Multi-element, Radionuclide and Stable Isotope Analysis of Kidney, Muscle and *Trichinella* Presence in Mountain Goat (*Oreamnos americanus*) from the South Mackenzie Mountain Region of the NWT

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ABSTRACT

Kidney and muscle of 17 mountain goats (*Oreamnos americanus*) from the south Mackenzie Mountain region of the NWT collected between 2011 and 2013 were analyzed for 33 elements plus mercury and radionuclides. The concentrations of most elements were significantly higher in kidney than in muscle, and only increased significantly ($P<0.05$) with age for arsenic, lead and thallium. The highest kidney:muscle ratio was observed for cadmium (252), followed by molybdenum (40.4). Total mercury concentration was 7.2 times higher in kidney than muscle. The stable isotope signatures for $\delta^{13}C$ and $\delta^{15}N$ indicate that the mountain goat consumes a generalist diet (grasses, lichens, shrubs), which is intermediate to the mountain caribou and the moose. Histological survey of goat kidney indicates low numbers of artifacts, with the most common being lymphohistiocytic inflammation (five out of 14 kidneys surveyed) and pigment deposits (four out of 14, with one scored a "two"). These are considered to be relatively minor changes, with no evidence of any significant changes that have been reported to be associated with high levels of cadmium and other elements. No relationship was observed between the age of the harvested goat, or the concentration of metals, and changes in the kidney. Tongue samples from nine mountain goats were negative for the presence of *Trichinella* spp. The results of the analysis for persistent organic pollutants (POPs) in three liver samples have not been completed yet.

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INTRODUCTION

Mountain goats (*Oreamnos americanus*) are found in the southern portion of the 130,000 km^2 Mackenzie Mountains along the Yukon (YK) - Northwest Territories (NWT) border generally south of 63^o N latitude. Until recently, studies of goats in the NWT were extremely limited (Veitch et al. 2002). More recently, surveys have been conducted in different parts of their range (Larter 2004, 2012). Currently the best estimate of the population size in the NWT is 1,200-1,500 animals. Harvest is almost exclusively by non-resident trophy hunters. From 1967-2013, 313 goats were harvested by non-residents; there is no annual quota on goat (Larter and Allaire 2013).

The concentration of cadmium in organs of other sympatric ungulates (particularly moose) inhabiting this area is high (Gamberg et al. 2005a, Larter 2009) and has resulted in consumption advisories (Larter and Kandola 2010). To document the levels of various elements and radionuclides in tissues of mountain goat we collected tissue samples from mountain goats harvested by the clients of outfitted guided hunts during the 2011, 2012, and 2013 hunting seasons. All goats were harvested between 3 August - 17 September. A histological analysis of kidneys was used to determine if any alterations in kidney structure known to be associated with elevated levels of cadmium or other metals were present. Additionally, a limited number of tongues were collected to be analyzed for the presence of *Trichinella* spp. and a limited number of livers and were collected to be analyzed for the presence of persistent organic pollutants (POPs).

This report summarizes the results of a detailed analysis of stable and radionuclide elements in the kidney and muscle of harvested mountain goats, and of the stable isotope constituent of goat muscle which provides some indication of the diet of mountain goats relative to other large mammals.

STUDY AREA

The study area is the southern portion of the Mackenzie Mountains which run along the border of the YK and NWT. All tissue samples came from mountain goats that were harvested in either the D/OT/01 or D/OT/02 zones operated by South Nahanni Outfitters and Nahanni Butte Outfitters, respectively (Figure 1).

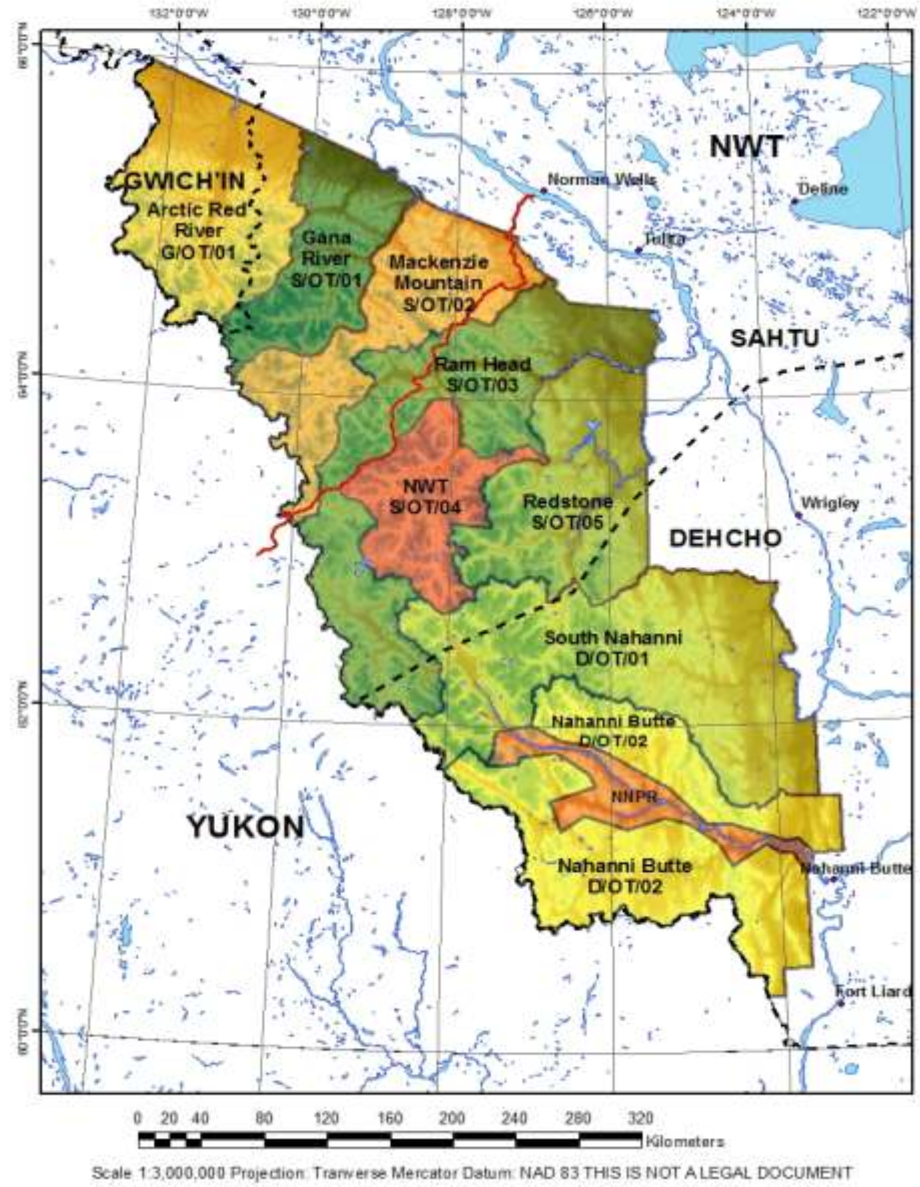

Figure 1. The Mackenzie Mountains of the NWT. Note that samples for this study came from animals harvested only in zones D/OT/01 and D/OT/02.

METHODS

TISSUE SAMPLE COLLECTION

Licensed outfitters were requested to voluntarily submit a variety of tissue samples from mountain goats harvested by their clients during the August/September hunting seasons in 2011, 2012, and 2013. Outfitters were provided with sampling kits, preservative (10% buffered formalin) and sampling instructions for the different tissues being collected. Where possible, data on sex, age (based upon counting horn annuli) and general location were also collected. Samples were kept cool, frozen, and/or fixed in 10% neutral buffered formalin at the main guide camps and were opportunistically transported to the Fort Simpson regional office where they were prepared for laboratory analysis and stored. Table 1 provides a summary of the individual tissues submitted for each analysis.

Table 1. Summary of harvest date, age, and individual tissues submitted for each analysis.

Sample ID	Date of kill	Age in years (horn annuli)	Elemental Analysis		Kidney Fixed Histo-pathology	Radio-nuclides (Muscle)	Stable Isotopes (Muscle)	Tongue for Trichinella	Liver for POP's
			Kidney	Muscle					
mtgoat106	23-Aug-11	9.5	X	X	X	X	X	Y*	
mtgoat107	3-Aug-11	7.5	X	X	X	X	X	N	
mtgoat108	22-Aug-11	4.5	X	X	X		X	N	
mtgoat110	4-Sep-11	2.5				X		Y*	
mtgoat116	26-Aug-11	11.5	X		X			N	
mtgoat118	16-Sep-11	4.5	X	X	X	X	X	Y*	
mtgoat119	12-Sep-11	3.5	X	X	X		X	Y*	
mtgoat120	17-Sep-11	6.5		X			X	Y*	
mtgoat121	11-Aug-12	11.5	X		X			Y	
mtgoat122	23-Aug-12	5.5	X		X	X		Y	
mtgoat123	6-Aug-12	5.5	X		X	X		Y	
mtgoat124	4-Sep-12	4.5	X		X	X		Y	
mtgoat131	15-Aug-13	5.5	X	X	X	X	X	Y	X*
mtgoat132	18-Aug-13	8.5	X	X	X	X	X	Y	X*
mtgoat133	23-Aug-13	8.5	X	X	X	X	X	Y	X*
mtgoat134	3-Aug-13	9.5				X		N	
mtgoat135	30-Aug-13	7.5				X		Y	
mtgoat136	18-Aug-13	8.5						Y	
Number of Samples		**18**	**13**	**9**	**13**	**12**	**9**	**14**	**3**

*indicates that the results of the analysis are not available for this report.

