measurements made on sea-run char as part of commercial fisheries (Lockhart et al. 2005).

The NCP sea-run char monitoring program has had two basic objectives. The first was to obtain detailed information on spatial concentrations in contaminants in sea-run char across much of their range. Spatially detailed studies of mercury levels in lake trout in lakes along the Mackenzie River determined that contaminant concentrations varied markedly, exceeding commercial sale guidelines in many lakes; high mercury levels were attributed to old fish living in smaller lakes with large watersheds (Lockhart et al. 2005; Evans et al. 2005). Thus, between 2004 and 2009, sea-run char were collected from six communities a year from the western Arctic east to the Labrador and northern Quebec coast and from as far south as Hudson Bay to as far north as Cornwallis Island. While sea-run char often were as old as lake trout collected in lakes along the Mackenzie River, mercury concentrations have been substantially lower (Evans and Muir 2008, 2009). Although the reasons for this are not being directly investigated in this project, they most likely are related to lower concentrations of methyl mercury in the marine waters and food consumed by sea-run char than in lake trout lakes along the Mackenzie River. Mercury concentrations tend to be higher in landlocked char (Muir et al. 2009b) with higher levels related to slow fish growth and cannibalism.

The second objective of the NCP char program was and continues to be to assess temporal trends in contaminants. The ability to assess temporal trends is increasing as the monitoring program continues and fish are monitored over more years. The ability to detect trends may also be increased if contaminant trends are pronounced. Limited data exist for contaminants in sea-run char prior to 2004, when this program began, with data collected prior to the early 1990s often limited in terms of the number of fish analyzed and other important metrics such as fish age and feeding characteristics. We are interested in several different questions or concerns with respect to contaminant trends. The first is the decline in legacy organic contaminants such as HCH, DDT and PCBs whose use has been banned under the Stockholm Convention and also in North Aermica and most of Europe for 20 years or more. This decline is slow to occur because many of these compounds have half lives of 10, 20 or more years (Hung et al. 2010; Li and Macdonald

2005). The second is time trends in compounds whose use was increasing until recently e.g., polybrominated diphenyl ethers and PFOS as well as other new compounds that have entered the market. A third is the special case of mercury which has been shown to have increased atmospheric emissions from Asian countries such as India and China potentially contributing to more anthropogenic mercury entering northern waters through atmospheric pathways (Pacyna et al. 2006; Weiss-Panzias et al. 2007); recent studies by Muir et al. (2009a) have found that anthropogenic mercury fluxes to northern lake sediments has continued to increase in most lakes. The final concern focuses on contaminant trends driven by climate change, generally viewed as a warming trend with the greatest trends of increase being observed in northern Canada. Warming trends may result in an increase in the movement of legacy organic contaminants (e.g. released from tree foliage and soils during forest fires; Eckhardt et al. 2007) from the mid-latitudes with a concomitant increase in transport to northern environments. Furthermore, increased warming may result in an increase in localized productivity and/or watershed inputs, resulting in increased contaminant delivery to the sediments and to biota (Stern et al. 2005; Outridge et al. 2007; Carrie et al. 2010).

Activities in 2009-2010

In 2009, sea-run char were successfully collected at all communities, i.e., Holman, Cambridge Bay, Pond Inlet, Pangnirtung, Iqaluit and Nain. Some of the October caught fish from Holman were lake trout. Char from Iqaluit were not provided until February 2010 and were from the Sylvia Grinnell River. Pond Inlet fish were provided in August but the shipment was mislaid and the cooler thrown out by the airline when the smell of rotting fish became evident. Twenty fish later were provided from a lake draining into the Salmon River. Both Iqaluit and Pond Inlet char are believed to have been sea-running populations. A subset may be analyzed for sulfur isotopes to confirm this. Nain fish were provided from Voisey's Bay (6) and Tikkuatokkak Bay (14). In August, we visited Pond Inlet, Pangnirtung, and Iqaluit in order to collect our sea-run char, conduct some marine food web sampling, discuss the NCP study results, and to collect landlocked char as part of a companion Arctic Net project with Michael Power at the University of Waterloo.

General features of fish caught in 2009

Our study design calls for 20 fish to be collected per location and these fish were either shipped whole to us (Cambridge Bay, Holman, Iqaluit and the winter Pond Inlet collection) or obtained when we visited the community in August (Pond Inlet, Pangnirtung, Iqaluit). Of the 18 fish provided by Holman, 14 were Arctic char and four were lake trout. Swanson et al. (2010) recently has reported on the co-occurrence of lake trout and Arctic char in lakes in the Cambridge Bay area. Scott and Crossman (1998) show the lake trout range as extending into Banks and Victoria Islands.

Length, weight, age, and gender were determined on all fish from each location. In addition, we have been measuring the liver, gonad, and stomach and noting the presence of parasites and/or disease. A fillet sample and the liver, stomach, and gonad were retained from each fish. Carbon and nitrogen isotope and percent moisture analyses are performed on all fish. Ten of the 20 fish from each location were selected for metals, legacy organic contaminants and PDBE and PFA analyses, with our sample archive consisting of various tissue samples from all 20 fish per location. Archived samples are maintained at -40°C in a walk-in freezer at the National Hydrology Research Centre which has a monitoring system overseen by commissionaires 24-hours a day, 365 days a year. Mercury data have been provided by the analytical laboratory while organochlorine contaminant analyses are ongoing. Highlights of our findings to date are as follows.

Results

Largest fish were from Cambridge Bay and Pond Inlet (summer) followed by Holman and Pangnirtung. Nain and Iqaluit fish were the smallest and youngest as has been observed in past years; these smaller fish sizes may be related to the more intensive fisheries operating in these areas. Mercury concentrations were very low in char at all locations. Furthermore, selenium which is believed to provide some protection from mercury toxicological effects

Table 1. Mean (± standard deviation) fork length, age, weight, and mercury, selenium, iron and zinc concentrations (wet weight basis) for sea-run char caught in 2009.

Location	Fork length (mm)	Age (yr)	Weight (gm)	Mercury (μg/g)	Selenium (μg/g)	Iron (μg/g)	Zinc (μg/g)
Holman	563 ± 193	11.4 ± 1.9	2,743 ± 2,415	0.07 ± 0.04	0.34 ± 0.07	3.94 ± 1.03	4.26 ± 0.63
Cambridge Bay	696 ± 67	13.1 ± 1.9	3,701 ± 1,122	0.08 ± 0.03	0.37 ± 0.09	4.30 ± 0.74	3.85 ± 0.30
Pond I.-summer	672 ± 70	n.d.	3,394 ± 1227	n.d.	n.d.	n.d.	n.d.
Pond I. -winter	584 ± 50	n.d.	2,584 ± 872	n.d.	n.d.	n.d.	n.d.
Pangnirtung	544 ± 59	12.1 ± 2.3	2,311 ± 744	0.06 ± 0.03	0.28 ± 0.06	2.91 ± 0.35	4.23 ± 0.30
Iqaluit	489 ± 62	8.6 ± 2.3	1,342 ± 581	0.03 ± 0.01	0.26 ± 0.02	2.95 ± 0.55	4.14 ± 0.46
Nain	515 ± 61	7.5 ± 2.3	1,746 ± 703	0.04 ± 0.02	0.29 ± 0.06	2.76 ± 0.72	3.53 ± 0.42

occurred in average concentrations 4.4 -7.9 times higher than mercury concentrations; these high selenium to mercury ratios contrast with land-locked char where ratios may be more in the 1-2 range. Muir et al. (2008) reported an average mercury concentration of 0.212 μg/g and an average selenium concentration of 0.579 μg/g in fish from Char Lake (selenium:mercury = 2.73); for Resolute Lake the values were values were 0.458, 0.451, and 1.01 μg/g, respectively, and for Amituk Lake the values were 1.425, 1.528, and 0.93 μg/g, respectively. Iron and zinc, important minerals in general nutrition, occurred in substantially higher concentrations than mercury in sea-run char; iron concentrations tended to be higher in the western Arctic (Holman and Cambridge Bay) than the eastern Arctic.

Temporal variations in mercury levels

Cambridge Bay has the longest record for investigating mercury time trends in sea-run char with fish measured for mercury in 1977, 1978, 1992, and 1993; weight was measured in all years and length in all but 1978. Mercury exhibited a general trend of increase over 1977-2009 based on a linear regression analysis; the Lowess smoother shows an increase in mercury concentrations over 2007-2009 (Fig. 1). Length also showed a linear trend of increase which will affect mercury trends as mercury concentration tends to be correlated with char length. However, char caught in 1992 and 1993 were approximately the same length as fish caught over 2007-2009 but mercury concentrations tended to be higher in the latter period. Using year, length and weight as variables in our General Linear Model analyses, variations in mercury level were described by year, length and weight, i.e., mercury concentrations are increasing with time. Factors affecting the variability in mercury concentrations are described by:

$$\text{Log (Hg)} = -13.4401 + 0.0058*\text{Year} + 0.0012*\text{Fork length (mm)} - 0.0001*\text{Wt (gm)}$$

$$\text{Adjusted multiple } R^2 = 0.20$$

While mercury concentrations appeared to be declining in Nain char between the 1998 and 1999 periods, the earliest these fish were measured for mercury, and 2007 and 2008, as reported in our last report, this was not a statistically significant trend (Fig. 2). Furthermore, when 2009 data are included, mercury appears to be increasing between 2007 and 2009 as observed for Cambridge Bay fish. However, this trend is driven by the fact that larger fish were provided over the same time period. Factors affecting the variability in mercury concentrations are described by:

$$\text{Log (Hg)} = -3.5999 + 0.0051*\text{Fork length (mm)} - 0.0004*\text{Wt (gm)}$$

$$\text{Adjusted multiple } R^2 = 0.34$$

While year is not a significant factor describing the 1998-2009 variation in mercury levels in Nain char, it is noteworthy that the increase in mercury concentration in 2009 was larger than the small increase in the size of fish provided. Additional analyses of the 2007-2009 data sets will be performed once stable isotope data are received.

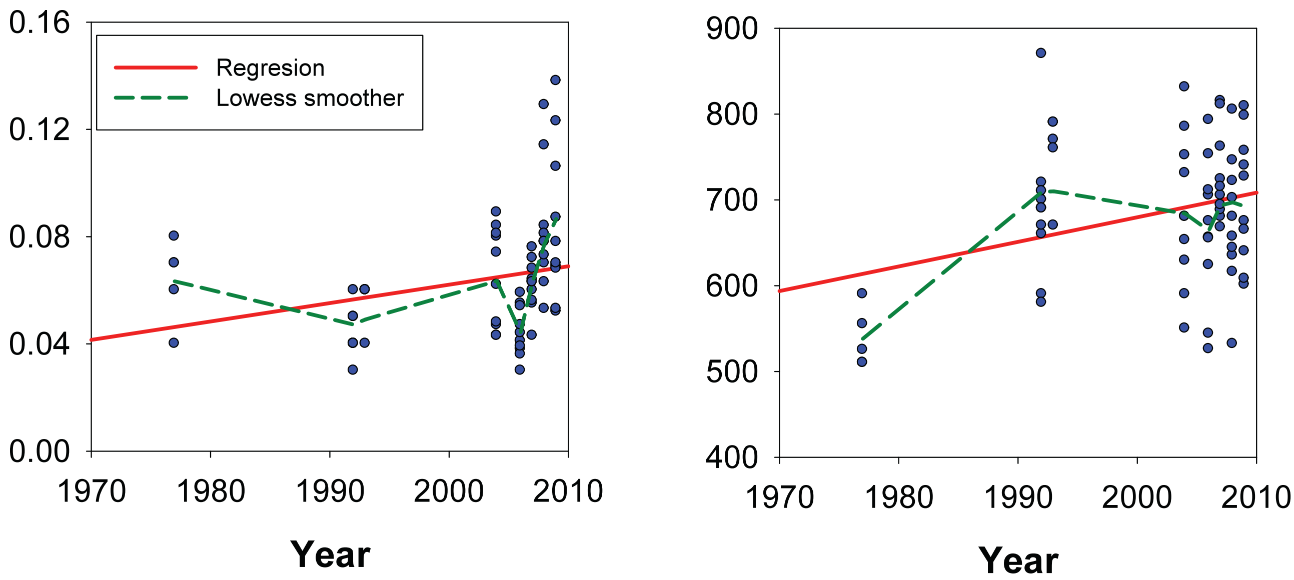

Figure 1. Time trends in log mercury concentrations (µg/g) in sea-run char collected at Cambridge Bay. A Lowess smoother has been run through the data.

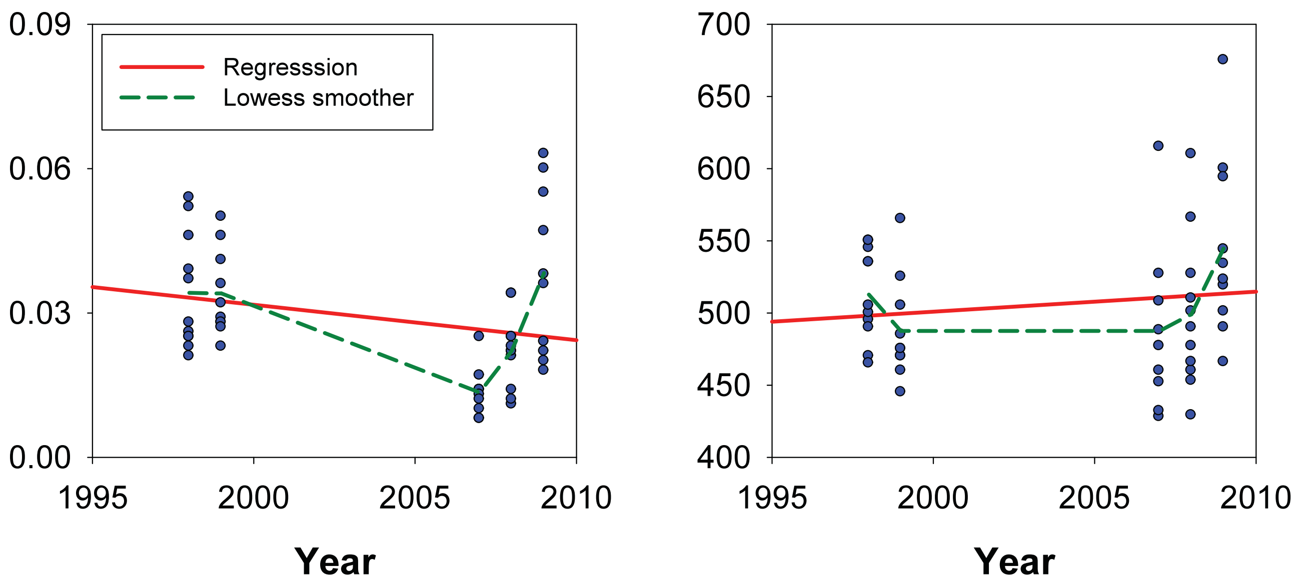

Figure 2. Time trends in log mercury concentrations (µg/g) in sea-run char collected at Nain. A Lowess smoother has been run through the data.

Temporal variations in POPs

Time trends in persistent organic contaminants have been explored (Fig. 3). At Cambridge Bay, most POPs occurred in lower concentrations over 2004-2008 than in 1987 with PCBs being the notable exception. In contrast, Pond Inlet, also analyzed in 1987, showed no evidence of POPs decline with the exception of HCH and possibly PCBs. Comparisons of 1987 data with more recent data are challenging because early measurements were made on whole body samples, whereas more recent measurements have been made on fillet; in addition, analytical methods have changed. We continue to try to locate archived char samples from these earlier periods for reanalyses. For Nain char, first analyzed in 1998, PCBs and, to a lesser extent, DDT and HCH concentrations, were lower in 2007 and 2008 than in 1998.

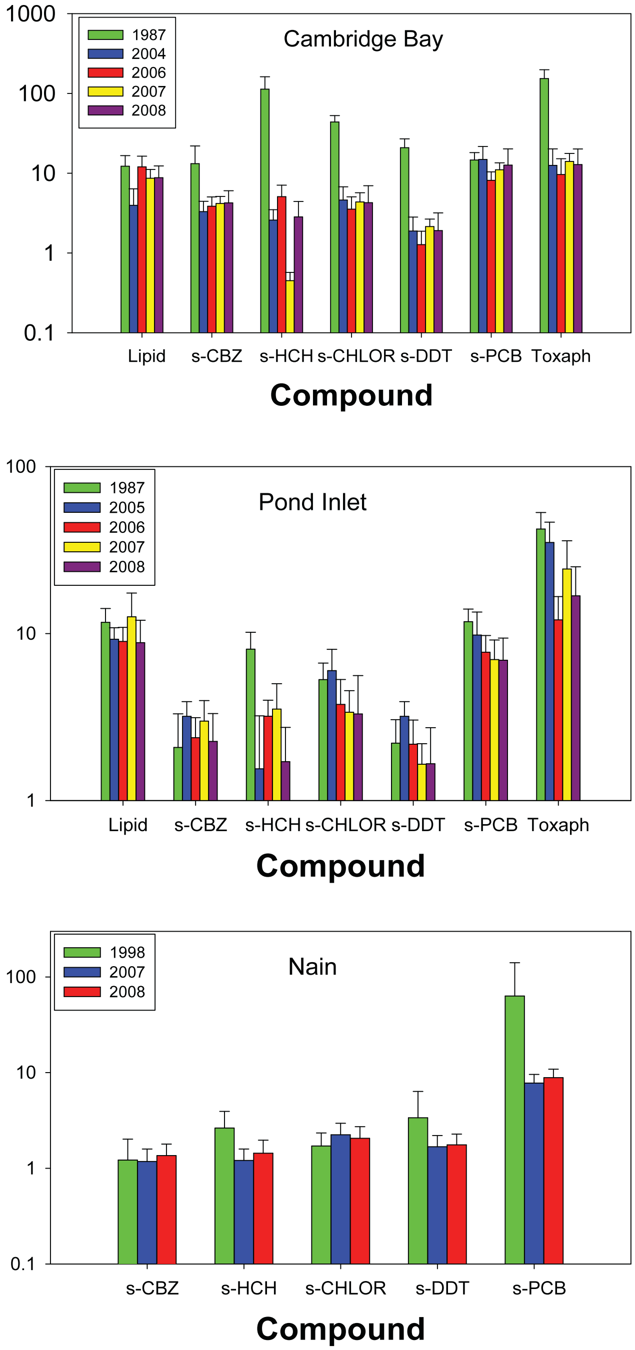

Figure 3. Time trends in lipids and persistent organic contaminants in sea-run char at Cambridge Bay, Pond Inlet, and Nain.

PDBEs

PBDEs occurred in low concentrations in sea-run char from Cambridge Bay, Pond Inlet, and Nain. PBDEs levels are in the general range observed for the early to mid 2002 in Quiet Lake (0.2 ng/g) in the Yukon but substantially lower than in Kusawa

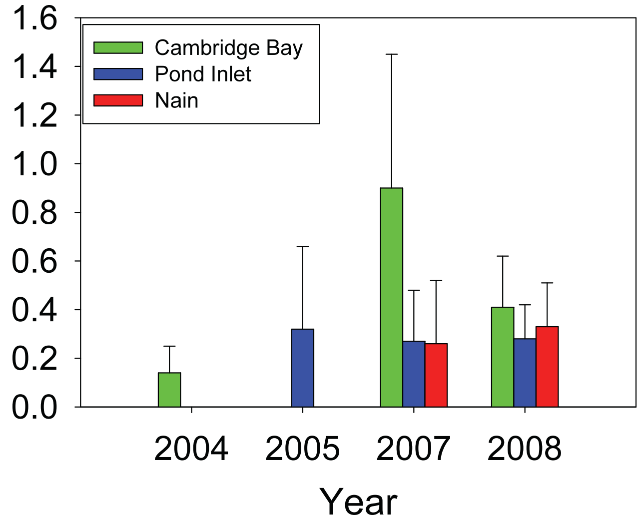

Figure 4. Temporal variability in PBDEs (ng/g wet weight) in sea-run char from Cambridge Bay, Pond Inlet, and Nain.

(2.6-7.5 ng/g) and Laberge (10.9-88.0 ng/g) lake trout (Stern et al. 2007). As more samples are analyzed, time trends will be investigated as in Muir et al. (2009b) for land-locked char.

Community consultations and presentations

Community consultations and collections went well. Fish were caught from Holman, Cambridge Bay, and Nain and shipped whole to Saskatoon in excellent condition. We visited Pond Inlet, Pangnirtung, and Iqaluit to collect the sea-run char, conduct marine food web sampling, to arrange for the collections of landlocked char populations and to talk about NCP char and seal studies: brief handouts where provided. Results of our research to date were reported at the September 2009 NCP workshop in Ottawa. Molleen Anaviapik with the Mittimatalik Hunters and Trappers and Javua Maniapik with the Pangnirtung Hunters and Trappers were able to attend the NCP workshop and meet with us, other researchers, agencies, and community members involved with NCP. An invited poster of this study was given at the 9th International Conference on Mercury as a Global Pollutant. Guiyang City, China. In addition, we continue to contribute to the AMAP expert work groups for mercury and POPs including an September meeting in Ottawa.

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Temporal trends of Persistent Organic Pollutants and Mercury in Landlocked Char in High Arctic Lakes

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Abstract

This long term study is examining trends over time of mercury and other trace elements, as well as legacy and new persistent organic pollutants (POPs) in landlocked Arctic char collected annually from three lakes near the community of Resolute Bay on Cornwallis Island (Amituk, Char and Resolute) and in Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. In 2009, arctic char samples were successfully collected from Lakes Amituk, Char, and Resolute. To assess trends over time, results from 2009 were combined with previous results from the same lakes. Mercury concentrations have increased in char from Amituk, Char and Resolute lakes, however, the increases are small (0.6-1.3% per year) and are not statistically significant. In Lake Hazen mercury is clearly showing a declining trend. The pesticide endosulfan was

Résumé

Cette étude à long terme se penche sur les tendances temporelles du mercure et autres éléments en trace, ainsi que des polluants organiques persistants (POP), anciens et nouveaux, chez l'omble chevalier dulcicole recueillis au moyen d'échantillons tous les ans dans trois lacs près de la collectivité de Resolute Bay, sur l'île Cornwallis (Amituk, Char et Resolute) et dans le lac Hazen, dans le parc national Quttinirpaaq, sur l'île d'Ellesmere. En 2009, des échantillons d'omble chevalier ont été prélevés dans les lacs Amituk, Char et Resolute. Afin d'évaluer les tendances temporelles, les résultats de 2009 ont été combinés aux résultats antérieurs pour les mêmes lacs. Les concentrations de mercure ont augmenté chez l'omble chevalier des lacs Amituk, Char et Resolute, mais ces augmentations sont faibles (de 0,6 à 1,3 % par année) et ne sont pas significatives, sur le plan statistique. Dans

detected in all landlocked char, however, the amounts were very low compared to other POPs. Brominated and fluorinated contaminants were also detectable at low concentrations in all char. The concentrations of brominated diphenyl ethers appeared to have reached a maximum in the past 5 years while information on levels of fluorinated chemicals is too limited to determine time trends. Elevated concentrations of fluorinated chemicals were confirmed by analysis of additional samples of char from Resolute Lake and from Meretta Lake which is upstream and closer to the source which is thought to be past use in fire fighting foams at Resolute airport.

Key messages

- Mercury concentrations appear to be increasing very slowly in arctic char from small lakes but are declining in Lake Hazen, the largest lake in this study
- Concentrations of endosulfan have increased over the past 20 years but overall are very low compared to other POPs
- Brominated and fluorinated chemicals are also detectable in char from all four lakes but at low levels compared to the legacy POPs such as PCBs.

le lac Hazen, les concentrations de mercure sont à la baisse. Le pesticide endosulfan a été détecté dans tous les ombles chevaliers, en concentrations cependant très faibles par comparaison aux autres POP. Des contaminants bromés et fluorés ont aussi été détectés à de faibles concentrations dans tous les ombles chevaliers. Les concentrations d'éthers de diphényle bromés ont semblé avoir atteint une valeur maximale au cours des cinq dernières années, et les données sur les concentrations de produits chimiques fluorés sont trop limitées pour établir des tendances temporelles. De fortes concentrations de produits chimiques fluorés ont été confirmées par analyse d'échantillons supplémentaires d'omble chevalier provenant des lacs Resolute et Meretta, situés en amont et plus près de la source qu'on croit être l'utilisation par le passé de mousse extinctrice à l'aéroport de Resolute.

Messages clés

- Les concentrations de mercure semblent augmenter très lentement chez l'omble chevalier des petits lacs et diminuer dans le lac Hazen, le plus grand de la présente étude.
- Les concentrations d'endosulfan ont augmenté durant les 20 dernières années mais, dans l'ensemble, sont très faibles par comparaison à celles d'autres POP.
- Les produits chimiques bromés et fluorés ont aussi été détectés dans l'omble chevalier de quatre lacs, mais à de faibles concentrations comparativement à celles d'anciens POP, tels les BPC.

Objectives

1. Determine long term temporal trends of persistent organic pollutants (POPs) and metals in landlocked Arctic char from lakes in the Canadian high arctic islands by analysis of annual or biannual sample collections.
2. Investigate factors influencing contaminant levels in landlocked char such as the influence of sampling time, water temperature, diet and climate warming.
3. Determine levels of current POPs and metals as well as "new" potential POPs in fish from lakes of importance to the community of Resolute Bay (Qausuittuq) and provide this information on a timely basis.

Introduction

Over the past few years the number of landlocked char populations and their food webs surveyed for contaminants in the Canadian arctic has increased significantly as a result of the PhD research by

Klaus Gantner (Gantner et al. 2009; Gantner et al. 2010a; Gantner et al. 2010b) and Heidi Swanson (Swanson and Kidd 2010; Swanson et al. 2010). Total mercury concentrations in char from 24 lakes showed a positive correlation with catchment-to-lake area ratio but concentrations were not related to latitude or longitude or food chain length (Gantner et al. 2010a). Mercury biomagnification in arctic lake food webs did not differ between lakes with and without anadromous Arctic char but was significantly higher in freshwater food webs than in the marine food web ((Swanson and Kidd 2010). Chételat et al.(2008) studied mercury levels in chironomid midges from many of the same lakes as Gantner et al and concluded that they were a major source of mercury for char.

While biological and foodweb processes are important and influence lake to lake variation the contaminant burdens of lakes in the high Arctic are ultimately derived from long-range atmospheric transport and deposition to the lake surface and from the lake catchment (Macdonald et al 2000). Local catchments are typically the primary source of water for arctic lakes (Wrona et al 2005). An intense 2-3 week runoff period (freshet) in spring/summer and direct precipitation both represent significant fractions of lake water budgets.

The sedimentary records of persistent organic pollutants (POPs) in small arctic lakes show that they reflect global trends in emissions (Muir et al. 1996; Stern et al. 2005; Breivik et al. 2006). Sedimentary records for mercury in 18 high arctic lakes showed overall increasing trends since the 1950s with anthropogenic fluxes in agreement with modeled estimates (Muir et al. 2009b). It follows that trends of these contaminants in lake food webs and in arctic char, the sole top predator fish in most high arctic lakes, should also be reflected relatively quickly in food webs and top predator fishes. This has been shown to be the case for fast changing contaminants such as PBDEs which increased by 59% in char from Lake Hazen over the period 2001-2008 (Muir et al. 2009a) reflecting 200-300 % increase in their use in consumer products in North America and Europe in the 1990s (Alcock et al. 2003). However, atmospheric emissions of mercury are changing relatively slowly. Mercury emissions are estimated to have increased by about 50% in Asia from 1990 to 2005 while declining in North America and Europe (AMAP/UNEP 2008; Pacyna et al. 2010). Small increases in mercury inputs could be obscured by year to year variation in biological and environmental factors influencing the availability of mercury.

This study reports on results of continued annual sampling and contaminant analysis of char at Resolute, Char and Amituk lakes on Cornwallis Island, as well as from Lake Hazen in Quttinirpaaq National Park on Ellesmere Island. Further details on past results from these study lakes are given in previous synopsis reports (Muir et al. 2005; Muir et al. 2006; Muir et al. 2007; Muir et al. 2008; Muir et al. 2009a).

Activities in 2009-10

Sample collection: Samples were successfully collected in July 2009 from Amituk, Char, and Resolute Lakes by our field team. Parks Canada approved sampling at Lake Hazen, which is in Quttinirpaaq National Park, but collection proved to be impossible due to lack of aircraft support to send a team there as result of the high cost of a dedicated flight. Instead we chose to analyse POPs in archived Lake Hazen samples from 2004-05 since they previously had only been analysed for mercury and 31 elements. Fish were dissected in Polar Continental Shelf Project labs at Resolute. Samples (skin- on fillets) were frozen in Resolute and then shipped to the Environment Canada labs, Burlington, Ontario, and stored at -20°C until analysis. Char otoliths were archived for future age determinations.

Chemical analysis: Analytical methods were unchanged from previous reports (Muir et al. 2006; Muir et al. 2007). All analyses were performed by the National Laboratory for Environmental Testing (NLET) at Canada Centre for Inland Waters in Burlington. Mercury and 31 other elements were analysed in Arctic char muscle (skinless). Organohalogen compounds were determined in homogenized char (muscle plus skin) samples. PCBs and OCPs were analysed in final cleaned up extracts were by gas chromatography with electron-capture detection (GC-ECD). All organohalogen analyses were conducted in the NLET “ultraclean” room (carbon and HEPA filtered air; positively pressured) to minimize background contamination. Toxaphene, endosulfan isomers, PBDEs and hexabromocyclododecane (HBCD) were analysed by low resolution GC-negative ion mass spectrometry (GC-NIMS) using a HP 5975 MSD. Toxaphene was determined as "total" toxaphene using a technical toxaphene standard and also by quantification of individual chlorobornanes (see Muir et al. (2004) for further details on methods). As of 2008 endosulfan sulfate was included in the GC-NIMS analysis.

Perfluorinated chemicals (PFCs) in char muscle were analysed using the method of Hansen et al which involved extraction with methyl tert-butyl ether (MTBE) and tetrabutylammonium hydrogen sulfate as an ion pairing reagent. The samples was then analysed by liquid chromatography tandem mass spectrometry as described by Butt et al. (2007). Major compounds analysed were perfluorohexanesulfonate (PFHxS), perfluoroheptanesulfonate (PFHpSA), perfluorooctane sulfonate (PFOS), perfluorooctanoate acid (PFOA), perfluorononanoate (PFNA), perfluorodecanoate (PFDA), perfluoroundecanoate (PFUnA) and perfluorooctansulfonamide (PFOSA).

Stable isotope analyses: Muscle from all fish analysed for mercury and POPs were analysed for stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) at University of Waterloo Environmental Isotope Lab in muscle samples using isotope ratio mass spectrometry.

Quality assurance (QA): Certified reference materials (CRMs) for heavy metals included DOLT-2, DORM-2 and TORT-2 (National Research Council of Canada) and 1588b cod liver from NIST (National Institute of Standards and Technology) for PCBs, OCPs, and PBDEs. CRMs and reagent blanks were also run with each sample batch of 10 samples. Blanks were generally <1% of measured values for individual OCPs and <5% for individual PCBs. Blanks for BDE 47 and BDE 99 ranged from 5-10% of values in samples while for BDE 209 blanks were up to 50% of sample values. All results for PBDEs were blank subtracted while no correction was used for PCB/OCPs. NLET organics and metals labs are participants in the NCP Quality Assurance Program. The NLET labs are accredited by the Standards Council of Canada through Canadian Environmental Analytical Laboratory program to the standard CAN-P-4D (ISO/IEC 17025).

Statistical analyses: Non-detect concentrations were replaced with a random number between 10% and 50% of the instrumental detection limit for calculation of arithmetic and geometric means and standard deviations. Results for each collection year were first tested for normality using the Shapiro-Wilk test. Results for all elements and POPs were log10 transformed in order to reduce coefficients of skewness and kurtosis to <2. Geometric mean concentrations and upper/lower 95% confidence intervals were calculated with log transformed data and back transformed for graphical presentation. Results for POPs were lipid adjusted by dividing by fraction lipid.

Capacity Building/Communications/Traditional Knowledge: The project depends on the help of local people in the Hamlet of Resolute. In 2009-10 Debbie Iqaluk again worked on the project and enabled us to collect fish from all our targeted lakes on Cornwallis Island in a wide range of weather and ice conditions. Timing of collections and number of samples collected relies heavily on the knowledge and experience of local people working on the project. This is particularly the case when the lakes have been ice covered, which is frequently the case in late July. The traditional method of getting onto the ice (sometimes by boat or by wading from shore) and angling from the surface proved very successful although a bit dangerous.

Results

Mercury and other elements: The trends of mercury over time in Arctic char from Amituk, Char and Resolute lakes are shown in Figure 1. While mercury levels appear to have increased from the 1990s, especially in Char and Amituk lakes, the increases calculated with the PIA statistical program (Bignert 2007) ranged from 0.6-1.3% when the 2009 results were included. This was not statistically significant. In Lake Hazen char, mercury concentrations have declined significantly in insectivorous char ($\delta 15N<12$) over the period 1990 to 2008. However, in piscivorous char ($\delta^{15}N>12$) from Lake Hazen there was no significant decline over the same period using the PIA program. Differences in water residence time, food web length, and watershed characteristics, as well as differences in proportions of piscivorous char, may help to explain the spatial and temporal

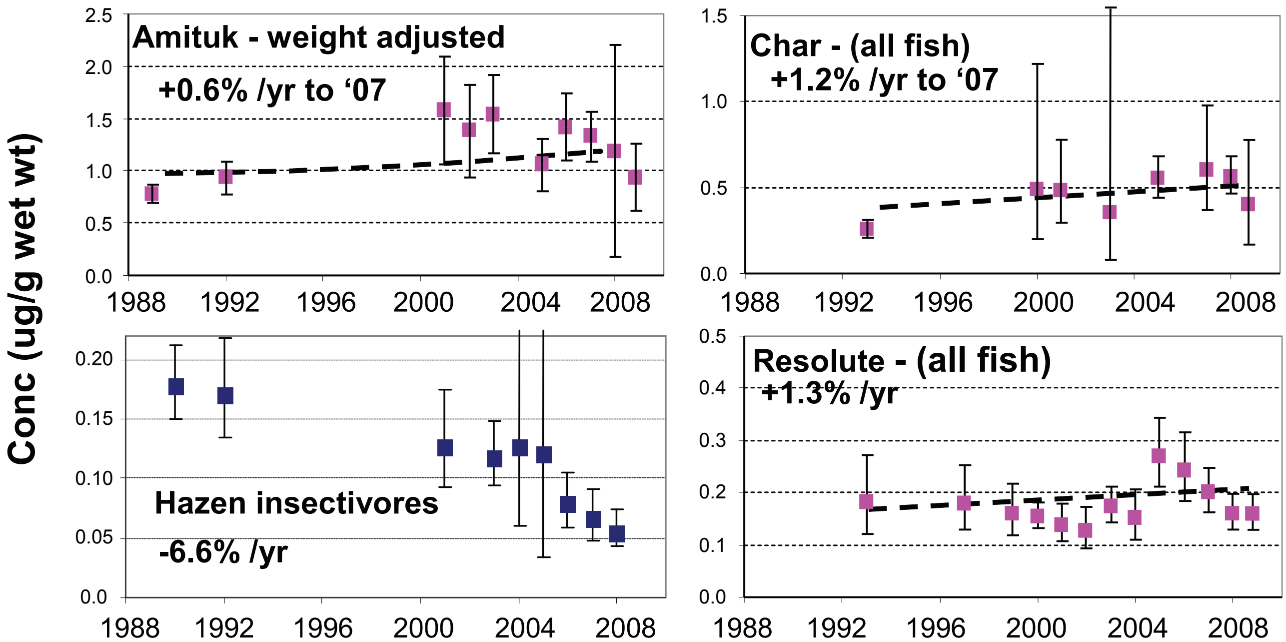

Figure 1. Trends of mercury (geometric means ± 95% confidence interval) in landlocked char from Amituk, Char, and Resolute lakes (early 90s-2009) and Lake Hazen to 2008. Results form Amituk and Resolute lakes are weight adjusted using analysis of covariance. Results for Lake Hazen are for insect eating char.

differences in mercury among the lakes (Gantner et al. 2010b). In addition to piscivory, differential consumption of various life stages of chironomids, the main diet item of char in high Arctic lakes, may affect lake to lake mercury patterns (Chételat et al. 2008). In Lake Hazen, in particular, mercury was higher and more variable in piscivorous char, i.e. those with $\delta^{15}N > 12$. Not shown are results for 31 other elements which were determined in all samples. We have reported on these previously (Muir et al. 2008). Generally 22 to 24 are above detection limits in char muscle.

Persistent organohalogen compounds: In previous reports we focussed on time trends of legacy POPs ((Muir et al. 2008; Muir et al. 2009a). Here we focus on endosulfan, PBDEs and PFCs for which there is much more limited information in landlocked arctic char.

Endosulfan: Analyses of α- and β-endosulfan as well as endosulfan sulphate were extended to sample extracts from earlier years. Previously, endosulfan isomers were determined by GC-ECD. We compared the α-endosulfan results for Char, Amituk and Resolute lakes determined by GC-NIMS analysis with those by GC-ECD. A total of 74 samples were available for comparison. The results showed that GC-NIMS and ECD results for α-endosulfan were strongly correlated ($r^2=0.32$; $P<0.001$) with the NIMS results averaging about 50% of those reported by ECD. This allowed the α-endosulfan results for all 4 lakes to be estimated using the equation:

$$\text{Log}[\alpha\text{-endoMS}] = 0.67^{*}\log[\text{a-endoECD}]-0.109$$

Figure 2 presents time trends of α-endosulfan in char. Most results prior to 2006 are estimated while those from 2007-2009 are GC-NIMS analyses. β-endosulfan was generally not detected (<0.01 ng/g) while endosulfan sulphate could not be estimated because it was not determined by GC-ECD. The results suggest that endosulfan concentrations were increasing during the 1990s until about 2004, particularly in Amituk and Resolute Lakes. Further reanalyses are planned to refine the estimated values.

PBDEs: Concentrations of tetra- and penta-brominated diphenyl ethers (PBDEs) increased significantly and rapidly in most of the lakes from the 1990s until about 2005 (Figure 2). The year for maximum concentrations varied. Maxima were

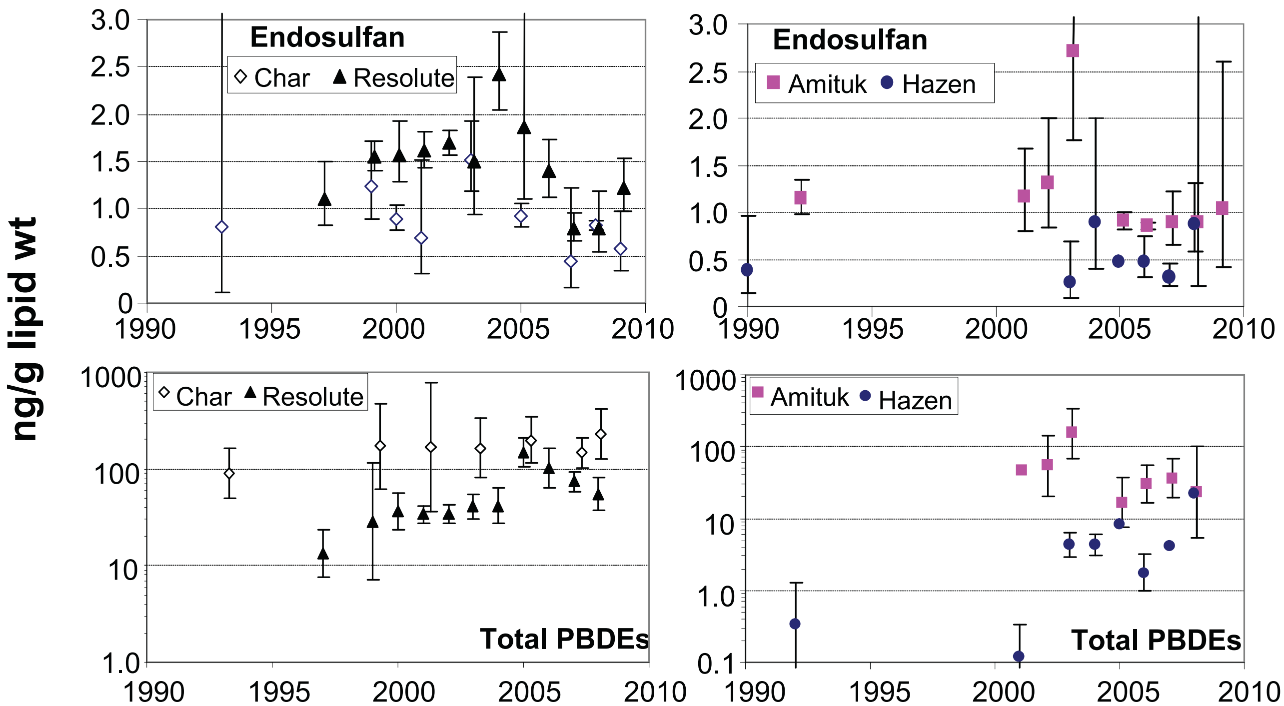

Figure 2. Trends of α-endosulfan (upper panels) and total PBDEs (lower panels) in landlocked char from Amituk, Char, Hazen, and Resolute lakes. Symbols are geometric means and vertical lines are 95% confidence intervals. Endosulfan results from the 1990s and early 2000s are estimated based on a strong correlation between concentrations determined by GC-ECD and those determined by GC-NIMS.

Table 1. Concentrations (ng/g wet wt) of major PFCs[1] in arctic char muscle from five Arctic lakes

PFC	Amituk		Char		Hazen			Meretta	Resolute	
	2007	2008	2007	2008	2003	2007	2008	2006	2007	2008
	11	3	5	9	10	3	10	10	14	10
PFOS	0.19	0.15	0.50	0.69	0.013	0.044	0.034	11	25	31
min	0.026	0.026	0.33	0.46	<0.005	0.035	0.007	7.6	13	13
max	2.5	0.48	0.64	1.6	0.027	0.061	0.13	20	53	122
PFOSA	0.10	0.093	0.081	0.053	0.006	0.016	0.012	0.77	0.030	0.51
min	0.042	0.053	0.043	0.01	0.005	<0.005	0.005	0.27	0.005	0.17
max	0.17	0.224	0.15	0.195	0.015	0.060	0.089	1.3	0.869	1.8
PFNA	0.11	0.136	0.21	0.17	0.20	<0.005	0.22	0.191	0.347	0.51
min	0.047	0.103	0.17	0.052	0.13	<0.005	0.081	0.085	0.166	0.17
max	0.33	0.191	0.28	0.82	0.28	<0.005	0.58	0.284	0.700	1.7
PFDA	0.055	0.004	0.060	0.006	0.025	0.022	0.078	0.026	0.013	0.007
min	0.021	<0.003	0.030	<0.003	0.010	0.018	0.027	<0.003	<0.003	<0.003
max	0.13	0.005	0.094	0.085	0.073	0.028	0.22	0.063	0.22	0.12

found in 2003 in Amituk, 2005 in Resolute and 2009 in Lake Hazen and in Char Lake. However, PBDEs in Char Lake have been elevated for a longer time period that in nearby Resolute Lake and have continued to increase although at a much slower rate than in the other lakes.

Perfluorinated chemicals: PFCs were previously reported for char collected in 2007 from Resolute, Char and Amituk Lakes (Muir et al. 2008). Here results have been updated to include Lake Hazen. Concentrations of PFOS and its precursor PFOSA in char from Lake Hazen were lower than in Amituk or Char Lake and over 1000x lower than in Resolute Lake (Table 1). PFOS and PFOSA were also elevated in char from Meretta Lake, which is upstream of Resolute Lake, were also analysed (Table 1). PFC concentrations in Lake Hazen were higher in 2008 than in 2003. Analyses of lake waters and sediments have shown that Amituk and Char have background concentrations that are expected in remote lakes receiving PFCs solely via atmospheric deposition (Stock et al. 2007) while Resolute and Meretta Lakes appears to have been contaminated with aqueous film forming foams used for fire fighting at most airports. The history of contamination of Meretta Lake by nutrients in sewage entering wetlands just west of the lake, and recovery after the waste effluent was stopped in 1998, is described by Douglas and Smol (2000).

Discussion and Conclusions

Analysis of trends of mercury in landlocked char from the four lakes in this study shows that with results from 2009 included, the small rates of increase in mercury are not statistically significant in the three smaller lakes on Cornwallis Island while it has declined in insect eating char from Lake Hazen. The small rate of increase in the Cornwallis Island lakes fits with the slow increase in global, and especially Asian, anthropogenic mercury emissions. The decline in Lake Hazen is more difficult to explain but could be related to changes in the food web because it is more pronounced in insectivorous char than in larger piscivorous char. Annual sampling and low within year variation is clearly needed to detect statistically significant trends of mercury.

This study has examined trends in levels of endosulfan in landlocked char for the first time. The interest in endosulfan is due to the recent proposal to list it as a POP under the Stockholm Convention. While endosulfan was detectable in all fish (as α-endosulfan and degradation product endosulfan sulfate) it was present at lower concentrations than the legacy OCPs such as chlordane.

The increase in PBDEs in landlocked char is in general agreement with observations for ringed seals in the Canadian arctic (Ikonomou et al. 2002; Ikonomou and Addison 2008) and for arctic air (Su et al. 2007). A decline would be expected considering that penta- and octa-PBDEs were phased out in Europe in 2004 and in the USA by the end of 2005 (de Wit et al. 2010).

The levels and trends of PFCs in landlocked char were updated in this report. The results from Lake Hazen suggest levels are increasing. However, temporal trend data are still limited because analyses only started 2006-07. Further analyses are underway to develop the full temporal trends for PFCs which are already available for other contaminants.

NCP Performance Indicators

Number of northerners engaged (directly) in the project: 1

Number of meetings/workshops held in the North by the project: 0

Number of students (both northern and southern) involved in the project in 2009-10: 1

Number of peer reviewed publications in 2009-10: 3

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

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Abstract

Our study is investigating whether contaminant levels are changing in fish in the Northwest Territories with a focus on Great Slave Lake which we have been studying since 1993. We are investigating lake trout in the West Basin (mainly near Hay River) and East Arm (near Lutsel K'e). We also are investigating burbot from the Fort Resolution area of the West Basin; sampling at Lutsel K'e was discontinued in 2004 but was resumed in 2007 under our companion Great Slave Lake project. Mercury concentrations are declining in lake trout and burbot at all three locations although the trend for East Arm lake trout is not statistically significant. HCH and DDT also are declining in lake trout and burbot as are PCBs for West Basin burbot; lake trout are showing no decline in PCB concentrations in either location. Spatial trend monitoring for mercury was conducted in Cli and Colville Lakes in 2008; there were only slight increases in length-adjusted mercury concentrations since the previous

Résumé

Notre étude consiste à déterminer si les concentrations de contaminants changent chez les poissons des Territoires du Nord-Ouest, l'accent étant mis sur le Grand lac des Esclaves, que nous étudions depuis 1993. Nous nous penchons sur le touladi de West Basin (principalement près de la rivière au Foin) et d'East Arm (près de Lutsel K'e). Nous étudions aussi la lotte du secteur de Fort Resolution dans West Basin; l'échantillonnage à Lutsel K'e a cessé en 2004 et repris en 2007, dans le cadre de notre projet connexe sur le Grand lac des Esclaves. Les concentrations de mercure chez le touladi et la lotte baissent aux trois endroits étudiés, mais la tendance pour le touladi d'East Arm n'est pas significative, sur le plan statistique. Les concentrations de HCH et de DDT sont aussi à la baisse chez le touladi et la lotte tout comme le sont les concentrations de BPC chez la lotte de West Basin; aux trois endroits étudiés, les concentrations de BPC ne diminuent pas. La surveillance des tendances spatiales du mercure a été réalisée dans les lacs Cli et Colville en 2008;

measurement. For Great Bear Lake, sampled as part of a different study, mercury levels in length-adjusted fish caught in 2009 were higher than in previous measurements. Overall, there is compelling evidence of an increase in mercury in lakes in the Northwest Territories with the increased most pronounced in smaller, shallower lakes with large watersheds. This issue was discussed within the Northwest Territories Regional Contaminants Committee with mercury advisories issued in summer 2010 for Kelly and Trout Lakes and extended for Cli and Lac Ste. Therese.

depuis la mesure précédente, une légère augmentation des concentrations de mercure corrigées en fonction de la longueur a été observée. Pour ce qui est du Grand lac de l'Ours, qui a fait l'objet d'un échantillonnage dans le cadre d'une autre étude, les concentrations de mercure corrigées en fonction de la longueur des poissons prélevés en 2009 étaient supérieures à celles des précédentes mesures. Dans l'ensemble, il existe de fortes preuves d'une augmentation des concentrations de mercure dans les lacs des Territoires du Nord-Ouest, et cette augmentation est plus prononcée dans les petits lacs peu profonds à bassins hydrographiques de grande taille. La question a fait l'objet d'une discussion au Comité régional des contaminants des Territoires du Nord-Ouest, et des avis concernant le mercure ont été publiés à l'été 2010 pour les lacs Kelly et Trout, puis étendus aux lacs Cli et Sainte-Thérèse.

Key messages

- Mercury levels in lake trout from Cli and Colville Lakes were similar in 2009 as in 2005 although length-adjusted comparisons were slightly higher in 2009. Length-adjusted mercury levels in lake trout from Great Bear were higher in February 2009 caught fish (2008 growing season) than in earlier years
- There also is a trend for mercury to be increasing in lake trout and burbot in Great Slave Lake with the trend most apparent for burbot and West Basin lake trout. The detection of time trends appears to be related to fish biology (burbot are more littoral than lake trout) and depth (the West Basin is shallower than the East Arm). Trends may be driven by global warming and/or an increase in mercury emissions.
- Among the legacy persistent organic contaminants, HCH is showing a strong trend of decline as is DDT for lake trout from both basins and burbot. In contrast PCBs are declining in West Basin burbot but not lake trout in either of the two study locations. Burbot from the East Arm, investigated under our enhanced monitoring project, are showing similar trends as West Basin burbot with the exception of PCBs which are not declining.
- Contaminant trends are strongly affected by the species considered, its ecology within the lake, and limnological differences between lakes.

Messages clés

- Les concentrations de mercure chez le touladi des lacs Cli et Colville ont été comparables en 2009 et en 2005, quoique les concentrations corrigées en fonction de la longueur étaient légèrement plus élevées en 2009. Chez le touladi du Grand lac de l'Ours, les concentrations de mercure corrigées en fonction de la longueur ont été plus élevées chez les poissons prélevés en février 2009 (saison de croissance 2008) que durant les années précédentes.
- Les concentrations de mercure ont aussi tendance à augmenter chez le touladi et la lotte du Grand lac des Esclaves, et cette tendance est plus évidente chez la lotte et chez le touladi de West Basin. La détection des tendances temporelles semble être associée à la biologie des poissons (la lotte étant une espèce plus littorale que le touladi) et à la profondeur (le West Basin est moins profond que l'East Arm). Le réchauffement planétaire ou l'augmentation des émissions de mercure ont peut-être influé sur ces tendances.
- Parmi les anciens contaminants organiques persistants, le HCH est fortement à la baisse tout comme l'est le DDT chez le touladi des deux bassins et chez la lotte. Par contre, les BPC sont à la baisse chez la lotte de West Basin, mais non chez le touladi à l'un ou l'autre des deux endroits étudiés. La lotte d'East Arm, étudiée dans le cadre de notre projet de surveillance

- While mercury trends of increase are slow in large lakes (Great Slave, Great Bear, Colville), these lakes are important in domestic fisheries with communities relying regularly on these fish; sports and commercial (Great Slave Lake) also are important. Mean mercury levels are below the 0.5 μg/g commercial sale guideline.
- While not studied, northern pike and walleye populations in smaller, shallower lakes with large watersheds may be showing pronounced increases in mercury concentrations and lakes which support a significant fishery should be investigated.

accrue, semble montrer des tendances semblables à la lotte de West Basin, à l'exception des concentrations de BPC qui ne diminuent pas.

- Les concentrations des contaminants sont fortement affectées par l'espèce étudiée, son écologie dans le lac et les différences, sur le plan de la limnologie, entre les lacs.
- Même si l'augmentation des concentrations de mercure est lente dans les grands lacs (Grand Lac des Esclaves, Grand lac de l'Ours et lac Colville), ces lacs sont importants pour les pêches intérieures, parce que des collectivités en dépendent régulièrement; la pêche sportive et commerciale (Grand Lac des Esclaves) sont aussi importantes. Les concentrations de mercure moyennes sont inférieures à la ligne directrice de 0,5 μg/g pour la vente commerciale de poisson.
- Bien que les concentrations de mercure n'ait pas été étudiées dans les populations de grand brochet et de doré jaune, leur augmentation pourrait être importante dans les lacs plus petits et moins profonds à bassins hydrographiques de grande taille ainsi que dans les lacs où la pêche est importante; cet aspect devrait être étudié.

Introduction

Great Slave Lake is a key component of NCP's biomonitoring program for contaminant trends with organic contaminant studies commencing on this lake in 1993. The lake was initially selected for study because of its size, accessibility, and the importance of fish to the commercial, domestic, and sports fishery. Sampling was periodic between 1993 and 1996 and then with the establishment of the NCP biomonitoring program in 1998, became annual with the exception of 2003. At that time, metals, including mercury, were added to the monitoring program and sampling became more rigorous with twenty fish of each species and from each location collected annually. Inexpensive measurements (length, weight, age, carbon and nitrogen isotopes, and percent moisture) were performed on all fish to provide metrics of their ecology. Contaminant analyses were performed on a subset of ten fish with a tissue archived maintained for all 20 samples per location, time and species. With ten to eleven years of high quality biomonitoring data and less rigorous NCP data going back to 1993 (length and weight were not always measured and often only five fish were analyzed), temporal trends are now beginning to be detected.

Two species of fish are being monitored for contaminant trends and at one or two locations in the lake. While the original rationale for study two locations (the West Basin and East Arm) was to consider the influence of the Slave River of contaminant loading and biomagnification in Great Slave Lake, the rationale has taken on new dimensions. The West Basin is shallower, warmer, and more productive and with a shorter residence time than the East Arm (Rawson 1955). Thus fish living in the West Basin may respond more rapidly to changes in contaminant inputs and other broad scale aspects of the lake environment, e.g., a warming trend, than the East Arm (Larsson et al. 1998; Berglund et al. 2001; Evans et al. 2005b).

Lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*) were selected for study because the former is important in the domestic, sport and commercial fishery (West Basin) while the liver of the latter is prized among First Nations communities and, because it is lipid-rich and hence high in persistent organic contaminants, merited monitoring (Kidd et al. 1995; Evans et al. 2005a; Ryan et al. 2005). However, greater appreciation is now being given to the differences in the ecology of the two species which, in turn, may affect how contaminant trends are realized. Lake trout (*Salvelinus namaycush*) is an omnivorous, cold-water stenotherm with a thermal optimum of ca. 10°C; as such it is confined to cold, deep and well-oxygenated waters during summer although it does venture into the littoral where the lake edge is steep-sided and deep (Rawson 1951; Scott and Crossman 1998). Burbot also is a predatory fish and while it resides in the hypolimnion, in addition to large northern rivers, its thermal optimum is 15.6°-18.3°C (Scott and Crossman 1998). In Great Slave Lake, burbot is found both in shallow waters and deep waters down to depths of 100 m (Rawson 1951). Burbot are more commonly captured by hook and line suggesting that they are an "ambush" predator whereas lake trout are more traditional "search" predator. While burbot can occupy similar cold water habitats as lake trout, their more enriched carbon isotopic signature (Evans 1995), especially in the East Arm, suggest that they are more littoral zone feeding in their carbon sources.

In addition to temporal trend monitoring of mercury and persistent organic contaminants, NCP allows for spatial monitoring on a periodic basis, i.e., every ca. 5 years. For fish in the Northwest Territories, the chemical of concern is mercury. As revealed in a series of stock assessment studies conducted in the late 1990s and early 2000s mercury concentrations were found to exceed commercial sale guidelines (0.5 μg/g) in many lakes along the Mackenzie River (Stewart et al. 2003 a, b; Lockhart et al. 2005). Companion studies determined that these higher mercury levels were related to a combination of old fish living in small lakes (Evans et al. 2005b). These investigations form the foundations of NCP's spatial monitoring program for mercury trends in lake trout. Colville Lake, Lake Belot, Kelly Lake, Lac Ste. Therese, Cli Lake, Great Bear Lake and Trout Lake were investigated as part of the current NCP blueprint; large increases in mercury concentrations recently were observed in Kelly, Trout and Lac Ste. Therese (Evans and Muir 2004, 2005, 2006, 2007, 2008, 2009). Similarly, Carrie et al. (2010) have reported a recent increase in mercury concentrations in burbot collected from the Mackenzie River at Fort Good Hope.

Objectives

1. Determine temporal trends in persistent organic contaminants, mercury, and other metals in lake trout at two locations (West Basin near Hay River, East Arm at Lutsel K'e) through annual sampling, extending the 1993-2008 data sets to 2009 and beyond.
2. Investigate factors affecting temporal variability in contaminants in lake trout including length, age, trophic feeding, and lipid levels.
3. Determine temporal trends in persistent organic contaminants, mercury and other metals in burbot in the West Basin (offshore of Fort Resolution) extending the 1993-2008 data sets to 2009 and beyond.
4. Investigate factors affecting temporal variability in contaminants in burbot including length, age, trophic feeding, and lipid levels.
5. Continue the multi-year program based on a 5-year cycle of monitoring mercury trends in lake trout at one or two locations in the Northwest Territories. The two locations selected for 2009 were Cli Lake and Colville Lake which were last studied in 2005.
6. Participate in and contribute information to AMAP and CACAR expert work groups for trend monitoring for POPs and mercury.
7. Communicate results to the communities and the commercial fisheries in a timely manner, including through the Northwest Territories Regional Contaminants Committee.

Activities in 2009-2010

Great Slave Lake – collections and biological measurements

In 2009-2010, 20 lake trout were collected from the Lutsel K'e area (East Basin) and northwest of Hay River (West Basin). In addition, 20 burbot were collected in the Fort Resolution area (near the Slave River inflow, West Basin). In addition, northern pike were collected from Fort Resolution and burbot from Lutsel K'e as part of our second Great Slave Lake study. Northern pike sampling was resumed at Fort Resolution in order to investigate mercury time trends in a strongly littoral zone fish. Collections were done by community members or by a commercial fisherman (Hay River). Fish were frozen and shipped whole to Environment Canada (Saskatoon) for processing. Total length, fork length (lake trout only), round weight, liver weight, gonad weight, stomach weight and gender were determined for all fish; features such as the presence of parasites, discolored liver, skinniness, and crude measures of stomach contents were noted. Aging structures (otoliths) were removed from all fish and age later determined for all fish. Approximately 100 gm of dorsal fillet, the liver and stomach were removed from all fish for analyses and/or archiving. A subsample of fillet was freeze-dried, percent moisture determined, and analyzed for carbon and nitrogen stable isotopes for all 20 fish from each location. Ten fish from each location were selected for organic contaminant and metal analyses with organic contaminant analyses.

Spatial trend monitoring – collections and biological measurements

Colville and Cli lakes were selected for spatial trend monitoring of mercury in 2009/2010. Colville Lake was previously monitored in 2005 and Cli Lake in 2006. Other lake trout lakes which could have merited periodic assessment based on Evans et al. (2005) and Lockhart et al. (2005) were remote and not readily accessible without additional funds. Twenty lake trout were collected from Colville Lake but only nine lake trout (and two whitefish) were collected from Cli Lake. In addition, we have been providing lake trout from Great Bear Lake for PBDE analyses as part of a Canada-wide Chemical Management Plan study led by Sean Backus. Subsamples of fish are returned to us to stable isotope and mercury analyses to supplement NCP mercury trend monitoring.

Chemical analyses

Organic contaminant analyses of lake trout muscle (skin on) and burbot liver are ongoing. Determinations will include PCB congeners and 30 OC pesticides (DDT, chlordane, toxaphene, etc.) and OC by-products (e.g. HCB, octachlorosytrene, etc.), and related compounds. Brominated flame retardants and perflurora acids and neutral precursor also will be determined. In brief: fish samples will be homogenized and Soxhlet extracted with dichloromethane-hexane (1:1). Organochlorines will be isolated by gel permeation chromatography (GPC) followed by Silica gel cleanup then analyzed by GC-ECD. Lipid will be determined using the GPC lipid fraction. PFAs will be analysed by LC-tandem MS. Perfluoroalkyl acids analyses will be conducted at Environment Canada-Burlington following Butt et al. (2007).

Muscle samples (lake trout and burbot) were analyzed for mercury using cold vapor atomic absorption spectrometry (CVAAS) and will be analyzed for 31 elements using Inductively Coupled Plasma-high resolution mass spectrometry (ICP-MS) by the National Laboratory for Environmental Testing (NLET) at EC-Burlington.

Muscle samples were analyzed for stable isotope ratios of carbon and nitrogen at EC-Saskatoon using isotope ratio MS on all fish to infer trophic position and carbon sources. We also determined percent moisture of fish tissue as part of our stable isotope analyses

Results and discussion

Spatial trend monitoring for mercury

Cli Lake is a 43 km^2 lake with a maximum depth of 86 m; it is in the Deh Cho near Fort Simpson. There is a large and modern lodge on the lake and at least three cabins. Mercury levels first were measured in fish in Cli Lake as a part of stock assessment studies in 1996 (Lockhart et al. 2005; Evans et al. 2005b). Mercury levels in lake trout were high averaging 0.79 μg/g: fish also were old with an average age of 15.7 yr (Evans et al. 2005b). Mercury levels were measured again in lake trout in 2005 as part of the NCP periodic assessment studies. Data are graphed in figure 1 but limited to fish 450-900 mm in length. In addition two data points for 2005 are not included as the fish could not be aged (and hence must be old) but the mercury concentrations were low and appear to be outliers: these two samples will be rerun. Only seven data points are available for 2009 caught fish. Temporal trends are difficult to evaluate because few large fish (>600 mm) were caught in 1996

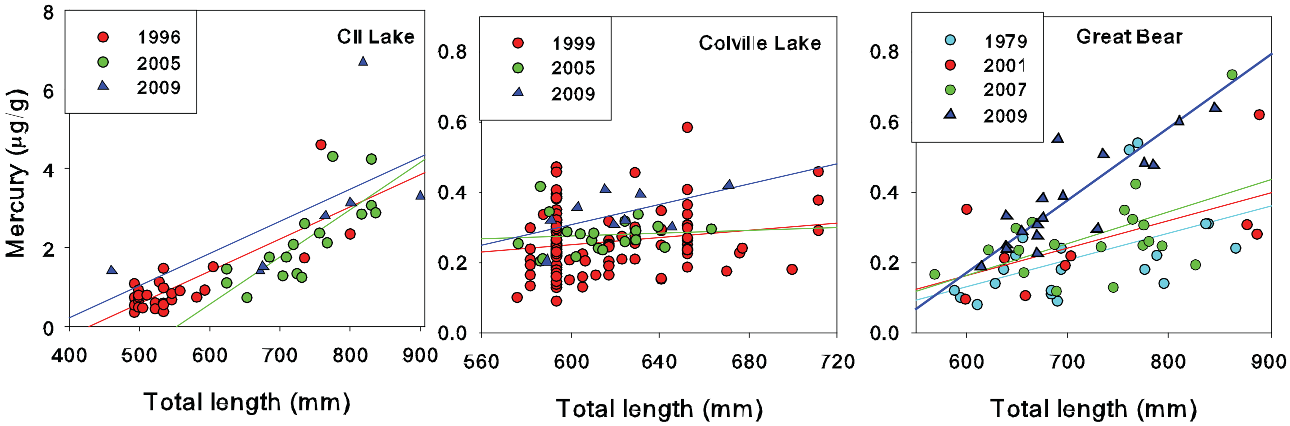

Figure 1. Mercury versus total length for lake trout caught at different times from Cli Lake, Colville Lake and Great Bear Lake. Original data have been edited to confine graphic presentation to the same length ranges for the years of study for each lake.

whereas this was the dominant size category in 2005 and 2009 when larger mesh nets were used. All that can be said is that mercury levels remain high in Cli Lake fish, with a possible slight trend of increase in 2009. Predicted mercury levels for a 650-mm trout were 1.81 µg/g in 1996, 1.17 µg/g in 2005, and 2.28 µg/g in 2009.

Colville Lake is a 437 km^2 with a maximum depth >20 m. It was first sampled as part of 1999 stock assessment studies (Lockhart et al. 2005); lake trout had a mean mercury concentration of 0.20 µg/g, a mean length of 512 mm and a mean age of 8.8 years. This relatively young age suggests greater fishing pressures than in Cli Lake; lake trout in Colville Lake also have a faster growth rate than in Cli Lake. The community of Colville Lake (population ca. 130) lives on the lake and is isolated with access only by air in summer and fishing is most likely an important source of food; there are a series of commercial tourist cabins on the lake. Lake trout were sampled again in Colville Lake as part of NCP periodic assessments. Data are graphed restricting fish to 575-715 mm in length to maximize comparisons of similar size fish across the years. The mercury length regression was similar in 1999 and 2005 whereas for 2009-caught fish, the slope and intercept were higher suggesting a small increase in mercury concentrations, especially for larger fish. Predicted mercury concentrations for a 650-mm lake trout were 0.25 µg/g in 1999, 0.27 µg/g in 2005 and 0.31 µg/g in 2009, again suggesting a modest trend of mercury increase.

Great Bear Lake has a surface area of 25,900 km^2, a maximum depth of 413 m and a mean depth of 71.7 m. Great Bear Lake was not part of the NCP monitoring program in 2009-2010 but data are included nevertheless because of our findings. Mercury levels were first measured in Great Bear Lake trout in 1978 and 1979 (Lockhart et al. 2005), and again in 2001 where mean fish length was

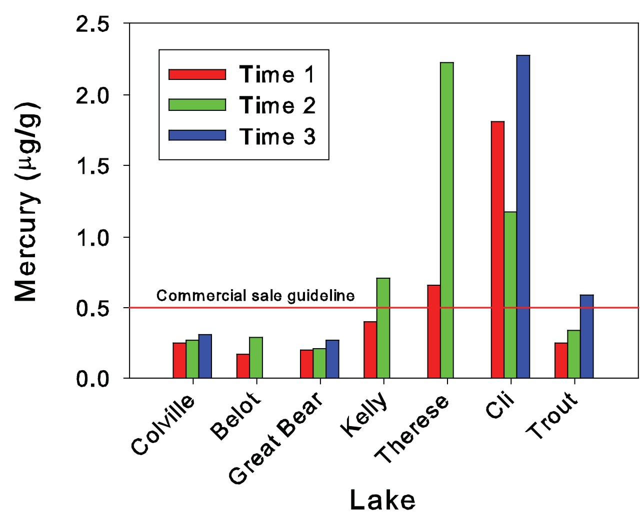

Figure 2. Length adjusted mercury concentrations for various times periods for collections in Colville, Belot, Great Bear, Kelly, Lac Ste. Therese and Trout Lakes from the early 1990s (Trout Lake) to 2009 (Colville, Cli and Great Bear). Length adjustments are based on 555-mm (Trout Lake), 600 mm (Kelly, Lac Ste. Therese) or 650 mm (Colville, Great Bear, Cli Lakes) depending on the size range of fish caught.

737 mm, mean age 19.9 years, and mean mercury concentration was 0.35 μg/g (Evans et al. 2005b). Lake trout were sampled again in 2007, as part of NCP studies, and in February 2009; trout caught in 2009-2010 have yet to be analyzed. Data are plotted for fish 550-900 mm in length. Slopes and intercepts are similar for 1979, 2001 and 2007-caught fish with 650-mm fish having a predicted mercury concentration of 0.17 μg/g, 0.20 μg/g and 0.21μg/g. For February 2009 (2008 growing season) the slope increased markedly with the predicted mercury concentration of 650 mm fish reaching 0.27 μg/g.

Eight lakes have been examined as part of our spatial trend monitoring program. Stark Lake, sampled in 2008 is not included in the data sets because these fish are believed to have migrated into the lake from the Lutsel K'e area of Great Slave Lake at the time of the sampling (Evans and Muir 2009). Considering the remaining seven lakes, length adjusted mercury concentrations are shown for the two or three times during which these lakes were sampled between the 1990s and 2009. Overall differences in mercury levels in lake trout between the seven lakes has previously been related to a combination of lake size, watershed:lake area ratio, and fish age (Evans et al. 2005) and these differences have been maintained. What is striking is the general tendency for mercury concentrations to be highest in the last year investigated with striking increases in Kelly Lake, Lac Ste. Therese, and Cli Lake; the Cli Lake increase may not be reliable because of the small number of fish sampled. In two of these lakes, mercury in the last sampling period exceeded the guideline for the commercial sale of fish and consumption advisories were recently issued; advisories issued earlier for Lac Ste. Therese and Cli Lake were maintained.

Northern pike and walleye have not been investigated as part of the NCP spatial trend monitoring program. Since these fish are most common in small, shallow lakes, and these are the types of systems which appear to be most vulnerable to mercury increases, some of the lakes investigated under Stewart et al. 2003 a, b; Lockhart et al. 2005; Evans et al. 2005b) should be revisited. We expect to be analyzing some pike and walleye from Deh Cho lakes in this fiscal year.

