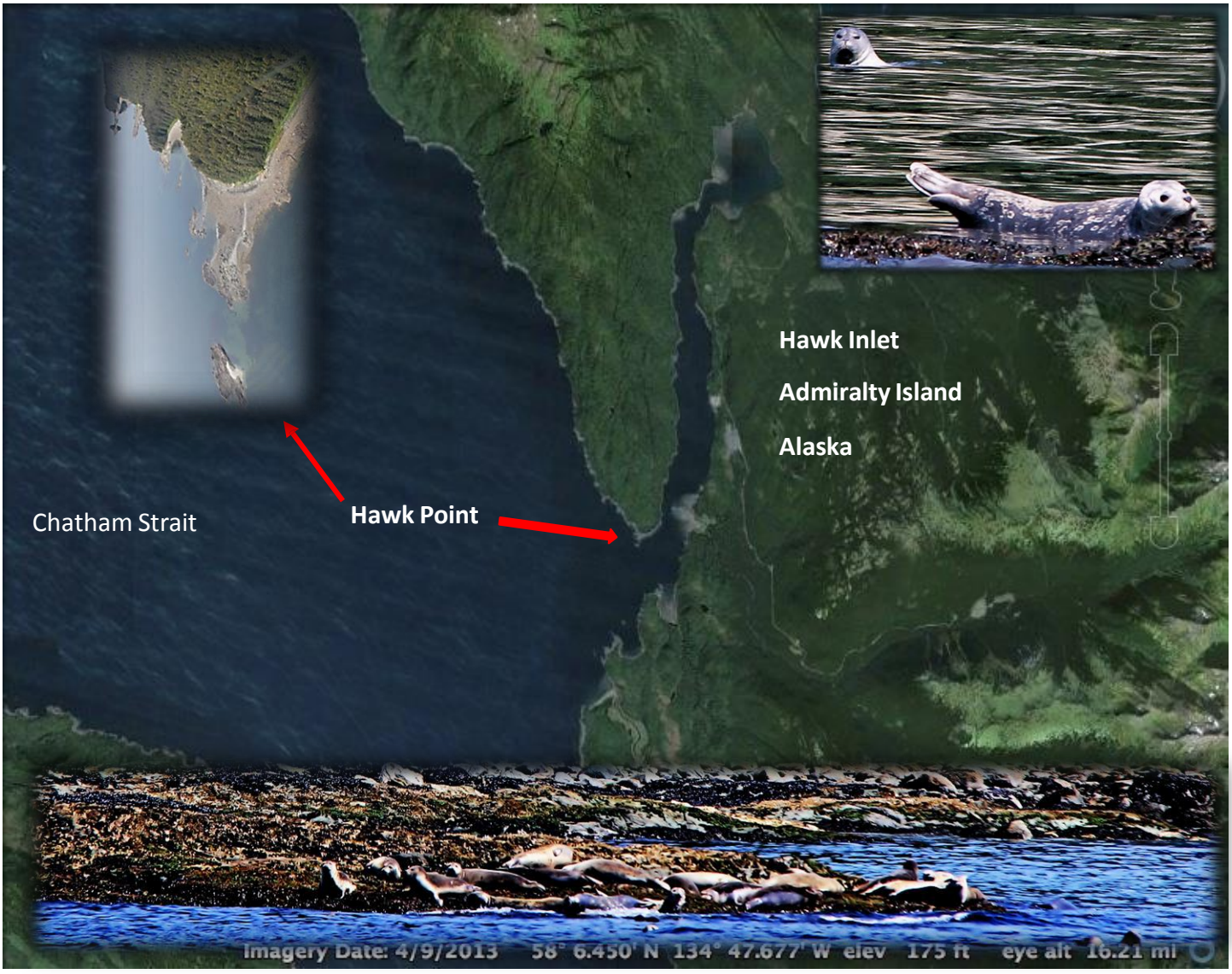
# *Legacy Cove Project Note* No. 2

## Trace Metal Levels in an Admiralty Island Harbor Seal (*Phoca vitulina*)

## Opportunistic Sample from Hawk Point, West Admiralty Island

**Friends of Admiralty**




**SUMMARY**: The Legacy Cove Project field team was provided with an opportunity to examine and analyze parts of harbor seal contributed by an Angoon subsistence hunter in May 2015. We made a visual assessment of the muscle, blubber, liver and kidney tissues donated from a single seal and had each tissue analyzed for eleven trace metals and organic contaminants. The seal, a large adult male, appeared to be in good health. The stomach was empty but did harbor stomach roundworm parasites. The seal's liver contained a very high concentration of total mercury. Silver, selenium and nickel were elevated relative to typical levels reported in scientific literature for marine mammals in Alaska and elsewhere.

