Title: Arctic Caribou and Moose Contaminant Monitoring Program

Project Leader:
Mary Gamberg, Gamberg Consulting, Whitehorse, Yukon Phone 867-668-7023, Fax 867-668-7024, E-mail mary.gamberg@northwestel.net;

Project Team Members:
Derek Muir, Environment Canada; Mitch Campbell, Department of Environment, Government of Nunavut; Troy Pretzlaw and Troy Hegel, Yukon Environment; Norman Barichello, Norman Sterriah, Gordon Peter, Ross River Dena Council.

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 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.

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.

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.

Yukon: 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.
Nunavut: 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.

General: 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 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).

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

Table 4. Fluorinated compounds in caribou liver and kidney ($ng \cdot g^{-1}$ 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	0.33
	2006	10	Liver	0.01	1.34	2.0	7.40
	2007	10	Liver	0.18	1.72	4.2	7.80

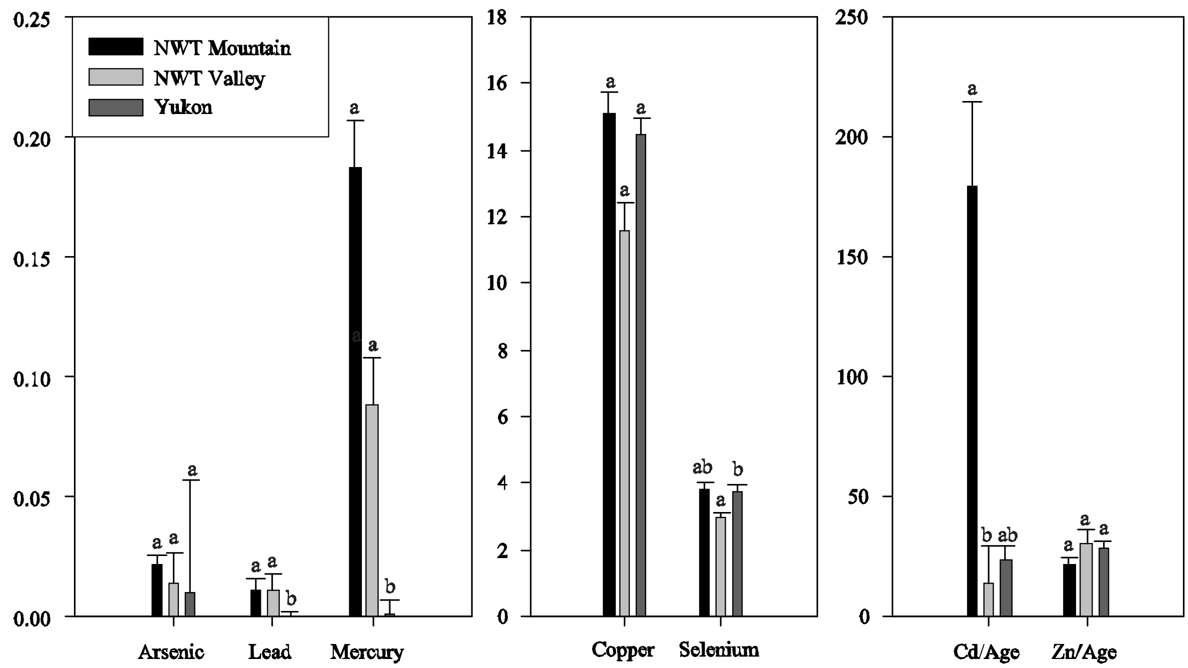

Figure 1. Median renal element concentrations (µg·g^{-1} dry weight) in male, fall-collected moose collected from NWT (2006) and Yukon (1994-2008). Within one element, bars with the same letter are not significantly different.

