Appendix H

Subsistence Foods Data Evaluations

Contents

Evaluation of Metals Concentrations in Caribou Tissues

December 19, 2002

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Evaluation of Metals Concentrations in Caribou Tissues

This technical memorandum describes the findings of chemical analyses for metals in ten caribou collected on April 15, 2002, near the Red Dog Mine operations, along the DeLong Mountain Regional Transportation System (DMTS). The sampling was conducted to provide information to the community in response to concerns about potential metals concentrations in caribou.

Background

In 2001, the Alaska Department of Public Health (ADPH) conducted a health study titled *Public Health Evaluation of Exposure of Kivalina and Noatak Residents to Heavy Metals from Red Dog Mine* (ADPH 2001). This evaluation included a description of metals analyses in caribou collected from near the Red Dog Mine in 1996. In reviewing the caribou data, ADPH came to the following conclusion:

> The average concentrations of metals found in caribou harvested near the Red Dog Mine and DMTS road were low. Eating caribou from the Western Arctic caribou herd does not pose a public health threat.

Caribou have historically been, and remain, an integral part of life for native northern Alaskans, both for subsistence and cultural reasons. Although the ADPH analysis indicated that potential impacts to area caribou were minimal to negligible, the importance of the resource and level of community concerns made further monitoring desirable. Teck Cominco Alaska Incorporated (Teck Cominco), in collaboration with Alaska Department of Fish and Game (ADFG), conducted additional sampling in April 2002 with the purpose of monitoring for any changes that may have occurred since the 1996 sampling event. The data generated during this sampling event will also be utilized in the upcoming human health and ecological risk assessments.

Methods

Ten caribou were harvested by ADFG personnel from two locations: six from near Mile 14 of the DMTS road (i.e., 14 miles from the port site) and four from approximately a mile southeast of the airstrip runway (near the mine). Table 1 provides the physical characteristics of the animals harvested in the 2002 sampling event. The sampling was conducted at this time because the animals had been in the area near the road and mine for longer than usual (i.e., for several months), perhaps due to the mild winter, and some had expressed concerns that the longer stay in the area might have resulted in increased tissue concentrations.

Necropsies were performed by ADFG on the same day as the animals were harvested. Muscle, liver, and kidney samples were frozen and shipped for chemical analysis. The remainder of the meat was donated to the Kotzebue Senior Center. Muscle, liver, and kidney tissues were sampled and analyzed for lead, zinc, cadmium, and arsenic. Care was taken to avoid collecting samples from any tissue areas that might be influenced by bullet fragments. Table 2 provides sample results for the 2002 Red Dog data, the mean concentrations for the 1996 Red Dog data set, and the means for all northern Alaska areas combined (including Red Dog) in that same 1996 data set.

Comparison with 1996 Northern Alaska Caribou Sampling

The 2002 Red Dog sample results were compared with metals concentrations in caribou collected in 1996 from near the Red Dog Mine and from North Slope locations monitored by the North Slope Bureau. Exponent requested sample concentrations for the individual animals in the 1996 study in order to analyze statistically any potential differences between groups. These data are contained within a manuscript submitted for publication and are not yet available. The comparisons provided in this memorandum were made by using the means and standard deviation data as presented in Figures 11-1 to 11-18 of ADPH (2001) and thus are subject to some uncertainty. More complete analyses, which would include the full range of the concentrations, can be made when the raw data become available.

Figure 1 provides a graphic comparison of means and standard deviation ranges for 2002 Red Dog data, 1996 data from the Red Dog area, and data from herds elsewhere in northern Alaska. The results of this comparison do not reveal obvious or consistent differences between tissue metals concentrations in the 2002 Red Dog data and the 1996 data sets. In many cases, the 2002 Red Dog mean concentrations were lower than most 1996 comparison groups (e.g., zinc and arsenic in all tissues, cadmium and lead in muscle tissue), although likely statistically similar in most cases. In one case, for liver lead, the 2002 Red Dog mean was higher than each of the 1996 comparison groups (including the 1996 Red Dog data). However, the lack of elevated lead concentrations in kidney and muscle in the 2002 data set suggests that the liver result reflects normal variation given the limited sample size and is not directly related to contributions from the mine. In all the comparisons, the magnitude of the variability within groups (as indicated by the standard deviation ranges) indicates that there is little real difference between means.

Comparison of Caribou from Mile 14 Area with Caribou from Mine Area

Figure 2 presents caribou tissue metals data from samples collected in 2002, grouped by the location at which the animals were shot (i.e., near the Mile 14 marker of the DMTS road, and near the mine, approximately 1 mile southwest of the airstrip). Although this type of comparison can be useful in examining spatial relationships of metals concentrations in animals, any conclusions made are limited by two factors. First, there are few animals in each group (six in the Mile 14 group and only four in the Mine group), and they may not be representative of a larger population. Second, the home range of caribou is much larger than the entire area encompassing the mine, DMTS road corridor, and port. Thus, not only would the individual caribou likely spend relatively little time in the two areas with which they are being associated in this analysis, but also the animals harvested in the two areas could well be part of the same group.

The results of this comparison do not reveal an obvious or consistent relationship between tissue metals concentrations and proximity to the mine at the time of capture. In some cases, the average metal concentration was lower near the mine (e.g., muscle and kidney zinc, kidney cadmium, and liver and kidney arsenic) and in some cases, it was lower near the Mile 14 marker (e.g., liver and kidney lead, liver zinc, and muscle arsenic). In almost all cases, however, the overlap in variability within groups renders apparent differences between group averages insignificant. This is evident in Figure 2 by the overlap in the standard deviation bars between groups.

Evidence in the literature suggests that organ metals concentrations in caribou and other animals are age-related. For this reason, metals concentrations are often age-adjusted prior to analysis. However, the relationship for a given metal and tissue does not appear to be consistent from one population to another in these studies. For example, Larter and Nagy (2000) analyzed metals concentrations in the kidneys of two caribou populations in northern Canada, the Bluenose herd in the Northwest Territories (NWT) and an arctic herd on Banks Island. Cadmium concentrations were positively correlated with age in the Bluenose herd ($r = 0.64$, $p = 0.002$). But in the arctic population, cadmium concentrations were negatively correlated with age as a result of one outlying data point ($r = -0.88$, $p = 0.05$). Excluding the outlying animal, there was no significant relationship between age and cadmium. There was also no significant relationship between kidney lead concentration and age.

In the 2002 Red Dog dataset, kidney cadmium was significantly (i.e., $p < 0.05$) correlated with age ($r = 0.71$, $p = 0.02$), whereas kidney lead was not ($r = 0.42$, $p = 0.22$). Most comparisons did not indicate a significant relationship between age and tissue metal concentration. This lack of association is likely a result of small sample size and an incomplete age distribution in the animals sampled.

The Student's t-test is a statistical test used to evaluate potential differences between two sets of data. In this analysis, the t-test was used to estimate the probability that metals concentrations in caribou from the Mile 14 area differ from concentrations in caribou from near the mine based on the relatively few measured concentrations. A *p*-value of 0.05 or less, for example, would indicate that there is a 95 percent (or greater) probability that the metal concentrations in a given tissue are different in the two geographical groups. *P*-values of 0.05 or lower are typically considered statistically significant. It should be noted, however, that statistical significance does not imply biological relevance. That is, two groups may differ statistically for a particular measurement, but if that difference is not large enough to cause a biological alteration, it may not be biologically relevant.

In the 2002 Red Dog data, there were four comparisons that indicated statistically significant differences: kidney arsenic ($p = 0.02$) was lower in the mine animals, while muscle cadmium ($p = 0.009$), muscle lead ($p = 0.005$), and liver lead ($p = 0.003$) were lower in the Mile 14 animals (Table 3a). When the current data were age-adjusted, there was only one statistically significant difference between the two groups, liver lead ($p = 0.02$) (Table 3b). Nevertheless, lack of consistent difference in all three types of tissue indicates that the differences observed are due to normal variation with small sample sizes.

Comparison with Literature Values

As another frame of reference, metals concentrations from the 2002 Red Dog samples were compared to Canadian caribou and Scandinavian reindeer metals concentrations reported in the literature (Figure 3). None of the populations included in the literature comparisons was known to have any specific metal exposure other than to the levels occurring naturally in the environment. No arsenic concentrations were identified in the literature for *Rangifer tarandus* (caribou/reindeer).

Figure 3 shows the Red Dog 2002 versus literature comparisons for lead, zinc, and cadmium. As with the other comparisons presented in this report, there were no obvious or consistent differences between the 2002 Red Dog data and metals concentrations reported in the literature. In most cases, there were reported values both above and below the concentrations in the 2002 Red Dog samples. And, as noted previously, there is a large degree of within-group variability, which is apparent in the overlap of the standard deviation bars in Figure 3. For example, although the average liver zinc concentration in the 2002 Red Dog samples is slightly higher than the average values reported in the literature, it is clear that after taking into account the within-group variability, there is no discernable difference between any of the groups. In all cases except muscle cadmium, the magnitude of the variability minimizes the significance of apparent differences in average concentrations. The muscle cadmium levels in the 2002 Red Dog samples, although higher than the literature values, are still very low (0.04±0.02 mg/kg wet weight) and considerably less than most of the other northern Alaska herds (Figure 1).

Conclusions

Three types of analyses were conducted on the 2002 Red Dog caribou sampling data to evaluate whether caribou present in the vicinity of Red Dog operations might be impacted by metals from the mine: 1) metals concentrations were compared to concentrations in caribou sampled in 1996 from near the mine and other areas of northern Alaska, 2) metals concentrations in caribou captured near the Mile 14 marker of the DMTS road were compared with concentrations in caribou captured near the mine, and 3) 2002 Red Dog concentrations were compared to literature values. The following observations can be made following these analyses:

- By comparison with northern Alaska caribou metals concentrations, there are no apparent significant elevations in tissue metals concentrations in the 2002 Red Dog caribou samples and no trends in concentrations relative to the 1996 data for Red Dog.
- None of the metals were consistently higher or lower in all tissues of the Red Dog caribou relative to caribou or reindeer from Canada, Scandinavia, or elsewhere in northern Alaska.
- Although within-group variability was high (thus limiting any inferences that can be made), the average liver lead concentration in the 2002 Red Dog samples was higher than in each of the northern Alaskan, Canadian, and Scandinavian comparison groups. Average liver lead was also higher in the mine caribou group relative to the Mile 14 caribou. Average lead concentrations, however, were lower than most of the northern Alaskan comparison populations.

- The average muscle zinc concentration in the 2002 Red Dog samples was lower than in each of the northern Alaskan, Canadian, and Scandinavian comparison groups. Average muscle zinc was also lower in the mine caribou group relative to the Mile 14 caribou.

- Four comparisons were statistically significantly different in the 2002 caribou harvested near the mine relative to those harvested near Mile 14. In the mine group, kidney arsenic was lower, while muscle cadmium, muscle lead, and liver lead were higher. After age adjustment, only liver lead was higher.

- Only kidney cadmium was significantly correlated with age in the 2002 Red Dog dataset.

Although a few potential differences were noted between the 2002 Red Dog data and the comparison groups, most are likely the result of small sample size and normal variation among individuals. The potential impact on human health, if any, will be further evaluated in the human health risk assessment. However, there is no indication that caribou metals concentrations differ from those in caribou in Alaska or from values reported in the scientific literature. The results from the most recent caribou harvest and metals analysis provide useful screening information for ongoing evaluations to ensure that wildlife in the area of the Red Dog Mine remains a healthy and safe resource.