**Prepared for Friends of Admiralty by Michelle Ridgway**
**Marine Ecologist**
***Oceanus Alaska***

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## INTRODUCTION

The Alaska Native Community of Angoon has an extensive history hunting harbor seals in the West Admiralty Island / Chatham Strait region. The Alaska Department of Fish and Game Subsistence Division reports that 31% of households in Angoon consume harbor seal, harvesting 450 pounds per year per active household (ADFG 1988). Neighboring tribal members in Hoonah, Juneau, Auke Bay and Douglas also partake of harbor seal from the Northern Chatham area, and have history of sharing foods from Hawk Inlet. They have expressed deep interest in health of the subsistence resources.

Harbor seals have been studied by the scientific and management community for decades. Like other members of the taxonomic family Phocidae, harbor seals have been found to retain and concentrate, "bioaccumulate", or biomagnify contaminants that are present in the prey they consume. As upper trophic predators, seals are therefore a useful indicator species for monitoring trace metals, organic contaminants and health of the foodweb in the ecosystem where they live. For this reason, the Legacy Cove team worked with a subsistence hunter from Angoon to learn as much as possible about concentrations of metals in muscles and organs of a seal harvested from Hawk Point, Admiralty Island.

## BACKGROUND /Impetus for sampling

Harbor seals (*Phoca vitulina*), or *tsaa* in the Tlingit language, are a ubiquitous marine mammal inhabiting southeast Alaska coastal waters. With respect to their diet, seals are near the top of the food web with only humans, killer whales and sharks as primary predators. They are largely piscivorous and commonly prey on a variety of species that occur in Hawk Inlet and Chatham Strait, including walleye Pollock, Pacific cod, capelin, eulachon, Pacific herring, sandlance, salmon, sculpin, flatfish (e.g., flounder and sole), octopus, and squid (ADFG 2015). Other seal prey species that occur in abundance on the seafloor and in the kelp beds around Hawk Point include rockfish, Irish lord, crab and halibut.

The NMFS National Marine Mammal Lab identified Hawk Inlet and adjacent the Chatham Strait coastal area as a "high density" area for harbor seal, with over 150 animals hauled out during annual August surveys 1997-2011 (See Figure 1 NMML data by Josh Landon, in map by K. Savage, NMFS PRD 2014 red circle area). Local fishermen and hunters report that seals at Hawk Point are very common and are likely residents of that immediate vicinity. During the May and July 2015 surveys, harbor seals were observed by Legacy Cove team members throughout Hawk Inlet, with aggregations of 12 – 20 animals at Hawk Point.

Understanding ecological linkages among species in the Hawk Inlet system is a key objective of the Legacy Cove Project. As upper level fish and invertebrate consumers, harbor seals play a prominent role in the transfer of energy and potential contaminants within Hawk Inlet. Therefore, determining harbor seal health, population status and interspecific interactions is a high priority.