Temporal trend monitoring: Great Slave Lake
Mercury time trends have been examined for burbot collected from the Fort Resolution area and lake trout from the Hay River and Lutsel K'e area. Various combinations of General Linear Model (GLM) analyses have been performed using length, weight, age, percent lipid and stable carbon and nitrogen as independent variables. The longest time period that can be considered include the commercial fish record but are limited to length and weight as independent variables, in addition to year. In brief, these analyses have determined that mercury concentrations are increasing significantly with time in West Basin burbot and lake trout but that for East Basin (Lutsel K'e) lake trout the trend of increase is not statistically significant (Fig. 3). The overall increase in mercury concentrations is

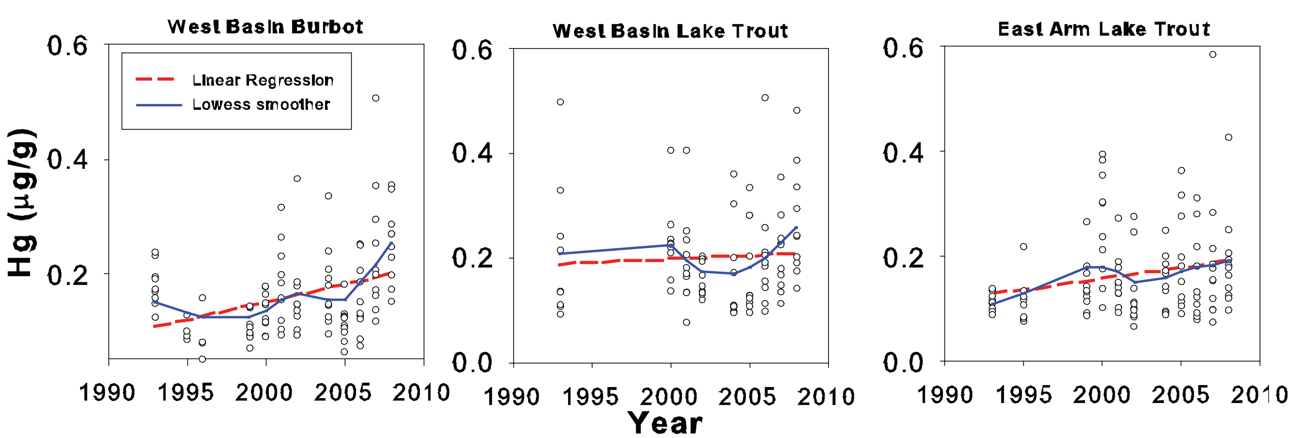

Figure 3. Mercury (log scale) time trends in lake trout collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake, 1993-2008. Also shown are burbot from Fort Resolution. Data are presented as the individual data points with a linear regression and Lowess smoother added to visualize trends. Analyses are based on dorsal fillet.

consistent with our spatial trend monitoring for lakes along the Mackenzie River. Burbot, as a more littoral zone fish than lake trout, is showing the stronger time trends. The slower time trend of increase for East Arm than West Basin lake trout may be related to the greater depth of East Arm than West Basin waters.

In contrast to mercury, HCH (Fig. 4) is showing a pronounced trend of decline in burbot from the West Basin and lake trout from the West Basin and East Arm. The slope for burbot (-0.425 ng/g/yr) is steeper than for West Basin (-0.119 ng/g/yr) and East Arm (-0.104 ng/g/yr) lake trout. DDT (not shown) is declining in both species in both locations. Similar declines in HCH have been noted for burbot at Fort Good Hope and lake trout in Lake Laberge (Stern 2009; Stern et al. 2009).

In contrast to burbot at Fort Good Hope (Carrie et al. 2010) PCB (Fig. 5) concentrations are decreasing in burbot from the West Basin with a slope of -4.00 ng/g/yr. PCBs in lake trout are showing a weak (but not statistically significant) trend of decrease (0.30-0.33 ng/g/yr) in the West Basin and East Arm.

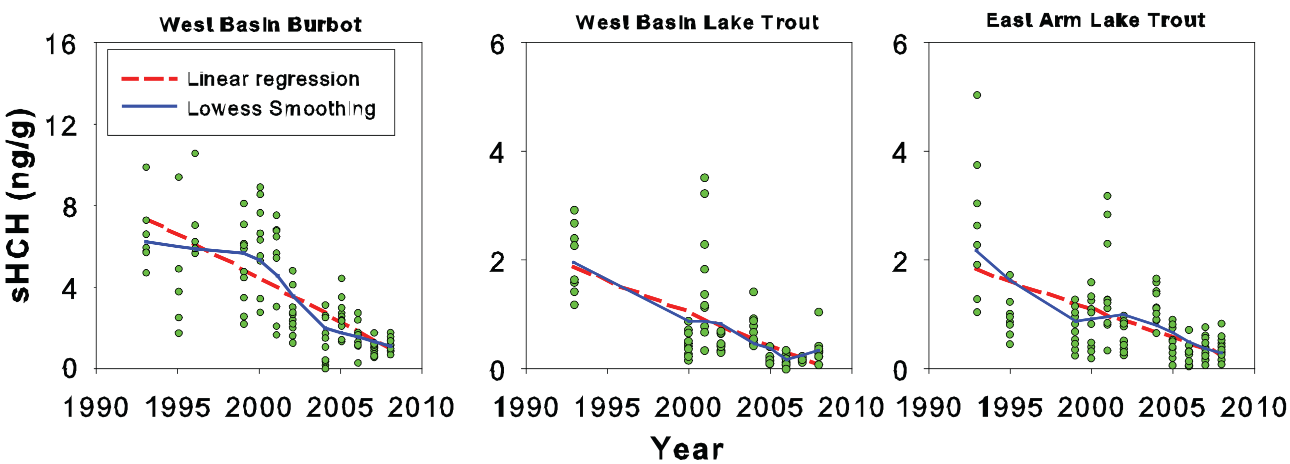

Figure 4. HCH (log scale) time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake, 1993-2008. Also shown are burbot (liver) from Fort Resolution. Data are presented as the individual data points with a linear regression and Lowess smoother added to visualize trends

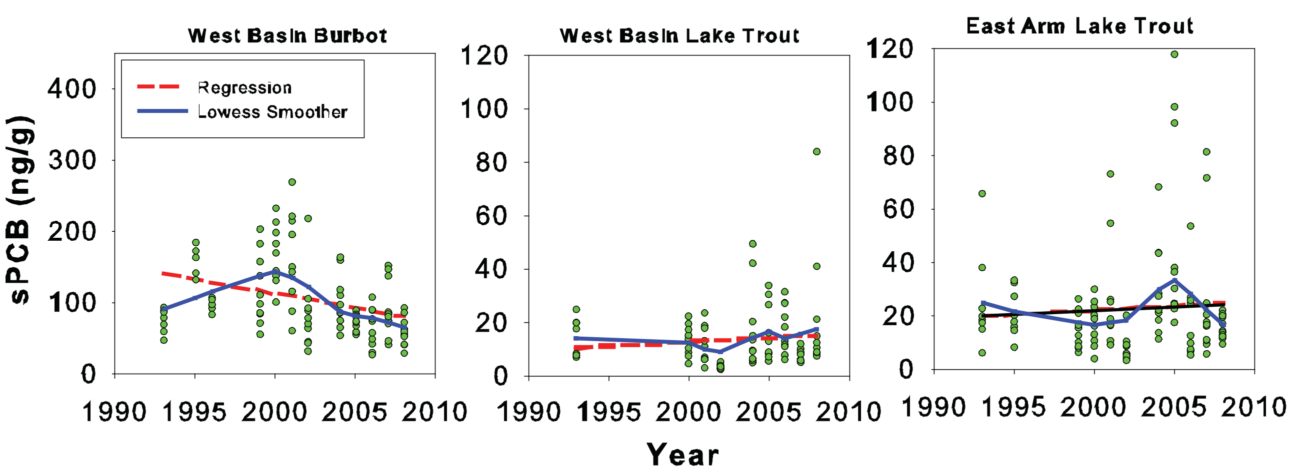

Figure 5. PCB time trends in lake trout (fillet) collected from the West Basin (Hay River) and East Arm (Lutsel K'e) of Great Slave Lake, 1993-2008. Also shown are burbot (liver) from Fort Resolution. Data are presented as the individual data points with a linear regression and Lowess smoother added to visualize trends.

Community interactions

Community interactions on this project continue to be very good and are an important part of its success. We have had an excellent long-term working relationship with Fort Resolution, Lutsel K'e and Shawn Buckley at Hay River. We also have had good interactions with Fort Simpson (Cli Lake collections), Colville Lake, and Deline (Great Bear Lake collections). Marlene worked actively on the Northwest Territories Regional Contaminants Committee, discussing the increased mercury levels, especially at Kelly Lake, Trout Lake and Lac Ste. Therese. In addition, Marlene held a Cumulative Impact Monitoring Program project in 2009-2010 (this was renewed in 2010-2011) which is allowing her to work with Fort Resolution and Lutsel K'e to begin to develop a community run limnological monitoring program which will complement this NCP study.

Expected Project Completion Date

This is a core NCP biomonitoring study with its duration expected to continue with the extensions in the NCP programs. It is encouraging that the monitoring has continued for a sufficient number of years that trends are now being detected. Furthermore, the collection of other variables related to fish biology (e.g., age and nitrogen isotopes) allows for the investigation of some of the factors in fish biology that may be affecting these trends. The collection of such data are necessary to better understand the effectiveness of management plans implemented to reduce the inputs of contaminants into the Arctic (e.g., HCH, DDT, PCBs) and how other factors such as contaminant change and increasing urban and technological growth in Asia may be impacting such trends (e.g., mercury).

Acknowledgments

Special appreciation is extended to Ernest Boucher for collecting burbot and lake trout from the Great Slave Lake area of Lutsel K'e, Gab Lafferty for collecting burbot and pike from Resolution Bay in 2009 and Shawn Buckley for collecting lake trout from the commercial fishery operating out of Hay River.

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Temporal trend studies of trace metals and halogenated organic contaminants (HOCs), including new and emerging persistent compounds, in Mackenzie River burbot, Fort Good Hope, NWT

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Abstract

Tissues from burbot collected at Fort Good Hope (Rampart Rapids) in December 2009 were analysed for organohalogen contaminants (OCs/PCPs/BFRs/FOCs) and heavy metals (Hg/Se/As). Data from this time point was combined with the existing metal (1985, 1989, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008) and OC (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008) data covering time spans of 24 and 21 years, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mean Hg concentrations in muscle and liver over the entire data sets were 0.349 ± 0.137 (n=425) and 0.086 ± 0.066 (n=409) μg g^{-1}, respectively. Muscle mercury levels are below the recommended guideline level of 0.50 μg g^{-1} for commercial sale. Major PBDE congener levels have increase significantly over the 19 year period from 1988 to 2008 but, are currently still about one order of magnitude less than those of PCBs.

Résumé

Des tissus de lotte prélevés à Fort Good Hope (rapides Rampart) en décembre 2009 ont été analysés pour déterminer s'ils contenaient des contaminants organohalogénés (pesticides organochlorés, biphényles polychlorés [BPC], produits ignifuges bromés et composés organiques fluorés) et des métaux lourds (Hg, Se et As). Les données de ce point dans le temps ont été combinées à celles qui existaient sur les métaux (1985, 1989, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008) et les composés organochlorés (1988, 1994, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008) sur une durée de 24 et de 21 ans, respectivement. Aucune corrélation significative entre la durée et les concentrations de mercure n'a été observée dans les muscles et le foie des deux sexes. Les concentrations moyennes de Hg dans les muscles et le foie des ensembles complets de données étaient de 0,349 ± 0,137 (n = 425) et de 0,086 ± 0,066 (n = 409) μg g^{-1}, respectivement. Les concentrations de mercure dans les muscles se

Since 1986, a consistent decline was observed in both PFOA and PFOS concentrations. Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

situent sous la concentration recommandée dans les lignes directrices, qui est de 0,50 µg g^{-1} pour la vente commerciale. Les concentrations de substances organoleptiques des principaux PBDE ont augmenté de façon significative au cours de la période de 19 ans entre 1988 et 2008, mais sont encore actuellement d'un ordre de grandeur de moins que ceux des BPC. Depuis 1986, une diminution régulière des concentrations de PFOA et de PFOS a été observée. En revanche, les concentrations de PFDA affichent une augmentation constante avec le temps. Les niveaux de PFNA et de PFUA ont été à leur plus haut en 2003.

Key Messages

- Mean Hg concentrations in muscle and liver over the entire data sets were 0.349 ± 0.137 (n=325) and 0.086 ± 0.066 (n=409) µg g^{-1}, respectively.
- Since the mid-1990s, a 1.6 and 2.0-fold increase in mercury concentrations has been measured in Fort Good burbot muscle and liver, respectively
- Muscle liver and mercury levels are below the recommended guideline level of 0.50 µg g^{-1} for commercial sale.
- Significant declines, 10- and 4-fold, occurred for both α- and γ-HCH over 20 year time period between 1988 and 2009. ΣPCBs and ΣDDT have increased significantly since the mid-1990s.
- Brominated flames retardant such as PBDEs have increase from 8.1 (PBDE 47) to 25.8-fold (PBDE 154) over the 20 year period from 1988 to 2009.
- Current ΣPBDE levels are approximately one order of magnitude less than those of PCBs.
- Since 1986, a consistent decline was observed in both PFOA and PFOS concentrations. Conversely, PFDA concentrations show a consistent increase overtime. PFNA and PFUA levels peaked in 2003.

Messages clés

- Les concentrations moyennes de Hg dans les muscles et dans le foie des ensembles complets de données étaient de 0,349 ± 0,137 (n = 325) et de 0,086 ± 0,066 (n = 409) µg g^{-1}, respectivement.
- Depuis le milieu des années 1990, une augmentation de 1,6 et de 2,5 fois des concentrations de mercure a été mesurée dans les muscles et dans le foie, respectivement, de la lotte de Fort Good.
- Les concentrations de mercure dans les muscles et dans le foie se situent sous la concentration recommandée dans les lignes directrices, qui est de 0,50 µg g^{-1} pour la vente commerciale.
- Des baisses importantes, de 10 et de 4 fois, des α- et γ-HCH sont survenues au cours de la période de 20 ans entre 1988 et 2009. Depuis le milieu des années 1990, les concentrations de ΣPCB et de ΣDDT ont augmenté de manière significative.
- Les ignifugeants bromés comme les PBDE ont augmenté de 8,1 (PBDE 47) à 25,8 fois (PBDE 154) au cours de la période de 20 ans entre 1988 et 2009.
- Les concentrations actuelles de ΣPBDE sont environ d'un ordre de grandeur moindre que ceux des BPC.
- Depuis 1986, on observe une baisse régulière des concentrations de PFOA et de PFOS. En revanche, les concentrations de PFDA affichent une augmentation constante avec le temps. Les concentrations de PFNA et de PFUA ont été à leur plus haut en 2003.

Objectives

To continue to assess long term trends and to maintain current data on levels of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic, lead and cadmium), organochlorine contaminants (e.g. PCBs, DDT, toxaphene) and new contaminants (e.g. brominated flame retardants, fluorinated organic compounds) in Mackenzie River burbot at Rampart Rapids (Fort Good Hope).

Introduction

With a few exceptions, minimal or no direct temporal trend information on organhalogen (OCs/PCPs/BFRs/FOCs) contaminants and heavy metals (Hg/Se/As) in fish are available in either the Arctic marine or freshwater environments. Due to a lack of retrospective samples and of past studies, much of the temporal trend data that are available are too limited to be scientifically credible because they are based on 2 or at most 3 sampling times. In addition, much of this is confounded by changes in analytical methodology as well as variability due to age/size, or dietary and population shifts. By comparison, temporal trend data for contaminants in Lake Ontario lake trout (Borgmann and Whittle 1991) and in pike muscle from Storvindeln Sweden are available over a 15 to 30 year period.

In the Mackenzie Basin over the last 150 years a steady increase in temperatures has been recorded. In particular, over the last 35 years temperatures have increase about a degree a decade, in the centre of the basin (Rouse et al., 1997). Rising temperatures in the region may be responsible for the increasing Hg levels in the FGH burbot (see Results) for several reasons: (a) melted permafrost, increased erosion and forest fires may release increasing amounts of Hg into the river; (b) the rate of Hg methylation processes may be increased by increasing temperature and nutrients, particularly in the wetlands and peatlands in the basin; and (c) possible changes in food web structure may have an effect on methylmercury (MeHg) biomagnification.

As outlined in the Northern Contaminants Program 2008-2009 call for proposals, the goal of temporal trend monitoring is to be able to detect a 10% annual change in contaminant concentration over a period of 10-15 years with a power of 80% and a confidence level of 95%. This requires sample collection and analysis of a minimum of 10 fish annually for a period of 10 to 15 years. Because of the importance of burbot to the subsistence diet of northerners residing in the Sahtu Region and because of the availability of current data sets and archived samples (1986-2008), Fort Good Hope (and the continued analysis of burbot) was selected as one of the priority sampling location for long temp temporal trend studies.

FWI currently maintains a very extensive archive of Fort Good Hope burbot sample tissues and data on trace metals (24 years and 14 time points; 1985, 1993, 1995, 1999, 2000, 2001, 2002, 2003 2004, 2005, 2006, 2007, 2008, 2009 and POPs (21 years and 12 time points; 1986, 1988, 1994, 1999, 2000, 2001, 2002, Jan04 (2003), 2004, 2005, 2006, 2007).

Activities In 2008/09

In December 2009, 40 burbot were collected from the Mackenzie River at Fort Good Hope (Rampart Rapids) by community residents. Heavy metal and HOC analyses for these samples are now complete and the results discussed below.

Results

Hg, Se, As:

Currently heavy metal (mercury, selenium and arsenic) time trend data from Fort Good Hope (Rampart Rapids) burbot tissues cover 24 years and 14 time points (1985, 1993, 1995, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009). Mean Hg concentrations in muscle and liver over the entire data sets were 0.349 ± 0.137 (n=325) and 0.086 ± 0.066 (n=409) $\mu g\ g^{-1}$, respectively. Muscle mercury levels in muscle are below the recommended guideline level of 0.50 $\mu g\ g^{-1}$ for commercial sale.

Mean mercury, selenium and arsenic concentrations for burbot muscle and liver samples for each collection year are shown in Tables 1 and 2, respectively. No significant correlation between length and mercury concentration was observed with muscle or liver for either sex. Mercury trends and levels in male and female burbot muscle and liver follow quite closely from the early 1990’s to 2008. Figure 1 shows a 1.6 and 2.0-fold increase in mercury concentrations in Fort Good burbot

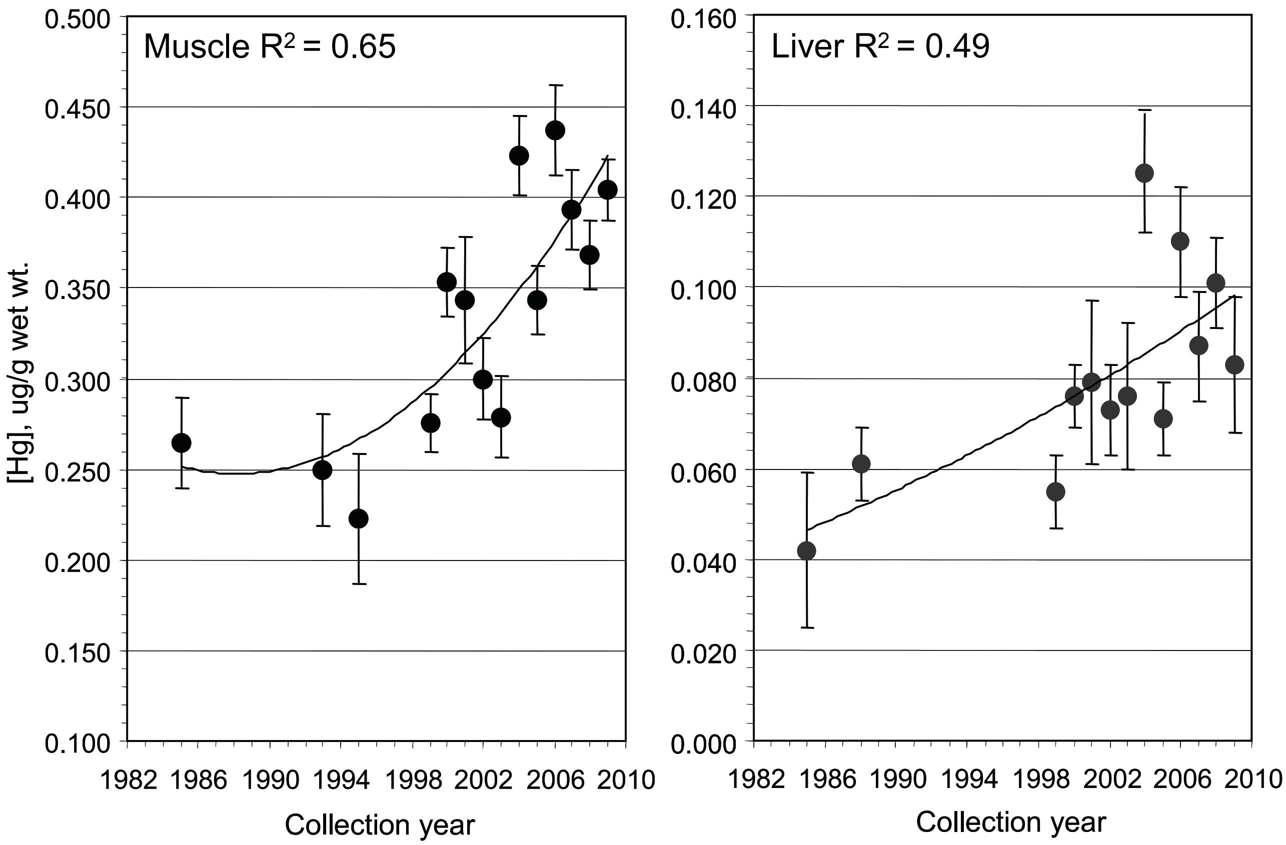

Figure 1. Mean Hg concentrations in muscle (left) and liver (right) from Fort Good Hope burbot (males + females).

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot muscle ($\mu g\ g^{-1}$).

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	10	633 (84)	0.222 (0.035)	0.358 (0.087)	–
Dec-93	M	7	677 (109)	0.231 (0.113)	0.534 (0.163)	2.291 (3.151)
Sept-95	M	2	–	0.265 (0.035)	–	–
Dec-99	M	21	676 (107)	0.286 (0.095)	0.395 (0.107)	0.637 (0.637)
Dec-00	M	21	699 (104)	0.345 (0.097)	0.478 (0.136)	1.333 (1.944)
Dec-01	M	10	720 (164)	0.342 (0.151)	0.581 (0.272)	3.106 (3.897)
Dec-02	M	12	699 (92)	0.297 (0.139)	0.427 (0.132)	1.555 (2.746)
Jan-04	M	9	705 (79)	0.336 (0.179)	0.377 (0.061)	3.324 (4.506)
Dec-04	M	17	681 (112)	0.413 (0.130)	0.523 (0.199)	1.011 (1.680)
Dec-05	M	13	616 (67)	0.301 (0.118)	0.434 (0.420)	1.663 (2.271)
Dec-06	M	17	700 (78)	0.389 (0.118)	0.401 (0.080)	0.873 (0.913)
Dec-07	M	16	642 (61)	0.420 (0.110)	0.520 (0.132)	0.522 (0.717)
Dec-08	M	15	624 (75)	0.410 (0.115)	0.506 (0.157)	0.310 (0.294)
Dec-09	M	22	703 (94)	0.406 (0.096)	0.405 (0.094)	0.354 (0.327)

continued on next page

[1]Wagemann 1985; [2]n = 20

Table 1. ***(continued)***

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	F	6	714 (140)	0.337 (0.136)	0.480 (0.126)	–
Dec-93	F	3	812 (133)	0.297 (0.035)	0.321 (0.009)	6.450 (0.984)
Sept-95	F	2	–	0.180 (0.085)	–	–
Dec-99	F	21	735 (101)	0.259 (0.108)	0.219 (0.104)[2]	2.626 (3.815)
Dec-00	F	15	732 (127)	0.364 (0.140)	0.460 (0.175)	1.929 (1.621)
Dec-01	F	10	747 (122)	0.336 (0.180)	0.304 (0.096)	1.098 (1.821)
Dec-02	F	17	727 (118)	0.294 (0.126)	0.400 (.297)	2.704 (3.258)
Jan-04	F	22	726 (98)	0.254 (0.179)	0.376 (0.125)	2.827 (3.425)
Dec-04	F	18	708 (115)	0.432 (0.138)	0.451 (0.114)	1.562 (2.075)
Dec-05	F	25	710 (104)	0.350 (0.112)	0.409 (0.120)	1.587 (1.942)
Dec-06	F	21	695 (106)	0.477 (0.174)	0.435 (0.121)	0.958 (1.179)
Dec-07	F	25	671 (111)	0.376 (0.115)	0.466 (0.152)	0.533 (0.777)
Dec-08	F	22	689 (118)	0.339 (0.114)	0.433 (0.156)	0.570 (0.706)
Dec-09	F	18	701 (110)	0.402 (0.125)	0.436 (0.098)	0.471 (0.706)

[1]Wagemann 1985; [2]n = 20

Table 2. Mean (standard deviation) concentrations of mercury, selenium and arsenic in Fort Good Hope burbot liver ($\mu g\ g^{-1}$).

Collection	Sex	n	Length	Hg	Se	As
Apr-85[1]	M	9	643 (82)	0.044 (0.019)	1.759 (0.558)	–
Dec-88	M	8	706 (84)	0.054 (0.026)	1.230 (0.555)	3.119 (1.725)
Dec-93	M	7	677 (109)	–	–	1.016 (1.328)
Dec-99	M	21	676 (107)	0.046 (0.024)	1.071 (0.628)[2]	0.607 (0.326)
Dec-00	M	21	699 (104)	0.064 (0.026)	1.646 (0.733)	0.585 (0.412)
Dec-01	M	10	720 (164)	0.063 (0.048)	1.434 (1.278)	0.839 (0.822)
Dec-02	M	12	699 (92)	0.063 (0.031)	1.437 (0.808)	0.771 (0.539)
Jan-04	M	9	705 (79)	0.126 (0.179)	1.981 (1.370)	1.994 (1.447)
Dec-04	M	17	681 (112)	0.111 (0.065)	3.267 (2.437)	0.496 (0.605)
Dec-05	M	13	616 (67)	0.053 (0.047)	1.677 (0.782)	0.527 (0.540)
Dec-06	M	17	700 (78)	0.094 (0.064)	1.939 (1.117)	–
Dec-07	M	16	642 (61)	0.076 (0.035)	2.090 (0.837)	–
Jan-09	M	15	324 (75)	0.114 (0.055)	3.416 (1.722)	0.335 (0.300)
Dec-09	M	22	703 (94)	0.064 (0.030)	2.038 (0.985)	–
Apr-85[1]	F	6	714 (140)	0.097 (0.098)	1.272 (0.715)	–
Dec-88	F	2	623 (86)	0.072 (0.035)	1.460 (1.529)	1.280 (1.018)
Dec-93	F	3	812 (129)	–	–	1.062 (0.546)
Dec-99	F	20	749 (77)	0.064 (0.069)	0.687 (0.552)[2]	1.353 (0.811)
Dec-00	F	15	732 (127)	0.094 (0.056)	1.203 (0.469)	0.632 (0.349)
Dec-01	F	10	747 (122)	0.098 (0.108)	1.235 (0.720)	1.074 (1.227)
Dec-02	F	17	727 (118)	0.082 (0.067)	1.488 (1.203)	1.063 (0.890)
Jan-04	F	22	726 (98)	0.057 (0.033)	1.245 (0.511)	1.522 (1.348)
Dec-04	F	17	700 (112)	0.138 (0.081)	2.616 (2.030)	0.489 (0.335)
Dec-05	F	25	710 (104)	0.080 (0.050)	1.585 (1.013)	0.489 (0.585)
Dec-06	F	21	695 (106)	0.125 (0.076)	1.906 (1.006)[3]	–
Dec-07	F	24	674 (113)	0.094 (0.098)	2.064 (1.096)	–
Jan-09	F	22	689 (118)	0.092 (0.059)	1.690 (1.095)	0.451 (0.401)
Dec-09	F	18	701 (110)	0.107 (0.141)	1.752 (1.023)	–

[1] Wagemann 1985; [2]n = 20

muscle and liver, respectively, since the mid-1990s. For selenium and arsenic no trends were observed in either the muscle or liver (Tables 1 and 2). The highest measured As concentration, 17.16 µg g^{-1}, occurred in a muscle sample from a female burbot collected in 1999.

Organohalogens:

Table 3-7 list the mean wet weight of major HOC group concentration for collection periods between 1988 and 2009. After lipid normalization, significant declines, 10 - and 4-fold, occurred for both α- and γ-HCH over this 19 year time period (Figure 2). β-HCH concentrations were below the detection limit in most samples. ΣPCBs and ΣDDT have increased significantly since the mid-1990s (see Carrie et al. 2010).

Major PBDE congener and homologue concentrations in selected burbot liver samples are listed in Table 5 (1988 to 2009). PBDE 47 is the most predominant PBDE congener residue in the burbot liver followed by PBDE 99, 100, 153 and 154.

Results for perfluoroalkyl compounds are shown in Table 6.

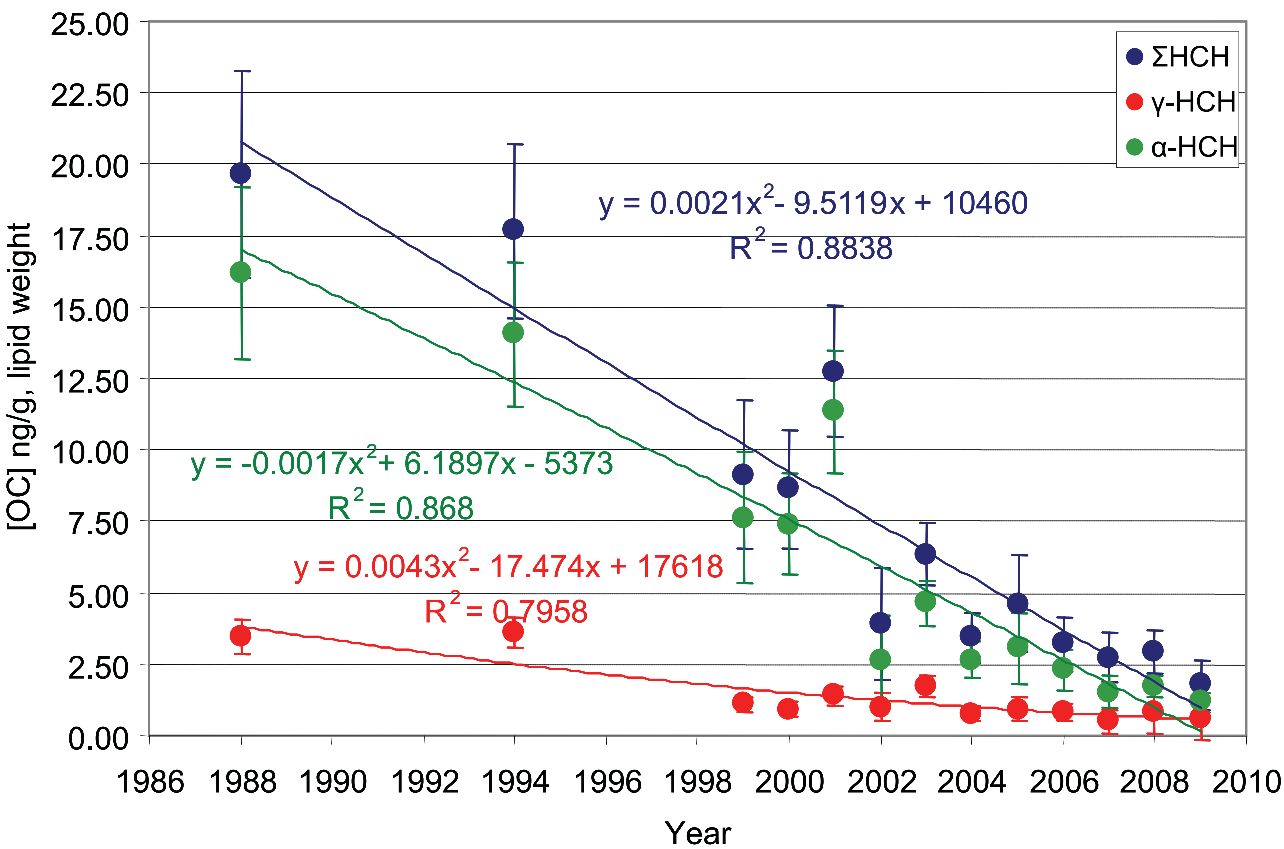

Figure 2. Lipid normalized SHCH, α-, γ-HCH concentrations in FGH burbot liver (1988–2009).

Table 3. OCs in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1}, ww)

Year	sex	n	% Lipid	ΣCBz	ΣHCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	HCBz	Oxychlor
1988	M + F	10	30.20 (13.47)	13.63 (4.21)	5.53 (1.71)	23.83 (7.37)	16.17 (5.25)	58.11 (18.45)	121.66 (38.62)	13.07 (4.06)	9.46 (1.58)
1994	M + F	9	30.56 (11.59)	8.63 (2.63)	5.13 (1.53)	17.34 (6.14)	18.96 (8.28)	50.05 (17.55)	93.70 (28.92)	8.17 (2.48)	9.23 (1.42)
1999	M + F	21	42.10 (13.31)	10.04 (3.81)	3.78 (1.38)	21.00 (8.04)	22.84 (8.59)	62.77 (22.29)	108.06 (40.74)	5.43 (2.17)	8.49 (1.70)
2000	M + F	20	36.22 (15.22)	8.72 (5.24)	3.29 (1.98)	19.02 (12.50)	21.24 (14.92)	54.62 (36.25)	94.02 (58.08)	4.78 (2.89)	8.28 (2.44)
2001	M + F	20	30.14 (15.00)	6.36 (3.06)	3.79 (1.67)	13.68 (6.99)	8.99 (5.96)	41.88 (21.26)	75.36 (48.54)	4.33 (1.90)	10.60 (2.67)
2002	M + F	12	27.33 (16.06)	4.69 (2.93)	1.40 (0.94)	17.83 (10.10)	22.18 (12.19)	37.97 (16.50)	143.61 (119.82)	4.54 (2.85)	17.64 (14.33)
2003	M + F	10	24.90 (5.77)	3.83 (3.08)	1.62 (0.57)	17.25 (18.71)	15.19 (12.72)	29.95 (21.29)	118.13 (109.79)	3.80 (3.00)	12.82 (11.27)
2004	M + F	9	24.73 (14.27)	4.05 (3.72)	0.87 (0.45)	25.35 (21.84)	35.65 (26.15)	57.62 (32.22)	201.65 (167.60)	3.90 (2.66)	24.89 (20.06)
2005	M + F	10	24.50 (12.12)	4.71 (2.14)	1.09 (0.61)	22.16 (12.40)	19.46 (9.28)	29.23 (8.49)	110.33 (67.35)	4.42 (2.01)	42.50 (23.38)
2006	M + F	10	32.74 (15.87)	3.77 (1.99)	1.00 (0.46)	21.42 (19.01)	35.53 (15.68)	61.84 (44.44)	158.00 (149.07)	3.59 (2.00)	5.25 (4.86)
2007	M + F	9	31.89 (10.25)	7.53 (3.20)	0.90 (0.44)	24.67 (11.80)	42.13 (15.73)	38.19 (17.57)	119.16 (72.60)	6.96 (3.03)	5.79 (2.78)
2008	M + F	9	39.09 (9.74)	8.83 (2.41)	1.19 (0.44)	15.26 (10.06)	38.59 (17.71)	101.86 (55.71)	289.16 (210.32)	6.52 (1.74)	3.38 (2.58)
2009	M + F	10	30.68 (14.59)	5.19 (2.63)	0.54 (0.33)	39.32 (15.85)	32.32 (22.51)	85.31 (39.57)	271.53 (187.86)	4.12 (2.36)	5.33 (3.15)

Table 4. Lipid normalized OCs concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1})

Year	sex	n*	ΣCBz	ΣHCH	α-HCH	γ-HCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Oxychlor
1988	M + F	10	48.50 (9.02)	19.67 (3.61)	16.19 (3.00)	3.48 (0.62)	84.67 (15.40)	57.34 (11.15)	206.05 (37.45)	215.97 (40.74)	9.46 (1.58)
1994	M + F	9	30.29 (8.48)	17.66 (3.03)	14.05 (2.51)	3.61 (0.52)	58.92 (11.35)	61.55 (6.42)	168.80 (22.62)	160.38 (27.00)	9.23 (1.42)
1999	M + F	21	23.55 (3.87)	9.12 (2.61)	7.64 (2.31)	1.10 (0.25)	49.18 (8.10)	53.58 (7.76)	148.85 (28.67)	126.74 (22.84)	8.49 (1.70)
2000	M + F	20	22.40 (5.31)	8.64 (2.09)	7.41 (1.79)	0.91 (0.26)	47.77 (13.83)	52.98 (16.76)	137.50 (40.16)	119.41 (32.92)	8.28 (2.44)
2001	M + F	19	21.05 (3.64)	12.76 (2.31)	11.34 (2.14)	1.42 (0.35)	44.58 (7.37)	27.52 (6.72)	138.19 (7.59)	117.55 (21.82)	10.91 (2.34)

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*only liver samples with lipid > 10 % included.

Table 4. ***(continued)***

Year	sex	n*	ΣCBz	ΣHCH	α-HCH	γ-HCH	ΣCHL	ΣDDT	ΣPCB	ΣCHB	Oxychlor
2002	M + F	12	15.63 (11.88)	3.89 (1.96)	2.66 (1.56)	1.02 (0.48)	80.63 (64.60)	95.62 (67.66)	162.67 (107.09)	487.58 (523.81)	17.64 (14.33)
2003	M + F	10	14.59 (9.64)	6.34 (1.08)	4.63 (0.82)	1.71 (0.38)	63.29 (58.34)	57.27 (41.69)	113.99 (62.86)	446.99 (350.00)	12.82 (11.27)
2004	M + F	9	16.75 (9.42)	3.39 (0.91)	2.62 (0.66)	0.76 (0.26)	133.85 (124.50)	168.22 (103.73)	257.46 (159.14)	883.24 (823.31)	25.38 (21.39)
2005	M + F	8	18.81 (8.02)	4.63 (1.69)	3.08 (1.24)	0.94 (0.39)	83.67 (41.03)	69.12 (36.06)	103.47 (46.49)	408.43 (208.31)	42.50 (20.38)
2006	M + F	8	16.62 (4.37)	3.20 (0.95)	2.30 (0.74)	0.85 (0.29)	62.22 (54.07)	112.70 (80.80)	151.22 (105.33)	445.42 (410.90)	15.04 (13.90)
2007	M + F	9	23.56 (6.03)	2.73 (0.87)	1.53 (0.59)	0.52 (0.41)	78.62 (30.26)	143.95 (68.04)	129.20 (59.81)	363.09 (168.67)	18.40 (6.81)
2008	M + F	8	17.13 (4.37)	3.03 (0.75)	1.69 (0.38)	0.96 (0.78)	41.20 (7.52)	102.71 (52.23)	283.38 (200.27)	803.57 (648.00)	9.54 (8.29)
2009	M + F	9	16.93 (6.49)	1.78 (0.87)	1.17 (0.33)	0.61 (0.73)	107.70 (61.18)	115.56 (73.82)	293.91 (166.30)	1032.16 (745.13)	22.22 (13.64)

*only liver samples with lipid > 10 % included.

Table 5. Major PBDE congener concentrations in Burbot liver from Fort Good Hope (mean and standard deviation, pg g^{-1} ww)

Year	Sex	n	% Lipid	PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154
1988	M + F	10	30.2 (13.5)	226.3 (280.3)	84.5 (130.6)	35.2 (46.7)	29.4 (44.7)	20.5 (28.9)
1999	M + F	4	35.0 (9.6)	582.8 (522.3)	370.1 (269.6)	207.7 (154.6)	161.3 (124.8)	157.5 (116.4)
2000	M + F	11	33.3 (13.1)	620.3 (628.9)	319.7 (273.9)	180.5 (182.7)	135.2 (133.9)	81.3 (84.2)
2002	M + F	10	24.8 (14.5)	680.5 (305.4)	383.3 (258.3)	200.6 (87.1)	111.9 (74.2)	191.4 (95.7)
2003	M + F	10	28.1* (11.5)	814.7 (618.9)	745.3 (583.2)	297.7 (190.9)	435.5 (330.1)	311.4 (216.0)
2005	M + F	10	17.3 (9.4)	718.4 (370.7)	516.0 (248.9)	210.7 (102.9)	111.7 (60.2)	170.1 (62.2)
2006	M + F	9	21.7 (16.3)	1822.9 (1913.5)	1281.5 (717.7)	1010.4 (522.9)	539.6 (359.8)	529.7 (344.7)
2007	M + F	9	23.56 (6.03)	800.4 (878.0)	709.1 (967.0)	361.8 (314.4)	86.8 (192.8)	72.7 (39.0)
2008	M + F	9	39.1 (9.74)	498.5 (228.0)	105.1 (110.7)	48.3 (62.7)	21.4 (25.6)	264.7 (64.1)
2009	M + F	9	35.2 (11.0)	808.7 (521.6)	926.4 (244.1)	476.8 (244.1)	242.0 (114.5)	191.2 (136.8)

*Some sample not the same as for OCs in Table 3

Table 6. FOC levels in Burbot liver from Fort Good Hope (mean and standard deviation, ng g^{-1} ww)*

Year	Sex	n	PFOA	PFNA	PFOS[a]	PFDA	PFUA	Total
1986	M + F	10	4.59 (6.84)	0.89 (0.72)	10.44 (5.90)	1.91 (2.13)	2.25 (4.90)	20.08
1999	M + F	10	4.03 (6.57)	3.89 (9.29)	9.89 (10.16)	1.20 (1.73)	1.44 (2.92)	20.45
2000	M + F	10	1.58 (5.01)	0.98 (3.11)	5.62 (7.81)	2.59 (2.66)	0.75 (1.65)	11.52
2001	M + F	10	1.44 (2.62)	1.57 (3.00)	4.52 (7.75)	36.85* (94.21)	0.70 (1.71)	45.08*
Jan-2004 (2003)	M + F	10	2.03 (3.28)	7.97 (8.03)	9.88 (10.16)	4.28 (3.96)	5.31 (3.96)	29.47
2006	M + F	10	1.07 (1.10)	4.71 (4.47)	1.93 (0.78)	8.27 (9.39)	mdl	15.98
2007	M + F	9	0.44 (0.99)	1.01 (1.13)	1.39 (1.25)	7.47 (7.52)	1.36 (1.42)	11.67
2008	M + F	10	7.62 (9.70)	6.74 (7.21)	20.73 (12.21)	7.07 (6.94)	mdl	42.16
2009	M + F	10	0.35 (0.67)	1.18 (1.93)	1.27 (1.39)	1.10 (1.97)	1.10 (1.01)	6.13 (5.22)

PDDoDA = mdl = 0.05; PFUA (mdl = 0.05); *Higher value due to one sample with a measured concentration of 304.24 ng g^{-1}. If this value is excluded then the mean value for PFDA and total FOCs for the 2001 samples are 7.15 (7.47) and 15.38 ng g^{-1}, respectively.

Expected Project Completion Data

Temporal trend studies are long-term propositions and thus annual sampling is projected into the foreseeable future

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Trace Metals and OrganoHalogen Contaminants in Fish from Selected Yukon Lakes: A Temporal and Spatial Study

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Abstract

Lake trout muscle samples collected from two Yukon Lakes, Kusawa and laberge, were analysed for a range of organohalogen (OCs/PCBs/BFRs/FOCs) and heavy metals (Hg/Se/As) contaminants. Currently heavy metal time trend data from Laberge and Kusawa Lake trout muscle cover 16 years, 13 and 11 time points, respectively. Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.22 (n=123) and 0.38 ± 0.25 (n=104) μg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale. No significant trends have been observed in the Laberge lake trout Hg levels over the last 16 years. In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009. As was observed

Résumé

Des contaminants organohalogénés (pesticides organochlorés, biphényles polychlorés, produits ignifuges bromés et composés organiques fluorés) et des métaux lourds (Hg, Se et As) ont été dosés dans des échantillons de muscle de touladis capturés dans deux lacs du Yukon, soit les lacs Kusawa et Laberge. La série chronologique des teneurs en métaux lourds du muscle de ces touladis s'étend sur 16 ans et est constituée de 13 dates d'échantillonnage pour le lac Laberge et de 11 pour le lac Kusawa. Pour l'ensemble des données, la concentration moyenne de Hg est de 0,47 ± 0,22 (n = 123) μg g^{-1} pour le lac Laberge et de 0,38 ± 0,25 (n = 104) μg g^{-1} pour le lac Kusawa. Ainsi, les concentrations sont tout juste inférieures à la limite de 0,50 μg g^{-1} établie pour la vente commerciale de poisson. Au cours des 16 dernières années, aucune tendance significative des concentrations de Hg dans les touladis du lac Laberge n'a été observée. Quant au lac Kusuwa,

with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to start to increase again around 2003/04.

on y a signalé une baisse importante des concentrations de mercure dans le muscle de touladis en 2001, qui a été suivie d'une augmentation constante de ces concentrations jusqu'en 2007. Des concentrations de Hg significativement plus faibles ont été mesurées dans le poisson prélevé en 2008 et en 2009. Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 ou 2004.

Key Messages

- Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 16 years, 13 and 11 time points, respectively
- The mean Hg levels in the Laberge and Kusawa trout muscle samples over the entire data sets were 0.47 ± 0.22 (n=123) and 0.38 ± 0.25 (n=104) μg g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale.
- No significant trends have been observed in the Laberge lake trout Hg levels over the last 16 years.
- In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009.
- As was observed with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to start to increase again around 2003/04.

Messages clés

- La série chronologique des concentrations de métaux lourds (mercure, sélénium et arsenic) dans le muscle de touladis des lacs Laberge et Kusawa s'étend sur 16 ans, et est constituée de 13 dates d'échantillonnage pour le lac Laberge et de 11 pour le lac Kusawa.
- Pour l'ensemble des données, la concentration moyenne de Hg dans le muscle de touladi est de 0,47 ± 0,22 (n = 123) μg g^{-1} pour le lac Laberge et de 0,38 ± 0,25 (n = 104) μg g^{-1} pour le lac Kusawa. Ainsi, les concentrations sont tout juste inférieures à la limite de 0,50 μg g^{-1} établie pour la vente commerciale de poisson.
- Au cours des 16 dernières années, aucune tendance significative des concentrations de Hg dans les touladis du lac Laberge n'a été observée.
- Quant au lac Kusuwa, on y a signalé une baisse importante des concentrations de mercure dans le muscle de touladis en 2001, qui a été suivie d'une augmentation constante de ces concentrations jusqu'en 2007. Des concentrations de Hg significativement plus faibles ont été mesurées dans le poisson prélevé en 2008 et en 2009.
- Comme on l'a observé pour le mercure, après une baisse rapide, les concentrations d'organochlorés corrigées en fonction de la teneur en lipide ont recommencé à augmenter vers 2003 ou 2004.

Objectives

The objective of this project is to maintain current data on contaminants levels in lake trout from two Yukon lakes (Laberge and Kusawa) to continue to assess the temporal trends of bioaccumulating substances such as trace metals (e.g. mercury, selenium, arsenic), organochlorine contaminants (e.g. PCBs, DDT, toxaphene), selected current use chemicals such as brominated flame retardants (e.g. PBDEs, HBCDD), and fluorinated organic compounds (e.g. PFOS and it's precursors) so as to determine whether the levels of these contaminants in fish (health of the fish stock) and thus exposure to people who consume them are increasing or decreasing with time. These results will also help to test the effectiveness of international controls.

Introduction

Historical studies have demonstrated that halogenated organic contaminants (HOCs) and mercury levels in top predators can vary considerably from lake to lake within a small geographic region but temporal trends of these contaminants have rarely been monitored in a sub-Arctic area for a long period of time. This study examines concentrations of a wide range of HOCs and trace metals in lake trout from two Yukon lakes (Laberge, Kusawa), over a span of 13 years (1993-2006). Recently, Ryan et al. (2005) reported that OC pesticide and PCB concentration were declining at various rates in lake trout (*Salveninus namaycush*) in three different Yukon lakes (Laberge, Kusawa and Quiet). For example, ΣDDT concentrations have decreased 39%, 85% and 84% in Kusawa, Quiet and Laberge lakes respectively. Spatial variations in OC/PCB levels were quite evident as Lake Laberge trout continued to maintain the highest levels over the 10 year period from 1992 to 2003 followed by Kusawa and then Quiet. These differences were related to a variety of factors especially the species morphological characteristics such as log age, log weights and fish lipid content. A decreasing trend in Quiet and Laberge lake trout lipid content, coupled with fluctuating condition factors and increases in body masses, suggest biotic changes may be occurring within the food webs due to fish population variations related to the cessation of commercial fishing or potentially an increase in lake plankton productivity related to annual climate variation.

Because of the importance of lake trout and burbot to the subsistence diet of northerners, the need to continue to assess the effect of climate variation on fish contaminant levels, the availability of current data sets and archived samples, Lakes Laberge and Kusawa were selected as the priority Yukon sampling location for long term temporal trend studies.

Activities in 2009/10

INAC (Whitehorse)/DFO (Winnipeg) together maintain a very extensive archive of fish tissues and data for Hg, Se, As, and HOCs in Yukon lakes (see Tables 1-4). In 2009, 10 lake trout were collected each from Kusawa, Laberge. 10 white fish and two inconnu for also collected from Laberge on the request of the First Nations.

Results and Discussion

Hg, Se, As:

Currently heavy metal (mercury, selenium and arsenic) time trend data from Laberge and Kusawa Lake trout cover 16 years, 13 and 11 time points, respectively (Table 1). Mean Hg concentrations in the Laberge and Kusawa muscle samples over the entire data sets were Mean Hg levels over the entire data sets for the Laberge and Kusawa samples were 0.47 ± 0.22 (n=123) and 0.38 ± 0.25 (n=104) ug g^{-1}, respectively. In both lakes, levels are just below the recommended guideline level of 0.50 μg g^{-1} for commercial sale. A significant correlation between length and muscle mercury concentration was observed in the Laberge ([HgT] = m*length + b, m=0.0013, b=-0.2892, r^2 = 0.59, p<0.001, n=123) and Kusawa ([Hg] = m*length + b, m=0.0018, b=-0.5046, r^2 = 0.52, p<0.001, n=104) trout. ANCOVA was used to assess the effects of year to year collections (temporal trends), length and length*year interactions (homogeneity of the slope between length and [Hg]). No significant trends have been observed in the Laberge lake trout Hg levels over the last 16 years. In Kusuwa Lake, after a significant drop in the trout muscle mercury concentrations in 2001, levels increased consistently until 2007. Significantly lower Hg concentrations were measured in the fish collected in both 2008 and 2009.

Table 1. Mean (standard deviation) concentrations of mercury, selenium and arsenic in lake trout muscle from Laberge and Kusawa Lakes. All levels are in μg/g.

	Year	n	Length	Hg	Se	As
Laberge	1993	13	483 (110)	0.44 (0.11)	0.45 (0.08)	0.15 (0.04)
	1996	18	472 (93)	0.32 (0.10)	0.32 (0.12)	0.12 (0.06)
	1998	7	700 (125)	0.61 (0.24)	0.42 (0.07)	0.18 (0.12)
	2000	6	590 (108)	0.43 (0.21)	0.66 (0.14)	0.13 (0.04)
	2001	22	639 (92)	0.54 (0.23)	0.57 (0.13)	0.10 (0.04)
	2002	5	570 (120)	0.38 (0.15)	0.61 (0.12)	0.11 (0.05)
	2003	8	593 (98)	0.56 (0.25)	0.47 (0.10)	0.10 (0.03)
	2004	5	614 (68)	0.54 (0.23)	0.38 (0.09)	0.09 (0.04)
	2005	10	606 (97)	0.50 (0.19)	0.47 (0.09)	0.06 (0.03)
	2006	1	800	0.68	0.45	0.08
	2007	9	674 (109)	0.70 (0.27)	0.42 (0.05)	0.08 (0.03)
	2008	10	580 (78)	0.37 (0.19)	0.43 (0.07)	0.06 (0.02)
	2009	10	538 (58)	0.41 (0.18)	0.41 (0.03)	0.06 (0.02)
Kusawa	1993	3	535 (72)	0.54 (0.21)	0.43 (0.17)	na
	1999	14	515 (106)	0.51 (0.17)	0.46 (0.11)	0.12 (0.07)
	2001	9	551 (108)	0.29 (0.11)	0.52 (0.09)	na
	2002	10	500 (74)	0.29 (0.09)	0.55 (0.07)	0.02 (0.01)
	2003	10	487 (90)	0.35 (0.13)	0.35 (0.24)	0.03 (0.02)
	2004	9	553 (117)	0.39 (0.13)	0.64 (0.14)	0.03 (0.01)
	2005	10	510 (118)	0.43(0.31)	0.60 (0.11)	0.01 (0.01)
	2006	9	568 (168)	0.56 (0.38)	0.59 (0.17)	0.02 (0.01)
	2007	10	446 (80)	0.36 (0.24)	0.57 (0.08)	0.02 (0.01)
	2008	10	471 (94)	0.24 (0.07)	0.54 (0.08)	0.02 (0.01)
	2009	10	453 (54)	0.23 (0.08)	0.56 (0.08)	0.02 (0.01)

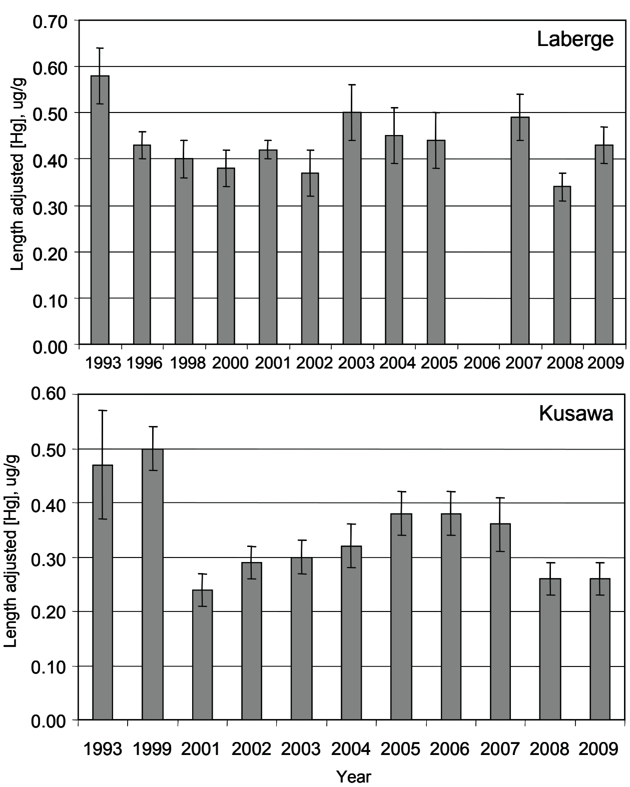

Figure 1. Length adjusted Hg concentrations in trout muscle from Lake Laberge (1993-2009) and Kusawa (1993-2009). Only Kusawa trout less than 700 mm in length were used in the ANCOVA.

Organohalogens:

Tables 2 and 3 list the mean wet weight HOC concentration in trout from Lake Laberge and Kusawa Lake, respectively, over the 16 year time period from 1983 to 2009. Figure 2 show the lipid adjusted concentration for several of the HOC groups in trout from both lakes. As was observed with the mercury, after a rapid decline, the lipid adjusted OC concentrations seem to start to increase again around 2003/04.

Major PBDE congener and ΣPBDE concentrations in Lake trout from Lakes Laberge, Kusawa and Quite are shown in Table 4. Levels in trout from Quite Lake are 1 to 2 orders of magnitude lower than those from Laberge and Kusawa.

Table 2. Mean (S.D.) HOC levels (ng/g wet wt.) in lake trout muscle from Lake Laberge

Laberge	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
1993	24	15 (2)	7.9 (0.9)	328.28 (121.49)	391.54 (132.69)	47.60 (8.84)	4.69 (0.78)	310.96 (62.36)	3.92 (0.57)
1996	13	22 (5)	9.6 (1.4)	209.32 (52.08)	236.51 (41.39)	53.38 (13.74)	6.50 (1.79)	212.23 (28.31)	4.90 (1.24)
2000	6	12 (2)	3.7 (0.8)	138.95 (60.89)	96.46 (14.21)	22.36 (5.84)	2.30 (1.08)	207.33 (49.90)	2.26 (0.59)
2001	16	14 (2)	4.9 (0.5)	139.71 (53.75)	89.46 (14.04)	26.37 (5.14)	0.80 (0.07)	154.20 (60.46)	2.11 (0.17)
2002	5	12 (4)	4.2 (0.9)	48.60 (8.81)	54.50 (11.58)	7.26 (1.59)	1.58 (0.50)	139.23 (16.88)	1.15 (0.25)
2003	8	12 (1)	4.7 (0.8)	81.01 (29.83)	61.48 (8.55)	7.44 (2.24)	0.54 (0.10)	179.31 (42.79)	1.21 (0.28)
2004	6	12 (4)	8.7 (3.9)	48.93 (34.30)	94.09 (60.68)	7.46 (4.90)	0.19 (0.09)	79.92 (52.01)	0.49 (0.28)
2005	10	14 (7)	2.0 (1.22)	28.94 (20.27)	50.91 (30.27)	2.61 (1.28)	0.16 (0.10)	34.50 (19.97)	0.35 (0.27)
2006	1	21	1.0	25.52	31.25	4.82	0.07	76.87	0.35
2007	9	14 (5)	1.2 (0.80)	37.36 (25.89)	43.98 (29.93)	5.32 (4.05)	0.10 (0.09)	25.78 (14.58)	0.27 (0.80)
2008	10	12 (5)	2.3 (1.1)	50.23 (36.89)	70.06 (41.29)	4.04 (2.88)	0.18 (0.08)	24.48 (16.85)	0.77 (0.23)
2009	10	10 (3)	2.9 (1.1)	28.92 (14.89)	35.33 (20.81)	2.30 (1.06)	0.14 (0.06)	37.60 (19.57)	0.60 (0.34)

Table 3. Mean (S.D.) OC levels (ng/g wet wt.) in lake trout muscle from Kusawa Lake

Kusawa	N	Age	% lipid	ΣPCB	ΣDDT	ΣCHL	ΣHCH	ΣCHB	ΣCBz
1993	10	19 (2)	1.8 (1.6)	85.62 (26.07)	44.16 (21.50)	17.33 (2.78)	1.21 (0.36)	120.80 (24.94)	1.15 (0.28)
1999	14	18 (1)	4.6 (3.0)	91.09 (11.85)	139.16 (19.72)	17.82 (2.74)	1.68 (0.23)	148.38 (29.29)	1.52 (0.20)
2001	9	12 (1)	2.4 (1.4)	48.55 (7.91)	56.58 (15.30)	7.45 (2.35)	0.91 (0.14)	61.03 (8.55)	0.84 (0.14)
2002	10	12 (1)	1.4 (0.8)	32.45 (3.66)	26.66 (4.15)	3.01 (0.48)	0.62 (0.08)	43.47 (5.02)	0.61 (0.09)
2003	9	9 (3)	5.8 (3.6)	8.16 (5.86)	8.21 (15.67)	3.50 (2.28)	0.14 (0.08)	45.05 (32.20)	0.44 (0.30)
2004	9	13 (4)	7.9 (4.7)	11.29 (3.78)	5.70 (3.70)	4.52 (2.16)	0.15 (0.07)	49.73 (30.17)	0.50 (0.27)
2005	10	15 (6)	0.61 (0.51)	5.48 (4.84)	2.35 (3.02)	1.17 (0.88)	0.03 (0.03)	12.37 (11.57)	0.12 (0.10)
2006	9	12 (4)	1.82 (1.49)	6.28 (4.58)	2.97 (2.57)	2.49 (1.84)	0.09 (0.06)	42.63 (34.97)	0.47 (0.26)
2007	9	10 (4)	1.52 (1.43)	9.88 (9.93)	2.35 (1.88)	2.78 (2.90)	0.10 (0.06)	22.44 (23.88)	0.42 (0.33)
2008	10	9 (2)	1.16 (0.42)	18.30 (27.27)	2.35 (0.94)	1.30 (0.40)	0.13 (0.26)	22.55 (7.87)	0.47 (0.13)
2009	10	9 (1)	1.51 (1.11)	5.11 (3.18)	1.56 (1.34)	1.90(1.44)	0.09 (0.06)	42.40 (34.41)	0.49 (0.26)

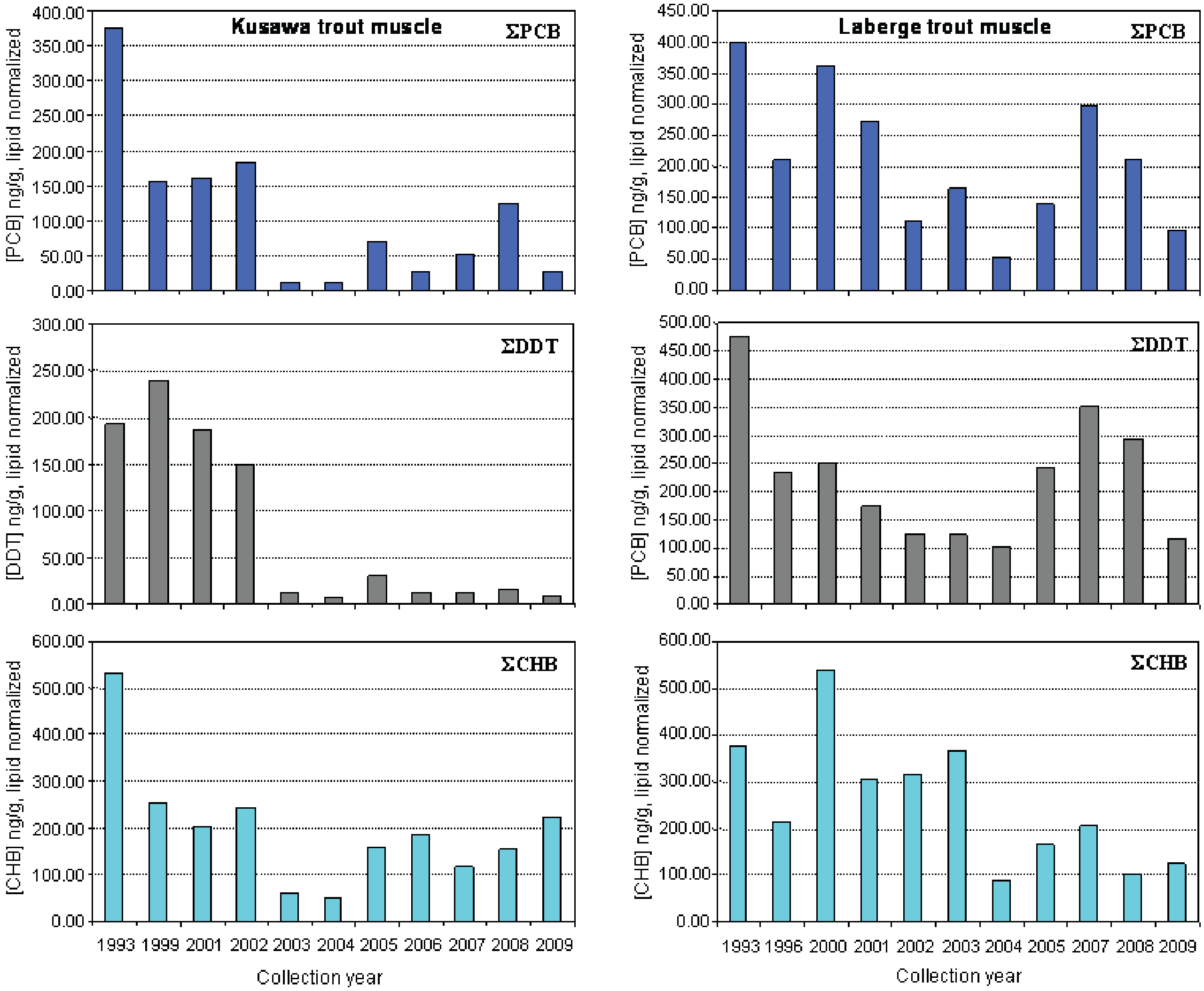

Figure 2. Lipid adjusted OC group concentrations in trout muscle from Kusawa and Laberge (1992-2009).

FOC levels in Kusawa and Laberge lake trout liver are noted below:

Laberge

2006 (n=1); PFOS = 2.18 ng g^{-1}, wet wt.

2007 (n=9); PFOS = 2.47 (1.86); PFNA = 5.78 (6.33); PFDA = 32.40 (30.34) ng g^{-1}, wet wt.

2008 (n=10); PFOS = 1.28 (2.31); PFNA = 0.06 (0.14); PFOSA = 1.31 (1.24) ng g^{-1}, wet wt

2009 (n=10); PFOS = 1.93 (1.60); PFNA = 1.39 (1.48); PFDA = 4,87 (6.55) ng g^{-1}, wet wt

Kusawa

2006 (n=9); PFOA = 2.93 (7.78) ng g^{-1}, wet wt.

2007 (n=9); PFOS = 0.50 (0.54); PFNA = 0.36 (1.08); PFDA = 12.78 (16.93) ng g^{-1}, wet wt.

2008 (n=9); PFOS = 0.44 (0.88); PFNA = 0.06 (0.14); PFDA = 0.10 (0.24); PFOSA = 0.32 (0.65), wet wt.

2009 (n=10); PFOS = 0.55 (0.60); PFNA = 0.40 (0.14); PFDA = 3.76 (5.24), wet wt.

Table 4. Mean (S.D.) PBDE levels (pg g^{-1}, wet wt.) in lake trout muscle from Lakes Laberge, Kusawa and Quiet Lakes

	Laberge	n	% Lipid	BDE 47	BDE 49	BDE 99	BDE 100	BDE 153	BDE 154
Laberge	1993	10	1.99 (1.69)	1481 (728)	348 (112)	2943 (1531)	700 (341)	642 (491)	1530 (1009)
	2000	6	0.45 (0.25)	4900 (1680)	2100 (240)	8590 (1170)	3380 (630)	5740 (1320)	4460 (1190)
	2003	8	0.41 (0.19)	3170 (1430)	1290 (750)	5890 (2860)	2450 (1200)	3920(4050)	3200 (2810)
	2005	10	2.04 (1.22)	2659 (1977)	165 (117)	4093 (2389)	1848 (1235)	740 (580)	986 (732)
	2006	1	1.01	24920	1630	35900	11370	4120	3240
	2007	9	1.20 (0.79)	5500 (901)	1100 (1130)	9680 (1627)	6700 (5850)	200 (560)	1900 (1450)
	2008	10	2.3 (1.1)	2389 (1207)	2175 (1476)	1721 (1222)	139 (99)	258 (152)	560 (211)
	2009	10	2.9 (1.1)	1590 (1815)	1546 (987)	2799 (1165)	1421 (729)	347 (141)	250 (355)
Kusawa	1999	10	3.01 (2.20)	4377 (2490)	nd	3636 (2011)	2573 (1623)	894 (622)	1495 (895)
	2001	10	2.78 (1.63)	700 (990)	130 (160)	720 (1090)	250 (250)	260 (480)	230 (330)
	2003	5	0.16 (1.12)	960 (1220)	360 (47)	2630 (3510)	950 (1260)	1180 (1590)	870 (1150)
	2006	9	1.82 (1.49)	1103 (1231)	66 (99)	824 (911)	446 (514)	136 (140)	202 (236)
	2007	9	1.60 (1.41)	9900 (1216)	300 (700)	12300 (1271)	3900 (5990)	1100 (830)	600 (790)
	2008	10	1.16 (0.42)	4178 (1781	6475 (2398)	1653 (1394)	294 (113)	58 (103)	1653 (609)
	2009	10	1.51 (1.11)	417 (135)	73 (88)	273 (106)	121 (53)	27 (10)	69 (38)
Quiet	1992	6	2.52 (0.71)	25 (20)	nd	18 (31)	3 (5)	6 (6)	11 (14)
	2001	5	0.94 (0.94)	28 (40)	nd	19 (32)	8 (10)	11 (7)	12 (14)
	2003	5	0.12 (0.09)	51 (106)	7 (4)	127 (273)	18 (41)	32 (71)	17 (35)

nd = non detect; Laberge 2004 and Kusawa 2004, 2005 samples are currently be re-analyzed. Results will be available by mid-July 2007.

Expected Project Completion Date

Temporal trend studies are long-term propositions and thus annual sampling is projected until well into the future.

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Arctic Caribou and Moose Contaminant Monitoring Program

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Abstract

The objective of this project is to determine contaminant levels in caribou and moose in the Canadian Arctic to determine if the animal populations remain healthy (in terms of contaminant loads), whether these important resources remain safe and healthy food choices for northerners and to see if contaminant levels are changing over time. In 2009/10, 20 Porcupine, 20 Qamanirjuaq and 7 Tay caribou were sampled. Results from the previous year's collections were analyzed. Renal cadmium and mercury were notably high in NWT moose collected from the Southern Mackenzie Mountains as compared with moose collected from the NWT Mackenzie/Liard Valleys and the Yukon. Since this is a remote, pristine area with no known local sources of contamination, it is likely that these high concentrations are coming from naturally high levels of these minerals in the local substrate. A health advisory was issued recommending limiting consumption of livers and kidneys from some NWT moose. There was a significant but slight decrease in copper in Yukon moose from 1994-2008. Copper concentrations in both NWT and Yukon moose are considered marginal. If copper is declining in Yukon moose over time, there is potential for a negative population effect, since copper deficiency can adversely affect

Résumé

Le projet a pour but de déterminer les teneurs en contaminants (métaux) chez le caribou et l'orignal de l'Arctique canadien, afin d'établir si les populations d'animaux demeurent saines (en ce qui concerne les charges des contaminants), si ces importantes ressources demeurent des aliments sûrs et sains pour les résidents du Nord et si les teneurs en contaminants varient dans le temps. En 2009-2010, 20 caribous de la harde de la Porcupine, 20 de la harde Qamanirjuaq et 7 de la harde Tay ont été échantillonnés. Les résultats des échantillonnages de l'année précédente ont été analysés. Les teneurs en cadmium et en mercure dans les reins étaient nettement élevées chez l'orignal des Territoires du Nord-Ouest (T.N.-O.) provenant du sud des monts Mackenzie, par comparaison aux teneurs mesurées chez l'orignal provenant des vallées du Mackenzie et de la rivière Liard (T.N.-O.) et du Yukon. Cette région étant éloignée et intacte et sans source connue de contamination, il est probable que de telles teneurs élevées résultent de teneurs naturelles élevées de ces minéraux dans le substrat de la région. Un avis de santé publique a recommandé de limiter la consommation de foie et de reins de certains orignaux des T.N.-O. De 1994 à 2008, on a observé une baisse significative, quoique légère, des teneurs en cuivre chez l'orignal du Yukon. Chez l'orignal des

reproduction. Although overall, mercury in the Porcupine caribou has not significantly increased or decreased over time, it does undergo cyclic changes. This cycle is likely driven by environmental factors and demonstrates the necessity for annual sampling, since sporadic sampling could result in erroneous conclusions, depending on where, in the cycle, the samples were taken. Levels of most elements measured in moose and caribou tissues 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. Heavy metals, including mercury, are very low in the meat (muscle) from both moose and caribou and this remains a healthy food choice.