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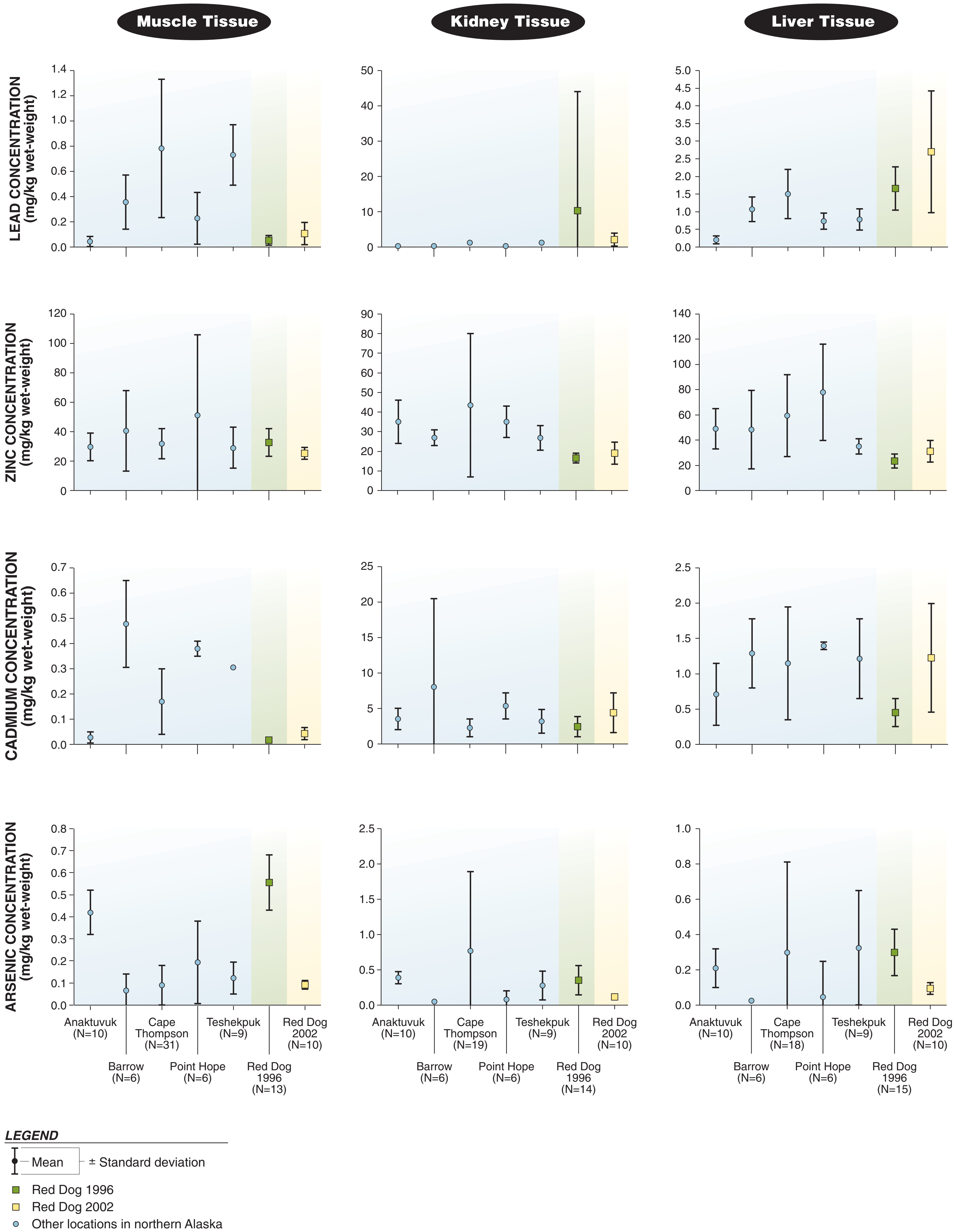

Figure 1. Comparison of metals concentrations in caribou samples from Red Dog area and from other locations in northern Alaska

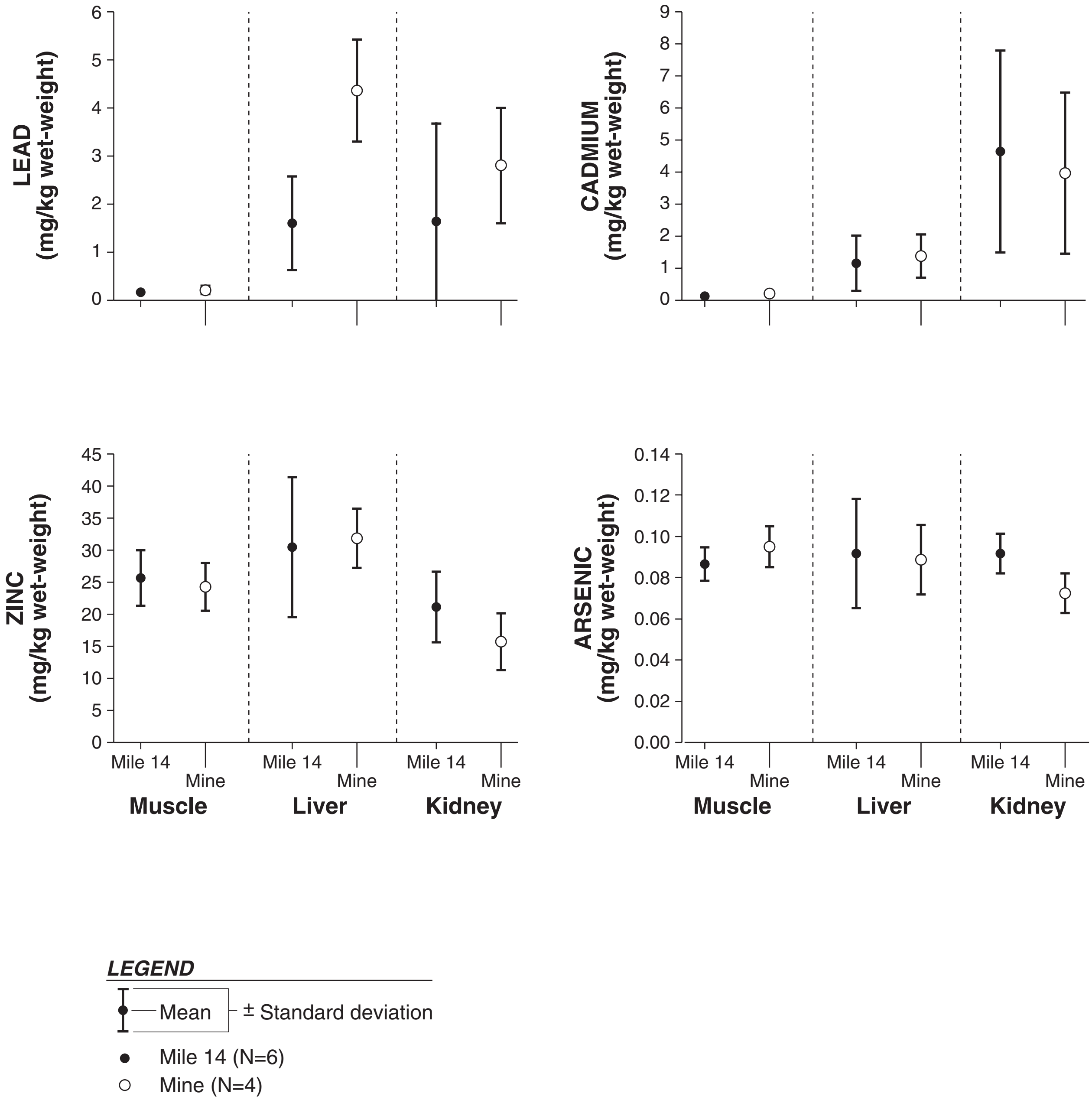

Figure 2. Comparison of metals concentrations in caribou from Red Dog mine area with caribou from Mile 14 area

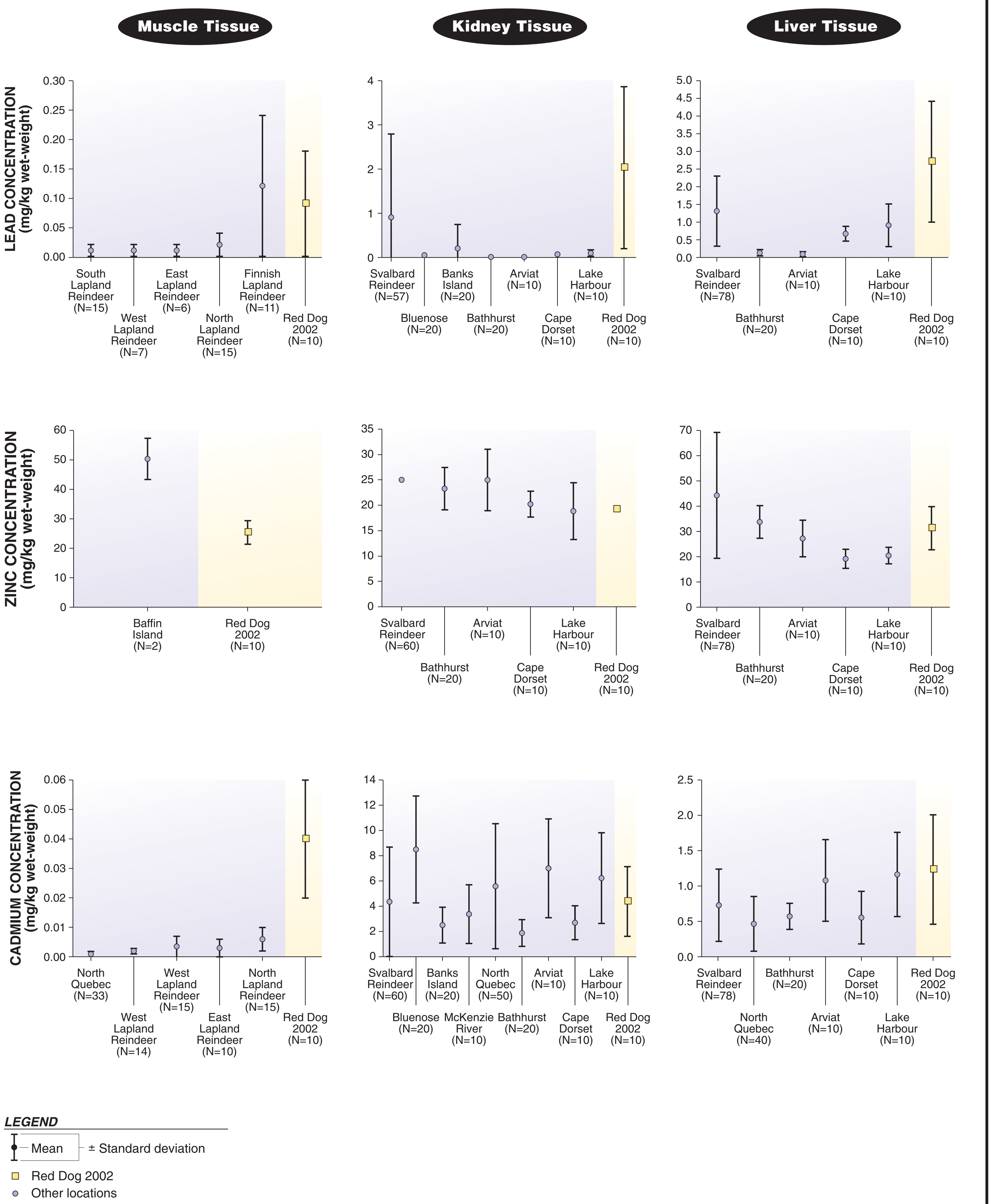

Figure 3. Comparison of metals concentrations in caribou samples from Red Dog area with literature values

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Table 1. Characteristics of caribou harvested for metals analyses in 2002

Sample Number	Estimated Age (years)	Male/ Female	Pregnancy Status	Location Collected	Notes[a]
02-01	4	Female	Pregnant	Mile 14	
02-02	7	Female	Pregnant	Mile 14	
02-03	13	Female	Pregnant	Mile 14	Gut shot
02-04	14	Female	Not pregnant	Mile 14	Shot through heart; no gross uterine abnormalities, parasites in liver
02-05	1	Bull	NA	Mile 14	Shot through chest
02-06	7	Female	Pregnant	Mile 14	Gut shot
02-07	7	Female	Pregnant	~1 mi SE of runway	
02-08	4	Female	Pregnant	~1 mi SE of runway	
02-09	14	Female	Pregnant	~1 mi SE of runway	Neck shot
02-10	3	Female	Pregnant	~1 mi SE of runway	Gut shot

Note: NA - not available

[a] Animals were collected with head shots unless otherwise noted.