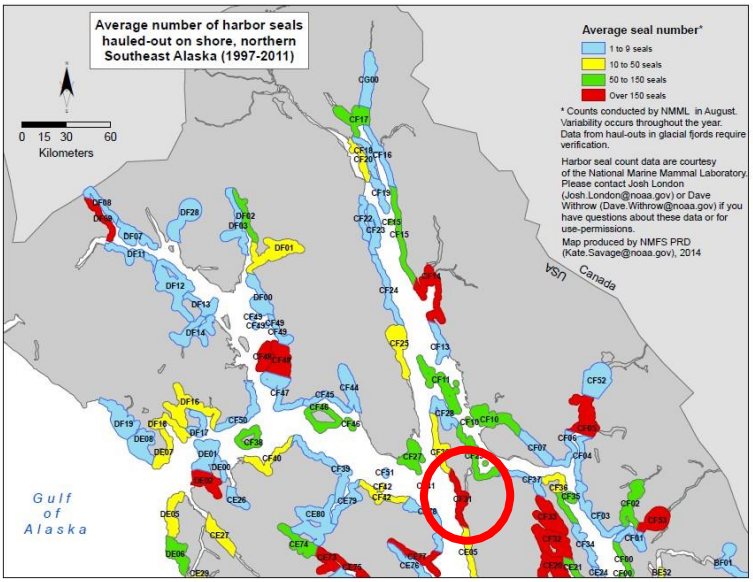


Figure 1. Josh Landen (NMML) data and map presentation by Kate Savage NOAA-NMFS Office of Protected Resources: Seal density in SE Alaska

## METHODS

A single male harbor seal (*Phoca vitulina*) was shot by Angoon Native hunter Ed Kookesh at Hawk Point, Admiralty Island, 18 May 2015 at approximately 1700 hours. Ed and his hunting partner processed the seal within three hours of killing it. The hunters offered some of the meat and organ tissues for biosampling. They removed the entire liver, a single kidney, about 500 grams of muscle and about 200 grams of fat for sampling. Additionally, they secured the stomach contents using cable ties to seal off the pyloris and esophageal junction, and excised the stomach for prey studies. The hunters estimated the seal weight and length and visually assessed its overall condition (Figure 2).

Figure 2. Harvested Harbor Seal

Tissues were placed in plastic bags, labeled, and immediately chilled in a sealed cooler. Cooler ice was rotated 3x daily to maintain a near-freezing temperature during transport to and holding in Auke Bay. Three days after harvest, tissues were processed and evaluated. All tissues were sub-sampled for further lab analysis under clean conditions, with lab-cleaned synthetic tools on a contaminant free surface, following the tissue handling, labeling and Chain of Custody protocols as outlined in Ridgway Legacy Cove Project sampling protocols, and authorized under NMFS permit 16094-03.


Tissues were shipped on ice to Seattle via Alaska Airlines Goldstreak, where they were analyzed by a certified commercial laboratory for Arsenic, Cadmium, Chromium, Copper, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Zinc and organotin compounds (Figure 3). Tissue condition and quantity met or exceeded laboratory requirements for analysis. Tissues were prepared using US EPA Method 3050B (for all metals but mercury); Method CLP-M was used for mercury. Tissues were analyzed using EPA Method 6010C for most metals; Method 7471A was used for mercury. Data are reported in mg/kg wet weight. Fat tissue was analyzed for butyltin ions by method 8270D. Analyses proceeded without incident, and met or exceeded laboratory QA/QC standards.

**Figure 3. Harbor seal tissue samples for lab analysis**

## RESULTS

The seal was an estimated 228 centimeters in length (measured flat, nose to flipper tip), and weighed an estimated 250 pounds. Hunters characterized it as a large, "fat" seal for the Chatham region. In comparison, adult male harbor seals in the Gulf of Alaska average about 155 cm and weigh about 186 lbs (Pitcher and Calkins 1979). Hunters estimated that it was an "older male", but no teeth were collected to verify age.

**Visual examination of tissues** On 21 May 2015, Kate Wynne (UAF SeaGrant Marine Mammal Expert) inspected tissues and excised portions of each tissue type for analysis. Wynne reported that based on the tissue observations, the seal appeared to be in good health. Specifically, she observed "a good layer of interstitial fat around the kidneys", and noted that muscle, fat and liver appeared healthy (Figure 4).

Figure 4. Harbor Seal kidney

Wynne also examined the stomach from this seal for prey items. She remarked it was "in excellent condition, very well chilled and fresh, weighed approximately 1.5 pounds". Upon opening the stomach, Wynne observed no intact prey items, and noted it is not uncommon to find seal stomachs empty, occurring "at a rate of about 50:50", based on her experience. The stomach was inverted and interstitial surfaces rinsed into a 2 mm steel mesh sieve. No fishbones, otoliths, scales or other hardparts from prey items were obtained in the sieve.

During the examination, Wynne noted the stomach lining had many lesions, exhibited signs of hemorrhaging, had patches of inflammation and was infested with (primarily) nematode parasites (Figure 5). Although the (presumed anasacan codworm) parasite load was substantial, Wynne identified no ulcers within the stomach, and indicated that the infestation was not 'severe'.