T.N.-O. et du Yukon, les teneurs en cuivre sont considérées comme marginales. Si les teneurs en cuivre sont à la baisse chez l'orignal du Yukon dans le temps, il existe un risque d'effet négatif sur les populations, parce qu'une carence en cuivre peut nuire à la reproduction. Même si dans l'ensemble les teneurs en mercure chez le caribou de la Porcupine n'ont ni augmenté ni diminué de manière significative dans le temps, elles sont soumises à des variations cycliques, qui sont probablement déterminées par des facteurs environnementaux. Il est donc nécessaire d'effectuer un échantillonnage annuel, parce qu'un échantillonnage sporadique pourrait mener à des conclusions erronées, selon le moment du cycle correspondant au prélèvement des échantillons. La teneur de la plupart des éléments mesurés dans les tissus d'orignal et de caribou ne constituait pas une préoccupation sur le plan de la toxicologie, bien que des teneurs en mercure et en cadmium dans les reins peuvent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. Les teneurs en métaux lourds, y compris celles du mercure, étant très faibles dans la viande (muscle) d'orignal et de caribou, les deux espèces demeurent des aliments sains.

Key Messages

- Levels of most elements measured in moose and caribou tissues are not of concern, although kidney mercury and cadmium concentrations may cause some concern for human health depending on the quantity of organs consumed. Moose and caribou meat (muscle) does not accumulate high levels of contaminants and is a healthy food choice.
- Copper may be declining in Yukon moose, which could negatively affect populations due to reduced reproduction associated with copper deficiency.
- Over the long term, mercury in the Porcupine caribou is stable, but does undergo a cycle. More research is being conducted to determine causes of the cycle and mercury dynamics within the caribou food chain.

Messages clés

- La teneur de la plupart des éléments mesurés dans les tissus d'orignal et de caribou ne constitue pas une préoccupation, bien que des teneurs en mercure et en cadmium dans les reins peuvent être préoccupantes pour la santé humaine, selon la quantité d'organes consommée. La viande d'orignal et de caribou (muscle) n'accumule pas de grandes concentrations de contaminants et constitue donc un aliment sain.
- Si les teneurs en cuivre sont à la baisse chez l'orignal du Yukon, il existe un risque d'effet négatif sur les populations, parce qu'une carence en cuivre peut nuire à la reproduction.
- À long terme, les teneurs en mercure chez le caribou de la Porcupine sont stables, mais sont soumises à des variations cycliques. D'autres études en cours permettront de déterminer les causes de ces variations ainsi que la dynamique du mercure dans la chaîne alimentaire du caribou.

Objectives

To determine levels of and temporal trends in contaminants in Arctic caribou and moose in order to:

- Provide information to Northerners regarding contaminants in these traditional foods, so that:
    - They may be better able to make informed choices about food consumption. This includes providing information for health assessments and/or advisories as required.
    - Wildlife managers can assess possible health effects of contaminants on Arctic moose and caribou populations.
- Further understand the fate and effects of contaminant deposition and transport to the Canadian Arctic.

Introduction

Moose and caribou provide an important food resource for Northerners across the Arctic, and have been designated in the NCP blueprint as key species for monitoring contaminants in the terrestrial Arctic ecosystem. Two barren-ground caribou herds, one from the eastern and one from the western Arctic, have been designated for annual sampling, and five additional caribou herds and two moose populations have been designated for sampling every five years.

Activities in 2009-2010

Tissue samples were collected from the Porcupine (N=20), Qamanirjuaq (N=20) and Tay (N=7) caribou herds. Sampling information was also collected for each animal, including gender, date and location of collection. Porcupine caribou were sampled by local hunters as part of the ongoing Yukon Hunter Survey Program. Samples from the Qamanirjuaq caribou herd were taken by a local hunter under the supervision of the local regional biologist. The Tay caribou were sampled as part of a facilitated traditional hunt in cooperation with the Ross River Dena and with support from Environment Yukon (logistical support in collecting and preparing biological samples). Additional samples and morphometric measurements were taken from the Tay caribou in accordance with the CARMA (CircumArctic Rangifer Monitoring and Assessment Program) protocol. Since the target of samples from 20 Tay caribou was not achieved during this hunt, the local outfitter has agreed to provide samples from as many successful Tay caribou hunts as possible in the fall of 2010.

Liver, kidney, muscle and incisors were collected from designated moose and caribou populations. All samples were prepared for analysis in Whitehorse, YT by the program coordinator and kidneys were analyzed for a suite of 31 elements at the National Laboratory for Environmental Testing (Environment Canada) using the inductively coupled plasma technique with mass spectroscopy, and for total mercury using cold vapour atomic absorption spectroscopy, under the supervision of Dr. Derek Muir. Remaining liver and muscle samples were archived at –50C at the INAC facility in Whitehorse, YT. Caribou teeth were aged by the project leader and a Yukon Environment technician in Whitehorse using the tooth cementum technique.

Although the concentration of Mercury in caribou muscle tissue is quite low, some northerners consume large quantities of caribou meat and so the total intake of Mercury from caribou meat may potentially be relatively high. To address this question, archived muscle tissue samples from Yukon caribou were analyzed for total Mercury at the University of Northern British Columbia. A subsample of these will also be analyzed for methylmercury, but those data are not yet available.

Although kidneys were analyzed for 31 elements, only results for 7 elements of concern were analyzed in detail (arsenic, cadmium, copper, lead, mercury, selenium and zinc). In 2006 NWT moose were collected from two regions in the Deh Cho area, the Mackenzie Mountains and the Mackenzie/Liard Valleys. Although both genders of moose were collected, only males were collected from the mountain region. Potential gender differences were then assessed only using moose collected from valley locations, and differences between locations were assessed using only male moose. Renal element concentrations were compared among the Yukon and two NWT locations (mountain and valley). A thorough analysis and discussion of element concentrations (including trends) in Yukon moose was published in 2005 (Gamberg et al. 2005). Using the current data to extend the analysis of temporal trends is difficult due to the absence of data from 2004-7, so the current data were compared to the average of previous years to determine if levels have changed significantly over the last 5 years. Similarly, element concentrations were compared between the Qamanirjuaq and Porcupine caribou herds. Temporal trends were assessed for both moose and caribou using a general linear model (recognizing the limits imposed by a 4-year data gap for Yukon moose). Only male, fall-collected animals were used for these analyses. In all statistical analyses, age was tested as a cofactor, and data were log-transformed to achieve normality. If normality was not achieved by this transformation, non-parametric tests were used to analyze the data.

Capacity Building and Training

Capacity building and training were to be found throughout this project, particularly in the facilitated traditional hunt of the Tay caribou herd. The camp environment was invaluable in providing opportunities for youth to learn current scientific methods as well as traditional knowledge and wisdom. Youth, hunters and elders all had the opportunity to discuss contaminants in caribou with scientists and to observe and participate in extracting samples for contaminant analysis as well as taking basic body condition measurements, specific samples and morphometric measurements as designated under the CARMA protocol. The project coordinator used samples from this project to teach a laboratory class at Yukon College (Renewable Resource Program) on contaminants in moose and caribou. This was a hands-on laboratory to teach 'trace element clean' laboratory practices and the aging of moose teeth. Results from this project were also used in a lecture given to Yukon college students. One Yukon college student assisted the project leader with laboratory work for one semester (approx. 3 hours/week) during which time she learned to process tissues for contaminant analysis and to age moose teeth. This student subsequently applied for and received several scholarships and grants that will allow her, in cooperation with the project leader, to pursue projects related to mercury in caribou and caribou population genetics. One of these projects will involve vegetation collection by the Yukon College student and a group of high school students under the Yukon Government 'Y2C2' program, and will incorporate 'trace element clean' sampling techniques for contaminant analysis.

Traditional Knowledge

This program relies on the traditional knowledge of both Aboriginal and non-Aboriginal people when collecting samples from caribou for analysis. In all cases local hunters use traditional knowledge when hunting caribou and ultimately submitting samples as well as providing food for their families. In Arviat, all samples were collected from the Qamanirjuaq herd by one local hunter who uses traditional knowledge on a daily basis, as well as when hunting for food for his community and providing samples for this project. This year, during the Tay caribou hunt, we had a unique opportunity to facilitate the flow of traditional knowledge from elders and traditional hunters to the youth of the community as well as biologists and scientists participating in the camp. The informal atmosphere fostered many casual conversations among all the camp members regarding contaminants, wildlife, wildlife management, traditional knowledge about caribou, wolves, the land in general and climate change, to the benefit of all involved.

Communications

The program was advertised in the fall of 2009 in newspapers (English and French), through posters and in the Outdoor Edge (magazine of the Yukon Fish and Game Association). A lecture and laboratory were presented at Yukon College (Renewable Resource Program) discussing the results of this program. A presentation was also given at a Summer Science camp for Aboriginal youths using games as a teaching tool. A radio interview (CBC) was given (along with the Chief Medical Officer of Health for the Yukon) about results of the program in February 2010.

Results of this project have been communicated to the YCC and NAC in the form of a detailed year-end report and will be presented at the NCP symposium anticipated for the fall of 2010. The project coordinator is available throughout the year to answer specific questions or address relevant issues from any of the participating groups or Regional Contaminants Committees as they arise. All data will be incorporated into the existing database for Canadian Arctic moose and caribou contaminants, currently maintained by INAC, Whitehorse. Plain language summaries, brochures and/or posters focussing on individual herds/ populations will be prepared and circulated to stakeholder groups in cooperation with each Regional Contaminants Committee. Special presentations may be made as the results dictate, or upon request, in cooperation with the Regional Contaminants Committees.

The project coordinator is a member of the Yukon Contaminants Committee (YCC), and provides updates on this project at each meeting of the YCC. Each hunter submitting samples to the program is sent a letter informing them about the Hunter Survey Program and the results to date. This form of communication has been in place for the duration of this project in the Yukon (15 years) and is supported by the YCC. The project leader normally arranges at least one radio interview regarding the program, (and often newspaper articles as well), and is available to attend public meetings or health fairs upon request, or to give presentations to local groups (school or college classes, Yukon Science Institute, Government biologists) to discuss the program and the current status of contaminants in wildlife in the Yukon. Data collected through this program was published in a special edition of Science of the Total Environment in 2005. When analysis of the Tay caribou have been completed, a public meeting will be held in Ross River, in cooperation with Yukon Environment and the Ross River Dena Council to present the results and answer questions about the program. Informational materials for the meeting will be developed in cooperation with Yukon Environment and the Ross River Dena Council.

Participating Government of Nunavut biologist (Mitch Campbell) includes project results in their ongoing communications with local communities and HTOs. This involves regularly scheduled community meetings, meetings with specific groups and newsletters. If requested by (and supported by) the NAC, the project leader will provide informational materials regarding contaminants in the Qamanirjuaq caribou herd.

Although the data gathered through this program is the technical property of NCP, the data is being made available to participating researchers and communities for public information purposes. Publication of the data in scientific journals is the responsibility of the project leader. All researchers participating in this program have agreed to abide by the Northern Contaminants Program Data and Sample Accessibility Agreement.

Results and Discussion

Results from the 2009/10 collection (including MeHg analyses) should be available by March 2011. Results from samples collected in 2008/9 have been analyzed and are presented here (Tables 1-3). Note that element results from 17 Qamanirjuaq

Table 1. Renal element concentrations ($\mu g \cdot g^{-1}$ dry weight) in moose collected in from Yukon and NWT (mean + standard deviation).

	Moose Kidneys			
	Yukon (2008)	NWT (2006)		
	Males	Valley Females	Valley Males	Mountain Males
N	21	14	29	18
Age	6.6 + 3.4	5.9 + 3.9	3.6 + 3.1	7.4 + 2.8
Arsenic	0.08 + 0.22	0.02 + 0.06	0.04 + 0.07	0.02 + 0.02
Cadmium	166.9 + 111.4	69.4 + 61.9	132.2 + 267.3	1000.9 + 787.8
Copper	14.8 + 2.1	13.8 + 4.4	13.4 + 4.4	14.9 + 2.7
Lead	0.01 + 0.01	0.10 + 0.26	0.18 + 0.84	0.02 + 0.02
Mercury	0.01 + 0.03	0.09 + 0.06	0.12 + 0.11	0.18 + 0.08
Selenium	4.0 + 0.9	2.7 + 1.3	3.1 + 0.9	3.8 + 0.9
Zinc	156.8 + 35.5	105.1 + 39.5	102.4 + 48.6	151.5 + 29.1

Table 2. Hepatic element concentrations ($\mu g \cdot g^{-1}$ dry weight) in moose collected from NWT (mean + standard deviation).

	Moose Livers		
	NWT (2006)		
	Valley Females	Valley Males	Mountain Males
N	14	29	18
Age	5.9 + 3.9	3.6 + 3.1	7.4 + 2.8
Arsenic	0.04 + 0.07	0.09 + 0.17	0.02 + 0.01
Cadmium	9.0 + 8.2	8.0 + 6.7	82.4 + 159.0
Copper	108.3 + 98.5	101.6 + 106.6	325.7 + 732.6
Lead	1.09 + 3.85	0.03 + 0.03	0.03 + 0.03
Mercury	0.04 + 0.04	0.04 + 0.04	0.12 + 0.07
Selenium	2.9 + 3.4	4.0 + 4.4	3.5 + 3.1
Zinc	75.3 + 19.2	84.5 + 36.8	80.5 + 41.5

Table 3. Renal element concentrations ($\mu g \cdot g^{-1}$ dry weight) in caribou collected in 2008 (mean + standard deviation).

	Porcupine	Qamanirjuaq	
	Males	Females	Males
N	20	7	10
Age	6.1 + 2.0	8.1 + 2.4	5.4 + 2.7
Arsenic	0.03 + 0.02	0.04 + 0.02	0.03 + 0.01
Cadmium	27.3 + 16.8	30.6 + 13.7	15.1 + 7.6
Copper	32.8 + 28.5	24.6 + 4.9	25.0 + 3.9
Lead	0.2 + 0.4	0.3 + 0.1	0.3 + 0.1
Mercury	1.34 + 0.60	5.11 + 1.85	3.28 + 1.53
Selenium	4.3 + 0.5	4.2 + 0.7	4.2 + 0.3
Zinc	138.4 + 33.7	107.4 + 19.2	104.3 + 7.4

caribou (2008) samples are presented while 3 are currently being analyzed. Results from the analysis of perfluorinated compounds from caribou samples collected in 2007 and 2008 are also presented (Table 4). In addition, results from moose collected in 2006 from the Deh Cho region of NWT have now been released to the public, and have been analyzed and presented along with the more recent results from Yukon moose (Tables 1, 2).

Renal Cd and Zn were positively correlated with age in moose. Renal Cd and Hg were notably high in NWT moose collected from the Southern Mackenzie Mountains as compared with moose collected from the NWT Mackenzie/Liard Valleys and the Yukon (Fig. 1). Since this is a remote, pristine area with no known local sources of contamination, it is likely that these high concentrations are coming from naturally high levels of

Table 4. Fluorinated compounds in caribou liver and kidney ($\mu g \cdot g^{-1}$ wet weight)

Herd	Year	N	Tissue	PFOS		PFCAs	
				min	max	min	max
Qamanirjuaq	2006	11	Kidney	0.02	0.07	0.1	0.53
Porcupine	2006	10	Kidney	0.01	0.03	0	0.33
	2006	10	Liver	0.01	1.34	2	7.4
	2007	10	Liver	0.18	1.72	4.2	7.8

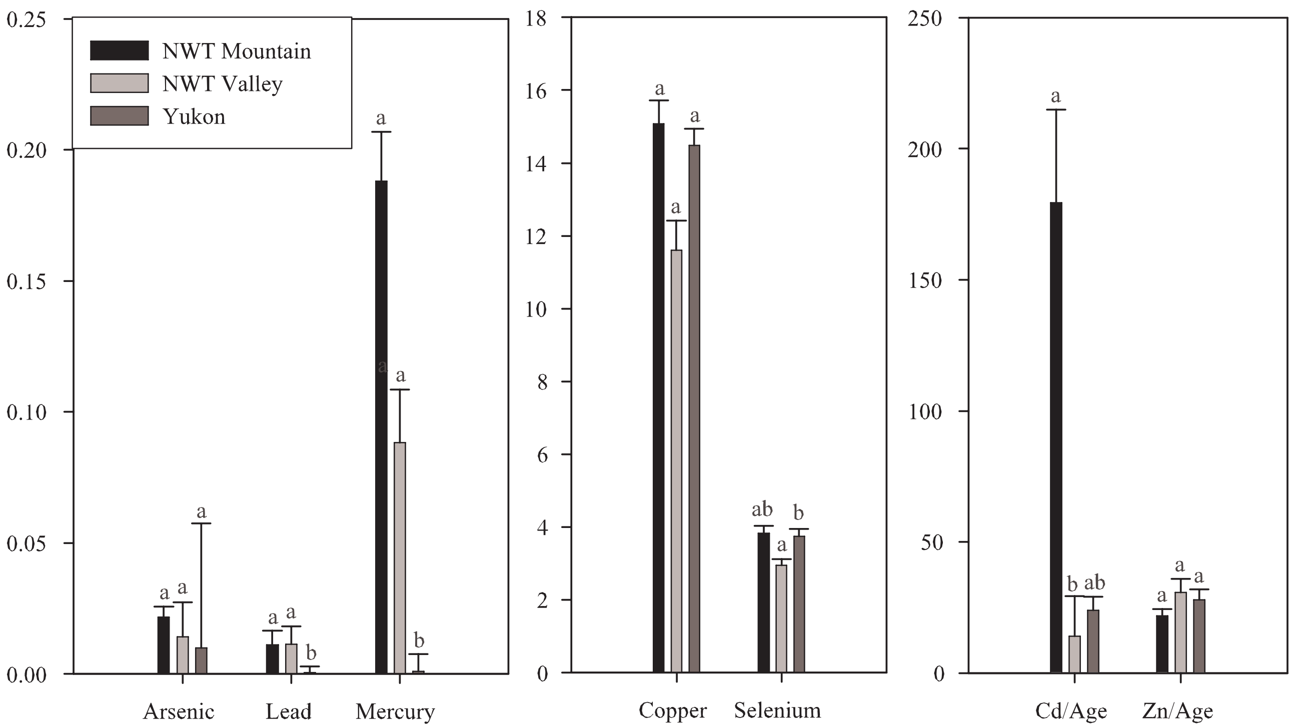

Figure 1. Median renal element concentrations ($\mu g \cdot g^{-1}$ dry weight) in male, fall-collected moose collected from NWT (2006) and Yukon (1994-2008). Within one element, bars with the same letter are not significantly different.

these minerals in the local substrate. As was more variable in Yukon moose due to a small number of moose with high concentrations of As in their kidneys. These moose were taken from an area known to be high in As due to local contamination from an old mine.

None of Cd, Cu, Se or Zn differed significantly between moose samples collected from the Yukon in 2008 and previously. However As, Pb and Hg were all significantly lower in the 2008 samples. All three of these elements are commonly found near or below the analytical detection limit, and the apparent decrease is likely due to lower detection limits in 2008 (previous samples were analyzed at Elemental Research Inc., Vancouver, while the 2008 samples were analyzed at NLET, Environment Canada, Burlington, which has lower detection limits for these elements).

There is a significant but slight decrease in Cu and increase in Zn in Yukon moose from 1994-2008. Figure 2 shows that although both elements tend to fluctuate together, with a 4 year gap in data (between 2004 and 2007) it is unclear whether the apparent trends reflect true increases or decreases, or simply reflect high annual variation in these elements. Zn is found at levels normal for domestic cattle (Puls 1994) in moose from Yukon and NWT while Cu concentrations found in moose from both

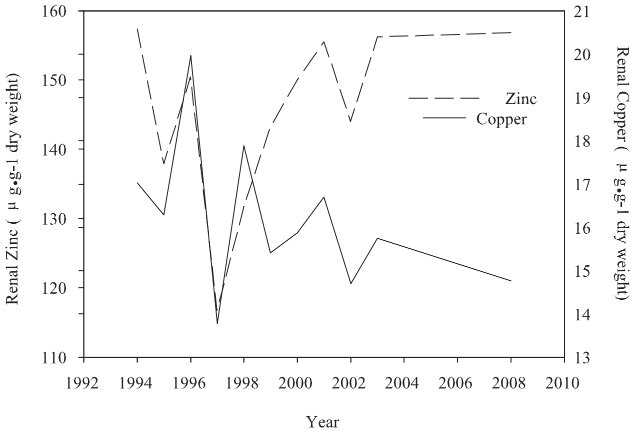

Figure 2. Renal copper and zinc concentrations (µg·g^{-1} dry weight) from Yukon moose

areas would be considered marginal for domestic cattle. If Cu is declining in Yukon moose over time, there is potential for a negative population effect, since Cu deficiency can adversely affect reproduction (Puls 1994).

Renal Cd, Zn and Hg increased with age in caribou. For the years 2006-2008, As, Cd, Cu and Zn were significantly higher in the Porcupine herd while Hg and Pb were higher in the Qamanirjuaq herd (Fig. 3). Note that since ages were not significantly different between the two herds, elements were not corrected for age for presentation of comparisons. Cu increased slightly over those 3 years in the Porcupine herd, but not the Qamanirjuaq. Se and Hg increased in the Qamanirjuaq herd while both elements decreased in the Porcupine caribou, although the two elements were not significantly correlated.

Longer term temporal trends were examined using fall-collected male Porcupine caribou from 1994-2008. Although As appears to be declining significantly over time, it is likely due to the lower detection limits at the current laboratory. Cu and Zn are increasing slightly over time and are highly correlated (Fix 4). The other elements tested (Cd, Pb, Hg and Se) have not significantly increased or decreased from 1994-2008. Although overall, Hg has not significantly increased or decreased over time, it does undergo cyclic changes (Fig. 5). This cycle is likely driven by environmental factors and may be related to the Pacific Decadal Oscillation, with caribou renal concentrations decreasing when the index is in a negative mode during the spring and summer and increasing when the index is in a

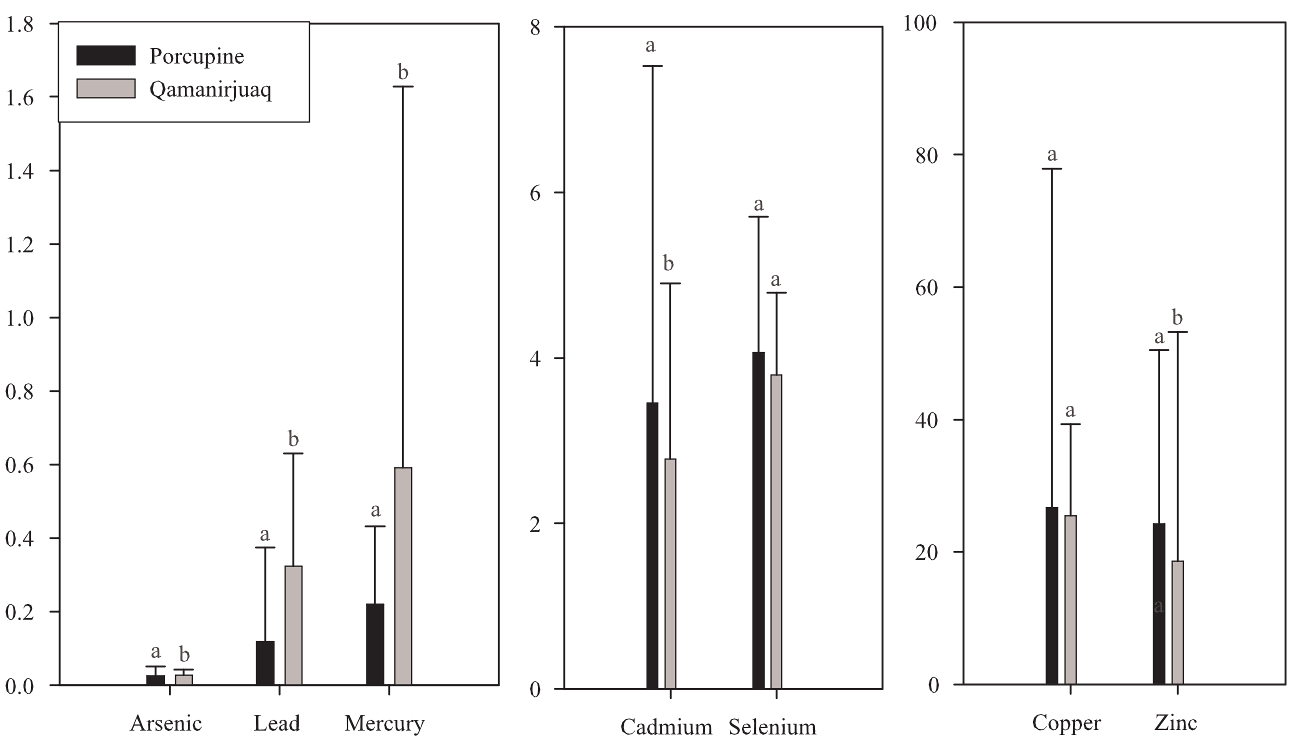

Figure 3. Median renal element concentrations (µg·g^{-1} dry weight) in Porcupine and Qamanirjuaq caribou collected 2006-2008. Within one element, bars with the same letter are not significantly different.

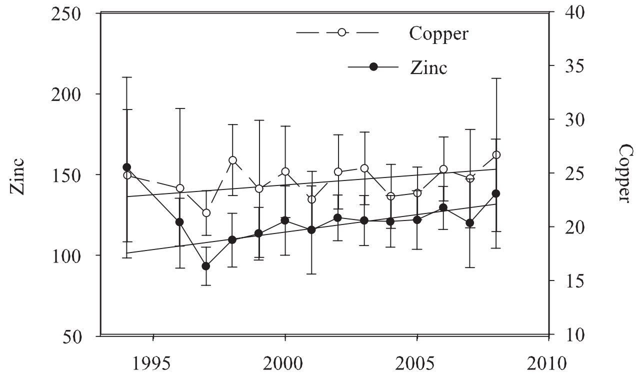

Figure 4. Mean renal element concentrations (μg·g^{-1} dry weight) in male, fall-collected Porcupine caribou.

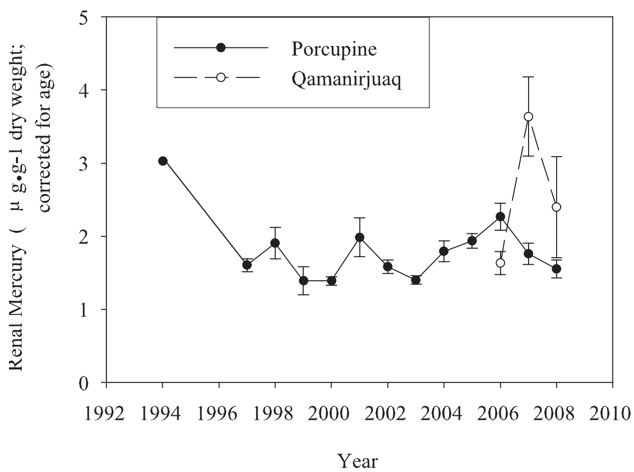

Figure 5. Renal mercury in the Porcupine and Qamanirjuaq caribou.

positive mode during that time. Further analysis is required to investigate this potential relationship further. The cyclic nature of changes in renal Hg in the Porcupine caribou demonstrates the necessity for annual sampling, since sporadic sampling could result in erroneous conclusions, depending on where, in the cycle, the samples were taken.

Average concentrations of Hg in Yukon caribou muscle tissue ranged from 0.002-0.006 μg·g^{-1} wet wt depending on the herd. The Porcupine and Hart River herds had the lowest, and the Carcross herd had the highest. With these concentrations, a 70 kg individual could consume between 6 kg (Carcross herd) and 18 kg (Porcupine/Hart herds) of meat every day before exceeding the guideline recommended by the World Health Organization (World Health Organization 1989). The recommended limit for women of childbearing age is lower so that this group could eat between 2 kg (Carcross herd) and 7 kg (Porcupine/Hart herds) every day.

PFOS concentrations in caribou ranged from 0.01–1.72 ng·g^{-1} wet wt while total PFCAs (sum of perfluoronona-, deca- and undeca PFCAs) ranged from 0.1–7. 8 ng/g wet wt (Table 3). These concentrations are within the range reported by Tittlemier and Chan (2006). While PFOS based chemicals have been phased out by their manufacturer they have been largely replaced by PFCA-based chemicals (USEPA 2000; Renner 2005). PFCAs have been increasing in ringed seals while PFOS has declined (Butt et al. 2007).

Levels of most elements measured in moose and caribou tissues 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 moose and caribou, the recommended maximum varying depending on species and herd (e.g. a maximum of 1 moose kidney/year or 32 Porcupine caribou kidneys/year). NWT Health and Social Services has advised limiting consumption of moose liver and kidney to the following: Moose from the Mackenzie/Liard River alleys – one serving of liver/week, one serving of kidney every two months; moose from the southern Mackenzie Mountains – one serving of liver every 3 months, kidney from these animals is not recommended for consumption. The health advisories for both territories confirm that heavy metals are very low in the meat (muscle) from both moose and caribou and this remains a healthy food choice.

NCP Performance Indicators

Number of northerners engaged in this project: 62 (Tay caribou collection 29, Porcupine caribou collection 24, Qamanirjuaq collection 3, Student volunteer 1, YTG staff 5)

Number of meetings/workshops held in the north: 5 (4 meetings, 1 camp for the Tay caribou collection)

Number of students involved in this project: 7

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

Expected Project Completion Date

This program is ongoing.

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Transport of mercury from thawing permafrost to lake sediments in the Mackenzie Delta, NWT

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Abstract

We examined mercury and Rock Eval carbon fractions in dated sediment cores from thermokarst lakes in the Mackenzie Delta, NWT. We found that sediment cores drawn from lakes with permafrost thaw slump development on their shorelines had higher sedimentation rates and lower total mercury, methyl mercury, and organic carbon fractions compared to lakes where thaw slumps were absent. Total mercury and methyl mercury concentrations were correlated with total organic carbon and S2 (labile algal-derived) carbon indicating an association between organic sedimentation and mercury in these sediments. Preliminary evidence suggests that thaw slump development increases inorganic sedimentation rates in lakes, while decreasing concentrations of organic carbon, mercury, and methyl mercury in sediments.

Résumé

Nous avons étudié le mercure et les fractions de carbone Rock Eval dans des carottes de sédiments provenant de lacs thermokarstiques du delta du Mackenzie dans les Territoires du Nord-Ouest. Les carottes de sédiments prélevées sur les rives de lacs où on avait observé des glissements dus au dégel se caractérisaient par un taux de sedimentation plus élevé et des teneurs en mercure total, en méthylmercure et en fractions de carbone organique plus faibles que celles de lacs où on n'observait aucun glissement. Les teneurs en mercure total et en méthylmercure étant corrélées avec la teneur en carbone organique total et en carbone S2 (carbone labile provenant des algues), cela indique une association entre la sédimentation organique et la teneur en mercure de ces sédiments. Selon les premiers résultats, les glissements dus au dégel font augmenter le taux de sédimentation organique dans les lacs,

alors qu'ils font baisser les teneurs en carbone organique, en mercure et en méthylmercure dans les sédiments.

Objectives

To analyze radiometrically dated lake sediment cores for trace metals and organic carbon fractions to determine if contaminant delivery in the past was correlated with accelerated permafrost degradation.

Introduction

This project was designed to determine how mercury and methyl mercury delivery to lakes and organic production is changing in the Mackenzie Delta region near Inuvik, where thawing permafrost is occurring on a large scale and is believed to be affecting freshwater ecosystems. This research will develop our understanding of mercury released to surface waters from areas affected by thawing permafrost, which clearly addresses NCP's strategic area of Pathways, Processes, and Effects, and specifically examines processes of contaminant deposition and the factors that influence the exchange of contaminants between different abiotic compartments of the Arctic environment. This project is co-funded by an NSERC Strategic Projects initiative that was approved in 2008.

Thawing permafrost is already changing the polar landscape and will likely accelerate in coming decades. Consequent to thaw, significant changes in hydrology, organic carbon pathways and freshwater resources are also expected (ACIA 2005). Currently, about one fifth of the exposed surface of the Earth is underlain by some form of permafrost, including 22% of the land area in the Northern Hemisphere (Davis 2001). Since the 1970s there has been a steady increase in permafrost temperatures in many Arctic regions including Alaska (Lachenbruch and Marshall 1986, Jorgenson et al. 2006), western Canada (Burn 2002) and Siberia (Pavlov 1994), although rates of permafrost melt have been different in some parts of eastern Canada (Serreze et al. 2000).

Recent studies predict that the influx of slump material from degrading permafrost into freshwater systems will introduce a variety of materials that were previously trapped in the frozen ice and soil (Kokelj and Burn, 2005; Kokelj et al., 2005). As the active layer deepens and more unfrozen flow pathways develop in the permafrost, increased geochemical weathering from drainages is expected (Hobbie et al. 1999, Kokelj et al. 2005, Prowse et al. 2006), leading to changes in freshwater chemistry, including increases in concentrations of ions such as Na^+, K^+, Mg^{+2}, SO_4^{-2}, Cl^-, and HCO_3^-, and decreases in dissolved organic carbon (Kokelj et al. 2005). The extent to which thawing permafrost will change the amount of metallic and organic contaminants entering freshwater lakes is a significant gap in our knowledge of how ecosystems will respond to climate warming. We know from studies of mercury from hydroelectric reservoirs that rapid decomposition and oxygen depletion in soils results in increased mercury and methyl mercury release to surface waters (St-Louis et al. 2004, Brigham et al. 2002), though comparable information for permafrost has not been collected. We also know from some studies on contaminated soils that continuous permafrost typically acts as an effective barrier preventing contaminants from infiltrating into the ground (e.g. Braddock and McCarthy 1996), and some (e.g., Curtosi et al. 2007) have predicted that thawing permafrost will release contaminants to surface waters with unknown ecological consequences. In addition, recent increases in algal productivity from pronounced climate warming in Arctic lakes may also increase contaminant delivery to lake sediments, and changing permafrost status has been implicated as one of the potential influences (Macdonald et al. 2005, Stern et al. 2005, Outridge et al. 2007, Carrie et al. 2010).

The consequences of thawing permafrost on the Hg cycle are complex but will likely involve several pathway elements including: 1) The exposure of old soil organic carbon to the liquid hydrological cycle (northern permafrost contains one of the largest organic carbon reservoirs in the world (McGuire et al. 2009); 2) The alteration of pathways for newly produced terrigenous organic carbon (e.g., switch from tundra to willows, and deepening of the active layer) and; 3) The alteration of aquatic productivity due to change in light regime or hydrology (Smol and Douglas 2007, Outridge et al. 2007). The connection with Hg cycle will, accordingly, include the exposure and release of Hg presently archived in frozen ground, the alteration of methylating activity for Hg cycling within northern aquatic systems (Macdonald and Loseto 2010), and change in the burial efficiency of Hg in aquatic sediments (Outridge et al. 2007). Depending on the how exactly the changes occur in a given location, these alterations could lead to increased exposure of methylated forms of Hg to foodwebs (e.g., by creating new wetlands) or decreased exposure (e.g., by dehydrating previously wet environments, by enhanced burial in sediments or by growth dilution (e.g., Pickhardt et al. 2002). Clearly, progress in understanding the risks Hg presents to aquatic foodwebs under a changing climate require a detailed understanding of the changes occurring in the organic systems.

Here we assessed mercury sedimentation in lakes with catchments affected by thawing permafrost in a case-control analysis of lakes where retrogressive thaw slumps are present and absent (Fig. 1). This study design is intended to provide an early indication of the influence of thawing permafrost on mercury delivery to lake sediments.

Activities in 2009-2010

We analyzed 8 sediment cores that were collected from lakes with physical characteristics in Table 1. The study lakes ranged in surface area from 0.8–9.2 ha with catchment area and maximum depth ranging from 6.6 – 45.1 ha and 2.7–10.5 m, respectively (Table 1). Four lakes had shoreline thaw slumps (disturbed lakes, denoted “b”) and four lakes had intact shorelines (undisturbed lakes, denoted “a” Figure 1).

Cores were radiometrically dated by ^{210}Pb, ^{137}Cs, and ^{226}Ra. We analyzed these dated lake sediment samples for mercury (Nippon Analyzer), methyl mercury (by GC-Atomic Fluorescence detector), and Rock-Eval organic analysis. We tested the hypothesis that mercury and methyl mercury sedimentation relates to autochthonous carbon (as determined by the Rock-Eval S2 fraction)

Table 1. Location and physical characteristics of the 8 study lakes located in the uplands directly to the east of the Mackenzie River Delta NWT, Canada. Morphometric data and slump activity were determined from air photo analyses and ground surveys undertaken during 2001–2005 (Kokelj et al. 2005). A_o is lake surface area, CA is catchment area, SA is area of retrogressive thaw slump, and Z_m is maximum depth of lake.

Lake	Latitude (°N)	Longitude (°W)	A_o (ha)	CA (ha)	SA (ha)	Slump status	Z_m (m)
I. Undisturbed Lakes							
2a	68° 50′ 26.7″	133° 66′ 07.1″	2.0	17.2	–	–	6.1
9a	68° 58' 05.8"	133° 53' 53.0"	3.1	29.3	–	–	2.7
14a	68° 31' 02.7"	133° 44' 55.4"	3.4	33.5	–	–	7.5
36a	68° 30' 10.4"	133° 42' 02.2"	0.8	6.6	–	–	9.5
II. Disturbed Lakes							
2b	68° 50' 72.8"	133° 67' 03.6"	4.9	15.9	0.95	Stable	3.4
9b	68° 58' 14.1"	133° 53' 59.3"	3.6	7.2	2.5	Active	3.0
14b	68° 31' 02.7"	133° 44' 55.4"	9.2	45.1	2.4	Active	10.5
36b	68° 30' 09.6"	133° 42' 05.2"	3.9	24.4	4.9	Stable	7.4

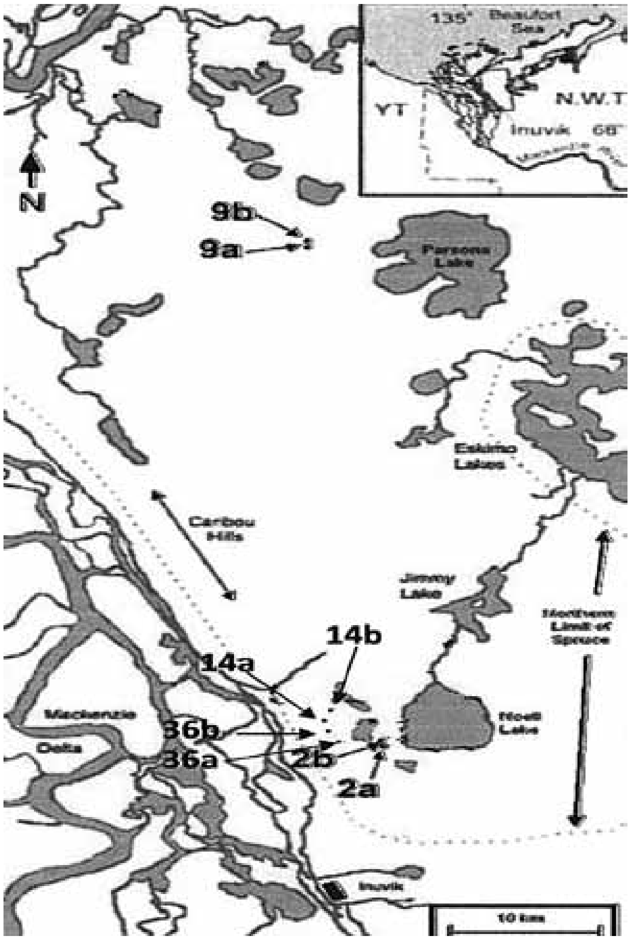

Figure 1 Study lakes in the Mackenzie Delta near Inuvik. Lakes denoted 'a' are undisturbed lakes, and those denoted 'b' have catchments disturbed by permafrost melting.

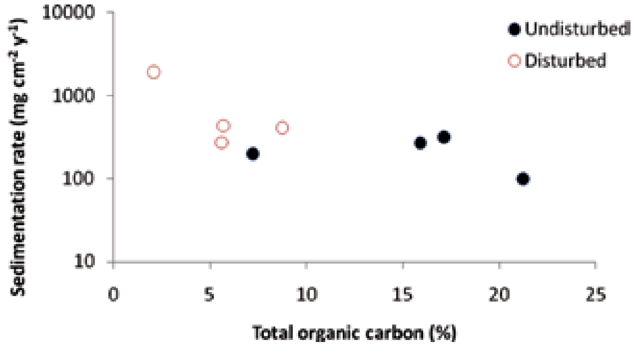

Figure 2. Sedimentation rates in sediment cores from eight study lakes (focus corrected to 50 Bq m^{-2} y^{-1} excess ^{210}Pb) plotted against the total organic carbon in surface sediments. Note that sedimentation rates in disturbed lakes tends to be higher than in undisturbed lakes, and total organic carbon is lower and likely 'diluted' by the higher inorganic sediment flux seen in disturbed lakes.

regardless of the lake's permafrost thaw history. Sediment accumulation rates for contaminants were established using radioisotope techniques which are routinely used in our labs following the methods described by Appleby (2001).

Results and Discussion

Surface sediments:

In our initial survey of 8 thermokarst lakes (Figure 1), we found that log sedimentation rates were inversely correlated to both total organic carbon ($r= 70$, $p<0.05$, Figure 2) and S2 carbon, a measure of labile, algal-derived organic matter ($r=0.72$, $p<0.05$). We compared sedimentation rates between lakes with permafrost thaw slumps (disturbed lakes) and those without thaw slumps (undisturbed lakes), and found that disturbed lakes had higher total sedimentation rates ($t = 2.35$, $p=0.05$, Figure 2). The disturbed lakes also had sediments with significantly lower total organic carbon ($t = 2.53$, $p<0.05$), suggesting that permafrost thaw slump development in the Mackenzie Delta region results in an increased influx of inorganic materials and a dilution of organic carbon fractions in sediments.

As with organic carbon concentrations, mercury concentrations in surface sediments from disturbed lakes were lower than in reference (undisturbed) lakes ($t = 2.92$, $p<0.05$), possibly due to the dilution of organic materials in lakes where thaw slumps are present. In the surface sediments from these 8 lakes, mercury concentration was significantly correlated to total organic carbon ($r=0.80$, $p<0.05$, Figure 3) and S2 carbon ($r=0.69$, $p=0.05$). Likewise methyl mercury in surface sediments was lower in disturbed lakes than undisturbed lakes ($t= 9.02$, $p<0.01$, $n=6$). The reduced sample size for methyl mercury was due to insufficient surface sediment available for methyl mercury analysis in two of the sediment cores. Methyl mercury was also significantly correlated to total organic carbon ($r=0.94$, $p<0.01$), S1 carbon ($r=0.92$, $p<0.01$), and S2 carbon ($r=0.89$, $p<0.05$), indicating an important association between methyl mercury formation and organic carbon sedimentation which is in turn influenced by permafrost status in these lakes. Taken together, the results suggest that dilution of organic matter by rapid influx of inorganic sedimentation in thaw slump lakes (Figure 2) reduces mercury and methyl mercury concentrations

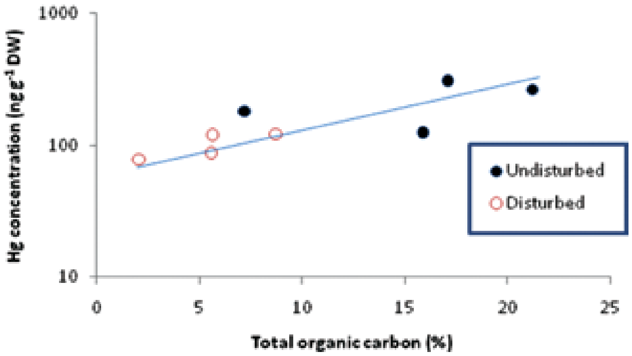

Figure 3. Mercury concentrations in surface sediments from eight separate lakes plotted against the total organic carbon in surface sediments. Note that Hg concentrations and total organic carbon is higher in undisturbed lakes than in disturbed lakes.

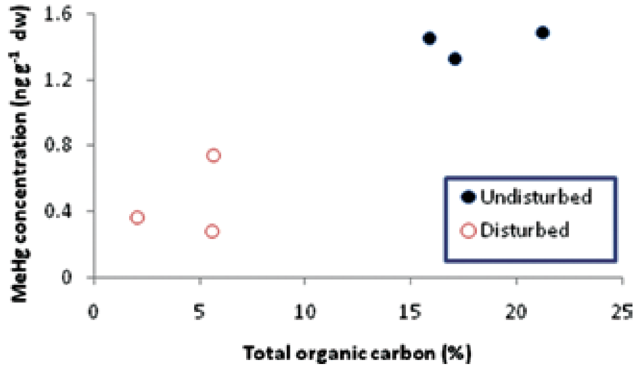

Figure 4. Methyl mercury concentrations in surface sediments from six separate lakes plotted against the total organic carbon in surface sediments. Six lakes are represented here because insufficient surface sediment for methyl mercury analysis was available for two of the eight study lakes.

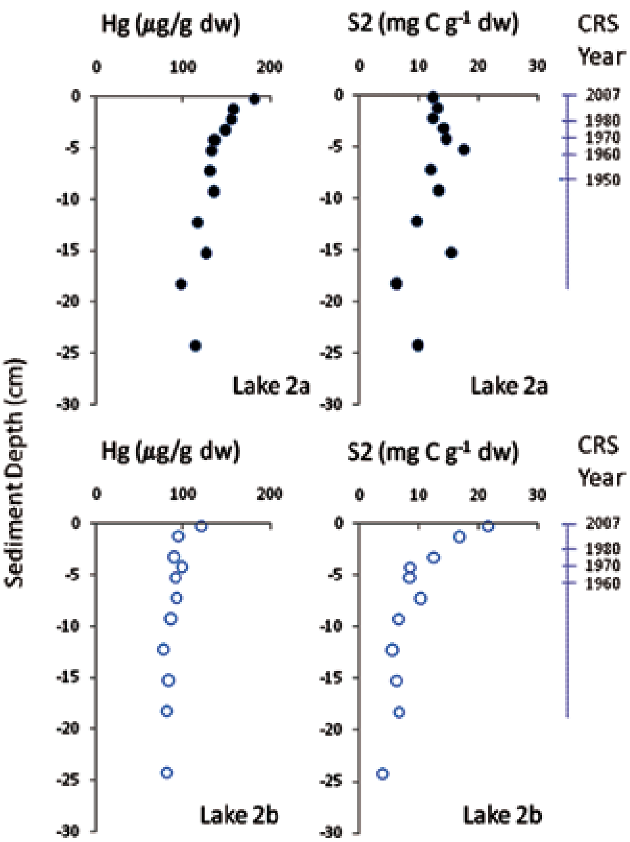

Figure 5. Sediment core profiles for mercury concentrations and S2 carbon in lakes 2a and 2b. Dates were determined by excess ^{210}Pb activity using the constant rate of supply model (Appleby 2001)

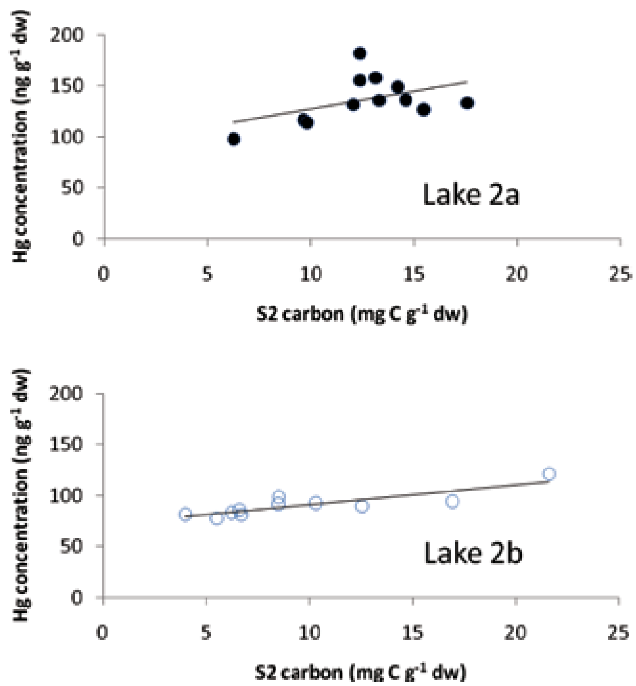

Figure 6. Correlations between Hg concentration and S2 carbon in sediment cores from Lakes 2a and 2b.

in these sediments. Increased sample sizes, a larger number of lakes, and greater statistical power will be desirable to confirm these trends.

Sediment cores:
Consistent with our analysis of surface sediments, total mercury and organic fractions (TOC, S2) in core profiles were lower on average in the disturbed lake (2b) than the reference lake (2a) (Figure 5). Mercury and S2 carbon increased in surface sediments relative to deeper sediments (Figure 5) as others have shown elsewhere in the Mackenzie region (e.g. Carrie et al. 2010). Both lakes showed this increasing trend in recent sediments, although the increase was more pronounced in Lake 2b. In the Lake 2b sediment core, total mercury concentrations in the different depth intervals correlated with total organic carbon ($r=0.87$, $p<0.001$), and S2 carbon ($r=0.86$, $p<0.001$) in those intervals. In Lake 2a, correlations between mercury and total organic carbon at different depth intervals were not apparent (TOC: $r=0.03$, $p=0.90$; S2: $r=0.46$, $p=0.13$) (Figure 6). The stronger correlations between mercury and organic fractions in 2b may have been due in part to the greater variation in TOC and S2 carbon content in that core.

Mercury and the organic carbon cycle:
The association between mercury concentrations in sediment and organic fractions (TOC, S1, S2) suggest that factors affecting organic delivery to sediments also affect mercury delivery to sediments. Kokelj et al. (2005) observed reduced DOC and POC in lakes with permafrost thaw slumps on their shorelines, and suggested DOC and POC removal by adsorption to ion rich clays exposed from thaw slump development. By contrast, shallow organic soils characteristic of undisturbed permafrost basins promote the release of DOC and POC via runoff from terrestrial to aquatic systems (Carrey 2003), and this may in turn promote the release of mercury from the terrestrial system in undisturbed catchments.

Our initial assessment of mercury in water and amphipods in our companion studies from these same lakes is revealing that lower concentrations of total Hg in water and amphipods, but higher Hg bioaccumulation factors in amphipods, are seen in lakes with thaw slump development (data not shown). We currently hypothesize that the higher bioaccumulation of mercury in amphipods from lakes with thaw slump development results from (1) increased Hg bioavailability due to lower concentrations of large and hydrophilic Hg complexes with DOC; and (2) less algal biodilution due to lower nutrients and lower phytoplankton biomass in lakes with thaw slump development. These results suggest mercury accumulation in food webs is importantly related to differences in organic carbon cycling among these lakes.

Conclusions

Sediment cores from thermokarst lakes with pronounced thaw slumps were compared with nearby reference lakes to assess the impact of thaw slump development on mercury and organic sedimentation in lakes of the Mackenzie Delta region. Preliminary assessments revealed that sediment cores from lakes disturbed by thaw slump development contained lower concentrations of total organic carbon and S2 organic fractions, lower mercury and methyl mercury concentrations, and higher total and inorganic sedimentation rates.

Preliminary NCP Performance Indicators

Number of northerners engaged in this project: 1

Number of meetings/workshops held in the North: 1

Number of students (both northern and southern) involved in this project: 2

Number of citable publications thus far: (e.g., in domestic/international journals, and conference presentations, book chapters): 4

Blais, J.M. Northern development, contaminants, and climate change: Multiple stressors and multiple challenges affecting Canada's northern regions. Keynote Lecture presented to the 15th Annual Conference of the Laurentian Chapter of the Society of Environmental Toxicology and Chemistry in Niagara on the Lake, ON, June 4, 2010 (Invited).

Thienpont JR, Rühland KM, Kokelj SV, Pisaric MFJ, Blais JM, Kimpe LE, and Smol JP. Determining baseline conditions in the Mackenzie Delta uplands using lake sediments. Poster Presentation at the 2010 Inuvik Petroleum Show, Inuvik, Northwest Territories; June 23-24, 2010.

Deison R, Kimpe LE, Kokelj SV, Pisaric MSJ, Thienpont JR, Smol JP, Blais JM. Mercury sedimentation in relation to permafrost thaw slump development in lakes of the Mackenzie Delta region, NWT. Poster presented at the 17th Annual Northern Contaminants Program Results Workshop, Ottawa, Ontario, September 27-29, 2009.

Blais JM, Houben A, French T, Kimpe LE, Thienpont J, Pisaric M, Smol JP. The impact of thawing permafrost on lakes of the Mackenzie Delta. Oral presentation at the 2009 Sudbury Restoration Workshop – Science for a Changing North, Sudbury, Ontario, October 27-29, 2009.

Expected Project Completion Date

December 2010

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Atmospheric deposition and release of methylmercury in glacially-fed catchments of Auyuittuq National Park, Baffin Island. (Year 2: 2009-10)

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Abstract

We investigated the deposition, storage and release of atmospheric mercury (Hg) and monomethylmercury (MeHg) in a catchment around Penny ice cap in Auyuittuq National Park, southern Baffin Island. Our analysis of snow and firn cores collected on the ice cap indicate that it can provide a record of net atmospheric Hg accumulation for the south Baffin region, but the detection of trends in the record will be limited by the post-depositional effects of meltwater percolation. On Penny ice cap, the bulk of net Hg and MeHg on the ice cap is associated with summertime or autumn precipitation, while late winter-spring deposition may be comparatively minor. The present-day net Hg accumulation rates estimated from this and other Arctic glacier sites are < 0.1 μg m^{-2} yr^{-1}, which is considerably less than figures obtained from lake sediment cores. Net Hg accumulation increases with ice accumulation rates, suggesting that the dominant process of atmospheric Hg deposition in snow on Arctic glaciers is through precipitation (wet deposition).

Résumé

Nous avons étudié les retombées, le stockage et le rejet des émissions atmosphériques de mercure (Hg) et de mercure monométhylé (MeHg) dans un bassin hydrographique entourant la calotte glaciaire Penny dans le Parc national Auyuittuq, du sud de l'île de Baffin. L'analyse des carottes de neige et de névé prélevées sur la calotte glaciaire indique que ces carottes peuvent fournir des données sur l'accumulation nette de Hg atmosphérique pour le sud de l'île de Baffin, mais la détection de tendances pour ces données sera limitée par les effets après sédimentation de la percolation de l'eau de fonte. Sur la calotte glaciaire Penny, la majeure partie des retombées nettes de Hg et de MeHg est associée aux précipitations estivales ou automnales, alors que les retombées hivernales et printanières sont mineures. Aujourd'hui, le taux d'accumulation nette de Hg estimé à cet endroit et à d'autres endroits situés sur des glaciers de l'Arctique est inférieur à 0,1 μg m^{-2} année^{-1}, ce qui est beaucoup moins que les valeurs obtenues pour les carottes de sédiments lacustres. L'accumulation nette de Hg augmente avec le taux d'accumulation dans la glace, ce qui donne à penser que le processus dominant des retombées

atmosphériques de Hg dans la neige des glaciers de l'Arctique est associé aux précipitations (dépôts humides).

Key Messages

- Field studies established the potential to develop a historical record of atmospheric mercury deposition from Penny ice cap. A 23-m core collected ion 2010 is being analyzed to this intent and should provide a ~35-40 yr long record, but detection of trends in the record will be limited by the effects of summer melt on Hg distribution in the snow.
- In Auyuittuq National Park, mercury deposition from the atmosphere is believed to be mainly brought by precipitation in summer and autumn.
- The net Hg accumulation rate in snow on the ice cap (and at other Arctic glacier sites) is considerably lower than reported figures from Arctic lake sediment studies.
- These comparisons also suggest that atmospheric Hg accumulation rates in Arctic snow on land increase with regional precipitation rates, which would argue in favour of a dominant wet deposition mechanism.

Messages clés

- Des études sur le terrain ont montré la possibilité d'établir des données historiques des retombées atmosphériques de Hg sur la calotte glaciaire Penny. Une carotte de 23 mètres prélevée en 2010 est en cours d'analyse à cette fin et devrait fournir des données sur une période d'environ 35 à 40 ans, mais la détection de tendances pour ces données sera limitée par les effets du dégel estival sur la répartition du Hg dans la neige.
- Dans le Parc national Auyuittuq, on pense que les retombées atmosphériques de Hg sont surtout associées aux précipitations estivales et automnales.
- Le taux d'accumulation nette de Hg dans la neige de la calotte glaciaire (et à d'autres endroits situés sur des glaciers de l'Arctique) est considérablement inférieur aux valeurs issues des études sur les sédiments lacustres de l'Arctique.
- Ces comparaisons donnent aussi à penser que le taux d'accumulation atmosphérique de Hg dans la neige de l'Arctique augmente avec le taux de précipitations régional, ce qui appuierait l'hypothèse d'un processus dominant associé aux dépôts humides.

Introduction and Objectives

This proposal is a continuation of a project initiated in 2008-09. It aims to improve our under-standing of the sources and processes that control the delivery of mercury (total mercury THg and monomethylmercury MMHg) to the aquatic foodweb in a glacierized catchment on southern Baffin Island. The project also contributes to an IPY initiative that seeks to identify deposition trends of contaminants in space and time across the Arctic. The common goal of these efforts is to improve current mass balance estimates of Hg in the Arctic (e.g., Outridge *et al.* 2008) and document recent temporal trends in deposition from the atmosphere, such that the pathways and processes by which Hg enter the Arctic food chain can be properly identified.

Activities in 2009-2010

Part of our work in 2009/10 was dedicated to completing the analysis of the field samples collected in 2007-09. Altogether, a total of 143 samples of snow and ice were analyzed for THg, and 129 for MeHg, many in duplicate. As well, we analyzed 36 samples of lake and stream water for both THg and MeHg. Dozens of field and laboratory blanks, standards and replicates were also measured for quality assurance.

In order to determine [THg] and [MeHg] in older and pre-historical ice-core samples, we also worked on developing a protocol to ensure that cores collected in past drilling campaigns can be handled and sampled in a controlled environment with minimum risk of mercury contamination in particulate or gaseous form. To achieve this, we undertook to modify the clean cold room at the Geological Survey of Canada (GSC). This was accomplished by the addition of CCl_4-impregnated charcoal pre-filters to the HEPA filters inside the clean room's ventilation system. As a result, the ambient gaseous Hg levels in the clean room were lowered below 10 ng m^{-3}. While this is still high compared to typical levels in remote Arctic air (< 1 ng m^{-3}), we believe that the risk of contamination of ice samples by exposure should be minimal provided that the exposure time is reduced to a minimum during core handling.

In early May, 2010, we recovered a 23-m long firn and ice core from the summit region of Penny ice cap. The core was obtained at the same site where several longer cores were previously obtained in 1995 (Fig. 1), including a 334-m, long, surface-to-bedrock core. The core was found to consist largely of infiltration ice, which suggests that summer melt rates have increased on Penny ice cap since 1995. Based on prior results, we estimate that the new core represents between 30 and 40 yr of accumulation, and should therefore overlap with the 1995 cores by 15 to 25 yr (Fig. 2). The core was bagged in 55-cm increments, and the sealed bags were shipped back frozen to the GSC's ice-core laboratory. The core will first be measured for electrical conductivity (ECM) and sulfate (SO_4^{2-}) which will allow for cross-matching of this record with the 1995 core. The remainder of the core will then be cleaned, sampled, melted and analyzed for [THg] and [MeHg] at ~10- to 30-cm resolution. As well, a selection of archived firn and ice samples from cores drilled in 1995 and 1996 (Fig. 2) will also be analyzed to verify the state of preservation of Hg and MeHg in the firn, and to compare modern levels of mercury with those preserved in ice strata formed under different climatic conditions.

Finally, snowpit samples and two 5-m firn cores were recovered from the North Eemian (NEEM) ice-coring project site in north-central Greenland (77.45° N; 51.06°W). The samples were brought back frozen at the GSC laboratory and analyzed for [THg] and [MeHg] at the Biosciences laboratory of the University of Ottawa using the same protocols and methods as for the Penny ice cap samples. The purpose of these analyses is to provide a basis for comparison of Hg accumulation rates on Baffin Island with other sectors of the Arctic (IPY project).

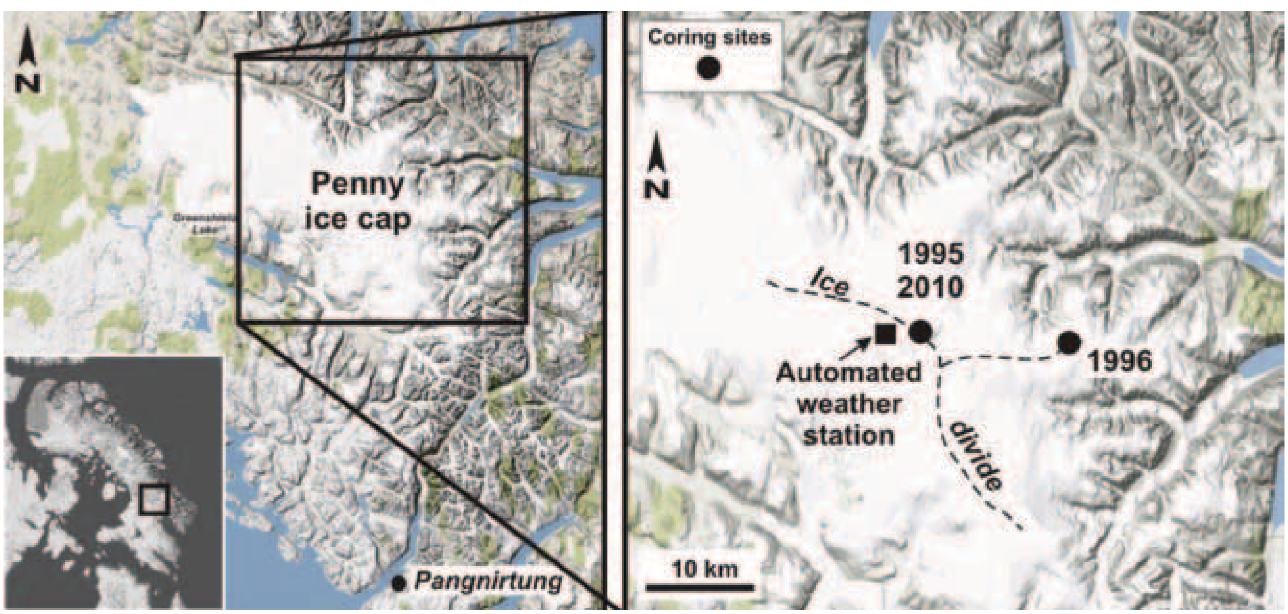

Figure 1. Location map of Penny ice cap, southern Baffin Island, showing the location of the 23-m long firn core obtained in 2010 as part of this project, in relation to the deep coring sites of 1995 and 1996.

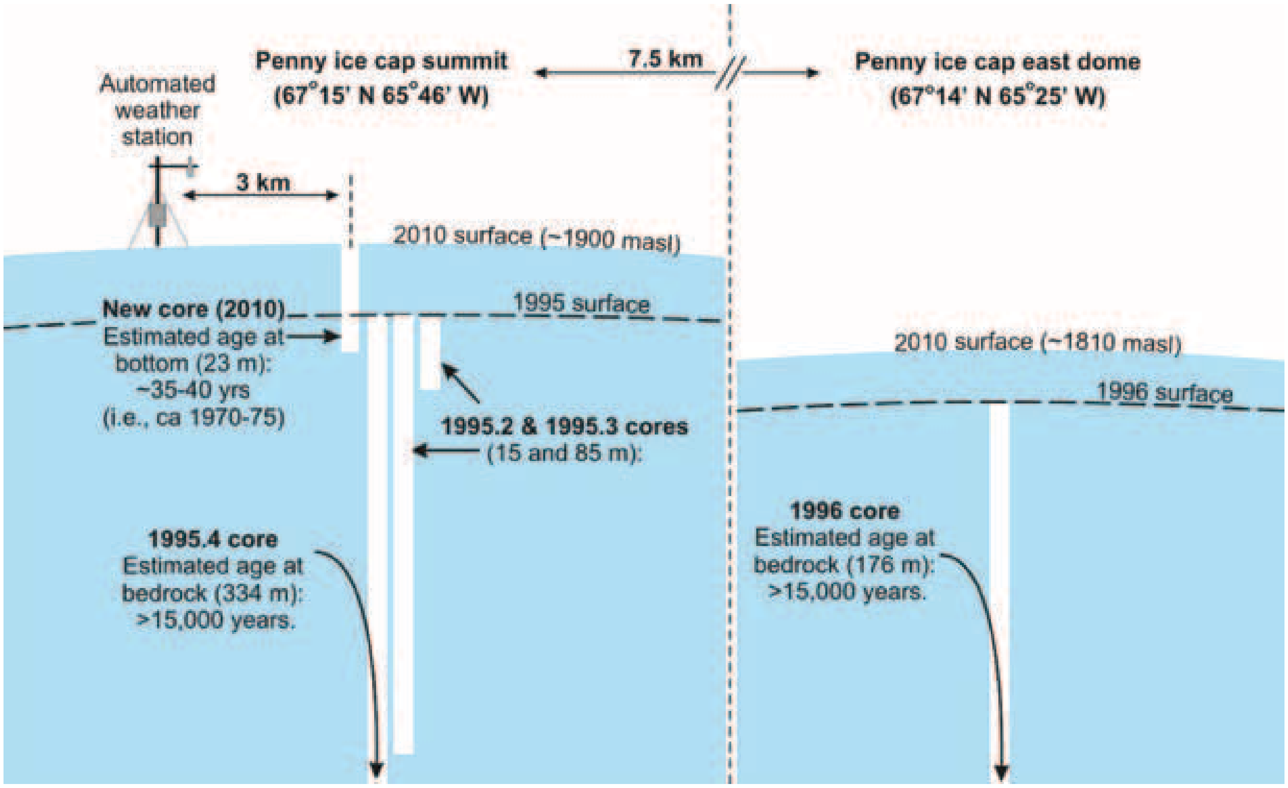

Figure 2. Schematic cross-section of the accumulation area of Penny ice cap showing the relative depths and lengths of the cores and boreholes from 2010 (this study) and 1995-1996.

Results and Discussion

The analysis of snow, firn and ice samples from Penny ice cap established several facts. First, there is a downward enrichment in THg and MeHg of ~1 ng L^{-1} and 0.1 ng L^{-1}, respectively, in the firn layers (> 1 m below surface) relative to near-surface fall/winter snow layers. Secondly, the vertical (depth-wise) sample-to-sample variance in [THg] and [MeHg] is >10 times (~0.5 ng L^{-1}) larger than the areal variance between surface snow samples at a scale of tens of km^2 (~0.04 ng L^{-1}). This is very likely due to the fact that Hg and MeHg in the snowpack are eluted by surface meltwater percolation in the summer, which redistributes water-soluble impurities in the underlying firn. Infiltration ice layers (i.e., layers of ice created by the refreezing of meltwater in the firn) are often associated with high [THg] and [MeHg], as the ice can act as a physical barrier against further elution. Seasonal or annual variations in [Hg] and [MeHg] can therefore not be resolved in firn and ice layers of Penny ice cap. Moreover, historical trends in THg or MeHg preserved in the firn will only be resolved if they exceed 0.5 ng L^{-1} $decade^{-1}$. Although these findings impose constraints on the development of an ice-core record of mercury deposition from the ice cap, it must be noted that the high percentage of infiltration ice in the firn (>40 % yr^{-1}) also limits considerably any gaseous exchange with the atmosphere below the annual snowpack depth. Clark *et al.* (2007) found that on Devon ice cap (77°N), the presence of infiltration ice helped to preserve past atmospheric variations of trace gases in the firn by reducing diffusivity. Thus somewhat paradoxically, the accumulation area of Penny ice cap, which experiences higher summer melt rates than Devon, could preserve past variations in Hg and MeHg deposition better than colder icefields, although at a lower temporal resolution.

Secondly, examination of [THg] and [MeHg] profiles through the snowpack (above the previous year's ablation surface), combined with records from a weather station operated on the ice cap, show that most of the mercury in these profiles is found in layers deposited between late summer and autumn (mid-July to October). These contributions amount to an estimated ~20-33 % of the mean annual burden of Hg in the ice cap's summit area. The remainder must be deposited in snow either in late spring (after mid-April) and/or in early summer. It is difficult to estimate what proportion of the net Hg accumulation, if any, might result from Atmospheric Mercury Depletion Events (AMDEs), but results of surface snow sampling in April suggest that this is probably a relatively small contribution. On this ice cap (and possibly on others), the bulk of Hg accumulation therefore seems to take place after the potential peak period of AMDEs and during the warmer half of the year, when southerly depressions and more open (ice-free) conditions on the sea lead to enhanced precipitation. At the study site however the elevation is 2600 m (don't remember exactly and indeed this may be above the height where AMDEs occur.

Measurements in samples from Penny ice cap and north-central Greenland confirmed previous findings from other sites (including Ellesmere and Devon islands) that [THg] in modern snow layers of Arctic glaciers is remarkably consistent and varies in a relatively narrow range of 0.30 to 0.70 ng L^{-1}, averaging ~0.60 ng L^{-1} (geometric mean). Net Hg accumulation rates vary inversely with the latitude and altitude of glaciers, but increase with ice accumulation rates. Lowest net Hg accumulation rates are found on northern Ellesmere ice caps and in central Greenland ($\leq$ 0.1 μg m^{-2} yr^{-1}), whereas the highest rates are found on ice caps of southern Baffin Island (Penny and Grinnell; 0.2-0.7 μg m^{-2} yr^{-1}). These results suggest that on land and/or above the marine boundary layer, the dominant process of atmospheric Hg deposition in Arctic snow is through precipitation (wet deposition), such that net Hg accumulation rates in terrestrial ice increase with higher precipitation rates at lower latitudes.

Conclusions

Results of our work indicate that the accumulation zone of Penny ice cap can provide an ice-core record of net atmospheric Hg accumulation for the south Baffin region at a sub-decadal scale resolution, but the detection of trends in the record will be limited by the post-depositional effects of meltwater percolation. A 23-m core collected in 2010 is now being analyzed and is expected to yield a ~35- to 40-yr long record.

The distribution of Hg and MeHg in the Penny ice cap snowpack suggest that the bulk of mercury accumulation in the ice cap is associated with summertime or autumn precipitation (wet deposition), while late winter-spring deposition linked (or not) with photochemical processes may be comparatively minor. The present-day net Hg accumulation rates estimated from this and other Arctic glacier sites are < 0.1 μg m^{-2} yr^{-1}, which is considerably less than figures derived from lake sediment cores (e.g., Muir *et al.*, 2009). Such estimates may be representative of Hg deposition away from the marine boundary layer, but deposition rates could be higher over High Arctic marine areas owing to the effect of Atmospheric Mercury Depletion Events. Net Hg accumulation rates vary inversely with the latitude and altitude of glaciers, but increase with ice accumulation rates, suggesting that the dominant process of atmospheric Hg deposition in snow on Arctic glaciers is through precipitation (wet deposition).