MULTI-ELEMENT ANALYSIS

Elemental samples were analyzed at the National Laboratory for Environmental Testing (NLET) at National Water Research Institute in Burlington, Ontario (National Laboratory for Environmental Testing 2003). Total mercury (NLET Method 02-2802) was analyzed by cold vapor atomic absorption spectrometry (CVAAS). A total of thirty-three elements were analyzed in tissues samples using NLET Method 02-2705 by Inductively Coupled Plasma-Sector Field spectrometry (ICP-SFMS Instrumental). The detection limit for most elements is 0.0001 mg/kg wet weight (ww), but for other specific elements the detection limit varied. For example, As (0.002 mg/kg ww), Pt (0.001 mg/kg), Sn (0.02 mg/kg ww), V (0.002 mg/kg ww), Pd (0.02 mg/kg ww) and Sb (0.001 mg/kg ww). Data were reported on a wet weight basis and converted to a dry weight basis using tissue specific moisture values.

Analytical accuracy and recovery rates were checked using several certified reference tissues from the National Research Council of Canada. Mean recoveries for the certified values were 78.3% [28.9% (Al) to 119% (Sr)] for DOLT-4 (dogfish liver), 102% [49% (Ga) to 106% (Tl)] for DORM-2 (dog fish muscle) and 91.9% [69.7% (Cr) to 109% (Pb)] for TORT-2 (lobster hepatopancreas). [Recovery rates are normally reported with a range that can be >100% at the top end.]

Recoveries from replicate injections were generally low for aluminum in some standard tissues, but recoveries for most elements ranged from 90-105%. A subsample from each tissue was dried to a constant weight to determine % moisture and this was used to convert wet weight concentrations to dry weight for statistical analyses. The NLET laboratory is certified by the

Canadian Association for Laboratory Accreditation (CALA) and actively participates in interlaboratory comparison programs through the Northern Contaminants Program at the Aboriginal Affairs and Northern Development of Canada.

RADIONUCLIDE ANALYSIS

Radionuclides were analyzed by Becquerel Laboratories Inc. (Mississauga, ON) a division of Maxxam Analytics using direct gamma spectrometry. Samples were counted for extended periods of time (e.g. 12- 24 hours) to resolve the ^{134}Cs isotope signal.

Muscle samples were analyzed using gamma spectrometry, which is a common method of analyzing anthropogenic and naturally-occurring gamma-emitting radionuclides in food (Macdonald et al. 1996). The method is useful because samples do not have to be processed and can be analyzed as fresh weight when used with high efficiency detectors. The samples were analyzed for all detectable gamma-emitting nuclides using standard methods.

Muscle samples were placed, unprocessed, in 250 g containers and the radioactivity counted using a 50% relative efficiency hyper-pure germanium detector. Samples were counted for times ranging from 7-24 hours, with a few samples counted over a weekend. The long count times were necessary to quantify the low levels of ^{134}Cs, and were required to differentiate the nuclide signal from background radiation. Peak areas were extracted using an interactive computer program developed by Becquerel Laboratories Inc. The concentrations reported by the laboratory were backdated to the day of collection using standard decay constants for the individual nuclides.

Three isotopes were quantified in the samples. Two of the nuclides, ^{134}Cs and ^{137}Cs, were known to be released from the Fukushima accident (Wetherbee et al. 2012), and the third, potassium-40 (^{40}K), is a radioactive isotope of potassium that is present in all biological material.

The decay constants used to calculate decay were: ^{134}Cs – 0.0009196 day $^{-1}$; ^{137}Cs – 0.0000629 day $^{-1}$; ^{40}K – 1.4 x 10^{-12} day $^{-1}$.

STABLE ISOTOPES

Muscle samples (1.0–1.5 mg dry weight) were analyzed at the Environment Canada stable isotopes laboratory for ^{15}N and ^{13}C using a Micromass Optima (Waters, Milford, MA, USA) continuous-flow isotope-ratio mass spectrometer directly coupled to a Carlo Erba NA1500 elemental analyzer (Elemental Microanalysis, Okehampton, UK). Samples were standardized against atmospheric nitrogen or Canyon Diablo PeeDee Belemnite (National Institute of Standards and Technology, Gaithersburg, MD, USA) using the equation ^{15}N or ^{13}C (‰) = $[(R_{sample}R_{reference})/(R_{reference})]$ 1,000, where $R^{15}N{:}^{14}N$ or $^{13}C{:}^{12}C$. Replicate samples had a precision of 0.05‰ (Houde et al. 2008).

Quality control of the analysis was performed using replicate analyses and duplicate samples. Duplicate samples were analyzed during the analysis, with the accuracy of total carbon analysis ranging from 1-5.8% and total nitrogen ranging from 0.6-7.5%. Accuracy of individual isotopes was in the same range of <1-7.6%.

HISTOLOGY

Paired frozen and formalin-fixed (10% buffered formalin) kidney samples were collected from as many animals as possible. Kidney portions were trimmed so that two sections from different areas of the kidney portion were prepared for histology. Tissue sections were embedded in paraffin, sectioned at 4 µm and placed on glass slides, and stained with hematoxylin and eosin. Both sections of each kidney were examined by a pathologist who was blind to the age, sex, location harvested, and cadmium levels of each animal.

A semi-quantitative scoring system based on Beiglbock et al. (2002) and Stoev et al. (2003) was used to evaluate histologic changes in the renal tissue. Each kidney section was assessed for the presence of the following changes: vacuolar or granular degeneration, necrosis, pyknosis and karyolysis of the proximal tubules, lymphohistiocytic inflammation, interstitial fibrosis, nephrocalcinosis, pigment deposits (intra- and extracellular), hemorrhage, cast formation, and thickened Bowman’s capsule, cellular swelling, and mesangial or endothelial swelling of the glomeruli. Each of the observed changes were given a score of 0 (normal), 1 (mild change), 2 (moderate change), or 3 (severe change). The location of the inflammation, nephrocalcinosis, pigment deposits, and hemorrhage were also recorded. Other changes not included in this list were noted.

TRICINELLA SPP. ANALYSIS

Frozen tongue samples were thawed to room temperature and trimmed to remove fat and connective tissue. The digestion assay for the detection of *Trichinella* spp. larvae in muscle tissue followed Forbes and Gajadhar (1999) and Forbes et al. (2008). A 5 g ww subsample of tongue tissue was used for the analysis.

Results were presented as larvae per gram of tissue tested (LPG). The analysis was conducted at the Veterinary Microbiology Lab at the University of Saskatchewan.

DATA ANALYSIS

Data were analyzed using Systat 11.00.01 (Systat Software, Chicago, IL). Statistical comparisons were made on a dry weight basis (dw), converted from wet weight (ww) basis using moisture content, or using log transformed dw to maintain normality. Tissue elemental concentrations are reported as arithmetic means, with standard deviation (SD), in accordance with Health Canada (2010) recommendations for human health risk assessment. Values below detection limit were substituted with a concentration one-half the detection limit. Sample sets with >50% samples below detection are summarized as <DL.

RESULTS

Tissues were available for analysis from a total of 18 mountain goats harvested between August 3, 2011 and August 30, 2013 (Table 1). Only eight animals had both kidney and muscle tissues for the elemental analyses, and only six animals had a complete suite of tissues so all analyses could be run on the individual. In total, the number of tissues submitted for individual analysis ranged from 9-13 (i.e., n = 9-13).

The mean age of harvested animals was 6.94 years (SD=2.64, n=18), ranging from 2.5-11.5 years. The age range available for multi-element analysis was 3.5-11.5 years, providing a limited sample size for determining relationships of elemental concentrations in kidney with age.

MULTI-ELEMENT ANALYSIS

A total of 22 kidney and muscle samples were analyzed for 33 elements in a multi-element scan and for total mercury by atomic absorption, giving a total of 34 elements. Platinum (Pt) (Detection Limit (DL) = 0.001 mg/kg ww) and palladium (Pd) (DL=0.01 mg/kg ww) were below detection in all muscle and kidney samples.