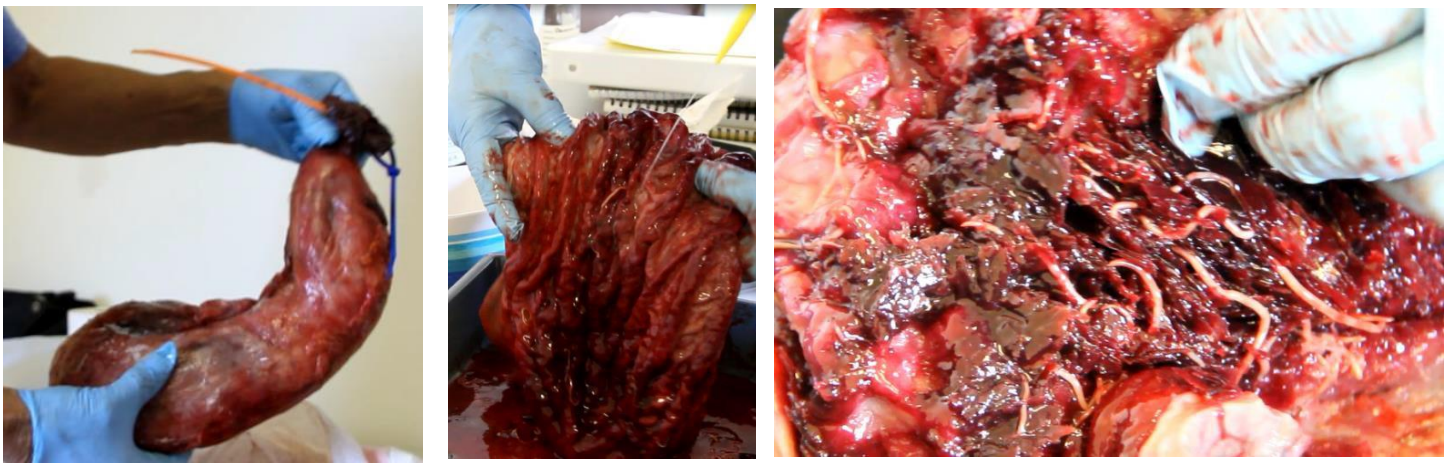

**Figure 5. Hawk Point Harbor Seal whole stomach (left), inverted stomach folds (center) and stomach lesions with roundworm aggregation (right).**

### Trace Metal and Organic Contaminant Results

Results of trace metal analyses are provided in the Table 1. Figures in bold were at or above laboratory instrument detection levels. Periodic Table abbreviations for metals tested: As-Arsenic, Cd-Cadmium, Cr-Chromium, Cu-Copper, Pb-Lead, Mn- Manganese, Hg-Mercury, Ni-Nickel, Se-Selenium, Ag-Silver, Zn-Zinc.

**Table 1. Hawk Point Male Harbor Seal Tissue Analysis Results**
**n=1 mg/kg fresh weight**

| Sample No. | Tissue Type | As | Cd | Cr | Cu | Pb | Mn | Hg | Ni | Se | Ag | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | FAT | **1** | 0.04 | **1.5** | **9.29** | **0.9** | **0.6** | **0.057** | **0.7** | 1 | 0.06 | **8.4** |
| 55 | MUSCLE | 1 | 0.04 | 0.1 | **2.08** | 0.4 | **0.16** | **2.18** | 0.2 | 1 | 0.06 | **21.1** |
| 57 | LIVER | 1 | **4.31** | **0.1** | **19.2** | 0.4 | **3.39** | **222** | 0.2 | **82** | **0.45** | **58.9** |
| 59 | KIDNEY | 1 | **12.3** | **0.2** | **7.99** | **0.5** | **0.83** | **6.3** | 0.2 | **3** | 0.06 | **38.6** |
| Max Concentration | | 1 | 12.3 | 1 | 19.2 | 0.9 | 3.39 | 222 | 0.7 | 82 | 0.45 | 58.9 |

**BOLD =** at or above limit of quantification

Only sample 54, FAT, was also analyzed for the bottom paint additive, Tributyltin (TBT). No TBT was detected in the seal fat above minimum detection levels (39 ppb). Results are summarized in Table 2.