Performance indicators

Results of our work have so far been presented at four different conference venues Listed below). Three manuscripts are in preparation for publication in peer-reviewed journals. Part of our findings will also be integrated as a contribution to the upcoming CACAR III report on mercury in the Arctic (B. Braune, coordinator). In the course of this project, meetings and consultations were also held in Iqaluit, Pangnirtung and in Pond Inlet (Parks Canada offices). 5-6 people attended the consultation session in Pangnirtung, the same number in Iqaluit and 4-5 people (including 2 elders) attended the one held in Pond Inlet. Half the Parks' staff in Pangnirtung and Pond Inlet consists of locals.

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Expected Project Completion Date

This project is expected to be completed by March 31, 2011.

Acknowledgments

Field work on Baffin Island in the spring of 2010 was accomplished with the invaluable support of Parks Canada staff, the people of the hamlet of Pangnirtung, and the Polar Continental Shelf Project (Kenn Borek Air). Our work was greatly facilitated by the field participation of Matthew Nakashuk (Parks Canada). Laboratory work and method development were conducted in Ottawa with the assistance of Anna Smetny-Sowa (B. Sc. student, Carleton University), Bei Wang (Ph.D. student, University of Ottawa) and Dr Eva Kruemmel (NSERC postdoctoral fellow, Inuit Circumpolar Conference for Canada). We thank Drs James Zheng and Kumiko Goto-Azuma who collected samples for us in north-central Greenland, and the NEEM steering committee for providing us with access to the drilling site.

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Characterizing contaminant-related health effects in beluga whales from the Western Canadian Arctic

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Abstract

Beluga whales (*Delphinapterus leucas*) in the Arctic may be vulnerable to the combined effects of contaminants and a changing climate. That said, very little is known about beluga health. We have been pioneering new methods to measure the health of beluga whales in close collaboration with Inuvialuit community members from Tuktoyaktuk and with other researchers working in the area. Our beluga whale health research continues, with a pilot year (2007-08) successfully completed and our second full programme year nearing its end (2009-10). Despite logistical and technical challenges in the field and in the laboratory, we have made considerable progress in being able to measure the health of beluga whales, and to explore the ways in which both contaminants and climate change are affecting health. A changing climate and ice regime may have dramatic impacts on contaminant pathways, food web productivity, and beluga feeding

Résumé

Le béluga (*Delphinapterus leucas*) de l'Arctique peut être vulnérable aux répercussions combinées des contaminants et du changement climatique. Cela dit, on en sait très peu sur sa santé. Nous avons mis à l'essai de nouvelles méthodes de mesure de la santé des bélugas en étroite collaboration avec les Inuvialuit de Tuktoyaktuk et avec d'autres chercheurs qui travaillent dans la région. Notre recherche se poursuit, après les travaux réussis d'une année pilote (2007-2008) et la deuxième année complète du programme qui arrive à terme (2009-2010). Malgré des problèmes logistiques et techniques sur le terrain et au laboratoire, nous avons beaucoup amélioré notre capacité de mesurer la santé des bélugas et d'explorer comment les contaminants et le changement climatique agissent sur la santé. La modification du climat et du régime des glaces peut avoir de graves répercussions sur le cheminement des contaminants, la productivité du réseau trophique et l'alimentation

ecology. If these two major stressors affect beluga health, reduce stock abundance or diminished quality of beluga whales may impact upon community harvests. Given the interest expressed by community members of Tuktoyaktuk and the success of our student training program, we look forward to a continuation of our field effort in 2010. This project represents an emerging collaboration between the Northern Contaminants Programme (NCP - INAC) and the Department of Fisheries and Oceans Canada *(Ecosystem Research Initiative and National Headquarters)*.

des bélugas. Si ces deux importants facteurs de stress ont une incidence sur la santé des bélugas, réduisent l'abondance des stocks ou diminuent la qualité des bélugas, cela pourrait se répercuter sur les récoltes. Étant donné l'intérêt exprimé par les membres de la collectivité de Tuktoyaktuk et le succès du programme de formation des étudiants, nous espérons pouvoir poursuivre nos travaux sur le terrain en 2010. Ce projet donne lieu à une nouvelle collaboration entre le Programme de lutte contre les contaminants dans le Nord (PLCN) d'Affaires indiennes et du Nord Canada et le ministère des Pêches et des Océans du Canada (Projet de recherche sur l'écosystème et administration centrale).

Key Messages

- a third year of field sampling has been successfully completed, with the participation of team members, collaborators and community members;
- 20 beluga whales were sampled at Hendrickson Island in the Beaufort Sea, including one fetus, seven females, and 12 males. The busiest sampling date was July 12 where 7 whales were landed and sampled whales were sampled;
- new beluga whale-specific genomics techniques were developed in collaboration with the University of Victoria, with a total of 15 gene primers now available;
- 20 beluga whale blubber samples were analyzed for priority contaminants, including PCBs and PBDEs at the DFO Laboratory for Aquatic Chemical Analysis in Sidney BC, and metabolites at NWRC;
- fatty acids relate to length, PCB and PBDE concentrations supporting a size driven diet and exposure to contaminants;
- preliminary results suggest that some gene expression endpoints correlate negatively with PCBs for the 2008 samples (2009 underway);
- circulating hormones such as vitamin A and thyroid hormones related to one another and did not relate to PCB concentrations;
- *in vitro* experiments using fresh blood obtained from Vancouver Aquarium belugas suggest that mercury is toxic to white blood cells at concentrations observed in some free-ranging populations of beluga.

Principales observations

- Nous avons mené à bonne fin une troisième année d'échantillonnage sur le terrain, avec notre équipe, des collaborateurs et des membres de la collectivité.
- Nous avons échantillonné vingt bélugas à l'île Hendrickson dans la mer de Beaufort, dont un fœtus, sept femelles et douze mâles. La journée d'échantillonnage la plus occupée a été le 12 juillet alors que nous avons capturé et échantillonné sept de ces baleines.
- De nouvelles techniques génomiques propres aux bélugas ont été mises au point en collaboration avec l'Université de Victoria, et nous disposons maintenant d'un total de 15 amorces.
- Nous avons analysé vingt échantillons de graisse de béluga pour la détection des contaminants prioritaires, dont les biphényles polychlorés (BPC) et les éthers diphényliques polybromés (EDP), aux Laboratoires d'expertises en analyses chimiques aquatiques du MPO à Sidney en C.-B., et des métabolites, au Centre national de la recherche faunique.
- Il y a un rapport des acides gras avec la longueur du corps et les concentrations de BPC et d'EDP, ce qui corrobore le lien entre la taille, le régime alimentaire et l'exposition aux contaminants.
- Les résultats préliminaires font croire que des paramètres de l'expression génétique sont corrélés négativement aux BPC dans le cas des échantillons de 2008 (étude de 2009 en cours);

- Il y a un rapport des hormones circulantes, comme la vitamine A et les hormones thyroïdiennes, entre elles, mais non avec les concentrations de BPC.
- Les expériences *in vitro* sur du sang frais obtenu des bélugas de l'aquarium de Vancouver font croire que le mercure est toxique pour les globules blancs à des concentrations observées chez certaines populations de bélugas en liberté.

Objectives

Characterize health risks associated with dietary intake, accumulation and metabolism of persistent contaminants in beluga whales.

Introduction

Beluga whales are at the top of the Arctic food web, rendering them vulnerable to contamination by a variety of persistent environmental contaminants that are transported from distant sources. Our research has demonstrated that complex environmental mixtures of POPs are affecting the health of free-ranging pinnipeds, and present a tangible risk to cetaceans, in several areas of southern Canada (Ross 2006; Mos *et al.* 2006; Tabuchi *et al.* 2006). Concerns about contaminants in the Canadian Arctic emanate, in part, from studies which demonstrate possible health effects in subsistence-oriented humans, polar bears and beluga whales (Dallaire *et al.* 2004; White *et al.* 1994; Braathen *et al.* 2004). Technical and logistical challenges have generally precluded health assessments in Arctic marine mammals, but new and emerging technologies provide an opportunity to build on past efforts and shed light on an important facet of Arctic contamination (Stern *et al.* 2005; Lockhart *et al.* 2005; Muir *et al.* 1999).

A complicating juxtaposition in the way of climate change may add a layer of stress to beluga whales, by altering contaminant pathways, or by reducing the condition of beluga whales (Macdonald 2005). Despite the wealth of information about pathways and fate of different classes of environmental contaminants over time and space in the Arctic little is known about adverse health effects associated with these contaminants in vulnerable species, including beluga whaleChanges in Arctic sea ice cover, temperature profiles, food web productivity, and beluga distribution and feeding ecology may profoundly change the course of contaminant fate in the Arctic environment, as well as the condition and health of beluga. Climate change has the potential to confound our understanding of mechanistic linkages between contaminant exposure and health effects, but may also have serious implications for the health of beluga whale populations. Our programme is designed to characterize condition and nutritional status of belugas in order to generate insight into the relationship between climate, contaminants and health of beluga.

Activities 2009/2010

This was an intensive year that incorporated a large field camp, and a series of efforts in the laboratory aimed at developing, validating and applying health assessment techniques to beluga whales.

Similar to 2008, all Hendrickson Island personnel worked as a team to sample whales efficiently, in addition to helping hunters remove beluga tissues for later processing. Science personnel in the field included Lisa Loseto (University of Victoria, DFO), Stephen Raverty (BC Animal Health Center), and Marie Noel (PhD student, University of Victoria). Also at our field camp were two students from Tuktoyaktuk (R. Walker and J. Noksana) for a youth mentoring program (FJMC funded). Camp was set up July 01 2009 and shut down July 22 2009.

Frank and Nellie Pokiak and their family were on site for tissue sample collections for G. Stern (DFO). Two FJMC monitors and their families participated in collecting beluga hunt data. In addition to mentoring the two students from Tuktoyaktuk, additional youth (as well as others on the island) participated opportunistically in our field program. Field work and tissue sample collections were supported by funds from FJMC (Loseto, Ross) and IPY (S. Ferguson).

Samples collected were submitted to the LEACA lab for analysis of PCBs and PBDEs. Lipid analysis and extractions for fatty acids were completed in Victoria and samples were sent to the FWI for fatty acid analysis. Liver and muscle samples were sent to the University of Winnipeg for stable isotopic analysis. Genomic extractions completed for blubber and QA/QC for new tissues has begun. Thyroid hormones, testosterone, cholesterol and vitamin A analysis were completed at IOS. Analysis of isoprotranes completed on urine and plasma. Method development for the simultaneous extraction and run of vitamin A and E was carried out. Finally, Hg toxicity tests were carried out on beluga blood collected from the Aquarium.

Results

Morphometrics

Samples were collected from 20 beluga whales for health assessments and contaminant analyses in collaboration with the Tuktoyaktuk community beluga hunt. Of the 20 whales harvested and sampled, 12 were male (mean length = 415 cm; σ = 23 cm), 7 were female that were significantly shorter in length ($p < 0.001$; mean length = 372 cm; σ = 10 cm), and one female had a male fetus that was full term (142 cm). Blubber thickness averaged 9 cm (σ = 1.7), with males averaging 10cm (σ = 1.4) and females 7.4cm (σ = 0.9).

PCB and PBDE concentrations in Beluga Whales

The PCB (182 congeners) concentrations in 2009 whales were significantly different between sexes, with males having nearly four times the concentrations of PCBs than females ($p < 0.0001$; male PCBs 3630 ng/g lw ± 1540; female PCBs 781 ng/g lw ± 487). On the other hand the PBDE (49 congeners) concentrations did not differ between the sexes ($p = 0.13$; male PBDEs 27.4 ng/g lw ± 13.3; female PBDEs 19.65 ng/g lw ± 7.7; Figure 1). The near full term fetus had PCB and PBDE concentrations slightly lower than the mother at 324 ng/g lw of PCBs and 12.4 ng/g lw of PBDEs.

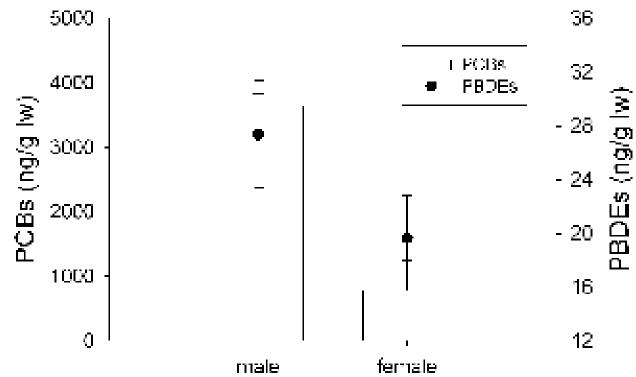

Figure 1: Total PCB concentrations (bars) and PBDE concentrations (closed symbols) in male and female beluga whales sampled in 2009.

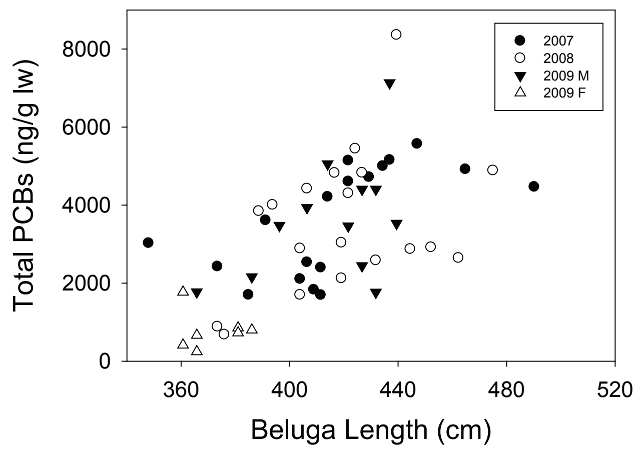

Figure 2: Total PCB concentrations correlated with total body length in 2007 belugas, likely due to a combination of age and feeding ecology, whereas the length trend for 2009 was related to sex.

PCB concentrations in males in 2009 did not differ from concentrations in 2007 and 2008 ($p = 0.98$; $r = 0.03$), whereas PBDE in did differ among years in males ($p = 0.04$). PBDE levels in males in were highest 2009 that was significantly higher than those in 2008 ($p = 0.04$) and not significantly different than 2007.

Concentrations of PCBs did relate with length when sexes were combined ($r= 0.6$; $p<0.0001$), yet among sexes the length trend was no longer significant (Figure 2). Concentrations of PBDEs did not significantly relate to length ($r = 0.12$; $p = 0.14$).

In 2009 there was another opportunity to sample both mother and a fetus to demonstrate the transplacental transfer of PCBs and PBDEs.

Unlike the 2008 mother and fetus where PCBs doubled in concentration in the fetus relative to the mother, the levels in the 2009 case were very similar between the two. These observations, coupled with an evaluation of pattern changes from mother to fetus, reflect the physico-chemical barrier at the level of the placenta. The PCB concentration in the mother (208.5 ng/g lw) was less than half of that in the fetus (557.8 ng/g lw) that was dominated by by heavier PCB congeners (hepta- to deca- PCBs). The reverse trend was observed for PBDEs whereby the mother had double the concentration (2.1 ng/g lw) than the fetus (1.03 ng/g lw). The fetus PBDE profile was dominated by tetra congeners with little contribution from heavier congeners.

Genomics

Blubber, skin, liver, kidney and muscle samples were taken from the 44 (24 from 2008 and 20 from 2009) Hendrickson Island beluga whales, preserved in RNA later and stored at -20°C until total RNA isolation. Blubber samples were divided into inner, middle, and outer blubber in order to investigate any possible variations in gene expression within the blubber layer.

Briefly, total RNA in those samples was isolated using the single-step RNA isolation method based on guanidine isothiocyanate / phenol / chloroform extraction with Trizol (Invitrogen Canada Inc., Toronto, Ontario, Canada) as a reagent. Total cDNA was produced using Superscript II RNase H- reverse transcriptase (Invitrogen Canada Inc). At present, RNA from all the 44 samples of blubber, skin, liver and muscle and 20 samples of kidney has been successfully extracted.

In order to assess the health of this beluga whale population, a total of 15 target genes were developed, including three housekeeping genes (ribosomal protein L8, Glyceraldehyde-3- phosphate dehydrogenase (GAPDH) and cytoplasmic B-actin). The expression of those specific genes was investigated using quantitative real-time polymerase chain reaction (*q*RT-PCR) and relative quantification (based on the best housekeeping gene):

- Ribosomal protein L8 (L8)
- Glyceraldehyde-3-phosphate Dehydrogenase (GAPDH)
- Cytoplasmic Beta Actin (CBA)
- Thyroid Receptor Alpha (TR-a)
- Thyroid Receptor Beta (TR-b)
- Estrogen Receptor Alpha (ER-a)
- Peroxisome Proliferator-Activated Receptor Gamma (PPAR-g)
- Retinoid X Receptor Alpha (RXR-a)
- Adiponectin
- Leptin
- Insulin-Like Growth Factor 1 (ILGF1)
- Vitamin D Receptor (VDR)
- Metallothionein 1 (MT1)
- Heat Shock Protein 70-1 (HSP70-1)
- Glucocorticoid Receptor (GR)
- Aryl Hydrocarbon Receptor (AhR)

Housekeeping genes are used to evaluate the quality of the data. Using the “crossing point method” (Pfaffl et al, 2004), L8 was found to be the most stable gene amongst the three housekeeping genes and was therefore chosen as a normalizer gene. L8 values were also used to identify outliers in the dataset.

We present here the results for two of the main toxicology-related genes: Aryl hydrocarbon receptor (AhR) and metallothionein (MT1) in the liver and/or skin samples of the 2008 beluga whales. Results from the 2009 field sampling are currently underway.

Aryl hydrocarbon receptor expression in beluga liver

Dioxin-like compounds such as certain PCB congeners exert their toxicity in part via the aryl hydrocarbon receptor (AhR), a soluble, ligand-activated transcription factor. The activation of AhR induces the transcription of multiple target genes including cytochrome P450 (Cyp 1A), a metabolizing enzyme.

The expression of AhR in the liver of the 2008 beluga males was not influenced by any biological variables such as age, length, or blubber thickness. Previous studies showed an increase with age of AhR expression in humans (Pitt *et al.*, 2001) and in Baikal seals (*Phoca sibirica*) (Kim *et al.*, 2005),

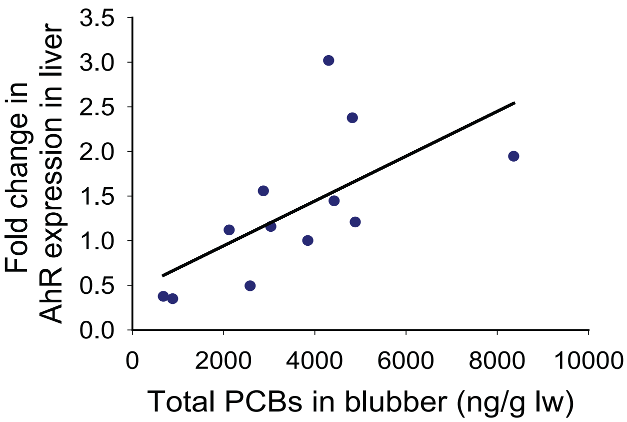

Figure 3: AhR expression in liver of the 2008 beluga males increased significantly with PCB concentrations in blubber. Fold change expression is relative to L8 expression which was the best normalizer gene in this case.

either reflecting the higher ability of adults to metabolize contaminants or increased contaminant concentrations in older individuals.

The expression of AhR increased significantly with PCB concentrations in beluga blubber ($r^2 = 0.41$; $p = 0.025$; Figure 1) and with Hg concentrations in liver ($r^2 = 0.59$; $p = 0.003$; results not shown) which is in agreement with the fact that liver is one of the major organ for metabolism. The relationship between AhR and Hg may reflect a co-correlation due to an inherent correlation between PCBs and Hg, rather than a causal relationship. In the present study, PCB concentrations in blubber and Hg concentrations in liver were significantly positively correlated with each other ($r^2 = 0.79$; $p = 0.000$).

Several studies have reported an increase in AhR expression with exposure to dioxin-like contaminants (Pitt *et al.*, 2001; Kim *et al.*, 2005). Jensen and Hahn (2001) also reported that the beluga AhR is a high affinity AhR suggesting that this species might be particularly sensitive to dioxin-like compounds. This is in agreement with the present study; even though the Western Arctic belugas are exposed to relatively moderate PCB concentrations, an up regulation of AhR was still detected.

Metallothionein (MT1) expression in beluga liver and skin

Metallothioneins are low molecular weight proteins that are able to bind to group II metals (i.e. Hg^{2+}) and therefore provide protection against their toxicity. The expression of MT1 was not influenced by any biological variables (age, length, blubber thickness) in our study.

No significant correlation was found between MT1 expression and Hg levels in liver suggesting that metallothioneins may not be the primary means of detoxification in liver (Figure 2). Previous studies showed that only 5% of Hg is bound to metallothioneins in liver (Wagemann *et al.*, 1986). On the other hand, there was a significant positive relationship between MT1 expression and Hg levels in skin ($r^2 = 0.51$; $p = 0.017$), suggesting that metallothioneins might play a in the detoxification of Hg in the skin of beluga.

Most studies have found that metallothioneins are most likely to play a role in the detoxification of inorganic Hg. In skin tissue of cetaceans and

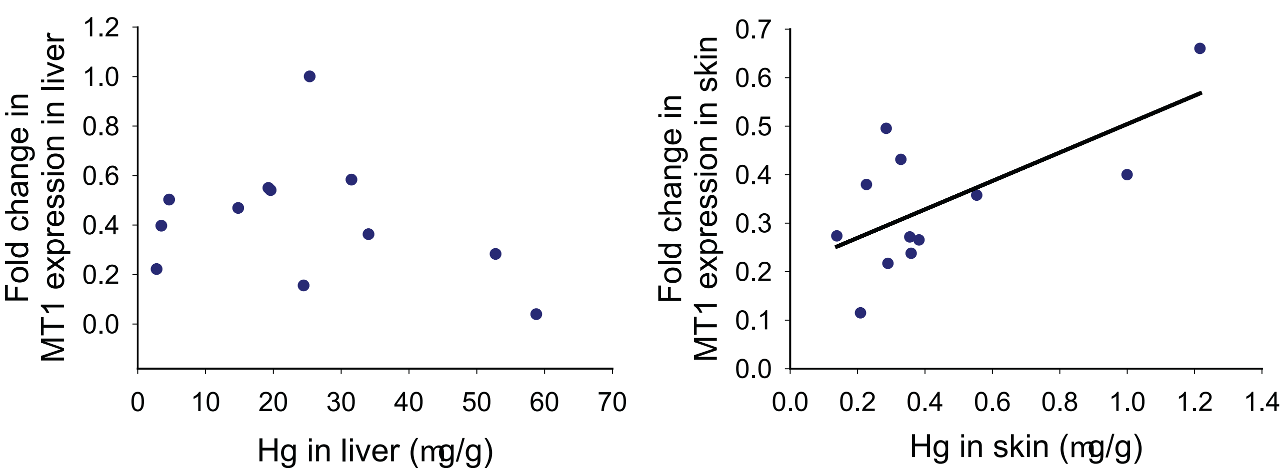

Figure 4: While there was no significant trend between MT1 expression in the liver of the 2008 beluga males and Hg levels, a significant increase with Hg concentrations was observed in skin.

pinnipeds, it has been reported that the majority (90%) of Hg is in the form of MeHg (Wagemann *et al*., 1998; Dehn *et al*., 2006). However, a study carried out in mice showed that exposure to MeHg was able to induce an increase in the transcription of MT1 (Leiva-Presa *et al*., 2004). The authors concluded that there might be two possible mechanisms of action: (1) MeHg is first converted into inorganic Hg which induces an increase in the expression of MT1; and/or (2) since MT is also a component of the antioxidant defence system, the increased MT1 expression following MeHg exposure might be a response to the production of reactive oxygen species

These preliminary results show that, even though the Western Arctic beluga whale population is exposed to moderate Hg and PCB concentrations, we were still able to detect up-regulations of two important toxicology-related genes. This indicates that individual whales are exposed to levels of contaminants that elicit physiological responses. The extent to which these responses may affect this population is unclear; however, our preliminary results do indicate that these whales might be at risk for adverse health effects due to chemical exposure.

Diet and Condition

Stable Isotopes

Stable isotopes of carbon and nitrogen had generally weak trends in relation to length relative to previous years (Table 1). There were no significant differences among male and female isotopic signatures. The only significant trend with length was observed for muscle $\delta^{15}N$ that was negative.

Lipid classes

Blubber and liver samples were extracted for lipid class and fatty acid analysis.

Lipid class analysis of blubber revealed a consistent domination of triglycerides which was typically greater than 97% of the total lipids, with trace amounts of phospholipids. On the other hand, liver samples were dominated by phospholipids that were typically greater than 80% of the total, followed by triglycerides at close to 10% of total followed by cholesterol esters and diglycerides.

Fatty acid profiles

Fatty acid data was summarized for the beluga blubber using a principle component analysis (PCA) using 38 fatty acids associated with diet. The first and second explained 74% of the variation (61% PC 1; 13% PC2). There did not appear to be differences between the sexes with FA profiles. The first PCA axis related to length ($r = 0.5$; $p = 0.03$), PCBs ($r = 0.74$; $p = 0.001$), and PBDEs ($r = 0.67$; $p = 0.002$). No trend was observed with stable isotopes measured in liver and muscle. Further analyses an interpretation is needed to determine the extent to which these results reflect dietary, condition and/or other influences.

Table 1. Mean carbon and nitrogen stable isotopes (per mil) for beluga liver and muscle samples. Correlations determined for beluga length trends for carbon and nitrogen isotopic values in beluga liver and muscle.

	$\delta^{15}N$	Std Dev	Length Trend	$\delta^{13}C$	Std Dev	Length Trend
2007						
liver	17.71	0.76	r = 0.5; p=0.04	-20.2	0.57	r = -0.6; p=0.004
muscle	16.54	0.63	r = 0.1; p=0.6	-18.44	0.38	r = -0.4; p=0.2
2008						
liver	16.85	1.2	r = 0.05; p=0.8	-18.76	0.93	r = -0.5; p=0.02
muscle	16.85	1.07	r = 0.3; p=0.1	-18	0.9	r = 0.3; p=0.1
2009						
liver	16.08	2.3	r = 0.001; p=0.5	-19.22	0.8	r = 0.03; p=0.5
muscle	13.39	1.5	r = - 0.24; p= 0.03	-18.25	1	r = -0.07; p=0.3

Table 2. Vitamin A (ug/g) in blubber among years and sexes and trends with length and PCBs.

	Vitamin A	Std Dev	Length Trend	PCB trend	n
2007					
Males	24.60	9.90	r = 0.7; p=0.015	r = 0.7; p=0.001	18
2008					
Males	32.30	11.60	r = -0.1; p=0.9	r = 0.44; p=0.06	18
Females	31.95	5.75			3
2009					
Males	53.06	8.61	r = 0.3; p=0.33	r = 0.3; p=0.4	12
Females	61.02	16.87	r = 0.6; p=0.1	r = 0.1; p=0.8	7

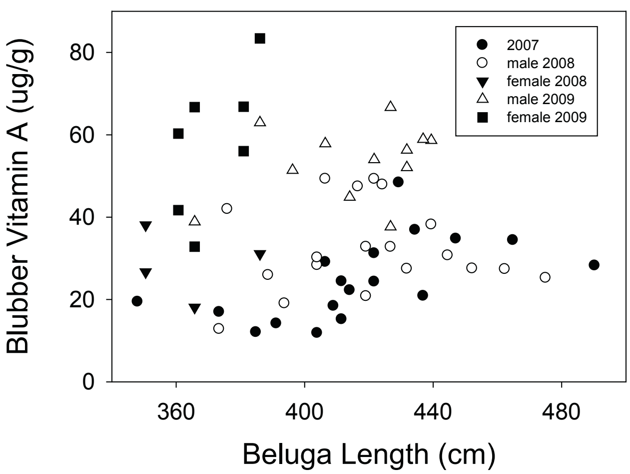

Figure 5: Vitamin A in males and females in 2007, 2008, 2009. Trend with body length was only significant in 2007.

Vitamin A in Blubber

Blubber vitamin A levels did not significantly differ between sexes (P = 0.4). Vitamin A was significantly higher in 2009, at over twice the levels measured in 2008 and 2007 ($p < 0.001$; Table 2).

In 2007, the positive trend observed with length and PCBs suggested that dietary sources were a driving factor of trends rather than a toxic effect on hormonal endpoints. The 2009 results have weak relationships with PCBs and length (Table 2; Figure 5).

Thyroid Hormones

Thyroid hormones were measured in serum. Free circulating T3 and T4 were determined along with total T3 and T4 in serum samples and levels did not differ between sexes. Thyroid levels did not relate to beluga length or contaminants. In 2008 both free and circulating thyroids had significant positive trends with vitamin A in blubber whereas trends in 2009 only T4 ($r = 0.74$; $p = 0.001$) and FT4 ($r = 0.65$; $p = 0.003$) were related to blubber vitamin A. These early results might suggest that contaminant concentrations are not high enough to disrupt thyroid hormone homeostasis, but a small sample size, and considerable confounding influences (age, sex, and condition) may have masked our preliminary assessment.

Mercury toxicity to white blood cells in beluga: a Vancouver Aquarium collaboration

While increasing anthropogenic emissions of mercury (Hg) have raised concerns about toxicity at the top of aquatic food webs, selenium (Se) is thought to confer a degree of protection to marine mammals. In this study, we are evaluating the *in vitro* toxicity of Hg to beluga white blood cells, and the protective effects of Se. Blood samples were collected the 20th of April (Aurora) and the 21st of April (Kavna and Imaq) from three adult (2 females and 1 male) beluga whales held at the Vancouver Aquarium (Vancouver, BC, Canada). Blood samples were drawn from the tail fluke vein into heparinised tubes (Vacutainer, BD) and kept at 4°C until the time of analyses, which occurred in 24 h after sampling.

After isolation of lymphocytes by Lymphoprep, cells were exposed during 66 h to several concentrations of $HgCl_2$ (mercuric chloride; 0 – control -; 0.1; 0.333; 1; 3.333 and 10 μM) with several ratios

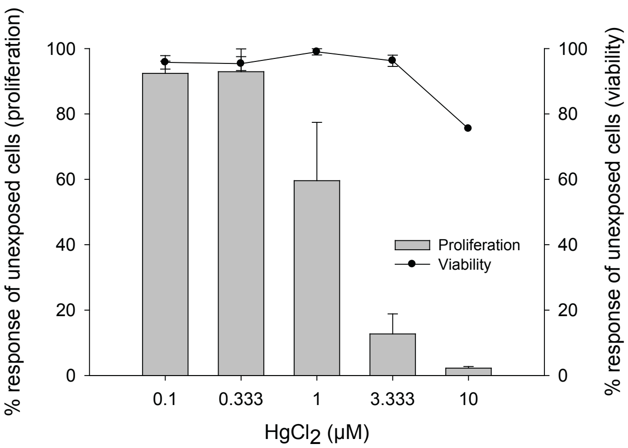

Figure 6: The proliferation of lymphocytes (bars) and their viability (lines) following different co-incubation exposures to inorganic mercury. Results are expressed as a (%) of the control response (unexposed cells) (n = 3; mean ± S.E.).

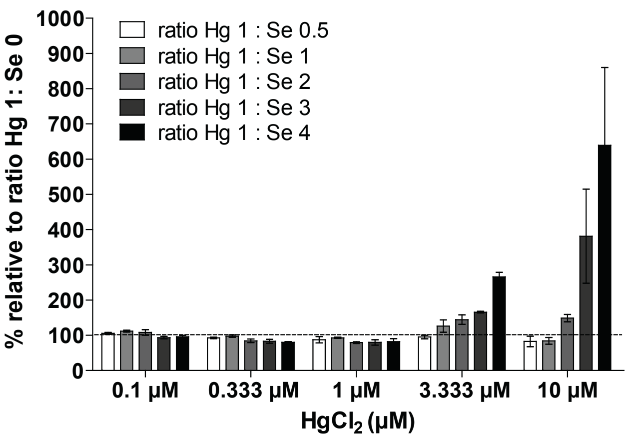

Figure 7: Selenium proved to exert a protective effect against Hg toxicity in lymphocyte proliferation assays (concurrent exposures to $HgCl_2$ and Na_2SeO_3). Results are expressed as a (%) relative to ratio Hg 1: Se 0 ($HgCl_2$ exposed cells) (n = 3; mean ± S.E.).

of $HgCl_2$: Na_2SeO_3 (1:0; 1:0.5: 1:1; 1:2; 1:3; 1:4). Lymphoblastic transformation and viability were evaluated. Results suggest that while Hg is toxic at concentrations observed in some free-ranging populations of beluga (Figure 6), Se provides a measure of protection (Figure 7). Further efforts to characterize the nature of the mode of action will substantiate the observations.

Expected Project Completion Date

Phase 1: Pilot study 2007-08: Field sampling and initial methods development.

Phase 2: Research effort 2008-09: second year of sampling, dedicated methods development and initial round of analyses. Partnership with IPY and ArcticNET.

Phase 3: Research effort 2009-10: Complete development and validation of methods; conduct a 3rd year of sampling; complete health measurements on existing samples; model climate scenarios; begin dedicated publishing.

Phase 4: Reporting out efforts 2010-11: complete publications in international scientific literature; carry out dedicated outreach efforts in multiple communities.

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A genomics based health study of ringed seals (*Phoca hispida*) along the Labrador coast: health in the face of global and local PCBs

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Abstract:

Saglek Fiord has been the site of a military radar station since the late 1950s. Due to historical operations in Saglek Bay, high PCB levels have been measured in surface sediments, marine invertebrates, fish, seabirds, and ringed seal (*Phoca hispida*). Preliminary data indicate that PCB levels in 24% of ringed seals exceed adverse health effects thresholds established in harbour seals (*Phoca vitulina*), underscoring the potential for local population impacts. Our study is designed to examine whether these elevated PCB levels are affecting the health of ringed seals. Since obtaining samples for health assessments is challenging, we devised two methods to obtain

Résumé

Le fjord Saglek est l'emplacement d'un poste de radar militaire depuis la fin des années 1950. En raison des activités qui se sont déroulées à la baie de Saglek depuis ce temps, on y a détecté des taux élevés de biphényles polychlorés (BPC) dans les sédiments de surface, les invertébrés marins, les poissons, les oiseaux de mer et le phoque annelé (*Phoca hispida*). Les données préliminaires indiquent que les taux de BPC chez 24 % des phoques annelés dépassent les seuils d'incidence néfaste sur la santé établis pour le phoque commun (*Phoca vitulina*), ce qui suppose d'éventuelles répercussions sur la population locale. Notre étude visait à déterminer si ces taux élevés de BPC ont

samples conducive to our study objectives: i) live-captures of sub-adult and adult ringed seals during our concurrent telemetry program, and ii) samples obtained in cooperation with local harvesting practices. We successfully obtained samples from 28 ringed seals (live-captures n=7; harvested n=21) for our study. Blubber PCB concentrations in ringed seal from Saglek Fiord are higher than levels found in Nachvak, Okak, and Anaktalak Fiords, and were higher than levels observed in other areas of the Canadian Arctic. PBDE concentrations in ringed seals from the Labrador coast are higher than levels found in other areas of the Canadian Arctic. Species-specific primers in support of quantitative polymerase chain reaction (qPCR) methods to measure ringed seal health have been successfully developed and tested for 10 of the 14 targeted genes. Over the coming year, we will finalize the development and validation of the ringed seal-specific genomics tools, and evaluate the relationship between contaminant levels and the expression of a variety of health endpoints.

une incidence sur la santé des phoques annelés. Puisqu'il est difficile d'obtenir des échantillons en vue d'une évaluation de l'état de santé, nous avons imaginé deux méthodes de prélèvement qui nous permettaient d'atteindre les objectifs de notre étude : i) capturer vivants des phoques annelés adultes et immatures dans le cadre de notre programme simultané de télémétrie; ii) prélever des échantillons en collaboration avec les chasseurs locaux. Nous avons réussi à prélever des échantillons de 28 phoques annelés (captures vivantes, n=7; produits de la chasse, n=21) pour notre étude. Les concentrations de BPC dans la graisse des phoques annelés du fjord Saglek sont plus élevées que celles des phoques des fjords Nachvak, Okak et Anaktalak, et plus élevées que les concentrations observées dans d'autres régions de l'Arctique canadien. Les concentrations d'éthers diphényliques polybromés (EDP) des phoques annelés des côtes du Labrador sont plus élevées que celles des autres régions de l'Arctique canadien. Nous avons réussi à créer des amorces propres à l'espèce à utiliser dans les méthodes de réaction de polymérisation en chaîne quantitative (PCR quantitative) en vue de mesurer l'état de santé du phoque annelé. Ces amorces ont fait l'objet d'essais sur 10 des 14 gènes ciblés. Au cours de l'année qui vient, nous terminerons la création et la validation des outils génomiques propres au phoque annelé, et nous évaluerons la relation entre les taux de contaminants et l'expression de divers paramètres de mesure de l'état de santé.

Key Messages:

- Tissue samples were successfully obtained from 28 ringed seals during 2009-10 using a variety of capture and sampling methods.
- ΣPCB concentrations in blubber of ringed seals from Saglek Fiord are elevated relative to the Canadian Arctic and other sites in northern Labrador.
- ΣPCB concentrations in blubber indicate that ~ 24% of the ringed seals from Saglek Fiord exceed health effects thresholds established in harbour seals (1.3 ppm).
- The development of new methods to measure the health of ringed seals will enable us to evaluate the effects of PCBs on the health of Saglek Fiord ringed seals.

Principales observations

- Nous avons réussi à prélever des échantillons de tissu de 28 phoques annelés au cours de l'année 2009-2010 au moyen de diverses méthodes de capture et d'échantillonnage.
- Les concentrations de BPC dans la graisse des phoques annelés du fjord Saglek sont élevées, par comparaison à d'autres régions de l'Arctique canadien et du nord du Labrador.
- Les concentrations de PCB dans la graisse indiquent qu'environ 24 % des phoques annelés du fjord Saglek ont des concentrations supérieures aux seuils d'incidence sur la santé établis pour le phoque commun (1,3 ppm).
- La mise au point de nouvelles méthodes de mesure de l'état de santé du phoque annelé nous permettra d'évaluer les répercussions des BPC sur le phoque annelé du fjord Saglek.

Objectives:

- Develop / adapt and validate techniques to measure the health of ringed seals using methods established in harbour seals.
- Assess the health of ringed seal using physiological, biochemical and molecular biomarker measurements.
- Determine organic contaminant (PCBs, PBDEs, OC pesticides) and mercury levels in ringed seal and report on the associations found between contaminant exposure and changes in biomarkers in ringed seal from the north Labrador coast.
- Incorporate local Inuit concerns into our study and communicate our results to the communities of Nunatsiavut through several avenues, including the kangidluasuk base camp (jointly operated by Parks Canada and the Nunatsiavut Government) and regular updates and reports to the Nunatsiavut Government.

Introduction:

Elevated PCB concentrations in ringed seal from the northern Labrador coast could represent a serious threat to the health of ringed seals, local wildlife that prey on ringed seals (e.g. polar bears) and humans. Marine mammals are especially vulnerable to elevated exposure of persistent organic pollutants as a result of their high trophic level, low detoxification capacity, large lipid reserves, and long life span (Boon et al. 1992; Nyman et al. 2003; Mos and Ross 2002). Because these compounds are persistent they accumulate through the food chain, reaching their highest levels in upper trophic organisms, like ringed seal (Assunção et al. 2007; Wolkers et al. 2008). Marine mammals, such as ringed seal can serve as a 'sentinel species' of marine ecosystem contamination (Ross 2000). Through this study, we will be reporting on levels and trends of contaminants in ringed seals, which will both support the assessment of ecological and human health risks and provide Inuit with important health information regarding a valued component of their traditional diet.

PCB concentrations in ringed seals of the same age and sex from the northern Labrador coast range from Arctic background (< 1,000 ng/g ww) to 15,000 ng/g (ww) (Kuzyk et al. 2005; ESG 2008). Organochlorine contaminants, including PCBs, were more recently measured in ringed seals from the Labrador coast as part of our coastal food-web study, and contaminant data to date have shown that elevated PCB levels in ringed seals still persist along the coast (Brown et al. 2009). PCB levels at the upper end of this range exceed all previously reported concentrations in ringed seals from northern Canada and exceed established health effects thresholds in another pinniped species, the harbour seal (*Phoca vitulina*). As such, some of the ringed seals from the north Labrador coast may be at risk for toxic effects including the disruption of vitamin A, retinoic acid receptor RARα expression levels, thyroid hormone physiology and immune function (Mos et al. 2006; Mos et al. 2007; Tabuchi et al., 2006). The disruption of such physiological processes may lead to developmental, reproductive, and immunological impacts, ultimately impacting the health of local populations. This wide range of exposure provides a near-unique opportunity to evaluate the effects of PCBs on the health of a wild marine mammal, as the concentrations of this chemical dominate those of other POPs. In this study, we will assess the exposure levels and health status of ringed seals using established biomarkers. We have chosen a suite of biomarkers that appear to elicit a response or have been correlated with, organochlorine exposure in studies of other pinnipeds.

Activities in 2009-10:

The summer/fall sampling program was extremely successful in meeting its objectives for collecting samples from both live-captured ringed seals during our satellite telemetry program and harvested animals on an opportunistic basis. Species-specific methods to measure ringed seal health have been, developed, tested, and proven to be successful using similar gene-specific tools which have been applied to harbour seals (*Phoca vitlulina*), killer whales (*Orcinus orca*), and beluga whales (*Delphinapterus leucas*) (Mos et al. 2006; Tabuchi et al., 2006; Noel et al, 2009; Buckman et al 2008).

2009 Field Collections: We obtained samples from 28 ringed seals (live-captures n=7; harvested n=21) for our study. Six ringed seal were collected via harvesting from Nachvak Fiord, 12 ringed seals were collected via harvesting and live-captures (as part of our satellite telemetry study) from Saglek Fiord, and 10 ringed seals were collected via harvesting from Okak Bay.

Live Capture of Sub-Adult & Adult Ringed Seals: Skin/blubber biopsies and blood (plasma and serum) were collected from the live-captured ringed seals. The blubber is being analyzed for contaminants, vitamins A and E and toxicological genes outlined in Table 1. The skin is also being analyzed for toxicological genes outlined in Table 1. The plasma and serum samples are being analyzed for circulatory vitamin A (retinol and retinyl palmitate), vitamin E (α-tocopherol), thyroid hormones (TT4, FT4, TT3, FT3), and protozoan *Toxoplasma gondii*.

Harvested Ringed Seals: Blood, liver, muscle, brain, kidney, heart and lungs, gonads, stomach, blubber and skin, lower jaw, vibrissae, claws, and the left fore-flipper were collected from harvested ringed seals. The blubber is being analyzed for contaminants, vitamins A and E and toxicological genes outlined in Table 1. Samples of the skin, liver, muscle, brain, and kidney were collected, placed in RNALater™ solution, and are being analyzed for the toxicological genes outlined in Table 1. The plasma and serum samples are being analyzed for circulatory vitamin A (retinol and retinyl palmitate), vitamin E (α-tocopherol), thyroid hormones (TT4, FT4, TT3, FT3), and protozoan *Toxoplasma gondii*.

Liver will be analyzed for phase I and II enzyme activities. The heart and lungs are being examined for heartworm (*Acanthocheilonema spirocauda*) and lungworm (*Otostrongylus circumlitus*). The radius bone will be analyzed for bone mineral density. The stomachs are being analyzed for Anisakis spp. The tongue, cheeks, diaphragm muscle, left fore-flipper muscle, and heart muscle are being analyzed for *Trichinella* sp. The age of the animals is being determined from dentinal and cemental growth layers in a canine tooth.

2009 Genomics – Method Development: One of the objectives of the 2009-10 pilot ringed seal health study was to establish species-specific primers in support of quantitative polymerase chain reaction (qPCR) methods to measure ringed seal health. Ringed seal specific primers have been successfully developed and tested for the following normalizer and toxicological genes (rpL8, GAPDH, Cytoplasmic β-actin, AhR, MT1, VDR, ER α RXR, GR, TR α and TRβ) using tissues collected from the summer and fall sampling period (Table 1). Species specific primer development is on-going.

Table 1. Genomic endpoints selected to evaluate impacts of contaminants on the health of ringed seals, and status in method development (QA/QC).

Health Indicator		Key Role of Gene	Status
rpL8	Normalizer gene	house keeping gene representative of sample quality	passed QA/QC
GAPDH	Normalizer gene	house keeping gene representative of sample quality	passed QA/QC
Cytoplasmic β-actin	Normalizer gene	house keeping gene representative of sample quality	passed QA/QC
AhR	Toxicology gene	upregulation with toxic insult to dioxins; role in adipogenesis and nuclear translocation	passed QA/QC
CYP1A1	Toxicology gene	metabolism of exogenous and endogenous compounds	pending
MT1	Toxicology gene	uptake, regulation of important metals; detoxification	passed QA/QC
VDR	Toxicology gene	binds vitamin D; role in organ system maintenance	passed QA/QC
RAR	Toxicology gene	binds vitamin A; role in tissue maintenance, reproduction	pending
TR α & TR β	Toxicology gene	binds thyroid hormone; role in development & differentiation	passed QA/QC

Health Indicator		Key Role of Gene	Status
ER α	Toxicology gene	binds estrogen; role in reproduction, lipid regulation	passed QA/QC
RXR	Metabolism gene	lipid degradation	passed QA/QC
IGF-1	Metabolism gene	growth and anabolism	pending
GR	Metabolism gene	indicators of stress	passed QA/QC
TNF α	Metabolism gene	cytokines/inflammatory response	pending

Note: AhR = Aryl hydrocarbon receptor; CYP1A1 = cytochrome P450; MT1 = metallothionein; VDR = vitamin D receptor; RAR = retinoic acid receptor; TR = thyroid receptor; ER = estrogen receptor; IGF = insulin like growth factor; GR = glucocorticoid receptor; TNF = tumour necrosis factor. **Status for blubber/skin tissue: Pending = primer has been sequenced but refinements are needed to pass QA/QC. Passed QA/QC = primer has been validated as ringed seal species.**

For each of these selected genes, cross-species information representative of other mammals was obtained from the NCBI GenBank repository (http://www.ncbi.nlm.nih.gov/), and aligned using the ClustalW program available at EMBL-EBI (http://www.ebi.ac.uk/clustalw/). The aligned cDNA sequences were used in the design of either degenerate or non-degenerate PCR amplification primers using Primer Premier V5.0 software. DNA amplification reactions were performed with a cDNA template generated from a reverse transcription reaction containing MMLV RNase H- reverse transcriptase, random hexamer primer, and total RNA isolated from skin and blubber tissue of ringed seals. For each expressed gene target, DNA bands of the correctly predicted size were isolated by excision following electrophoretic separation on an agarose gel and purified by DNA-binding column chromatography. Isolated DNA was sequenced in both directions either directly or following ligation into a plasmid vector. Each cDNA sequence was annotated by comparison with the GenBank repository using an NCBI nucleotide-BLAST analysis (http://www.ncbi.nlm.nih.gov/).

Once the desired ringed seal-expressed cDNA sequences were identified, they were used, along with the Primer Premier software, to design gene-specific qPCR primers for quantitative determination of the steady-state abundance of individual transcripts in sample tissues as represented by reverse-transcribed cDNA. Such quantitative determination is performed on an Eppendorf Mastercycler ep realplex system using SYBR-based detection. qPCR primer sets were rigorously examined for specificity under stringent amplification reaction conditions. DNA amplicons generated from each qPCR primer set were then isolated and sequenced to confirm the correct targeting of specific expressed gene sequence. Primer pairs that pass all quality control measures are being used in the assessment of specific mRNA transcript levels in the ringed seal.

Complementary Studies – marine food web & ringed seal satellite telemetry: The marine food web study and ringed seal satellite telemetry study are sub-projects within our ArcticNet Nunatsiavut Nuluak program, but will have direct implications to understanding the contaminant exposure and health effects in ringed seals from the north Labrador coast. These two studies complement the ringed seal health study by controlling for some of the confounding factors (e.g. feeding ecology and behaviour) that may influence ringed seal health and the effects measured.

During the summer and fall of 2009, benthic invertebrates, phytoplankton, zooplankton, fish and ringed seal were collected for our marine food web study in Nachvak, Saglek, Okak, and Anaktalak Fiords (Figure 1). All sampling for benthic invertebrates, fish and seal was completed from a long-liner vessel (MV *Whats Happening*) and sampling for pelagic phytoplankton (using a CTD-rosette system), zooplankton (using zooplankton tows) and deepwater fish (using the Agassiz and Rectangular Mid-Water Trawls) was completed from the CCGS Amundsen in November, 2009. Ringed seal blubber samples were collected and analyzed for fatty acids (inner and outer half), while muscle and whole blood samples were analyzed for $\delta^{13}C$ and $\delta^{15}N$. Fish and invertebrate fatty acid, stable isotope and contaminant analyses are on-going.

Figure 1: Location of the study areas in Nunatsiavut (Nachvak, Saglek, Okak and Anaktalak Fiords). Note: Although long range transport is the primary source of contaminants to Nunatsiavut, local sources of PCBs also exist at Saglek Bay due to historical operations at the former military radar site.

Satellite Platform Transmitter Terminals (PTTs) were deployed on six ringed seals during the months of August and September in 2009. A PTT and data logger (both in a single unit) were attached to the dorsal fur (between the scapulae) of each ringed seal with fast-setting epoxy glue. Each satellite PTT will relay location and diving behaviour data for 4-8 months. Standard morphometric measurements, a blood sample, and two or three fat biopsies (one or two 3.5 mm and one 8.0 mm) were taken on each animal.

Capacity Building and Training: In 2009, we (ESG, Parks Canada, and the NG) applied for funding through the Nasivvik Centre for Inuit Health and Changing Environments to hire 11 students, to work as research assistants in several Nunatsiavut Nuluak research programs, including the ringed seal health study, the marine food web study, and the ringed seal satellite telemetry study. During the summer, six of the eleven students worked as research assistants off the local long-liner vessel (MV *Whats Happening*) in Saglek and Nachvak Fiords assisting scientists with ringed seal health research. The student intern program has helped to develop capacity, promote environmental education, training and careers, primarily amongst youth, in Nain and other Nunatsiavut and Nunavik communities. Subsequent, to the summer field work one of the Inuit students (Dorothy Angnatok) travelled to Victoria to attend the 2009 ArcticNet Annual Science Meeting.

Communications: Short summary reports for each of the programs within ArcticNet Nunatsiavut Nuluak (ANN), including the ringed seal health study were provided to the Nunatsiavut Government, Parks Canada, and the Torngat Fisheries Co-Management Board in the fall/winter of 2009. The reports summarized field work, major outcomes/results and detailed next steps.

From June 1-4, 2010 we attended the Tukisinnik Community Research Forum in Nain, Labrador. We presented background information, current research and preliminary results for our ringed seal health study, the marine food web study, and the ringed seal satellite telemetry study. This information was communicated to the Nunatsiavut Government, community members, Parks Canada, Industry, Torngat Joint Fisheries Board, and the Torngat Wildlife and Plants Co-Management Board. Open discussions concerning existing research activities were held across the three days. We also participated in a youth forum and put together a session that introduced youth to scientists leading the Nunatsiavut Nuluak research programs, our research, and the relevance of our research in Nunatsiavut. As part of the youth session we included a hands-on activity highlighting some of the work we do in the field, how we do it, and the equipment we use. A plain-language summary (in English and Inuktitut) of the ANN work was handed out at the forum and circulated around to Nunatsiavut communities and government offices (see Figure 2 – cover of ANN newsletter).

Figure 2: Cover page of the ArcticNet Nunatsiavut Nuluak (ANN) newsletter handed out at the Tukisinnik Community Research forum and circulated around to Nunatsiavut communities and government offices.

On June 16, 2010 we held our annual Saglek Stakeholder Meeting in St. John's, NL. Results of our ArcticNet Nunatsiavut Nuluak research programs, including the ringed seal health study were communicated to the stakeholders, including Inuit organizations.

Traditional Knowledge: The kANGIDLUASUk base camp that we operate from during July and August provides the opportunity for the integration of Inuit Knowledge in the Nuluak project, including the ringed seal health study. The base camp, and more importantly the Inuit connections that it fosters, anchors all facets of our project and strongly engages northerners in the scientific process through the bilateral exchange of knowledge, technology, and training. Traditional knowledge and Inuit concerns were partly responsible for the genesis of this program and will continue to be extremely important to the program in the future. Anaktalak Bay is used often for harvesting of foods, such as ringed seal. However, because of mining activities Inuit have voiced concerns with regard to the health and quality of harvested foods from the region and are beginning to go elsewhere to harvest (e.g. Okak Bay). Consequently, our studies have included Okak Bay to address these concerns and so that the information needed by the NG for policy decisions can be acquired. We have heard concerns from Inuit at base camp about possible health effects that elevated levels of contaminants may be having on ringed seals in this and other areas. During the Tukisinnik Community Research Forum in Nain we heard concerns from Inuit about elevated levels in ringed seal from areas further south along the Labrador coast (e.g. Lake Melleville and Hopedale). Consequently, we are considering expanding our ringed seal research further south along the Labrador coast. This health study will allow us to address these concerns. We also heard concerns regarding PCB concentrations in different biological tissues of ringed seals that have the elevated levels of PCBs.

A pilot project entitled, "Tukisimakatigennik (understanding together): Inuit Knowledge and scientific inquiry into contaminants trends in Nunatsiavut" was successfully funded by NCP this year and will complement our ringed seal health study, ringed seal telemetry study, and marine food web study in Nunatsiavut. While working alongside hunters in the field, project team members of the ringed seal health study will be carrying out interviews during the spring, summer, and fall months of 2010. This information will be collected and documented in a way that is both informative to community members, hunters, and research scientists. One of the objectives for the ringed seal health study is to learn from local hunters and document their descriptions of ringed seal health. For example, observations on an animal's weight, organ tissue appearance, blubber thickness, etc. This information will contribute to both the Community Based Monitoring and Research study and Environmental Monitoring and Research study on ringed seals in Nunatsiavut.

Results:

ΣPCB concentrations in the blubber of ringed seals from Saglek Fiord ranged from 81 to 9,505 ppb ww, with an arithmetic mean concentration of 919 ppb ww. While, ringed seals from Nachvak, Okak, and Anaktalak Fiords ranged from 66 to

4,481 ppb ww, with arithmetic mean concentrations of 469, 292, and 303 ppb ww, respectively (Figures 3; Table 2). Average ΣPCB concentrations in Saglek Fiord are higher than average PCB concentrations in Nachvak, Okak, and Anaktalak Fiords ($p<0.05$). 24% of the ringed seal blubber PCB concentrations from Saglek Fiord exceed established health effects thresholds in harbour seals (*Phoca vitulina*), while 10%, 5% and 0% of ringed seals from Nachvak, Okak, and Anaktalak, respectively, exceed the health effects threshold.

Ringed seals from the Labrador coast (2008) have the highest level of PBDEs found in the Canadian Arctic when compared to concentrations reported in a review by de Wit et al. (2006) (Figure 4). The ΣPBDE levels of northern Labrador ringed seals found in 2008 were approximately five to twenty-five times higher than ringed seals from other areas across the Canadian Arctic. ΣPBDE concentrations in the blubber of ringed seals from Nachvak, Saglek, Okak, and Anaktalak Fiords ranged from 2 to 145 ppb lw, with arithmetic mean concentrations of 28, 23, 24, and 49 ppb lw, respectively (Table 2). No significant differences ($p>0.05$) for ΣPBDE concentrations in ringed seal blubber were found among the four fiords.

Health Endpoints: Species-specific primers have been successfully developed and tested for 10 of the 14 targeted genes. Primer development for ringed seals is on-going.

Discussion and Conclusions:

Our preliminary results suggest that ΣPCB levels in approximately 24% of the ringed seal from Saglek Fiord exceed established health effects thresholds (1.3 ppm; Mos et al. 2010) in harbour seals (*Phoca vitulina*). While 10%, 5% and 0% of ΣPCB levels in ringed seals from Nachvak, Okak, and Anaktalak Fiords, respectively, exceed harbour seal health effects thresholds. ΣPCB concentrations in blubber indicate that ringed seals from Saglek Fiord are elevated relative to the Canadian Arctic and remainder of the northern Labrador coastline. Our preliminary results also suggest that ringed seals from Nachvak, Saglek, Okak, and Anaktalak Fiords have the highest level of PBDEs found in the Canadian Arctic when compared to concentrations reported in a review by de Wit et al. (2006).

Our project is delivering a series of new health assessment tools for ringed seals, which will be used to generate insight into the effects of PCBs on their health. Within the next year we will complete the circulatory hormone (thyroid and vitamin A & E) measurements and we will begin to study the molecular physiological responses to PCBs using our newly developed ringed seal specific primers on the 2009 ringed seal samples ($n=28$). We will also complete the aging of the ringed seals. OC pesticide and THg measurements for the 2009 ringed seal samples are being

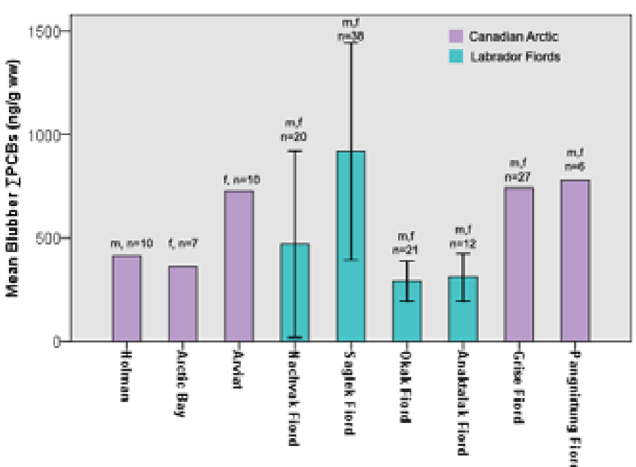

Figure 3: Average ± 95 CI ∑PCBs (2006-2008) concentrations in ringed seal blubber from Nunatsiavut (Nachvak, Saglek, Okak, and Anaktalak) and from ringed seals across the Canadian Arctic (CACAR II).

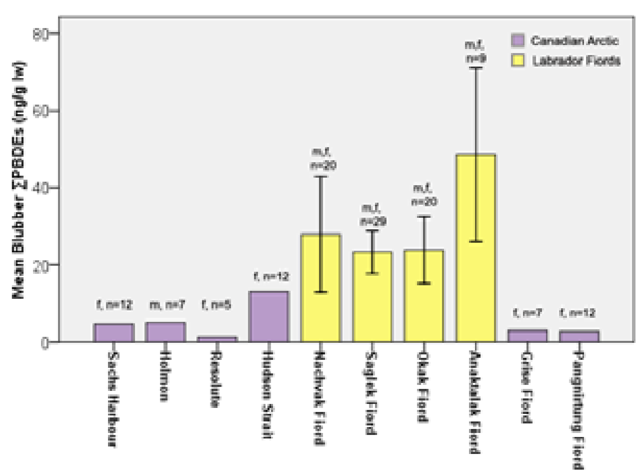

Figure 4: Average ± 95 CI ∑PBDEs (2008) concentrations in ringed seal blubber from Nunatsiavut (Nachvak, Saglek, Okak, and Anaktalak) and from ringed seals across the Canadian Arctic (de Wit et al. 2006).

Table 2. ΣPCBs and ΣPBDEs concentrations in ringed seal blubber from Nunatsiavut Fiords (Nachvak, Saglek, Okak, and Anaktalak) from 2006 to 2008.

Species: Ringed seal		ΣPCBs (blubber)			ΣPBDEs (blubber)	
location	Year	N	(ng/g wt)	N	year	(ng/g lw)
Nachvak Fiord	2008	20	469 (88-4481)	20	2008	28 (4-145)
Saglek Fiord	2006-08	38	919 (81-9505)	29	2008	23 (6-64)
Okak Fiord	2008	21	292 (66-1002)	20	2008	24 (2-71)
Anaktalak Fiord	2006-08	12	308 (75-687)	9	2008	49 (11-86)

completed at the GLIER in Windsor, ON. Heart and lungs have been sent to Dr. Lena Measures at the Maurice Lamontagne Institute in Mont Joli, QC and are being examined for heartworm (*Acanthocheilonema spirocauda*) and lungworm (*Otostrongylus circumlitus*). The radius bones are being archived in -20° freezers and will be analyzed for bone mineral density once a larger sample size is established. The stomachs have been analyzed for stomach contents and have been sent to Dr. Andria Jones at the University of Guelph and are being analyzed for *Anisakis* spp. The tongue, cheeks, diaphragm muscle, left fore-flipper muscle, and heart muscle have been sent to Dr. Andria Jones and are being analyzed for *Trichinella* sp. Muscle and RBCs are currently being analyzed for $\delta^{13}C$ and $\delta^{15}N$ stable isotopes at the GLIER. Blubber samples are currently being analyzed for fatty acids (inner and outer half) at Dr. Sara Iverson's laboratory at Dalhousie University.

Expected Project Completion Data:

This was a pilot year for the Labrador ringed seal health program. The objectives of this first year study were to design and apply a field sampling programme conducive to health assessments, and to initiate the development of a new genomics tool box to measure health of ringed seals. The second and third years of the program are focusing on increasing our sample size through the collection of ringed seal samples using three strategies: a live capture of pups during the spring pupping season, a summer capture of sub-adults and adults during a concurrent telemetry study, and from harvested sub-adults and adults during the spring and summer months. By targeting pups, we aim to minimize confounding factors (age, sex, reproduction, and moulting) and address the issue of health risks in an age group that is particularly exposed as a result of placental and/or lactational transfer of organochlorine contaminants from their mothers. The fourth year will focus on the completion of the analyses and holistic interpretation of the data. Expected project completion date is March 2014.

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Examination of the Biotransformation Efficacy of Precursors of Perfluorooctane sulfonates (PFOS) in Top Trophic Level Animals from the Canadian Arctic

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Abstract

Evidence shows that levels of the highly bioaccumulative perfluorinated sulfonate (PFSA) known as perfluorooctane sulfonate (PFOS), as well as levels and patterns of other PFSA, in tissues (mainly liver) can vary significantly among top wildlife predators of the arctic marine food web. Despite recent reductions in production, PFOS remains the most concentrated PFSA in the tissues of arctic wildlife, although in general the source to wildlife is not well understood. PFSA differences in arctic wildlife may be related to a variety of factors including exposure, bioaccumulation and biomagnification via their respective food webs, but also species-specific biotransfor-

Résumé

Certaines constatations révèlent que les taux du sulfonate perfluoré très bioaccumulatif appelé perfluorooctanesulfonate (PFOS) et les taux et tendances d'autres sulfonates perfluorés dans les tissus (surtout le foie) peuvent varier beaucoup chez les prédateurs de niveau supérieur du réseau trophique marin de l'Arctique. Malgré les récentes réductions de production, le PFOS demeure le sulfonate perfluoré le plus concentré dans les tissus de la faune arctique, bien que, règle générale, on en connaisse mal la source chez les animaux sauvages. Les différences de taux de sulfonates perfluorés chez les animaux sauvages de l'Arctique peuvent dépendre d'une variété de facteurs, dont

mation of accumulated PFOS-precursors such as perfluorooctane sulfonamide (FOSA) and *N*-ethyl-perfluorooctane sulfonamide (*N*-Et-FOSA). There may be several enzyme classes and/or isoforms that mediate FOSA and *N*-Et-FOSA metabolic degradation, which can ultimately result in PFOS formation. For example, PFOS to FOSA concentration ratios have been found to be much higher in the liver of arctic polar bears (*Ursus maritimus*) and ringed seals (*Pusa hispida*) compared to that of beluga whales (*Delphinapterus leucas*), which implies elevated enzyme-mediated capacity to metabolize PFOS precursors in the bears and seals.

In the present study, we tested the hypothesis that these three top arctic mammalian predators can differentially deplete pure linear FOSA and *N*-Et-FOSA, which is consistent with the contrasts in the ratios of residual PFOS to precursor concentration ratios found in the livers of these free-ranging animals. Using proven enzymatically viable tissues, a hepatic microsomal assay approach was used where microsomes were extracted from cryopreserved polar bear, beluga whale and ringed seal liver tissues as well as the laboratory rat (*Rattus rattus*) as a mammalian control model. In addition to the inclusion of buffer blanks, the overall study design for FOSA and *N*-Et-FOSA *in vitro* depletion assays for bear, whale, seal and rat microsome included controls (enzymatically non-activated) and samples (enzymatically activated). Results showed that regardless of the hepatic microsomes used, the rate of FOSA depletion was very slow even up to a maximum *in vitro* assay incubation of 90 min, as largely insignificant depletion of FOSA was observed. However, for incubation times as short as 10 min. extensive depletion of *N*-Et-FOSA was observed for the rat control and polar bears, slightly less so for ringed seals, and substantially less for beluga whale, with corresponding FOSA formation *in vitro* in the order of rat≈polar bear>ringed seal>beluga whale. These studies are facilitating a better understanding of the biological fate of PFOSA precursors of PFOS, and the contribution of such metabolism to PFOS bioaccumulation among these top trophic level arctic predators. This work will be of significant value to northerners, whose cultural lifestyle depends on these subsistence foods, and thus are exposed to PFOS and precursor compounds.

l'exposition, la bioaccumulation et la bioamplification dans les réseaux trophiques respectifs, mais également la biotransformation, qui varie selon l'espèce, des précurseurs accumulés de PFOS, comme les sulfonates perfluorés et le *N*-éthyle perfluorooctane sulfonamide (*N*-EtFOSA). Il peut y avoir de nombreuses classes d'enzymes et d'isoformes qui médient la dégradation métabolique des sulfonates perfluorés et du *N*-EtFOSA pour finir par produire le PFOS. Par exemple, on a constaté que le rapport des concentrations de PFOS sur celles des sulfonates perfluorés est beaucoup plus élevé dans le foie de l'ours polaire (*Ursus maritimus*) et du phoque annelé (*Pusa hispida*) de l'Arctique que dans celui du béluga (*Delphinapterus leucas*), ce qui donne à penser que la capacité enzymatique de métaboliser les précurseurs du PFOS est plus élevée chez l'ours et le phoque.

Dans la présente étude, nous avons posé comme hypothèse que ces trois principaux prédateurs mammifères de l'Arctique pouvaient manifester différents degrés d'appauvrissement en sulfonates perfluorés et *N*-EtFOSA, ce qui concorde avec les contrastes observés entre les rapports du PFOS résiduels sur les concentrations de précurseurs dans le foie de ces animaux en liberté. Nous avons extrait des microsomes du tissu hépatique congelé enzymatiquement viable d'ours polaire, de béluga et de phoque annelé, de même que du rat de laboratoire (*Rattus rattus*), à titre de mammifère témoin. En plus d'un témoin tampon, le concept général de l'étude de l'appauvrissement en sulfonates perfluorés et en *N*-EtFOSA *in vitro* dans les microsomes de l'ours, du béluga, du phoque et du rat prévoyait des témoins (enzymatiquement non activés) et des échantillons (enzymatiquement activés). Les résultats révèlent que, peu importe les microsomes hépatiques utilisés, le taux de disparition des sulfonates perfluorés est très lent, même après une incubation *in vitro* maximale de 90 minutes, après laquelle on a observé un appauvrissement très minime. Toutefois, après des incubations aussi courtes que 10 min., on a observé une grande diminution de *N*-EtFOSA chez le rat témoin et chez l'ours polaire, légèrement inférieure chez le phoque annelé et très inférieure chez le béluga, avec une formation correspondante de sulfonates perfluorés *in vitro*, dans cet ordre : rat ≈ours polaire>phoque annelé>béluga. Les travaux permettent de mieux comprendre le devenir biologique des sulfates perfluorés précurseurs des PFOS, et la contribution du métabolisme en jeu à la bioaccumulation du PFOS chez ces prédateurs de niveau trophique supérieur de l'Arctique. Ces travaux sont importants pour les habitants du Nord, dont le mode de vie et la culture s'appuient sur ces aliments de subsistance et qui sont par conséquent exposés aux PFOS et aux composés précurseurs.

Key Project Messages

- In all *in vitro* assays for polar bear, ringed seal and beluga whale, as well as those of control rat, the rate of FOSA depletion was very slow, as insignificant depletion of FOSA was observed, with no concomitant PFOS formation.
- For incubation times as short as 10 min. extensive *in vitro* depletion of N-Et-FOSA was observed for the rat control and polar bears microsomes, slightly less so for ringed seals, and substantially less for beluga whale, with corresponding FOSA formation *in vitro* in the order of rat≈polar bear>ringed seal>beluga whale.
- These studies are facilitating a better understanding of the biological fate of PFOSA precursors of PFOS, and the contribution of such metabolism to PFOS bioaccumulation among these top trophic level arctic predators.

Principales observations

- Dans tous les essais *in vitro* effectués chez l'ours polaire, le phoque annelé et le béluga, de même que chez l'animal témoin, le rat, la disparition du sulfonates perfluorés était très lente, car on n'a observé qu'un appauvrissement minime en sulfonates perfluorés, sans formation concomitante de PFOS.
- Pour une durée d'incubation aussi courte que 10 minutes, nous avons observé un appauvrissement *in vitro* en N-EtFOSA dans les microsomes du rat témoin et de l'ours polaire qui était important, légèrement inférieur chez le phoque annelé et bien moindre chez le béluga, avec une formation correspondante de sulfonates perfluorés *in vitro* dans cet ordre : rat ≈ours polaire>phoque annelé>béluga.
- Ces travaux permettent de mieux comprendre le devenir biologique des sulfates perfluorés précurseurs des PFOS, et la contribution du métabolisme en jeu à la bioaccumulation du PFOS chez ces prédateurs de niveau trophique supérieur de l'Arctique.

Project Objectives

The overall objective of this proposal is to comparatively examine the depletion and preliminary kinetics of PFOS precursors, specifically FOSA and N-Et-FOSA, as well as metabolite formation, *in vitro* using microsomal assay with enzymatically viable liver tissues of polar bears, ringed seals and beluga whales from the Canadian arctic. Another goal is to compare the present *in vitro* results with e.g. FOSA and PFOS concentrations and concentration ratios reported in the tissues (liver) of free-ranging animals in the Canadian arctic.