Table 2. Metals data in caribou collected in 2002

Sample Number	Arsenic (200.8) (mg/kg wet)	Cadmium (200.8) (mg/kg wet)	Lead (200.8) (mg/kg wet)	Zinc (200.8) (mg/kg wet)
Samples collected at Mile 14				
02-01-Tissue	0.09 *U*	0.01 *U*	0.02	32.8
02-02-Tissue	0.09 *U*	0.01 *U*	0.023	25
02-03-Tissue	0.1 *U*	0.04	0.097	25
02-04-Tissue	0.08 *U*	0.05	0.065	20.6
02-05-Tissue	0.08 *U*	0.03	0.05	22.3
02-06-Tissue	0.08 *U*	0.03	0.037	27.9
Collected near mine				
02-07-Tissue	0.09 *U*	0.08	0.067	20.1
02-08-Tissue	0.09 *U*	0.08	0.209	22.3
02-09-Tissue	0.09 *U*	0.05	0.261	27.9
02-10-Tissue	0.11 *U*	0.05	0.207	27
Max	0.11 *U*	0.08	0.261	32.8
Median	0.09 *U*	0.05	0.066	25.0
Mean	0.09 *U*	0.04	0.10	25.1
1996 Red Dog mean (n=13)	0.55	0.01	0.050	32.0
Approx. 1996 S.D. range for Red Dog	0.42 to 0.68	0.01	0.01 to 0.09	21 to 41
Approx. 1994–1996 S.D. range all studies	0 to 0.68	0.01 to 0.65	0 to 1.3	0 to 105
Samples collected at Mile 14				
02-01-Liver	0.07 *U*	0.36	0.766	20.3
02-02-Liver	0.09 *U*	0.77	1.61	26.7
02-03-Liver	0.1 *U*	1.96	3.41	44.6
02-04-Liver	0.08 *U*	0.58	1.39	25.4
02-05-Liver	0.07 *U*	0.68	0.715	22.2
02-06-Liver	0.14 *U*	2.49	1.66	43.9
Collected near mine				
02-07-Liver	0.09 *U*	2.36	5.59	34.2
02-08-Liver	0.11 *U*	1.24	3.9	30.1
02-09-Liver	0.08 *U*	1.05	4.83	26.3
02-10-Liver	0.07 *U*	0.78	3.14	36.8
Max	0.14 *U*	2.49	5.59	44.6
Median	0.09 *U*	0.92	2.40	28.4
Mean	0.09 *U*	1.23	2.701	31.1
1996 Red Dog mean (n=13)	0.30	0.45	1.700	22.0
Approx. 1996 S.D. range for Red Dog	0.2 to 0.4	0.25 to 0.6	1.0 to 2.25	19 to 23
Approx. 1994–1996 S.D. range all studies	0 to 0.8	0.25 to 2.4	0.2 to 2.25	19 to 115
Samples collected at mile 14				
02-01-Kidney	0.08 *U*	1.29	0.366	12.4
02-02-Kidney	0.1 *U*	4.48	1.16	23.4
02-03-Kidney	0.08	9.87	5.82	27.9
02-04-Kidney	0.1 *U*	4.28	0.807	19.7
02-05-Kidney	0.09 *U*	1.62	0.347	18.5
02-06-Kidney	0.1	6.17	0.714	25.1
Collected near mine				
02-07-Kidney	0.07 *U*	6.59	2.55	16.5
02-08-Kidney	0.08 *U*	1.61	1.22	9.99
02-09-Kidney	0.08 *U*	5.64	3.34	20.7
02-10-Kidney	0.06 *U*	1.99	4.02	15.3
Max	0.10	9.87	5.82	27.9
Median	0.08 *U*	4.38	1.19	19.1
Mean	0.08 *U*	4.35	2.034	18.9
1996 Red Dog mean (n=13)	0.35	2.50	10.000	17.0
Approx. 1996 S.D. range for Red Dog	0.1 to 0.55	1 to 3.5	0 to 45	15 to 20
Approx. 1994–1996 S.D. range all studies	0 to 1.9	0 to 20	0 to 45	9 to 80

Note: S.D. - standard deviation
U - undetected at value shown

Table 3a. Comparison of caribou metal concentrations in animals from near mine and Mile 14 (*p*- values)

	Arsenic	Cadmium	Lead	Zinc
Muscle	0.18	0.009	0.005	0.64
Liver	0.79	0.69	0.003	0.83
Kidney	0.02	0.74	0.32	0.13

Table 3b. Comparison of age-adjusted caribou metal concentrations in animals from near mine and Mile 14 (*p* -values)

	Arsenic	Cadmium	Lead	Zinc
Muscle	0.81	0.41	0.13	0.64
Liver	0.71	0.96	0.02	0.92
Kidney	0.51	0.58	0.14	0.48

Assessment of Metals Concentrations in Ptarmigan Collected Near the DMTS

January 3, 2005

Exponent®

Technical Memorandum

Assessment of Metals Concentrations in Ptarmigan Collected Near the DMTS

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Assessment of Metals Concentrations in Ptarmigan Collected Near the DMTS

This technical memorandum describes the findings of chemical analyses for metals in eight ptarmigan collected in June and July of 2004. Five of the birds were collected near the Red Dog Mine operations, along the DeLong Mountain Regional Transportation System (DMTS) road, and three were collected from reference locations. The sampling was conducted to evaluate the potential for metals from fugitive dust to bioaccumulate into food sources collected as part of the local subsistence diet, and to provide additional data on subsistence foods resources for use in the ongoing DMTS risk assessment.

Background

Historical transport of ore concentrate over a 52-mile haul road from the Red Dog lead/zinc mine in northwest Alaska to a seaport has been associated with elevated lead levels on moss growing near the road, raising concerns within the local community regarding the safety of subsistence foods. These concerns are being evaluated in the ongoing human health risk assessment for the DMTS (Exponent 2004a).

Ptarmigan were selected as a good candidate species to evaluate bioaccumulation of metals into subsistence foods, and to provide additional data on subsistence foods resources for use in the DMTS risk assessment. Ptarmigan are typically harvested on an opportunistic basis; native residents do not identify ptarmigan as a primary food item. However, ptarmigan have the potential to come into more prolonged direct contact with fugitive dusts associated with DMTS-related activities than other subsistence foods being evaluated. This is because ptarmigan actively consume soil and gravel as a necessary part of their digestive process. As a result, individual ptarmigan may consume materials directly from the roadbed, the road shoulder, and the developed areas of the port, where metals concentrations tend to be highest. Ptarmigan are also non-migratory, so they have the potential to spend long periods of time in a relatively small range.

The ptarmigan data described in this technical memorandum will be incorporated into the human health assessment forthcoming in 2005. The ptarmigan data will supplement data already available on metals in environmental media (e.g., soil) and in other foods (i.e., berries, sour dock, caribou, and fish).

Methods

Adult willow ptarmigan (*Lagopus lagopus*) were collected consistent with methods described in the *Phase II Field Sampling and Analysis Plan for the DMTS for the Fugitive Dust Risk Assessment* (Exponent 2004b). Five ptarmigan samples were collected from near the DMTS road and three ptarmigan samples were collected in the terrestrial reference area using a shotgun with steel shot. Each ptarmigan sample consisted of one individual adult bird. Following collection, the ptarmigan were frozen whole and shipped to a dissection lab. The dissected samples were delivered to the analytical laboratory for analysis of antimony, barium, cadmium, lead, thallium, and zinc in breast muscle, liver, and kidney tissues.

Individuals were aged and sex was determined for each bird. Age determinations were made by examining the area of black pigment on one of the wing weathers, specifically primaries 8 and 9. If the amount of area covered by black pigment on Primary 8 was equal to or greater than the area of black pigment on Primary 9, the ptarmigan was classified as an adult. If the amount of black pigment on Primary 8 was less than that on Primary 9, the individual was classified as a juvenile. These methods are consistent with those reported by Bergerud et al. (1963), and used by multiple researchers for the same purpose.

Sex was determined by first examining whether yellow egg yolk sacs (indicating a female) or testes (indicating a male) were present inside the abdomen. If the abdomen was not intact after dissection, the tail feathers were examined. Individuals were classified as females if brown pigment was present on the tail rectrices feathers and on the two central greater upper tail coverts. If those areas were black as opposed to brown, individuals were classified as males. These methods are consistent with those reported by Bergerud et al. (1963).

All of the birds examined were classified as after hatch year (adults), and three of those birds were females. The age and sex information is summarized in Table 1.

Tissue concentration data were analyzed to evaluate potential differences between metals concentrations in ptarmigan collected near the road and ptarmigan collected from reference locations. The analysis was conducted using an un-paired Student's *t*-test, using GraphPad Prism® version 4.02 for Windows® (GraphPad Software, San Diego, California USA). The *t*-test is a statistical method used to evaluate potential differences between two sets of data. In this analysis, the *t*-test was used to estimate the probability that metals concentrations in ptarmigan collected near the road differ from concentrations in ptarmigan from reference areas, based on the relatively few measured concentrations. A *p*-value of 0.05 or less, for example, would indicate that there is a 95 percent (or greater) probability that the metal concentrations in a given tissue are different in the two geographical groups; *p*-values of 0.05 or lower are typically considered statistically significant.[1] It should be noted, however, that statistical significance does not imply biological relevance. That is, two groups may differ statistically for a particular measurement, but if that difference is not large enough to cause a biological alteration, it may not be biologically relevant.

The *t*-test would be the best tool available to statistically compare the two groups of ptarmigan, provided metals concentrations are normally distributed in the population of birds of which the study birds were part.[2] However, given the small number of samples that could be collected, we also analyzed potential differences using a "non-parametric" test, or one in which the validity does not rely on the way the samples are distributed. For the non-parametric analysis, a Mann-

[1] In the remainder of the document, the word "significant" indicates statistical significance.

[2] In a "normal" distribution, if one were to collect enough samples, there would be an equal number of samples with concentrations less than and greater than the average concentration. In addition, for every sample less than the average, there would be another sample greater than, but equally different from, the average.

Whitney test was used. Although statistically significant differences were not found using the *t*-test, statistical significance was attained in some comparisons using the non-parametric Mann-Whitney test. Thus, only results of the non-parametric test are reported below.

Comparison of Ptarmigan from Areas Near DMTS with Ptarmigan from Reference Area

Concentrations in the five ptarmigan samples collected near the DMTS were compared with concentrations in the three ptarmigan samples collected from the reference area. The reference area and the sample locations are shown on Figure 1. The reference area was selected because of its relative proximity to the site, in a location beyond topographic features in the prevailing upwind direction.

The data for antimony, barium, cadmium, lead, thallium, and zinc in ptarmigan muscle, liver, and kidney are presented in Table 2. Table 2 also shows average concentrations derived from reference samples and from near-road samples. These data were analyzed statistically to evaluate whether near-road concentrations were significantly higher than reference conditions and these comparisons are presented graphically in Figures 2 through 4.

Concentrations of antimony and thallium were lower than or equal to reference concentrations in all three tissues, as shown in Table 2 and Figures 2 through 4. In addition, antimony was never detected in muscle, liver, or kidney and thallium was never detected in muscle and infrequently detected in liver and kidney. This strongly suggests that there is no site-related increase for antimony or thallium.