Table 2. Summary of bottom paint additive, Tributyltin in a blubber sample from an adult male harbor seal.

| CAS Number | Analyte | RL | Result | Q |
|---|---|---|---|---|
| 36643-28-4 | Tributyltin Ion | 39 | < 39 | U |
| 14488-53-0 | Dibutyltin Ion | 58 | < 58 | U |
| 78763-54-9 | Butyltin Ion | 41 | < 41 | U |

Reported in µg/kg (ppb)

Quality control analyses results for method blanks, laboratory duplicates, RPDs and matrix spikes are contained in Level I laboratory reporting documents and will be summarized in future Legacy Cove formal project reports.

**DISCUSSION**

Heavy metals occur in the natural environment and are both sequestered and eliminated by animals depending upon their health needs, health status and physiological capability to manage levels and forms of metals. Understanding heavy metal levels in marine mammals is complex, and varies by region, local geologic chemistry, as well as varies by species, gender and age of the animal. Further, the level of one metal may be mediated by organic complexing processes and/or other metals that work like antioxidants. Nonetheless, some basic comparisons of the heavy metal data above to existing data are provided here for background and context. Note that metal levels safe for human consumption are well-documented in human health and seafood literature and are ***not*** addressed here (see Arnold and Middaugh 2004).

Data are presented for Alaskan harbor seal, other Alaskan seals in the pinniped family phocidae (the phocid, or earless seals), and for phocid seal globally (Figure 6.). Thousands of data points are available for trace metal levels in pinnipeds and other marine mammals, but because phocids have highly evolved, unique organ functions for processing metals, data from the 1,228 individual phocid seals summarized in Table __ provides a robust context in which to evaluate levels observed in the Hawk Point harbor seal.

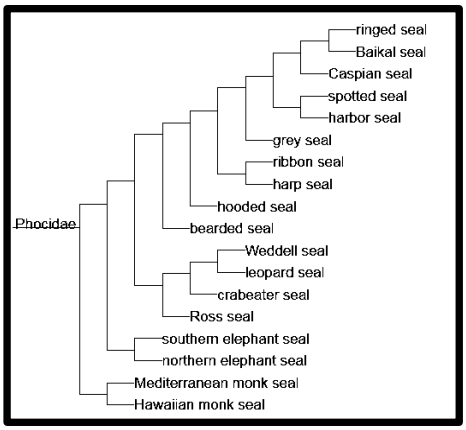


**Figure 6. The family of phocid seals and relationships to harbor seal are shown here:**

Based upon comparison with the published values in Table __, tissues collected from the single Hawk Point seal had concentrations of the metals Arsenic, Cadmium, Chromium, Copper, Lead, Manganese and Zinc that were roughly within the ranges of concentrations detected in phocid seals sampled elsewhere in Alaska and globally. However, concentration of four metals, Mercury, Nickel, Silver, Selenium, and lead concentrations in liver, kidney and/or blubber, were slightly or extremely high relative to reported levels in Alaska or globally.

***Lead*** Lead concentrations in the Hawk Point seal liver and kidney were 10 times levels seen in other Alaskan phocid seal liver and kidney samples, but within reported ranges for phocid seal liver and kidneys from California, Sweden and the Baltic region.

***Silver*** At 0.45 mg/kg in liver, this seal had twice the mean for harbor seals reported from Kodiak (0.21 mg/kg), a higher mean, but within the range, of concentration measured in other phocid seal (bearded, ringed and spotted) in Alaska. Some studies indicate that high silver levels in the marine food web suggest a linkage with benthic fauna, like crab, bivalves and other shellfish (review in Dehn et al 2006).

***Nickel*** All tissues analyzed for nickel in the Hawk Point seal had concentrations exceeding the range of nickel concentrations reported for phocid seals in Alaska and Sweden. At 0.2 to 0.7 mg/kg in fat, liver, muscle and kidney, concentrations substantially exceed those reported for Alaska bearded seals (mean of 0.06-0.08 mg/kg (n=24)) (Quakenbush and Citta 2009). Nickel concentrations in harbor, grey and ringed seals from Sweden that included all tissues (blubber, liver, kidney) ranged from $\leq$0.006 - 0.078 mg/kg (n=109) (Frank et al 1992). At the time of this writing, no data on nickel values in harbor seals in Alaska are available for comparison.