Introduction

Poly- and perfluorinated compounds (PFCs) are a class of chemicals that are used in many industrial and commercial applications, primarily for their stain repellency properties. Commercial applications include carpets, textiles, paper and food packaging, and aqueous film forming foam for fire-fighting. PFCs are recognized as global environmental contaminants and are ubiquitously detected in humans, abiotic media and wildlife, including those from remote environments. PFC contamination in the Canadian arctic has been widely reported by several research groups (Butt et al. 2010). In fact, the Canadian arctic is probably the best monitored of any geographic region with respect to the PFCs. Much of the monitoring efforts thus far have concentrated on two classes of PFCs, the perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs). Higher trophic level arctic wildlife has been shown to have comparatively elevated levels of PFCs (Butt et al. 2010; Houde et al. 2006; Letcher et al. 2010). For example, PFOS concentrations in polar bears are among the highest PFOS concentrations in wildlife measured globally (Dietz et al. 2008; Letcher et al. 2010, Smithwick et al. 2005, 2006). In the Arctic, recent tissue levels of PFOS have been reported to be considerably lower in beluga whale, narwhal and walrus from southeast Baffin Bay (Tomy et al. 2004, 2008), and in various seal species including ringed seal from Alaska/Beaufort Sea (Powley et al. 2008; Quakenbush and Citta 2008), ringed seals from east Greenland (Bossi et al. 2005a), and ringed seals from the Canadian arctic (Butt et al. 2007). The PFCAs and PFSAs are extremely persistent with no known environmentally-relevant degradation processes.

The source of PFOS in arctic wildlife is not well understood. Unlike the legacy POPs, PFCAs and PFSAs may be formed through the abiotic and biotic transformation of precursors. For example, the perfluorooctane sulfonamide alcohols (FOSEs) have been shown to degrade via atmospheric oxidation to PFOS (D'eon et al. 2006; Stock et al. 2007). FOSEs and the related perfluorooctane sulfonamides (PFOSAs) have been detected in Canadian arctic air (Butt et al. 2010; Shoeib et al. 2006; Stock et al. 2007). In addition, PFOS has been shown to be formed through the biotransformation of FOSEs and FOSAs (Tomy et al. 2004; Xu et al. 2004). The key intermediate in the formation of PFOS appears to be FOSA. In fact, Xu et al. (2004) observed the direct formation of PFOS after incubating rat liver slices with FOSA.

In the majority of arctic wildlife, PFOS is the dominant PFC measured. In contrast, FOSA levels are measured at much lower levels. Of relevance to this proposal, ringed seals and polar bears have been shown to have very high PFOS to FOSA concentration ratios (Butt et al. 2010; Dietz et al. 2008). Interestingly, this trend is not observed in some cetaceans, including beluga whales from the Canadian arctic (Tomy et al. 2004) and pilot whales from the Faroe Islands (Bossi et al. 2005b). These trends have also been observed in cetaceans from the Mediterranean Sea (Kannan et al. 2002) and melon-headed whales from Japan (Hart et al. 2008). The discrepancy in PFOS to FOSA concentration ratio trends between cetaceans and other mammals (notably ringed seals and polar bears) may be due to differences in diet. Alternatively, these trends may represent differences in the ability to biotransform FOSA to PFOS and perhaps other PFOS precursors. Presently, the potential for arctic wildlife to biotransform PFOS precursors that lead to PFOS formation is not known.

Activities in 2009-2010

This is a new project under NCP (Pathways, Processes and Effects), and builds on several other past NCP funded project to the PIs and team members (Letcher et al. 2009a, Tomy et al. 2009, Muir et al. 2009) that have measured PFOS to precursor (e.g. FOSA) concentration ratios in top trophic level animals.

Liver samples

Liver samples that have been collected and preserved (<-80°C) to maximize the activity of CYPs are currently available for several individual beluga whales from WHB (Arviat) and the St. Lawrence River estuary (see McKinney et al. 2006), two East Greenland polar bears (collected in 2008), and ringed seals, and presently archived at EC's Wildlife Specimen Bank at EC-NWRC (Table 1).

Hepatic microsome preparation and** in vitro **microsomal assays

The hepatic microsome preparation and *in vitro* FOSA and N-Et-FOSA depletion incubation assay was performed according to methods carried out and described for, e.g., captive sled dog (Verreault et al. 2008, 2009), beluga whales (McKinney et al. 2006, 2010 unpublished data), Baltic grey seals (Li et al. 2003) and polar bears (Letcher et al. 2009b). In the present study, microsomes were isolated from cryopreserved polar bear (n=1), beluga whale (n=2) and ringed seal (n=2) liver tissues (Table 1) as well as the laboratory rat as a mammalian model species (from pooled (n = 17) adult male Wister Han rats; BD Gentest) (McKinney et al. 2010 unpublished data).

Table 1. Collection location and date and biological data for liver samples of polar bear, ringed seal and beluga whale from the Canadian Arctic.

Sample ID	Species	Collection region	Collection date (YYYY/MM)	Sex	Age class
PB1	Polar bear	Iceland[a]	2008/06	F	Adult
BW1	Beluga whale	Western Hudson Bay, Canada	2003/08	M	Adult
BW2	Beluga whale	Western Hudson Bay, Canada	2003/08	F	Adult
RS1	Ringed seal	Cumberland Sound, Canada	2001/07	F	Adult
RS2	Ringed seal	Cumberland Sound, Canada	2001/07	F	Adult

[a] PB1 was stranded in Iceland as the sea ice retreated during summer. It is thus likely to be an individual from the East Greenland population.

As described in McKinney et al. (2010 unpublished data), liver microsomes for all of the present rat, polar bear, ringed seal and beluga whale samples were prepared by differential ultracentrifugation. Liver tissues will be thawed on ice and minced, after which an aliquot of approximately 1.0 g will be added to 4 ml of cold phosphate buffer (0.1 M KH_2PO_4 and 0.1 M Na_2HPO_4, pH 7.4) and homogenized with an Ultra-Turrex. The homogenate was centrifuged at 9,000 g (15 min, 4°C), and 2 ml of the supernatant (S-9) were centrifuged at 100,000 g (60 min, 4°C). The pellet was resuspended in 2 ml of cold phosphate buffer and stored in liquid nitrogen until use in the *in vitro* microsomal assays. The catalytic activity of CYP1A1 was measured to ensure that the CYPs are catalytically active. The total microsomal protein concentration was determined in triplicate using commercially available bovine serum albumin as the standard. Fluorescence was measured using a multiwell plate reader.

The hepatic *in vitro* assays was performed similarly as described elsewhere (McKinney et al. 2010 unpublished data), but with modifications for the FOSA and *N*-Et-FOSA substrates under study. Liver microsomes were used in quadruplicate sample assays with a NADPH regenerating system, triplicate control samples without the NADPH regenerating system added, as well as blank samples. The NADPH regenerating system was composed of solution A (31 mM NADP+, 66 mM glucose-6-phosphate and 66 nM $MgCl_2$ in H_2O) and solution B (40 U/ml glucose-6-phosphate dehydrogenase in 5 mM sodium citrate). The test and control samples (final volume: 1 ml) was combined on ice and consisted of a phosphate buffer (pH 8.0; 80 mM $NaH_2PO_4{\cdot}H_2O$, 6 mM $MgCl_2{\cdot}6H_2O$ and 1 mM Na_2EDTA), the reconstituted FOSA or *N*-Et-FOSA in acetone (3 μl; 10.0 μg/ml) and 1 mg of hepatic microsomal protein. The blank samples contained the phosphate buffer and 1 mg of hepatic microsomal protein. The sample mixtures were covered with solvent-washed aluminum foil and pre-incubated at 37°C for 5 min. The assay was initiated by the sequential addition of NADPH regenerating system (50 μl of solution A and 10 μl of solution B) to the test samples and 60 μl of phosphate buffer to the control and blank samples, and allowed to proceed for 90 min in a 37°C shaking (90 rpm) water bath. The enzyme reaction was terminated by the addition of 1 ml of ice-cold 0.5 M NaOH. At this time, internal standards were spiked (to the incubated buffer mix, i.e., $^{13}C_8$-FOSA (for FOSA) and d-*N*-Et-FOSA (for *N*-Et-FOSA). These fractions were either stored briefly at 4°C or used immediately for chemical analysis and determination of FOSA, $^{13}C_8$-FOSA, *N*-Et-FOSA, d-*N*-Et-FOSA and/or PFOS.

Chemical analysis of incubated assay solutions
The determination of FOSA, *N*-Et-FOSA and PFOS, as associated internal standards, in the incubated assay solution extracts was done using an LC-ESI(-)-MS/MS based method that has been described previously (Chu and Letcher 2008, 2009, Gebbink et al. 2009).

Quality assurance of chemical analysis
The Letcher Lab-Organics Research Group at EC-NWRC has participated in the NCP III Phase I, 2, 3 and the recent Phase 4 QA/QC round (results submitted in June 2010) for PCBs, OCs, PBDEs, PFCs (including FOSA, *N*-Et-FOSA and PFOS) and metals/elements.

Capacity Building
This new project took advantage of previously collected samples that have been archived at EC's Wildlife Specimen Bank (EC-NWRC), and were collected in the past by Inuit hunters in the specified northern communities. The activity supports the pre-postdoctoral research and training of Ms. Melissa McKinney, postdoctoral research and training of Dr. Craig But, as well as that of Dr. Shaogang Chu.

Communications
New results will be presented at NCP 2010 Results Workshop to be held Sept. 28-30 in Whitehorse, Yukon. Via the project leaders and team members, the final analysis of the contaminant data generated in this project will be made available to each Inuit community that has participated in the study. Whenever necessary and on a regular basis, the PIs has endevoured to respond to any inquires or concerns of northern communities. The PIs are also making every reasonable effort to communicate in person with the communities.

The territorial contaminants committees (TCCs) are vital conduits to local officials and community members of changes in our understanding of chemical contaminants in the arctic food web, as ultimately represented by the top trophic level wildlife such as polar bear, ringed seal and beluga whale. The PIs see their role in assisting the TCCs in effectively communicating new scientific information, and the impacts they (potentially) have on the health of their communities and the wildlife on which their present and traditional way of life depends.

All publications that result from NCP research, education and communication projects will be reported to pscowen@ucalgary.ca for inclusion in the NCP Publications Database.

Traditional Knowledge
The traditional knowledge of polar bears, ringed seals and beluga whale and their food webs are being enhanced by this research initiative. Local communities will be learning more about how the bioaccumulation and fate of PFCs (e.g., PFOSAs and PFOS) in top predator wildlife, which is representative of human exposure as these animals, are consumed as country foods. Furthermore, a better understanding of changes in the types and levels of PFCs that are in these animals will benefit the traditional knowledge of what and how much can be consumed of prey animals.

Results

Enzymatic viability was indicated by ethoxyresorufin-O-deethylase (EROD) activities ranging from 120 pmol/mg protein/min in the rat, to 199-694 pmol/mg protein/min for the seals and whales to 2167 pmol/mg protein/min for the bear (Table 2).

An initial screen was performed on possible FOSA depletion (using 30 nM $^{13}C_8$-FOSA in the incubation medium) with the available polar bear microsomes (Table 1). These polar bear microsomes possessed high enzyme activity, as indicated by the EROD activity rate of several thousand pmol/mg protein/min (Table 2). Sample assays were run so that incubation mixtures could be collected and analyzed at 0 min and every 10 min up to 90 min (10 time intervals). Regardless, with the polar bear microsomes no obvious $^{13}C_8$-FOSA depletion was observed even after a maximum possible assay time of 90 min.

In a larger scale assay set quadruplicate assays were performed for all rat and arctic species microsomes (Table 1) with $^{13}C_8$-FOSA as well as *N*-Et-FOSA (37.5 nM each) as substrates. Assuming that the depletion of $^{13}C_8$-FOSA would be minimal and *N*-Et-FOSA depletion being more substantial, residual concentrations of 37.5 nM down to low nM concentrations would still

Table 2. Polar bear (PB), beluga whale (BW), ringed seal (RS) and rat (RAT) liver microsomal protein content and ethoxyresorufin-*O*-deethylase (EROD) activity.

Sample ID	Microsomal yield[a] (mg protein/g tissue)	EROD[a] (pmol/mg protein/min)
PB1	15 (±2)	2167 (±99)
BW1	7.3 (±0.3)	694 (±41)
BW2	9.0 (±0.3)	309 (±6)
RS1	18 (±1)	397 (±15)
RS2	19.9 (±0.4)	199 (±10)
RAT	NA	120

NA: not available.
[a]Mean (± range) of inter-day duplicate assays ($n = 3$ replicates/assay), except RS2 microsomal yield is mean (± SD) of single day replicates and RAT EROD data is from microsome provider (BD Gentest).

permit detection and quantification by LC-ESI(-)-MS/MS (Chu and Letcher 2008, Gebbink et al. 2009), of depleted $^{13}C_8$-FOSA and *N*-Et-FOSA and the possible FOSA (from *N*-Et-FOSA deethylation) that could be formed. With $^{13}C_8$-FOSA as well as *N*-Et-FOSA as substrates, again no obvious depletion of $^{13}C_8$-FOSA was observed for any of the microsomes under study. However, for *N*-Et-FOSA the results showed that *N*-Et-FOSA was virtually eliminated whereas it was largely depleted for ringed seal and much less so for beluga whale. Furthermore, the *in situ* formation of FOSA was observed where the amount formed was highest for polar bear, less so for ringed seal and virtually not at all for beluga whale. The depletion of *N*-Et-FOSA and formation of FOSA demonstrated that such metabolic capacities were greatest for polar bear followed by ringed seal and then beluga whale. The rat control microsomes showed *N*-Et-FOSA depletion and FOSA formation that was similar to polar bear. However, these results from this assay set were considered semi-quantitative due to an apparent analytical loss of $^{13}C_8$-FOSA and *N*-Et-FOSA by non-metabolic factors, and thus low and contrasting recovery efficiencies.

Subsequent tests revealed that the recovery efficiency of $^{13}C_8$-FOSA was around 70% whereas for *N*-Et-FOSA it was around 30%. Further tests revealed that a substantial portion of the *N*-Et-FOSA was being lost to adsorption to particles in the incubation suspension, and in particular when the necessary assay buffer was present. The incubation solution extract was modified from methanol to a solution of 80% acetonitrile/20% methanol, which resulted in highly quantitative recovery efficiencies of virtually 100% for both $^{13}C_8$-FOSA and *N*-Et-FOSA.

A second round of assays was designed using the new extraction procedure but focusing only on *N*-Et-FOSA depletion and FOSA formation. That is, the only substrate in the assays was *N*-Et-FOSA (37.5 nM). Also, similar concentrations of $^{13}C_8$-FOSA and d-*N*-Et-FOSA were spiked as internal standards for FOSA and *N*-Et-FOSA, respectively, after termination of the incubation and prior to the incubation solution extraction.

Discussion and Conclusions

The results of the initial screen examining possible FOSA depletion in the polar bear microsomes that demonstrated no obvious depletion of FOSA even after to maximum possible assay time of 90 min, indicated that FOSA is slowly metabolized, and in fact too slowly within the maximum incubation period of the *in vitro* assay. Based on the strong likelihood that FOSA depletion would even be slower (and thus not observed) with ringed seal and beluga whale microsomes, it was decided to expand on the substrates in the assay to include FOSA as well as the FOSA precursor *N*-Et-FOSA. *N*-Et-FOSA is known to be inherently low or non-detectable in the liver of free-ranging polar bear, ringed seal and beluga liver (Butt et al. 2010; Dietz et al. 2008). However, Benskin et al. (2009) reported

N-Et-FOSA depletion *in vitro* by a deethylation reaction (mediated by CYP2C9) in human liver microsomes, and within minutes rather than hours in their assays.

In the present study and in a larger scale assay set using quadruplicate assays for all rat and arctic species microsomes (Table 1) and with $^{13}C_8$-FOSA as well as N-Et-FOSA as substrates, no obvious depletion of $^{13}C_8$-FOSA was observed for any of the microsomes. However, for N-Et-FOSA the results showed that N-Et-FOSA was virtually eliminated whereas it was largely depleted for ringed seal and much less so for beluga whale. Furthermore, the *in situ* formation of FOSA was observed where the amount formed was highest for polar bear, less so for ringed seal and virtually not at all for beluga whale. The depletion of N-Et-FOSA and formation of FOSA demonstrated that such metabolic capacities were greatest for polar bear followed by ringed seal and then beluga whale. The rat control microsomes showed N-Et-FOSA depletion and FOSA formation that was similar to polar bear. However, these results were considered semi-quantitative due to an apparent analytical loss of $^{13}C_8$-FOSA and N-Et-FOSA by non-metabolic factors, and thus low and contrasting recovery efficiencies.

Subsequent tests revealed that the recovery efficiency of $^{13}C_8$-FOSA was around 70% whereas for N-Et-FOSA it was around 30%. Further tests revealed that a substantial portion of the N-Et-FOSA was being lost to adsorption to particles in the incubation suspension, and in particular when buffer was present. The incubation solution extract was modified from methanol to a solution of 80% acetonitrile/20% methanol, which resulted in tested recovery efficiencies of virtually 100% for both $^{13}C_8$-FOSA and N-Et-FOSA.

The results for the second round of quadruplicate assays using the new extraction procedure, and focusing only on N-Et-FOSA depletion and FOSA formation, showed quantitative results as found previously. That is, N-Et-FOSA was virtually eliminated whereas it was largely depleted for ringed seal and much less so for beluga whale. Also, the *in situ* formation of FOSA was observed where the amount formed was highest for polar bear, less so for ringed seal and virtually not at all for beluga whale. This reaffirmed that N-Et-FOSA metabolism and FOSA formation was greatest for polar bear followed by ringed seal and then beluga whale.

These studies facilitate a better understanding of the biological fate of PFOSA precursors of PFOS, and the contribution of such metabolism to PFOS bioaccumulation among these top arctic predators (Butt et al. 2010, Letcher et al. 2010). The preset results from this one year research study has laid the foundation for future research, which will seek to determine the rates of N-Et-FOSA metabolic depletion and FOSA formation among these top arctic predators. Furthermore, other PFOS, as well as PFSA and PFCA, precursor are of interest for study with respect to metabolic depletion.

NCP Performance Indicators

Major deliverables from this project will be at least one publication in a peer-reviewed scientific journal. Any publications will be made available to, community representatives and the NWT and Nunavut Contaminants Committee during or by the end of the 2010-2011. Results will also be presented at appropriate, scientific workshops and conferences.

The number of northerners engaged in this project
Numerous individual were involved in the collection of polar bear, ringed seal and beluga whale liver samples. With respect to northerners, the polar bear liver samples were collected from an animal from Iceland, and via Icelandic collaborators at the University of Iceland, Environment Agency of Iceland and the District Veterinarian of East Húnaþing, Iceland. The beluga whale liver tissues were collected with the help of Mr. Mark Eetak (Arviat). The liver samples of ringed seals from the Cumberland Sound were collected by local hunters and trappers and provided via Dr. Gregg Tomy.

The number of meetings/workshops for this project held in the North
This is a focused one-year research project, and no meetings or workshops have as yet been held in the north. However, the NCP 2010 Results Workshop is to be held in the north (Whitehorse, Yukon) and we plan to present this study at this place and time.

The number of students (both northern and southern) involved in this NCP project
The students involved in this project in 2009-2010 have been southerners and are as follows:

Ms. Melissa McKinney: PhD candidate, Carleton University, Dr. Letcher as supervisor

Dr. Craig Butt: Postdoctoral Fellow currently located at the Nicholas School of the Environment & Earth Sciences, Duke University, Durham, NC, U.S.A.

The number of citable publications

a. *Domestic/international journals, book chapters, etc.*
   As this is a new project and only of one year duration, the number of citable publications, etc. from or related to this project as of 2009-2010 is currently only 1 (McKinney et al. 2010 unpublished data)

b. *Conference and workshop presentations*
   As this is a new project and only of one year duration, conference and workshop presentations related to this project will be in 2010-2011. In addition to the NCP 2010 Results Workshop in Sept. 2010, other (and related) presentations have been planned as listed below:

R.J. Letcher, M.A. McKinney, G.T. Tomy, S.G. Chu, R. Dietz, C. Sonne, D.C.G. Muir, C. Butt, S. De Guise. 2010. Differential perfluorooctane sulfonate (PFOS) levels in Arctic marine top predators and the influence of biotransformation of PFOS precursors. 31st Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 7-11, Portland, OR, U.S.A.

G.A. MacInnis, R.J. Letcher, M.A. McKinney, G.T. Tomy, M. Lebeuf, J. Fång, Å Bergman, C.H. Marvin. 2010. Investigation of HBCD metabolism in marine mammals using a hepatic microsomal *in vitro* assay. 30th International Symposium on Halogenated Persistent Organic Pollutants (DIOXIN 2010), Sept. 12-17, San Antonio, TX, U.S.A.

M.A. McKinney, R. Dietz, C. Sonne, K. Skirnisson, K. Karlsson, E. Steingrímsson, R.J. Letcher. 2009. Comparative hepatic microsomal metabolism of PBDE (including BDE209) and DBDPE flame retardants in top predators of the arctic marine food web: Polar bears, beluga whales and ringed seals. 30th Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Nov. 19-23, New Orleans, LA, U.S.A.

Expected Project Completion Date

All aspects of this one year project (e.g., data generation, data compilation and interpretation, data interpretation and writing of papers) are expected to be fully completed during 2010-2011.

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Scavenging Amphipods – Sentinels for Penetration of New and Historic Organic Contaminants into Food Webs in the Deep Arctic Ocean

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Abstract

Archived specimens of the scavenging amphipod *Eurythenes gryllus*, collected from 2000-4000 m in the Arctic Ocean on five expeditions between 1983-1998, were analysed for total mercury (ΣHg), methyl mercury (MeHg), polychlorinated biphenyls (PCBs) and other industrial organochlorines, and organochlorine pesticides (OCPs). Future measurements will include brominated flame retardants (BFRs) and perfluorinated chemicals (PFCs). Large differences in contaminant levels were found among the five expeditions. Median ΣHg concentrations ranged from 0.070 to 0.366 $\mu g\ g^{-1}$ wet weight while median MeHg concentrations ranged from 0.00355 to 0.0235 $\mu g\ g^{-1}$ wet weight and accounted for 1.7 to 20.1% (mean 5.0%) of ΣHg. The ΣHg and MeHg were not correlated with $\delta^{13}C$ nor with $\delta^{15}N$, but were

Résumé

Nous avons analysé des spécimens archivés de l'amphipode détritiphage *Eurythenes gryllus*, prélevés entre 2000 et 4000 m de profondeur dans l'océan Arctique, dans le cadre de cinq expéditions, de 1983 à 1998, afin de déterminer s'ils contiennent du mercure total (Hg), du méthylmercure (MeHg), des biphényles polychlorés (BPC), d'autres composés organochlorés industriels et les pesticides organochlorés (POC). Nous comptons mesurer plus tard les produits ignifuges bromés (PIB) et les substances chimiques perfluorées (SCP). Nous avons constaté de grandes différences entre les cinq expéditions au chapitre des taux de contaminants. Les concentrations médianes de Hg variaient de 0,070 à 0,366 $g.g^{-1}$ de poids humide, alors que les concentrations médianes de MeHg variaient de 0,00355 à 0,0235 $g.g^{-1}$ de poids humide et consti-

positively and significantly correlated with wet weight (ΣHg $r^2 = 0.167$, $p = 0.0008$, n=64; MeHg $r^2 = 0.422$, $p = 0.0004$, n=25). Median concentrations of total organochlorines ranged from 1910-39600 ng g^{-1} lipid weight, with order of abundance Σchlorobornanes > ΣPCBs ~ ΣDDTs > chlordanes > Σmirex compounds > Σchlorobenzenes ~ octachlorostyrene ~ α-hexachlorocyclohexane > pentachloroanisole. No correlations were found with $\delta^{13}C$ nor with $\delta^{15}N$ except for ΣCHBs, which was weakly and positively associated with $\delta^{13}C$ ($r^2 = 0.083$, $p = 0.047$). Concentrations of organochlorines were generally, but not always, higher in *E. gryllus* than those reported in smaller marine benthic scavenging amphipods. Enantioselective accumulation was found for the chiral OCPs *o,p*'-DDT, *cis*- and *trans*-chlordane, nonachlor MC6 and oxychlordane.

tuaient de 1,7 à 20,1 % (moyenne de 5 %) du Hg. Le Hg et le MeHg n'étaient pas corrélés aux isotopes $\delta^{13}C$ et $\delta^{15}N$, mais étaient positivement et fortement corrélés au poids humide (Hg $r^2 = 0{,}167$, $p = 0{,}0008$, n=64; MeHg $r^2 = 0{,}422$, $p = 0{,}0004$, n=25). Les concentrations médianes des composés organochlorés variaient de 1910 à 39600 ng.g^{-1} de poids lipidique, dans l'ordre d'abondance suivant : chlorobornanes > BPC > DDT > chlordanes > mirex > chlorobenzènes ~ octachlorostyrène ~ hexachlorure de benzène > pentachloroanisole. Aucune corrélation à $\delta^{13}C$ ni $\delta^{15}N$ sauf pour les CHB, qui étaient faiblement et positivement associés à $\delta^{13}C$ ($r^2 = 0{,}083$, $p = 0{,}047$). Les concentrations d'organochlorés étaient généralement plus élevées chez *E. gryllus*, mais pas toujours, que celles rapportées pour de plus petits amphipodes détritiphages benthiques marins. On a constaté une accumulation énantiosélective dans le cas des POC chiraux, de l'*o,p*'-DDT, du *cis*- et du *trans*-chlordane, du nonachlor MC6 etc. et de l'oxychlordane.

Key Messages

- The deep sea scavenging amphipod *Eurythenes gryllus* was sampled in western and central Arctic Ocean basins between 1983-1998 and analysed for total mercury (ΣHg), methyl mercury (MeHg), polychlorinated biphenyls (PCBs) and other industrial organochlorines and organochlorine pesticides (OCPs).
- Large differences in contaminant levels were found which appeared to be related more to location than to trophic indicators ($\delta^{13}C$ and $\delta^{15}N$ stable isotopes).
- Organic contaminants in *E. gryllus* were generally, but not always, higher than those reported in smaller benthic scavenging amphipods.
- These deep-sea amphipods probably do not record the general contamination of abyssal waters, but rather the vertical flux of occasional large particles (carcasses) and thus provide an independent way of viewing the time course of some contaminants in the upper interior ocean – a difficult location to sample by other means.

Principales observations

- Des échantillons de l'amphipode détritiphage de haute mer *Eurythenes gryllus* ont été prélevés à l'ouest et au centre des bassins de l'océan Arctique de 1983 à 1998. Nous avons analysé leur teneur en mercure total (Hg), en méthylmercure (MeHg), en biphényles polychlorés (BPC) et d'autres composés organochlorés industriels et pesticides organochlorés (POC).
- Nous avons constaté de grandes différences entre les taux de contaminants qui semblent davantage liées à l'emplacement qu'aux indicateurs trophiques (isotopes stables $\delta^{13}C$ et $\delta^{15}N$).
- Les concentrations de contaminants organiques d'*E. gryllus* étaient généralement plus élevées, mais pas toujours, que celles rapportées pour de plus petits amphipodes détritiphages benthiques marins.
- Ces amphipodes de haute mer ne subissent probablement pas la contamination générale des eaux abyssales, mais plutôt le flux vertical des grosses particules occasionnelles (carcasses). Par conséquent, ils procurent un moyen indépendant d'observer l'évolution dans le temps de certains contaminants dans les couches supérieures de la mer intérieure, où il serait difficile de procéder à un échantillonnage autrement.

Objectives

- Archived specimens of the scavenging amphipod *Eurythenes gryllus*, collected in 1983 and between 1996 and 1998 from offshore locations in western and central Arctic Ocean basins, are analysed for total mercury ((ΣHg) and methyl mercury (MeHg), polychlorinated biphenyls (PCBs) and other industrial organochlorines, organochlorine pesticides (OCPs), and selected new persistent chemicals: brominated flame retardants (BFRs) and perfluorinated chemicals (PFCs).
- Nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) stable isotope analyses are used to define trophic position reflecting carrion consumed prior to the last moult.
- Biomagnification factors (BMFs) are determined by comparing contaminant concentrations with published values in potential food sources from different trophic levels (invertebrates, fish, ringed seal, beluga and polar bear).

Introduction

Many pathways have been examined which deliver and redistribute contaminants in the Arctic Ocean, but few studies have documented their penetration to the abyssal regions. Excluding contaminated harbour areas, concentrations of legacy polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in surface sediments of the Canadian Archipelago and Canada Basin are very low. This creates severe challenges to using marine sediments as indicators of deep-ocean contamination and may also imply that contaminants are recycled in deep-ocean food webs rather than buried in sediments.

Marine benthic invertebrates provide another means of assessing transfer of contaminants to the deep ocean. The fauna is usually comprised of individuals with a relatively small body size, a short life cycle and low proportion of body weight stored as lipids. For these reasons, it has been difficult to determine temporal trends of fat-soluble persistent organic contaminants such as OCPs and PCBs in lower trophic level marine biota (Hargrave et al., 1992, 1993, 2000). Benthic lysianassid amphipods such as *Eurythenes gryllus* are an exception to this generality. These relatively large (mature females up to 10-12 cm in body length) and long-lived (5-10 years) scavengers feed on carcasses of fish and mammals that reach the seabed. They represent the only amphipod species large enough to permit analysis of contaminants in individual specimens (Svendsen et al., 2007). Individuals up to 8 cm in length have been collected from 2076 m on the Alpha Ridge in the central Arctic Basin (Hargrave et al., 1995) and from 1650 m in central Baffin Bay (Templeman, 1967). They have a diverse diet comprised of both invertebrates and vertebrate carrion (Blankenship and Yayanos, 2005) and are able to locate bait placed on the bottom using chemoreception. They feed rapidly to satiation to store lipids that will sustain basic metabolic processes for up to 6 months in juveniles and more than one year in mature females (Hargrave et al., 1994, 1995). Previous studies have shown that levels of POPs in *E. gryllus* collected in the central Arctic Ocean may be similar to those in marine mammals (Hargrave et al., 1992,1993; Svendsen et al., 2007; *cf.* Muir et al., 1992) suggesting that these invertebrates could serve as sentinel organisms for new and historic POPs in food webs of the arctic and other deep ocean basins.

Investigation of deep ocean penetration is particularly timely for substances which have recently been added to, or are being considered as additions, to international protocols such as the Stockholm Convention. Covaci et al. (2008) quantified polybrominated diphenyl ethers (PBDEs), a class of brominated flame retardants (BFRs), in two species of deep-sea fish from the Mediterranean Sea. PBDEs, as well as PCBs and OCPs, were also found in deep-sea fish from the Sulu Sea (Ramu et al., 2006). Svendsen et al. (2007) reported PBDEs and hexabromocyclododecane (HBCD) in *E. gryllus* collected at 100 m depth north of Svalbard in 2002.

This research was conducted to determine penetration of legacy and new organic contaminants and mercury to the abyssal Arctic Ocean, as indicated by body burdens in *E. gryllus*. Substances investigated are total mercury (ΣHg) and methyl mercury (MeHg), PCBs, OCPs, BFRs and perfluorinated chemicals (PFCs),.

Activities in 2009-2010

Collection and storage

E. gryllus were collected on various expeditions between 1983 - 1998 using traps with protected bait (Hargrave et al. 1994). The specimens examined in this study were selected from the archive at Freshwater Institute, Winnipeg where they were held frozen at -18°C. They were previously stored at Bedford Institute of Oceanography, Dartmouth, NS from the collection date until 2004 when they were transferred to Winnipeg. Table 1 gives the collection information.

Table 1. Collection data for *E. gryllus.*

Expedition	Location	Dates	Depth, m	N	Length. mm	Dry weight, g	Wet weight, g	Lipid %
CESAR-83	Lomonosov/Alpha Ridge: 85o48.45'N, 110o43.66'W	Apr. 15, 1983	2075	13	52.76-75.70	0.56-2.36	2.80-9.29	28.8-62.6
SCICEX-96	Central Arctic Basin (3 stations): 79o53'N, 114o30'W; 78o10'N, 143o03'W; 77o22'N, 150o40'W	Sept. 29-Oct. 11, 1996	3643- 3745	11	21.69-62.68	0.051-1.55	0.14-3.57	34.2-61.7
SHEBA-97	Canada Abyssal Plain: 75°17.6'N, 149°57.8' W	Dec. 25-26, 1997	3700	15	35.37-54.21	0.30-0.71	0.81-2.04	43.7-62.6
SHEBA-98	Chukchi Abyssal Plain: 79°32.6'N, 159°57.5'W	Aug. 29, 1998	3500	15	41.41-52.82	0.37-0.97	1.05-3.09	53.9-68.2
SCICEX-98	Lomonosov Ridge/ Markov Basin: 89o55.4'N, 49o56.4'W	Aug. 9, 1998	4250	10[a]		0.32-0.42[b]	1.35-1.42[b]	19.8-30.6

[a] 10 pools of 13-19 small amphipods in each.
[b] Range of weights and lipid contents of each pool.

Analytical methods

Mercury

After heating and digesting in hydrochloric and nitric acids, ΣHg is determined using cold vapour atomic absorption (CVAAS) (Armstrong and Uthe, 1971).

MeHg: The tissue is homogenized with acidic sodium bromide and cupric sulfate and extracted with toluene. Aqueous sodium thiosulfate is added to a measured portion of the separated toluene layer and the solution is vortex mixed. A measured portion of the thiosulfate layer is removed, aqueous potassium iodide is added and this solution is extracted with toluene. The final extract is injected into a gas chromatograph and MeHg is measured by GC-ECD (Uthe et al., 1972).

Stable isotopes

Carbonates are removed from the samples with the dropwise addition of 1 M HCl and gentle swirling in a vial until no further reaction is observed. Most samples require only a few drops. The samples are drained, rinsed with a few drops of water and dried. After drying, the samples are analysed for $\delta^{15}N$ and $\delta^{13}C$ using continuous flow ion ratio mass spectrometry (CFIR-MS) at the University of Winnipeg Stable Isotope Laboratory.

Organic contaminants:

The following target chemicals were sought:

- PBDEs (BDEs 47, 99, 100, 153, 154. 209).

- Non-BDE BFRs: 1,2-dibromo-4-(1,2-dibromoethyl)cyclohexane (TBECH), 2,3-dibromopropyl-2,4,6-tribromophenyl ether (DPTE), hexabromocyclododecane (HBCD).
- Fluorinated chemicals (perfluorononanoic, -decanoic, -undecanoic and -dodecanoic acids (PFNA, PFDA, PFUA, PFDoDA), perfluorooctane sulfonamide (PFOSA), perfluorooctane sulfonate (PFOS).
- PCBs (CBs 1, 3, 4/10, 7, 6, 8/5, 19, 18, 17, 24/27, 16/32, 26, 25, 31, 28, 33, 22, 45, 46, 52, 49, 47, 48, 44, 42, 41/71, 64, 40, 74, 70/76, 66, 95, 56/60, 91, 84/89, 101, 99, 83, 97, 87, 85, 136, 110, 82, 151, 144/135, 149, 118, 134, 114, 131, 146, 153, 132, 105, 141, 130/176, 179, 137, 138, 158, 178/129, 175, 187, 183, 128, 185, 174, 177, 171, 156, 201/157, 172/197, 180, 193, 191, 200, 170, 190, 198, 199, 196/203, 189, 208, 195, 207, 194, 205, 206, 209).
- Other industrial and incidentally produced organochlorines: octachlorostyrene (OCS), tetra-, penta- and hexachlorobenzenes (CBZs), pentachloroanisole (PCA).
- OCPs and metabolites (hexachlorocyclohexanes = HCHs, hexachlorobenzene = HCBz, DDT compounds, chlordanes and related cyclodienes, chlorobornanes (ΣCHBs and CHB congeners), mirex and photomirex.
- Chiral OCPs: enantiomers of *cis*- and *trans*-chlordane (TC, CC), nonachlor MC6, oxychlordane (OXY), α-HCH, *o,p*'-DDT.

Determination of PCBs and OCPs in biological tissues is routinely done by the Stern laboratory in NCP core monitoring studies and a version of this methodology is used here. *E. gryllus* tissue is spiked with internal standards (PCBs 30 and 204) and homogenized with dichloromethane. Anhydrous sodium sulfate is added to remove water and an aliquot of the extract is taken for gravimetric lipid determination. A second aliquot is cleaned up on Florisil, reduced into isooctane, and analysed for PCBs and most OCPs by gas chromatography-electron capture detection (GC-ECD) (Stern and Addison, 1999; Stewart et al., 2003). CHBs are determined by GC-electron capture negative ion high resolution mass spectrometry (GC-ECNI-HRMS) (Braekevelt et al., 2001).

Analysis of PBDEs is done by GC-ECNI-low resolution mass spectrometry (LRMS) (Tomy et al., 2008a). The non-BDE BFRs 1,2-dibromo-4-(1,2-dibromoethyl) cyclohexane (TBECH) and 2,3-dibromopropyl-2,4,6-tribromophenyl ether (DPTE) are determined by GC-electron impact-HRMS (Tomy et al., 2008b) while HBCD (Tomy et al., 2008a) and the PFCs are done by liquid chromatography-tandem mass spectrometry (LC-MS/MS) (Tomy et al., 2004).

Enantiomers of chiral OCPs are determined using a BGB-172 column (15 m x 0.25 mm i.d., 0.25 μm film) and GC-ECNI-LRMS (Borgå and Bidleman, 2005; Kurt-Karakus et al., 2005). The order of enantiomer elution is (–), (+) for α-HCH and (+), (–) for TC, CC and OXY, determined by using pure (+) enantiomer standards of these compounds. The elution order for *o,p*'-DDT is assumed to be (–), (+) by reference to Buser and Müller (1995), who used a similar chiral column. The elution order of MC6 has not been determined.

Results and discussion

Single amphipods were analysed for all expeditions except for SCICEX-98, where 13-19 small individuals were pooled. Length (mm) and weight (g) of amphipods from the other expeditions are given in Table 2 and were correlated:

$$\text{Wet weight} = 1.263 \times 10^{-6} \times \text{Length}^{3.66} \qquad r^2 = 0.901$$

Stable isotopes and mercury

Table 2 summarizes the stable isotope data and mercury content The $\delta^{15}N$ was positively and significantly correlated with $\delta^{13}C$, $r^2 = 0.115$ ($p = 0.004$). Inferred trophic levels (Hobson and Welch, 1992; Hobson et al., 1995) ranged from 2-5 on CESAR-83, 2-4 on SCICEX-96, 2-5 on SHEBA-97, 2-5 on SHEBA-98 and 2-4 on SCICEX-98.

The ΣHg over all expeditions ranged from 0.055 to 0.915 $\mu g\ g^{-1}$ wet weight. Median concentrations were in the order: CESAR-83 (0.366) > SCICEX-96 (0.234) > SHEBA-97 (0.185) > SHEBA-98 (0.092) > SCICEX-98 (0.070). The ΣHg was not significantly correlated with $\delta^{13}C$ nor with $\delta^{15}N$, but was positively and significantly correlated with wet weight ($r^2 = 0.167$, $p = 0.0008$, n=64).

MeHg was determined in five individuals (or pools, for SCICEX-98) from each expedition and ranged from 0.00185 to 0.0496 $\mu g\ g^{-1}$ wet weight. MeHg accounted for 1.7 to 20.1% (mean 5.0%) of ΣHg and median concentrations were in the order: CESAR-83 (0.0235) > SHEBA-97 (0.00991) > SCICEX-96 (0.00680) > SCICEX-98 (0.00358) ~ SHEBA-98 (0.00355). MeHg was not correlated with $\delta^{13}C$ nor with $\delta^{15}N$, but was positively and significantly correlated with wet weight (($r^2 = 0.422$, $p = 0.0004$, n=25).

Table 2. Stable isotope data and mercury content of *E. gryllus.*

Expedition	δ¹³C	δ¹⁵N		ΣHg µg g⁻¹ wet wt.				MeHg µg g⁻¹ wet wt		
	range	range	n	range	mean±SD	median	n	range	mean±SD	median	n
CESAR-83	-22.80 to -26.90	9.75-20.39	13	0.221-0.915	0.445±0.233	0.366	13	0.00936-0.0496	0.0247±0.0164	0.0235	5
SCICEX-96	-22.16 to -26.29	6.35-16.98	11	0.117-0.872	0.298±0.212	0.234	11	0.00367-0.0100	0.00693±0.00240	0.00680	5
SHEBA-97	-23.27 to -26.69	5.31-20.89	15	0.689-0.525	0.244±0.130	0.185	15	0.00479-0.0122	0.00897±0.00279	0.00991	5
SHEBA-98	-22.90 to -26.82	5.56-22.89	15	0.0548-0.174	0.0975±0.0317	0.0924	15	0.00185-0.00424	0.00326±0.00091	0.00355	5
SCICEX-98	-22.70 to -25.23	10.38-17.79	10[a]	0.0582-0.0959	0.0712±0.0101	0.0697	10[a]	0.00272-0.0149	0.00670±0.00523	0.00358	5[b]

a) 10 pools of 13-19 small amphipods in each.
b) 5 pools of 13-17 small amphipods in each.

Organic contaminants

At this stage, only results for organochlorine contaminants are available. Analyses of BFRs and PFCs will continue in the coming year on a no-cost basis to NCP, and final results will be reported in 2010-2011.

Organochlorines

Results for OCPs, PCBs and industrial or incidentally produced organochlorines are summarized in Table 3 as ng g^{-1} lipid weight (lw). Sums are given for multicomponent chemicals: ΣCHBs = chlorobornanes quantified vs. technical toxaphene; ΣDDTs = *p,p'*- and *o,p'*- isomers of DDT, DDE and DDD; ΣCHLs = TC, CC, *trans*- and *cis*-nonachlor (TN, CN), OXY; ΣMRXs = mirex and photomirex; ΣPCBs = sum of 104 congeners; ΣCBZs = 1,2,4,5- and 1,2,3,4-trichlorobenzenes, pentachlorobenzene, HCBz. Reported as single compounds are α-HCH, PCA and OCS. The general abundance of these in the amphipods was ΣCHBs > ΣPCBs ~ ΣDDTs > CHLs > ΣMRXs > ΣCBZs ~ OCS ~ α-HCH > PCA. Median concentrations (ng g-*1* lw) of total measured organochlorines were: SCICEX-98 (39600) > CESAR-83 (14400) > SCICEX-96 (8350) > SHEBA-98 (3850) > SHEBA-97 (1910).

Log concentrations of organochlorine sums (or single compounds for α-HCH, OCS and PCA) were regressed vs. $\delta^{13}C$ and $\delta^{15}N$, but no correlations were significant except for ΣCHBs, which was positively but weakly associated with $\delta^{13}C$ ($r^2 = 0.083$, $p = 0.047$). One chemical (α-HCH) was negatively correlated with wet weight ($r^2 = 0.14$, $p = 0.008$), but regressions for other chemicals were not significant.

Homologue profiles of PCBs for all expeditions were dominated by penta-, hexa- and heptachlorobiphenyls, which together accounted for 76-91% of ΣPCBs. The contribution of tetrachlorobiphenyls was slightly greater for the two SHEBA studies (13-16% of ΣPCBs) compared to CESAR and SCICEX (5-9% of ΣPCBs). Profiles for SHEBA-97 and SCICEX-98 are shown in Figure 1.

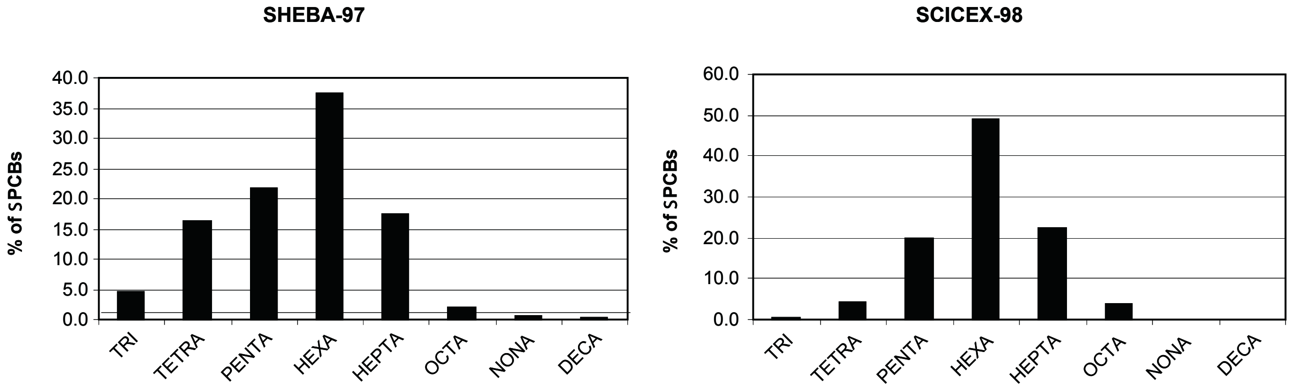

Figure 1. Profiles of PCB homologues in E. gryllus

The distribution of DDT compounds varied greatly among the expeditions. Percentages of *o,p*'- + *p,p*'-DDTs were highest on SCICEX-96 (35.2%) and CESAR-83 (25.5%), intermediate on SHEBA-98 (21.4%) and SHEBA-97 (18.8%), and lowest on SCICEX-98 (8.9%). The reverse order was found for metabolites *o,p*'-DDE + *p,p*'-DDE: SCICEX-96 (80.9%), SHEBA-97 (56.9%), SHEBA-98 (53.2%), CESAR-83 (50.6%) and SCICEX-96 (35.2%). Percentages of *o,p*'-DDD + *p,p*'-DDD ranged from 23.9-29.6% on all expeditions except SCICEX-98 (10.3%). Profiles of DDT compounds are shown in Figure 2 for SCICEX-96 and SCICEX-98.

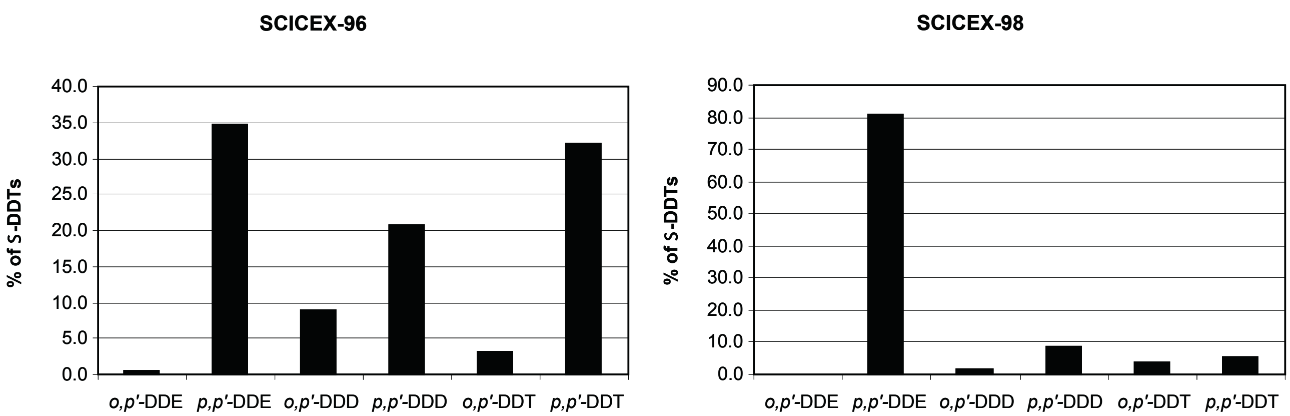

Figure 2. Profiles of DDT compounds in E. gryllus

Profiles of chlordane compounds were similar among the expeditions, with TN accounting for 46.0-54.6% of ΣCHLs. As percentages of ΣCHLs, other chlordanes were: CC (19.4-28.3%) > CN (8.9-13.4%) > TC (7.9-10.3%) > OXY (2.5-9.2%).

Svendsen et al., (2007) analysed 10 individual *E. gryllus* which were collected from 100 m depth at a station northeast of Svalbard in 2002, and results are compared with our study in Table 4 (104 congeners in both studies). Mean concentrations of ΣPCBs and Σ*p,p*'-DDTs in the Svalbard amphipods were similar to the five-expedition means in our study; while Svalbard levels of TN and HCB were higher, and α-HCH and OXY lower than ours.

Hargrave et al. (1992, 1993) reported ΣPCBs and OCPs in *E. gryllus* collected over Alpha Ridge in 1983 (Table 4). Compared to overall results in this study, their mean ΣDDTs and α-HCH levels were similar, ΣPCBs (estimated as Aroclor 1254) were about a factor of two lower, and ΣCHBs were a factor of two higher. HCBz and OXY were substantially higher in the Hargrave et al. (1992) study.

Concentrations of organochlorines are generally, but not always, higher in *E. gryllus* than in smaller marine benthic scavenging amphipods. Mean concentrations of ΣPCBs and Σ*p,p'*-DDTs were 327±273 and 297±227 ng g^{-1} lw in *Anonyx nugax* from Resolute Bay and Barrow Strait in 1993 and 311±199 and 158±30 ng g^{-1} lw in animals from northern Baffin Bay in 1998 (Svendsen et al., 2007). Levels lower than the overall mean (Table 4) but within the range of expedition means (Table 3), for *E. gryllus* were found in *Paramphitoe hystrix* from the Yermak Plateau (northwest of Svalbard): 1424±566 ng g^{-1}lw ΣPCBs and 1836±721 ng g^{-1} lw Σ*p,p'*-DDTs (Svendsen et al., 2007). CHBs in small amphipods (*A. nugax*, *Tmetonyx cicada*, *Onisimus* sp.) collected from the Canadian Ice Island between 1986-1989 averaged 1730±1240 ng g^{-1} lw (Hargrave et al., 1993), which is similar to means encountered on the SHEBA expeditions (Table 3).

Table 3. Organochlorines in E. *gryllus*, ng g^{-1} lipid weight.

	ΣCHLs[a]	ΣDDTs[b]	α-HCH	ΣCHBs[c]	Σmirex[d]	ΣCBZs[e]	OCS[f]	PCA[g]	ΣPCBs[h]
CESAR-83									
range	232-2070	729-28900	1.5-15.4	593-18330	19.8-252	10.6-28.5	5.9-60.8	4.9-17.9	1020-19440
mean±SD	842±571	6130±7360	6.9±4.8	7620±5940	84.3±64.9	19.3±4.6	28.4±20.1	11.1±3.9	5900±4890
median	568	3970	4.7	5200	58.7	19.3	19.2	11.3	4540
n	13	13	13	13	13	13	13	13	13
SCICEX-96									
range	150-1050	485-2380	4.4-14.8	1430-9700	10.0-64.6	13.7-25.2	4.4-30.1	1.9-18.3	586-4010
mean±SD	504±342	1390±603	10.1±3.9	4930±3030	38.0±20.7	19.3±4.8	14.6±11.1	11.6±6.5	2200±1150
median	450	1350	11.0	4400	42.7	18.8	11.5	9.3	2050
n	6	6	6	6	6	6	6	6	6
SHEBA-97									
range	56.4-602	83.0-1560	4.5-10.5	441-5450	5.8-53.5	4.3-27.3	1.5-18.9	0.75-13.4	310-2480
mean±SD	190±159	375±424	7.3±0.1.7	1490±1460	16.4±13.3	10.2±8.3	7.2±5.0	4.7±4.7	758±623
median	141	182	7.3	1070	11.3	6.2	6.1	2.4	486
n	11	11	11	11	11	11	11	11	11
SHEBA-98									
range	164-538	239-1230	4.6-9.4	1230-4900	9.0-39.2	6.0-15.4	5.2-30.2	0.76-4.4	496-2730
mean±SD	305±122	577±289	6.3±1.4	2530±1220	21.9±10.1	8.8±3.0	10.2±7.1	2.3±0.9	1140±702
median	285	513	6.0	2190	18.4	7.5	8.5	2.3	815
n	11	11	11	11	11	11	11	11	11

	ΣCHLs[a]	ΣDDTs[b]	α-HCH	ΣCHBs[c]	Σmirex[d]	ΣCBZs[e]	OCS[f]	PCA[g]	ΣPCBs[h]
SCICEX-98									
range	1390-4140	4010-22200	10.8-45.8	12000-42400	104-439	14.4-48.4	17.6-74.9	3.6-15.6	4640-21300
mean±SD	2620±1080	11700±6660	29.3±13.8	24800±11700	208±112	31.9±13.3	44.4±21.5	9.3±5.4	11240±6000
median	2400	7910	28.1	20500	165	33.1	37.7	9.0	8500
n	10	10	10	10	10	10	10	10	10

[a] *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor and oxychlordane.
[b] *p,p'*- and *o,p'*- isomers of DDT, DDE and DDD.
[c] based on total peak area of samples and technical toxaphene standard.
[d] mirex + photomirex.
[e] 1,2,3,4- and 1,2,4,5-tetrachlorobenzene, pentachlorobenzene and hexachlorobenzene.
[f] octachlorostyrene.
[g] pentachloroanisole.
[h] 104 congeners.

Table 4. Comparison of organochlorine measurements in *E. gryllus*, ng g-1 lipid weight.

	Location	ΣPCBs[a]	α-HCH	HCBz	Σ*p,p'*-DDTs[b]	ΣCHBs	TN	OXY
This study, five expedition means	see Table 1	4276±5320	11.6±11.0	6.9±4.7	4009±6189	8256±10410	458±545	49.2±71.6
Svendsen et al., 2007	North of Svalbard	4175±3865	5.3±0.7[c]	83±64	5753±5617		1068±1062	11.8±3.9
Hargrave et al., 1992, 1993	Alpha Ridge 1983	2249±12439[d]	<4-12	<60-258	6505±4740	16500±7900		563±661

[a] 103-104 congeners.
[b] *p,p'*- isomers of DDT, DDE and DDD.
[c] Estimated from α-HCH = 75% of ΣHCHs (Svendsen et al., 2007).
[d] Estimated as Aroclor 1254.

Chiral OCPs

Approximately half of the *E. gryllus* extracts have been analysed for enantiomers of the chiral chlordane-related compounds TC, CC, MC6 and OXY, and for *o,p'*-DDT, using the BGB-172 column. Enantiomers of α-HCH were also screened, but in most samples were below levels required for good chromatograms. Results of chiral analysis are reported as enantiomer fraction (EF) in Table 5, where EF = peak areas of the (+)/[(+) + (–)] enantiomers for TC, CC, OXY and *o,p'*-DDT, and areas of the first/(first + second) eluting peaks for MC6. EFs of racemic standards were: TC 0.500±0.004, CC 0.501±0.002, MC6 0.498±0.006, OXY 0.501±0.003 and *o,p'*-DDT 0.502±0.006.

The EFs of *o,p'*-DDT in *E. gryllus* were >0.5 in every case, indicating depletion of the (–) enantiomer which shows the greater estrogenic activity (Hoekstra et al., 2001). Mean EFs were highest on SCICEX-98 (0.814), while lower and remarkably similar mean EFs were found on the other expeditions (0.607-0.617).

Among the chlordane-related compounds, EFs of nonachlor MC6 were always <0.5, showing depletion of the first-eluting enantiomer. Mean EFs ranged from 0.434-0.468 on the different expeditions. The (+) enantiomer of metabolite OXY was enriched in all samples with mean EFs between 0.581-0.650. Enantioselective metabolism of TC and CC was ambivalent, showing depletion of (+) or (–) in different specimens.

Table 5. Enantiomer fractions[a] of OCPs in *E. gryllus*.

	TC	CC	OXY	MC6	*o,p'*-DDT
CESAR-83					
range	0.492-0.529	0.391-0.524	0.580-0.813	0.292-0.496	0.558-0.671
mean±SD	0.517±0.013	0.482±0.047	0.650±0.093	0.434±0.07	0.617±0.051
n	7	7	6	6	6
SCICEX-96					
range	0.484-0.496	0.494-0.526	0.559-0.630	0.460-0.474	0.566-0.663
mean±SD	0.492±0.005	0.507±0.013	0.589±0.028	0.468±0.064	0.617±0.036
n	5	5	5	5	5
SHEBA-97					
range	0.448-0.517	0.413-0.517	0.589-0.740	0.450-0.479	0.529-0.683
mean±SD	0.491±0.023	0.481±0.036	0.631±0.056	0.467±0.010	0.607±0.046
n	7	7	6	7	7
SHEBA-98					
range	0.465-0.502	0.494-0.535	0.560-0.609	0.410-0.478	0.599-0.631
mean±SD	0.485±0.014	0.513±0.014	0.581±0.015	0.457±0.023	0.617±0.012
n	8	8	8	7	8
SCICEX-98					
range	0.463-0.502	0.504-0.522	0.580-0.623	0.454-0.486	0.614-0.889
mean±SD	0.478±0.014	0.513±0.007	0.602±0.016	0.464±0.013	0.814±0.113
n	5	5	5	5	5

[a] EF = (+)/[(+) + (–)], except for MC6, for which EF = first/(first + second) eluting enantiomer.

Mean EFs for the five expeditions ranged from 0.478-0.517 for TC and 0.481-0.513 for CC. By comparison, mean EFs in *P. hysterix* from the eastern Arctic Ocean were: TC 0.445, CC 0.617 and *o,p*'-DDT 0.793 (Borgå and Bidleman, 2005).

E. gryllus are scavengers and feed on carcasses of different animals. Enantioselective metabolism differs among species and even among tissues of the same animal; for example, different EFs have been reported for chlordane compounds in blubber and liver of marine mammals (Hoekstra et al., 2003; Wiberg et al., 2000). To indicate the deviation from racemic regardless of which enantiomer was enriched or depleted, EFs were converted to the quantity DEVrac = absolute value of (0.500 – EF) (Kurt-Karakus et al., 2005). Final statistical analysis will be done when the rest of the samples have been run for the chiral compounds, but preliminary analysis indicates no significant relationship between $\delta^{15}N$ and DEVrac, nor among the DEVrac values for most compounds. A significant positive relationship was found between DEVrac of OXY vs. CC ($r^2 = 0.76$, $p < 0.0001$), but not OXY vs. TC.

Reported EFs of chiral chlordanes, *o,p*'-DDT and PCBs were close to racemic in arctic pelagic invertebrates and fish, but showed stronger deviation from racemic in higher trophic level organisms (Borgå and Bidleman, 2005; Hoekstra et al., 2003; Warner et al., 2005, Wiberg et al., 2000). Biomagnification factors from copepods (*Calanus* sp.) to bowhead whale (*Balaena mysticetus*) differed by a factor of 3.5 for the two enantiomers of α-HCH and by a factor of 9.3 for *cis*-chlordane.

Other differences were less dramatic, but nevertheless showed selective biomagnification of enantiomers; e.g. factors of 1.4 and 1.6 for OXY and heptachlor *exo*-epoxide (Hoekstra et al., 2003). In a comparison of invertebrates living at different depths in the eastern Arctic Ocean, Borgå and Bidleman (2005) found that ice amphipods (*Gammarus wilkitzkii*) contained nearly racemic α-HCH, chlordanes and *o,p*'-DDT, while greater deviation from racemic was found for these chemicals in epibenthic (*Themisto libellula*) and benthic (*T. libellula*, *P. hystrix*) amphipods. It was noted that highly nonracemic profiles for α-HCH in benthic amphipods were similar to those in deep ocean water; but it was uncertain whether the nonracemic profiles arose from diet or exposure to water.

Given the life history of these amphipods, they provide a very different insight into contaminant pathways than other species presently monitored. Specifically, they tell us about the loss of bioaccumulating and biomagnifying compounds from the upper ocean into the abyss. The vertical particle flux is exceptionally low to the interior basins of the Arctic Ocean (Honjo et al., 2010); thus, we anticipate that the deep-sea amphipods do not record the general contamination of abyssal waters by POPs, but rather the vertical flux of occasional large particles (carcasses) and thus provide an independent way of viewing the time course of some contaminants in the upper interior ocean – a difficult location to sample by other means.

Recent work to construct contaminant budgets and inventories (HCHs, Macdonald et al., 2000; Hg, Outridge et al., 2008) instruct us that time scales for declines in these compounds in marine fish and mammals following emission controls depends on the inventory in the upper ocean and the rates of loss from the photic zone. Indeed, the loss of contaminant from the photic zone, which in the Arctic may rely especially on the flux of large detritus, may be a key determinant of the loss rate and pathway. We note also that this pathway may be undergoing significant change due to the relocation of ice edge boundaries (e.g., Macdonald et al., 2005), which control distributions of many large animals including fish and mammals. Thus, the determination of contaminant burdens in archive samples of these scavenging amphipods is particularly timely and provides a baseline against which to evaluate modern fluxes occurring in an Arctic Ocean becoming seasonally clear of ice.

The amphipod *Orchomenella pinguis* has been proposed as a bioindicator of PAH and metals contamination in Greenland coastal areas (Bach et al., 2009). As noted in a recent article drawing parallels between native experience and western science (Carmack and Macdonald, 2008 (see p 277, right side, bottom paragraph), amphipods are organized in biogeographical domains that have significance to natives; it makes great sense, accordingly, to incorporate TK into the application of scavenging amphipods to monitor POPs and Hg in coastal waters.

NCP performance indicators

Student Ryan Binder (Inuvik) spent a week at Freshwater Institute to learn techniques of sample processing.

Expected project completion date:

Continued quantitative and chiral analysis and final data interpretation will be conducted during 2010-2011 to complete the project. A supplementary report will be submitted for the 2010-2011 year.

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Enhanced investigations of the factors affecting long-term contaminant trends in predatory fish in Great Slave Lake, the Northwest Territories

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Abstract

We have been conducting enhanced studies of Great Slave Lake in order to better understand the factors affecting the different contaminant trends we are seeing in lake trout and burbot. Sediment cores collected from the West Basin and East Arm have been dated and mercury concentrations determined along with sedimentation rate and metrics of lake productivity. There is no obvious trend of increasing mercury concentrations in lake sediments in recent years. The rate at which mercury is being deposited in the sediments reflects changes in sedimentation rates which differ in the two regions. While there is evidence that productivity has increased in recent years, this evidence may be biased by the fact that young sediments at the lake surface will have had less degradation of organic matter than sediments deeper in the core. Commercial fishing pressures on lake trout in the West Basin continue to decline which would allow improved fish survivorship; lake trout may be becoming more abundant and larger than in the 1990s. Mercury trend monitoring was resumed for pike at Fort

Résumé

Nous avons effectué des études plus poussées du Grand lac des Esclaves, afin de mieux comprendre les facteurs qui ont une incidence sur les tendances des différents contaminants rencontrés chez le touladi et la lotte. Nous avons daté les carottes de sédiments prélevées dans le bassin ouest et le bras est, et nous en avons mesuré les concentrations de mercure, le taux de sédimentation et les indices de productivité du lac. Il n'y a pas eu de tendance à la hausse évidente des concentrations de mercure dans les sédiments du lac au cours des dernières années. Le taux de sédimentation du mercure reflète les modifications des taux de sédimentation qui diffèrent dans les deux régions. Il y a des signes d'augmentation de la productivité au cours des récentes années, mais il se peut que ces signes découlent du fait que les matières organiques des jeunes sédiments de surface du lac se dégradent moins que celles des sédiments les plus profonds de la carotte. La pression exercée par la pêche commerciale au touladi dans le bassin ouest continue de diminuer, ce qui permettra d'améliorer la survie du poisson. Le touladi pourrait devenir

Resolution; no trend of increase was observed, possibly because the data sets and increase are too small to detect. Mercury trend monitoring for burbot also was resumed at Lutsel K'e; these fish are showing a pronounced trend of increase in mercury concentrations. Mercury concentrations remain below the 0.5 μg/g commercial sale guideline, except for very large fish (>800 mm). Community interactions have been excellent and a Cumulative Impact Monitoring Program project was funded in 2009-2010 to hold a workshop to discuss monitoring techniques and renewed in 2010-2010 where basic limnological monitoring will be started by Lutsel K'e and Fort Resolution.

plus abondant et plus gros que dans les années 1990. On a repris la surveillance des tendances du mercure chez le brochet à Fort Resolution. On n'a observé aucune tendance à la hausse, probablement parce que la série de données et l'augmentation sont trop petites pour permettre de dégager une tendance. La surveillance de la tendance du mercure chez la lotte a également repris à Lutsel K'e. La lotte manifeste une forte tendance à la hausse des concentrations de mercure. Les concentrations de mercure restent inférieures à la recommandation de 0,5 μg/g pour la pêche commerciale, sauf dans le cas des très gros poissons (>800 mm). Nos interactions avec la collectivité ont été excellentes, et un projet a été financé dans le cadre du Programme de surveillance des effets cumulatifs en 2009-2010, en vue de la tenue d'un atelier pour discuter des techniques de surveillance. Cet atelier sera repris en 2010-2011, alors qu'on commencera la surveillance limnologique de base près de Lutsel K'e et de Fort Resolution.

Key Messages

- There is little evidence of a pronounced increase in mercury concentrations in sediment cores collected in the West Basin and Great Slave Lake in recent years: mercury flux rates reflect sedimentation rates which differ with the location.
- While measures of lake productivity suggest an increase in productivity in recent times, this evidence may also be driven by the fact that organic matter in young sediments has not had as much time to be consumed by benthos and to degrade as sediments deeper in the core.
- Whitefish and lake trout catches in the commercial record continue to decline which should result in a reduced mortality of these fish in the West Basin. These fish may become more numerous (with recruitment) and larger fish may be available for the domestic harvest (because of their reduced mortality). However, while changes in the commercial fish record potentially could affect contaminant trends in West Basin fish (we have seen no evidence of this to date), it would not affect trends in the East Arm, where the commercial fishery does not operate.

Principales observations

- Il n'y a guère de signes d'augmentation importante des concentrations de mercure dans les carottes de sédiments prélevées dans le bassin ouest et le Grand lac des Esclaves au cours des dernières années : les taux du flux de mercure reflètent les taux de sédimentation qui diffèrent selon l'emplacement.
- Alors que les mesures de productivité du lac font croire à une augmentation récente de la productivité, les résultats peuvent également être attribuables au fait que la matière organique des jeunes sédiments n'a pas encore eu le temps d'être consommée par le benthos et de se dégrader comme les sédiments plus profonds de la carotte.
- Les captures de corégone et de touladi de la pêche commerciale continuent de diminuer, ce qui pourrait se traduire par un fléchissement de la mortalité de ces poissons dans le bassin ouest. Ces poissons pourraient devenir plus nombreux (avec les naissances), et les particuliers auront de plus gros poissons à pêcher (en raison de la réduction de leur mortalité). Toutefois, si les modifications de la pêche commerciale peuvent avoir une incidence sur les tendances des contaminants chez les poissons du bassin ouest (nous n'en avons observé

- Northern pike mercury monitoring resumed at Fort Resolution in 2008. There is no trend for mercury increase even when NCP data are combined with the commercial fish record. It is possible that the mercury increase is too small and the years of NCP monitoring too few to detect a trend.
- Burbot monitoring resumed at Lutsel K'e in 2008. There is a distinct trend of mercury increase.
- Burbot and northern pike mercury concentrations are below the 0.5 μg/g commercial sale guideline, on average, with only large pike (>800 mm) often exceeding this guideline.

aucun signe à ce jour), cela n'aurait pas de répercussion sur les tendances dans le bras est, où il ne se fait pas de pêche commerciale.

- La surveillance du taux de mercure chez le grand brochet a repris à Fort Resolution en 2008. Il n'y a pas de tendance à la hausse du taux de mercure même lorsqu'on combine les données du PLCN à celles de la pêche commerciale. Il est possible que l'augmentation des concentrations de mercure soit trop petite, et que la surveillance ne se fasse pas depuis assez longtemps pour qu'on puisse détecter une tendance.
- La surveillance de la lotte a repris à Lutsel K'e en 2008. Il y a une tendance à la hausse distincte des concentrations de mercure.
- Les concentrations de mercure chez la lotte et le grand brochet sont inférieures à la recommandation de 0,5 μg/g pour la pêche commerciale, en moyenne, sauf pour les gros brochets (>800 mm), dont les concentrations dépassent souvent cette valeur recommandée.

Project Description

Objectives

Assess time trends in mercury and persistent organic contaminants (including mercury, HCH, DDT, PCBs) concentrations and fluxes in dated sediment cores from Great Slave Lake. Determine how fluxes differ regionally as a function of hydrological and limnological regime.

1. Determine time trends in the productivity of Great Slave Lake through carbon isotope, Rock-Eval, and phytoplankton analyses of dated sediment cores collected in March 2009.
2. Investigate the relationship between contaminant and productivity time trends in the sediments with contaminant and biological trends in lake trout (Hay River, Lutsel K'e and periodic sampling in the Simpson Islands) and burbot (Fort Resolution, periodic sampling at Lutsel K'e).
3. Determine mercury concentrations in northern pike from Fort Resolution and mercury and persistent organic contaminant concentrations in burbot from Lutsel K'e and to assess whether mercury concentrations are showing a trend of continued increase.
4. Continue to review and synthesize the historic record for Great Slave Lake to assess changes and the mechanisms of change in the fisheries and limnology of the lake.
5. Integrate the findings of these studies into our core program which is investigating time trends in contaminants in lake trout and burbot in Great Slave Lake.
6. Work with local and other agencies to develop a long-term monitoring program for Great Slave Lake which will complement NCP's contaminant trend monitoring program.
7. Participate in and contribute information to AMAP expert work groups for trend monitoring for POPs and mercury.
8. Communicate results to the communities and the commercial fisheries in a timely manner.

Introduction

One of the primary goals of the Northern Contaminants Program (NCP) is determining contaminant trends in biota which are important in traditional diets at a number of representative locations throughout Canada's Arctic and subarctic environments. Analyses focus on the actual chemicals of concern and metrics of the organism being measured which may be important variables in affecting contaminant body burdens. For fish, these metrics are length, weight, age, percent lipid, and carbon and nitrogen isotopes (Rasmussen et al. 1990; Bentzen et al. 1999; Evans et al. 2005 a, b; Ganter et al. 2009, 2010 a, b). Unlike the early beginnings of NCP in the 1990s, contaminant levels are not measured in other compartments of the animal's environment, i.e., water, sediment, and food items. Thus, it can be difficult to ascribe changes in contaminant levels in the organism to changes in contaminant levels (and loadings) in its environment. Furthermore, environmental changes, irrespective of changes in contaminant inputs, can affect contaminant pathways and the levels in the organism being monitored. For example, changes in the trophic status, algal assemblages, carbon sources, etc. of aquatic ecosystems can affect contaminant pathways and uptake in a number of ways (Berglund et al. 2001; Houde et al. 2008). Similarly, it has been argued that changes in commercial fishing pressure, by affecting the population size and growth rates of fish, can affect contaminant levels in top predators (Ryan et al 2005; Ryan 2006). More recently, global warming has been raised as an issue of concern including its potential impacts on permafrost melt, enhanced delivery of contaminants from the watershed to the aquatic environment, and increased volatilization from southern reserves and subsequent long-range atmospheric transport northwards (Rouse et al. 1997; ACIA 2005; Prowse et al. 2006). Stern et al. (2005), Outridge et al. (2007) and Carrie et al. (2010) all have related increased concentrations and fluxes of mercury and persistent organic pollutants (POPs) to subarctic and high Arctic sediments to increased productivity resulting from warmer temperatures which has resulted in enhanced contaminant mobilization and movement with aquatic environments, including to the sediments.