Raw data for each of the samples tested are in Appendix 1 and summarized in ww (Table 2) and dw (Table 3). Some elements [e.g. silver (Ag), beryllium (Be), bismuth (Bi)] were below detection in >50% of samples of a particular tissue and hence are reported as <DL.

Table 2. Mean concentration, with standard deviation, minimum and maximum, in muscle and kidney for all mountain goat samples. Concentrations for elements are in mg/kg ww.

	Muscle (mg/kg ww)					Kidney (mg/kg ww)					Kid:mus Ratio
	n	Mean	SD	Min.	Max.	n	Mean	SD	Min.	Max.	
Age (y)	9	6.50	2.12	3.50	9.50	13	6.96	2.73	3.50	11.5	-
Moisture (%)	9	72.8	3.24	65.6	76.0	13	79.5	1.88	76.4	82.1	-
Dry Fraction	9	0.27	0.03	0.24	0.34	13	0.21	0.02	0.18	0.24	-
Total Mercury	9	0.0048	0.0039	<0.002	0.0110	13	0.03	0.04	0.006	0.16	7.18
Antimony	9	0.03	0.05	0.003	0.165	13	0.01	0.01	<0.001	0.05	0.26
Aluminum	9	7.19	13.5	0.11	41.4	13	0.28	0.28	0.05	1.15	0.04
Arsenic	9	0.03	0.029	0.005	0.08	13	0.022	0.02	<0.002	0.066	0.82
Barium	9	0.69	1.14	0.02	3.44	13	0.39	0.28	0.141	1.14	0.56
Beryllium	9	0.00039	0.001	<0.0001	0.0021	13	<0.0001	-	<0.0001	0.0004	0.33
Bismuth	9	0.00021	0.0002	<0.0001	0.0006	13	<0.0001	-	<0.0001	0.0003	0.52
Cadmium	9	0.02	0.014	0.004	0.05	13	5.78	6.32	1.07	22	252
Calcium	9	118	125	22.8	359	13	76.8	14.5	59.5	116	0.65
Cobalt	9	0.02	0.03	0.0023	0.10	13	0.04	0.02	0.02	0.08	2.44
Chromium	9	0.23	0.35	0.015	1.15	13	0.06	0.07	0.005	0.21	0.28
Cesium	9	0.23	0.16	0.08	0.57	13	0.20	0.18	0.02	0.59	0.87
Copper	9	1.54	0.66	0.67	3.03	13	2.76	0.39	2.27	3.44	1.79
Iron	9	41.29	29.2	17	116	13	44.0	18.8	22.9	81.3	1.07
Gallium	9	0.0028	0.01	<0.0001	0.0157	13	0.0002	0.0002	<0.0001	0.0007	0.08
Lanthanum	9	0.02	0.02	0.0003	0.0691	13	0.0013	0.0013	0.0003	0.0048	0.09
Lithium	9	0.03	0.04	0.01	0.12	13	0.08	0.06	0.01	0.19	3.01
Magnesium	9	221	19.4	199	245	13	130	10.6	117	149	0.59
Manganese	9	0.46	0.72	0.11	2.35	13	0.84	0.21	0.53	1.3	1.82

	Muscle (mg/kg ww)					Kidney (mg/kg ww)					Kid:mus Ratio
	n	Mean	SD	Min.	Max.	n	Mean	SD	Min.	Max.	
Molybdenum	9	0.01	0.01	0.001	0.024	13	0.32	0.14	0.15	0.64	40.4
Nickel	9	0.06	0.08	0.009	0.274	13	0.05	0.03	0.01	0.10	0.85
Lead	9	0.11	0.27	0.003	0.836	13	0.03	0.02	0.005	0.083	0.25
Palladium	9	<0.01	-	<0.01	<0.01	13	<0.01	-	<0.01	<0.01	1.46
Platinum	9	<0.001	-	<0.001	<0.001	13	<0.001	-	<0.001	<0.001	1.46
Potassium	9	3456	461	2770	4310	13	2237	181	2060	2580	0.65
Rubidium	9	8.48	2.97	3.64	12.9	13	6.91	2.54	2.43	10.2	0.81
Selenium	9	0.30	0.23	0.02	0.64	13	1.16	0.58	0.43	2.24	3.87
Silver	9	<0.0001	-	<0.0001	0.0003	13	0.0014	0.0014	0.0003	0.005	14.7
Tin	9	0.14	0.13	0.01	0.33	13	0.13	0.10	<0.02	0.35	0.96
Strontium	9	0.16	0.24	0.018	0.751	13	0.09	0.03	0.03	0.13	0.59
Thallium	9	0.0013	0.00	<0.0001	0.01	13	0.02	0.0242	0.0025	0.09	12.5
Uranium	9	0.0012	0.00	<0.0001	0.01	13	0.0016	0.0019	0.0002	0.0064	1.29
Vanadium	9	0.04	0.08	0.001	0.25	13	0.0017	0.0009	<0.001	0.0030	0.05
Zinc	9	39.8	13.5	27.8	72.5	13	24.8	6.02	19.3	39.9	0.62

Table 3. Mean concentration, with standard deviation, minimum and maximum, in muscle and kidney for all mountain goat samples. Concentrations for elements have been converted to dw basis (i.e., mg/kg dw).

	Muscle (mg/kg dw)					Kidney (mg/kg dw)					Kid:mus Ratio
	n	Mean	SD	Min.	Max.	n	Mean	SD	Min.	Max.	
Age (y)	9	6.50	2.12	3.50	9.50	13	6.96	2.73	3.50	11.5	-
Moisture (%)	9	72.8	3.24	65.6	76.0	13	79.5	1.88	76.4	82.1	-
Dry Fraction	9	0.27	0.03	0.24	0.34	13	0.21	0.02	0.18	0.24	-
Total Mercury	9	0.017	0.015	<0.004	0.041	13	0.164	0.185	0.030	0.75	9.38
Antimony	9	0.11	0.22	0.01	0.68	13	0.03	0.06	<0.003	0.20	0.31
Aluminum	9	25.3	46.7	0.46	143	13	1.33	1.27	0.25	5.12	0.05
Arsenic	9	0.10	0.10	0.02	0.28	13	0.10	0.10	<0.01	0.31	1.06
Barium	9	2.43	3.976	0.082	11.9	13	1.93	1.54	0.71	6.38	0.79
Beryllium	9	0.001	0.002	<0.0002	0.007	13	<0.0002	-	<0.0002	0.002	0.46
Bismuth	9	<0.0001	-	<0.0001	0.002	13	<0.002	-	<0.0002	0.001	0.69
Cadmium	9	0.08	0.04	0.01	0.15	13	28.3	31.0	5.0	101.7	343
Calcium	9	430	443	85	1237	13	376	70.2	277	516	0.88
Cobalt	9	0.06	0.10	0.01	0.34	13	0.21	0.11	0.10	0.41	3.32
Chromium	9	0.89	1.31	0.06	4.29	13	0.31	0.34	0.02	1.03	0.35
Cesium	9	0.82	0.55	0.29	2.04	13	0.93	0.80	0.11	2.71	1.14
Copper	9	5.58	2.03	2.80	10.4	13	13.5	1.521	10.1	15.8	2.41
Iron	9	150	99.0	70.0	400	13	211	76.7	124	349	1.40
Gallium	9	0.010	0.02	<0.0002	0.05	13	0.001	0.001	<0.0002	0.003	0.11
Lanthanum	9	0.053	0.08	0.001	0.24	13	0.007	0.007	0.002	0.026	0.12
Lithium	9	0.092	0.12	0.029	0.41	13	0.38	0.32	0.05	1.05	4.16
Magnesium	9	819	87.8	712	955	13	640	81.141	507	795	0.78