***Selenium*** The Hawk Point seal had 82 mg/kg selenium in its liver and 3 mg/kg in the kidney. The hepatic level is substantially higher (55x) than levels seen in Alaskan harbor seals elsewhere (mean 1.6 mg/kg, n=23 – Alaska DSHS 1997), 28x the concentration of selenium observed in Kotzebue spotted seals (mean 2.99 mg/kg hepatic selenium, Moses et al 2008), and 17x the highest reported mean level for bearded and ringed seals in Alaska phocid seals (mean 3.07-4.79 mg/kg, n=29) (Quakenbush and Citta 2009, Alaska DSHS 1997).

The Hawk Point seal liver sample concentration of 83 mg/kg is also higher than the range of selenium reported for 225 seal livers sampled in California, Canada and Sweden, where phocid seal liver selenium ranged 0.69 – 52 mg/kg, n=225; (Brookens 2007, Alaska DSHS 1997, Frank et al 1992). Higher levels of selenium were reported for grey seal in the contaminated Baltic region of Sweden n = 15, 9.9 – 332 mg/kg; a few of the highest selenium concentration values exceed the Hawk Point seal liver level (Frank et al 1992).

Selenium is considered an essential nutrient for harbor seals, and plays a key role in regulating mercury levels and mercury forms in many marine mammals. Thus it is difficult to evaluate the health implications of the high levels observed in the Hawk Point seal without further analysis.

***Mercury (Hg)*** Total mercury (THg) concentrations found in the muscle, kidney and liver of the Hawk Point seal were among the highest reported for any phocid seal , and exceed all THg values reported for muscle, kidney and liver in Alaskan seals available at the time of this writing (Table 3).

The Hawk Point harbor seal *liver* THg concentration of 222 mg/kg is 17 – 326 times the maximum concentrations found in any tissue of Alaskan phocid seals reported at the time of this writing. Its *kidney* THg values are 3-20 times higher than THg concentrations in *kidney* samples from other Alaskan phocid seals.

When compared to THg levels in harbor seals worldwide, the wet weight concentration in the Hawk Point seal liver is 1.3 – 123 times higher than levels found in muscle, blubber, kidney and liver with few exceptions: harbor seal livers from San Miguel Island CA had THg concentrations of 341 and 700 mg/kg wet weight (Anas 1974). When compared to a broader geographic area and other phocid species, the wet wt THg concentration in the Hawk Point seal is 3 to 26X higher than values reported for Sweden, Canada, Greenland, coastal US. Total mercury concentrations up to 730 mg/kg THg have been reported for Swedish seals in the Baltic Sea, an area contaminated with heavy metals (Frank et al 1992).

Table 3. Total Mercury concentrations in Hawk Point Male Seal compared to Alaska-wide Phocid Total Mercury Concentrations