Average concentrations of barium and zinc in near-road samples were somewhat elevated relative to reference averages for all tissue/metal combinations except zinc in muscle. Elevations were not, however, statistically significant (Figures 2-4, Table 2). Average cadmium concentrations from near-road samples were also about two-fold higher than reference conditions in all three tissues, but none were significantly elevated. Average lead concentrations were also elevated relative to the average reference condition for muscle, liver, and kidney. The only comparison identified as statistically significant was lead in liver and kidney relative to reference concentrations (Figures 3 and 4), but the absence of statistical significance for some of the other metals may not be definitive as a result of the relatively small sample size.

Thus, based on the data currently available, lead concentrations in liver and kidney samples from near-road samples are elevated relative to average reference concentrations. In addition, the lack of statistical significance for the apparent elevation of lead in muscle and of cadmium in muscle, liver, and kidney relative to reference concentrations may also be due to a lack of power to detect differences because of small sample sizes.

Comparison with Literature Values

Metals concentrations in the 2004 DMTS road and reference area samples were compared to data available in the scientific literature for metals in ptarmigan, in order to provide another frame of reference. Available data were summarized for liver and kidney cadmium, lead, and zinc concentrations in ptarmigan collected from locations worldwide. Most of the studies were conducted to evaluate whether metals were elevated in ptarmigan at locations with an established or suspected soil or aerial deposition source. In each of these investigations reported in the literature, however, data were also reported for areas identified as reference locations. Tables 3 and 4 show liver and kidney concentrations for cadmium, lead, and zinc in ptarmigan that were identified as having no known specific metal exposure other than to the levels occurring naturally in the environment. Very limited data were available for lead and zinc and no data were available for thallium or barium in the literature reviewed. Lead and zinc concentrations in liver at literature reference locations were similar to concentrations in liver detected in Red Dog reference samples.

Data for cadmium concentrations in ptarmigan tissues were more widely available. Many of these studies identified substantial increases in concentrations of cadmium with age, and also showed that concentrations are highest in the kidney, followed by the liver, with muscle tissue having the lowest concentrations (Myklebust et al. 1999). Of the five studies that reported data for cadmium in ptarmigan kidney, four studies reported means and ranges of concentrations lower than those identified at either the Red Dog reference or near-road samples (Table 4). Similarly, three of the four studies reporting cadmium concentrations in liver identified lower concentrations than Red Dog reference or near-road samples (Table 3). Cadmium concentrations reported were not, however, markedly different and there is some indication in these data that mineralized “ore belt” areas have concentrations similar to or higher than those identified in the Red Dog data. For example, Larison et al. (2000), who presented data from a mineralized alpine area in Colorado, reported cadmium concentrations in ptarmigan liver and kidney higher than those identified in the data from Red Dog ptarmigan tissues.

Larison et al. (2000) reported concentrations of cadmium in kidney tissue related to soil with elevated naturally occurring metals (i.e., “ore belt” areas) in the Colorado Rocky Mountains and in areas without naturally elevated values or any other known sources. Average concentrations in kidneys of adult birds from mineralized “ore belt” areas were up to 10 times higher than those from areas away from the “ore-belt.” These concentrations were also consistent with the kidney cadmium concentrations identified in the Red Dog reference location and near-road locations. Larison et al. (2000) identified a mean kidney concentration of 99.4 mg/kg wet weight (range 47.4 to 188 mg/kg wet weight) for adult ptarmigan aged 24 months, and 115.5 mg/kg wet weight (range 98.6 to 143 mg/kg wet weight) in adult ptarmigan aged 36 months (Table 4). In comparison, the Red Dog average concentrations in kidney tissue were 51.6 mg/kg at the reference location and 80.9 mg/kg in the near-road samples. In contrast, Larison et al. (2000) identified a mean adult kidney concentration of 15.6 mg/kg wet weight in birds from areas away from the “ore belt.” No soil concentration data were provided, but the authors did interpret the elevated tissue concentrations and some population data collected in their investigation as indicating that cadmium toxicity might be limiting the distribution of ptarmigan in this habitat.

Larison reported only limited data for cadmium in liver, but a figure provided there identified a range of liver concentrations from 3.0 to 32.0 mg/kg wet weight, which is higher than the range identified in the reference or near-road samples collected at Red Dog (Table 3).

Other authors evaluated metals in ptarmigan tissue in consideration of other potential sources. Myklebust et al. (1993, 1999) and Wren et al. (1994) evaluated long-range aerial deposition of metals in Norway from multiple industrial sources and Kålås et al. (1995) evaluated ptarmigan tissue concentrations to evaluate the potential impact of a Russian nickel smelter. Reference location concentrations identified by these authors were all lower than either reference or near-road concentrations identified in the Red Dog samples.

Overall, evaluation of the literature values indicates that the reference area concentrations reported in most studies were lower than concentrations identified in reference or near-road samples at Red Dog, with the exception of the naturally mineralized alpine area in Colorado (Larison et al. 2000), where higher concentrations were reported for cadmium in kidney and liver tissue.

Conclusions

Two types of analyses were conducted on the 2004 ptarmigan sampling data to evaluate whether tissue concentrations of metals in ptarmigan harvested near the DMTS road might be elevated near the mine or transportation corridor: 1) metals concentrations in near-road samples were compared to concentrations in reference area samples, and 2) metals concentrations in near-road samples were compared to literature values. The following observations can be made following these analyses:

- Concentrations of antimony and thallium were lower than or equal to reference concentrations in all three tissues. In addition, antimony was never detected in muscle, kidney, or liver tissue, and thallium was never detected in muscle and infrequently detected in liver and kidney tissue. This strongly suggests that there is no site-related increase for antimony or thallium.

- Average concentrations of barium and zinc in near-road samples were somewhat elevated relative to reference averages for all tissue/metal combinations except zinc in muscle. Average cadmium concentrations from near-road samples were also about two-fold higher than reference conditions in all three tissues. None of these elevations were identified as statistically significant, although conclusions were limited by sample size.

- Lead concentrations in liver and kidney tissues from near-road samples were elevated relative to reference concentrations. The elevated values in liver and kidney tissues were identified as significant. Lead concentrations in DMTS-area samples were also elevated relative to limited data available in the scientific literature.

These findings will be further evaluated within the human health risk assessment. Although concentrations of some metals appear to be elevated in ptarmigan tissues, overall concentrations are still quite low and risk calculations will help in determining the public health implications, if any, of these data.

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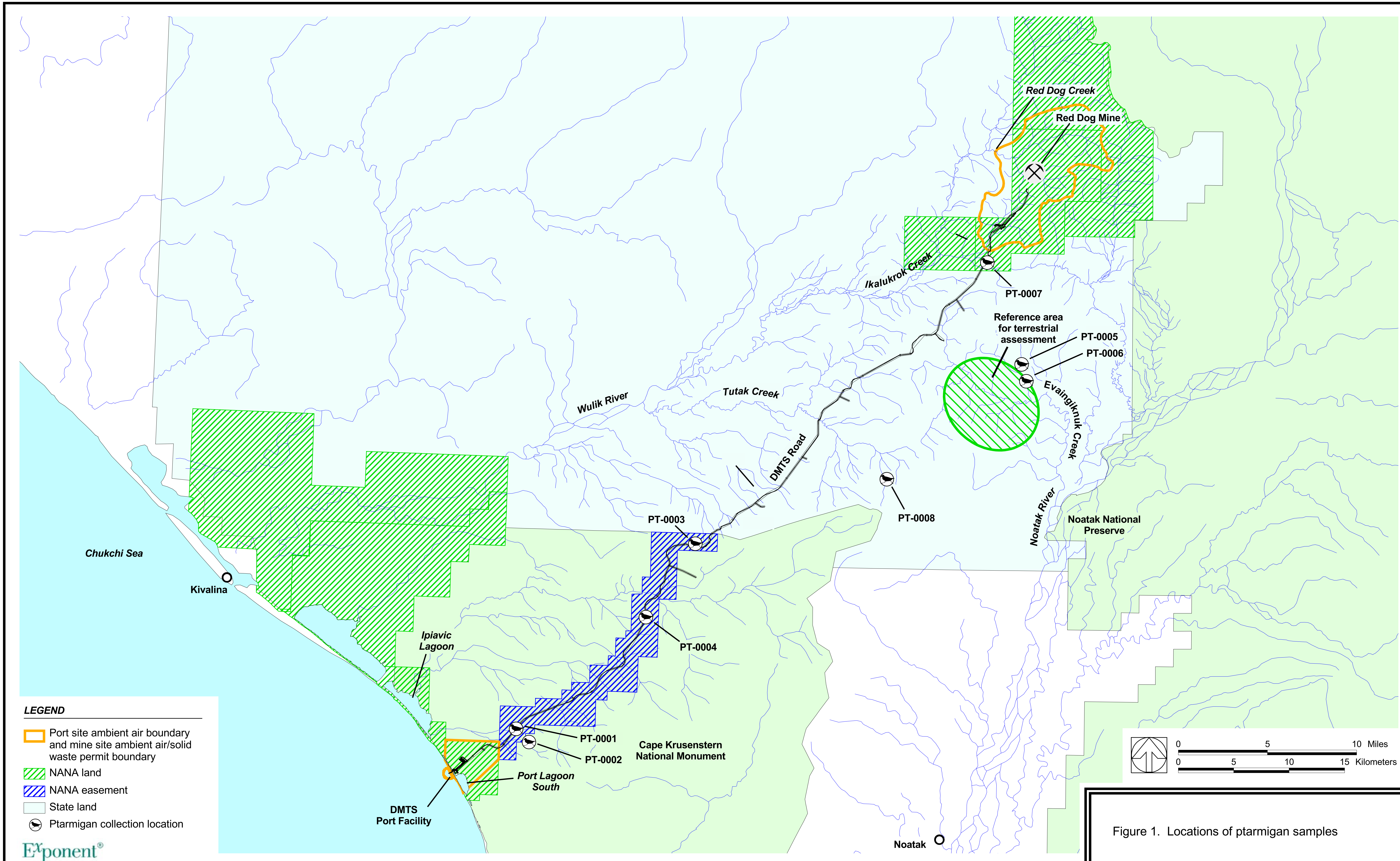


Figure 1. Locations of ptarmigan samples

8601997.001 3500 | Dec 28, 2004 | ptarmigan Fig 1 view | ptarmigan Fig 1 layout | j:\red_dog\projects\techmemos_1104.apr