	Muscle (mg/kg dw)					Kidney (mg/kg dw)					Kid:mus Ratio
	n	**Mean**	**SD**	**Min.**	**Max.**	**n**	**Mean**	**SD**	**Min.**	**Max.**	
Manganese	9	1.63	2.46	0.47	8.10	13	4.08	0.89	2.94	6.08	2.50
Molybdenum	9	0.03	0.02	0.004	0.08	13	1.54	0.57	0.73	2.70	53.5
Nickel	9	0.21	0.28	0.033	0.94	13	0.24	0.13	0.07	0.53	1.17
Lead	9	0.42	1.01	0.013	3.12	13	0.14	0.11	0.03	0.37	0.32
Palladium	9	0.02	0.002	0.015	0.02	13	0.04	0.01	0.02	0.05	1.89
Platinum	9	<0.002	-	<0.002	0.002	13	<0.002	-	<0.002	0.005	1.89
Potassium	9	12883	2369	9546	16130	13	10941	910	9657	12907	0.85
Rubidium	9	31.8	12.7	13.5	53.4	13	34.0	13.2	11.7	53.9	1.07
Selenium	9	1.10	0.81	0.07	2.30	13	5.55	2.37	2.07	9.50	5.06
Silver	9	<0.0002	-	<0.0002	0.001	13	0.007	0.007	0.002	0.025	19.3
Tin	9	0.54	0.54	0.03	1.36	13	0.66	0.55	<0.05	1.96	1.23
Strontium	9	0.57	0.82	0.067	2.59	13	0.47	0.15	0.12	0.67	0.82
Thallium	9	0.004	0.01	<0.0002	0.021	13	0.07	0.10	0.013	0.40	17.8
Uranium	9	0.004	0.01	<0.0002	0.024	13	0.008	0.010	0.001	0.034	1.82
Vanadium	9	0.13	0.29	0.004	0.88	13	0.008	0.004	<0.003	0.013	0.07
Zinc	9	147	49.5	95.8	266	13	120	24.9	96.6	184	0.82

The concentration (dw) of individual elements in kidney and muscle were compared statistically using ANOVA, with age as a co-factor (Table 4). Results are only reported for elements that were above detection in a majority of samples in both tissues. For the majority of metals, there was no significant difference ($p>0.05$) between the concentration in the kidney and muscle, or, the concentration was higher in kidney (Figure 2). The concentrations of aluminum (Al), magnesium (Mg), potassium (K) and antimony (Sb) were higher in muscle than kidney, although the concentration of Al in one muscle sample was very high (41.4 mg/kg ww) and may have been caused by contamination of the sample. The concentration of most elements was not correlated to age (Table 4). Plotted geometric mean values (Figure 2) show the poor relationship between tissue concentration and age for mercury (Hg), cadmium (Cd) and molybdenum (Mo) and the higher concentrations observed in kidney for the three elements.

The highest kidney: muscle ratio on a ww basis (251) was observed with cadmium (Cd), indicating the ability of the metal to accumulate preferentially in the kidney (Tables 2, 3). The next highest ratios were observed for molybdenum (Mo) (40.4) and silver (Ag) (14.7). Total mercury (Hg) was over seven times higher in kidney than muscle, although the concentrations of Hg in both tissues were relatively low. Aluminum (Al) was 26 times higher in muscle than kidney, possibly because of the one extreme value (41.4 mg/kg ww) which may be an outlier, or caused by contamination.

Table 4. Summary of statistical comparison of elemental concentrations in muscle and kidney using ANOVA, with age as a co-factor. NS- not statistically significant (i.e., P>0.05); P<0.001 - significant at 99.9%, P<0.01 – significant at 99.0 %; P<0.05 – significant at 95%).

Element	Significance	Order of Tissue	Effect of Age
Mercury	P<0.001	Kidney > Muscle	NS
Aluminum	P=0.01	Muscle > Kidney	NS
Arsenic	NS	-	P <0.05
Barium	NS	-	NS
Cadmium	P<0.001	Kidney > Muscle	NS
Calcium	NS	-	NS
Cobalt	P<0.001	Kidney > Muscle	NS
Chromium	NS	-	NS
Cesium	NS	-	NS
Copper	P<0.001	Kidney > Muscle	NS
Iron	P<0.05	Kidney > Muscle	NS
Gallium	NS	-	NS
Lanthanum	NS	-	NS
Lithium	P<0.01	Kidney > Muscle	NS
Magnesium	P<0.001	Muscle > Kidney	NS
Manganese	P<0.001	Kidney > Muscle	NS
Molybdenum	P<0.001	Kidney > Muscle	NS
Nickel	NS	-	NS
Lead	NS	-	P < 0.05
Potassium	P<0.05	Muscle > Kidney	NS
Rubidium	NS	-	NS
Antimony	P<0.05	Muscle > Kidney	NS
Selenium	P<0.001	Kidney > Muscle	NS
Tin	NS	-	NS
Strontium	NS	-	NS
Thallium	P<0.001	Kidney > Muscle	P<0.001
Uranium	P<0.05	Kidney > Muscle	NS
Vanadium	NS	-	NS
Zinc	NS	-	NS

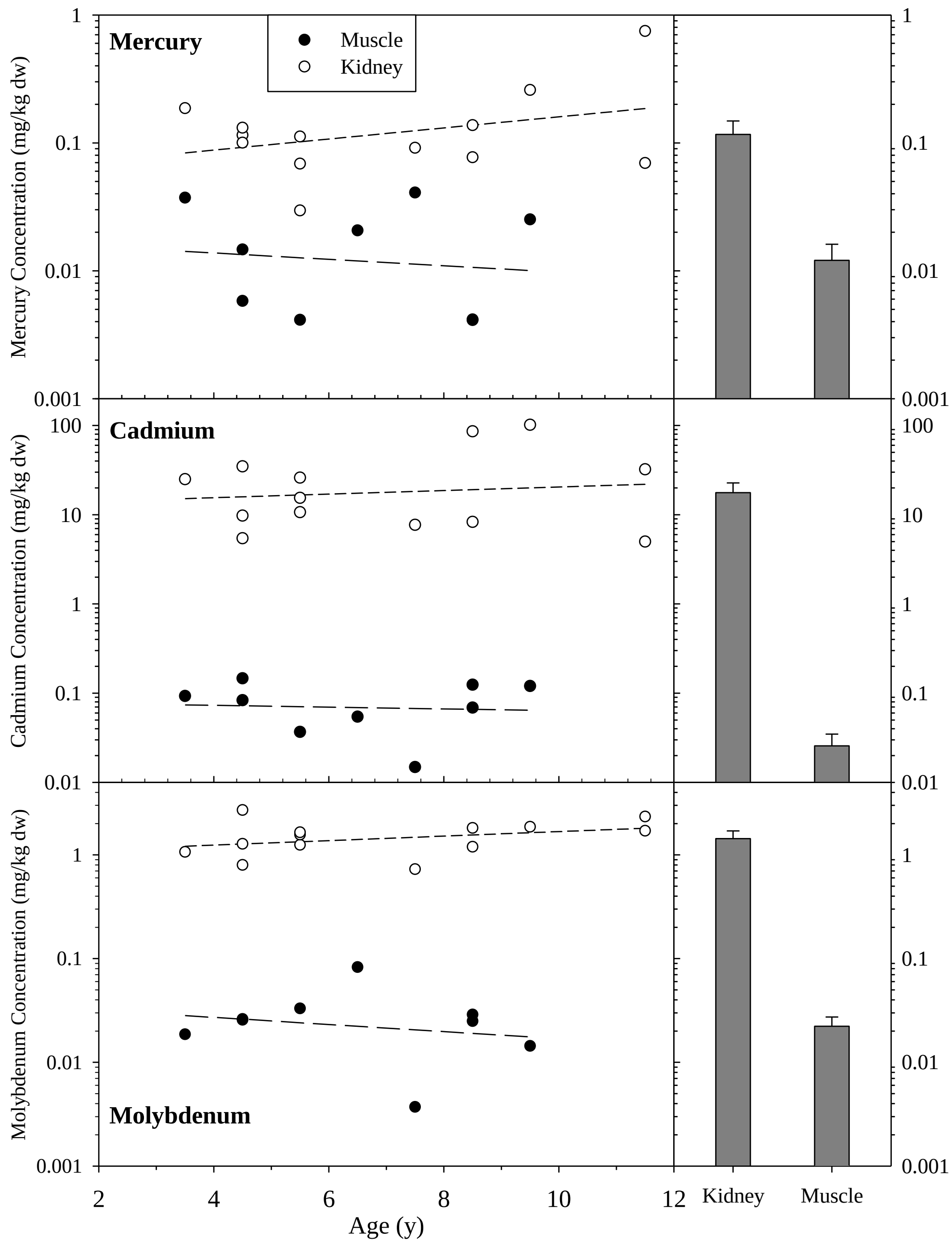

Figure 2. Relationship between tissue concentration and age for three elements (Hg, Cd, Mo). Regressions were not statistically significant for these three elements. Side panels show geometric mean (with GSD) concentrations for kidney and muscle.

RADIONUCLIDE ANALYSIS

Muscle samples were analyzed for radiocesium isotopes and naturally-occurring ^{40}K on three separate occasions with different detection limits for the major nuclides. Raw data are reported in Table 5.

The calculation of mean values for radionuclides in the goat samples is complicated by the rapid decay of the ^{134}Cs observed in 2011 and the higher detection limit for ^{40}K reported by the lab (<1000 Bq/kg) in 2013. ^{134}Cs had a mean concentration of 1.49 Bq/kg (SD=1.00, n=4) in 2011, the year of the Fukishima nuclear accident, and declined to levels below the detection limits by 2012. ^{137}Cs remained relatively consistent in most samples, with a mean value of 6.46 Bq/kg (SD=7.16, n=12) in muscle although the two highest values were observed in the 2011 collection.