**Total Mercury (THg) levels in Hawk Point Seal Compared to Alaska Phocids THg Levels**

| Species | Locale | n | Liver mg/kg | Kidney mg/kg | Muscle mg/kg | Blubber mg/kg | Hawk X factor |
|---|---|---|---|---|---|---|---|
| Harbor Seal | Hawk Point, SE | 1 | 222 | 6.3 | 2.18 | 0.057 | --- |
| Harbor Seal | Prince Wm Sound | 98 | 13.4 | --- | --- | --- | 17X |
| Harbor Seal | Pribilof Islands | 3 | 0.6-8.9 | --- | --- | --- | 25X |
| Spotted Seal | Kotzebue | 5 | 1.991 | 0.437 | 0.169 | --- | 111X |
| Spotted Seal | Diomede | 34 | 0.68 | 0.31 | --- | --- | 326X |
| Ringed Seal | Barrow | 64 | 2.47 | 1.94 | --- | --- | 90X |
| Ribbon Seal | Diomede | 40 | 1.17 | 0.51 | --- | --- | 190X |
| | **Alaska Total** | **245** | | | | **MAX X** | 326X |
| | | | | | | | |
| Harbor Seal | California | 40 | 0.151-163 | --- | --- | --- | 1.3X |
| Harbor Seal | California | 26 | 1.8 | 1.611 | 0.755 | 0.107 | 123X |
| Harbor Seal | Oregon-Washington | 6 | 0.3-81 | --- | --- | --- | 2.7X |
| Harbor Seal | NE USA | 34 | 64.8 | --- | --- | --- | 3.4X |
| Harbor Seal | San Miguel (1971) | 4 | 81-700* | --- | --- | --- | 0.3X |
| Harbor/ Ring | Sweden | 92 | 0.72-66 | 0.72-66 | --- | --- | 3X |
| Grey Seal | Baltic Sweden | 15 | 77-110 | max 730 * | --- | --- | 0.3X |
| Ringed | Arctic Canada | 260 | 32.9-8.34 | 1.49-2.05 | --- | --- | 26X |
| Bearded | Canada/Greenland | 62 | 37.5 | --- | --- | --- | 6X |
| Ringed Seal | Canada/Greenland | 445 | 0.32-25.5 | --- | 0.32-25.5 | --- | 9X |
| | **Other Areas Total** | **984** | | | | **MAX X** | **123X** |

**This project note is intended to provide an update on results of study and analysis of tissues from a single harbor seal, and to provide some context for interpreting the level of trace metals found in seal body tissues. Complete data and further discussion will be provided in future formal reports for the Legacy Cove Project by Friends of Admiralty. NOTE: the far right column "X Factor" indicates comparative concentration values as if they were linear. We presume that higher or increased metal concentration values are not linear functions.**

These and other data show that total mercury is retained in the liver at higher concentrations than other organs. Indeed, the liver is an organ responsible for filtration, containment and processing of metals and other elements in mammalian bodies. Mercury levels vary considerably with age of an animal, health status, and depends upon interaction with other metals and organic processes. The contaminant concentrations reported herein are from a single individual seal, that, based on size and sex, has greatest potential to accumulate high concentration of total mercury (Marino et al. 2011) and may or may not reflect levels found in the greater Chatham area population. Regardless, when compared to metal concentrations found in 1,228 other phocid seals worldwide, the highly elevated concentrations of mercury and other metals found in the liver and kidney of the Hawk Point seal are noteworthy and provocative. Additional research on metals in the broader food web, including potential metal sources, extent of detoxification in various tissues, and potential impacts on seal populations and humans who consume seals merit further examination and in-depth analysis.

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**APPENDIX A. Trace and Heavy Metal Levels in Alaskan and other harbor seals and other phocid seals**

**Summary of Hawk Point Seal metal levels and highlights of metal levels found in published and grey literature**

**All values are reported in mg/kg wet weight unless otherwise noted.**

**Arsenic (As)** Hawk Point – fat, muscle, liver and kidney levels = 1.0 mg/kg **MAX 1.0 mg/kg ww**

Alaska Harbor Seal Liver mean 0.8 mg/kg n = 23 (Alaska DSHS 1997)

Alaska Phocids – Bearded Seal n = 21 mean 0.31-0.58 mg/kg (Quakenbush and Citta 2009)

Bearded Seal n = 3 mean 0.386 mg/kg (Alaska DSHS 1997)

Bearded Seal Norton Sound n = 14 mean 0.17 (Becker et al 1997)

Ringed seal liver n = 14 mean 1 mg/kg (in Alaska DSHS 1997)

Ringed seal kidney n = 2 mean 3.1 mg/kg (in Alaska DSHS 1997)

Kotzebue Spotted Seal n=5, means: blubber 2.704 mg/kg, muscle 0.172 mg/kg, liver 0.415 mg/kg, kidney 0.281 mg/kg (Moses et al 2008)

Other values Swedish harbor, grey, ringed seal n = 109. Arsenic range for all species, blubber, liver, kidney 0.83 – 4.7 mg/kg – high values from polluted Baltic region (Frank et al 1992)

**Cadmium (Cd)** Hawk Point – fat = 0.04 ; muscle = 0.04 ; liver = 4.31 ; kidney = 12.3 mg/kg ww **MAX 12.3 mg/kg ww**

Alaskan values:

Alaska Harbor Seal Liver mean 6.6 mg/kg n = 23 (Alaska DSHS 1997)

