Brief communication

Differences in radionuclide and heavy metal concentrations found in the kidneys of barren-ground caribou from the western Northwest Territories 1994/95 to 2000/01

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Abstract: Aluminum, nickel, cadmium, mercury, and lead concentrations were measured in the kidney tissue of known aged barren-ground caribou wintering in the western Northwest Territories harvested during winter 1994/1995 and during winters 2000/2001 and 2001/2002. ^{40}K, ^{137}Cs, and ^{210}Pb concentrations were measured in the kidney tissue of known aged barren-ground caribou during winter 2000/2001 and compared to concentrations in winter 1993/1994 reported in Macdonald *et al.* (1996). Renal concentrations of aluminum were higher ($P<0.001$) in winter 2000/2001 than winter 1994/1995. Contrastingly renal concentrations of mercury were lower ($P<0.001$) in winter 2000/2001 than 1994/1995. ^{137}Cs ($P<0.02$), ^{40}K ($P=0.01$), ^{210}Pb ($P<0.01$) had lower renal concentrations in winter 2000/2001 than 1993/1994. Renal concentrations of cadmium ($P<0.001$) and ^{137}Cs ($P<0.04$) had a positive relationship with caribou age. We also document renal concentrations of arsenic, copper, selenium, zinc, ^{232}Th, ^{226}Ra, and ^{235}U in the kidneys of caribou harvested in winters 2000/2001 and 2001/2002. Renal zinc concentrations were positively correlated with the age of caribou.

Key words: Cape Bathurst caribou population, cadmium, mercury, *Rangifer tarandus*.

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Introduction

Larter & Nagy (2000) compared the concentrations of 5 heavy metals (aluminum, cadmium, nickel, mercury, and lead) in the kidneys of barren-ground caribou harvested from the Tuktoyaktuk area of the Cape Bathurst caribou (Nagy *et al.*, 2005) winter range in 1995 with concentrations in kidneys of Banks Island Peary caribou and other barren-ground caribou populations. Macdonald *et al.* (1996) reported radionuclide concentrations (^{40}K, ^{137}Cs, and ^{210}Pb) in the kidneys of caribou harvested during winter 1993/94 from the same winter range. In winter 2000/2001, nine caribou were harvested in a similar location of the Cape Bathurst winter range as in 1995. An additional caribou was harvested in the same area in winter 2001/02. This provided us the opportunity to compare concentrations of heavy metals and radionuclides in the kidneys of barren-ground caribou wintering in a similar area of their winter range over time. Data comparing concentrations of heavy metals and radionuclides in terrestrial country food sources over time are rare (Braune *et al.*, 1999; Macdonald, 2002; Gamberg *et al.*, 2005), and are key in addressing the issues of natural cycles in element concentrations and changes in elemental deposition from local and global sources.