The naturally-occurring ^{40}K remained at a mean level of 108 Bq/kg (SD=29.7, n=7), and was reported as below a detection limit of 1,000 Bq/kg in 2013. The level of ^{40}K is relatively consistent at ~100 Bq/kg in large mammals, and the mean value reported for 2011 and 2012 samples confirm those levels in this species.

Table 5. The mean (standard deviation) concentration of radiocesium isotopes and ^{40}K in mountain goat muscle. Values reported by have been back-dated to the time of harvesting.

				Cesium-134		Cesium-137		Potassium-40	
Sample ID	**Date of analysis**	**Collection Date**	**Number of days used to Calculate decay**	**Concentration at Time of Analysis**	**Back dated to Day of Harvest**	**Concentration at Time of Analysis**	**Back dated to Day of Harvest**	**Concentration at Time of Analysis**	**Back dated to Day of Harvest**
mtgoat 106	11-May-12	23-Aug-11	262	0.7	0.89	13	13.2	71	71
mtgoat 107	12-May-12	3-Aug-11	283	1.4	1.82	2	2.2	140	140
mtgoat 110	13-May-12	4-Sep-11	252	<1	<1	27	27.4	96	96
mtgoat 118	14-May-12	16-Sep-11	241	2.2	2.75	6	6.4	100	100
mtgoat 122	7-May-13	23-Aug-12	257	<2	<2	3.2	3.3	120	120
mtgoat 123	7-May-13	6-Aug-12	274	<2	<2	1.1	1.1	150	150
mtgoat 124	23-Mar-13	4-Sep-12	200	<2	<2	4.7	4.8	<160	<160
mtgoat 131	5-Oct-13	15-Aug-13	51	<1.0	<1.0	3	3.0	<1,000	<1,000
mtgoat 132	5-Oct-13	18-Aug-13	48	<1.0	<1.0	5	5.2	<1,000	<1,000
mtgoat 133	5-Oct-13	23-Aug-13	43	<1.0	<1.0	5	4.9	<1,000	<1,000
mtgoat 134	5-Oct-13	3-Aug-13	63	<1.0	<1.0	2	2.0	<1,000	<1,000
mtgoat 135	5-Oct-13	30-Aug-13	36	<1.0	<1.0	5	4.9	<1,000	<1,000
Mean (with standard deviation) For ^{134}Cs 2011 samples only, ^{137}Cs all samples, ^{40}K 2011 and 2012 samples only					**1.82 (0.93)**		**6.46 (7.16)**		**108 (29.7)**

STABLE ISOTOPES

The stable isotope signatures for $\delta^{13}C$ and $\delta^{15}N$ reflect the composition of the diet of the individual animals tested and vary according to the species of plant present in the diet. The %C, %N and the two stable isotopes for the individual mountain goat samples collected in 2011 and 2013 are presented in Table 6 and summarized in Table 7. One value of %N was very low (3.73) and was far outside the range of other samples. The data in Table 7 are presented with and without the outlier to demonstrate the effect of removing the value.

Mean isotope values are presented in Figure 3 with the data from other NWT large mammals, including the 2011 mountain goat data (Larter et al. 2014 submitted). The data are consistent with the interpretation that mountain goats are generalist feeders that consume grasses, mosses, lichens and shrubs. Although individual food species, and hence isotope ratios, vary seasonally, all the mountain goats in this study were harvested in August and September of the respective years, which removes seasonality as a potential sources of variation.

The %C, %N, $\delta^{13}C$ and $\delta^{15}N$ values were regressed against age to determine if age was significantly correlated. Of the four parameters tested, age was significantly correlated only with $\delta^{13}C$ ($P=0.001$, $r^2=0.79$, $n=10$) (Figure 4), which could indicate a change of diet with age. There was no significant difference ($P>0.05$) in the four parameters, or age, between the 2011 and 2013 collections.

Table 6. Stable isotopes in mountain goat muscle harvested in 2011 and 2013.

Sample	Age	Collection Date	Total %C	Repeat	Total %N	Repeat	$\delta^{13}C$	Repeat	$\delta^{15}N$	Repeat
mtgoat 106	9.5	23-Aug-11	49.79		15.00		-24.17		1.52	
mtgoat 107	7.5	3-Aug-11	49.21		15.09		-24.29		1.50	
mtgoat 108	4.5	22-Aug-11	51.29	50.81	14.83	14.75	-24.75	-24.80	2.12	2.28
mtgoat 118	4.5	16-Sep-11	50.59		15.00		-24.86		0.59	
mtgoat 119	3.5	12-Sep-11	49.82		15.23		-24.87		0.86	
mtgoat 120	6.5	17-Sep-11	63.47		3.73		-28.32		0.87	
mtgoat 131	5.5	15-Aug-13	59.72	56.33	17.70	16.42	-24.49	-24.62	1.84	1.80
mtgoat 132	8.5	18-Aug-13	55.21		16.00		-24.40		2.11	
mtgoat 133	8.5	23-Aug-13	53.00		15.56		-24.05		1.06	
mtgoat 134	9.5	3-Aug-13	54.86		16.45		-23.95		2.65	
mtgoat 135	7.5	30-Aug-13	47.40	48.82	14.38	14.80	-24.65	-24.64	1.69	1.80
Mean (SD)			**53.1 (4.88)**		**14.5 (3.67)**		**-24.8 (1.21)**		**1.53 (0.64)**	
DUPLICATE ANALYSIS										
mtgoat 119	3.5	12-Sep-11	49.74		15.29		-24.54		1.20	

Table 7. Mean carbon and nitrogen content of muscle, with mean $\delta^{13}C$ and $\delta^{15}N$. Data are presented for all samples (2011-2013) tested, and with one outlier removed.

	With Outlier Included					**With Outlier Removed**				
	n	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Age	11	6.9	2.11	3.5	9.5	10	6.9	2.22	3.5	9.5
Total %C	11	53.1	4.88	47.4	63.5	10	52.1	3.65	47.4	49.7
Total %N	11	14.5	3.67	3.73	17.7	10	15.5	0.97	14.4	17.7
$\delta^{13}C$	11	-24.8	1.21	-28.3	-24.0	10	-24.5	0.33	-24.9	-24.0
$\delta^{15}N$	11	1.53	0.64	0.59	2.65	10	1.59	0.63	0.59	2.65