While national and international agreements have had many successes in the reduced releases of POPs such as HCH and DDT to the environment, with some evidence of PCB declines (Hung et al. 2005; Li and Macdonald 2005; Riget et al. 2010), there is considerably less evidence for a decline in mercury. Various lines of research and considerations suggest that mercury concentrations are or could be increasing in the environment with increased Asian emissions which are counteracting reductions in North American and European emissions (Lohman et al;. 2008; AMAP/UNEP 2008; Muir et al. 2009; Pacyna et al. 2010). Similarly, our Great Slave Lake monitoring program is providing evidence that HCH and DDT levels are declining in burbot and lake trout while PCB trends are less evident; mercury levels appear to be increasing (Evans and Muir 2007, 2008, 2009).

This report (and study) is based on an expansion of the core Great Slave Lake trend monitoring program for burbot and lake trout with the overall goal the determination to what extent changing conditions in the Great Slave Lake ecosystem are changing contaminant levels in monitored fish and contaminant inputs. This is being accomplished through sediment core studies, a closer examination of the limnological and fisheries records for Great Slave Lake, and additional predatory fish sampling.

Activities in 2009-2010

Activities in 2009-2010 focussed on additional analyses of the sediment cores collected in March 2009; collection and analyses of northern pike from Fort Resolution and burbot from Lutsel K'e for contaminant trend analyses; and the integrated analyses of factors affecting time trends in burbot and lake trout under our core Great Slave Lake monitoring study. In addition, we received Cumulative Impact Monitoring Program funding which allowed us to work towards a complementary community-based limnological monitoring program with Fort Resolution and Lutsel K'e.

Results and discussion

Sediment cores

Mercury and mercury flux rates have been determined on two of the three cores collected in March 2009; mercury analyses on the third core and POPs analyses are ongoing. Mercury concentrations in the West Basin core average 83.2 ng/g; there was no obvious temporal trend (Fig. 1). Mercury concentrations, at 31.5 ng/g, were substantially lower in the East Arm core; no trend in concentration with time was apparent. Although mercury concentrations were ca. 2.6 times lower in the East Arm than West Basin core, mercury concentrations in lake trout and burbot exhibited considerably smaller differences in concentration between the two regions of the lake (Evans and Muir 2009) indicating that mercury concentrations in sediments are not strongly linked with mercury concentrations in fish. Mercury flux rates showed a long-term trend of increase at the East Arm site while the trend was more variable for the West Basin site; trends in mercury flux largely reflect trends in sedimentation rate.

S2, a measure a measure of algal remains in the sediments, showed a pronounced distinct trend of increasing concentrations since the 1990s; this trend did not mirror trends in sedimentation rates and mercury concentrations. Some caution must be exercised in examining pronounced increases in S2 concentrations in the uppermost (and youngest) sediment layers. Algal carbon is subject to various degradation processes including consumption by benthic organisms which live in and on the sediments and to microbial decay. Thus, a certain component of the loss of algal carbon with depth simply reflects the degradation of organic material with time. Physical evidence of this degradation is evident in the physical examination of core samples, i.e., diatom remains can be increasingly difficult to examine with depth because of the significant dissolution of valves which becomes more pronounced with depth; similarly, the S2 profile must to a certain extent reflect the natural degradation of algal remains with depth, irrespective of changes in lake productivity. As with mercury concentrations, the pronounced increase in S2 concentrations over 1990-2009 is not reflected in a similarly strong increase in mercury concentrations in lake trout and burbot. S2 concentrations were higher in East Arm sediments possibly because of lower sedimentation rates which resulted in less dilution of algal carbon and/or higher productivity; this site is located in a fairly shallow inlet where the vertical mixing would be less than the more offshore sites in the West Basin. Littoral zone algae and biofilms also could be a significant component of this carbon. In the Slave River at Fort Fitzgerald, total phosphorus and dissolved phosphorus concentrations showed a linear trend of increase over 1989-2006 but not 1996-2006 (Glozier et al. 2009); thus the increase in mercury concentrations in West Basin lake trout and burbot in the past decade do not have their explanation in increased productivity as a result of increase TP loading to the basin.

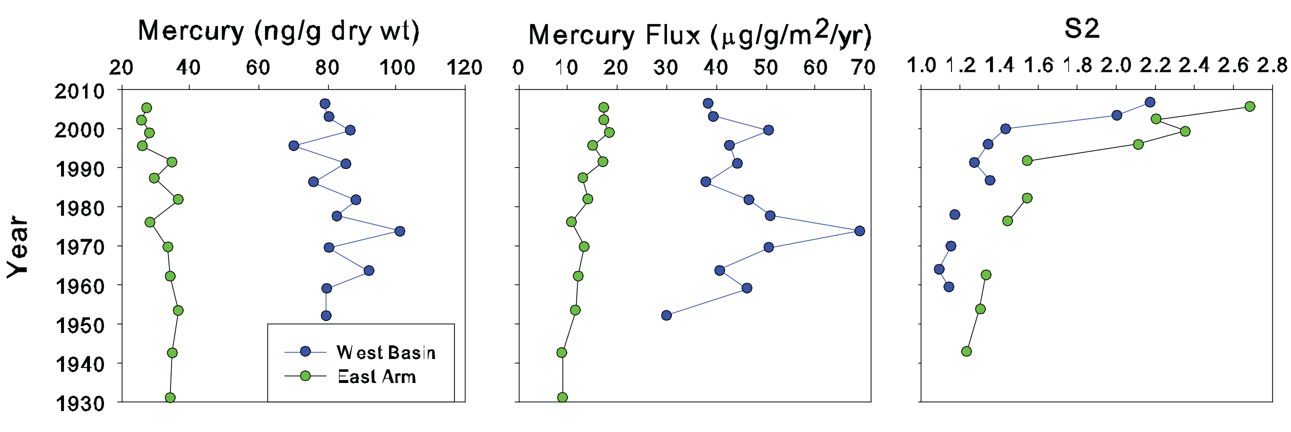

Figure 1. Time trends in mercury concentration and flux in sediments cores collected in the West Basin and East Arm of Great Slave Lake, March 2009. The red line marks 1993 when the NCP lake trout and burbot program began.

Commercial fish record

New data have been obtained from the commercial fish record for the West Basin extending the record to 2009. Lake whitefish catches continued to decline through the 2000s as have lake trout, most likely due to reduced fishing effort (Fig. 2). This reduced fishing effort may explain why lake trout collected from the commercial fishery (Hay River) have been showing an increase in mean length and age; these factors are considered in trend analyses, i.e., that increases in mercury concentrations in lake trout are not due to older and larger fish being analyzed in later than earlier years. Burbot also are caught in the commercial fishery but their numbers are not routinely recorded and presumably were a minor component of the catch. In the 2002-2003 fishing season, 58,407 kg of burbot were recorded from the fishery versus 62,783 kg lake trout. Thus, it is possible that some attributes of burbot biology in the West Basin are driven by changing mortality from the commercial fishery; alternately burbot are becoming more abundant in the West Basin and thus vulnerable to commercial catches.

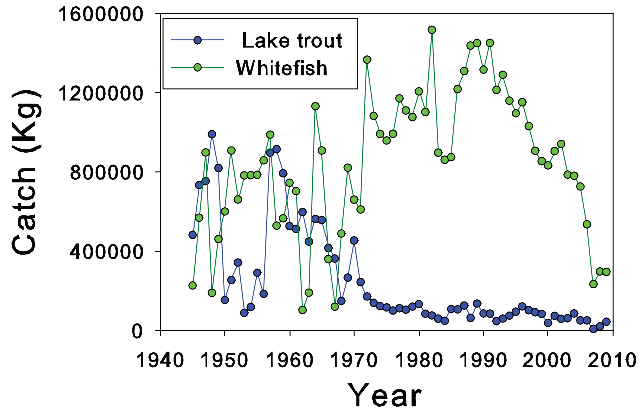

Figure 2. Commercial fish record for lake trout and whitefish from the Great Slave Lake commercial fishery.

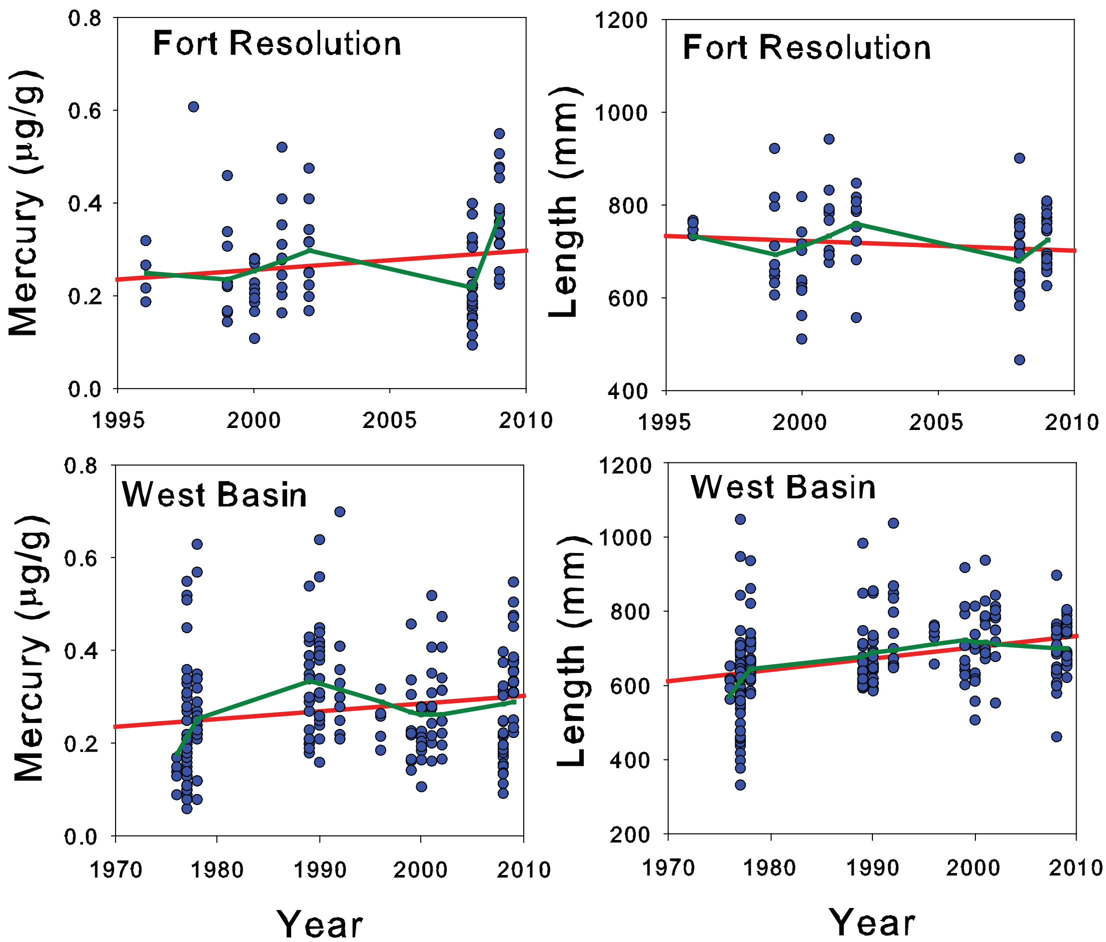

Figure 3. Time trends in mercury concentrations and fish length in northern pike caught from Fort Resolution (upper panels) over 1996-2009 and the combined commercial fish record and the Fort Resolution data for 1976-2008. Also shown is the linear regression (red line) and a Lowess Smoother (green line; f=0.5).

Time trends in mercury in northern pike

Northern pike collections from the Fort Resolution area resumed in 2008 and 2009; this allowed us to track mercury time trends in a littoral predator. Mercury showed a trend of increase with the converse observed for fish length; highest mercury concentrations overall were observed in 2010 (Fig. 3). Data were analyzed using a General Linear Model (GLM) with length, weight and year as independent variables: stable isotope and age data have yet to be received. Year did not emerge as a statistically significant factor. Similarly, incorporating the commercial fish pike data into the Fort Resolution data base showed a general increase in mercury concentrations but fish length also increased. According to the GLM analytical outcome, variations in mercury were explained by fish length alone. Long-term trends of mercury in northern pike clearly do not reflect trends in productivity (S2) for the West Basin core (Fig. 1). Data also were edited to exclude very large (>800 mm) and very small fish (<500 mm) with a similar outcome. Given that mercury levels are increasing in lake trout and burbot in the West Basin (Evans and Muir 2009), it is probable that mercury levels also are increasing in northern pike but the increase and the years of NCP sampling to small to detect this trend. Large pike, >800 mm long are likely to have mercury concentrations >0.5 µg/g as if common with other predatory fish.

Time trends in Burbot – Lutsel K'e

Contaminant trend monitoring for burbot at Lutsel K'e discontinued after 2004 but was resumed under this project in 2008 and 2009. Two archived fish from 1993 were located and these samples run for mercury. Regrettably, the entire fish were not located and so total length could not be determined. Mercury showed a pronounced trend of increase over 1993-2009, and also 1999-2009. Interestingly, mercury levels in 2008 and 2009 were not appreciably different from those observed in 2004. Similarly, Stern et al. (2009a) and Carrie et al. (2010) observed substantial variations in mercury levels in Fort Good Hope burbot over 2004-2008 with 2007 and 2008 values similar to 2004 values (0.41 -0.42 µg/g). A relatively uniform length range of burbot were provided annually over the course of the study with only a slight trend towards larger fish. Mercury concentrations are ca. 2.5 times lower in Lutsel K'e burbot than Fort Good Hope, possibly reflecting the greater connection with localized watersheds inputs in the Fort Good Hope fish: Fort Good Hope burbot also tend to be larger, at ca. 620-640 mm versus ca. 550 mm on average for Lutsel K'e fish in recent years. Mercury levels in Lutsel K'e fish are more similar to Teslin Lake (0.13 µg/g; mean length 590 mm) but lower than in Fox Lake (mean 0.24 µg/g; mean length 454 mm), Kusawa Lake (0.24 µg/g, mean length 471 mm) and Lake Laberge (0.37 µg/g mean length 580 mm) in the Yukon (Stern et al. 2009b). As previously noted, mercury concentrations tend to be lower in predatory fish in large lakes than in smaller lakes with warmer waters and a relatively larger littoral zone (Evans et al. 2005b).

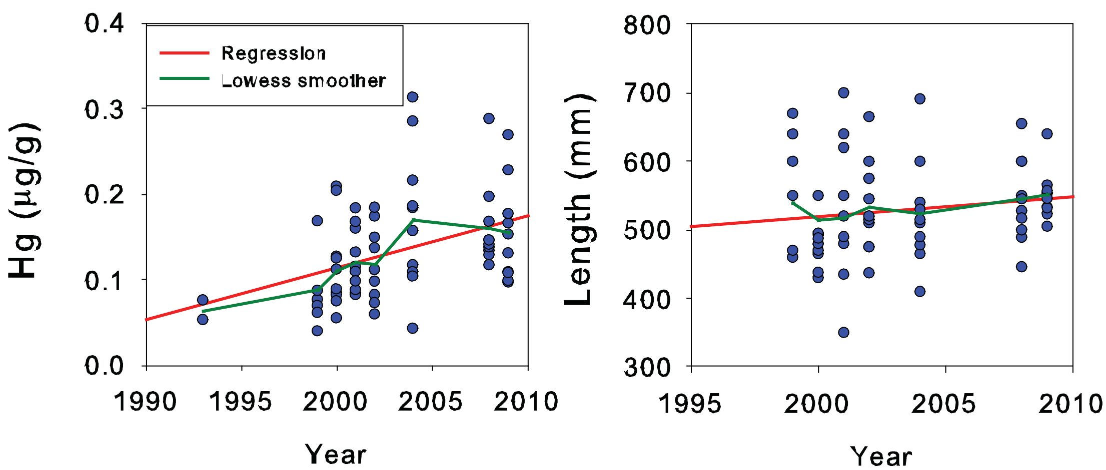

Figure 4. Time trends in mercury concentrations and length for burbot caught from Lutsel K'e.

Capacity Building

We received a Cumulative Impact Monitoring Program grant to develop the first steps of a community based monitoring program with partnerships with Lutsel K'e and Fort Resolution. An initial small workshop, planned for March, was so popular that it was expanded to include communities from the Deh Cho and a larger series of presentations. Deanna Leonard, with Fisheries and Oceans Canada (DFO), had additional funds which were directed towards the greater costs of this larger workshop. A renewed CIMP proposal was submitted and approved for 2010-2011 funding. It will build on the fact that both communities operate boat surveys of the fishing occurring in their areas. Basic limnological sampling will be conducted during these surveys and, as capacity is added, more parameters added in 2011-2012.

Expected Completion Date

This project is continuing in 2010-2011 with pike and burbot monitoring at Fort Resolution and burbot monitoring at Lutsel K'e continuing. In addition, we will be assessing two more lakes in the Mackenzie River Basin for changes in mercury levels in predatory fish: this spatial trend monitoring was removed from our core Great Slave Lake study. Given the large concerns with increased mercury levels in predatory fish in the NWT, especially smaller, warmer water bodies, we believe that this spatial monitoring should continue. Furthermore, from a scientific perspective, it is providing a stronger data base for the argument that mercury concentrations are increasing in waters in the Mackenzie River Basin as a consequence of anthropogenic activity i.e., increased atmospheric emissions, specifically mercury and/or greenhouse gases.

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Anticipating the Effect of Climate Change on Contaminant Exposure in the Arctic

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Abstract

Climate change is occurring most rapidly in the North and an urgent question is how this might affect the exposure of Northern people and wildlife to persistent organic contaminants. The issue is highly complex, as there are at least five different types of mechanisms by which a changing climate might impact the exposure of Northerners to persistent organic contaminants. Those are (i) changes in chemical use and emissions, (ii) changes in the extent of contaminant delivery to the Arctic ecosystem, (iii) changes in the processing of contaminants within the physical Arctic environment, (iv) changes in the processing of contaminants within Arctic food chains, and (v) changes in exposure due to changes in the life-style of Northern populations. Indirect effects related to changes in the Northern diet and in chemical emissions are likely to be most important, whereas the significance of direct effects of climate change on contaminant transport and distribution will depend on complex processes associated with changing sea ice and snow cover and food chain structure. A newly

Résumé

Le changement climatique se produit plus rapidement dans le Nord, et une question urgente se pose : quelles seront les répercussions de ce changement sur l'exposition des habitants et de la faune du Nord aux contaminants organiques persistants? C'est une question très complexe, car le changement climatique peut influer sur l'exposition des habitants du Nord aux contaminants organiques persistants par au moins cinq grands types de mécanismes : i) les modifications des utilisations et des émissions chimiques; ii) les modifications de l’ampleur de la propagation des contaminants dans l'écosystème de l'Arctique; iii) les modifications du traitement des contaminants dans l'environnement physique de l'Arctique; iv) les modifications du traitement des contaminants dans la chaîne alimentaire de l'Arctique; v) les modifications de l'exposition amenées par l’évolution du mode de vie des populations nordiques. Les répercussions indirectes liées aux changements de régime alimentaire et d'émissions chimiques dans le Nord seront probablement plus importantes, quoique l'importance des répercussions directes du changement climatique

developed model of contaminant fate in a seasonally ice-covered ocean will aid in the assessment of the importance of changes in the processing of contaminants within the physical Arctic environment on the exposure of Northerners.

sur le transport et la répartition des contaminants dépendra de processus complexes associés aux modifications de la glace marine et au couvert de neige, ainsi qu'à la structure de la chaîne alimentaire. Un tout nouveau modèle du devenir des contaminants dans un océan que la glace recouvre de façon saisonnière aidera à évaluer l'importance des modifications du traitement des contaminants dans l'environnement physique de l'Arctique en ce qui concerne l'exposition des populations du Nord.

Key Messages

- Among the multitude of mechanisms by which a changing climate might impact the exposure of Northerners to persistent organic contaminants, indirect effects are likely to be most important. This includes forced or voluntary changes in the Northern diet, and increased chemical emissions at Northern latitudes because of increased commercial, industrial and agricultural activities.
- Direct effects of a changing climate (i.e. changes in temperature, precipitation patterns and atmospheric mixing) on the long range transport and accumulation of contaminants in the Arctic are likely to be minor, unless they are amplified by changes in the Arctic cryosphere or aquatic food chain structure.
- A new model of air-ocean exchange of organic contaminants in a seasonally ice-covered ocean has been developed to predict the changes in the delivery of atmospheric contaminants to the Arctic Ocean that are expected to occur as the ice free period is increasing in length.

Principales observations

- Parmi les nombreux mécanismes par lesquels le changement climatique peut influer sur l'exposition des habitants du Nord aux contaminants organiques persistants, les répercussions indirectes sont probablement les plus importantes. Ces répercussions comprennent des modifications forcées ou volontaires du régime alimentaire des populations du Nord, et l'augmentation des émissions chimiques aux latitudes nordiques, en raison de l'augmentation des activités commerciales, industrielles et agricoles.
- Les répercussions directes du changement climatique (c.-à-d. les changements relatifs à la température, aux régimes de précipitations et aux brassages atmosphériques) sur le transport à grande distance et l'accumulation des contaminants dans l'Arctique seront probablement mineures, à moins qu'elles soient amplifiées par des modifications de la cryosphère arctique ou de la structure de la chaîne alimentaire aquatique.
- Il a été mis au point un nouveau modèle d'échange des contaminants organiques entre l'océan et l'atmosphère dans un océan couvert de glace de façon saisonnière, afin de prédire les modifications de la propagation des contaminants atmosphériques dans l'océan Arctique à laquelle on s'attend si la période sans glace se prolonge.

Objectives

Long-term:

- To identify and describe mechanisms by which a changing climate may affect the exposure of Arctic populations to organic contaminants and mercury, including changes in chemical use and emissions, in the delivery of contaminants to the Arctic ecosystem, in their processing within the Arctic physical environment and in the human food chain.
- To estimate the likely magnitude of changing contaminant exposure in the Arctic in response to different scenarios of climate change.
- To assess to what extent a changing climate may confound contaminant time trends obtained by analyzing residue levels in marine organisms from the Arctic.

Short-term

- To anticipate and to formulate hypotheses of how a changing Arctic climate may impact the exposure of Arctic residents and wildlife to organic contaminants and mercury
- To develop a dynamic, seasonally-resolved model quantifying the efficiency of air-to-marine food chain transfer in the Arctic for different contaminants and under different environmental conditions

Introduction

Considerable progress has been made over the last decade in terms of the capability to describe quantitatively the transport of organic contaminants over long distances, and in particular their accumulation in remote ecosystems such as the Arctic. Specifically, through the development and application of numerical simulation models of variable complexity, we have gained (i) a mechanistic and quantitative understanding of global cold-trapping process (Scheringer et al., 2000, Wania & Su, 2004), (ii) an appreciation of the influence of an organic chemical's partitioning and degradation characteristics on its large scale mobility and distribution (Wania, 2003, 2006), (iii) insight into the long-term temporal development of contaminant distributions as influenced by transport pathways and emission histories (Gouin & Wania, 2007; Wania, 2007), and (iv) an idea of the potential influence of climate variability on contaminant concentrations (MacLeod et al. 2005; Ma et al., 2004).

Much less well developed is our understanding of how a changing climate will affect contaminant mobility and distribution in the coming decades. Although first identified as an issue more than ten years ago (McKone et al., 1996; Kidd et al., 1998), the approaches so far have been largely conceptual and purely speculative (Macdonald et al., 2003, 2005), and first attempts at a quantitative treatment, albeit useful, are far from comprehensive and conclusive (McKone et al., 1996; MacLeod et al., 2007; Dalla Valle et al., 2007). It transpires that the direct effect of temperature on contaminant mobility is likely much smaller than indirect effects caused, e.g., by the effect of warming temperatures on the extent of Arctic snow and sea ice cover (Macdonald, 2005; Meyer & Wania, 2007). Future predictive efforts will have to anticipate and seek to parameterize those indirect effects, in particular if they have the potential to influence important contaminant amplification processes (Macdonald, 2005).

This project's ambition is to anticipate and predict the changes in contaminant exposure of Arctic residents and wildlife that may result from a rapidly changing climate. For this purpose the project will involve the development and application of a number of conceptual and numerical models that describe various aspects of the contaminant route from initial emission into the environment to accumulation at the top of Arctic food chains, including humans. Even if fraught with very substantial uncertainties, the predictions of such models appear to be the only means of estimating the magnitude of future changes in exposure. Predictions of major increases in exposure would constitute an important early warning prior to those changes actually occurring.

The determination of time trends in Arctic atmosphere and biota constitutes the core of NCP's activities aimed at evaluating the effectiveness of international agreement. It is thus of crucial importance to understand the part of the variability in those time trends that is not due to changes in emissions, but caused by a changing environment. By seeking to quantify the confounding effect of Arctic climate change on contaminant time trends, this project aims to facilitate the difficult task of deducing changes in global emissions from measured trends in the concentrations of air and biota sampled in the Arctic.

Activities in 2008-2009

One of the main activities in the past project year was a literature review aimed at identifying potential mechanisms by which a changing climate may affect the exposure of wildlife and humans in the Arctic to contaminants. This was done in preparation for a number of simple model simulations which will seek to assess the relative significance of the various identified mechanisms for human exposure to contaminants. Eventually, the effort in this project is to be focused on a mechanistic and quantitative understanding of those climate-dependent processes believed to have the largest potential to change the contaminant exposure of Northerners.

The second major activity was the development of a new model of contaminant fate in the Arctic surface ocean with the aim to establish a quantitative link between the concentrations of contaminants in the Arctic atmosphere and in the lowest trophic levels of the marine food chain. When eventually linked with an Arctic marine food chain model (Czub et al., 2008, Undeman et al., 2010), this model will allow us to estimate the air-to-organism transfer efficiency for different contaminants and different environmental conditions.

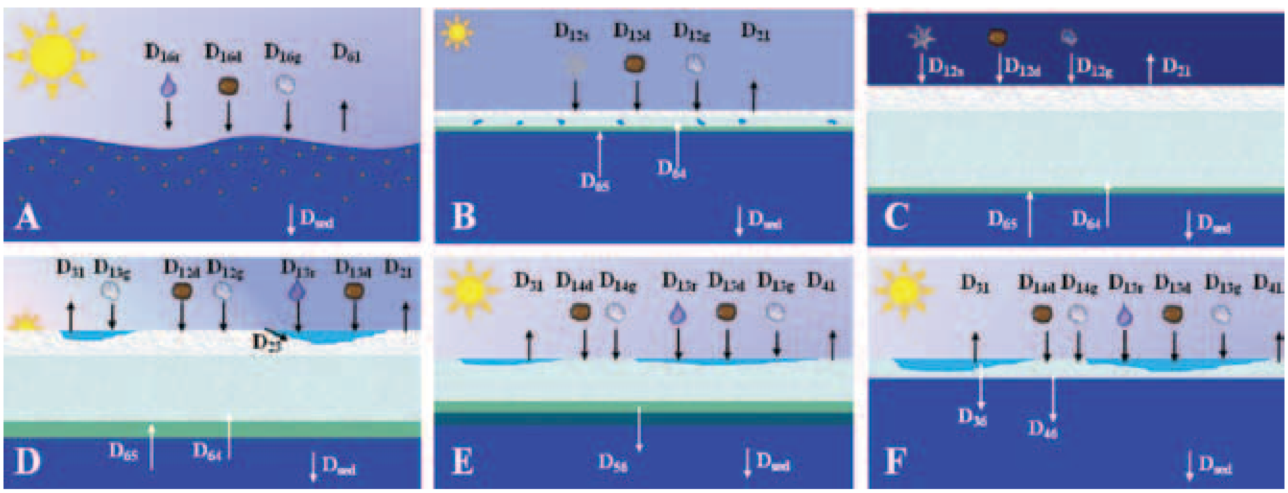
In previous multimedia fate models, sea ice is either ignored completely, or viewed simply as a barrier to the exchange of gas phase contaminants across an air-ocean boundary; however, the environmental processes involved in the formation, growth and melt of sea ice are not considered, resulting in no knowledge of how sea ice effects the fate of contaminants on a global scale. It was the aim of this work to create a model for the Arctic Ocean which incorporated sea ice and treated it as something more than merely a transient barrier to gas exchange, in hopes of being better able to predict the fate of contaminants in the marine Arctic environment under environmental conditions varying as a result of climate change.

In order to describe the complex set of processes that may impact the physical fate of contaminants in the Arctic surface ocean, the model is fully dynamic, i.e. allow for time-variant environmental parameters and contaminant concentrations and fluxes. In particular, it describes dynamically the annual cycles of (i) sea ice formation, snow deposition on sea ice, and subsequent melting of both snow and sea ice, and (ii) primary production of both ice algae and pelagic phytoplankton, and in the resulting cycling of particulate organic carbon in the water column. The output of the model is the annual time course of contaminant concentrations in various compartments and the contaminant fluxes between them.

The model has been designed to simulate a section of the Arctic ocean of a user-defined size. The default area is 1 km x 1 km. The simulated ocean environment consists of 6 compartments, numbered #1 to #6. The atmospheric compartment (#1) is 1 km high, well mixed, and has a seasonally variable temperature. Precipitation in the form of rain or snow and dry-deposited particles carry contaminants from the atmosphere to surface compartments, based on the physical-chemical properties of the contaminant being studied. Two-directional gas exchange occurs with the surface compartment(s) in contact with the atmosphere. The snow pack compartment (#2) is assumed to form a uniform layer over the entire surface of the sea ice compartment and increases steadily in depth during winter (Environment Canada, 2002–2008). With the onset of spring melt, the snow pack melts to form melt ponds (#3) on the surface of the sea ice compartment. Unlike the snow pack, melt ponds are assumed to only cover a fraction of the surface of the sea ice (Tschudi et al., 2005).

The sea ice compartment (#4) is made up of hard, dense consolidated ice (Bunt, 1963). It also undergoes a seasonal cycle of growth and melt. During the period of melt pond presence, a fraction of the sea ice surface is in contact with the atmosphere, and so contaminants can be added to the sea ice via dry deposition. It is assumed that all wet deposition to the surface during the frozen period will enter the snow pack or melt ponds. The algae-enriched bottom ice compartment (#5) represents the bottom few centimeters of the ice (to a maximum depth of 10 cm). Algae become concentrated in this bottom ice during the formation and growth of the ice, generating a visually distinct layer (Garrison et al., 1989). The bottom ice compartment is made up of a looser assembly of ice crystals, which allows sea water to flush through (McConville and Wetherbee, 1983). The top 50 m of the Arctic ocean, known as the polar or surface mixed layer, is taken to be the well-mixed surface sea water compartment (#6) (Aagaard et al. 1981, Walsh, 2008).

Several compartments (snow pack, melt ponds, sea ice and bottom ice) are transient and interact with other compartments differently at different times of the year, giving rise to a seasonal dependence to many transport processes. The differential applicability of certain transport processes based on the time of the year is coded into the model through the use of a set of scaling factors that adopt a value of either zero or one, depending on whether a certain transport process occurs or does not at a given time of the year. Effectively, it allows transport processes to be turned on or off. Each simulated year consist of three major periods, the first is the freezing period, where the frozen compartments appear and grow in size to their maximum volumes, the second is the subsequent melting period, in which the frozen compartments melt away, and the third is the ice free period, in which no frozen compartments are present. Figure 1 displays the sequence of events during one year as described in the model.



Diagrams illustrating the seasonal changes in the compartments and contaminant transport processes within the Arctic Ocean model. Six distinct time periods correspond to the ice-free period (A, “summer”), the onset of sea ice formation (B, “freeze-up”), the period of sea ice growth (C, “polar winter”), the reappearance of the sun (D, “polar sunrise”), and the melt periods (E, “bottom ice melt”, F, “ice melt”). During different times of the year different fate processes are taking place.

A (“summer”) designating the period of open water (default: August 15 to August 31). During this period contaminants can be transported from the atmosphere to the sea water compartment with rain (described by a D-value $D16_r$), particles ($D16_d$), or via dry gaseous deposition ($D16_g$). The chemicals can also volatilize from sea water to air (D_{61}). Particulate matter is assumed to settle out of the surface sea water and into deeper ocean layers at a user-defined rate, taking along sorbed contaminant (D_{sed}). This process occurs all year long. It is assumed that there is no input of contaminants or particulate matter from the deep sea to the surface sea water compartment (Honjo et al., 2000).

B (“freeze-up”) represent the period of first sea ice formation until polar sunset (September 1 - October 15). Sea ice begins to form and caps the sea water compartment. After the formation of ice, snow starts to accumulate on the sea ice preventing exchange of contaminants between sea ice and the atmosphere. Atmosphere surface exchange is thus between air and snow pack either by snow fall ($D12^s$), particle deposition ($D12^d$), or diffusive gas exchange (D_{12g}, D_{21}). Algae can grow in the bottom ice compartment (Garrison et al., 1989). Contaminant can be incorporated into the sea ice as it forms (D_{65}, D_{64}).

C ("polar winter"): Sun sets and no further growth of algae occurs until the sun rises again (October 16 to March 21). The sea ice layer and snow pack continue to thicken over the course of the cold sunless period, with all atmospheric input of contaminants occurring to the snow pack.

D ("polar sunrise"): With the sunrise (March 21) algae in the bottom ice compartment is again able to grow. Despite the presence of sun, snow pack melt and ice pond formation does not begin until May 1. It is assumed that following May 1 precipitation falls in the form of rain, and that this rain will enter the melt ponds. The water temperature is still cold enough to prevent the melt of the sea ice at this time.

E ("bottom ice melt"): Bottom ice melts, releasing algae and particulate matter contained therein to the sea water compartment (D_{56}). It is thought that the algae contained in the bottom ice compartment seeds spring algal blooms in the sea water compartment (Meguro et al., 1967, Tamelander et al., 2009, Becquevort et al., 2009) (May 15-June 15).

F ("ice melt"): Following the completion of the melt of bottom ice the sea ice begins to melt (D_{46}) on June 16. Sea ice continues to melt and melt ponds continue to grow due to precipitation input until August 1, when melt ponds begin to drain into the sea water (D_{36}) and the last of the sea ice melts away, beginning the ice free period on August 15.

The model requires the user to input several physic-chemical properties of the compound of interest, namely the air-water partition coefficient (K_{AW}), the octanol-water partition coefficient (K_{OW}), and three Abraham solute descriptors, namely the hydrogen bond acidity (α), the hydrogen bond basicity (β) and the logarithm of the hexadecane air partition coefficient (L_{16}), as well as the half life in each compartment, the rate of reaction with hydroxyl radicals and the activation energies in air and water. The model also allows for several environmental parameters to be varied: the average monthly temperature in air and sea water, the OH radical concentration in air, the amount of snow and rain fall, annual emissions and months of maximum emission, the monthly average wind speed, monthly depth of snow, sea ice and bottom ice compartments and average monthly fractional ice cover over the sea water compartment can all be adjusted by the user. Emissions to the modelled Arctic Ocean environment can occur to the atmospheric and/or sea water compartment. Air and water represent the mechanisms by which contaminants enter the Arctic environment via long range transport. A fractional emission to both sea water and atmosphere is also possible.

We are currently evaluating the model using Hargrave et al. (1994, 1997, 2000)'s data on the seasonality of contaminant fate in the Canadian Arctic marine environment. Another dataset used for evaluation is by Sobek and Gustafsson (Gustafsson et al., 2005, Sobek et al. 2006ab) who measured contaminant distribution among the phases present in the marginal ice zone of the Barents Sea (ice, snow, ice-interstitial water, seawater in the melt layer underlying the ice, and in ice-rafted sediment, bacteria, size-fractionated zooplankton, phytoplankton). Once properly evaluated, the new model will be a tool that links the two major means the NCP relies upon to establish contaminant time trends in the Arctic – periodic concentration measurements in Arctic air and measurements of time trends in higher marine organisms.

Results and Discussion

Mechanisms by Which a Changing Climate Affects Contaminant Exposure in Arctic. We have identified five different types of mechanisms by which a changing climate may affect the exposure of Northern populations to contaminants (Kidd et al., 1998, Macdonald 2005, Macdonald et al., 2005, Dalla Valle et al., 2007, Lamon et al., 2009). The first relates to **changes in chemical use and emissions**, i.e. changes in what and how much chemicals are used, and where and when chemicals are used. For example, higher temperatures in traditional contaminant source areas could lead to higher rates of emissions from contaminant reservoirs in the build environment. Lamon et al. (2009) concluded from global model calculations that higher rates of primary PCB emissions in a warmer world would be the most important change in the global fate of PCBs.

If a changing climate causes the Northward expansion of world regions susceptible to vector-borne diseases, such as Malaria, this could result in insecticide applications in areas closer to the Arctic. Furthermore, higher temperatures in the North could increase activities that result in the emissions of contaminants within the Arctic. For example, a longer growing season will make agricultural activities such as growing potatoes and raising cattle possible in areas that could not previously sustain them (Traufetter 2006). This will inevitably result in the use of pesticides. Similarly, increased ship traffic on a seasonally ice-free Arctic Ocean will also result in increased emissions of contaminants at high Northern latitudes. Finally, local-scale exposure to some contaminants could also be increased if containment at waste sites is compromised due to for e.g. degradation of permafrost, which can act as an impermeable barrier to chemical transport (Macdonald et al., 2005).

The second set of mechanism by which Northern contaminant exposure will change in response to climate change relates to **changes in the extent of contaminant delivery to the Arctic ecosystem** (Macdonald et al., 2003). Most contaminants reach the Arctic through long range atmospheric transport, but for some contaminants oceanic transport plays a role. The extent of contaminant transfer from source regions to the Arctic could change due to changes (i) in the extent of contaminant mobilization in source regions, (ii) in the extent of contaminant degradation in non-Arctic regions, and (iii) in the efficiency of atmospheric and oceanic long range transport pathways. Meyer and Wania (2007) using a global transport model identified latitudinal temperature gradients and macro-diffusive atmospheric transport coefficients as having a strong influence on the transport and accumulation of organic contaminants in the Arctic. MacLeod et al. (2005) and Lamon et al. (2009) have already explored the impact of changes in atmospheric wind fields on atmospheric long range transport and predict slightly higher global mobility of organic contaminants under future climate scenarios.

Not studied so far are the influence of potential changes in oceanic circulation as well as of the changing global cryosphere, in particular changes in the Arctic sea ice cover and the seasonal snow cover across the Northern hemisphere. It is expected that the phase transition of water at the freezing point (McDonald et al., 2005, Meyer & Wania, 2007) amplifies the direct temperature effects on contaminant fate and distribution (McKone et al., 1996). Finally, contaminant delivery to the Arctic could be enhanced if contaminants in environmental reservoirs in non-polar latitudes become re-mobilized. In particular, re-emission of contaminants from the large reservoirs in the forests and bogs of the Northern Boreal could possibly be brought about by temperature changes, by increased number of forest fires (Eckhart et al., 2007), or by changes in organic carbon pools (e.g. Nieboer, 2005, Lohmann et al., 2007).

The third type of mechanism relates to **changes in the processing of contaminants within the physical Arctic environment**, which includes those resulting from changes (i) in the extent and length of an ice cover and a seasonal snow cover, and (ii) in the primary productivity of the aquatic systems in the Arctic (marine and fresh water). When exploring the sensitivity of global model calculations to various input parameters, Meyer and Wania (2007) identified sea ice cover as the parameter most influential for the accumulation of persistent organic contaminants in polar marine ecosystems. Others have since explored the potential impact of higher temperatures, longer ice free periods, and higher primary production in aquatic systems on the potential for contaminant bioaccumulation. Using a model, Borgå et al. (2010) predicted that increased temperature and increased concentrations of particulate organic matter - as a result of increased primary productivity - would cause less overall bioaccumulation of organic contaminants in the Arctic marine food web. Reduced bioavailability, due to increased organic particle load, was identified as the most influential parameter for less water soluble contaminants. This is consistent with the findings of earlier studies comparing the bioaccumulation of contaminants in aquatic systems of different tropic status: generally the more productive aquatic ecosystems are believed to reduce the extent of contaminant bioaccumulation (Berglund et al., 2001, Larsson et al., 1998).

It is thus somewhat surprising that Carrie et al. (2010) attribute an observed increase in the concentration of PCBs in Mackenzie River burbot from 1985 to 2008 to increased primary productivity, which in turn is the result of warmer temperatures and reduced ice cover. Although there appears to be general agreement that sediment concentrations of organic contaminants increase with primary productivity of an aquatic system (Berglund et al., 2001, Kuzyk et al., 2010), opinions diverge whether this should result in more or less bioaccumulation of organic contaminants in fish. Reduced bioaccumulation in pelagic organisms can be mechanistically rationalized by reduced dissolved concentrations of hydrophobic contaminants in more productive systems (Larsson et al., 1998, Borgå et al., 2010). Increased bioaccumulation in more productive systems is less easily explained, because higher contaminant concentrations in sediments with higher organic matter content could only result in higher biota uptake, if the fugacity of the contaminants is increased (deBruyn and Gobas, 2004, Gobas and McLean 2003).

In lakes or coastal areas strongly influenced by glacial run-off, the accelerated melting of glaciers in a warming climate is another mechanism that could increase the delivery to Arctic ecosystems of organic contaminants stored over decades. This has been demonstrated for a small alpine lake in the Swiss Alps (Bogdal et al., 2009, 2010).

Changes in the processing of contaminants within the food chains of the Arctic constitute the fourth type of mechanism. Such changes are the most difficult to foresee. For example, changes in the primary productivity of arctic aquatic systems, as discussed above, could have a profound impact on individual species and on the assembly of organisms forming food webs. Changes could be caused by the impact on the bioenergetics (changed growth rates, reproduction rate, life spans) and dietary preferences of individual species. The relative abundance of different species may shift, leading to changes in the food chain structures under changed environmental conditions.

The fifth type of mechanism relates to changes in exposure due to **changes in the life-style of Northern populations**, in particular changes in diet composition. Undeman et al. (2010) recently compared the susceptibility of different human subpopulations living in different climates to be exposed to bioaccumulating contaminants. Susceptibility to exposure was largely determined by the properties of the food web. For most persistent chemicals emitted to air, the Arctic subpopulation had the highest susceptibility index, which could be attributed to the presence of seal in the diet, which is a highly potent magnifier of persistent organic contaminants. Undeman et al. (2010) suggest that “any major effects of climate on exposure to contaminants are likely to be indirect, via modifications of food chain structure (e.g. elimination of marine mammals in the Inuit diet, changes in the balance between fish/meat/dairy and other foods in the human diet)”. We hypothesize that one of the major determinants of future changes in the organic contaminant exposure of Northern residents will be potential changes in dietary composition, namely a continued transition from country foods to store-bought foods. This transition may be accelerated by climate change, e.g. if longer ice-free conditions reduce the cost of shipping and increase the availability and affordability of southern foods in Northern communities. Such a transition may also be forced upon Northerners if climate change would result in a decrease in the populations of traditional food animals or if changing climatic conditions should impede the hunt for those animals.

NCP Performance Indicators

The number of northerners engaged in your project: This project does not involve any Northerners.

The number of meetings/workshops you held in the North: This project does not foresee any meetings/workshops in the North or anywhere else.

The number of students (both northern and southern) involved in your NCP work: The CLEAR project supports one graduate student at the University of Toronto, who is working on this project.

The number of citable publications: As this project is in its first year, there are no citable publications yet.

Expected Project Completion Date

The project is planned to last four years, and thus is expected to be completed in 2013.

Acknowledgments

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Interspecies sensitivity of arctic marine birds to methylmercury exposure

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Abstract

Mercury (Hg) has been increasing in some marine birds in the Canadian Arctic over the past several decades. However, there is a lack of information on the effects of Hg exposure on avian reproduction. The most bioavailable and toxic form of Hg is methylmercury (MeHg) and nearly 100% of the Hg transferred by breeding female birds to their eggs is MeHg. Given that reproduction is one of the most sensitive endpoints of MeHg toxicity, we brought eggs of thick-billed murres into the laboratory where they were dosed with graded concentrations of MeHg to determine the relative sensitivity of the developing embryo to MeHg. Preliminary results suggest that the thick-billed murre has a relatively low sensitivity to MeHg exposure.

Key messages

- Preliminary results suggest that the thick-billed murre has a relatively low sensitivity to methylmercury (MeHg) exposure.

Résumé

Le mercure (Hg) a augmenté chez quelques oiseaux de mer de l'Arctique canadien au cours des dernières décennies. Toutefois, nous manquons de renseignements sur les effets de l'exposition au mercure sur la reproduction aviaire. La forme de mercure la plus toxique et la plus assimilable est le méthylmercure (MeHg), et la presque totalité du mercure transféré par la femelle à ses œufs est du MeHg. Étant donné que la reproduction est l'un des paramètres les plus sensibles de la toxicité du MeHg, nous avons rapporté au laboratoire des œufs de Guillemot de Brünnich. Nous les avons dosés avec des concentrations progressives de MeHg en vue de détermine la sensibilité relative des embryons au MeHg. Les résultats préliminaires suggèrent que la sensibilité du Guillemot de Brünnich à l'exposition au MeHg est relativement faible.

Principales observations

- Les résultats préliminaires font croire que la sensibilité du Guillemot de Brünnich à l'exposition au méthylmercure (MeHg) est relativement faible.

Objectives

- To determine the relative sensitivities of arctic marine bird species to methylmercury (MeHg) exposure based on the most sensitive life stage, embryonic development.
- Based on the MeHg sensitivity and existing Hg temporal trend data for arctic marine bird species (i.e. rates of Hg increase/change in eggs), predict when environmental Hg exposure levels may reach critical thresholds for reproductive impairment in the species tested.
- To determine the effects of MeHg exposure on the neuro-signaling pathways of the developing avian brain using changes in neurochemical parameters (e.g. neuroreceptor concentrations) as a biomarker of Hg exposure.
- In 2009/10, the research focussed on the thick-billed murre.

Introduction

Based on information available for the last Canadian Arctic Contaminants Assessment Report, Fisk et al. (2005) recommended that biological effects research in Canadian arctic species other than polar bears is needed, and Wiener et al. (2003, p. 434) have suggested that "*obtaining information on the reproductive sensitivity of wild, fish-eating birds to methylmercury exposure is perhaps the most pressing research need concerning the avian ecotoxicology of mercury*."

Total mercury (Hg) has been increasing in marine birds and mammals in some regions of the Canadian Arctic and in West Greenland over the past several decades (Braune et al. 2005a,b). In particular, retrospective analyses of Hg in archived seabird eggs have shown steady increases in several species of marine birds, including the thick-billed murre (*Uria lomvia*), breeding in the Canadian Arctic (Braune 2007). Mercury biomagnifies up the food chain (Atwell et al. 1998, Campbell et al. 2005) making those species feeding at high trophic positions (e.g. thick-billed murres) more vulnerable to Hg exposure via their diet.

Mercury is an extremely potent embryo toxicant, and dietary Hg is rapidly transferred to avian eggs on a dose-dependent basis, making reproduction one of the most sensitive endpoints of Hg toxicity (Wolfe et al. 1998). The most bioavailable and toxic form of Hg is methylmercury (MeHg) and nearly 100% of the Hg transferred to eggs is MeHg with the majority (about 85-95%) being deposited into the albumen (Wiener et al. 2003). Therefore, Hg concentrations found in the egg are a good indicator of Hg risk to avian reproduction (Wolfe et al. 1998). Some of the documented effects of Hg on avian reproduction include reduced hatchability due to increases in early mortality of embryos, eggshell thinning, reduced clutch size, and embryonic deformity (Thompson 1996, Wolfe et al. 1998). Where no embryotoxic data exist for wild species, embryotoxic thresholds for Hg based on captive breeding studies are often used generically for a wide range of avian species even though there is no reason to believe that the embryos of all birds are equally sensitive to the harmful effects of MeHg (Heinz et al. 2009). Therefore, Heinz et al. (2006) developed a protocol by which the eggs of wild birds could be brought into the laboratory and injected with graded concentrations of MeHg chloride to determine threshold levels of harmful effects. Although they have now generated MeHg dose-response relationships for a number of different avian species (Heinz et al. 2009), no work has been done on alcids (e.g. murres).

Studies have shown that neurochemical parameters, such as neurotransmitter concentrations of acetylcholine (muscarinic [mACh]) and glutamate (N-methyl-D-aspartic acid [NMDA], are significantly affected by low-level dietary exposure to MeHg in adult birds and mammals; thus there is a potential to use specific neurochemical changes as biomarkers of Hg exposure and effects in wildlife (Basu et al. 2006, 2007; Scheuhammer et al. 2008). These two neurotransmitter receptors (mACh, NMDA) play important roles in the regulation and control of reproductive hormones and, therefore, their perturbation may signify early impacts to reproductive potential. Because low doses of MeHg are generally more toxic in developing embryos than in adults, it is of considerable interest to determine the effects of MeHg exposure on the neuro-signaling pathways of the developing brain, and to relate these changes to more commonly used endpoints of toxicity, such as decreased hatchability.

Activities in 2009/2010

Sample collection/experimental: In June 2009, we collected 120 fresh, unincubated thick-billed murre eggs from a colony on Coats Island (62°30'N, 83°00'W) in northern Hudson Bay. Eggs were kept in foam-lined coolers in the field at 8°-15° C until they could be transported to the National Wildlife Research Centre (NWRC) laboratories in Ottawa. Eggs were cleaned and randomly assigned to artificial incubators (Brinsea Z6 contact incubators). On incubation day 5, eggs were assessed for viability and randomly assigned to 10 groups of 12 eggs each. Eggs were then dosed with environmentally-relevant graded concentrations of MeHg chloride (methylmercury (II) chloride, PESTANAL®, analytical standard from Sigma-Aldrich) dissolved in safflower oil as follows: control (not injected but same handling as other eggs), vehicle-control (injected with undosed safflower oil (vehicle)), and dose groups of 0.05, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 $\mu g\ g^{-1}$ MeHg on a wet-weight (ww) basis in the egg following the protocol of Heinz et al. (2009). Heinz et al. (2006) demonstrated that the MeHg dose introduced into the air cell of an egg passes through the inner shell membrane and into the albumen, and those authors concluded that air cell injections are a safe way to get good dose-response results. Therefore, the dissolved MeHg was injected into the air cell through a hole drilled in the egg and subsequently sealed with surgical tape. After dosing with MeHg, eggs were returned to the incubators and allowed to develop. During incubation, egg viability was assessed periodically by candling and/or use of an Avitronic digital egg monitor. Survival to 90% of development was used as the endpoint measurement to compare embryo survival of the control eggs and eggs injected with graded concentrations of MeHg. Those embryos which survived to pipping (starring of eggshell indicating beginning of hatch) were euthanized by decapitation. All embryos were examined for any gross anatomical anomalies. Embryos (including the fecal sac and chorioallantoic membrane) were then weighed, homogenized and analyzed for total Hg (THg). MeHg was analyzed in three carcasses from each dose group in order to determine the proportion of MeHg:THg. We also harvested brain tissue from 68 thick-billed murre embryos for measurement of the neurotransmitters acetylcholine (muscarinic [mACh]) and glutamate (N-methyl-D-aspartic acid [NMDA]). The brains were removed, weighed and stored in liquid nitrogen for individual analysis of NMDA and mACh receptor density and THg. MeHg is being analyzed for three brains (pooled) from each dose group in order to determine the proportion of MeHg:THg.

Analytical methods: NMDA and mACh receptor levels are assayed in embryonic brain tissue homogenates using methods described previously for adult birds and mammals (Basu et al. 2006, 2007; Scheuhammer et al. 2008). In brief, receptors are labelled with tritiated compounds having high specific affinity for these receptors, and their concentrations quantified by beta-counting (Perkin-Elmer microplate liquid scintillation counter). THg is analyzed in freeze-dried samples using a direct Hg analyzer (Milestone DMA-80), according to a standardized protocol (NWRC Method No. MET-CHEM-AA-03G) as described in detail by Weech et al. (2004). The method employs direct combustion of solid samples in an oxygen-rich atmosphere. Organic Hg (primarily present as MeHg in biological tissues) is quantified by extraction of organomercurials into toluene followed by back-extraction into sodium thiosulphate and measurement of total Hg in the final extract using a direct Hg analyzer (DMA-80) as described in Scheuhammer et al. (1998). Although the methylmercury chloride (PESTANAL®, Sigma-Aldrich) used to prepare the dose solutions is certified as 99.2% pure MeHg, we are having dose solutions analyzed to confirm the composition.

Capacity Building: One Inuk assistant from Coral Harbour (Josiah Nakoolak) was hired to help with the field work at Coats Island in 2009, as has been the case for more than 20 years at the site.

Communications: Birgit Braune (Project Lead) offered to meet with the Niqiit Avatittinni Committee (NAC) in Iqaluit to discuss her projects in more detail in June 2009. Coral Harbour is the nearest community to Coats Island and Grant Gilchrist (Project Team Member) gives presentations on the work that Environment Canada is doing on arctic birds at the school and elsewhere in Coral Harbour about every two years. Grant gave a presentation on the marine bird research going on at Coats Island, East Bay and other areas in the region in Coral Harbour in April 2009, and in Ivujivik, Quebec, in August 2009.

Traditional Knowledge: The field component (i.e. egg collections) for this study is an extension of monitoring activities already taking place at Coats Island, and therefore, there was no additional opportunity for incorporation of traditional knowledge.

Results

Of the 120 eggs incubated, 55 (46%) reached at least 90% development. Six eggs across dose groups were lost to bacterial infection. Organic Hg averaged 96.3% ± 2.3% of THg in the embryo carcasses or undeveloped eggs with no significant difference among dose groups (ANOVA: $n=30$; $F_{0.05(1),8,21}=1.41$; $p=0.25$). The THg measured in the embryo carcasses or undeveloped eggs, corrected for the THg concentration in the control eggs, were highly correlated (regression coefficient/slope=0.995, r=0.98) with the dose groups (Figure 1) indicating that the embryos were, indeed, exposed to the MeHg doses administered to the eggs. A dramatic decrease in embryo survival to 90% of development occurred between the 0.8 and 1.6 μg g^{-1} ww dose groups (Figure 2). We also harvested brain tissue from 68 thick-billed murre embryos for measurement of neurotransmitter receptors. Measurements of NMDA and mACh receptor density are currently underway for the brain tissue from the thick-billed murres and sub-samples are being screened for other potential neurochemical endpoints by colleagues at the University of Michigan.

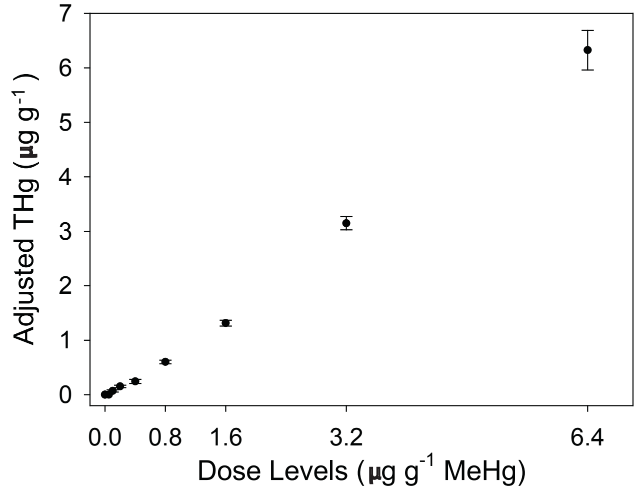

Figure 1. THg (mg g^{-1} wet weight) measured in the embryo carcasses or undeveloped eggs adjusted for the THg concentration in the control eggs vs the dose concentrations administered to the eggs (control/vehicle-control (0), 0.05, 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 mg g-1 MeHg on a wetweight basis).

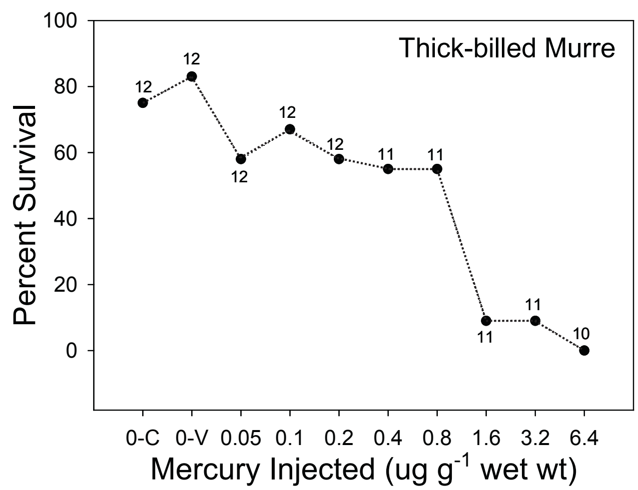

Figure 2. Preliminary dose-response results for survival of thick-billed murre embryos through 90% of development. Results not corrected for maternally-deposited Hg. Sample size for each dose group is indicated on the graph. Six eggs across dose groups were lost to bacterial infection.

Discussion and Conclusions

It has been shown that reproductive success in birds can decrease by 35-50% due to dietary MeHg exposure insufficient to cause obvious signs of toxicity in adults (Wolfe et al. 1998). The currently accepted lowest observed adverse effect level (LOAEL) for Hg in avian eggs is 0.5 $\mu g\ g^{-1}$ ww (range 0.5–1.0 $\mu g\ g^{-1}$ ww) as determined from multi-generational feeding studies in ring-necked pheasants (*Phasianus colchicus*) and mallards (*Anas platyrhynchos*) (Fimreite 1971, Heinz 1976). Based on a review of the literature, Thompson (1996) concluded that, overall, Hg concentrations in excess of 2.0 $\mu g \cdot g^{-1}$ ww in eggs seem to have some detrimental effect leading to the suggestion that concentrations of 0.5 to 2.0 $\mu g \cdot g^{-1}$ ww of Hg in eggs are sufficient to induce impaired reproductive success in a variety of bird species. The uncorrected data for the thick-billed murres show that there was a dramatic decrease in embryo survival to 90% of development between the 0.8 and 1.6 $\mu g\ g^{-1}$ ww dose groups. To put those concentrations into a real-world context, the average THg concentration in thick-billed murre eggs from the Prince Leopold Island colony in 2009 was 0.40 $\mu g\ g^{-1}$ ww, and for the Coats Island colony, 0.16 $\mu g\ g^{-1}$ ww (Braune, unpubl. data).

Heinz et al. (2009), who developed the protocol we are using, suggested that MeHg injected into the egg is two to four times more embryotoxic than maternally-deposited MeHg but that the sensitivity relative to other species was the same whether the MeHg was injected or deposited naturally by the mother. A recent study, in which eggs of 26 species of birds were dosed with MeHg, demonstrated that the sensitivity of avian embryos to MeHg can vary dramatically among species with median lethal concentrations (LC_{50}) ranging from 1 $\mu g \cdot g^{-1}$ ww or higher in eggs of the low sensitivity group (e.g. mallard, hooded merganser *Lophodytes cucullatus*, lesser scaup *Aythya affinis*, laughing gull *Larus atricilla*) to <0.25 $\mu g \cdot g^{-1}$ ww in eggs of those species (e.g. osprey *Pandion haliaetus*, white ibis *Eudocimus albus*, snowy egret *Egretta thula*) exhibiting high sensitivity (Heinz et al. 2009). Preliminary interpretation of the uncorrected data suggests that the thick-billed murre would likely fall into the low sensitivity group. In 2010-2011, we plan to continue our work using arctic tern (*Sterna paradisaea*) eggs.

NCP Performance Indicators

- In 2009, one northerner, who has worked with us for over 20 years, participated in the field work (see Capacity Building). Annual consultation with northern communities is integral to the permitting process and thus engages the local HTA's (i.e. Coral Harbour).
- There was one planned meeting in the North for 2009 which did not occur and there were two meetings which did take place (see Communications).
- There were two southern graduate students which participated in the project in 2009, one (K. Elliott) in the field and one (J. Rutkiewicz) in the lab.
- Since the work is only now starting to generate data, no peer-reviewed publications have, as yet, been produced. Preliminary data have been presented at one NCP Results Workshop and in 2 departmental reports.

Expected Project Completion Date

March 31, 2011

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Education and Communications

Dehcho First Nations Participation on the NWT Regional Contaminants Committee (NWT RCC)

Project Leaders:

Ms. Carrie Breneman (Acting Resource Management Coordinator), Ms. Dahti Tsetso (Resource Management Coordinator) and Ms. Ria Letcher (Executive Director) of Dehcho First Nations.

Project team:

Dehcho First Nations (based in Fort Simpson, NT) provides representation for all of the member communities in the Dehcho Region which includes: Liidlii Kue First Nation, Fort Simpson; Deh Gah Gotie Dene Council, Fort Providence; Katlodeeche First Nation, Hay River Reserve; JMR First Nation, Jean Marie; Ka'a'gee Tu First Nation, Kakisa Lake; Pehdzeh Ki First Nation, Wrigley; Nahanni Butte Dene Band, Nahanni Butte; Sambaa K'e First Nation, Trout Lake; West Point First Nation, Hay River; Fort Simpson Metis Local, Fort Simpson and Fort Providence Metis Local, Fort Providence.

Abstract

As part of Dehcho First Nations' (DFN) membership on the Northwest Territories Regional Contaminants Committee (NWT RCC), DFN has been educating and communicating to its members the message of the Northern Contaminants Program. DFN has and will continue to communicate with its members about contaminants, research and other priorities and to gather information and feedback. The awareness and education of contaminants will inform traditional land users on the research results and activities. DFN's past and continued participation the NWT RCC has and will continue to enable concerns in the Dehcho Region to be brought to the NWT RCC and appropriately addressed.

In 2009 and 2010, DFN has participated in the NWT RCC by attending meetings, conference calls and communicating via email. DFN also served as a liaison between the NWT RCC and the local communities in the Dehcho Region and transferred information from the NWT RCC to the local community and brought concerns from the local communities to the NWT

Résumé

Les Premières nations du Dehcho, dans le cadre de leur travail au sein du Comité régional des contaminants des Territoires du Nord-Ouest, ont éduqué leurs membres et leur ont fait part des points principaux du Programme de lutte contre les contaminants dans le Nord. Les Premières nations continuent de communiquer avec leurs membres au sujet des contaminants, de la recherche et des autres priorités, et elles recueillent des renseignements et des commentaires. Grâce à la sensibilisation et à l'éducation sur les contaminants, les utilisateurs traditionnels des terres seront au courant des résultats des recherches et des activités. La participation des Premières nations du Dehcho au Comité régional a permis et continuera de permettre que les préoccupations soulevées dans la région du Dehcho soient présentées au Comité régional pour qu'on les traite comme il se doit.

En 2009 et 2010, les Premières nations du Dehcho ont participé au Comité régional en assistant aux réunions, aux conférences téléphoniques et en correspondant par courriel. Les Premières nations du Dehcho ont aussi joué le rôle de liaison entre le

RCC. Participation in the NWT RCC, allowed DFN to provide provided comments and input regarding socio-cultural considerations to project researchers.

Comité régional et les comités locaux de la région du Dehcho, ont partagé les renseignements du Comité régional aux collectivités locales et ont fait part des préoccupations des collectivités locales au Comité régional. En participant au Comité régional, les Premières nations du Dehcho ont pu faire des commentaires et donner leur avis au sujet des questions socioculturelles que doivent prendre en considération les chercheurs des projets.

Key Messages

DFN through continual participation in the NWT RCC:

- Provides a forum for the two-way transfer of contaminants information that is relevant to the Dehcho Region between residents, researchers, the Northern Contaminants;
- Enables socio-cultural input and considerations to be identified for research projects occurring in the North; and
- Enables local communities and residents in the Dehcho Region to provide concerns regarding contaminants and for these concerns to be appropriately addressed.

Messages clés

Les Premières nations du Dehcho, grâce à leur participation continue au Comité régional :

- offrent un forum pour l'échange bidirectionnel des renseignements sur les contaminants pertinents pour la région du Dehcho entre les résidants, les chercheurs et le Programme des contaminants dans le Nord;
- permettent de cerner les avis et les considérations socioéconomiques au sujet des projets de recherche qui se déroulent dans le Nord;
- permettent aux collectivités locales et aux résidants de la région du Dehcho de présenter leurs préoccupations au sujet des contaminants pour qu'on les traite comme il se doit.

Objectives

Dehcho First Nations (DFN) will facilitate the process of collaborative study, assessment and communication of information to residents of their region regarding the presence and possible effects of contaminants in the air, land, water and wildlife, from long range transport sources as well as local contaminants sources as appropriate.

Specific objectives include:

- To education and communicate with its members information regarding the Northern Contaminants Program;
- To gather information from communities in the Dehcho Region regarding contaminants, NCP research and other priorities;
- To attend the social/cultural review meetings and attend the annual NCP Results Workshop; and
- To work with researchers to initiate and organize research projects in the Dehcho Region and to identify and address community concerns within the Dehcho Region with the NWT Regional Contaminants Committee.

Introduction

The NWT Regional Contaminants Committee (NWT RCC) was established in 1997 with a primary focus on the Northern Contaminants Program. The NWT RCC was formally known as the NWT Environmental Contaminants Committee (NWT ECC). Members are identified by their participating aboriginal organizations and government agencies to represent community concerns relating to contaminants and the NCP program. The committee's role is to develop strategies and priorities each year and provide technical advice, traditional knowledge and perspectives to researchers and the NCP Management team.

Since it has become a member of the NWT RCC, DFN has been educating and communicating to its members the message of the Northern Contaminants Program. DFN has and will continue to communicate with its members about contaminants, research and other priorities and to gather information and feedback. The awareness and education of contaminants will inform traditional land users on the research results and activities. DFN's past and continued participation the NWT RCC has and will continue to enable concerns in the Dehcho Region to be appropriately addressed.

Activities in 2009-2010

In 2009/2010, DFN has participated and communicated with the NWT RCC and was involved with the RCC via conference calls, emails and meetings. DFN attended the Social/Cultural Review meetings and plans to attend the annual NCP Results Workshop (September 2010 in Whitehorse, YK).

DFN has continued to work with researchers to initiate and organize research projects in the Dehcho region. In 2009/2010, DFN reviewed numerous research proposals to evaluate several socio-cultural criteria including: communication back to the local community; relevance of the project to Northerners, incorporation of traditional knowledge and local capacity building.

DFN has also continued to work towards educating and communicating to its members the messages of the Northern Contaminants Program. Most recently, DFN worked as a liaison to Trout Lake and brought forward concerns from local community members to NWT RCC regarding the recent public health advisory for the consumption of lake trout in Trout Lake. As a result, of DFN's participation in the NWT RCC, a public meeting will be held in Trout Lake to educate local community members on the public health advisory and to enable community concerns to be brought forth to the NWT RCC.

DFN has also been sponsoring an Annual Youth Ecology Camp which has included activities and information related to traditional knowledge and ecology. Last years annual camp was held at Cli Lake and information on water ecology was presented.

Results

Not applicable.

Discussion and Conclusion

DFN will continue to participate in NWT RCC and will continue to communicate with their members. DFN will continue to raise community concerns in the NWT RCC and will enable these concerns to be addressed.

Expected Project Completion Date

Not applicable.

Gwich'in Tribal Council Communication & Education of the NCP

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Project team:
NWTRCC.
Designated Gwich'in Organizations,
Gwich'in Renewable Resource Councils,
Gwich'in Communities

Abstract

The Gwich'in Community Liaison for the Northern Contaminants Program is the Lands Manager. This position enables the Gwich'in to be a member of the NWT Regional Contaminants Committee (RCC) and participate in research programs established by the Northern Contaminants Program (NCP).

The Lands Manager has continued to promote dialogue and information between the Gwich'in communities, Designated Gwich'in Organizations (DGO's), Gwich'in Renewable Resource Councils (RRC's), the Gwich'in Tribal Council (GTC), NCP representatives, and NCP scientists.

The Lands Manager has participated in NWT RCC meetings including proposal reviews and communications material reviews, and provided relevant contaminant information materials to Gwich'in communities and organizations. The Lands Manager has also attended the NCP annual results workshop held in Ottawa in October 2009.

Résumé

La liaison communautaire des Gwich'in pour le Programme de lutte contre les contaminants dans le Nord est le gestionnaire des terres. Ce poste permet aux Gwich'in d'être membres du Comité régional des contaminants des Territoires du Nord-Ouest (Comité régional) et de participer aux programmes de recherche mis sur pied dans le cadre du Programme de lutte contre les contaminants dans le Nord (PLCN).

La gestionnaire des terres continue de faire la promotion du dialogue et de l'échange des renseignements entre les collectivités des Gwich'in, les organismes désignés gwich'in, le Conseil gwich'in des ressources renouvelables, le Conseil tribal des Gwich'in, les représentants du PLCN et les scientifiques du PLCN.

La gestionnaire des terres a participé à des réunions du Comité régional, y compris pour l'examen des propositions et du matériel de communication, et elle a fait part des renseignements pertinents sur les contaminants aux collectivités et aux organisations des Gwich'in. La gestionnaire des terres a aussi participé à l'atelier annuel sur les résultats du PLCN tenu à Ottawa en octobre 2009.

Key Project Messages

- The Gwich'in Tribal Council (GTC) Lands Manager has continued to promote dialogue and information exchange between the Gwich'in communities, Gwich'in Organizations including the Gwich'in Tribal Council, NCP representatives, and NCP scientists.
- The GTC Lands Manager had the opportunity to attend workshops (e.g. NCP results workshop) including information sessions and training courses to enhance capacity to carry out the duties of the NWT RCC membership.
- The GTC Lands Manager actively participated in both in-person and conference call meetings of the NWT RCC throughout 2009/10.
- The GTC Lands Manager provides information and feed back to the NWTRCC during proposal reviews that is relevant to the region, including traditional knowledge, communications strategy, community capacity development, organization contacts, etc for the researchers conducting studies with the GSA and the NWT.
- The GTC Lands Manager is the first contact for all research projects within the GSA and reviews and comments on all research projects to be conducted within the GSA.