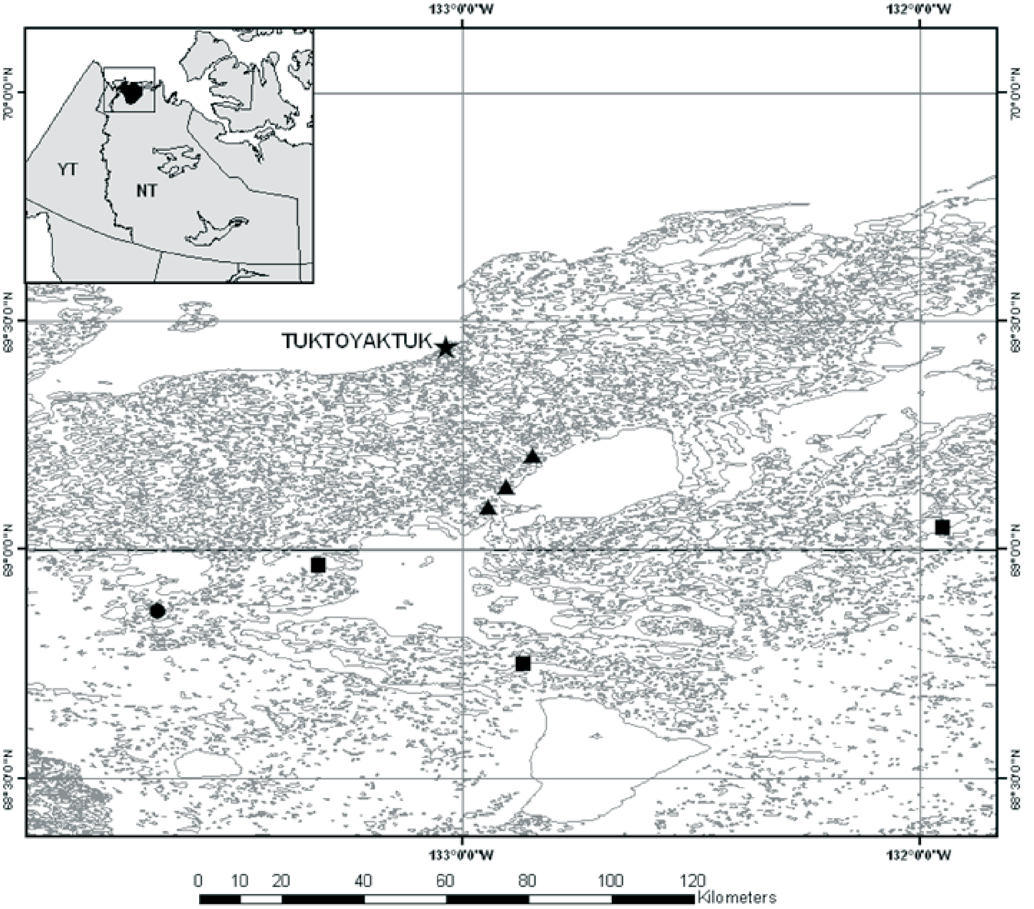

Fig. 1. The locations where caribou samples were collected south of Tuktoyaktuk, NT. Solid triangles (▲) winter 1994/95, solid squares (■) winter 2000/01, and the solid circle (●) winter 2001/02. Inset shows core Cape Bathurst caribou winter range.

Methods

The collection of sampled animals in winter 1994/1995 is described in detail in Larter & Nagy (2000). In 2000, hunting parties departed in search of caribou during November and December 2000 to the south of Tuktoyaktuk, NT (Fig. 1).

Hunters departed into a similar area in March 2002. Caribou distribution was such that there was a much lower success rate for harvesting caribou in winters 2000/2001 and 2001/2002 than in 1994/1995. Eleven caribou in total were collected during winters 2000/2001 (n=10) and 2001/2002 (n=1) in areas not too distant from where wintering caribou were collected in February 1995 (Fig. 1). One set of samples from 2000/2001 was spoilt leaving us with samples from 5 male and 5 female caribou between the 2 winters. We will use winter 2000/2001 to identify these pooled samples throughout the rest of the paper.

For the winter 2000/2001 the age of each sampled animal was determined by counting cementum annuli from the root of the first incisor (Matson, 1981). Diet composition was determined for a random sample of 4 animals by microhistologically analyzing (Sparkes & Malechek, 1968) the plant fragments of the stomach contents outlined in Hansen *et al.* (1976) at the Composition Analysis Laboratory, Fort Collins, Colorado, USA. A 20-g sample (wet weight) of kidney tissue (n=10), cleaned of fat, was forwarded to the Elemental Research Inc. Laboratory, North Vancouver, British Columbia for determination of heavy metal concentrations by inductively coupled plasma-mass spectrometry (ICP-MS). See Larter & Nagy (2000) for a more detailed description of the analysis. Samples were analyzed for concentrations of arsenic, aluminum, cadmium, copper, lead, mercury, nickel, selenium, and zinc. Heavy metal concentrations are reported as µg g^{-1} dry weight. A 20-g sample (wet weight) of kidney tissue (n=9; insufficient tissue from March 2002 sample) was forwarded to Atomic Energy of Canada Limited's Whiteshell Laboratory. Radionuclide concentrations were determined for ashed tissue by gamma spectrometry. See Macdonald *et al.* (1996) for a more detailed description of the analysis. Samples were analyzed for ^{241}Am, ^{137}Cs, ^{40}K, ^{210}Pb, ^{226}Ra, ^{232}Th, and ^{235}U. Radionuclide concentrations are reported as Bq kg^{-1} wet weight (ww). We log-transformed all radionuclide concentrations for all statistical analyses.

We used ANOVA with animal age and year (1994/1995 and 2000/2001) as factors for all heavy metals and radionuclides with data from both years. Data are reported as arithmetic means and standard errors for heavy metals and as geometric means and standard errors for radionuclides. We used regression analysis to determine if there was a correlation between age and the concentrations of cadmium, copper, selenium, and zinc from winter 2000/2001 samples.

Table 1. The effect of time and age on various heavy metal (1994/95 *versus* 2000/01) and radionuclide (1993/94 *versus* 2000/01) concentrations found in the kidneys of Cape Bathurst barren-ground caribou. Mean (arithmetic for heavy metals, geometric for radionuclides) and S.E. are provided where no significant factor effect. Concentration of heavy metals reported as µg g^{-1} dry weight and radionuclides as Bq kg^{-1} wet weight. Bold indicates significance (P<0.05).