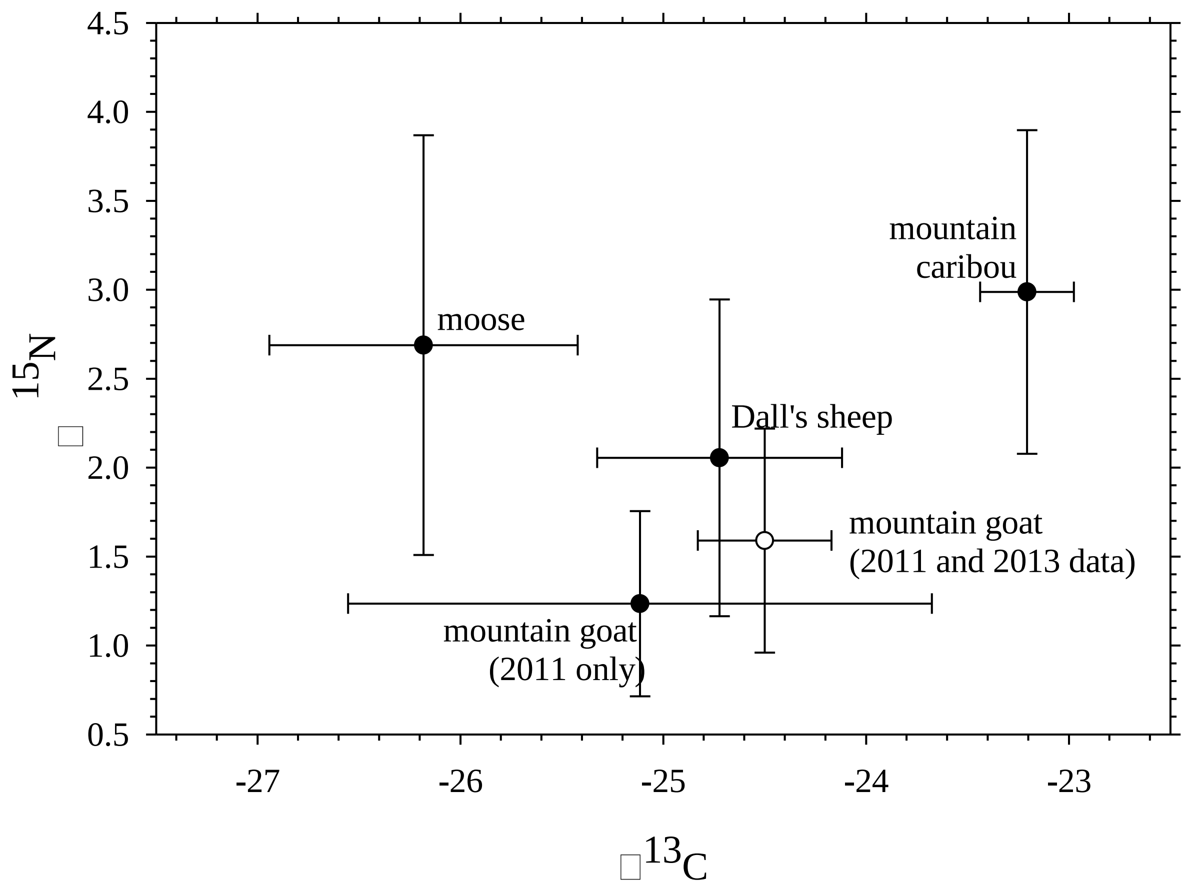

Figure 3. Comparison of mountain goat stable isotope patterns with other NWT large mammals from Larter et al. 2014 submitted. Data for 2011 mountain goats (black symbol) are from the original publication, while the open symbol shows the stable isotope signature for 2011 and 2013 data combined (with one outlier removed).

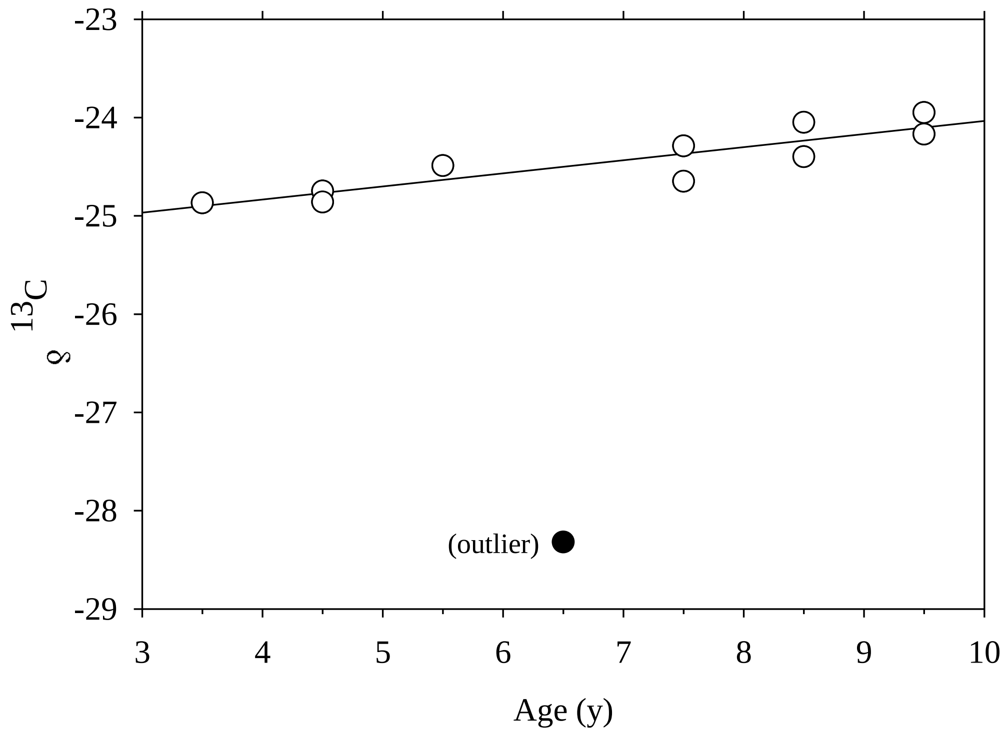

Figure 4. Significant increase of $\delta^{13}C$ signature relative to age of the harvested animal. The regression line is calculated without the outlier point.

HISTOLOGY

The histological analysis of mountain goat kidneys was conducted by N. Jane Harms, DVM, MVetSc, Dipl. ACVP who provided the analysis and interpretation of the data in 2012, 2013 and 2014. Table 8 provides a summary of the results.

Unedited text from Harms (2012) states "Of the six mountain goat kidneys examined, 1/6 had mild (one) vacuolar or granular degeneration of the proximal tubules, 1/6 had mild (one) lymphohistiocytic inflammation predominantly within the cortical interstitium, and 1/6 had mild pigment deposits. The pigment was located intracellularly. None of the animals had hemorrhage in the cortex, proximal tubular epithelium with swollen nuclei, proximal tubular epithelium with pycnotic nuclei, proximal tubular epithelium with karyolitic nuclei, necrosis of proximal tubular epithelium, interstitial fibrosis, nephrocalcinosis, cast formation within tubules, thickened Bowman's capsules, swelling of the glomeruli, or endothelial and/or mesangial proliferation."

Unedited text from Harms (2013) states "Of the four mountain goat kidneys examined, 1/4 had mild (one) lymphohistiocytic inflammation predominantly within the cortical interstitium, 1/4 had mild pigment deposits, located intracellularly, and 1/4 had moderate pigment deposits, located intracellularly and in the glomeruli."

Unedited text from Harms (2014) states "Of the three mountain goat kidneys examined, 3/3 had mild (one) lymphohistiocytic inflammation predominantly within the cortical interstitium, 1/3 had mild pigment deposits, located intracellularly. Two of the goat kidneys showed mild autolysis."

The most frequent changes noted in the kidney were lymphohistiocytic inflammation (five out of 14 kidneys surveyed) and pigment deposits (four out of 14, with one scored a "2"). There was no clear relationship between metal concentration, particularly cadmium, and histological changes in the kidney. Also, there was no clear relationship between the age of the animals and the changes in kidney. The histological changes observed are considered to be relatively minor, with no evidence of any significant changes consistent with those reported to be associated with high levels of cadmium and other elements. The results for individual animals are presented in Appendix 2 with the concentration of several metals known to cause biological effects in kidney at high concentrations.

Also of note, was the kidney from goat 133 showed evidence of lymphocytic arteritis, and the kidney from goat 132 showed evidence of eosinophilic granulomatous inflammation likely associated with the presence of a larval helminth parasite.

TRICHINELLA SPP. ANALYSIS

Nine of the 14 available tongue samples were analyzed for the presence of *Trichinella* spp.; all nine tongues tested negative for *Trichinella* presence.

Table 8. Summary of the histological analysis of mountain goat kidney in animals harvested in 2011, 2012, and 2013 (Harms 2012, 2013, 2014).

Analysis Report Date	N	Score	Changes in Proximal Tubules					Lymphohistiocytic inflammation	Interstitial fibrosis	Nephrocalcinosis	Pigment deposits	Hemorrhage (location, distribution)	Cast formation	Changes in the Glomeruli		
			Vacuolar or granular degeneration	Pycnotic nuclei	Swollen nuclei	Karyolysis	Necrosis							Thickened Bowman's capsule	Swelling	Endothelial and/or mesangial proliferation
March 28, 2012	**6**	1	1/6	0	0	0	0	1/6	0	0	1/6	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February 28, 2013	**4**	1	0	0	0	0	0	1/4	0	0	1/4	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	1/4	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February 1, 2014	**3**	1	0	0	0	0	0	3/3	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	1/3	0	0	0	0	0

DISCUSSION

Levels of contaminants in mountain goat were generally higher in kidney than muscle tissue and most elements did not show a positive correlation with age. Total mercury levels were over seven times higher in kidney than muscle but were relatively low and similar to those reported for co-habiting Dall's sheep (Larter et al. 2014 submitted.). Cadmium had the highest kidney:muscle ratio at 251, showing the ability to accumulate in the kidney. Co-habiting moose bioaccumulate cadmium (Gamberg et al. 2005b) and willow, a primary food source of moose, hyperaccumulates cadmium (Vandecasteele et al. 2002). Some of the highest levels of cadmium in moose tissues have been reported for the southeast Yukon (Gamberg et al. 2005a, b) and the southern Mackenzie Mountains (Larter and Kandola 2010, Larter et al. 2014 submitted.). Cadmium levels we report for mountain goat kidney are substantially lower than those reported for co-habiting moose which resulted in a human health advisory (Larter and Kandola 2010). Levels we report are well below levels of concern.