Messages clés

- La gestionnaire des terres du Conseil tribal des Gwich'in a continué de promouvoir le dialogue et l'échange des renseignements entre les collectivités des Gwich'in, les organismes gwich'in, y compris le Conseil tribal des Gwich'in, les représentants du PLCN et les scientifiques du PLCN.
- La gestionnaire des terres du Conseil tribal des Gwich'in a eu l'occasion de participer à des ateliers (p. ex. l'atelier sur les résultats du PLCN), y compris à des séances d'information et à des formations visant à rehausser la capacité d'effectuer les tâches confiées aux membres du Comité régional.
- La gestionnaire des terres du Conseil tribal des Gwich'in a participé activement à des réunions et à des conférences téléphoniques du Comité régional en 2009 et 2010.
- La gestionnaire des terres du Conseil tribal des Gwich'in fournit des renseignements et des commentaires au Comité régional pendant l'examen des propositions. Les renseignements pertinents pour la région comprennent entre autres des connaissances traditionnelles, une stratégie de communication, le développement des capacités communautaires et les personnes-ressources d'organisations. Ces données seront utilisées par les chercheurs qui mènent des études dans la région visée par le règlement de la revendication des Gwich'in et les Territoires du Nord-Ouest.
- La gestionnaire des terres du Conseil tribal des Gwich'in est la première personne-ressource pour tous les projets de recherche effectués dans la région visée par le règlement de la revendication des Gwich'in et elle examine et commente tous les projets de recherche menés dans cette région.

Objectives

The objectives of this project are to facilitate the process of collaborative study, assessment and communication of information to residents of the Gwich'in Settlement Area (GSA) about the presence and possible effects of contaminants in the air, land, water and wildlife. The Lands Managers goals are:

1. To promote the role of the Gwich'in Tribal Council (GTC) as a partner in the NCP.
2. To assist the Gwich'in Communities to identify proposed research projects & development and/or contaminant concerns.
3. To inform and educate the public and the Gwich'in Participants about contaminants within the GSA.
4. To increase capacity at the regional / local level.
5. To coordinate and/or assist with regional contaminant studies.
6. To identify complementary environmental issues and funding sources.
7. To review NWT Proposals for the NCP for social/cultural criteria prior to full technical reviews.
8. To actively participate in all NWT RCC meetings and related tasks.

Introduction

This was the eleventh year that the GTC has been actively involved in the Northern Contaminants Program. Over the course of involvement with the NCP the Gwich'in representative for the GTC has established a very good track record. The Gwich'in are concerned about long range contaminants and want to continue to be well informed about levels of contaminants in their traditional foods and/or the environment within which they practice their traditional and cultural activities. Participation in the NCP through the NWT RCC provides a valuable opportunity for two-way communication about contaminants in the GSA and the NWT.

Activities in 2009 - 2010

- The Lands Manager attended several teleconferences of the NWT RCC by phone and two in person meetings.
- The Lands Manager attended the NCP results workshop in Ottawa, Ont in 2009.
- On-going communication of the results from the CACAR 2.
- Continued to relay information to the Gwich'in communities through the Lands Manager and Aboriginal partners of the NWT RCC, which will relay major concerns to the NCP management committee and vice versa.
- The Lands Manager attended Gwich'in Renewable Resource Council meetings in 2009 and early 2010 to discuss the NCP with the community members and to continue to relay the importance of the NCP to community members. Communities visited were Fort McPherson, Tsiigehtchic, Aklavik and Inuvik.
- The Lands Manager attended the GTC Annual Assembly in August 2009 in Inuvik and set up a table with NCP resource information and reports and discussed the program with Participants of the Gwich'in Annual Assembly requesting information about the NWT RCC and Northern Contaminants Program.
- The Lands Manager included in the annual report the membership of the GTC on the NWT RCC, the objectives of the committee and the GTC's Lands Managers role on the NWT RCC.
- A proposal was submitted to NCP for continued participation of the GTC in NCP activities and the NWT RCC in 2010/11.

Results

In addition to the activities outlined above, the Lands Manager highlighted several concerns from Gwich'in communities and organizations to the NWT RCC during the teleconference calls and proposal reviews. These concerns ranged from long term monitoring of contaminant levels in important traditional foods such as caribou, berries, fish and marine mammels such as beluga whales and seals to local contaminants concerns including water quality issues, to relationships between contaminants and human health concerns.

The Gwich'in Participants continue to harvest traditional foods for subsistence as the cost of living in Gwich'in communities is very expensive. The traditional diet for Gwich'in participants consists of caribou, fish and berries that are gathered throughout the GSA, including beluga and caribou that is harvested from the Beaufort Coast. Contamination through long range transport of different chemicals used in industrial nations are of great concern to the Gwich'in Participants and continued research within the GSA and Beaufort Delta to track these levels are very important to the Gwich'in Participants.

Discussion and Conclusions

In 2009/2010, the Lands Manager has continued to address concerns of the residents of the Gwich'in Settlement Area by gathering, organizing, and distributing information when requested, not only to the participants of the GSA, but also to the NCP NWT RCC, researchers and the GTC. The Lands Manager attended workshops, and meetings to enhance capacity to carry out the duties of the NCP NWT RCC membership. Furthermore, based on requirements of the information by the residents of the Gwich'in Settlement Area, it has been demonstrated that this position is an integral part of the NCP and the Gwich'in Settlement Area.

The GTC NCP NWT RCC representative was nominated Vice Chair for the 2009/10 term and assisted the NCP Secretariat when the Chair was not available to participate in agenda development and chairing the NWT RCC meetings. The GTC NCP NWT RCC representative also attended the NCP Management Committee meeting held in November 2009 to discuss the review and amendments of the NCP funding envelopes.

The GTC is confident that the Lands Manager will continue this successful relationship in the future with NCP NWT RCC. The Lands Manager sits on other committees and working groups in the NWT and the Yukon and information and capacity gathered through the NWT RCC assist the Lands Manager in being able to participate in a meaningful manner on these committees and working groups, including Protected Area Strategy Working Group, Cumulative Impact Monitoring Program Working Group, NWT Water Stewardship Strategy Working Group Yukon Socio-Economic and Environmental Assessment Board Review Committee, etc.

Expected Project Completion Date

The Lands Manager will continue to represent the Gwich'in Participants by continuing to be a part of the NWT RCC, and address concerns relating to contaminants in the Gwich'in Settlement Area, including the Beaufort Delta.

North Slave Métis Alliance Participation on the NWT Regional Contaminants Committee

Project Leader:

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Project team:

Sheryl Grieve, Shannon Hayden, Bill Enge, all employees of the North Slave Métis Alliance based in Yellowknife, NWT. P.O. Box 2301, X1A 2P7. NSMA board of directors, elders, members and youth, all c/o the NSMA.

Abstract

The North Slave Métis Alliance provided office support and staff to review contaminant related information, distribute it to the North Slave Métis community, and to transmit community concerns back to the Regional Contaminants Committee. The liaison person also participated in monthly committee meetings by phone or in person, and an annual review of research applications.

Key Messages

The key take-away messages of the NCP program are

- the health benefits of a traditional life style and country food based diet,
- a balanced evaluation of the known contaminant related risks,
- honest assessment of quality and availability of contaminant related information, and

Résumé

L'Alliance des Métis de North Slave a offert un appui pour le travail de bureau et des employés afin d'examiner les renseignements liés aux contaminants, en faire part à la communauté métisse de North Slave et faire part des préoccupations de la communauté au Comité régional des contaminants. La personne responsable de la liaison a aussi participé aux réunions mensuelles par téléphone ou en personne et à un examen annuel des demandes de recherche.

Messages clés

Les messages clés à retenir du Programme de lutte contre les contaminants dans le Nord :

- les bienfaits pour la santé du mode de vie traditionnel et d'une alimentation basée sur les aliments traditionnels;
- une évaluation équilibrée des risques liés aux contaminants connus;
- une évaluation honnête de la qualité et de la disponibilité des informations liées aux contaminants;

- trusted, local advice about dietary and lifestyle choices.

- des conseils de confiance et provenant de la région au sujet des choix en matière d'alimentation et de mode de vie.

Objectives

- collect, store, retrieve, analyze and interpret contaminant related information, and distribute relevant information to community
- maintain a staffed office in the community with email, phone, etc.
- receive and respond to community questions and requests
- transmit community concerns to RCC
- participate in monthly meetings and annual proposal review
- prepare and submit proposals, and report on behalf of the community.

Introduction

The Regional Contaminants Committee serves an important role in assisting Canada and its Aboriginal Communities in the North to communicate with each other regarding environmental contaminants.

Activities in 2009-2010

- Capacity Building
  - Access to understandable information.
  - Education of members, BOD, staff.
  - Contribute to office functionality
- Communications
  - Regular emails (49) and newsletters (3)
  - Telephone and in person meetings (46)

Results

- Attend Social/Cultural Review meetings,
- submit proposals on behalf of NSMA,
- work with researchers to provide support,
- Attend NCP Results workshop,
- Talk to community members and bring forth their concerns to the NWT RCC.
- attend AGA

Discussion and Conclusion

NWT RCC Members represent the people in their regions at the NCP Results Workshop and at NWT RCC meetings. The North Slave Métis Alliance (NSMA) represents the indigenous Métis community which has used and occupied the North Slave region (that area between and including Great Bear Lake and Great Slave Lake, the Mackenzie River and Contwoyto and Artillery Lakes) since before the establishment of effective Crown control. Our members are all descended from the historic Métis community which took either Métis Scrip or Treaty 11 in Fort Rae, in 1921. Groups of Métis residing in Lac La Martre, Snare Lake, and Yellowknife were represented by Métis counselors during the signing of Treaty 11. Our community is defined by shared language, culture, genealogy, territory and history, not by municipal boundaries, administrative regions, or by other First Nation Settlement Areas.

The majority of our members currently reside in the City of Yellowknife (including the historic Métis settlements in Rainbow Valley, School Draw, and Willow Flats, Yellowknife River, along the Ingraham Trail), but some do still live, and many have roots in Lac La Martre, Snare Lake, Rae Lakes, Fort Rae, Edzo, Dettah, Snowdrift, Fort Reliance, Fort Providence, Hay River, and Fort Resolution. Old Fort Providence, Old Fort Rae, and Old Fort Island are historic North Slave Métis settlements that are currently not serviced (police, fire, education, healthcare, communications) and are therefore not occupied full time.

Some members reside temporarily outside of the NWT for employment or educational purposes, and there are strong family connections between NSMA members and the South Slave Métis, as well as the Métis in BC, Alberta, Saskatchewan, and Manitoba.

As is typical of all Métis communities, the NSMA population is highly mobile, and communication is a challenge. Without the RCC it is highly unlikely that the indigenous North Slave Métis community would be a able to maintain an awareness of issues, and have their communal voice heard by decision makers and researchers. It is essential that the RCC continue to operate, and we continue to encourage the establishment of multi-year funding as envisioned by the MVRMA as part of the CEAM/CIMP obligations of Government.

NCP Performance Indicators

- the number of northerners engaged in project = 201
- the number of meetings/workshops held in the North = 16
- the number of students (both northern and southern) involved in NCP work = 3
- the number of citable publications = 0

Expected Project Completion Date

Ongoing, annual.

Sahtu Participation in the Northwest Territories Regional Contaminants Committee

◆ Project Leaders:

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and,

Howard R. Townsend
Lands Advisor, Sahtu Lands & Resources Department
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◆ Project team:

Robert Kelly, Lands Manager Trainee
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Mr. Kelly left the team in March of 2009. The lead was then resumed by Mr. Townsend.
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Abstract

The Lands Advisor and the Lands Trainee, under the direct supervision of the President of the Sahtu Secretariat Incorporated, (SSI), participated in the NWT Regional Contaminants Committee, (NWT RCC). Continued funding for the SSI's participation ensured continued regional representation on the committee, while allowing for much needed capacity building under this direct one-on-one mentorship. This involved preparing for monthly conference calls

Résumé

Le conseiller en gestion foncière et le stagiaire de la gestion des terres, sous la supervision directe du président du Secrétariat du Sahtu, ont participé au Comité des contaminants environnementaux des Territoires du Nord-Ouest. L'allocation de fonds permanents pour la participation du Secrétariat a permis d'assurer le maintien de la représentation régionale au Comité, tout en répondant au besoin pressant de renforcer les capacités grâce à ce mentorat individuel direct. Le conseiller et le stagiaire

or in-person meetings to discuss matters related to contaminants in the Sahtu Settlement Area in the NWT.

By attending the two "face to face" meetings held in Ottawa and Yellowknife, the Sahtu Secretariat Incorporated, (SSI), continued to be informed of current environmental monitoring, human health, and education and communication projects related to long-range contaminants, as well as meet individuals involved in the NCP and potentially create future working partnerships. These opportunities benefited the Sahtu by developing a regional awareness of current issues and concerns.

devaient notamment préparer les téléconférences ou les réunions en personne tenues chaque mois afin de discuter des questions liées aux contaminants présents dans la région visée par le règlement du Sahtu dans les Territoires du Nord-Ouest.

En assistant aux deux réunions en personne qui ont eu lieu à Ottawa et à Yellowknife, le Secrétariat, par le truchement de ses représentants, s'est tenu informé des projets actuels de contrôle environnemental, de santé humaine, d'enseignement et de communication liés aux contaminants transportés sur de longues distances. De plus, il s'est entretenu avec des personnes jouant un rôle dans le Programme de lutte contre les contaminants dans le Nord et pourra peut-être mettre en place des partenariats de travail à l'avenir. Ces circonstances favorables profitent au Sahtu en sensibilisant la région aux questions et préoccupations actuelles.

Key Messages

- Climate change, however it is being caused, is often discussed by people. At the present time increased attention is focusing on water and the effects of climate change to water and the associated fisheries. Climate change is relevant to this committee if contaminants are being released to our food chain and our traditional foods.
- At present, people have confidence in their food off the land and from lakes and rivers. They want it to continue to be safe. Recently, however; the subject of mercury in fish was raised again and we are waiting to receive the final recommendations regarding those results from regulatory agencies.

Messages clés

- Les résidants abordent souvent la question des changements climatiques quelle que soit son origine. Pour l'instant, l'accent est mis sur l'eau et les effets des changements climatiques sur l'eau et l'industrie des pêches qui y est liée. Les changements climatiques sont pertinents pour ce comité si des contaminants sont émis dans notre chaîne alimentaire et touchent nos aliments traditionnels.
- Actuellement, les résidants ont confiance en la qualité de la nourriture en provenance de leur territoire ainsi que des lacs et rivières. Ils veulent en conserver la salubrité. Récemment, cependant, le sujet du mercure dans les poissons a de nouveau été soulevé, et nous attendons de recevoir les recommandations définitives au sujet de ces résultats de la part des organismes de réglementation.

Objectives

The main objectives for the NWT RCC were to assist within the NCP Education / Communications envelope by providing input on the direction that the NWT Regional Contaminants Committee would like to go. This direction included assessing past communications materials, and communication strategies to capacity building.

The Sahtu Secretariat Incorporated, (SSI) tried to ensure that we had a contact person, (the Lands Advisor assumed this role), to aid in circulating

NCP publications and communications materials to Sahtu communities as well as to collect input from these communities where applicable.

Through distribution of NWT RCC and NCP communications materials, the message that traditional foods are safe, healthy and nutritious continued to be disseminated. In addition, SSI communicated its contaminants concerns to the NWT RCC and the NCP, and worked toward finding appropriate funding to address any concerns. By participating in the committee, we continued SSI's long-term involvement with the program.

Introduction

Maintaining the current level of understanding and participation of the SSI in the NWT RCC with regards to contaminants issues in the NWT is very important. There is also a strong need for continued Sahtu participation on the committee to keep the committee and the NCP informed of any long range and local contaminants concerns in the Sahtu Settlement Area. SSI implements the Sahtu Dene Council's interests on a day to day basis, and monitors all research within the Sahtu Settlement Area, particularly through the review of all applications for research.

The SSI participant acts as a point of contact for the community members, and can discuss contaminants issues with members of the committee who may be able to provide direct assistance or find appropriate assistance to address concerns. A variety of contaminants related presentations are made to the NWT RCC throughout the year, and this information can be forwarded to other members of the Sahtu Secretariat Incorporated as appropriate.

Activities in 2009 – 2010 Progress to Date

The SSI has had over 10 years of past involvement with the NCP. This reporting period, the representative participated through:

- Attendance at the 29th to 30th September 2009, "Face to Face" NCP Results Workshop in Ottawa.
- Participation in the 16th October 2009, conference call which discussed the NCP Results workshop and information to be taken to the NCP Management Team Meeting.
- Participation in the 6th November, conference call regarding the NCP Blueprint.
- Attendance at the 9th to 11th March 2010, "Face to Face" meeting in Yellowknife. The purpose of that meeting was to assess and select submitted research proposals for the coming year.
- Participation in the 8th April conference call related to the release of research results that were recently published relating to increasing mercury levels near the Sahtu community of Fort Good Hope. Discussions on whether to respond to media were very good. The final decision was to not respond but to focus on going to Fort Good Hope to talk to the community about the results of the researcher's work. Unfortunately individual schedules did not allow this trip to go ahead. Action by the Committee in regards to this subject is still outstanding as of this date.
- Participation in the 14th May 2010, conference call. Discussed were the preliminary results of the Human Health Risk Assessment on Lake Trout from Trout Lake as well as the other lakes included in the results submitted to Health Canada.

As well as the events listed above, the Lands & Resources Department also participated in several other meetings related to an environmental assessment of a mining related activity, Sahtu Implementation Committee meetings, the Protected Areas Strategy PAS program, Cumulative Impact Monitoring Program, First Nations Forestry Program, NWT Wildlife Act draft legislation, the NWT Environmental Audit, as well as assistance to the District Land Corporations, and several other issues related to lands and resources. In many instances, conflicting schedules were beyond the department's control.

Previously, the SSI completed a Public Service Announcement, NCP research and information translation to Slavey in 2004-05. The NCP also funded a 10 day contaminants related workshop in Yellowknife, (2003-04), at the INAC Taiga Lab, where the regional representative participated in the training.

Participation on the NWT RCC has led to investigating local contaminants concerns, and the SSI has been involved in past LCC projects. Overall, participation on the NWT RCC has kept the region informed of contaminants information and ensured that relationships between the regions continue to develop capacity and awareness.

Results

A representative, (most often the Lands Advisor, participated in NWT RCC monthly meetings, (conference calls and in-person). This person:

- analyzed past successes and strategies for future endeavors;
- reviewed relevant materials prior to meetings, and following meetings;
- The communities are more aware of issues and our office.

Discussion and Conclusions

Participation on the Northern Contaminants Program (NCP), Northwest Territories Regional Contaminants Committee (NWT RCC); as well as assistance from Indian and Northern Affairs Canada (INAC), and Government of the Northwest Territories (GNWT); have all provided an opportunity to give experience to the SSI on contaminants issues, as well as contaminants issues from long-range transport. These valuable results from the NCP are helpful to the Sahtu Dene Council, and studies will continue to be relevant to the Dene people, particularly with impending development from different industries.

The goal is to train through mentoring a Lands Manager to further promote this program throughout the Sahtu Settlement Area, in advance of this development. This will be a key objective for the coming year.

Expected Project Completion Date

Realistically contaminants and pollution monitoring, and the corresponding interagency dialogue to address it will likely be ongoing.

Participation on the NWT Regional Contaminants Committee

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Project team:
Fort Smith Metis Council
Fort Resolution Metis Council
Hay River Metis government Council
Northwest Territory Metis Nation

Abstract

Participated:

- as a representative for the Northwest Territory Metis Nation.
- attended social/cultural review for 2009-10 NCP proposals
- provided regular updates to the NWTMN membership
- represented community concerns at regular scheduled meetings
- provided assistance to researchers as needed
- attended scheduled in-person and teleconference calls

Key Messages

- Traditional foods are still the best for the aboriginal population, and are still safe to consume

Résumé

Participation :

- a représenté la Nation métisse des Territoires du Nord-Ouest
- a participé à l'examen socioculturel des propositions du PLCN pour 2009-2010
- a présenté des comptes rendus réguliers aux membres de la Nation métisse des Territoires du Nord-Ouest
- a présenté les préoccupations de la collectivité lors de réunions ordinaires
- a fourni de l'aide aux chercheurs au besoin
- a assisté aux réunions en personne ou par conférence téléphonique prévues au calendrier.

Messages clés

- Les aliments traditionnels demeurent ce qu'il y a de mieux pour la population autochtone, et ils peuvent toujours être consommés sans danger

- Keep membership informed on issues that are important: water, climate change, wildlife issues, and food security
- Explain how contaminants make it into our food chain in the NWT
- New and emerging contaminants information

- Tenir les membres informés des enjeux importants, comme l'eau, le changement climatique, les questions touchant la faune et la sécurité alimentaire
- Expliquer comment les contaminants se retrouvent dans la chaîne alimentaire des Territoires du Nord-Ouest
- Renseignements sur les nouveaux contaminants.

Objectives

- To provide a forum, where the membership can bring concerns forward, and have them brought to the NWTRCC for discussion.
- Provide the NWTMN membership with timely information on contaminant related issues
- Provide a uniquely northern perspective to the review of proposals that will have work done within the NWT

Introduction

As contaminants are identified in the northern food chain, and having possible effects on human residents, timely information to the public will allow for educated food choices. This is an important aspect of the Northern Contaminants Program: investigations of contaminants and their effects on human populations in Canada's Arctic. Traditional foods are still the best choices for the aboriginal residents of the NWT, is an important message to keep passing on.

Activities in 2009-2010

Prepared monthly reports on activities. Attended 5 teleconference calls for the year. Time constraints has not allowed for full participation on this committee. Sat as chair of the committee for the year.

Results

Discussions on the contaminants issue is a topic that is readily talked about. There seems to be quite extensive knowledge on the issue of contaminants and their impacts, at least here in the south slave area of the NWT.

Discussion and Conclusions

The NWTRCC is an excellent format for the aboriginal residents of the NWT to discuss contaminants issues. The NCP has a mandate to deal with contaminants that of a long-range nature. Unfortunately the residents of the Mackenzie River basin do not suffer from the same contaminants as the Arctic coast people. The problems that are seen by the residents in the Mackenzie River basin are contaminants problems that have a local source, either from within the river basin itself, or from sources that are not international by nature (not long-range). Attempts in the past have been made to accommodate local contaminants concerns by accessing other Government funded programs. These programs are usually small in nature, and have a small budget attached, along with short term commitments. These style of programs are usually good for the work that is wanting to be done in the river valley, but, these programs are usually short term, not allowing for any meaningful work to be completed.

Expected Project Completion Date

March 31,2010 is the agreed to completion date for this report.

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see below

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Delorme, J. 2010 Fort Resolution Metis Council – staff member, Fort Resolution, NT

Tay Caribou Facilitated Hunt: School and Community Education Programs in Ross River, Yukon

Project Leader:

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Project team:

Troy Pretzlaw, Troy Hegel, Remy Rodden, Randy Fraser, Environment Yukon; Norman Sterriah, Gordon Peter, Norman Barichello, Ross River Dena Council; Thomas Jirousek, Dept. of Education, Yukon Territorial Government (Ross River School).

Abstract

This is a companion project to the Northern Contaminants Program core project 'Arctic Caribou and Moose Contaminant Monitoring Program' which sampled the Tay caribou herd as part of a facilitated traditional spring harvest in cooperation with the Ross River Dena, Environment Yukon and Yukon Education. The objective of this project was to provide an education component to the facilitated hunt and to encourage youth to experience a traditional hunt alongside traditional hunters and community elders. Nineteen community members (eleven youth) attended a firearms safety and hunter education program offered in the Ross River School and in the community in general by Environment Yukon. A one-day school program was given in the Ross River School including programs on contaminants, caribou ecology, general ecology and caribou physiology, and using games, videos, music and hands-on activities as educative tools. A one-week hunting camp was held in the Tay caribou traditional area that included 23 community members. Seven caribou and one wolf were taken during the hunt. Measurements were taken for management purposes, samples were taken for contaminant analysis and then the animal was treated in a traditional way (butchered in the case

Résumé

Il s'agit d'un projet connexe au projet central « Programme de surveillance des contaminants chez le caribou et l'orignal de l'Arctique » du Programme de lutte contre les contaminants dans le Nord qui a échantillonné la harde des caribous Tay dans le cadre d'une récolte traditionnelle du printemps facilitée, en collaboration avec le Conseil des Dénés de Ross River, Environnement Yukon et Éducation Yukon. Le projet avait pour but d'offrir un volet d'éducation à la chasse facilitée et d'encourager les jeunes à participer à une chasse traditionnelle aux côtés de chasseurs traditionnels et d'aînés de la collectivité. Dix-neuf membres de la collectivité (dont onze jeunes) ont assisté au programme d'éducation des chasseurs et d'utilisation sûre des armes à feu offert par Environnement Yukon aux élèves de l'école de Ross River et à la collectivité en général. Un programme éducatif d'un jour a été offert à l'école de Ross River. On y traitait des contaminants, de l'écologie des caribous, de l'écologie générale et de la physiologie du caribou en faisant appel à différents outils didactiques : jeux, vidéos, musique et activités interactives. On a tenu un camp de chasse d'une semaine regroupant 23 membres de la collectivité sur le territoire traditionnel du caribou Tay. Sept caribous et un loup ont été pris pendant la chasse. On a accumulé des données à des fins de

of caribou, and skinned in the case of the wolf). This provided youth an opportunity to learn scientific methods as well as traditional techniques. Some of the older youth participated in the hunting activities while the younger children spent time in the camp with the elders, cutting and cooking caribou, ice-fishing and listening to stories. Throughout the camp there were opportunities for informal discussions and questions on a wide array of topics, ranging from contaminants in caribou to traditional wisdom on climate change. A video was made of the camp, which will be used to educate local youth about traditional practices.

gestion, prélevé des échantillons pour l'analyse des contaminants, puis on a procédé à des méthodes traditionnelles d'abattage des animaux (le caribou a été débité et le loup dépouillé). Les jeunes ont ainsi eu l'occasion de se familiariser avec les méthodes scientifiques et les techniques traditionnelles. Certains élèves parmi les plus âgés ont pris part aux activités de chasse tandis que les plus jeunes sont restés au camp avec les aînés pour découper et faire cuire de la viande de caribou, pêcher sur la glace et écouter des récits. Pendant toute la durée du camp, les élèves ont eu l'occasion de participer à des discussions informelles et à poser des questions sur un vaste éventail de sujets, tels que la présence de contaminants chez le caribou et la sagesse traditionnelle pour s'adapter au changement climatique. On a tourné une vidéo du camp, qui sera utilisée pour enseigner des pratiques traditionnelles aux jeunes de la région.

Key Messages

- It is important to provide opportunities for northern youth to experience traditional knowledge first-hand and to learn from elders in their communities.
- Hunting camps can provide an invaluable opportunity for the transfer of knowledge among youth, hunters, elders and scientists.

Messages clés

- Il est important d'offrir aux jeunes du Nord des occasions d'acquérir sur place des connaissances traditionnelles et de leur permettre d'apprendre auprès des aînés de leur collectivité.
- Les camps de chasse peuvent offrir une occasion inestimable pour échanger des connaissances entre les jeunes, les chasseurs, les aînés et les scientifiques.

Objectives

- To provide an education component to the facilitated hunt planned for the Tay caribou herd under the Northern Contaminants Program core project 'Arctic Caribou and Moose Contaminant Monitoring Program.
- To encourage youth to experience a traditional hunt alongside traditional hunters and community elders

Introduction

Moose and caribou provide an important food resource for Northerners across the Arctic, and have been designated in the NCP blueprint as key species for monitoring contaminants in the terrestrial Arctic ecosystem. Under the Northern Contaminants Program core project 'Arctic Caribou and Moose Contaminant Monitoring Program', the Tay herd from the Ross River area of the Yukon was scheduled to be sampled in 2009/10. This herd was selected because it is one of two Yukon caribou herds found to have unusually high concentrations of cadmium in the early 1990's. The other herd (Finlayson) receives more hunting pressure since it is more accessible, so wildlife managers supported this program as an effort to facilitate a shift to concentrate hunting pressure more on the Tay herd.

The intent of the project was to involve Kaska youth , traditional hunters and elders in the collection of the caribou, to use the opportunity to educate camp participants about caribou management and contaminants in the environment, to provide training specifically on taking samples from caribou for contaminant analysis and to allow the biologists and scientists involved to learn traditional knowledge directly from the hunters and elders.

While the underlying purpose of this activity was to acquire caribou samples for the contaminant program, collecting the samples as part of a community hunt and adding the education components to the program brings general education enrichment to this small community. Youth from Ross River have few of the education opportunities available in bigger northern centers such as Whitehorse, so bringing opportunities to the community is invaluable, and is fully supported and encouraged by the Ross River School. In addition it encourages local youth to view their elders as positive and successful role models.

Activities in 2009-2010

In preparation for this program, a firearms safety and hunter education program was offered in the Ross River School in January 2009 and in the community in general in October 2009, by Environment Yukon (Randy Fraser). Both programs were considered a success, with eleven youth attending the school program and eight community members attending the community program.

A one-day school program was given in the Ross River School on March 2, 2009. 'Caribou Day' began with the students being welcomed into the school by a full size stuffed caribou (transported to Ross River for the occasion) and local musician/environmental educator Remy Rodden playing and singing his own composition 'Caribou'. The classes were divided into four groups, and four environmental educators cycled through the classrooms during the day and delivered programs on contaminants, caribou ecology, general ecology and caribou physiology. The educators used games, videos, music and hands-on activities throughout the programs. A community lunch of caribou smokies was provided (with the assistance of the school principal and secretary) for the school and community members.

A 7-day hunting camp was held March 6-12, 2010 in the Tay caribou traditional area. Participating in the camp were: 2 biologists, 2 technicians, 1 conservation officer (from the community), 1 videographer and 23 community members. Of the community members, 6 were youth, 5 were elders and 10 were hunters. Over the course of the week, 7 caribou and one wolf were taken. In each case, measurements were taken for management purposes, samples were taken for contaminant analysis and then the animal was treated in a traditional way (butchered in the case of caribou, and skinned in the case of the wolf). During this process, youth were taught how to take measurements and samples by the biologists and technicians, and how to skin and butcher caribou by the hunters. Some of the older youth also participated in the hunting activities. The younger children did not actually hunt, but spent time in the camp with the elders, cutting and cooking caribou, ice-fishing and listening to stories. Throughout the camp there were opportunities for informal discussions and questions on a wide array of topics, ranging from contaminants in caribou to traditional wisdom on climate change. A video was made of the camp, which will be used to educate local youth about traditional practices.

Capacity Building and Training

Capacity building and training were to be found throughout this project. The Firearms Safety and Hunter Education Program provided not only training and education in this area, but also the opportunity for community members to obtain their Possession and Acquisition License. The school program provided education to the school students as well as the teachers, providing them with a list of resources for accessing more information and/or assistance with teaching contaminants and ecology. The camp environment was invaluable in providing opportunities for youth to learn current scientific methods as well as traditional knowledge and wisdom. The informal atmosphere fostered many casual conversations among all the camp members regarding contaminants, wildlife, wildlife management, traditional knowledge about caribou, wolves, the land in general and climate change, to the benefit of all involved.

Communications

A summary of the project will be communicated to the Yukon Contaminants Committee and presented at the NCP results workshop anticipated for the fall of 2010. A meeting may be held in Ross River to discuss results of this and the associated 'Contaminants in Arctic Moose and Caribou Project', or the communication may be in the form of a brochure (or both), at the discretion of and request by the Ross River Dena. A video was made of the camp by the Ross River Dena, which included interviews with scientists and elders. This video will be used to educate local youth about traditional practices.

Traditional Knowledge

This program used traditional knowledge throughout, beginning with hunting the caribou. An early spring had initiated caribou movement earlier in the year than usual, so hunters and elders had to plan carefully to find any caribou in the area. The structure of the camp made it possible for youth to learn hunting techniques and wisdom from the hunters and elders, as well as how to butcher caribou and skin a wolf. Some of the younger children were interested to learn how to ice-fish from the elders as well as how to cook caribou. A 'smoke-rack' was set up to smoke some of the meat and roast the caribou heads. For this, the fire had to be tended constantly, which created an ideal opportunity for children (and others) to listen to stories and traditional wisdom from the elders.

While the school and community programs were very valuable educative tools, the hunting camp provided an ideal structure for the casual and free flow of information and wisdom among scientists, hunters, elders, youth and other community members. Equally valuable was the opportunity for local youth to experience other community members as hunters, fishers and elders in a natural environment and interacting with the land in traditional ways. These positive role models will encourage respectful and wise use of the land by the youth participating in the camp.

NCP Performance Indicators

- Number of northerners engaged in this project: 96 (including Yukon territorial government, school students and teachers, camp participants, and firearms safety and hunter education program participants). Note that 100% of people involved in this project were northerners.
- Number of meetings/workshops held in the North: 8 (4 meetings, 1 camp , 2 school workshops, 1 community workshop)
- Number of students involved in the work: 40 (elementary school students)
- Number of citable publications: 0

Expected Completion Date

The project has been completed.

Acknowledgements

The project leader would like to acknowledge the strong support of Yukon Environment in this project, specifically: Randy Fraser (Firearms Safety and Hunter Education Programs), Remy Rodden, Maurice Lamrock, Olivia Hell (School Program), Troy Pretzlaw, Ryan Drummand, Kyle Russel, Debra Morris (Hunting Camp). I would also like to acknowledge the support of the Ross River School, particularly principal Thomas Jirousek and administrative support Judy Sisson, and the Ross River Dena Council, particularly Gordon Peter, Norman Sterriah and Norman Baricello. Finally I would like to acknowledge the support of the hunters and elders who participated in the camp and were so generous with their stories and their knowledge.

Continuing to meet the information needs of Nunatsiavummiut

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Abstract

In 2009-10, the CRC continued to communicate and educate Nunatsiavummiut on contaminants, wild foods and health issues so that they may make informed decisions in their daily lives. With two committees within NG, the Interim Research Committee and an NCP funded Nunatsiavut Health and Environment Review Committee (NHERC), the CRC is providing advice and assistance to the development of a research protocol for Nunatsiavut as well as ensuring that contaminant issues/information are now provided to each of the communities and gathered in a regional hub, therefore strengthening the already existing relationship between the CRC and the region.

Résumé

En 2009-2010, la CRC a continué de renseigner les Nunatsiavummiut au sujet des contaminants, de la nourriture sauvage et des questions de santé, de sorte qu'ils puissent prendre des décisions éclairées au quotidien. En sa qualité de membre de deux comités au sein du gouvernement du Nunatsiavut, soit le comité intérimaire de la recherche (Interim Research Committee) et le comité d'examen de la santé et de l'environnement du Nunatsiavut (Nunatsiavut Health and Environment Review Committee, ou NHERC) qui est financé par le Programme de lutte contre les contaminants dans le Nord (PLCN), la CRC offre de l'aide et des conseils en vue de l'élaboration d'un protocole de recherche pour le Nunatsiavut et veille à ce que les questions ou l'information relatives aux contaminants soient dorénavant communiquées à chacune des collectivités et regroupées au sein d'un centre de coordination régionale, renforçant ainsi les liens déjà solidement établis entre la CRC et la région.

Key Messages

- The CRC strives to, in a culturally relevant manner, continue its communication efforts on contaminants, research and the environment, conduct research and promote mutually beneficial relationships between the communities of Nunatsiavut and outside scientists;
- Nunatsiavummiut have a number of concerns about their health and the environment around their communities. The creation of the NHERC has helped these communities come together with common issues, gain understanding of common issues in other regions and understand NCP's mandate.
- Two much needed research stations will be erected in Nunatsiavut this summer/ fall. One will be built in Nain and another just south of Torngat Mountains National Park, on Labrador Inuit Lands in Saglek Fiord. Both of these stations will help facilitate and direct research in the region and well as build capacity and provide new opportunities for Nunatsiavummiut.

Messages clés

- Tout en tenant compte des différences culturelles, la CRC poursuit ses efforts en matière de communication de renseignements sur les contaminants, la recherche et l'environnement, mène des recherches et facilite les relations entre les collectivités du Nunatsiavut et les scientifiques d'ailleurs.
- Les Nunatsiavummiut ont un certain nombre de préoccupations au sujet de leur santé et de l'environnement où évoluent leurs collectivités. La création du NHERC a permis à ces collectivités de faire front commun en ce qui a trait aux enjeux collectifs, d'analyser les problèmes également observés dans d'autres régions et de saisir la nature du mandat du PLCN.
- Deux stations de recherche dont la région a absolument besoin seront construites au Nunatsiavut à l'été ou à l'automne. L'une d'elles sera construite à Nain et l'autre juste au sud du parc national des Monts-Torngat, dans les terres des Inuit du Labrador, dans le fjord de Saglek. Les deux stations contribueront à faciliter et à orienter les recherches dans la région ainsi qu'à renforcer la capacité et à créer de nouvelles possibilités pour les Nunatsiavummiut.

Objectives

The objective of the Northern Contaminants Program (NCP) is to reduce or, wherever possible, eliminate contaminants in traditionally harvested foods while providing information that assists informed decision making by individuals and communities related to their food use.

This year the Nunatsiavut Government NCP Researcher:

- Assisted residents of Nain, Hopedale, Postville, Makkovik, Rigolet and Happy Valley-Goose Bay by providing information about risks, the means to reduce risks, and information on the benefits of traditionally harvested foods to support residents in making informed decisions;
- Assisted communities of the Nunatsiavut and the Lake Melville area in becoming involved with contaminant issues and activities that affect the people and the region
- Sits on the Nunatsiavut Government's Interim Research Advisory Committee which is responsible for reviewing proposals and ensures research in the region follows guidelines set by NG, is culturally sensitive, has all/any permits required by NG;
- Is a member of the BOD for Nasivvik;
- Assisted in securing funds for a much needed research centre which will be constructed in Nain this summer. This research centre will be equipped with the facilities that are much needed in the region. This includes a wet and dry lab, accommodations, library, freezers etc.;

- As part of her ongoing work on the issue of local contaminant sources at abandoned military sites, the CRC continues to be the first point of contact between the Provincial Government of NFLD and Labrador and the community of Hopedale, Nunatsiavut, ensuring that the residents of Hopedale are well informed of the results of work in Hopedale.
- Traveled on the CCGS Amundsen from Iqaluit to Anaktalak Fiord, Nunatsiavut in November, 2009. This was a great opportunity to see first hand the science taking place on board the ship in her own region. During this time, the CRC worked closely with the Schools on Board program, including students from Nunatsiavut who participated, and gave a presentation about her role as CRC and the NCP. (Appendix A)

Introduction

Nunatsiavummiut are sustained by the animals, birds, fish and plants of the region. Research has shown that contaminants are present in these food sources due to the environment being contaminated by varying sources of pollution (local and distant) which are then transported to the north via atmospheric and oceanic mechanisms. Also, climate change effects are becoming more evident in the Canadian Arctic. The levels of contaminants in these foods which sustain Nunatsiavummiut and potential effects they may have on residents of the coastal communities are of concern to the Inuit of Nunatsiavut. The Nunatsiavut Government Research Office helps to ensure that Nunatsiavummiut are heard and their concerns with regard to both national and local contaminants issues are assessed and communicated. The current issues for Nunatsiavut Inuit are similar to those of other Inuit regions, but there are also local concerns that need to be communicated.

Hopedale, Labrador, a community of approximately 625 residents, has a former US Air Force early-warning radar station near the community, has been voicing concern of possible contamination for a number of years. The assessment and subsequent remediation of this contamination is now being led by the Government of Newfoundland and Labrador. The CRC is working closely with the Provincial Government and the community to begin working on a clean up plan. A community meeting is scheduled for June 2010 to bring back results of studies done in a residential subdivision of Hopedale where barrels and debris are found underneath and around people's homes. Results are showing some locations with elevated levels of substances such as: fuels, PCB's, lead, cadmium, zinc etc.

In order for Nunatsiavut Inuit to be informed about wise food choices the NG Research Office must coordinate efforts between Inuit Tapiriit Kanatami, NCP, university and government researchers and our communities. Following the objectives of the Northern Contaminants Program, the NG's Researcher acts as a key resource person and provides information to the population in a culturally relevant and plain language format on contaminant-related issues. The NHERC has proven to be a very helpful tool in ensuring that each Inuit community is represented and has a voice, not only when dealing with NCP related research, but also through our National Inuit Organization; ITK. ITK is also a member of this committee.

Activities 2009-2010

Communication

Avativut Newsletter
This newsletter is a publication that the NG Research Office has developed and used to communicate to the Labrador Inuit population about such things as the benefits and risks of wild foods, the most recent knowledge on contaminants, health and environmental issues and to update people on current research activities in the region. The existence of a regional person and their involvement in this publication has enhanced the NG's ability to communicate such information in a culturally-relevant and timely manner. The main focus of the Avativut newsletter is on the benefits of consuming wild foods so as to reinforce the understanding among the general population that they are still the most nutritious foods for Nunatsiavummiut to eat. Additional updates of new and ongoing research activities and relevant facts about health and environment issues in the region are also provided in this newsletter which is printed in English and Inuktitut (Labrador dialect). A section of the Avativut Newsletter is

also set aside for environmental news from each of the Nunatsiavut communities, giving each community a chance to share their concerns and accomplishments with the coast regarding environment and health issues.

Participation in Research Projects

Although many of the issues that the NG is currently dealing with related to the issue of contaminants are associated with local source problems (e.g. Hopedale radar base) in the eyes of community members there remains the need to address these concerns. The public does not make the separation between local and long range sources and therefore communication activities in the region this year have had to deal with the issue of contaminants in a coordinated and combined manner. The NHERC has made some progress is explaining the difference through community representatives. Regional review of NCP proposals through NHERC has also raised awareness of projects in communities in Nunatsiavut, thus creating interest in having similar research done in other communities. Although there is some understanding of why research is important, it is necessary continue to communicate research information and explanations about why it is necessary. The NG are hosting the first ever research forum in Nain this year and this will hopefully ignite some interest and understanding to research are well as begin to build a research vision for Nunatsiavut.

ArcticNet Nunatsiavut Nuluak: Understanding and responding to the effects of climate change and modernization in Nunatsiavut.

Nunatsiavut Nuluak project, funded by ArcticNet and co-led by the Nunatsiavut Government and the Environmental Sciences Group of the Royal Military College of Canada, was initiated in the spring of 2006 to address Inuit concerns of environmental change and human activities which may be contributing to these changes in northern Labrador. The objectives of the program are to create a baseline inventory and comparative assessment of fiord based ecosystems (Saglek, Okak, Anaktalak and Nachvak Fiords) and document and incorporate Inuit knowledge and concerns in all facets of the program. In the summer of 2009, the Environmental Sciences Group, Parks Canada, the Nunatsiavut Government and ArcticNet, with support from the Nasivvik Centre and International Polar Year, were able to give 10 students a chance to work side by side with Inuit from Nunatsiavut and Nunavik as well as researchers from several universities and government agencies through the kANGIDLUASUk student program. These areas included research on contaminants in the marine ecosystem, sampling of small organisms in water, vegetation sampling, research on glaciers, collection of samples and more.

Temporal Trends and spatial variations in persistent organic pollutants and metals in sea-run char from the Canadian Arctic

Sea-run Arctic char are eaten by many Arctic communities and are valued as a good food source in addition to other food items such as seals and appropriate store bought food. In the past few years, samples were taken from Nain, Nunatsiavut and results are now showing a decrease in levels of mercury which is good news. Although NCP has decided to cut back on some of its long term monitoring sites, it is hoped that because of these new and not so common results, funds will become available for Dr Evans to continue her research in Nunatsiavut.

Nasivvik Centre for Inuit Health and Changing Environments

The Nasivvik Centre is a multidisciplinary research and training centre funded by the Canadian Institutes of Health Research-Institute of Aboriginal Peoples' Health. The Centre is focused on building capacity in Inuit health research through trainee support and strategic funding initiatives in key environmental health areas of importance to Inuit communities.

The Nasivvik Centre also provides part of the funding for the Inuit Research Advisor (IRA) in Nunatsiavut, John Lampe. In cooperation with the CRC and the Nunatsiavut Government, the IRA position has led to better overall research coordination among projects funded under the various research programs going in Nunatsiavut and an enhancement of training opportunities associated with research. The CRC is a member of the Board of Directors for the Nasivvik and takes part in meetings and conference calls to deal with any issues regarding the centre including reviewing funding proposals.

Nunatsiavut Health and Environment Review Committee

The Nunatsiavut Contaminants Committee (Now the NHERC) began in late 2007. This committee consists of the CRC who is the Chair of the committee, the Nunatsiavut Inuit Research Advisor, Director, Nunatsiavut Government Environment Division, NG Dept. of Health, ITK, NCP and a representative from each of the 5 communities along the coast and Upper Lake Melville (ULM). The current co-chair is Ed Tuttauk from Northwest River (ULM). This committee has experienced a high turnover of membership from some communities, but it is hoped that the *Tukisinnik Research Forum* being held in Nain in June 2010, will ignite more interest in the region about research and generate interest in the people in assisting with the development of a research vision for Nunatsiavut. The CRC is responsible for securing funding for the committee and coordinating the committee activities, preparing for face to face meeting and teleconferences which include logistical planning, travel arrangements, orientation of new members, preparing minutes, disseminating proposals for review, collecting information, preparing documents and ensuring regional concerns are forwarded to the NCP. Terms of Reference for the NHERC have been developed.

Ongoing Daily Communications and Research Coordination

In addition to these specific activities, a number of ongoing communication responsibilities are fulfilled by the NG Research Office staff. Daily activities of the Research Office include responding to community concerns, providing information to the Nunatsiavut Government, communities, and individuals on issues relating to contaminants, the environment and health, and acting as a liaison for the various people proposing to, and currently conducting research in the region. Additionally, the research staff acts as a liaison for interactions between the regional organizations and ITK and the NCP. This involves regular interaction with various individuals and ongoing communications efforts.

Discussion and Conclusions

The CRC continues to be an essential part of the work of the Nunatsiavut Government. This is especially true for the residents of Hopedale, and will continue to be so for other Nunatsiavut communities who have concerns about contaminants. The NG Research Office continues to educate and empower the people of Labrador to better understand and deal with contaminants in their environment and traditional foods, and be aware of research and general environmental issues.

The Nunatsiavut Government Contaminants Researcher continues to:

- Support the activities undertaken by NG and NCP in providing information on research about contaminants, their effects on wildlife and humans through consumption of wild foods which are based on the varied language and geographic needs of individuals and communities of Labrador;
- Enhance decision making abilities of Labrador Inuit through the delivery of information on risks and benefits of contaminants and wild foods relevant to the region in an accurate, timely and accessible manner;
- Develop regionally relevant resource materials in consultation with the coastal communities and appropriate agencies (i.e. Department of Health and Social Development, DIAND-NCP, ITK etc.). These materials include educational materials such as a quarterly newsletter; all publications are produced in both Inuktitut and English;
- Use the research results from studies conducted in the region to aid in effective delivery of information;
- Be a member of the NG Interim Research Advisory Committee, responsible for interacting with and assisting outside researchers with community consultations. This assistance also includes negotiating research agreements between researchers and community organizations and reporting project results to communities in a timely and responsible manner. The Research Office determines, in consultation with community representatives who are responsible for communication on contaminant, health and environment

issues, which medium(s) best suit the information needs of the community, etc. This person will continue to assist in the development of a Protocol and Guidelines for Research conducted in Nunatsiavut.

- Continue to act as Chair of the NHERC, ensuring that communities are involved with in and informed about community concerns in the region, coordinates all logistical and administrative aspects of the committee
- Take part in research projects and communication of research results when appropriate.

Date of Completion

This is an ongoing project in Nunatsiavut.

Acknowledgements

The NG CRC would like to thank Dr. Chris Furgal, Assistant Professor, Trent University, for his invaluable assistance and support in carrying out projects funded under the Northern Contaminants Program. Also, we thank Eric Loring, Inuit Tapiriit Kanatami, for his involvement and guidance in these activities. The Environmental Sciences Group for their contributions to the research projects in Hopedale. The support of the Department of Lands and Natural Resources ensures the continuation of the NG Research Office mandate. We would also like to give special thanks to Louisa Kojak Interpreter/Translator, NG, and Wilson Jararuse for the translation of communication materials and well as the Nunatsiavut Government's Community Liaisons for their assistance in activities related to the issues discussed in this report.

References

Lampe, J., Murphy, F., Furgal, C., and Craig, L. 2000. Country food, nutrition and health: Developing effective communication strategies in Labrador (Year 2). *In*, Kalhok, S. (Ed.) Synopsis of Research Conducted under the 1999-2000 Northern Contaminants Program. Department of Indian Affairs and Northern Development, Ottawa, ON. ISBN: 0-662-29320-7. pp: 271-280.

Appendix A

Mary Denniston giving presentation on the Amundsen, November 2009

Students on Amundsen, November 2009

Nunatsiavut Inuit Research Advisor

Project Leader:

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Mary Denniston, Northern Contaminants Researcher, NG
Michele Wood, Researcher/Evaluator, Department of Health and Social Development, NG
Jamie Brake, Archaeologist, Torngasok Cultural Centre, Nain

Abstract

The Inuit Research Advisor (IRA) program continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunatsiavut. Nunatsiavut Government (NG) encourages researchers to consult/meet with Inuit Community Governments and NG Departments/Divisions in developing their proposals. Reviews to proposals are initiated; involving appropriate NG departments, Inuit Community Government(s) and staff ensuring a comprehensive review to the proposals.

Together with IRAs in the other Inuit regions of Canada, the Nunatsiavut IRA works towards achieving a new way of knowledge sharing and engagement of Inuit in Arctic science in the region. The IRA's had a training session on September 27-28 2009 to enhance their responsibilities. In addition to NCP support, the program is co-funded by ArcticNet and the Nasivvik Centre for Inuit Health and Changing Environments.

Résumé

Le conseiller en recherche inuite (CRI) continue à constituer le premier palier d'une approche mieux coordonnée ayant pour objectif de favoriser la participation des collectivités et de coordonner les sciences de l'Arctique au Nunatsiavut. Le gouvernement du Nunatsiavut encourage les chercheurs à consulter et à rencontrer les administrations des collectivités inuites et les ministères et divisions du GN lorsqu'ils élaborent leurs propositions. Les propositions sont examinées, notamment par les ministères concernés du GN, les administrations des collectivités inuites et le personnel, qui se chargent de l'examen exhaustif des propositions.

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 Inuit en ce qui concerne les sciences de l'Arctique dans la région. Les CRI ont eu une séance de formation les 27 et 28 septembre en vue d'assumer des responsabilités élargies. Le financement des activités est conjointement assuré par le Programme de lutte contre les contaminants dans le Nord (PLCN), ArcticNet et le Centre Nasivvik pour la santé des Inuit et les changements environnementaux.

Key Messages

- In 2009-10 the IRA undertook various tasks in liaison with the Northern Contaminants Program (NCP), ArcticNet, Nasivvik Centre, and Nunatsiavut Government (NG) in the areas of research promotion and coordination, public education and information. The IRA distributes all promotional items, notices etc. from the three funding agencies to all of the NG Assembly and employees.
- The IRA has also served as liaison for partners such as Inuit Tapiriit Kanatami (ITK), Inuit Circumpolar Council (ICC), Nunatsiavut Nuluak, Nunatsiavut Inuit Community Governments, International Polar Year (IPY), researchers, students, and other organizations.
- The IRA oversaw the management of the Nunatsiavut Government Research Office, serving as the first point of contact for all researchers conducting work in Nunatsiavut and requiring contact with or assistance from the Nunatsiavut Government. The IRA is the Chair and administrator of the Nunatsiavut Government Research Advisory Committee (NGRAC). The IRA has communicated with 75 researchers from 1st April 2009 to 31st March 2010. This year the IRA Chaired 10 NGRAC meetings.
- The IRA served as liaison, contact and assistant to research projects taking place in Nunatsiavut. This assistance ranged from linking the researchers with appropriate individuals and/or organizations such as NG departments and Inuit Community Governments in Nunatsiavut to providing input on research proposals and plans.
- The IRA is a member of the NCP funded Nunatsiavut Contaminants Committee called the Nunatsiavut Health and Environment Review Committee (NHERC). As a member of this committee the IRA reviewed all proposals that were submitted to the NCP associated with the Nunatsiavut Region.
- The IRA has undertaken diverse tasks for the host organization Nunatsiavut Government (NG) ranging from attending NG workshops, researcher workshops and collaborating with many researchers and organizations.

Messages clés

- En 2009-2010, le CRI a exécuté diverses tâches en collaboration avec le PLCN, ArcticNet, le Centre Nasivvik et le gouvernement du Nunatsiavut (GN) dans les secteurs de la promotion et de la coordination de la recherche, de l'éducation du public et de l'information. Le CRI diffuse tous les articles de promotion, avis, etc., provenant des trois organismes de financement à l'ensemble de l'Assemblée du GN et aux employés.
- Le CRI assure également la liaison avec des partenaires comme l'Inuit Tapirit Kanatami (ITK), le Conseil circumpolaire inuit (CCI), le Nunatsiavut Nuluak, les administrations des collectivités inuites du Nunatsiavut, l'Année polaire internationale (API), les chercheurs, les étudiants et d'autres organismes.
- Le CRI a supervisé la gestion du bureau de la recherche du gouvernement du Nunatsiavut, en faisant office de point de contact initial pour tous les chercheurs effectuant de la recherche au Nunatsiavut et ayant besoin de communiquer avec le gouvernement du Nunatsiavut ou d'obtenir son aide. Le CRI est le président et l'administrateur du comité consultatif de la recherche du Nunatsiavut. Le CRI a communiqué avec 75 chercheurs du 1er avril 2009 au 31 mars 2010. Cette année, le CRI a présidé dix réunions du comité consultatif.
- Le CRI a 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, par exemple les ministères du GN et les administrations des collectivités inuites du Nunatsiavut, et il a fait des suggestions quant aux propositions et plans de recherche.
- Le CRI fait partie du Comité des contaminants du Nunatsiavut, comité financé par le PLCN et désormais appelé comité d'examen de la santé et de l'environnement du Nunatsiavut (Nunatsiavut Health and Environment Review Committee ou NHERC). À titre de membre de ce comité, le CRI a passé en revue toutes les propositions qui ont été présentées au PLCN en ce qui a trait à la région du Nunatsiavut.

- Le CRI a accompli diverses tâches pour l'organisme d'accueil, le gouvernement du Nunatsiavut (GN), entre autres, il a assisté à des ateliers donnés par le GN ou des chercheurs et a collaboré avec un grand nombre de chercheurs et d'organismes.

Objectives

- Provide liaison support for and promote research in Nunatsiavut. The IRA has communicated with 75 researchers and made presentations at the NCP and ArcticNet Annual meetings.
- Promote more community-based research in the region. There have been more community led research projects such as the projects led by the Inuit Communities of Nain and Rigolet and the Inuit Corporation in North West River.
- Assist in the development of local capacity for research in Nunatsiavut. The IRA has a list of research assistants and interpreters/translators from each Inuit Community who are willing to work with researchers on their project.
- Provide information regarding research in Nunatsiavut and opportunities for local involvement.
- Liaise with national organizations and other Inuit regions in matters related to Arctic science and research. The IRA was a member of Inuit Nipingit a National Inuit Committee on Ethics and Research that developed a response to the Tri-Council Policy Statement on Research Ethics.

Activities in 2009-2010

- Managed the Nunatsiavut Government Research Office and served as Chair to the NG Research Advisory Committee, making contact with virtually all researchers, students and organizations visiting the Labrador Inuit Land Claim Area.
- Undertook socio-cultural review of NCP proposals in March 2010.
- Attended the IRA Program Review Meeting, April 8-9, Ottawa plus additional comments on the draft correspondence.
- Participated in the IRA Training on the 27-28 September.
- Attended the 17th Annual NCP Results Workshop, September 29 - October 1, 2009, Ottawa. The IRA made a presentation and had a poster.
- The IRA attended the Blueprint review session for Education and Communications in Ottawa on the October 1st, 2009.
- Attended the first ArcticNet Regional Science Meeting/Workshop held in Kuujjuaq from 10-12 November 2009.
- Attended ArcticNet's Sixth Annual Scientific Meeting (ASM2009), 8 to 11 December 2009, Victoria, British Columbia. The IRA made a presentation and had a poster.
- Attended the first official IAC Meeting in Ottawa on February 22.
- Maintained the Nunatsiavut Research list recording contact with all researchers visiting the region. Provided this list to all funding organizations.
- Kept Nunatsiavut Government Assembly, Staff and Research Advisory Committee informed of all NCP, ArcticNet and Nasivvik activities and opportunities.
- Participated in teleconferences with other regional IRAs.
- Promoted NCP, ArcticNet, Nasivvik activities and opportunities at the Nunatsiavut community and regional level through word of mouth and the distribution of promotional materials.

- Assisted in the preparation of the Nunatsiavut NCP Newsletter (Avativut)
- Attended the National Inuit Committee on Ethics and Research (NICER) now titled Nipingit meeting and in Ottawa February 23. Plus attended teleconferences and sent in comments on additional documents on TCPS. Provided input into the design for the national and Nunatsiavut posters on research ethics.
- Developed a Research Assistant List for researchers of all the Inuit communities in Nunatsiavut plus the upper lake Melville area.
- See attached Research Contact list for all contacts the IRA made with researchers during the 2009-10 fiscal year.

Results

The IRA program in Nunatsiavut continues to provide a coordinated process by which Inuit and researchers can become connected for more effective and meaningful research in the disciplines of environmental science, contaminants and human health.

NCP Performance Indicators

- The number of northerners engaged in the IRA project: 100 plus.
- The number of meetings/workshops you held in the North: 20.
- The number of students (both northern and southern) involved in your NCP work: 20.
- The number of citable publications (e.g., in domestic/international journals, and conference presentations, book chapters, etc): 2 conference presentations.

Expected Project Completion Date

This is an ongoing project.

Attachment

2009-10 Nunatsiavut IRA Research Contact List

1. Y. Anita Li, "The Prevalence of Human Papillomavirus and Its Impact on Cervical Dysplasia in Labrador". Michele sent in responses to our questions;
2. Dr. Suzanne E. Mills, "Effecting change in long-standing institutions: Aboriginal employment and labour unions in northern resource development projects." ;
3. Linda Liebenberg, "Pathways to Resilience";
4. Marc Choquette, "Healthy Living in Schools and Substance Abuse among Youth (Part 2)";
5. Paul Pigott, "sikkuginnait Kanuittusuatuinnanik Inuttut ice typology";
6. Dan Michelin and Sarah Blake, "Changing Climate, Changing Health, Changing Stories";
7. Frances Ross, "Northern Knowledge: Creating locally-relevant educational materials from community consultations and northern ecological studies";
8. Heather R. Ochalski, Community-led reduction of domestic violence in Aboriginal communities: rebuilding from resilience;
9. Dr. Colin P. Laroque and Dr. Mariana Trindade, Creating an extensive tree-ring sampling network in Labrador using living trees;
10. Dr. Trevor Bell and Dr. Martin Sharp, Recent Glacier Change in the Torngat Mountains, northern Labrador;
11. Luise Hermanutz, Nain Portion CiCAT - Climate Change Impacts on Canadian Arctic Tundra Ecosystems: Interdisciplinary and Multi-scale Assessments/ ArcticNet - Impacts of vegetation change in the Canadian Arctic: local and regional assessments;
12. Maria M'Lot/ Amanda Karst, "Remote Communities Quality of Life Project. Phase Three";
13. Colin Jones, NG Research Permit to conduct Harlequin Duck aerial surveys;
14. Lori Ann Roness Consulting, AAEDIRP research projects;
15. Dr. Andria Jones, "Engaging Northern communities in the monitoring of country food safety";
16. Audrey R. Giles, Ph.D., work with the Nunatsiavut Government, the Canadian Red Cross, and Transport Canada to better understand residents of Nunatsiavut's aquatic-related behaviours to develop, pilot,

and disseminate culturally sensitive and effective aquatic injury prevention resources for use within Nunastsiavut communities;

17. Dan Michelin and Sarah Blake, "Changing Climate, Changing Health, Changing Stories: a capacity development approach to community-based participatory health adaptation research in Nunatsiavut";
18. Dr. Andria Jones, DVM, PhD, Development of community-derived public education strategies in Nunatsiavut - Complementary research to International Polar Year (IPY) Project 2006-SR1-HW-141: Engaging communities in the monitoring of zoonoses, country food safety and wildlife health (Principle Investigator: Manon Simard) Nasivvik complementary funding Approved 2009;
19. Catharyn Andersen, "Aspects of Behaviour relating to Inuttitut in Nain, Nunatsiavut.";
20. Joseph M. Culp, The ARCTIC Freshwater BIOdiversity Research and Assessment NETwork: ARCTIC-BIONET;
21. Dr. Larry Felt, Harvest and Use of Country Foods in Nunatsiavut;
22. Dr. Marlene Evans, Temporal trends and spatial variations in persistent organic pollutants and metals in sea-run char from the Canadian Arctic;
23. Laura Fleming, MA Candidate, Climate Change Adaptation Management of Wildlife Resources;
24. David Bruce, A Study of the Atlantic Aboriginal Post-Secondary Labour Force;
25. Vincent Brodeur, wildlife biologist, M.Sc., Ministère des Ressources naturelles et de la Faune, Population dynamics and space use by migratory caribou of Québec-Labrador: impacts of industrial activities and climate change;
26. Christina Goldhar, M.A. Candidate, Assessing the vulnerability of drinking water systems in Nunatsiavut, Labrador
27. Brian Pritchard, MUN, Archaeological Identities and Interaction: Understanding Indigenous-European Relations and Cultural Developments in Central Labrador;
28. Pema Thinley, University of New Brunswick, Community Based Ecotourism as a Sustainable Development Option for the Communities in Jigme Singye Wangchuck National Park, Bhutan(South East Asia): A Learning from Torngat Mountain National Park Reserve, Canada
29. Sabina Wilhelm, Environment Canada, Monitor Common and Thick-billed Murre populations;
30. Sebastian Luque, Foraging behaviour of ringed seals in Saglek Bay, Labrador;
31. Beatrix Arendt, Hopedale Archaeology Project 2009 Fieldwork;
32. Scott Gilliland, Canadian Wildlife Service: Ecology of Surf Scoters Moulting in Northern Labrador;
33. Sherilee Harper, M.Sc. Candidate, potential impacts of climate change on surface drinking water quality and infectious gastrointestinal illnesses in Nunatsiavut, Canada;
34. Hermanutz, Luise, A., CiCAT - Climate Change Impacts on Canadian Arctic Tundra Ecosystems: Interdisciplinary and Multi-Scale Assessments (as seen in 2008 proposal). ArcticNet - Impacts of vegetation change in the Canadian Arctic: local and regional assessments (as seen in 2008 proposal). Climate change impacts on shrubs, berry biology and traditional use of berries in Nunatsiavut (2009);
35. J. Bruce Pollard, Environment Canada, North Atlantic Population Canada Goose Banding;
36. Reimer/Biasutti-Brown, Royal Military College, Marina Biasutti-Brown, Nunatsiavut Government, Stable isotope and fatty acid food web model of an Arctic coastal nearshore environment: evaluating the effects of climate change and modernization on trophic transfer and bioaccumulation in northern Labrador;
37. Chris Furgal, PhD, Update on "An Integrated Research Program on Arctic Marine Fat and Lipids: The Urqsuk Program;

38. Jenneth Curtis, Parks Canada, Ramah Bay Quarry Archaeological Research Project and, Sallikuluk Archaeology and Oral History Project;
39. Shelley Garland, Wildlife Division, Department of Environment & Conservation, 2009-2010 National Peregrine Falcon Survey - with additional small mammal, invertebrate and botany collections;
40. Phillips, Frank, Institute for Environmental Monitoring, NL Small Mammal Monitoring Network;
41. Jennifer Thorburn, Aboriginal English in Canada: A case study of Nain, Labrador;
42. Leroy Metcalfe, Sikumiut/Aurora - Inuit Knowledge of Postville and Makkovik;
43. Heather Igloliorte, A Century of Labradorimiut Artistic Production: 1890 to 1990 (working title);
44. Peggy Baikie/ DHSD, Survey of Seniors in Nunatsiavut;
45. Kristie Jameson, Food Security Network of Newfoundland & Labrador;
46. Kirk Dombrowski, Resource Development and Emerging Informal Structures in Northern Labrador, Nain June of 2009, and continue until August 2009, a one month follow-up visit and community presentation will take place in April or May of 2010;
47. Juliana Coffey, Torngat Wildlife, Plants and Fisheries Secretariat, 2010 Inuit observations of Land and Sea: Kavisilik (Atlantic salmon) and IKaluk (Arctic charr);
48. Jennifer Mitchell, Torngat Wildlife, Plants and Fisheries Secretariat, Moose Population and Density Estimate Survey Proposal – Area east of Moose Management Area 56 (Kaipokok) and north to Nain;
49. John Reid, New Economy Development Group, Fur Institute of Canada, 2010 Identification of Climate Change Impacts and Adaptation Measures by the Community Based Members and Organizations of the Fur Institute of Canada;
50. Amelia Fay, MUN, 2010-11 Black Island Archaeology Project: An Extraordinary Woman, An Extraordinary Life: Excavating Mikak's House to Explore the Status of Women and the Effects of Colonialism in 18th Century Labrador;
51. Paul H. MacDonald, Environment Canada, Gathering Aboriginal Traditional Knowledge from Nunatsiavut Community Members to Inform the National Recovery Strategy for Boreal Caribou;
52. Hilary Blake, Labrador Bachelor of Social Work, St. Thomas University, create networks with individuals and organizations for the purpose of building on and/or creating resources within the community of Nain;
53. Perry Billingsley, INAC, Assessing the Impacts of Self-Government;
54. Dianne Kinnon, NAHO, Respiratory Health Initiatives Environmental Scan – First Nations, Inuit, and Métis;
55. Alain Cuerrier, PhD, Université de Montréal, Climate change impact on Canadian Arctic tundra: how berry producing shrubs and medicinal plants are responding to warming and how it will affect Inuit health, Nasivvik Complementary Funding Initiative Proposal;
56. Garth Cant and Erina Okeroa, University of Canterbury, New Zealand, Co-Management of the Torngat Mountains National Park;
57. Evelyn Winters and Dr. Sharon Taylor, Nunatsiavut Government, Community Healing Project;
58. Catherine Carry, National Aboriginal Health Organization, Respiratory Health Initiatives Environmental Scan – First Nations, Inuit, and Métis;
59. Agata Durkalec, Trent University, ice monitoring and travel safety;
60. Jen Organ, Dalhousie University, Halifax, NS, Food Security, Ice, Climate and Community Health;
61. Dr. Ian J. MacRae, Contemporary Studies & Journalism, Wilfrid Laurier University, Siqqituq (Crossing Over): Land, Language, Culture and Tradition in the Canadian Arctic;

62. Stephanie Power, focus would be how involvement with physical activity and sport initiatives can lead to positive community development, as well as aid in health promotion;
63. Stephanie Cosgrove, University College Falmouth, The outcome is hoped to be a book of photographic work which incorporates oral history and text from the communities in the area, as a way of raising awareness of the impact of climate change;
64. Gerlis Fugmann, Justus Liebig University, Giessen, Germany, Circumpolar Concepts of Autonomy. Autochthon Development Perspectives of Inuit Societies. (Preliminary title);
65. Markus Dyck, Queen's University: Spatial ecology and bioenergetics of a keystone carnivore in a changing environment;
66. Charlie Mattina, Master's of Environmental Studies (Nature-based Recreation and Tourism) Candidate, Parks and Tourism, Lakehead University: Climate Change and Tourism Change in Northern Communities: A Vulnerability and Resilience Assessment;
67. EdwardTuttauk, Sivunivut Inuit Community Corporation Inc,North West River, NL: Traditional Local Freshwater Sources And Historical Hazardous Ice Areas In Lake Melville;
68. Derek Muir, Priority Substances Exposure Section, Aquatic Ecosystem Protection Research Division, Environment Canada: Contaminants in George River caribou; NCP Ringed seal collection in 2010;
69. Larry Felt, MUN, Possible joint, Atlantic Aboriginal Economic Development Integrated Research Program (AAEDIRP), the Atlantic Policy Congress of First Nation Chiefs Secretariat, The Organization of Nunatsiavut Elders and NG, research on elder knowledge and values in economic development policy;
70. David C. Natcher, Ph.D., Associate Professor, Department of Bioresource Policy, Business & Economics University of Saskatchewan Saskatoon, Larry Felt, MUN, and hopefully the Torngat Secretariat and NG, expand the harvest work we have done to seals within a larger context of nutrition and food security;
71. Larry Felt, MUN, The Torngat Wildlife and Plants Co-Management Board and the Torngat Joint Fisheries Board are working collaboratively with university researchers, the OK Society and a project manager to produce a documentary on char, salmon and caribou;
72. Sarah Erickson, AngajukKâk Director, Nain Inuit Community Government and Tom Sheldon Environment Division, Nunatsiavut Government: The development of an Inuit focused community monitoring program in Nain, Nunatsiavut: a pilot study for building capacity while adapting for a healthy future;
73. Scott Gilliland, Canadian Wildlife Service: Exploratory Winter Eider Survey: Hudson's Strait and Labrador Coast;
74. Dianne Kinnon, Director, Inuit Tuttarvingat (formerly Ajunnginiq Centre), National Aboriginal Health Organization: Respiratory Health Initiatives Environmental Scan – First Nations, Inuit, and Métis, Case Study Questionnaire;
75. Chris Furgal, PhD, Associate Professor, Indigenous Environmental Studies Program, Trent University and Tom Sheldon, Director, Environment Division, Department of Lands and Resources, Nunatsiavut Government: Inuit Knowledge and Geospatial Ontologies: The development of an Inuit Knowledge land classification and management system for environment and development in Nunatsiavut;

Improving communication, capacity and outreach with frontline workers in the Inuvialuit Settlement Region

Project Leader:

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Key Messages

- Projects that will continue into next year are the NCP-IRC Website, the NCP-IRC Newsletter and the initiation of the Long Term Strategy involving communities. In addition, the IRA will continue developing monitoring infrastructure by continuing to develop and update an internal IRA researcher/student database as part of website development.
- IRA's can be part of successful partnerships with researchers in which they are full participants throughout the process of community consultation, research and results. (i.e., MOM's, Cook Books series) A recent example of this is the workshop held in Inuvik with researcher, Mary Gamberg and the IRA. Community organizations in attendance

Messages clés

- Les projets qui se poursuivront au cours de la prochaine année sont le site Web du PLCN et de la SRI, le bulletin du PLCN et de la SRI et la mise en place de la stratégie à long terme faisant appel aux collectivités. De plus, le CRI continuera d'élaborer une infrastructure de surveillance en poursuivant l'élaboration et la mise à jour d'une base de données interne sur les chercheurs et les étudiants dans le cadre de la création du site Web.
- Les CRI peuvent établir avec des chercheurs des partenariats productifs dans le cadre desquels ils participent pleinement au processus de consultation des collectivités, à la recherche et à l'obtention de résultats (c.-à-d. MOM, la série de livres de cuisine). Par exemple, l'atelier qui a eu lieu récemment à Inuvik avec la

discussed with Mary ways to increase opportunities for Northern students to be part of projects like her in training or educational aspects.