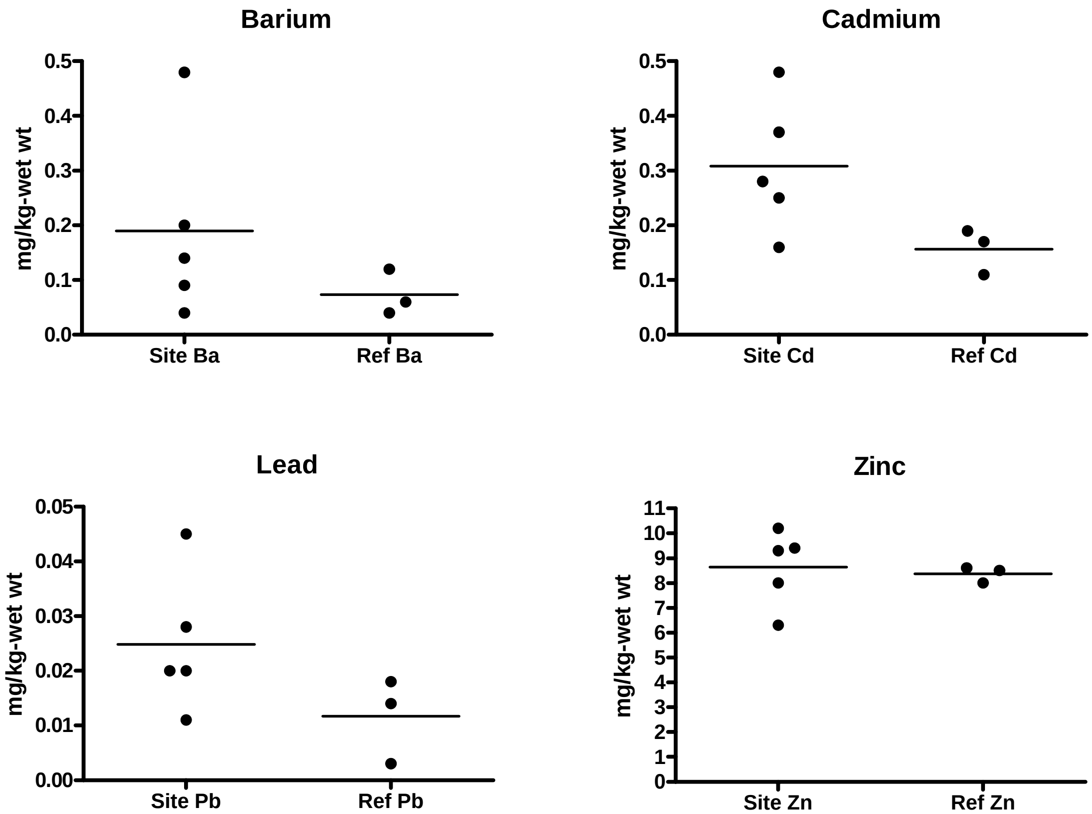
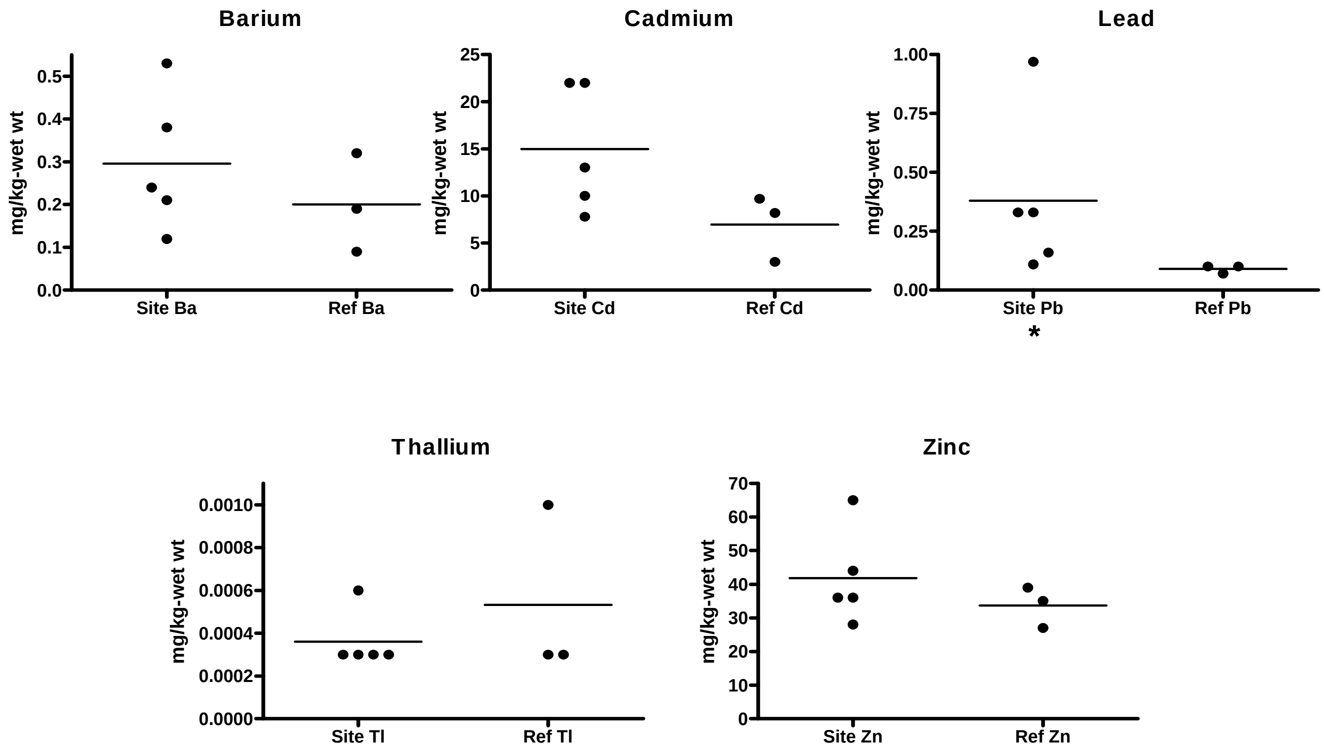
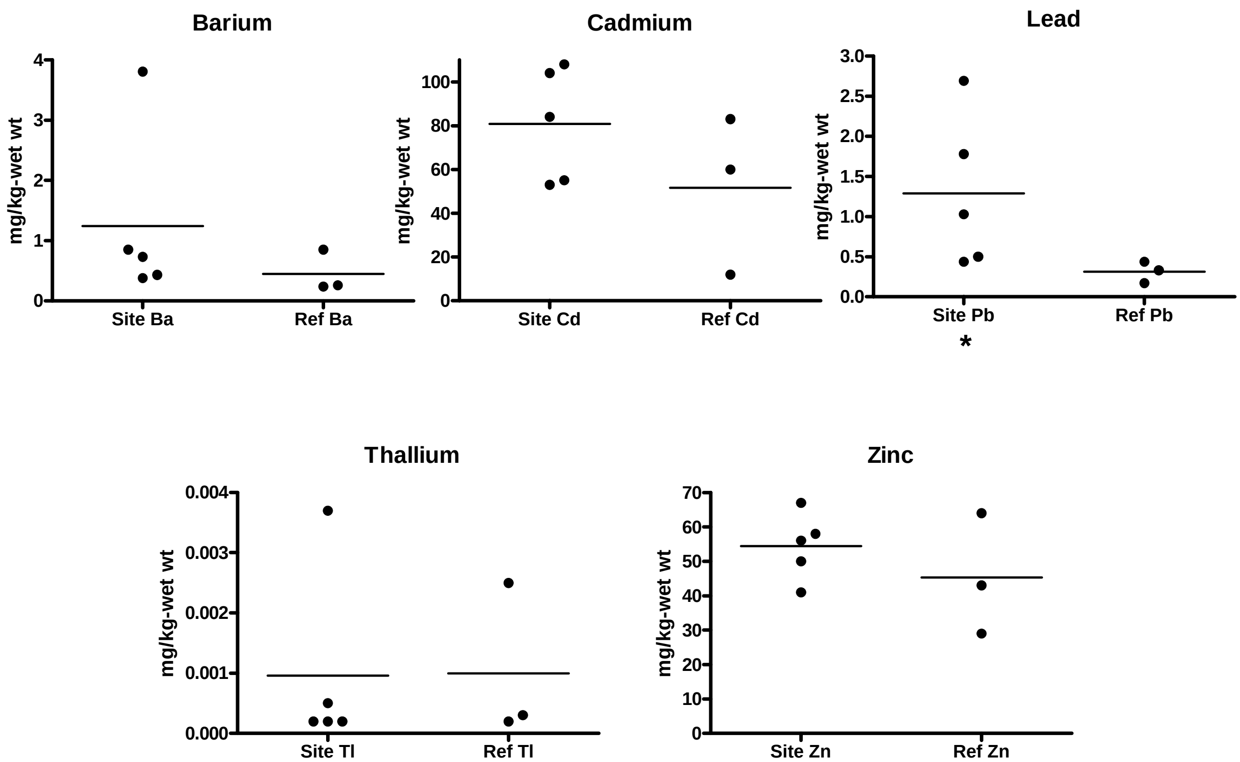


Figure 2. Ptarmigan muscle metals concentrations



*Site concentrations significantly different than reference concentrations (p≤0.05)

Figure 3. Ptarmigan liver metals concentrations (mg/kg-wet weight)



*Site concentrations significantly different than reference concentrations ($p \leq 0.05$)

Figure 4. Ptarmigan kidney metals concentrations

Table 1. Willow ptarmigan collected for DMTS fugitive dust risk assessment, 2004

Bird ID	Sex	Age[a]
PT0001	Male	Adult
PT0002	Female	Adult
PT0003	Male	Adult
PT0004	Male	Adult
PT0005	Female	Adult
PT0006	Male	Adult
PT0007	Male	Adult
PT0008	Female	Adult

[a] The age of all ptarmigan samples was after the hatch year, i.e., they were adults.

Table 2. Metals concentrations in ptarmigan muscle, liver, and kidney tissue

Survey Station	Antimony (mg/kg wet)	Barium (mg/kg wet)	Cadmium (mg/kg wet)	Lead (mg/kg wet)	Thallium (mg/kg wet)	Zinc (mg/kg wet)
Ptarmigan Muscle Tissue						
Near Road						
PT1	0.0020 *U*	0.040 *J*	0.28	0.020	0.00057 *U*	9.4
PT2	0.0014 *U*	0.20 *J*	0.16	0.028	0.00055 *U*	8.0
PT4	0.0014 *U*	0.14 *J*	0.48	0.020	0.00057 *U*	9.3
PT3	0.0014 *U*	0.09 *J*	0.37	0.011	0.00057 *U*	10.2
PT7	0.0013 *U*	0.48 *J*	0.25	0.045	0.00052 *U*	6.3
Median:	0.0014 *U*	0.14 *J*	0.28	0.020	0.00057 *U*	9.3
Mean:	0.00075 *U*	0.19	0.31	0.025	0.00028 *U*	8.6
Standard Deviation:	0.00014 *U*	0.17	0.12	0.013	0.000010 *U*	1.5
Reference						
PT5-REF	0.0018 *U*	0.12 *J*	0.19	0.018	0.00058 *U*	8.0
PT6-REF	0.0014 *U*	0.06 *J*	0.17	0.0029	0.00057 *U*	8.5
PT8-REF	0.0017	0.039	0.11 *J*	0.014	0.0006 *U*	8.6
Median:	0.0017	0.06 *J*	0.17	0.014	0.0006 *U*	8.5
Mean:	0.0011	0.072	0.16	0.011	0.00028 *U*	8.4
Standard Deviation:	0.00050	0.043	0.040	0.0076	0.0000087 *U*	0.34
Ptarmigan Liver Tissue						
Near Road						
PT1	0.0015 *U*	0.21 *J*	22.5	0.33	0.00060	44.2
PT2	0.0014 *U*	0.12 *J*	7.8	0.33	0.00058 *U*	64.8
PT4	0.0015 *U*	0.53 *J*	13.4	0.16	0.00058 *U*	35.9
PT3	0.0014 *U*	0.38 *J*	10.1	0.11	0.00056 *U*	28.2
PT7	0.0013 *U*	0.24 *J*	22.3	0.97	0.00052 *U*	35.9
Median:	0.0014 *U*	0.24 *J*	13.4	0.33	0.00058 *U*	35.9
Mean:	0.00071 *U*	0.29	15.2	0.38	0.00034	41.8
Standard Deviation:	0.000039 *U*	0.16	6.8	0.34	0.00014	14.1
Reference						
PT5-REF	0.0014 *U*	0.32 *J*	8.2	0.065	0.00057 *U*	38.9
PT6-REF	0.0015 *U*	0.19 *J*	9.7	0.099	0.00060 *U*	35.3
PT8-REF	0.0013 *U*	0.085	3.0 *J*	0.10	0.0010	26.6
Median:	0.0014 *U*	0.19 *J*	8.2	0.099	0.00060 *U*	35.3
Mean:	0.00070 *U*	0.20	7.0	0.088	0.00054	33.6
Standard Deviation:	0.000052 *U*	0.12	3.5	0.020	0.00043	6.3
Ptarmigan Kidney Tissue						
Near Road						
PT1	0.0012 *U*	0.85 *J*	55.3	1.0	0.00049	50.1
PT2	0.0012 *U*	0.73 *J*	52.6	1.8	0.00049 *U*	41.0
PT4	0.0012 *U*	0.38 *J*	108	0.44	0.00049 *U*	56.4
PT3	0.0012 *U*	0.43 *J*	84.4	0.50	0.00048 *U*	57.8
PT7	0.0013 *U*	3.8	104 *J*	2.7	0.0037	67.1
Median:	0.0012 *U*	0.73 *J*	84.4	1.0	0.00049 *U*	56.4
Mean:	0.00062 *U*	1.2	80.9	1.3	0.0010	54.5
Standard Deviation:	0.000020 *U*	1.5	26.2	0.95	0.0015	9.7
Reference						
PT5-REF	0.0012 *U*	0.85 *J*	59.5	0.44	0.00049 *U*	43.4
PT6-REF	0.0013 *U*	0.24 *J*	83.2	0.33	0.00051 *U*	63.8
PT8-REF	0.0012 *U*	0.26	11.9 *J*	0.17	0.0025	28.6
Median:	0.0012 *U*	0.26	59.5	0.33	0.00051 *U*	43.4
Mean:	0.00062 *U*	0.45	51.6	0.32	0.0010	45.3
Standard Deviation:	0.000011 *U*	0.35	36.3	0.14	0.0013	17.6