Levels of ^{40}K we report for mountain goats is consistent with that found in large mammals and is similar to that found in other large mammals co-habiting the study area (Larter et al. 2014 submitted). ^{134}Cs was released in the Fukishima nuclear accident in March 2011 and was detected in muscle samples of mountain goat collected during the 2011 hunting season; it was not detected in subsequent years. ^{134}Cs was also detected in Dall's sheep sampled during the 2011 hunting season but not in co-habiting moose or caribou (Larter et al. 2014 submitted). ^{134}Cs has a rapid decay (2.1 years) and differences in dietary items could explain ^{134}Cs detection. Mountain goats and Dall's sheep have a more generalist diet (see Figure 3) and likely ingested specific food items that accumulated the nuclide. Moose have a high dietary willow component (Risenhoover 1989) and caribou have a high lichen component (Gustine et al. 2012) and more restrictive diets. Mountain goat and Dall's sheep samples were collected earlier in the hunting season than moose and caribou which could also be a factor in our detection results. Radionuclide levels we report are low and not of concern from either a mountain goat health perspective or human consumption perspective.

Michelsen et al. (1996) noted that plants in northern environments may have a wide range of nitrogen isotope signatures. Additional variation comes from changing plant phenology. Samples came from mountain goats harvested during a six week period each year. Stable isotope signatures are consistent with mountain goats being generalist feeders. The signatures are more similar to co-habiting Dall's sheep than to co-habiting moose or caribou (Larter et al. 2014 submitted).

The histological changes observed in the kidneys are considered to be relatively minor. There is no evidence of any significant changes one might expect with elevated levels of cadmium or other metals. Future monitoring of mountain goats in the southern Mackenzie Mountains could include sampling to try to identify parasite fauna including the unidentified renal parasite found in this study.

In general, prevalence of *Trichinella* spp. infection is higher in furbearer, carnivore and omnivore species that scavenge, hunt or exhibit cannibalism than in small mammal species such as rodents (Appelyard and Gajadhar 2000, Schmidt et al. 1978). *Trichinella* spp. is prevalent in grizzly bears (73%) and wolves (86%) found in the Mackenzie Mountains (Larter and Allaire

2014), but was not found in any of the nine mountain goats sampled. No moose (n=21), caribou (n=24), or Dall's sheep (n=21) sampled in the study area tested positive for *Trichinella* spp. (Larter 2014), therefore it would appear that larger herbivorous prey populations in the area also have a low prevalence of *Tricinella* spp.

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Appendix 1. Concentrations of elements in muscle and kidney in (mg/kg ww).

Sample Number	mtgoat106	mtgoat107	mtgoat108	mtgoat118	mtgoat119	mtgoat120
Collection	23-Aug-11	3-Aug-11	22-Aug-11	16-Sep-11	12-Sep-11	17-Sep-11
Tissue	Muscle	Muscle	Muscle	Muscle	Muscle	Muscle
Age (y)	9.5	7.5	4.5	4.5	3.5	6.5
% Moisture	72.2	73.1	72.8	65.6	73.2	71.0
Total Mercury	0.007	0.011	0.004	0.002	0.01	0.006
Silver	< 0.0001	0.0003	0.0002	< 0.0001	< 0.0001	< 0.0001
Aluminum	1.29	0.41	12.8	1.26	6.63	41.4
Arsenic	0.022	0.017	0.018	0.009	0.074	0.08
Barium	0.157	0.049	1.26	0.103	1.07	3.44
Beryllium	0.0001	< 0.0001	0.0006	0.0001	0.0003	0.0021
Bismuth	0.0002	< 0.0001	0.0004	< 0.0001	0.0004	0.0006
Cadmium	0.0334	0.004	0.0227	0.0504	0.0249	0.0158
Calcium	43.6	22.8	107	58.4	306	359
Cobalt	0.0115	0.004	0.0198	0.0083	0.007	0.0974
Chromium	0.059	0.015	0.068	0.039	1.15	0.219
Cesium	0.568	0.0794	0.0977	0.417	0.21	0.117
Copper	1.35	1.46	1.42	2	1.48	3.03
Iron	26.4	23	36.2	40.1	34.4	116
Gallium	0.001	0.0002	0.0049	0.0009	0.0024	0.0157
Lanthanum	0.0315	0.0004	0.019	0.0016	0.0091	0.0691
Lithium	0.02	0.01	0.02	0.01	0.01	0.12
Magnesium	199	242	199	245	210	244
Manganese	0.192	0.164	0.481	0.258	0.307	2.35
Molybdenum	0.004	0.001	0.007	0.009	0.005	0.024
Nickel	0.034	0.009	0.061	0.022	0.064	0.274
Lead	0.023	0.031	0.055	0.016	0.836	0.047
Palladium	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Platinum	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Potassium	3370	4310	3000	3650	3240	2770
Rubidium	6.27	3.64	7.7	11	8.82	5.52
Antimony	0.015	0.003	0.009	0.01	0.034	0.01
Selenium	0.64	0.02	0.45	0.52	0.16	0.12
Tin	0.02	0.1	0.08	0.05	0.06	0.01
Strontium	0.049	0.018	0.111	0.063	0.291	0.751
Thallium	0.0001	< 0.0001	0.0006	0.0072	0.001	0.0015
Uranium	0.0002	0.0001	0.0014	0.0003	0.0016	0.0071
Vanadium	0.005	0.001	0.042	0.004	0.017	0.254
Zinc	35.3	35.7	72.5	46.6	28.2	27.8

Sample Number	mtgoat131	mtgoat132	mtgoat133	mtgoat106	mtgoat107	mtgoat108
Collection	15-Aug-13	18-Aug-13	23-Aug-13	23-Aug-11	3-Aug-11	22-Aug-11
Tissue	Muscle	Muscle	Muscle	Kidney	Kidney	Kidney
Age (y)	5.5	8.5	8.5	9.5	7.5	4.5
% Moisture	75.8	76.0	75.7	78.4	79.3	80.0
Total Mercury	< 0.002	< 0.002	< 0.002	0.056	0.019	0.023
Silver	< 0.0001	< 0.0001	< 0.0001	0.0008	0.0008	0.001
Aluminum	0.25	0.11	0.53	0.19	0.1	0.05
Arsenic	0.011	0.005	0.006	0.066	0.035	0.009
Barium	0.032	0.035	0.02	0.549	0.241	0.215
Beryllium	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001	< 0.0001
Bismuth	< 0.0001	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001
Cadmium	0.0089	0.0165	0.0302	22	1.6	1.09
Calcium	51.8	27.3	86.5	59.9	68.1	68.2
Cobalt	0.0044	0.0053	0.0023	0.0628	0.0289	0.0815
Chromium	0.18	0.226	0.156	0.005	0.214	0.16
Cesium	0.226	0.18	0.135	0.587	0.0567	0.0691
Copper	1.16	1.29	0.67	3.18	2.44	2.89
Iron	42.1	36.4	17	54.1	36	39.2
Gallium	< 0.0001	< 0.0001	0.0001	0.0004	0.0004	< 0.0001
Lanthanum	0.0004	0.0003	0.0041	0.0008	0.001	0.0003
Lithium	0.01	0.02	0.01	0.17	0.04	0.04
Magnesium	231	211	208	149	149	136
Manganese	0.113	0.153	0.131	0.905	0.953	0.825
Molybdenum	0.008	0.006	0.007	0.403	0.151	0.16
Nickel	0.018	0.017	0.025	0.074	0.034	0.035
Lead	0.004	0.003	0.005	0.023	0.069	0.025
Palladium	< 0.01	< 0.01	< 0.01	<0.02	<0.02	<0.02
Platinum	< 0.001	< 0.001	< 0.001	<0.002	<0.002	<0.002
Potassium	3900	3380	3480	2480	2180	2580
Rubidium	12.9	9.68	10.8	6.01	2.43	7.5
Antimony	0.005	0.007	0.165	0.003	0.003	0.002
Selenium	0.38	0.4	0.02	1.94	0.43	0.95
Tin	0.29	0.28	0.33	<0.02	0.12	0.14
Strontium	0.037	0.029	0.089	0.105	0.085	0.068
Thallium	0.0008	0.0002	0.0001	0.0056	0.0031	0.0173
Uranium	0.0001	< 0.0001	0.0001	0.0004	0.0003	0.0023
Vanadium	0.001	0.001	0.001	<0.002	0.002	0.002
Zinc	39.1	35.3	37.6	39.9	20.3	19.3

