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Cadmium and other elements in tissues from four ungulate species from the Mackenzie Mountain region of the Northwest Territories, Canada

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ABSTRACT

Tissue samples from four ungulate species from the south Mackenzie Mountain region of the Northwest Territories (NT), Canada, were analysed for stable and radioactive elements and ^{15}N and ^{13}C stable isotopes. Elevated Cd concentrations in moose (*Alces americanus*) kidney have been observed in the region and are a health care concern for consumers of traditional foods. This study examined the factors associated with, and potential renal effects from, the accumulation of cadmium, and interactions with other elements in four sympatric ungulate species. Mean renal Cd concentration was highest in moose (48.3 mg/kg ww), followed by mountain caribou (*Rangifer tarandus caribou*) (13.9 mg/kg ww) and mountain goat (*Oreamnos americanus*) (5.78 mg/kg ww). No local sources of Cd were evident and the elevated levels in moose are considered to be natural in origin. Conversely, total Hg concentration was significantly higher in mountain caribou kidney (0.21 mg/kg ww) than in moose (0.011 mg/kg ww). ^{134}Cs ($t_{½}$=2.1 y) in mountain goat and Dall's sheep (*Ovis dalli*) muscle is evidence of deposition from the Fukushima reactor accident in 2011. ^{137}Cs ($t_{½}$=30.2 y) in all four ungulates is primarily a remnant of the nuclear weapons tests of the 1960s. The levels of both nuclides are low and the risk to the animals and people consuming them is negligible.

Stable isotope $\delta^{15}N$ and $\delta^{13}C$ signatures in muscle showed a separation between the mountain caribou, with a lichen-dominated diet, and moose, which browse shrubs and forbs. Isotope signatures for mountain goat and Dall's sheep showed generalist feeding patterns. Differences in elemental and radionuclide levels between species were attributed to relative levels of metal accumulation in the different food items in the diets of the respective species. Kidneys from each species showed minor histological changes in the proximal tubule and glomerulus, although glomerular changes were rare and all changes were rare in mountain goat kidney. Kidney function was not expected to be affected in any species.

Provisional Monthly Intake recommendations from the WHO indicate that Cd in moose organs will continue to be a public health care concern. However, traditional foods continue to be an important nutritional component of northern diets, particularly in consideration of the shift towards store-bought food.

1. Introduction

Moose and caribou are an important traditional and cultural resource for Canada's northern First Nation communities. In the Dehcho region, dried and cooked moose and caribou are some of the most frequently consumed traditional foods (Receveur et al., 1996). A survey of diets in Dene communities reported that the amount of land animals consumed (cooked, dried and organ meats) was equal to the amount of fish consumed (Batal et al., 2005). A shift away from traditional foods has resulted in a decrease in the nutritional value of the diet in some First Nation communities (Receveur et al., 1997), however even small amounts of traditional foods provide significant benefits, especially to children (Nakano, 2005). Consumption advisories due to elevated metal concentrations may further erode the confidence in traditional foods (McAuley and Knopper, 2011).

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The concentrations of chemicals of potential concern are generally lower in terrestrial wildlife than in marine wildlife, but elevated levels of cadmium, have been found in caribou and moose in areas of northern Canada (Braune et al., 1999; Gamberg et al., 2005a, 2005b; Larter and Kandola, 2010). A review of cadmium in waterfowl, seabirds, terrestrial and marine mammals in areas with no known local anthropogenic Cd source showed a very broad range of natural concentrations (0.196–196 mg/kg dw in kidney), with terrestrial mammals generally lower than seabirds and marine mammals (Mochizuki et al., 2008). Renal cadmium concentrations reported in Yukon moose were higher than in many regions in Canada (Braune et al., 1999; Gamberg et al., 2005b), and equal to the highest concentrations reported (Glooschenko et al., 1988). Regional variability is likely a function of local natural sources of the metals, soil types, the plant species present and other factors that define accumulation in the biophysical environment (Gough et al., 2013; Reimann et al., 2015).

A consequence of high metal concentrations in harvested wildlife is the potential for traditional harvesters to be exposed to metal concentrations that could increase the risk of adverse health effects (Van Oostdam et al., 1999). A study in the Dehcho region of the NWT led to a public health advisory which recommended no consumption of moose kidneys from the southern Mackenzie Mountains (SMM) due to cadmium concentrations (Larter, 2009; Larter and Kandola, 2010). There were similar findings in moose in Alaska (Arnold et al., 2006) and in barren-ground caribou in the NWT (Larter and Nagy, 2000). The European Food Safety Authority has recommended a tolerable weekly intake of 2.5 μg/kg BW (EFSA, 2012), a reduction to 40% of the original WHO provisional tolerable weekly intake recommendation of 25 μg/kg body weight (JECFA, 2010). The conservative recommendations are based on new information on Cd pharmacokinetics and the effects in the kidney, and they may lead to stricter guidelines on the consumption of traditional foods.