Element	n	Time	Age	Mean ± S.E.
Cd	30	*P*=0.100	***P*<0.001**	Range 14.8-211.0
Pb	30	*P*=0.059	*P*=0.310	0.195 ± 0.012
Al	30	***P*<0.001**	*P*=0.304	Range 0.8-6.0
Ni	30	P=0.985	*P*=0.989	0.135 ± 0.025
Hg	30	***P*<0.001**	*P*=0.131	Range 2.2-21.1
^{137}Cs	14	***P*=0.019**	***P*=0.036**	Range 29.6-90.4
^{40}K	14	***P*=0.010**	*P*=0.817	Range 81.3-128.9
^{210}Pb	14	***P*=0.007**	*P*=0.472	Range 16.1 ± 39.4
Cu[1]	10	n/a	*P*=0.430	21.9 ± 0.09
Se[1]	10	n/a	*P*=0.110	6.50 ± 0.67
Zn[1]	10	n/a	***P*<0.001**	Range 122.0-179.0

[1] Heavy metal concentration only available from 2000/2001 samples, results based upon regression analysis.

Results

There were significant effects of time for aluminum, mercury, ^{137}Cs, ^{40}K, and ^{210}Pb (Table 1). Aluminum was higher in 2000/2001 than in 1994/1995 (1.48±0.17 *vs.* 3.60±0.43 µg g^{-1}dw). Mercury, ^{137}Cs, ^{40}K, and ^{210}Pb were all lower in 2000/2001 than in 1993/1994 (5.40±0.52 *vs.* 10.45±0.85 µg g^{-1}dw, 35.9±0.11 *vs.* 67.6±0.12 Bq kg^{-1} ww, 95.2±0.05 *vs.* 106.0±0.09 Bq kg^{-1} ww, and 20.7±0.08 *vs.* 34.9±0.06 Bq kg^{-1} ww, respectively.

There were significant effects of age for cadmium and ^{137}Cs, both showed a positive relationship with age (Table 1). There was a positive (P<0.01) relationship between the concentrations of zinc and cadmium in samples from 2000/2001. The y-intercept for the cadmium age relationship was similar to that for winter 1994/1995, but the slope was marginally steeper (P=0.06) from winter 2000/2001.

There were no detectable levels for arsenic, ^{232}Th, ^{241}Am, and ^{235}U in any of the winter 2000/2001 samples. Only 2 samples had detectable levels of ^{226}Ra (mean 2.0 Bq kg^{-1} ww). Renal concentrations of lead and nickel remained low during both winters.

The range in ages of the caribou sampled in winter 1994/1995 was 2-13 years (mean 6.1; median 5.5 years). The range in ages of caribou sampled in winter 2000/2001 was 0-16 years (mean 6.4; median 5.0 years). This is based on the assumption that the caribou birth month is May (Matson, 1981).

The mean amount of lichen in the diet of caribou in winter 1994/1995 was 87.2% (n=20) *vs.* 92.1% (n=4) in the diet of caribou in winter 2000/2001.

Discussion

Lichen has been implicated as an accumulator of atmospheric pollutants (Thomas *et al.*, 1992), and there is concern about biomagnification in the lichen-caribou-wolf food chain (Kelly & Gobas, 2003). The winter diet of barren-ground caribou in the western Northwest Territories has a substantial lichen component (Scotter, 1967; Larter & Nagy, 1996). The winter dietary lichen component was high and not substantially different for caribou sampled in different winters, and therefore it is unlikely to be a factor in any differences we report in the heavy metal and radionuclide concentrations of caribou kidneys. However, for substances with a more rapid turnover, like ^{137}Cs, animals collected earlier in the winter may have accumulated less from the lichen in the diet.

All samples were collected within a <900 km^2 area located in the core of the *ca.* 34 000 km^2 wintering range of the Cape Bathurst caribou population (J.A. Nagy *et al.*, unpubl. data). Samples were not collected from the exact same geographic location during each winter however there is no evidence of any localized point source of any heavy metals or radionuclides or reason to believe that the differences in renal concentration of substances over time we report is due to sampling location.