Sample Number	mtgoat116	mtgoat118	mtgoat119	mtgoat121	mtgoat122	mtgoat123
Collection	26-Aug-11	16-Sep-11	12-Sep-11	11-Aug-12	23-Aug-12	6-Aug-12
Tissue	Kidney	Kidney	Kidney	Kidney	Kidney	Kidney
Age (y)	11.5	4.5	3.5	11.5	5.5	5.5
% Moisture	78.6	76.4	77.5	81.3	79.8	76.7
Total Mercury	0.16	0.031	0.042	0.013	0.006	0.016
Silver	0.0039	0.0008	0.0006	0.0008	0.0012	0.0011
Aluminum	0.3	0.11	1.15	0.17	0.23	0.22
Arsenic	<0.004	0.026	0.056	< 0.002	0.036	0.025
Barium	0.155	0.358	0.548	0.255	0.157	0.455
Beryllium	< 0.0001	< 0.0001	< 0.0001	0.0003	0.0003	0.0002
Bismuth	0.0003	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002
Cadmium	1.07	8.2	5.62	6.03	2.16	3.6
Calcium	59.5	86.3	116	70.5	78.2	76.5
Cobalt	0.0456	0.0525	0.0261	0.0217	0.0688	0.0849
Chromium	0.077	0.064	0.166	0.011	0.011	0.068
Cesium	0.0245	0.281	0.246	0.0229	0.152	0.498
Copper	3.37	2.94	2.27	2.53	2.78	3.44
Iron	29.8	74.3	53.1	23.1	40.1	81.3
Gallium	0.0003	< 0.0001	0.0007	0.0001	0.0002	0.0003
Lanthanum	0.0008	0.0006	0.0016	0.0022	0.0004	0.0004
Lithium	0.02	0.03	0.02	0.08	0.01	0.14
Magnesium	123	127	126	117	128	118
Manganese	1.3	1.13	0.682	0.819	0.601	0.86
Molybdenum	0.5	0.637	0.24	0.319	0.253	0.365
Nickel	0.046	0.049	0.03	0.014	0.086	0.069
Lead	0.019	0.022	0.083	0.005	0.05	0.021
Palladium	<0.02	<0.02	<0.02	< 0.01	< 0.01	< 0.01
Platinum	<0.002	<0.002	<0.002	< 0.001	< 0.001	< 0.001
Potassium	2190	2450	2170	2070	2100	2430
Rubidium	2.87	9.26	7.52	5.76	8.97	8.59
Antimony	0.014	0.008	0.045	< 0.001	0.001	0.001
Selenium	1.57	2.24	1.08	0.6	1.13	1.94
Tin	0.16	0.11	0.16	0.16	0.01	0.04
Strontium	0.025	0.128	0.079	0.104	0.127	0.1
Thallium	0.0032	0.0941	0.0173	0.0025	0.0193	0.018
Uranium	0.0004	0.0002	0.002	0.0003	0.0043	0.0015
Vanadium	0.002	0.003	0.003	0.001	0.001	0.003
Zinc	24	28.8	29.9	19.3	19.8	28.8

Sample Number	mtgoat124	mtgoat131	mtgoat132	mtgoat133
Collection	4-Sep-12	15-Aug-13	18-Aug-13	23-Aug-13
Tissue	Kidney	Kidney	Kidney	Kidney
Age (y)	4.5	5.5	8.5	8.5
% Moisture	80.1	82.1	81.9	81.1
Total Mercury	0.02	0.02	0.014	0.026
Silver	0.005	0.0014	0.0003	0.0003
Aluminum	0.46	0.33	0.17	0.11
Arsenic	0.003	0.007	0.004	0.016
Barium	0.141	1.14	0.569	0.24
Beryllium	0.0004	< 0.0001	< 0.0001	0.0001
Bismuth	0.0002	< 0.0001	< 0.0001	0.0001
Cadmium	1.95	4.65	15.6	1.57
Calcium	72.7	79.7	75.9	87.3
Cobalt	0.0204	0.0263	0.0253	0.0199
Chromium	0.031	0.023	0.008	0.006
Cesium	0.0364	0.12	0.249	0.206
Copper	2.43	2.52	2.36	2.71
Iron	37.8	22.9	56.3	24.4
Gallium	0.0003	< 0.0001	0.0001	0.0001
Lanthanum	0.0028	0.0003	0.0048	0.0007
Lithium	0.15	0.08	0.19	0.03
Magnesium	126	142	130	123
Manganese	0.727	0.525	0.685	0.907
Molybdenum	0.255	0.295	0.217	0.344
Nickel	0.026	0.095	0.058	0.027
Lead	0.015	0.007	0.017	0.013
Palladium	< 0.01	< 0.01	< 0.01	< 0.01
Platinum	< 0.001	< 0.001	< 0.001	< 0.001
Potassium	2060	2200	2080	2090
Rubidium	3.78	8.7	8.24	10.2
Antimony	0.001	0.001	< 0.001	0.017
Selenium	0.65	1.04	0.94	0.62
Tin	0.01	0.35	0.24	0.18
Strontium	0.086	0.118	0.121	0.088
Thallium	0.0071	0.0076	0.0065	0.0073
Uranium	0.0012	0.0002	0.0009	0.0064
Vanadium	0.001	0.001	0.002	< 0.001
Zinc	19.7	20.9	26.1	25.2

Appendix 2. Histological results of mountain goat kidneys from 2011-2013 with the concentrations of seven metals found in those kidneys for comparison (Harms 2012, 2013, 2014).

									Proximal Tubular Epithelium														Glomeruli				
Field ID	Age	Cd ppm dw	Cu ppm dw	Ni ppm dw	Pb ppm dw	Zn ppm dw	Se ppm dw	Hg ppm dw	Vacuolar or granular degeneration	Pycnotic nuclei	Swollen nuclei	Necrosis	lymphohistiocytic inflammation	location of inflammation	Karyolysis	Interstitial fibrosis	Nephrocalcinosis	Location of nephrocalcinosis	Pigment deposits	pigment intra or extracellular	Hemorrhage (location, distribution)	Cast formation	Thickened BC	Swelling	Endothelial and/or mesangial proliferation	Comments	Frozen (yes or no)
106	9.5	101.7	14.7	0.34	0.11	184.5	8.97	0.26	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0	Multifocally, proximal tubules faded, moderate multifocal congestion in medulla	
107	7.5	7.71	11.8	0.16	0.33	97.8	2.07	0.09	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0	Multifocally, proximal tubules faded	
108	4.5	5.45	14.5	0.18	0.13	96.6	4.75	0.12	0	0	0	0	1	very small foci in cortical interstitium	0	0	0	-	0	-	0	0	0	0	0	Proximal tubules autolysed	
116	11.5	5.00	15.8	0.22	0.09	112.2	7.34	0.75	1	0	0	0	0	-	0	0	0	-	1	intracellular	0	0	0	0	0		
118	4.5	37.5	12.5	0.21	0.09	122.2	9.50	0.13	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0	Moderate multifocal congestion in distal cortex and medulla	yes
119	3.5	25.0	10.1	0.13	0.37	133.1	4.81	0.19	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0		yes
121	11.5	32.3	13.5	0.075	0.027	103.3	3.21	0.070	0	0	0	0	1	cortical interstitium	0	0	0	-	2	intracellular and in glomeruli	0	0	0	0	0		no
122	5.5	10.7	13.7	0.425	0.247	97.8	5.58	0.030	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0	moderate autolysis	no
123	5.5	15.5	14.8	0.296	0.090	124	8.33	0.069	0	0	0	0	0	-	0	0	0	-	0	-	0	0	0	0	0	cortex and medulla are moderately congested	no
124	4.5	9.78	12.2	0.130	0.075	98.8	3.26	0.100	0	0	0	0	0	-	0	0	0	-	1	intracellular	0	0	0	0	0		no
131	5.5	26.0	14.1	0.532	0.039	117.0	5.82	0.112	0	0	0	0	1	cortical interstitium	0	0	0	n/a	0	n/a	0	0	0	0	0	mild autolysis	no

Field ID	Age	Cd ppm dw	Cu ppm dw	Ni ppm dw	Pb ppm dw	Zn ppm dw	Se ppm dw	Hg ppm dw	Proximal Tubular Epithelium															Glomeruli				
									Vacuolar or granular degeneration	Pycnotic nuclei	Swollen nuclei	Necrosis	lymphohistiocytic inflammation	location of inflammation	Karyolysis	Interstitial fibrosis	Nephrocalcinosis	Location of nephrocalcinosis	Pigment deposits	pigment intra or extracellular	Hemorrhage (location, distribution)	Cast formation	Thickened BC	Swelling	Endothelial and/or mesangial proliferation	Comments	Frozen (yes or no)
132	8.5	86.1	13.0	0.320	0.094	144.0	5.19	0.077	0	0	0	0	1	cortical interstitium	0	0	0	n/a	0	n/a	0	0	0	0	0	multifocal areas of moderate eosinophilic granulomatous inflammation with giant cells in cortex, few cross-sections of helminth parasites, approx.. 100 um, but not often within the areas of inflammation	no
133	8.5	8.30	14.3	0.143	0.069	133.3	3.28	0.137	0	0	0	0	1	mild, multifocal arteritis in few small and medium sized arteries in cortex	0	0	0	n/a	1	intracellular	0	0	0	0	0	mild autolysis, mild multifocal lymphocytic ateritis with a small amount of necrotic nuclear debris	no