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 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

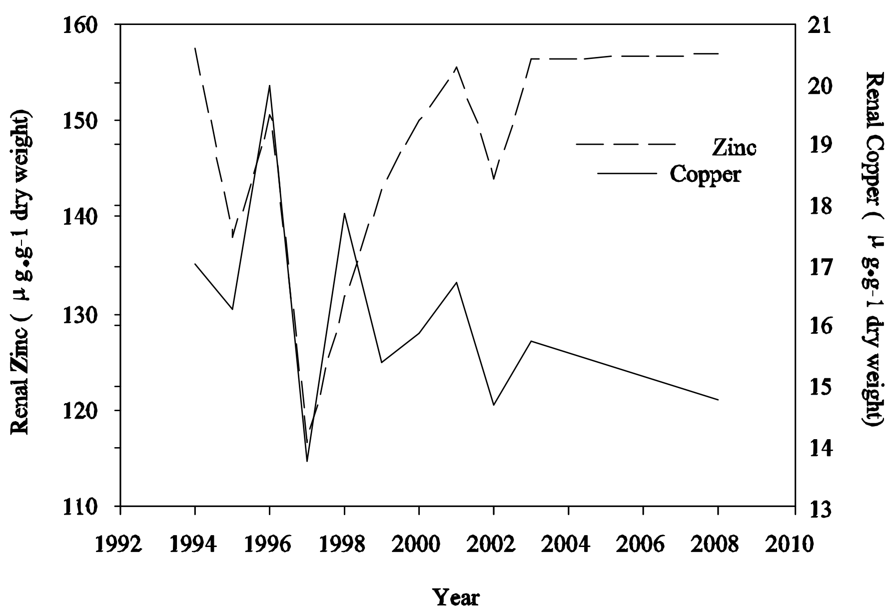

Figure 2. Renal copper and zinc concentrations (µg·g^{-1} dry weight) from Yukon moose

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 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.

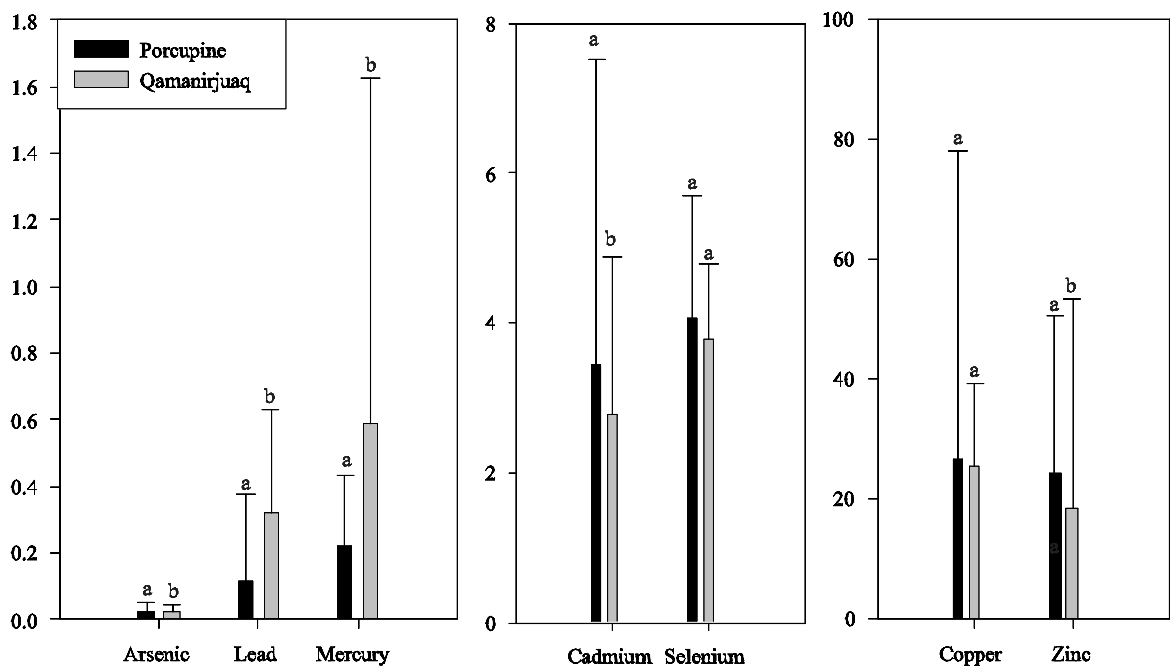

Figure 3. Median renal element concentrations ($\mu g \cdot g^{-1}$ dry weight) in Porcupine and Qamanirjuaq caribou collected 2006-2008. Within one element, bars with the same letter are not significantly different.

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 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.