The significant decrease in mercury concentration of caribou kidneys between 1994/95 and 2000/01 is both consistent and inconsistent with findings reported from caribou elsewhere. During a similar time period 1994-1998 mercury concentration in the kidneys of Bluenose-east (Nagy *et al.*, 2005) caribou dropped significantly from *ca.* 8 to *ca.* 2 μg g^{-1} wet weight (Gamberg *et al.*, 2005), with an additional decrease to 1.55 μg g^{-1} wet weight by 2002 (Macdonald, 2002). The concentration of mercury in the kidneys of caribou from the Beverly population dropped from *ca.* 9 μg g^{-1} wet weight in 1994 to *ca.* 6 μg g^{-1} wet weight in 2000 (Gamberg *et al.*, 2005). In contrast the concentration of mercury in the kidneys of caribou from the Porcupine caribou has been relatively stable, ranging from *ca.* 0.3-0.5 μg g^{-1} wet weight from 1994-2003 (Gamberg *et al.*, 2005). Each of these populations of caribou inhabit huge geographic areas, and winter in different geographic areas of the Northwest Territories, Yukon Territory, Nunavut, and/or Saskatchewan; Porcupine caribou are the furthest north and west, Beverly caribou are the furthest south and east, with the Bluenose-east caribou found between the other two populations. There is certainly no clear pattern of mercury concentration in caribou kidneys over time. Differences in the lichen component of the winter diet between geographic locations and between years may play a role in the differences in mercury concentrations in caribou kidneys, as may different background levels in the environment.

We have no explanation for the significant increase in the concentration of aluminum in the kidneys of caribou over time. However, between 1994 and 2000 a significant increase in renal aluminum concentrations for caribou from the Beverly population was reported (Gamberg *et al.*, 2005). The concentration of nickel and lead in caribou kidneys remained low in comparison with levels reported for caribou elsewhere in northern Canada (Elkin & Bethke, 1995; Gamberg *et al.*, 2005), and similar between the two sampling times. The concentrations of copper, selenium, and zinc we report for the 2000/2001 samples were similar to or lower than concentrations reported from caribou elsewhere in northern Canada Gamberg *et al.*, 2005).

The release of ^{137}Cs into the environment has come from atmospheric nuclear weapons testing, which peaked in the 1960s and in 1986 by the Chernobyl power plant accident (Peterson, 1970; Macdonald *et al.*, 2007). Subsequently, with a 30 year physical half-life and the virtual ceasing of nuclear weapons testing there has been a documented reduction in the concentrations of ^{137}Cs found in many caribou and reindeer populations in northern Canada, Alaska, and Greenland (Macdonald *et al.*, 2007). Therefore we expected to see renal concentrations of ^{137}Cs to be lower than those reported from 1993/94 (Macdonald *et al.*, 1996).

Relatively little is known about ^{210}Pb accumulation in caribou, and there have been major differences reported in the levels of natural radioactivity (Macdonald *et al.*, 1996). In the Canadian Arctic ^{210}Pb may arise from several sources including localized anthropogenic sources (Ford *et al.*, 1995). We found a significant decrease in the concentrations of ^{210}Pb in caribou kidneys from winter 1993/94 to winter 2000/01. To our knowledge there are no localized point sources where caribou harvested in 1993/94 would have been exposed to that caribou harvested in 2000/2001 were not exposed to. Possibly this difference is related to differences in levels of natural radioactivity over time.

Cadmium bioaccumulates in the tissues of animals and because of its role in filtering waste products from the blood, the kidney often concentrates heavy metals and therefore is a preferred tissue for measuring heavy metal concentrations (Larter & Kandola, in press). Crête *et al.* (1989) and Larter & Nagy (2000) have documented increasing cadmium concentrations in the kidneys of caribou with age. Therefore we expected to find an age effect for renal cadmium concentrations. The renal concentrations we report for cadmium in kidneys is similar to that reported for barren-ground caribou elsewhere (Crête *et al.*, 1989; Elkin & Bethke, 1995; Gamberg *et al.*, 2005).

A significant positive relationship between the concentration of zinc in caribou kidneys and caribou age has not been documented. Larter & Nagy (2000) did not test caribou kidneys for zinc concentration. However, concentrations of cadmium and zinc in the kidneys of moose have demonstrated a positive relationship (Larter & Kandola, in press).

The metabolism and clearance of ^{137}Cs from *Rangifer* has been well studied during the 1960's and after the Chernobyl nuclear accident (see Åhman, 2007). Because it is an analogue for potassium, a relatively high fraction is absorbed from the diet and it is cleared at a rapid rate (biological half-life of 7 days in summer and 18 days in winter, Åhman, 2007). Other studies of similar Canadian caribou populations (Macdonald *et al.,* 2007) reported no relationship between muscle ^{137}Cs and a negative correlation between age and ^{137}Cs concentration in liver. The positive correlation reported here between kidney ^{137}Cs concentration and age may be related to several factors including changes in ^{137}Cs intake and excretion associated with aging. However, further study to determine the strength of the correlation and its reason is required.

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