Concerns have also been expressed about exposure to mercury through traditional diets in the NWT (Schuster et al., 2011), largely because of the intake of methylmercury in fish. Man-made radionuclides, such as cesium and iodine isotopes, are also of concern for northern residents. These isotopes are released during the major nuclear accidents Chernobyl and Fukushima, and transport to the Arctic, followed by accumulation in lichen and other vegetation and in wildlife (Macdonald et al., 1996, 2007). In many cases, the reasons behind the regional elevation of individual metals in large game species are unclear, and the importance of the local mineralization of soils (Reimann et al., 2015) relative to atmospheric deposition from distant anthropogenic sources is not well defined.

There is a need to better understand the potential impacts of elevated concentrations, or the opposite condition, deficiencies, in large mammal populations and the role of metals in wildlife disease (Murray et al., 2006). Renal cadmium levels in some moose populations are within the range at which kidney dysfunction may occur (Outridge et al., 1994; Beiglböck et al., 2002). Changes associated with elevated renal cadmium include granular degeneration in proximal tubules, glomerular endothelial proliferation and necrosis of renal proximal tubular epithelium (Stoev et al., 2003; Beiglböck et al., 2002). Critical concentrations ranging from 30 (Outridge et al., 1994) to 60 mg/kg (ww) (Aughey et al., 1984) have been suggested as the concentration at which early signs of kidney effects have been observed in mammals. In Sweden, low copper concentrations in liver, possibly caused by interference in absorption caused by molybdenum, have been proposed as a factor in moose wasting syndrome (Frank, 2000) and neurological disorders (Zatta and Frank, 2007). Vikøren et al. (2011) compared the concentrations of several elements in three ungulate species in Norway and reported that 28% of roe deer and 9% moose had Se concentrations below the levels considered to be deficient in domestic animals. The same study found large differences in hepatic Cu concentrations between species, with much higher concentrations found in moose (median: 222 mg/kg dw) than roe deer (112 mg/kg dw) or reindeer (105 mg/kg dw). Suboptimal concentrations of hepatic Se and Cu were noted in a moose population with reduced condition and productivity (Vikøren et al., 2011).

Here we report the concentrations of stable elements and radionuclides in kidney and muscle of four large mammal species (mountain moose (*Alces americanus*), mountain caribou (*Rangifer tarandus caribou*), Dall's sheep (*Ovis dalli*) and mountain goat (*Oreamnos americanus*)) collected from non-resident hunts in the southern Mackenzie Mountains (SMM) of the Northwest Territories in Canada. The objective of the study is to determine if renal histological changes are present in the moose with known elevated renal Cd concentrations. A second objective is to investigate the factors behind the accumulation of elements, including Cd, in the four ungulate species by correlating elemental patterns with the diets in each ungulate species inferred from stable isotope signatures in muscle samples, and to examine interspecific and intertissue relationships with other metals and radionuclides. Due to the timing of the study in 2011, muscle tissues were also analysed for man-made radioisotopes (e.g., ^{134}Cs and ^{137}Cs) that were dispersed during the reactor accident in Fukushima Japan in March, 2011 (Wetherbee et al., 2012).

2. Materials and methods

2.1. Sample collection

Tissue samples (kidney, muscle) were collected opportunistically by outfitters and their guides from non-resident hunts of moose, mountain caribou, Dall's sheep and mountain goat during the 2010–2013 hunting seasons in the southern Mackenzie Mountains. A first incisor tooth was collected from moose and mountain caribou. Samples from Dall's sheep and mountain goat were collected exclusively in zones D/OT/02 (Nahanni Butte Outfitters – NBO), and D/OT/01 (South Nahanni Outfitters – SNO). Most moose and mountain caribou samples were collected in these two zones, but additional samples also came from zones S/OT/05 (Redstone Trophy Hunts – RED), and S/OT/01 (Gana River Outfitters – GAN) (Fig. 1). Samples were processed following Larter (2009). Incisor teeth (I1) from moose and mountain caribou were forwarded to Matson's Laboratory in Milltown, Montana (Matson, 1981) for aging by cementum analysis. The age of Dall's sheep and mountain goats was determined by counting horn annuli.

A total of 173 tissue samples from four ungulate species were collected. Thirty-two kidney and 12 muscles samples were collected from 33 moose (2010–2013), 26 kidney and 10 muscle samples from 26 mountain caribou (2010–2011, 2013), 59 kidney and 10 muscle samples from 59 Dall's sheep (2010–2013), and 13 kidney and 11 muscle samples from 16 mountain goats (2011–2013). The sample set included matched muscle and kidney samples from 11 moose, 10 mountain caribou, 10 Dall's sheep, and 8 mountain goats. The harvested animals were exclusively males.

Ages were available for all Dall's sheep and mountain goat samples and a smaller number of moose and caribou, however because the samples were provided by hunters who generally choose larger, older animals, the distribution of ages was relatively narrow for most species. Ages of the 59 Dall's sheep sampled ranged from 7–13 years (mean 9.88 years), and for the 16 mountain goats sampled ranged from 3 to 11 years (mean 6.26 years). Ages of 25 of the 33 moose sampled ranged from 3 to 14 years (mean 7.04) and ages of 17 of the 26 caribou sampled ranged from 2 to 8 years (mean 5.91 years).