- In all Inuit regions, there is a need to have concise understanding about the roles, responsibilities and structure of the IRA position. There is a need to develop an IRA Manuel and short Guides for researchers, students, host organizations and communities that clearly defines how to consult with an IRA and their Region.
- An IRA must have a good understanding of their regions resources for research (Schools, Research Centre's, etc) by researching how Governments, organizations and communities presently interact when dealing with research.

chercheuse Mary Gamberg et le CRI en est une illustration. Les organismes communautaires présents ont discuté avec M[me] Gamberg des façons d'accroître les possibilités, pour les étudiants du Nord, de participer à des projets comme le sien portant sur la formation ou des aspects éducatifs.

- Dans toutes les régions inuites, il est essentiel de bien comprendre les rôles et les responsabilités du CRI ainsi que la structure de son poste. Il faut créer un manuel pour les CRI et de petits guides destinés aux chercheurs, aux étudiants et aux organismes et collectivités hôtes qui définissent clairement la manière de consulter un CRI et sa région.
- Le CRI doit avoir une bonne compréhension des ressources de sa région en matière de recherche (écoles, centres de recherche, etc.) en étudiant la façon dont les gouvernements, les organismes et les collectivités communiquent actuellement concernant la recherche.

Objectives

- **Define IRA Role:** Assist with the development, with fellow IRA's and funding organizations, an in-depth IRA Manual and Consultation Guides for researchers, students, communities, and host organizations.
- **Newsletter/Website:** Continue to gather, evaluate and disseminate information on researchers, their projects, and the results of their work for beneficiaries to access through the IRC Health and Environment website and the IRC-NCP newsletter.
- **Database:** Further develop and update internal database of NCP, ArcticNet and Nasivvik research for the IRA to better assist and help researchers and beneficiaries who seek information about research in the region.
- **Partnerships:** Foster already established partnerships with other Inuit organizations, Governments, and national organizations to develop guides to benefit and educate researchers, students and other beneficiaries who seek jobs or careers in Science. (i.e., Gwich'in Renewable Resource Board (GRRB), Environment and Natural Resources (ENR), Canadian Wildlife Service (CWS), Department of Fisheries and Oceans (DFO) and Fisheries Joint Management Committee (FJMC).
- **Community Long Term Strategy:** Involve more Inuvialuit and Inuvialuit organizations in the development of a Long Term Strategy on communicating about contaminants through meetings and presentations. There is a need to have a more accurate representation of beneficiaries across the Inuvialuit Settlement Region.
- **Advertisement:** Continue to develop communication materials like the newsletter and guides, which are region specific utilizing local artists, students and other beneficiaries to gather advice on what beneficiaries think best represents them in their changing environment. This type of outreach could easily be accomplished by local and regional contests held in newspapers, IRC Board Summary's or on the internet.

- **Training/Education:** As IRA, there is a need to more efficiently communicate with researchers and beneficiaries on what the NCP, ArcticNet and Nasivvik have to offer students and communities. Information about Scholarships, funding and other opportunities for training and education should be made accessible via the newsletter, website and possible guides.

Plain Language Summary:

Newsletter

Building on successful communication, capacity building and outreach initiatives in the ISR, the Inuit Research Advisor (IRA) undertook a number of projects. The IRC Regional Newsletter was very successful and appreciated by communities and frontline workers in and outside of the ISR. With 4 editions published throughout this fiscal year, the newsletter has kept Inuvialuit communities, researchers and regional frontline workers up to date on what research is occurring in the ISR. Articles were written primarily by the Inuit Research Advisor, but many other contributions were made from researchers, project leads and even community members. For example, the IRA regularly requested updates from the three funders, ArcticNet, Nasivvik and NCP, which were included in each edition. Also, researchers such as Lisa Loseto of DFO contributed updates on the Hendrickson Island Beluga Project, and Meghan McKenna of ITK and Lorna Skinner of NCP gave updates on their respective organizations. Also, included in the newsletter are articles of more relevance to communities, such as those on local events, usually featuring youth and elders that people they are familiar with, and postings of opportunities for communities to apply to such as the Health Canada Climate Change and Health Adaptation Program. To date, there have been 6 editions of the newsletter printed and distributed, 2 from 2008 and 4 for 2009. The IRA wants to continue with the newsletter and make it available digitally (on the IRC website and by e-mail subscription) as well as in print form.

The cost of the newsletter has nearly doubled from the previous years because in 2008 there were only 2 newsletters and in 2009 the IRA did not account for this in the budget. Also, when the first estimates were made in 2008 the printer and designer company's were different. In 2009, the IRA had to change designers and printers used so now the newsletters are being printed out of Edmonton rather than Yellowknife and the prices are much different depending on how the newsletter is being shipped. In some editions, the newsletter is sent by ground where it is cheaper during months when we have access by winter roads or ferry and increased when these accesses are closed and the newsletters have to flown in to the region.

Inuvik Regional Working Group meetings

The first working group meeting was held in summer of 2009. There were representatives from various territorial and regional departments that attended to discuss improving communication of research results and information sharing. Some of the departments that took part included, Aurora College, Fisheries and Oceans Canada, Aurora Research Institute, Beaufort Delta Health and Social Services Authority, Inuvialuit Land Administration and Resource, Wildlife and Economic Development. The group discussed research licensing, data sharing and communication about the numerous research projects that are taking place in the region. It was recognized by those present that communication of research in the north, specifically in our region, is not on par with the amount of research that is occurring. From our discussions we found numerous gaps in communication and understanding of each other's protocols, not just from the licensing bodies but with Aboriginal organizations like IRC. We then decided that if the working group was to continue a Terms of Reference (TOR) needed to be developed and a plan set for a new working relationship. In order to be successful, the group needs to commit to meet at least twice a year to focus on building stronger relationships, data sharing and regional research priorities and messaging. The plan is to hold 1 more meeting in January and 2 others later in the year. The meetings will be held during working hours and the IRA will provide all meals and break time snacks and refreshments for participants who attend. The agenda for the 2 later meetings of 2010 have not yet been confirmed or set.

Community Tours

The tour consisted of 6 meetings –one was held in each Inuvialuit community. These meetings were held at local offices and venues throughout the region. The following dates, locations, and researched topics are documented: Paulatuk (August) meeting was held at the Visitors Centre Hotel Banquet Hall. Proposed projects included small scale caribou count for region around Paulatuk. Ulukhaktok (September) meeting was held at the Community Hall. The proposed project is to look at Fish Lake b/c of water and fish. Aklavik meeting was held at the Hamlet Chambers. The proposed project is h Pylori, or possibly another water quality project. Sachs Harbour (October) the meeting was held at the Hamlet Chambers. No clear decision on any proposed project as of yet. Tuktoyaktuk (November) meeting was held at the Hamlet Chambers and the Youth Centre. No clear decision on any proposed project as of yet. Inuvik (November) held in the IRC Foyer. The proposed project included looking at water quality and specifically looking at water quality in the sewage lagoon.

IRC Website updates 2010:

The IRC website finalized updating of the Inuit Research Advisor page in January 2010. The page can be viewed at www.irc.inuvialuit.com/community/inuitresearchadvisor/html. It is now a priority of the IRA to keep information on this page updated throughout the year. IRC has hired a web based consultant who already manages the IRC website to do this work. This work however, can be paid for through other sources of funding that the IRA gets from ArcticNet and Nasivvik. It will be more important to keep this information up to date as it contains current accurate such information such as IRA contact, IRA calendar and it's a place where people accessing the internet from anyway and easily upload the IRC Regional Research Newsletter and any other pertinent documents to the position. It will be a very useful tool to ensure proper communication about the IRA position, planned events and updates as they are made available.

Hendrickson Island Beluga Camp

This summer researchers were up at Hendrickson Island again to sample beluga with community and hunters from Tuktoyaktuk. Researchers are asking questions about beluga health to better understand their condition now and how things may change in the future. Two students from Tuktoyaktuk participated at the beluga camp in a youth mentoring program. Inuvik Fisheries and Oceans also visited the camp and helped with camp logistics and science. In partnership with the out-of-town scientists were a family from Tuk who were collecting tissues as part of a long term sample program with DFO. As part of the FJMC beluga monitoring program two monitors and their families were out collecting harvest data from the Tuktoyaktuk hunters.

Inuvik Research Working Group Meeting

The IRA held the first Inuvik Research Working Group meeting on September 3rd 2009 at the Midnight Sun Recreation Complex. The purpose of the group was to look at whether the community thought there was a need to have an established research working group that comes together twice a year to give updates on current research occurring in the region.

Participants included various government and aboriginal organizations that deal with research in the ISR as well as the GSA. During the meeting the IRA prepared and handed out information packages and did a PowerPoint presentation for the participants. The information packages contained information about the IRA position, ethics facts sheets, research guides and other materials that the participants were encouraged to share with their offices.

Results included discussions around other potential partners, discussed gaps in the current sharing of research information and results and brain stormed ways we could better communicate amongst one another on a regular basis.

NCP 6th Annual Scientific Meeting, Ottawa, Ontario

The IRA attended the Northern Contaminants Program (NCP) 6th Annual Scientific Meeting in September 2009. The IRA along with counterparts from Nunavut and Nunatsiavut presented ourselves and our various respective activities and projects we had been involved with during the year. During the NCP Working Group we discussed the four blueprints – areas of research and administration. These being Human Health, Education and Communications, Environmental Monitoring and Administration.

Inuit Research Advisor's Training Workshop
This workshop took place in late September 2009 at the ITK offices. It was organized by Nasivvik and ITK with all other funding and support organizations involved with developing the training outline and facilitation of the training modules. There were four modules: introduction to research methods, critical review of research, ethics, and an introduction to all three funders Nasivvik, NCP and ArcticNet.

Discussions and Conclusions

The Inuit Research Position is finally being standardized and established. After the IRA review the key challenges and benefits of the IRA position will have been clearly established. This will indicate where we need to build or change in order that the IRA position is helpful in aiding communities in defining their own research questions, will continue to build Western Arctic research capacity, and generate excitement for both science and research in general for the younger generation. The IRA manual, network building and continuation of projects undertaken by Inuit Research Advisors are a great start in helping us to reach these goals.

Expected Project Completion Date

March 31, 2011.

Inuit Circumpolar Council – Canada Activities in Support of Global Contaminants Instruments and Activities

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Abstract

This report outlines ICC Canada's activities funded by Northern Contaminants Program (NCP) in the fiscal year of 2009/2010. ICC Canada is working nationally and internationally to address the issue of contaminants in the Arctic. Activities include support to the NCP in the Management Committee, blueprint and proposal reviews, workshop organizations and participation, and preparations for the Canadian Arctic Contaminants Assessment Report III. Further, ICC Canada was very engaged in work related to the United Nations Environment Programme (UNEP), and was part of the Canadian delegation to the Stockholm Convention on Persistent Organic Pollutants (POPs). Negotiations were difficult but successful, and nine new chemicals have been added to the annexes for a total of 21 restricted or banned chemicals. ICC Canada continued to support Arctic Council activities, such as work for the Mercury Assessment of the Arctic Monitoring Assessment Programme (AMAP), where ICC Canada is co-authoring two chapters. ICC Canada is now also working on a communication strategy with other aboriginal partners, such as Inuit Tuttarvingat, ITK and Pauktuutit.

Résumé

Ce rapport fait état des activités du Conseil circumpolaire inuit (CCI) Canada financées par l'intermédiaire du Programme de lutte contre les contaminants dans le Nord pendant l'exercice 2009 2010. Le CCI Canada travaille à l'échelle nationale et internationale à régler les questions relatives aux contaminants dans l'Arctique. Les activités comprennent le soutien du Programme de lutte contre les contaminants dans le Nord au sein du comité de gestion, un plan et l'examen des propositions, l'organisation d'ateliers et la participation à des ateliers ainsi que les préparatifs pour le troisième rapport d'évaluation sur les contaminants dans l'Arctique canadien. De plus, le CCI Canada a beaucoup investi dans des travaux liés au Programme des Nations Unies pour l'environnement, et il a participé à la délégation canadienne à la Convention de Stockholm sur les polluants organiques persistants. Les négociations ont été difficiles, mais elles ont porté fruit. Neuf nouveaux produits chimiques ont été ajoutés aux annexes, pour un total de 21 produits chimiques dont l'utilisation est restreinte ou interdite. Le CCI Canada a continué de soutenir les activités du Conseil de l'Arctique, comme les travaux relatifs au rapport d'évaluation des niveaux de mercure du Programme de surveillance et d'évaluation de l'Arctique. Le CCI Canada est d'ailleurs co auteur pour deux chapitres de ce rapport. Le CCI Canada travaille aussi à l'élaboration d'une stratégie de communication avec d'autres partenaires autochtones, comme Inuit Tuttarvingat, Inuit Tapiriit Kanatami et Pauktuutit.

Key Messages

- ICC Canada worked actively to support NCP by working on the Management Committee, Environmental Trends and Monitoring Subcommittee, Blueprint Review Committee, and organizing committees of the joint NCP/AMAP Health Assessment Symposium, as well as the NCP Results Workshop.
- ICC Canada was part of the Canadian delegation to the Stockholm Convention on POPs, where nine new chemicals have been added to the annexes.

Messages clés

- Le CCI Canada a travaillé activement afin de soutenir le Programme de lutte contre les contaminants dans le Nord en siégeant au comité de gestion, au sous comité sur les tendances et la surveillance environnementales, au comité d'examen du plan et aux comités d'organisation du symposium conjoint sur l'évaluation de la santé du Programme de lutte contre les contaminants dans le Nord et du Programme de surveillance et d'évaluation de l'Arctique et en participant à l'atelier sur les résultats du Programme de lutte contre les contaminants dans le Nord.

- UNEP Governing Council agreed to negotiations for a legally binding agreement on mercury. ICC Canada continues its work to ensure that a strong agreement on mercury will be achieved.
- NSERC approved an Industrial R &D Fellowship study that is hosted by ICC Canada and investigates mercury isotopes in ice cores and snow samples to identify mercury pathways and sources to the Arctic. First snow samples have been pre-concentrated and will be analyzed as soon as possible.

- Le CCI Canada a pris part à la délégation canadienne à la Convention de Stockholm sur les polluants organiques persistants, qui a permis d'ajouter neuf nouveaux produits chimiques aux annexes.
- Le conseil d'administration du Programme des Nations Unies pour l'environnement a accepté de négocier un accord juridiquement contraignant sur le mercure. Le CCI Canada continue ses travaux visant à s'assurer qu'un accord solide sera conclu.
- Le Conseil de recherches en sciences naturelles et en génie du Canada a approuvé une bourse postdoctorale de R et D industrielle grâce à laquelle sera réalisée une étude du CCI Canada sur les isotopes de mercure dans les noyaux de glace et les échantillons de neige afin de comprendre la circulation du mercure et ses sources dans l'Arctique. Les premiers échantillons de neige ont été préconcentrés et seront analysés dès que possible.

Introduction

Inuit are Arctic Indigenous peoples living in Russia (Chuktoka), the U.S.A. (Alaska), northern Canada and Greenland. The Inuit Circumpolar Council (ICC) was founded in 1977, when Inuit across the circumpolar Arctic recognized that they need to have a united voice to represent them internationally, and to represent circumpolar Inuit in the respective countries. Since then, ICC has been growing into an internationally renowned organization with offices in each of the four countries. ICC is working successfully to address Inuit concerns on matters and overarching issues such as health, the environment, and culture. Among ICC's principle goals are the promotion of Inuit rights and interests on an international level and the development and encouragement of long-term policies that safeguard the Arctic environment.

A very important issue for Inuit is contaminants which undergo long-range transport, bioaccumulate in the Arctic ecosystem and lead to very high concentrations in some Inuit populations, potentially impacting their health and well-being. Funding by the Canadian government, and in particular the Northern Contaminants Program (NCP) of the Department of Indian and Northern Affairs (INAC), has enabled ICC Canada to work effectively on addressing the issue of contaminants in the Arctic. ICC Canada is part of the NCP Management Committee, is directly involved with contaminant research in the Arctic, works within the Arctic Monitoring Assessment Programme of Arctic Council, and represents Inuit at the United Nations Environment Programme and related meetings.

This report outlines ICC Canada's activities funded by NCP in the fiscal year of 2009/2010. The reporting requirement is detailed in the contribution agreement and addresses the deliverables as stated in ICC Canada's proposal 'International Inuit Contaminant Activities in Support of Global Instruments and Activities' for 2009/10.

Eva Kruemmel, Ph.D., is ICC Canada's Senior Health Research Officer and the principal investigator who assumes the NCP related tasks and management duties. The work was further supported by Duane Smith, ICC Canada's President, Violet Ford, ICC Canada's Vice-President, Pitseolalaq Moss-Davies, Research Coordinator, James Kuptana, Research Assistant and Stephanie Meakin, Science Advisor at ICC Canada.

General NCP activities

ICC Canada continues to support the NCP by participating as an active member in the relevant committees. Eva Kruemmel participated at the Management Committee Meetings in April 2009 and November 2009, reviewed pertinent documents and provided comments as requested. As a member of the Environmental Trends Subcommittee ICC Canada participated at pertinent teleconferences, reviewed proposals and provided comments there and via email as necessary.

Eva Kruemmel was a member of the organizing committee for the joint NCP/AMAP Health Assessment Meeting in Iqaluit, participated in teleconferences, and helped to coordinate Indigenous participation in the meeting. Eva Kruemmel participated in the meeting, which took place 10-12 June 2009 in Iqaluit, and gave a presentation about international policy on environmental contaminants.

Eva Kruemmel participated at a preparatory teleconference for the planning of the NCP 2009 Results Workshop, organized with the support of the NCP secretariat a cultural focus session at the Results Workshop, and gave a presentation on ICC's international action on contaminants. Violet Ford, ICC Canada's Vice-president, gave a keynote address at the NCP Results Workshop, which summarized ICC's activities on contaminant issues, and highlighted the successful partnership with the Canadian government in general and NCP in particular. The speech is attached to this report (Attachment A).

Eva Kruemmel was part of the Blueprint Review Committee for the Environmental Trends and Monitoring Envelope, attended the meeting and provided comments.

Eva Kruemmel provided input in the draft outlines of the third Canadian Arctic Contaminants Assessment Report (CARCAR III), and attended the CARCAR III mercury workshop organized by Environment Canada in Toronto, March 9-11, 2009.

Detailed activities according to deliverables in the 2009/10 proposal

I. Support for Stockholm Implementation, review and input in documents, travel to Fourth Meeting of the Conference of the Parties of the Stockholm Convention
Eva Kruemmel reviewed the relevant documents, took part in preparatory teleconference with government departments and provided stakeholder comments to Environment Canada. Eva Kruemmel attended the Stockholm Convention as part of the Canadian delegation for ICC Canada, and provided input and support at daily briefings and throughout the meeting. The negotiations at the Stockholm Convention proved to be very difficult, but in the end, nine new contaminants were being added to the annexes. Eight chemicals were added to Annex A (for elimination): α- and β-HCH, HexaBB, chlordecone, PeCB without any exemptions; lindane with a specific exemption for pharmaceutical use of head lice and scabies for humans; Penta-BDE and Octa-PDE with specific exemptions for articles containing the substances and inserting a new section in Part IV to Annex A which permits recycling of articles containing the two substances. PFOS and the related substances were most controversial. Finally, it was agreed to list it in Annex B (restricted use), with the addition of many uses such as for photo-imaging, fire-fighting foam, insect baits for leaf-cutting ants (acceptable purposes with no timeline to reduce PFOS); metal plating, leather and apparel, textiles and upholstery, paper and packaging, as well as rubber and plastics (specific exemptions: timeline for reduction of 5 years). Unfortunately no agreement could be found on a non-compliance mechanism and the discussion was referred to COP 5 (to take place 2011 in Brazil).

Eva Kruemmel also presented ICC Canada's contaminant-related work with NCP and AMAP at a side-event at the convention.

A meeting report of these activities was provided to the NCP as part of ICC's interim report in September 2009.

Eva Kruemmel participated in further de-briefing meetings (by phone and in person) which took place after the Stockholm Convention, and in which Margaret Kenny, Vincenza Galantone, and France Jacovella reported on progress within the government on the activities decided on during the Stockholm Convention.

ICC Canada's activities at the Stockholm Convention, meeting outcomes and implications where covered in various presentations and communication materials, such as:

- NCP/AMAP Health Assessment Symposium in Iqaluit, June 8 – 9 2009, where representatives for regional and territorial committees, national aboriginal partner organizations (such as ITK), and international partners were present
- NCP Results Workshop, Ottawa, September 29 – 30 2009, where representatives for regional and territorial committees, and national aboriginal partner organizations (such as ITK) were present
- Briefing notes and meeting reports
- Newsletter contributions presented at an IRA meeting at Inuit Tuttarvingat (NAHO), February 23rd, which were then additionally sent via email to Shannon O'Hara and John Lampe for consideration in their regional newsletters. The newsletter contributions are attached (Attachment B).

II. POPS Review Committee (POPRC) Related activities

ICC Canada has been unable to participate at the POPRC meeting in 2009, but has applied to NCP for funding to attend the meeting this year (October 2010).

In 2009, pertinent documents to POPRC meetings were reviewed and Eva Kruemmel was in contact with government scientists who attended past POPRC meetings (i.e., Derek Muir and Gregg Tomy) to acquire more specific information on matters discussed at the meetings and the meeting outcomes. The obtained information was used in communication materials (such as above mentioned newsletters) and briefing notes.

III. Inuit input into the UNECE LRTAP process

Eva Kruemmel reviewed documents for the 45th Session of the Working Group on Strategies and Review (WGSR) to the Convention on Long-Range Transboundary Air Pollution (LRTAP), United Nations Economic Commission for Europe (UNECE), August 31st to September 4th, 2009, and provided stakeholder comments to Environment Canada. The stakeholder comments on this meeting were attached to ICC's interim report to NCP in September 2009.

Eva Kruemmel also reviewed documents for the 27th Session of the Executive Body (EB) to the Convention on Long-Range Transboundary Air Pollution (CLRATP), UNECE, Dec. 14 – 18, 2009, and provided stakeholder comments to Environment Canada. The stakeholder comments are attached (Attachment C).

Eva Kruemmel has been in frequent contact with Cheryl Heathwood (per phone and in face-to-face meetings) on questions regarding the LRTAP Convention, to inquire about further information and new developments, and to provide direct feedback about ICC's position on issues in question at LRTAP meetings.

IV. Mercury related work

IV. i) United Nations Global Mercury Programme

Discussions at the UNEP Global Mercury Programme are underway to create a global legally binding agreement on mercury. ICC Canada's work is directed to further the discussions and provide the circumpolar Inuit perspective, since Inuit are particularly vulnerable to mercury exposure due to their often high consumption of marine mammals. In previous UNEP meetings, ICC Canada called for the creation of a strong, global legally binding agreement on mercury, and lobbied for support from other Nationals and organizations. Details have been provided in the previous Annual Report to NCP. Activities in 2009/10 focused on preparations for the upcoming Intergovernmental Negotiation Committees. In particular, ICC is a member of the non-governmental organization (NGO) group Zero Mercury Working Group (ZMWG), which is funded by UNEP and provides stakeholder inputs and participates at relevant meetings (such as Open-ended Working Group (OEWG) meetings on mercury, and Intergovernmental

Negotiation Committee (INC) meetings for a global treaty on mercury). Eva Kruemmel works actively with this group, and has been funded by this group in the past to attend relevant meetings. The ZMWG also works with respective governments to prepare for UNEP meetings, and teleconferences with Environment Canada and participants of the Canadian delegation to mercury relevant UNEP meetings have been organized by Eva Kruemmel to enable an information exchange of relevant positions in preparation to those meetings.

Additionally, ICC Canada participated in the regular stakeholder processes initiated by Environment Canada, for example a UNEP stakeholder meeting on September 28th at Environment Canada (Eva Kruemmel attended in person), as well as a UNEP partnership meeting held on February 8th at Environment Canada (this meeting was attended by Stephanie Meakin by phone).

Eva Kruemmel wrote briefing notes on mercury, which were sent to ICC's Board of Directors, the Executive Members, and Eric Loring (ITK). Information on the mercury negotiation process was also incorporated into Chapter 1 of the AMAP Mercury Assessment, which is currently in preparation (see below), as well as the newsletter articles that were shared with the IRA's and sent to Shannon O'Hara and John Lampe for inclusion into regional newsletters.

IV. ii) Arctic Monitoring and Assessment Programme Hg Experts Working Group

Efforts of the Mercury Experts Working Group are currently focussed on the development of the Mercury Assessment, which should be published in spring 2011. The assessment will provide input into the negotiation process on a global agreement on mercury, and has a high priority for ICC. ICC Canada's activities included participation in teleconferences and preparatory meetings for the Mercury Assessment, and the attendance of the Hg Expert Working Group meeting September 22-25, 2009. Eva Kruemmel also co-authored Chapter 1 (introduction) and Chapter 8 (health) of the assessment, participated in various teleconferences and email-exchanges on those chapters, reviewed the other chapters as part of the internal review process, and provided comments.

V.iii.) laboratory analysis of Hg isotopic fingerprinting, data analysis and compilation to start once funding secured

MeHg in the Arctic food web has been rising, and it is suspected that anthropogenic emissions are the reason for increasing MeHg concentrations. However, the mechanisms of how atmospheric Hg enters the arctic food-web are still not known. ICC proposed to investigate this through collaboration with the University of Ottawa (David Lean) and Trent University (Holger Hintelmann).

ICC submitted an Industrial Fellowship application to NSERC which built on a project funded by IPY and NCP that is led by David Lean and Christian Zdanowicz (University of Ottawa and Geological Survey Canada). Samples taken for this study from the Penny ice cap in Auyuittuq National Park are proposed to being analyzed for isotopic mercury fingerprints to determine the source of mercury to the arctic food-web. The application was successful, and Eva Kruemmel started working on this project in October 2009.

Eva Kruemmel submitted a separate proposal for the NCP Management Committee meeting in October for funds to do Hg isotope analysis for this project. The funding was granted, however, due to a delay in the reporting by Trent University, the funds have not yet been received. Nonetheless, snow samples from Greenland were provided to Holger Hintelmann at Trent University to test the method and determine which mercury concentrations in melted ice and snow are necessary to enable a meaningful analysis of mercury isotopes in those samples. The snow samples have been pre-concentrated at Trent University, and will be run for mercury isotope analysis as soon as possible.

IV. iv.) Monitoring of 9th International Conference on Hg as a Global Pollutant Guiyang, China

This activity also was directed to keep up-to-date on new developments in mercury research, which may be helpful in advancing global mercury negotiations. Eva Kruemmel obtained abstracts from the conference and reviewed those and other documents from this meeting and integrated this information in the general mercury work.

V. Regional and International/industrial Chemical Activities Related to NCP and Inuit Interests

ICC Canada started a process to improve and enhance communication of its work to other Aboriginal partners in the regions and ITK. In particular, ICC Canada proposed meetings of the NCP Aboriginal Partners Committee prior to NCP Manager Committee meetings, and is working on a broader communication strategy that also involves an enhanced information exchange with ITK. So far, Aboriginal partnership meetings were not possible at the last two NCP Manager Meetings, but will hopefully be held at future meetings.

Eva Kruemmel also had numerous meetings with Inuit Tuttarvingat of the National Aboriginal Health Organization (NAHO), ITK, and Chris Furgal of Trent University, to discuss possibilities of a common communication strategy on environmental health risks (including contaminants). Pauktuutit (the national Inuit women's organization) also joined the discussions more recently. Currently, Chris Furgal is working on a proposal that could be submitted to various funding agencies to enable the organizations to work together on a common communication strategy and its implementation. Eva Kruemmel reported these activities at the last NCP Management Meeting in April 2010, and was asked to include the regions (particularly Andrew Dunford and Janet Brewster from Iqaluit, Nunavut) in the discussions.

As of now, communication material on ICC's activities on contaminants has been provided through presentations, briefing notes and newsletter contributions as explained above.

VI. AMAP-related activities (review of documents – SAON, SWIPA, etc.)

Eva Kruemmel has been working with the Initiating Group (IG) of the Sustaining the Arctic Observing Network (SAON), and is now part of the SAON Steering Group (SG). As such, she participated at SAON teleconferences and worked with other PPs and CAFF representatives on a proposal on how to better integrate traditional knowledge and Indigenous participation in the SAON process. The group is also trying to achieve good involvement of community-based monitoring (CBM) within SAON. In October 2009, people from the ELOKA (Exchange for Local Observations and Knowledge of the Arctic) project joined the discussions. As part of ELOKA, it was planned to develop an inventory on CBM projects and research, and to assist Arctic communities in the development of their own research projects. To share their experiences and achieve a broader involvement, Shari Gearheard, Mark Parsons and Henry Huntington from the ELOKA group organized a workshop in Ottawa on March 1st 2010. The workshop was attended by various interested participants, including David Hik from the SAON SG, Scot Nicols (ITK), as well as James Kuptana and Eva Kruemmel from ICC Canada. At the workshop, ELOKA was viewed as a good initiative to support CBM projects within SAON. As a first step it was decided to develop a briefing paper that would be shared with participants at the SAON funders meeting March 18 – 19, 2010, to solicit further support. The briefing note is attached to this report (Attachment E).

Eva Kruemmel participated at the SAON funders meeting March 18-19 2010 in Miami, and co-chaired a breakout group on human health and well-being on March 18th together with Joan Nymand Larsen. As part of this work, Eva Kruemmel and Joan Nymand Larsen prepared a PowerPoint presentation to share with the plenary (which was presented by Joan Nymand Larsen the next day), and prepared a workshop report after the meeting (the meeting agenda and workshop report are attached). The outcomes were used in a SAON announcement for the International Journal of Circumpolar health (the announcement is attached, Attachment F), and will be part of a report on SAON developments and further steps to Arctic Council's upcoming Senior Arctic Officials meeting.

ICC Canada participated at the AMAP Health Expert Group meeting, which took place June 8-9, 2009 as well as the following NCP/AMAP Health Assessment Symposium in Iqaluit, as described earlier.

Eva Kruemmel attended the AMAP Heads of Delegation Meeting in Copenhagen, November 10 – 11, 2009, and the following Senior Arctic Officials Meetings (November 12 – 13, 2009) along with ICC's political leadership and other ICC delegates.

Eva Kruemmel participated in the external review process for the AMAP strategic framework review, and the internal review process during the AMAP meeting in San Francisco February 8 – 10 and the subsequent AMAP Heads of Delegation meeting (February 11 – 12, 2010).

James Kuptana provided input into Chapter 5 of the sea-ice component of the SWIPA report. Additions from James were contributed from ICC Canada's traditional knowledge study of the changes in Beaufort Sea and Amundsen Gulf sea ice.

Miscellaneous Activities

- Eva Kruemmel attended the Arctic Contaminants Action Program (ACAP) Working Group meeting that took place in September 16th – 18th 2009 in Ottawa and was asked by Cheryl Heathwood (Environment Canada, host for this meeting) to present a talk on NCP and involvement of aboriginal partners at that meeting. Eva Kruemmel prepared a PowerPoint presentation with support from Eric Loring (ITK) and gave this presentation at the ACAP meeting on September 17th. (The presentation is available on the ACAP website at: http://www.ac-acap.org/files/WGM%202009.09.16-18%20Ottawa/4_Presentations/ICC_ACAP_NCP_Sept09.ppt)
- Eva Kruemmel has been asked to co-convene a contaminant session at the upcoming IPY Conference in Oslo (June 8 – 12, 2010). Eva has reviewed and rated abstracts for this session, and participated in planning efforts for the session.
- ICC Canada (Eva Kruemmel and James Kuptana) attended the State of the Arctic Conference, March 16 – 19, 2010, in Miami.
- ICC Canada continues to sit on the Board of Directors and committees for various organizations with environmental and human health objectives and attends pertinent meetings, including:
  - Nasiviik Centre for Inuit Health and Changing Environments –Laval University
  - ArcticNet - The Integrated Natural/Human Health/Social Study on the Changing Arctic
  - Nipingit – The National Inuit Committee on Ethics and Research, which has been initiated by ITK and Inuit Tuttarvingat of the National Aboriginal Health Organization
- As part of the Nipingit activities, and sponsored by Inuit Tuttarvingat, ICC Canada created a poster to promote interest in research and research ethics in the Inuit regions. The poster makes the link between international policies and research in the Canadian Arctic, will be printed in English as well Inuit dialects and will be distributed to the Inuit regions with the support of Inuit Tuttarvingat.

NCP Performance Indicators

This proposal supported:

- work by James Kuptana, who is continuing his undergraduate studies at Trent University
- the organization of a session at the NCP/AMAP Health Assessment Symposium in Iqaluit
- contributions to two chapters of the AMAP Mercury Assessment

Expected Project Completion Date

Work is ongoing

Acknowledgments

NCP was acknowledged in all presentations and speeches given as part of the funded work.

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Attachments

A) Speech by Violet Ford at NCP Results Workshop

B) Newsletter Contributions

C) Stakeholder comments to Environment Canada for the 27th Session of the Executive Body (EB) to the Convention on Long-Range Transboundary Air Pollution (CLRATP), UNECE, Dec. 14 – 18, 2009

D) ELOKA briefing for SAON Funders Meeting

E) Meeting agenda and Human Health Breakout Session Report for SAON Funders Meeting

F) SAON announcement for International Journal of Circumpolar Health

Arctic contaminants: Exploring effective and appropriate communication between Inuvialuit communities and researchers

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Abstract

Using contaminants research conducted through the International Polar Year's Circumpolar Flaw Lead System Study, Environmental Monitoring Projects from the Northern Contaminants Program, and Phase II of ArcticNet, this project explores the communication of research results with the Inuvialuit community of Sachs Harbour, NT. Project objectives are to consider participants' knowledge and perceptions of contaminants research and how research is communicated to communities; examine current communication methods used; and discuss, from a community perspective, how contaminants research can be communicated to communities in accessible, understandable, and relevant

Résumé

En se fondant sur les recherches sur les contaminants de l'Étude sur le chenal de séparation circumpolaire réalisée dans le cadre de l'Année polaire internationale, les projets de surveillance environnementale du Programme de lutte contre les contaminants dans le Nord et la phase II d'ArcticNet, ce projet explore la communication des résultats de recherche à la collectivité inuvialuit de Sachs Harbour (Nunavut). Les objectifs de ce projet sont d'examiner les connaissances et les perceptions des participants à l'égard de la recherche sur les contaminants et la façon dont les résultats sont communiqués aux collectivités, d'étudier les méthodes de communication qui sont utilisées actuellement et de discuter, selon une optique

ways. Conducted in a participatory framework, this community-focused, collaborative study uses participatory video, semi-directive interviews and discussion groups, which offers participants the opportunity to engage in and lead the two-way dialogue, determining how their knowledge is represented.

Over the course of three visits in the community, ten initial interviews and numerous informal meetings have occurred to date to establish the information and understanding participants retained through any and all previous research communication efforts, such as presentations, reports, and contact with researchers. Preliminarily results indicate that 'contaminants' and 'contamination' are still viewed as very broad terms that include oil spills, garbage, and pollution from the south. This suggests that contaminants information, as perceived and communicated by researchers, is not retained in detail by most locals. Low levels of concern regarding the safety of eating country foods indicate that they are still regarded as being a healthy choice, and residents have commented that they intend on continuing to consume these foods. Additionally, the words 'climate change' and 'contaminants' were often used interchangeably by participants, indicating the need to develop a baseline understanding about contaminants to enable an understanding of the interactions of contaminants with climate change.

communautaire, de la façon dont les résultats des recherches sur les contaminants peuvent être communiqués aux collectivités de manière accessible, compréhensible et pertinente. Menée dans un cadre participatif, cette étude communautaire et collaborative fait appel à des vidéos participatives, à des entrevues semi directives et à des groupes de discussion. Les participants ont ainsi l'occasion d'entamer et de diriger un dialogue et de déterminer comment leurs connaissances sont représentées.

Dix entrevues initiales et de nombreuses réunions officieuses ont eu lieu jusqu'à maintenant pendant trois visites communautaires afin de déterminer quels renseignements les participants ont compris et retenus dans le cadre de tous les efforts de communication des résultats de recherche précédents, comme des présentations, des rapports et des discussions avec des chercheurs. Les résultats préliminaires indiquent que « contaminants » et « contamination » sont toujours considérés comme des termes très larges qui comprennent les déversements de pétrole, les déchets et les matières polluantes en provenance du sud, ce qui signifie que l'information sur les contaminants, telle qu'elle est perçue et communiquée par les chercheurs, n'est pas retenue en détail par la plupart des résidants locaux. Les gens s'inquiètent peu des risques liés à la consommation d'aliments du pays, ce qui signifie que ces aliments sont toujours considérés comme étant un choix santé, et les résidants ont indiqué qu'ils avaient l'intention de continuer à les consommer. De plus, les participants ont utilisé les mots « changements climatiques » et « contaminants » comme s'ils étaient interchangeables, ce qui signifie qu'il faut travailler à obtenir une compréhension de base des contaminants pour que les gens puissent comprendre les interactions entre les contaminants et les changements climatiques.

Key Messages

- The process of communicating contaminants research to Northern communities requires further attention, and requires a bottom-up, community-centred focus.
- While research in the North is viewed to be important, contaminants information communicated through presentations and reports are not being retained by locals.

Messages clés

- Il faut porter plus d'attention au processus de communication des résultats de recherche sur les contaminants aux collectivités du Nord et mettre l'accent sur une communication par la base axée sur les collectivités.
- Bien qu'on considère que la recherche dans le Nord est importante, l'information sur les contaminants communiquée par l'intermédiaire de présentations et de rapports n'est pas retenue par les résidants locaux.

- Communicating contaminants research needs to be explored from a community perspective that addresses the message in ways that are applicable and relevant to the daily lives of Northerners.

- Il faut explorer la communication des résultats des recherches sur les contaminants selon une optique communautaire et aborder la question de manière pertinente et applicable au quotidien des résidants du Nord.

Objectives

- Bring forward Inuvialuit knowledge and perceptions of contaminants, contaminant research, and how research is communicated and made accessible to communities
- Discuss contaminants issues in the context of their applicability to the daily lives of community members, and in the broader context of local and scientific knowledge of climate variability and overall environmental research throughout the North
- In conjunction with community members, explore culturally relevant and appropriate means of communicating contaminants research between Inuvialuit communities and researchers
- Use the contaminants research being conducted in the Beaufort Sea region as part of NCP Environmental Monitoring projects, ArcticNet Phase II and IPY CFL studies as the sources of research results to be discussed, as detailed above, with community members
- Present the process and outcomes of this project in the form of a community-led participatory video accompanied by a guide/report, developed in conjunction with community participants and with the regional Inuit Research Advisor, that incorporates a communications protocol for disseminating contaminants information
- Empower community members to engage in contaminants research occurring within and around their communities

Introduction

For over twenty years, Northerners have received information about contaminants and the potential impacts on wildlife and human health. Despite improved message sensitivity, years of considerable effort disseminating this complex information has resulted in only general awareness of contaminants issues (Myers and Furgal 2006). There has been little evaluation of past communication programs from the perspectives of Northern residents, and greater focus has been placed on the intended audience with less consideration of the communication process. It is suggested that we progress beyond rewriting research guidelines and instead focus on the way the research process itself is constructed (Gearheard and Shirley 2007).

In order for researchers and frontline workers to best inform community members about contaminants research, the voices in the community need to be heard; it must not be assumed that the best way to communicate results to communities is known without consulting the community members themselves. As such, this project focuses on exploring ways to best communicate contaminants research to Northern communities using a bottom-up approach that actively involves community members in the research process. Additionally, this project aims to develop a genuine collaborative research relationship with the community (Nickels et al. 2007) that encourages Northerners to be at the forefront of the research project, as there is a need for community-specific projects that can identify whether the objectives of contaminants communication efforts are being met (Furgal et al. 2005). Contaminants research conducted through the International Polar Year's Circumpolar Flaw Lead System Study, Environmental Monitoring Projects from the Northern Contaminants Program, and Phase II of ArcticNet are used as a case study to explore effective and culturally appropriate means of communicating technically complex contaminants research results with the Inuvialuit community of Sachs Harbour, NT.

Participatory research methodology has been used to examine adaptive capacity to climate change (Berkes and Jolly 2001) and local observations of climate change and sea ice in Sachs Harbour (Nichols et al. 2004); these projects provide a beneficial frame of reference and point of departure in working with the community of Sachs Harbour and with contaminants research. Using participatory video in conjunction with semi-directive interviews and focus groups will allow for participants, in addition to the PI, to guide the discussion (Huntington 1998), enabling the dialogue to truly incorporate different ways of knowing. The participatory paradigm and process through which communication is explored, in addition to the community-centred focus, distinguishes this project from previous contaminant-communication studies, as the process through which we explore communication is a means of communication in itself.

Activities in 2009-2010

Initial consultations in March 2009 confirmed that the community of Sachs Harbour would be interested in this project. As this study is highly relational, it requires extended periods of time spent in the community to ensure that the project accommodates participants' lives. The intention of the first trip to Sachs Harbour in July 20-August 21, 2009, arranged in consultation with the community, was to enable Breanne Reinfort (project PI) to begin establishing relationships, start a dialogue about project ideas, and identify interested community participants. Posters advertising the project were set up in several locations in the community, and Reinfort presented her ideas at the Hamlet Council meeting in August 2009. Informal meetings with individuals or small groups of people provided an open forum for people to express their questions, concerns and ideas for this project. In some instances, discussions freely led to local perceptions and concerns of contaminants, which helped begin the process of developing questions to be considered during the semi-directive interview and focus group discussions. Information sheets and consent forms were drafted as part of the ethics approval process, and were reviewed by participants, and at any point if they are deemed unsuitable, new forms will be created. Additionally, preliminary filming of life around town, to act as background footage, began. In consultation with several hunters and Elders, it was decided that the next trip should occur in October-November 2009.

For the second trip, Reinfort spent November 1-20, 2009 in the community, a time-frame that was acknowledged to be too short for the nature of this work. Eight preliminary semi-directive interviews were scheduled to take place; however only three were successful. One informal video session was recorded surrounding the preparation of country foods, framed as a type of 'cooking show'. Multiple attempts at setting up meetings with youth were unsuccessful, yet two individuals Reinfort met with expressed interest in being more involved in the project, such as developing a survey to be distributed among the community to people who are both participating and not participating in the interview aspect of the project. Additional filming of the town and residents in winter was conducted. In consultation with several participants, the following trip was suggested to occur beginning in February or March, 2010, to complete the preliminary interviews, work on the collaborative survey, and begin group discussions with the contaminants information.

By March 28-May 26, 2010 (the most recent trip), ten semi-structured interviews have occurred, in addition to many informal, non-video recorded meetings, and survey development is in progress. Filming of muskox and ice fishing was conducted on the land, in addition to the process of making muskox dry meat and cleaning muskox hides.

Three posters have been presented on this project thus far: one was presented by Reinfort at the 2008-2009 Northern Contaminants Program Results Workshop (Ottawa, September 28-30, 2009) and the same poster was presented by Gary Stern at the Circumpolar Flaw Lead System Study All-Hands Meeting (Winnipeg, November 1-5, 2009) where it was awarded an honourable mention. A second poster was presented by Reinfort at the 2009 ArcticNet Annual Scientific Meeting (Victoria, December 8-11, 2009), and a third poster was presented by Reinfort at the 2010 International Polar Year Oslo Science Conference (Oslo, June 8-12, 2010), where it received the Best Poster Award for Theme 6: Science Education, Outreach, and Communication.

a) Capacity Building

By using current contaminants research as a case study in how to communicate scientific results, participants in the project are engaged in contaminants issues in a way that is relevant and applicable to them. Conducted within a participatory methodological framework that endeavours to challenge the roles of 'the researcher' and 'the researched' (Kindon 2003), this community-focused, collaborative study involves interested locals in all project stages. Participatory video, used during semi-directive interview and focus group discussions, offers participants the opportunity to identify and develop the questions and topics to be discussed, engage in and lead the investigative inquiry, facilitate two-way dialogue, and determine how their knowledge is represented. Filming the discussions, editing the video footage, and storyboarding are other ways participants engage with the project. A questionnaire incorporating rank-ordered and open-ended questions to complement the video aspect is being created with youth participants for distribution throughout the community. There are opportunities for participants to make presentations to middle school classes, regarding contaminants research or their involvement in this project, highlighting the importance of communication within and among the community in a way that is relevant and applicable. In emphasizing collaborative inquiry and celebrating local knowledge, this project aims to be an emancipatory process with the potential to increase local capacity in contaminant issues, encouraging Northern involvement, empowerment, and leadership in Arctic research.

Most of the capacity building opportunities mentioned will occur in the 2010-2011 fiscal year, as 2009-2010 work largely focused on the initial consultations, communications, raising awareness, setting up the project, and establishing relationships with individuals. In a way, the capacity building in a different sense has largely been on Reinfort's part as she becomes familiar with community life and culture, working on establishing a different presence as a researcher working in collaboration with the community.

b) Communications

Since this project is about the communication of contaminants research results to the community and involves participants in all stages of the project, dissemination of research results is an ongoing and iterative process. The participatory paradigm and process through which communication is explored, in addition to the community-centred focus, distinguishes this project from previous communication efforts, and was developed for participants to consider the effectiveness and appropriateness of this project as a possible means for communicating contaminants research. Thus, the process through which we explore communication is a means of communication in itself.

Prior to the start of this project, in February, 2009, Reinfort gave a presentation to the NWT RCC in conjunction with the review process of the 2009-2010 NCP funding proposal, describing the proposed work. In March, 2009, Reinfort and Stern (Project Team Member) joined colleagues from ArcticNet and the IPY CFL project on a community tour to Sachs Harbour which enabled personal contact to be established. Since this project heavily involves members of the community, consultations as to the best time to arrange Reinfort's first trip were determined to be the summer of 2009. During this first trip, Reinfort distributed posters around the community advertising the project, and presented her ideas at the Hamlet Council meeting in August 2009. As relationship-building is central to this project, Reinfort concentrated on informal meetings with locals to discuss the project, spending time speaking with people at the Sachs Harbour Community Corporation, Health Centre, Aulavik National Park Office, and in peoples' homes. A plain language summary of the project will be appearing in the next IRC newsletter as assembled by Shannon O'Hara (IRA) that are distributed to communities in the Inuvialuit Settlement Region. Copies of posters that Reinfort presented at several recent conferences are being given to the community for educational display and as material for project discussion.

c) Traditional Knowledge

Knowledge sharing forms the basis of this communication project, because by sharing, knowledge is viewed as a collective benefit (Smith 1999). Local traditional knowledge is an integral part of the dialogue surrounding this project; however the focus moves beyond *what* (knowledge as topic) and focuses more on *how* (knowledge as process). Thus, this project incorporates how local knowledge is communicated between community experts and researchers, incorporated into scientific studies, and how knowledge is attributed and interpreted.

Additionally, if scientific information is expected to be adequately disseminated in Northern communities, it is pertinent to discuss culturally appropriate modes of communicating these results to different audiences (e.g. frontline workers, hunters, youth, Elders, etc.) while forming open, honest relationships. Since Indigenous knowledge encompasses cultural knowledge on social customs, contexts, ethics and worldviews, it is extremely important to the relational aspect of this project. Conducting the project with a 'bottom-up' focus enables the perceptions and knowledge of locals regarding contaminants information to be heard, valued, and attributed, thus advising researchers on how to disseminate their research cross-culturally in an appropriate and relevant manner.

Results

Preliminary observations from June-August, 2009: Contaminants discussions frequently involved concern that the town's drinking water supply, being in proximity to an abandoned weather station, was being contaminated due to leaching lead paint and potentially asbestos; additional concerns regarded subterranean gases such as methane being released as permafrost melts and the land sinks.

Preliminary results from November 2009: The first interviews indicated that contaminants were consistently referred to as oil spills, and conversations frequently turned to climate change and the state of the ice. Only one of the three participants expressed any concern about eating country foods due to contaminants.

Preliminary results from March-May, 2010: Most participants have found research in the North to be a 'good idea' and are aware of the various means used by researchers to communicate their findings. Research presentations in the community are seen as positive; however, only 20% of participants could remember learning anything about contaminants at these presentations. The same 20%, who are actively engaged in research initiatives, were the only ones to identify specific contaminants that are being studied by researchers. Talking about contaminants usually lead to discussions about the visual changes seen on the land due to climate change. Contaminants are not currently viewed as a threat to consuming country foods, as several participants expressed that Sachs Harbour is too far North to have yet received contaminants in their food.

Discussion and Conclusions

The need for culturally appropriate communication of contaminants messages has been emphasized through the past several years of NCP's Education and Communication projects; instead of working exclusively with frontline workers, this project focuses on collaborating with community participants to explore a different way of approaching the concept of communicating contaminants research. In Sachs Harbour, this project has received much positive feedback for how it is being conducted, and it has been continually emphasized that the extended time that Reinfort spends in the community is greatly appreciated. This illustrates the importance of long-term visits within the community and the value in open, honest relationship-building both prior to and during the project.

Through the first year of this project, perceptions, concerns, and levels of comprehension about contaminants are shown to be variable, consistent with findings by Oakes (2009), Furgal et al. (2003), and Myers and Furgal (2005). Initial interviews with participants were conducted to establish the information and understanding they had retained through any and all previous research communication efforts, such as presentations, reports, contact with researchers, etc. These interviews remain to be transcribed and fully analyzed, but they have preliminarily indicated that 'contaminants' and 'contamination' are viewed as very broad terms that include oil spills, garbage, and pollution from the south, suggesting that contaminants information is not retained by most locals. Low levels of concern regarding the safety of eating country foods indicate that they are still regarded as being a healthy choice, and residents have commented that they intend on continuing to consume these foods.

Many participants expressed the importance of scientific research in the North and that research presentations to the community are beneficial, but there was the tendency to speak more of climate change than contaminants; changes in the environment are recognized visually, enabling an easier interaction with climate change research, whereas invisible contaminants still represent a difficult issue with which to contend. The words 'climate change' and 'contaminants' were often used interchangeably by participants, indicating the need to develop a baseline understanding about contaminants so as to better understand their impacts on, and how they are affected by climate change.

It is critical that this baseline level of understanding is not presented in a way that propagates the current method of presenting information; the next steps in this project involve in-depth discussion groups where participants interact directly with contaminants information to explore how contaminants research can be communicated from a community perspective in a way that is relevant to their daily lives. Work will focus on appropriate messages and ways to deliver the messages within the community, to other communities, and provide guidelines and suggestions to researchers on how to communicate their contaminants findings. The collaborative survey currently in progress will be disseminated throughout the community, and towards the end of the project, a survey will be co-developed to evaluate this project for its usefulness in communicating contaminants research findings. This work will continue to be video-recorded to document the process of this project, and to act as a potential communication tool for delivering the community's perspective on contaminants messages.

NCP Performance Indicators

- Number of northerners engaged in project: 23 to date
- Number of meetings/workshops held in the North: 28 semi-directive interviews/informal meetings to date; additional group meetings are planned as the project continues
- Number of students involved in NCP work: currently two, anticipated six as project continues
- Number of citable publications: 3 posters presented at conferences, to date

Expected Project Completion Date

Anticipated completion in February 2012, following video premiere in Sachs Harbour and defence of the thesis associated with this research.

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Beluga Communication Package for Inuvialuit Settlement Region (ISR)

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Abstract

The traditional hunt for belugas is an important cultural and nutritional event in the Inuvialuit Settlement Region (ISR). The beluga whale remains an important part in the healthy diet for many Inuvialuit. Therefore it is critical that any scientific information communicated back to Inuvialuit is done in a cultural appropriate and contextual manner to reflect overall picture of beluga health. Beluga research is being conducted on many fronts to understand the health of the beluga population and the health of the ocean

Résumé

La chasse traditionnelle du bélouga est une activité culturelle et nutritionnelle importante dans la région désignée des Inuvialuit. Le bélouga est un élément important d'un régime sain pour un grand nombre d'Inuvialuit. Il est donc essentiel que tous les renseignements scientifiques qu'ils reçoivent leur soient communiqués de façon appropriée sur les plans culturel et contextuel afin de leur donner un aperçu général de la santé des bélougas. Des recherches sur le bélouga sont menées selon divers angles afin de comprendre la santé des bélougas et

they inhabit. Local knowledge of the beluga is being gathered and shared in the traditional Inuvialuit ways. Bringing these two knowledge systems together in the form of a contextualized communication package is the goal of this study. Foremost to the success of this project is the need to train a local youth to help bridge the two knowledge systems and develop and communicate beluga information back to the community. The program was achieving the goal of better communication using a holistic approach by incorporating all science programs together and so the program began to shift focus toward better integrating the community to share their knowledge. This will strengthen the partnership between science and community by opening up a opportunity for the community to share their knowledge and observations with scientists.

de l'océan dans lequel ils vivent. Les connaissances locales sur le bélouga sont regroupées et communiquées par les moyens traditionnels des Inuvialuit. Cette étude a pour but de mettre en commun ces deux systèmes de connaissances dans le cadre d'une trousse de communication contextualisée. Pour assurer le succès de ce projet, il est essentiel de former la jeunesse locale afin de jeter un pont entre les deux systèmes de connaissances et de préparer l'information sur les bélugas pour la communiquer aux collectivités. L'objectif était d'améliorer la communication dans le cadre d'une approche holistique en regroupant tous les programmes scientifiques, puis l'orientation a changé et on a commencé à mieux intégrer les collectivités pour qu'elles communiquent leurs connaissances. On renforcera ainsi le partenariat entre les scientifiques et les collectivités en permettant à ces dernières de communiquer leurs connaissances et leurs observations.

Key Messsages

- Communication package being lead and delivered by a local organization Tuktoyaktuk Hunters & Trappers Committee and local youth Rebecca Pokiak to develop and deliver a communication package incorporating both science and local knowledge of the beluga whale to the community.
- Work with scientist to contextualizing scientific information about the overall health of beluga whales into one communication package
- Combining local knowledge and observations into scientific results will be the focus of the next phase of the program

Messages clés

- Le projet de trousse de communication est dirigé et réalisé par une jeune femme de la région : Rebecca Pokiak, du Comité des chasseurs et des trappeurs de Tuktoyaktuk, une organisation locale qui élaborera et offrira une trousse de communication comprenant des connaissances scientifiques et locales sur le bélouga à l'intention des collectivités.
- Travailler avec des scientifiques pour mettre en contexte l'information scientifique sur la santé générale des bélugas et la regrouper dans une trousse de communication.
- La prochaine phase du projet consistera à combiner les connaissances et les observations locales avec les résultats scientifiques.

Objectives

a. To work with the local community and provide them with the tools (material, mentoring, and training) to develop a relevant communication product for their (my own) community.

b. Work closely with beluga research scientists to learn what their findings are concerning the health of beluga whales in and near my community of Tuktoyaktuk, to synthesize findings and develop a regional and community strategy that integrates all programs (NCP, ArcticNet and IPY)

c. Increase the cohesiveness among western arctic beluga programs funded within and outside of NCP that will enable all project participants to be fully aware of all on going western arctic beluga studies.

d. Collaborate more closely with ITK, FJMC and traditional knowledge programs (Inuit Knowledge Center) to incorporate regional insight and community knowledge on the health and well being of beluga whale along side western science.

e. Work closely with the community of Tuktoyaktuk –in asking community members what information they would like to receive from scientists.

f. Provide an ongoing opportunity for the inclusion of traditional knowledge to be incorporated together with scientific information

Introduction

Communicating contaminants information has evolved over the years in placing specific scientific results into a greater contextual package for community's members to understand the overall health of arctic animals. The beluga whale research taking place in the Inuvialuit Settlement Region (ISR) provides an excellent opportunity to bring scientist and community members together in the development of an overall communication package that includes not only contaminant data but information about the overall health of the beluga whale. This communication effort is partnered and conducted by local residence throughout the course of the year. This provides the opportunity for local insight from community elders and youth. The principle investigator of this project, a youth from Tuktoyaktuk, has been working for the past few years with both the community hunters and the beluga whale researchers to facilitate better communication. This communication strategy will focus its efforts entirely within the community framework.

All NCP funded projects are encouraged to have a strong communication strategy with local community members as well as community involvement in projects. To reduce community consultation redundancy and increase the cohesiveness of these beluga research programs, it was suggested that a unified communication strategy/ package should developed for use when presenting results back to the community. Thus, all beluga programs could be presented together to enhance the clarity of the progress being made on beluga research. There are a large number of beluga health related research programs taking place at Hendrickson Island (hunting area for community of Tuktoyaktuk) that fit under the umbrellas of IPY, NCP, ArcticNet and DFO funded projects, that are required to present research results back to the communities. Therefore, the creation of a holistic communication package that summarized all beluga related research in partnership with ITK would elevate the number of presentations and any confusion associated with the multiple programs on beluga as well as offer a new an unique perspective on developing successful communication practise.

Activities 2009/2010

Spring Invited Lectures

The year began with the program being invited to share and participate in the First Nations Tradition Foods Conference in Nanaimo BC, lead by Dr. Peter Ross (April 17-18 2009). The event focused on the health benefits of traditional foods along with presenting recent studies on contaminants (http://www.snuneymuxw.ca/snuneymuxw_gallery/seafood.htm). Given the commonality of concerns it was an ideal opportunity to share knowledge and experience between both aboriginal cultures. L. Loseto and N. Pokiak were able to attend. N. Pokiak gave a lecture about traditional lifestyles in Tuktoyaktuk and how she and her family work together with scientist to learn from one another about below. She spoke about the importance of working together on beluga whale health. The presentation was well received.

Summer Field Related Activities 2009

This year the beluga program at Hendrickson Island decreased in size as S. Ostertag/L. Chan did not carry out a field component for 2009. We continued to work closely with other science programs to integrate and present them under one umbrella to communities for approval. One of the tools that helped bring the group together was the pamphlet created that described the research taking place at the island (Appendix

1). Since our sampling efforts took place on Hendrickson Island, we focused our communication efforts with the community of Tuktoyaktuk, as hunters from other ISR communities to not visit Hendrickson Island. However, the pamphlets were distributed to the Inuvialuit Game Council (IGC), FJMC, Inuvik HTC and the DFO Inuvik Area office.

Once approvals were received R. Pokiak advertised the research program at the school and posted applications for the youth program (Kitty Hall, post office and the THTC office in Tuktoyaktuk). Two summer students were hired again to participate in the field program. R. Pokiak helped to prepare the students for work at Hendrickson island. One of the students (J. Noksana) took an interest on traditional knowledge surrounding the beluga hunt. In addition to helping out with the science aspects of the program she also spent time with F. and N. Pokiak to learn more about their observations and knowledge they wanted to share.

The beluga sampling program took again took on a holistic field approach in July 2009. The integration of field efforts enhanced communication and awareness among science and community sampling programs. All participants worked closely together to sample whales in partnership with the hunters. This year when the hunters were approached for permission to sample the whale the pamphlet was provided that detailed the program and people involved. On the island were several families who participated and helped with the program. The coordinated presence at the field camp helped facilitate communication with those who wanted to learn more about the program.

Hendrickson Island Beluga Sampling Team 2009

Program	Field Personal	Operations
FJMC Whale Monitoring	John Panalutluk, Ronald Felix (and family)	Record morpho, Jaw (age)
NCP Stern, Tomy	Pokiak Family	Tissue sampling chemicals
NCP Ross/Loseto	Loseto, Noel, Ross	Tissue sampling health
CFL Ferguson/ Raverty	S. Raverty	Tissue sampling disease
FJMC Loseto/ Ross	R. Walker, J. Noksana	Mentoring/ training

The two students (R. Walker, J. Noksana) wrote about there projects and experience on the island that was then published in the Tusaayaksat (Appendix 2).

Fall Communication Events

A summary of field activities was submitted to the Tukoyaktuk HTC and FJMC in September 2009. Additionally, photos of the individual hunters with their whales were sent to the TukHTC to share with the hunters. The student articles were released in the fall issue of the Tusaayaksat that was well received by community. Additionally L. Loseto and M. Noel prepared a short communication piece about Hendrickson Island for the IRC Inuit Health Newsletter (S. O'Hara).

Prior to the annual NCP meeting in September R. Pokiak was invited to sign up for the Inuit Research Advisor Training Workshop training offered by ITK and Nasivvik (Sept 27-28 2009) in Ottawa. L. Loseto and E. Loring presented on behalf on R. Pokiak for the program at the NCP workshop. As a young mother it is sometimes hard to leave the community to attend such workshops and training and its important for research programs to understand the difficult realities at the community level and the need to provide family support to attend important activities.

The Hendrickson Island program and the partnership between community and science resulted in the invitation of N. Pokiak and L. Loseto to give a joint lecture to the Assistant Deputy Minister of DFO Science in Ottawa (Nov 27 2009). The talk was titled: Perspectives and Values: Lessons learned from a collaborative beluga research program in Tuktoyaktuk NT. Travel and support was provided by the communications program. Additionally N. Pokiak invited to be a guest speaker at the National Aboriginal Health Organization (NAHO) conference that took place just before the ADM lecture in Ottawa.

Photo: Dr. W.W.Wright (DFO ADM Science) introducing N. Pokiak, Dr. L. Loseto and their lecture to the seminar series (Ottawa, Nov 27 2009).

Following the fall communication events part of the team attended the ArcticNet meeting in Victoria to meet and discuss the next steps forward. J. Noksana, one of the mentoring students attended the meeting and wrote a report about her experience to share back at school. The project had reached a phase whereby bring the science community together in a team fashion was progressing but the social and TEK component needed more attention. M. Pokiak who was out at Hendrickson Island was interested in the program and learning more about it. Her background and experience in creating a beluga traditional knowledge exhibit at the Prince of Whales Museum in Yellowknife had significant application for this program. L.Loseto, E. Loring held meetings with M. Pokiak and social science expert M. Andrachuck to begin planning a new phase for the program.

Winter Meetings and Communications

Attended and presented at the Inuvialuit Game Council meeting in Inuvik on March 8th.

The presentation was a holistic beluga group presentation given by L. Loseto, S. Ostertag and R. Pokiak. Prior to presenting to Game Council R. Pokiak reviewed all of our science slides and advised on how to better share information with the community and how to better address questions they would have. L. Loseto and S. Ostertag summarized all science programs in a holistic approach, and R. Pokiak summarized her communications program and presented the next steps and new phase of the program that would integrate TEK and social science aspects.

A similar presentation was given the following day in Tuktoyaktuk for the HTC, Hamlet and the Tuktoyaktuk Community Corporation. All boards were brought together to hear about the entire program and provide feedback to the new TEK component that would begin this summer.

Following the positive feedback a meeting was held in Yellowknife to draft the new proposal for NCP that would incorporate TEK. Additionally a new pamphlet was drafted for the summer of 2010 that would focus on TEK application to science titled “sharing knowledge on beluga and beluga health”.

Finally some feedback was provided on the pamphlets and a common comment was there was too much text to read through. This will be taken into consideration for the next pamphlet.

Conclusion

The Northern Contaminants Program continues to try and find new innovated tools to communicate scientific information back to communities. With many research programs and scientists working on beluga whales in the ISR it important programs communicate with one another and develop and effective communication strategy with community partners. Working with a community lead, R. Pokiak as well as elders such as N. Pokiak has pushed the program to try new ways of communicating which as strengthened the ability of scientists to share knowledge with communities. While the program continues to try out new and innovative ways of communicating it is now moving toward the final objectives that will encourage community members to share their knowledge with science. This part of the program will be lead by two community youth that will likely grow in bring in new partners and ways of sharing knowledge.

The Nunavik Inuit Research Advisor: Building Health and Environment Research Capacity in *Kativik Regional Government* (KRG)

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Abstract
The Nunavik Inuit Research Advisor (IRA) continues to serve as the first step in a more coordinated approach to community involvement and coordination of Arctic science in Nunavik. The IRA position is housed within the Renewable Resources Department of the Kativik Regional Government (KRG) and works closely with the Nunavik Nutrition Health Committee (NNHC) and the Makivik Research Center. The objective of the IRA position in Nunavik is to help facilitate research both at the program level, assisting researchers from the Northern Contaminants Program (NCP), ArcticNet and Nasivvik, as well as preparing communities in advance of research. Together, with IRAs in the other Inuit regions of Canada, the Nunavik IRA works towards achieving a new way of knowledge

Résumé
Le conseiller en recherche inuite au Nunavik (CRI) est toujours la première étape d'une approche plus concertée en matière de participation communautaire et de coordination des sciences arctiques au Nunavik. Le CRI travaille à l'administration régionale Kativik (Ressources renouvelables, Environnement et Aménagement des terres) et collabore étroitement avec le Comité de la nutrition et de la santé du Nunavik et le Centre de recherche du Nunavik de la Société Makivik. Le CRI au Nunavik est chargé de faciliter les recherches dans le cadre du programme en aidant les chercheurs du Programme de lutte contre les contaminants dans le Nord, d'ArcticNet et de Nasivvik, ainsi qu'en préparant les collectivités aux recherches. Avec les CRI d'autres régions inuites du Canada, le CRI du Nunavik cherche un nouveau moyen de

sharing and engagement of Inuit in Arctic science and research. In addition to NCP support, the Nunavik IRA position is co-funded by ArcticNet and the Nasivvik Centre for Inuit Health and Changing Environments.

mettre en commun les connaissances et de faire participer les Inuit aux activités scientifiques et aux recherches dans l'Arctique. En plus de l'appui du Programme de lutte contre les contaminants dans le Nord, le travail du CRI du Nunavik est cofinancé par ArcticNet et le Centre Nasivvik pour la santé des Inuits et les changements environnementaux.

Key Messages

- Shifting the way we see and do research in the Arctic and in Inuit communities.
- Providing input and direction to three major Arctic Research Programs (NCP, Nasivvik and ArcticNet).
- Helping researchers and communities coordinate and communicate information.
- The IRA is developing to be a first point of contact for all researchers conducting work in Nunavik.
- The IRA sits on the Nunavik Nutrition and Health Committee providing a voice in the NCP proposal process and communication of NCP health information to Nunavik communities.
- The IRA undertook a number of diverse tasks for KRG ranging from attending workshops/meetings to collaborating and networking with researchers.
- The IRA also undertook a number of tasks for both ArcticNet and Nasivvik, helping to create linkages and avoid overlap in research activities.

Messages clés

- Changer notre façon de voir et de mener des recherches dans l'Arctique et les collectivités inuites.
- Offrir des commentaires et une orientation dans le cas de trois grands programmes de recherche en Arctique (Programme de lutte contre les contaminants dans le Nord, Nasivvik et ArcticNet).
- Aider les chercheurs et les collectivités à coordonner et à communiquer l'information.
- Le CRI est le premier point de contact pour tous les chercheurs qui mènent des recherches au Nunavik.
- Le CRI est membre du Comité de la nutrition et de la santé du Nunavik. Il fournit son point de vue concernant le processus de propositions du Programme de lutte contre les contaminants dans le Nord et la communication de l'information sur la santé aux collectivités du Nunavik.
- Le CRI a entrepris diverses tâches pour l'administration régionale Kativik. Il a entre autres assisté à des ateliers et à des réunions et a collaboré avec des chercheurs et établi des liens avec eux.
- Le CRI a aussi entrepris certaines tâches pour les programmes ArcticNet et Nasivvik. Il a contribué à créer des liens et à éviter les chevauchements dans les activités de recherche.

Objectives

- Provide liaison support and help communicate NCP research back to Nunavik communities
- Facilitate and foster more community-based research
- Assist in the development of local research capacity
- Provide information regarding research in Nunavik and opportunities for local involvement

- Liaise with national and international organizations and other Inuit regional organizations in matters related to Arctic science and research
- Communicate with, and inform, the Nunavik population about contaminants research and the results of NCP studies.
- Provide support and advice to communities (e.g. review and provide advice on the adjudication of proposals) on research from the NCP.
- Provide support and direction for researchers coming to work in Nunavik and help with communicating the results back (e.g. to communities, policy makers, local decision makers) in a responsible and collective manner.
- Identify opportunities for youth to become engaged in NCP research and science.
- Member of the NNHC

Activities in 2009-2010

Rynee Kokiapik worked as the Nunavik IRA from September 2009 to April 2010, taking over the role from Greg Brown. The following list provides a summary of activities for the duration of Rynee's employment:

- Attended the IRA Training Workshop with Annie Baron in Ottawa, ON from September 27- 29, 2009.
- Attended the 17th Annual NCP Results Workshop in Ottawa, ON from September 29 – October 1st, 2009
  - Promoted and provided information on relevant research initiatives in Nunavik
  - Networked and communicated with researcher planning future projects in Nunavik
- Participated In the NNHC Meeting In Quebec June 2009
  - Attended Food Securtity Conference lead by Chris Furgal
  - Developed new criteria for NCP proposal review
  - Discuss Nunavik role in ethic review
  - Provided comments to the development of Childcare Center Nutrition Project
  - Heard presentations about omega-3 fatty acid as protective factors of alcohol prenatal exposure.
- Participated in the NNHC meeting in November 2009 in Kuujjuaq, QC.
  - Reviewed research from the NCP results workshop
  - Reported back from the recent launch of the NCP Human Health Assessment
  - Provided updates on lead use in Nunavik communities
- Participated in the NNHC meeting in Quebec City in February 2010
  - Reviewed NCP proposal
  - Provided input on research being conducted and communicated in Nunavik
  - Commented and provided direction on new NCP proposals.
- Attended the ArcticNet Annual Scientific Meeting (ASM), December 8-11 2009, Victoria, B.C.
  - Coordinated the selection of Nunavik candidates for the NCP/ ArcticNet Inuit Travel Bursary
  - Evaluated graduate student posters and selected a candidate for the Inuit Partnership of Excellence Award
- Drafted the *Nunavik Inuit Research Advisor: Building Health and Environment Research Capacity in* Kativik Regional Government *(KRG)* proposal for NCP.
- Participated in teleconferences with other regional IRAs
- Participated and reviewed all Nunavik proposal for Nasivvik
- Communicated regularly with the ITK ArcticNet Coordinator and ITK NCP lead.

- Informed relevant KRG staff of all NCP, ArcticNet and Nasivvik activities and opportunities.
- Promoted NCP, ArcticNet, Nasivvik activities and opportunities at the Nunavik community and regional level through word of mouth and the distribution of promotional materials

Results

The IRA program continues to grow and become better understood in communities and regional organizations in Nunavik. As research continues with programs like the NCP, Nasivvik and ArcticNet, and as some whine down like the International Polar Year (IPY), there is a huge need for an IRA to help with communication of research, to help provide direction with programs to assist communities in understanding what research is being conducted and to shift research into being more Inuit focused. We have begun to see many success, however some challenges with this position still exist. As this position grows and as more youth are engaged in research we will see a shift towards more responsible and meaningful research in Nunavik communities. The IRA continues to provide a coordinated process by which Inuit and researchers can become connected for more effective and meaningful research in the disciplines of environmental science, contaminants and human health.

Expected Project Completion Date

This is an ongoing project.