Table 3. Summary of data for metals in ptarmigan liver

Author	Type of Area	Location		N	Cadmium Mean (median) (ppm wet wt)	Cadmium Range (ppm wet wt)	Lead Mean (median) (ppm wet wt)	Zinc Mean (median) (ppm wet wt)
Red Dog Data (2004)[a]								
	Northwest Alaska mineralized reference location and areas adjacent mine transport road	Reference location	Adult Willow Ptarmigan	3	7 (8.2)	3 – 9.7	0.088 (0.099)	33.6 (35.3)
		Near-road location–potential mining transport impact	Adult Willow Ptarmigan	5	15.2 (13.4)	7.8 – 23	0.38 (0.33)[b]	41.8 (35.9)
Myklebust et al. (1993)[c]								
	Alpine central Norway–possible high natural cadmium	Lower cadium diet	Adult Rock Ptarmigan	19	(3.63)	2.0 – 7.6		
			Adult Willow Ptarmigan	31	(5.28)	2.0 – 11.2		
Myklebust et al. (1999)[d]								
	Alpine central Norway–possible high natural cadmium		Adult Willow Ptarmigan	31	5.5			
Kalas et al. (1995)[c]								
	Norway near nickel smelter and reference areas	Reference area	Adult Willow Ptarmigan	9	(1.8)		(0.17)	(29)
		Range of concentrations in areas thought to be affected	Adult Willow Ptarmigan	14/3	(2.3–2.2)		(0.18–0.24)	(26.5–25.8)
		Range of concentrations in areas thought to be affected	Juvenile Willow Ptarmigan	8/3	(0.24–0.46)		(0.35–0.41)	(28.7–23.9)
Larison et al. (2000)[a]								
	Colorado alpine	"Ore belt" areas and areas removed from ore belt	White-tailed Ptarmigan (ages not specified)	39	NA	3.0 – 32.0		

Note: NA - not available

[a] Determined to be different from reference location at a p value of 0.05.

[b] Median kidney values (dry wt converted to wet weight)

[c] Mean kidney values (dry wt converted to wet weight).

[d] Mean kidney values (wet wt).

Table 4. Summary of data for metals in ptarmigan kidney

					Metals Data (ppm wet wt)				
					Cadmium		Lead	Zinc	
Author	Type of Area	Location		N	Mean (median)	Range	Mean (median)	Mean (median)	Range
Red Dog Data (2004)[a]									
	Northwest Alaska mineralized reference location and areas adjacent mine transport road	Reference location	Adult Willow Ptarmigan	3	51.6 (59.5)	11.9 – 83.2	0.32 (0.33)	45.3 (43.4)	43.4 – 63.8
		Near-road location–potential mining transport impact	Adult Willow Ptarmigan	5	80.9 (84.4)	52.6 – 108	1.3 (1.0)[b]	54.5 (56.4)	41 – 67.1
Myklebust et al. (1993)[c]									
	Alpine central Norway–possible high natural cadmium	Lower cadmium diet	Adult Rock Ptarmigan	19	28.7	15.3 – 51.8			
		Higher cadmium diet	Adult Willow Ptarmigan	31	37.3	21.2 – 85.0			
Myklebust et al. (1999)[d]									
	Alpine central Norway–possible high natural cadmium		Adult Willow Ptarmigan	31	41.3				
Kalas et al. (1995)[c]									
	Norway near nickel smelter and reference areas	Reference area	Adult Willow Ptarmigan	9	11.4[e]		0.11[e]	26.4[e]	
		Range of areas thought to be most affected	Adult Willow Ptarmigan	14/3	(21.5–26.9)[e]		(0.22–0.21)[e]	(29.1–31.9)[e]	
Larison et al. (2000)[a]									
	Colorado alpine	Areas removed from "ore belt"	Adult White-tailed Ptarmigan	12	15.6±7.4				
		"Ore belt" areas	Juvenile (6 months) White-tailed Ptarmigan	NA	21.4±5.8	16.99 – 27.9			
			Juvenile (9-23 months) White-tailed Ptarmigan	NA	59.5±29.7	40 – 120			
			Adult (24+ months) White-tailed Ptarmigan	NA	99.4±36.6	47.4 – 188			
			Adult (36+ months) White-tailed Ptarmigan	NA	115.5±24.0	98.6 – 143			
Wren et al. (1994)[a]									
	Norway - ten locations thought to primarily represent natural metals with some long-range aerial dep.	Lowest cadmium location	Juvenile Willow Ptarmigan	4	1.3	0.9 – 2.1		24.5	21.1 – 29.0
		(thought to be natural sources)[f]	Adult Willow Ptarmigan	2	7.3	7.2 – 7.4		30.8	28.8 – 32.7
		Highest cadmium location juvenile (thought to be natural sources)	Juvenile Willow Ptarmigan	4	4.3	2.8 – 8.3		22.6	19.1 – 24.7
			Adult Willow Ptarmigan	5	39.0	26.4 – 51.1		34.9	28.5 – 41.6
		Highest cadmium location adult (thought to be natural sources)	Adult Willow Ptarmigan	6	48.5	36.3 – 71.0		40.2	34.9 – 50.0

Note: NA - not available

[a] Mean kidney values (wet wt).

[b] Determined to be different from reference location at a p value of 0.05.

[c] Median kidney values (dry wt converted to wet weight)

[d] Mean kidney values (dry wt converted to wet weight).

[e] Determined to be different than reference in the Kruskal-Wallis test at the 0.004 level for cadmium and for zinc at the 0.008 level (Kalas et al. 1995).

[f] Cadmium concentrations were more variable in the 10 locations than zinc and thus the highest and lowest from those locations were used in comparisons for zinc.

Assessment of Metals Concentrations in Salmonberry and Sourdock Collected Near the DMTS

April 7, 2005

Exponent®

Technical Memorandum

Assessment of Metals Concentrations in Salmonberry and Sourdock Collected Near the DMTS

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April 7, 2005

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Assessment of Metals Concentrations in Salmonberry and Sourdock Collected Near the DMTS

This technical memorandum describes the findings of chemical analyses for metals in salmonberries and sourdock collected in the summer of 2004 in the vicinity of the Red Dog Mine operations, near the DeLong Mountain Regional Transportation System (DMTS). The sampling was conducted to provide information to the community in response to concerns about potential metals concentrations in subsistence foods.

Background

Historical transport of ore concentrate over a 50-mile haul road from the Red Dog lead/zinc mine in northwest Alaska to a seaport has been associated with elevated lead levels on moss growing near the road, raising concerns within the local community regarding subsistence foods. Initial studies of berries and sourdock, which are part of the local subsistence diet, suggested little impact from mine-related activities. In 2001, the Alaska Division of Public Health (ADPH) conducted a health study entitled *Public Health Evaluation of Exposure of Kivalina and Noatak Residents to Heavy Metals from Red Dog Mine* (ADPH 2001). This evaluation included a description of metals analyses in berries collected from near the haul road and port facilities in 2001. In reviewing the berry data, ADPH concluded that "The concentrations of heavy metals detected in the salmonberries are consistent with typical background levels and do not pose a public health concern." However, additional berry data collected later in 2001 by the Alaska Department of Environmental Conservation (E&E 2002) and Exponent (2002) suggested there may be elevated concentrations of metals in areas near port facilities. These and other subsequently collected data are being used in the ongoing risk assessment.

In May 2004, the Alaska Community Action on Toxics (ACAT) published a report entitled *Analysis of Reports on Elevated Levels of Heavy Metals in Plants Used for Subsistence near Red Dog Mine, Alaska*, in which they concluded that metals concentrations in subsistence plant foods are elevated and made a number of public health recommendations (ACAT 2004). The conclusions in the ACAT report were based almost exclusively on an analysis conducted by Dr. Fred Youngs, a chemist at the University of Massachusetts and the director of the Citizen's Environmental Laboratory in Boston, MA (ACAT Appendix). However, subsequent reviews by ADPH (2004) and Exponent (2004) revealed numerous errors in data characterization and reporting by Dr. Youngs, as well as a generally flawed methodology resulting in unsupported conclusions. Although the ACAT report was based on a flawed methodology, many of ACAT's public health recommendations were in line with the efforts already put forth by Teck Cominco (Exponent 2004).

This technical memorandum reports on the results of the salmonberry and sourdock sampling conducted as part of a comprehensive assessment of potential impacts to human health and the environment associated with metals released during overland transport of ore concentrate. The overall purpose of this sampling effort was two-fold: 1) To provide additional data for the ongoing risk assessment, and 2) to generate the information necessary to provide accurate and up-to-date public health recommendations regarding subsistence food harvest in the region.

Methods

In summer 2004, salmonberry and sourdock samples were collected from three traditional harvesting locations at increasing distance from the port facilities: a) Ipiavik South, i.e., on the south end of Ipiavik lagoon, 1.5 miles northwest of the port; b) Kivalina South, approximately 3 miles southeast of Kivalina and 12 miles northwest of the port; and c) Kivalina North, approximately 1 mile northeast of Kivalina and 17 miles northwest of the port (Figure 1). Washed and unwashed samples were analyzed for lead and cadmium, two metals that had previously been identified as chemicals of concern for the site. Metals concentrations were compared between sites, and to samples collected in 2001 from Ipiavik South and from a reference location near Noatak. The Noatak samples represent the best available background data, given the relative proximity to the site, and a location beyond topographic features in the prevailing upwind direction. To evaluate potential differences between sampling locations and years, data were analyzed using a one-way analysis of variance (ANOVA), with a Bonferroni's multiple comparison post-test using GraphPad Prism® version 4.02 for Windows® (GraphPad Software, San Diego California USA). An ANOVA is a statistical test used to evaluate potential differences between multiple (i.e., three or more) sets of data. In this analysis, an ANOVA was used to estimate the probability that metals concentrations in salmonberries and sourdock differ between locations (Ipiavik South, Kivalina South, Kivalina North, and Noatak) or whether changes in concentrations occurred between 2001 and 2004. It can identify overall differences, but a post-test is necessary to make individual comparisons (i.e., between two sites or between two dates) and to identify where the likely differences, if any, occur. The result of the post-test is a *p*-value. A *p*-value of 0.05 or less, for example, would indicate that there is a 95 percent (or greater) probability that the metals concentrations in a given tissue are different in the two groups being compared; *p*-values of 0.05 or lower are typically considered statistically significant[1]. It should be noted, however, that statistical significance does not necessarily imply biological relevance. That is, two groups may differ statistically for a particular measurement, but if that difference is not large enough to cause a biological alteration, it may not be biologically relevant.

Results

The 2004 sampling effort was designed to answer three questions: 1) Do metals concentrations in subsistence plant foods differ at harvest sites with increasing distance from the DMTS road and port facility? 2) Have metals concentrations in salmonberries and sourdock at a traditional harvest site near the port facility (Ipiavik South) changed between 2001 and 2004? and 3) Are

[1] In the remainder of the document, the word "significant" indicates statistical significance.

metals concentrations in subsistence plant foods different at traditional harvest sites near the port facility (Ipiavik South) or Kivalina (Kivalina South and North) from reference conditions (Noatak)?