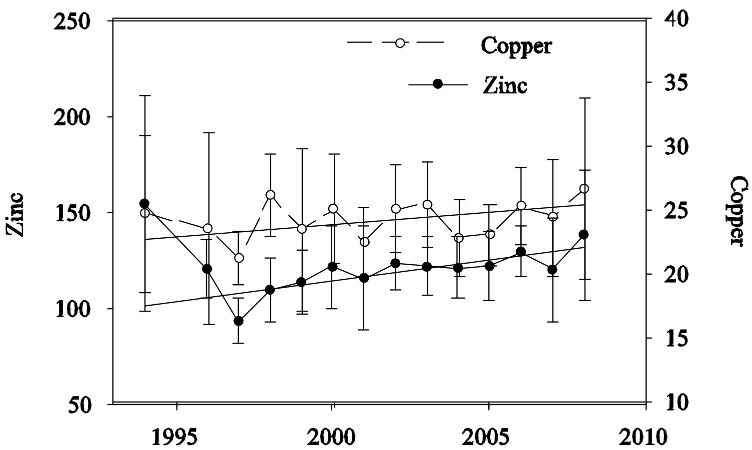

Figure 4. Mean renal element concentrations (µg·g^{-1} dry weight) in male, fall-collected Porcupine caribou.

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.

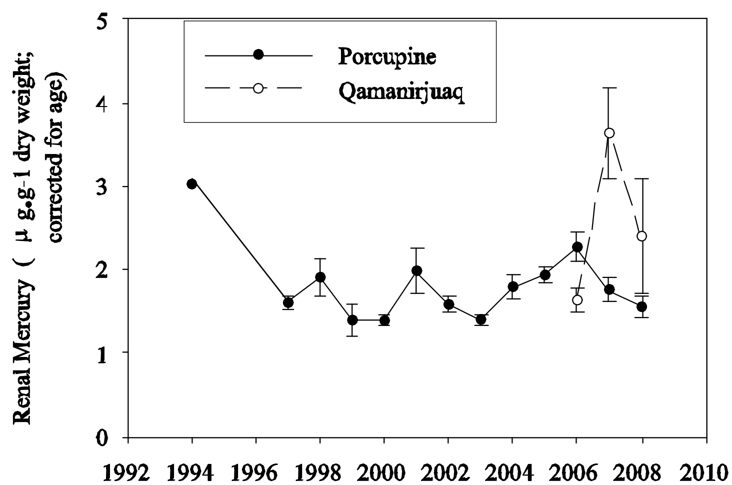

Figure 5. Renal mercury in the Porcupine and Qamanirjuaq caribou.

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.

Acknowledgements
Many thanks to Alpine Aviation, Mitch Campbell, Frank Nutarasungnik and Yukon Environment staff, especially Tena Fox, Krista Funk and Angela Milani. I would also like to acknowledge the support of the Ross River Dena Council and the Ross River Community in collecting samples from the Tay caribou, particularly Norman Barichello, Norman Sterriah and Gordon Peter. Thanks also to Xiaowa Wang from NLET for meticulous handling of our samples. I would like to acknowledge the efforts of all hunters who submitted samples to this program – without them, this work would not be possible. This project was funded by the Northern Contaminants Program, Department of Northern Affairs and administered by the Yukon Conservation Society.

References

Butt, C. M., D. C. G. Muir, I. Stirling, M. Kwan and S. A. Mabury (2007). Rapid Response of Arctic Ringed Seals to Changes in Perfluoroalkyl Production Environ. Sci. Technol. 41: 42-49.

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

Puls, R. 1994. Mineral levels in animal health: diagnostic data. Sherpa International, Clearbrook, BC. 356 pp.

Renner, R. 2005. Piecing together the perfluorinated puzzle. Anal. Chem. Jan 2005 Issue pp. 15A-16A.

Tittlemeir, S. and Chan, L. 2006. Estimation of dietary exposure to perfluorinated carboxylates and sulfonates via consumption of traditional foods. In: Simon, S. and Stow, J. (Eds).Synopsis of Research conducted under the 2005-2006 Northern Contaminants Program, Indian and Northern Affairs Canada, Ottawa ON pp. 88-94.

U.S. Environmental Protection Agency. 2000. Perfluorooctyl sulfonates: proposed significant new use rule. Fed. Regist., 65:62319-62333.

World Health Organization. 1989. Mercury - Environmental Aspects. Environmental Health Criteria No. 86, Finland. 115 pp.