Salmonberry Metals Concentrations

Table 1 and Figure 2 present salmonberry cadmium and lead concentrations for the three sites sampled in 2004 (Ipiavik South, Kivalina South, and Kivalina North), and for 2001 samples collected at Ipiavik South and Noatak (reference). Although there were no significant differences in metals concentrations between washed and unwashed salmonberries, results are presented for both.

Comparison of 2004 Salmonberry Metals Concentrations at Different Locations

Lead was not detected in over half the salmonberry samples collected at Kivalina South and Kivalina North, and in the samples where lead was detected, the concentrations were only slightly above the detection limit (Table 1). Salmonberry cadmium concentrations were the same at all three 2004 harvest sites (Ipiavik South, Kivalina South, and Kivalina North).

Comparison of 2004 Salmonberry Metals Concentrations with 2001 Concentrations

Cadmium concentrations from all three 2004 collection sites were similar to 2001 concentrations from Ipiavik South. However, lead concentrations were lower at all sites in 2004 compared to concentrations from Ipiavik South in 2001 ($p \leq 0.001$). Mean lead concentrations in washed samples were approximately four times higher at Ipiavik South in 2001 vs. 2004 (0.028 mg/kg vs. 0.007 mg/kg, respectively) (Table 1). The relationship between 2001 and 2004 metals concentrations was the same whether unwashed or washed samples were evaluated. Thus, these data suggest that salmonberry lead concentrations have decreased at Ipiavik South since 2001.

Comparison of 2004 Salmonberry Metals Concentrations with Reference Concentrations

There were no differences between 2004 salmonberry lead and cadmium concentrations from all sites compared to 2001 reference conditions, as measured at the Noatak harvest site. These results suggest that minor differences between metals concentrations in salmonberries at the 2004 harvest sites may be due to natural variation in environmental conditions.

Sourdock Metals Concentrations

Table 2 and Figure 3 present sourdock cadmium and lead concentrations for the three sites sampled in 2004 (Ipiavik South, Kivalina South, and Kivalina North), and for Ipiavik South and Noatak (reference) in 2001. Although there were no significant differences between washed and unwashed sourdock, results are presented for both.

Comparison of 2004 Sourdock Metals Concentrations at Different Locations

There were no significant differences in sourdock cadmium for any of the three harvest sites sampled in 2004 in either washed or unwashed samples. Lead concentrations were not significantly different in washed samples between the three sites. In fact, the highest lead concentrations in the washed samples were found at the harvest site furthest removed from the port. The mean lead concentration at Kivalina North was 0.098 mg/kg, compared to mean concentrations at Ipiavik South and Kivalina South of 0.076 mg/kg and 0.041 mg/kg, respectively. These differences were not statistically significant, and likely represent natural variation. In unwashed samples, lead concentrations were significantly higher at Ipiavic South than Kivalina South ($p \leq 0.01$) and Kivalina North ($p \leq 0.05$).

Comparison of 2004 Sourdock Metals Concentrations with 2001 Concentrations

Sourdock cadmium concentrations at all three 2004 harvest sites sampled were not significantly different from concentrations at Ipiavik South in 2001. However, in 2004 lead concentrations from both washed and unwashed sourdock from Ipiavic South and Kivalina South were lower than concentrations at Ipiavik South in 2001 ($p \leq 0.001$). Sourdock lead concentrations at Kivalina North were also lower than in 2001 samples from Ipiavik South, in both unwashed ($p \leq 0.001$) and washed ($p \leq 0.05$) samples.

Comparison of 2004 Sourdock Metals Concentrations with Reference Concentrations

Sourdock cadmium concentrations in 2004 were lower at Ipiavik South ($p \leq 0.01$), Kivalina South ($p \leq 0.001$), and Kivalina North ($p \leq 0.01$) than reference concentrations from Noatak for both washed and unwashed samples. Lead concentrations were significantly higher compared to reference only in Kivalina North 2004 washed samples ($p \leq 0.05$) and Ipiavik South 2004 unwashed samples ($p \leq 0.001$). Given the low magnitude of concentrations in all samples and the relatively small part of the diet comprised of sourdock (or green vegetation, in general), these minor differences are unlikely to be relevant from a public health perspective.

Conclusions

In designing the 2004 subsistence plant food sampling program, we selected three traditional harvest locations outside the restricted ambient air boundary of the DMTS port and haul road, in order to focus on areas where harvest currently occurs. The design allowed for a spatial evaluation of conditions relatively near the port, at Ipiavik South, and conditions in areas more distant from the port, at Kivalina South and Kivalina North. In addition, a primary aim of the study was to generate adequate information to provide useful public health recommendations. Thus, it was hoped that with these data, specific recommendations could be made regarding locations for safe harvest of berries and sourdock, and areas where restrictions, if any, may be warranted.

Site Comparisons — There were no significant differences in cadmium or lead concentrations in salmonberries harvested from any of the three sites evaluated. There were no significant differences in cadmium concentrations in sourdock harvested from any of the three sites evaluated in 2004. Lead concentrations in unwashed sourdock samples were significantly elevated at Ipiavik South compared to the other two sites, but not in washed samples.

Reference Comparisons — 2004 metals concentrations were the same as or significantly less than reference concentrations, with the exception of sourdock lead, which was significantly elevated only in washed samples from Kivalina North and unwashed samples from Ipiavic South.

Washed vs. Unwashed Comparisons — At any given site, there was no significant difference between concentrations in washed and unwashed samples, providing further support for the conclusion that fugitive dust from road and port activities is not significantly affecting subsistence foods.

2004 vs. 2001 Comparisons — We also evaluated whether metals concentrations in salmonberries and sourdock have changed since the last sampling effort in 2001. Data from 2001 suggested that lead concentrations in salmonberries and sourdock from Ipiavik South might have been influenced by road- and port-related activities. Many fugitive dust control improvements have been implemented at road and port facilities since that time (Exponent 2002, 2004b). Lead concentrations were lower in 2004 than in 2001 in both salmonberries and sourdock. Cadmium concentrations were the same in 2004 and 2001 in both salmonberries and sourdock.

Taken together, these results support continued subsistence harvesting of berries and other vegetation, without restrictions, in areas as close to the port as Ipiavik South. Areas within the port and road ambient air boundary were not evaluated because access restrictions are currently and will continue to be in place.

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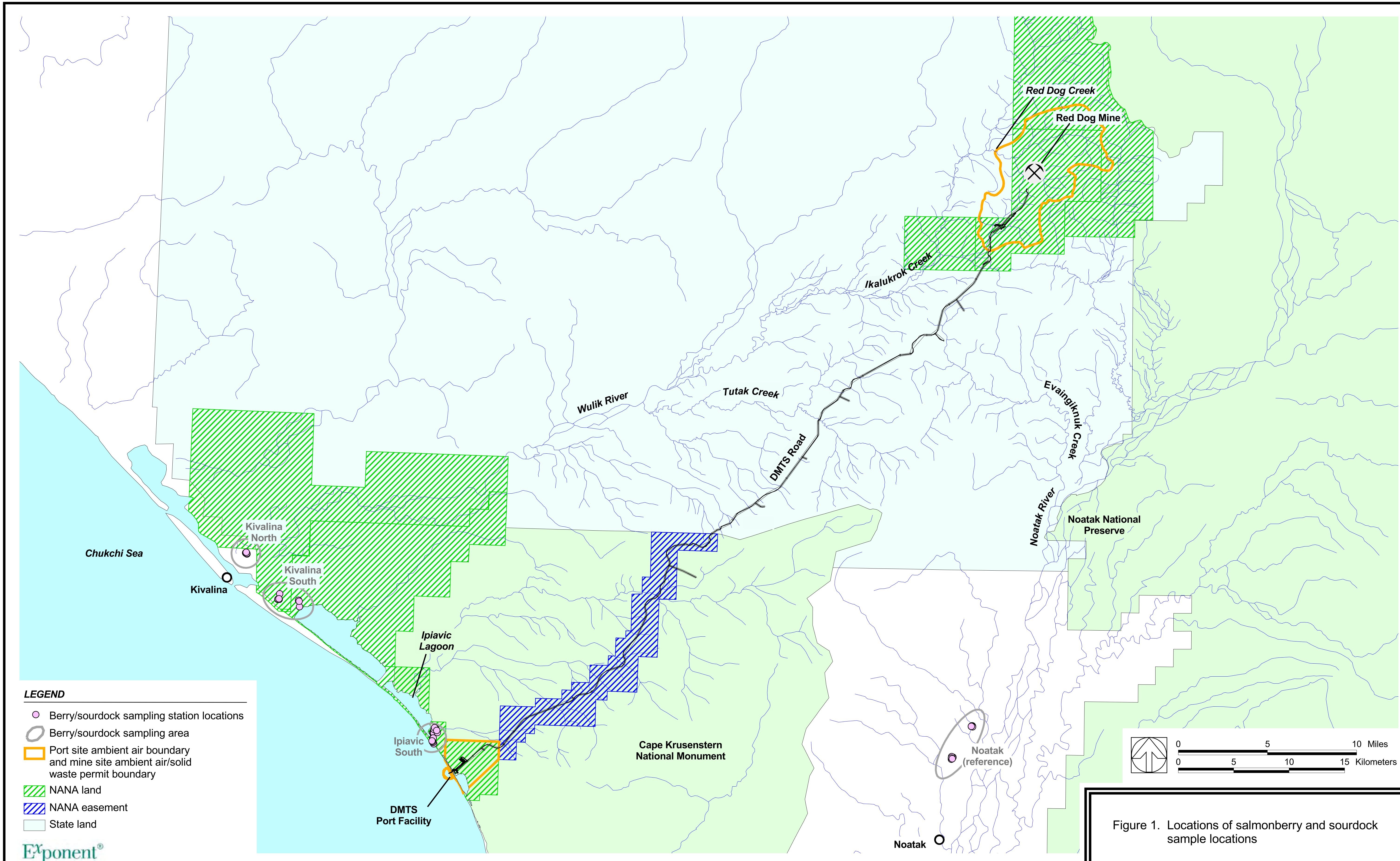

Figure 1. Locations of salmonberry and sourdock sample locations

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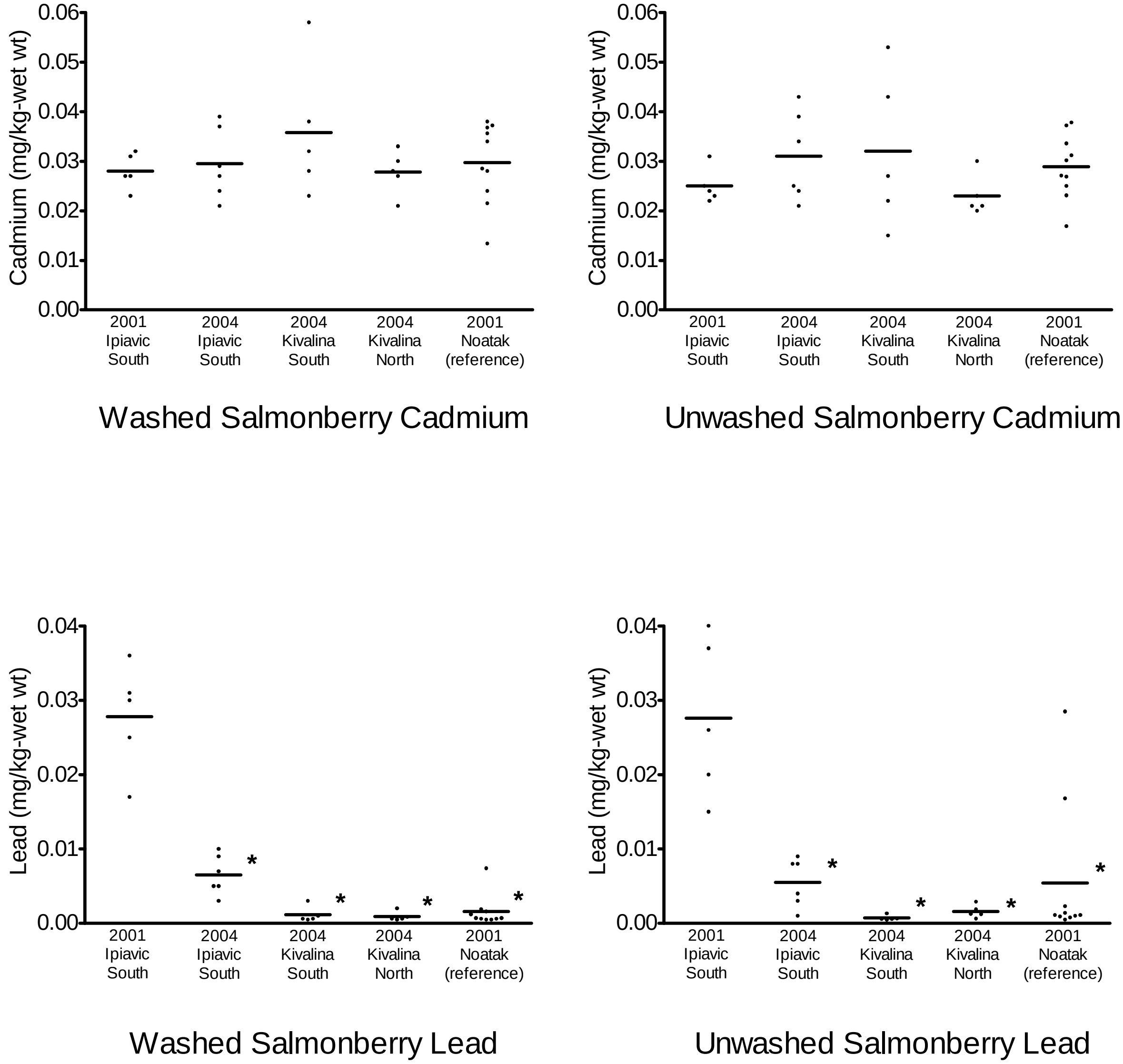
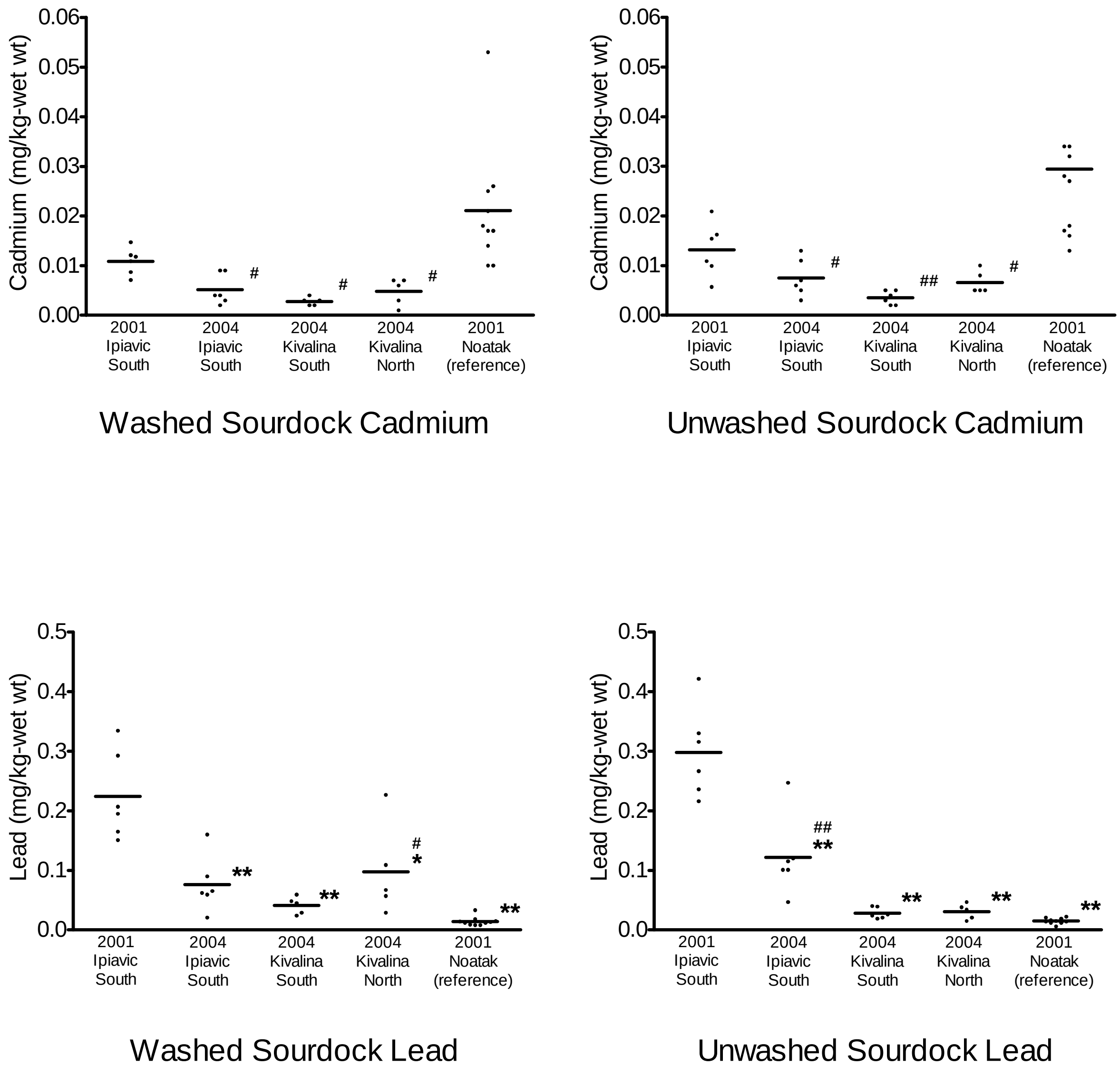
Figure 2. Salmonberry cadmium and lead concentrations



*Significantly different from 2001 Ipiavik South concentrations ($p \leq 0.001$). There were no significant differences between 2004 concentrations from Ipiavik South, Kivalina South, or Kivalina North and 2001 reference concentrations from near Noatak.

Figure 3. Sourdock cadmium and lead concentrations



* Significantly different than 2001 Ipiavik South concentrations (*$p \leq 0.05$; **$p \leq 0.001$).
\# Significantly different than 2001 Noatak reference concentrations (#$p \leq 0.05$; ##$p \leq 0.001$).

Table 1. Salmonberry cadmium and lead concentrations (mg/kg-wet weight)

		Washed Samples			Unwashed Samples		
	Sample	Cadmium	Lead		Cadmium	Lead	
Ipiavik South, 2004							
	A-1	0.039	0.010		0.043	0.008	
	A-2	0.037	0.009		0.039	0.009	
	A-3	0.029	0.007		0.034	0.004	
	A-4	0.027	0.005		0.024	0.003	
	A-5	0.021	0.003		0.025	0.008	
	A-6	0.024	0.005		0.021	0.001	*U*
	Mean	0.029	0.007		0.031	0.006	
	SD	0.007	0.003		0.009	0.003	
Kivalina South, 2004							
	B-1	0.028	0.001	*U*	0.022	0.001	*U*
	B-2	0.058	0.001		0.053	0.001	*U*
	B-3	0.032	0.003		0.027	0.001	*U*
	B-4	0.038	0.001	*U*	0.043	0.001	*U*
	B-5	0.023	0.001	*U*	0.015	0.001	
	Mean	0.036	0.001		0.032	0.001	
	SD	0.014	0.001		0.016	0.000	
Kivalina North, 2004							
	C-1	0.021	0.001	*U*	0.021	0.002	
	C-2	0.033	0.002		0.021	0.001	
	C-3	0.027	0.001		0.020	0.001	*U*
	C-4	0.028	0.001	*U*	0.023	0.001	
	C-5	0.030	0.001	*U*	0.030	0.003	
	Mean	0.028	0.001		0.023	0.002	
	SD	0.004	0.000		0.004	0.001	
Ipiavik South, 2001							
	6	0.023	0.031		0.024	0.040	
	7	0.027	0.036		0.025	0.037	
	8	0.032	0.017		0.031	0.026	
	9	0.027	0.025		0.023	0.015	
	10	0.031	0.030		0.022	0.020	
	Mean	0.028	0.028		0.025	0.028	
	SD	0.004	0.007		0.004	0.011	
Noatak, 2001							
	22	0.036	0.0006		0.027	0.0009	
	23	0.038	0.002		0.030	0.017	
	24	0.024	0.0005		0.023	0.029	
	25	0.013	0.007		0.017	0.001	
	26	0.022	0.0005		0.025	0.0008	
	27	0.037	0.0007		0.027	0.001	
	28	0.037	0.001		0.037	0.0005	
	29	0.029	0.0006		0.038	0.001	
	30	0.029	0.002		0.034	0.002	
	31	0.034	0.0007		0.031	0.001	
	Mean	0.030	0.002		0.029	0.005	
	SD	0.008	0.002		0.006	0.009	

Note: SD - standard deviation
U - not detected in sample; one-half the detection limit was used to calculate statistics

Table 2. Sourdock cadmium and lead concentrations (mg/kg-wet weight)

		Washed Samples		Unwashed Samples	
	Sample	Cadmium	Lead	Cadmium	Lead
Ipiavik South, 2004					
	A-1	0.004	0.059	0.006	0.101
	A-2	0.002	0.090	0.003	0.115
	A-3	0.003	0.065	0.005	0.120
	A-4	0.009	0.062	0.013	0.101
	A-5	0.004	0.160	0.007	0.247
	A-6	0.009	0.021	0.011	0.047
	Mean	0.005	0.076	0.007	0.122
	SD	0.003	0.047	0.004	0.066
Kivalina South, 2004					
	B-1	0.004	0.059	0.004	0.019
	B-2	0.003	0.024	0.004	0.033
	B-3	0.002	0.029	0.002	0.040
	B-4	0.002	0.048	0.003	0.024
	B-5	0.003	0.045	0.005	0.021
	Mean	0.003	0.041	0.003	0.027
	SD	0.001	0.014	0.001	0.009
Kivalina North, 2004					
	C-1	0.007	0.227	0.005	0.047
	C-2	0.003	0.067	0.008	0.021
	C-3	0.006	0.057	0.005	0.038
	C-4	0.007	0.109	0.010	0.015
	C-5	0.001	0.029	0.005	0.034
	Mean	0.005	0.098	0.007	0.031
	SD	0.002	0.078	0.003	0.013
Ipiavik South, 2001					
	12	0.012	0.151	0.0209	0.316
	13	0.012	0.207	0.0162	0.236
	14	0.011	0.165	0.0057	0.216
	15	0.007	0.195	0.0109	0.267
	16	0.015	0.293	0.0099	0.330
	17	0.009	0.334	0.0154	0.422
	Mean	0.011	0.224	0.013	0.298
	SD	0.003	0.073	0.005	0.075
Noatak, 2001					
	32	0.053	0.013	0.075	0.015
	33	0.017	0.015	0.013	0.014
	34	0.010	0.033	0.016	0.021
	35	0.026	0.012	0.034	0.014
	36	0.014	0.009	0.018	0.019
	37	0.010	0.008	0.017	0.012
	38	0.018	0.008	0.034	0.006
	39	0.021	0.018	0.032	0.022
	40	0.017	0.014	0.028	0.016
	41	0.025	0.012	0.027	0.012
	Mean	0.021	0.014	0.029	0.015
	SD	0.012	0.007	0.018	0.005

Note: SD - standard deviation