Barrow Bearded Seal kidney n=38 mean 31.47 mg/kg range 1.3 – 94.47 mg/kg (Dehn et al 2006)

Barrow Bearded Seal liver n=38 mean 8.66 mg/kg range 0.57-33.6 mg/kg (Dehn et al 2006)

Barrow Ringed Seal kidney n = 66 mean 14.7 mg/kg <0.01-50.7 mg/kg (Dehn et al 2006)

Barrow Ringed Seal liver n = 66 mean 3.64 mg/kg; range <0.01-11.84 mg/kg (Dehn et al 2006)

Barrow Spotted Seal kidney n=18 mean 2.58 mg/kg; range 0.79-7.76 mg/kg (Dehn et al 2006)

Barrow Spotted Seal liver n=17 mean 0.39 mg/kg; range 0.09-2.18 mg/kg (Dehn et al 2006)

Alaska Ringed seal liver mean 5 mg/kg (n=2) (Alaska DSHS 1997)

Kivalina Bearded Seal n=21 mean 0.94-5.24 mg/kg (Quakenbush and Citta 2009)

Kotzebue Spotted Seal n=5 mean liver 0.478 mg/kg, kidney 3.488 mg/kg (Moses et al 2008)

Other values

Canada/Greenland Ringed seal kidney mean 37 mg/kg; n=30 (Alaska DSHS 1997)

Swedish Harbor, Grey, Ringed Seal n= 109. Cadmium range for all species, all tissues (blubber, liver, kidney) 0.02 – 5.41 mg/kg – highest values from polluted Baltic region (Frank et al 1992)

Arctic Canada ringed seal kidney n = 179 mean 21.1-47.7, range 0.12-111 mg/kg (Dehn et al 2006)

Arctic Canada ringed seal liver n = 157 mean 5.06-11.9, range <0.01 – 44.6 mg/kg (Dehn et al 2006)

**Chromium (Cr)** Hawk Point – fat = 1.5 ; muscle = 0.1 ; liver = 0.1 ; kidney = 0.2 mg/kg ww **MAX 0.2 mg/kg ww**

Alaskan values:

Alaska Phocids Bearded Seal n=21 mean 0.07-0.13 mg/kg (Quakenbush and Citta 2009)

Other values

3 Swedish seal spp (Harbor, Grey, Ringed) n= 109. Chromium range for all species, all tissues (blubber, liver, kidney) 0.53 – 0.17 mg/kg – highest values from polluted Baltic region (Frank et al 1992)

**Copper (Cu)** Hawk Point – fat = 9.29 ; muscle =2.08; liver = 19.2 ; kidney = 7.99 mg/kg ww **MAX 19.2 mg/kg ww**

Alaska Phocids: Bearded Seal n=21 mean 21.82-40.71 mg/kg (Quakenbush and Citta 2009)

Kotzebue spotted seal n=5 mean blubber 0.12 mg/kg, muscle 1.3 mg/kg, liver 16.4 mg/kg, kidney 4.09 mg/kg (Moses et al 2008)

Other values

3 Swedish seal spp (Harbor, Grey, Ringed) n= 109. Copper range for all species, all tissues (blubber, liver, kidney) 3.0 – 24.0 mg/kg region (Frank et al 1992)

**Lead (Pb)*** Hawk Point – fat = 0.09 ; muscle = 0.04 ; liver =0.4; kidney = 0.5mg/kg ww **MAX 0.5 mg/kg ww**

Alaskan phocids: Bearded seal 0.03-0.04 mg/kg Kivalina (Quakenbush and Citta 2009)

Kotzebue spotted seal: n=5 mean blubber 0.0415 mg/kg, muscle 0.0573 mg/kg, liver 0.0105 mg/kg, kidney 0.0165mg/kg (Moses et al 2008)

Other values

California harbor seal liver N = 40 Range Lead <0.007 – 62.057 mg/kg (Brookens et al 2007)

3 Swedish seal spp (Harbor, Grey, Ringed) n= 109. Lead range for all species, all tissues (blubber, liver, kidney) 0.04 - 0.91 mg/kg (Frank et al 1992)

**Manganese (Mn)** Hawk Point – fat = 0.6; muscle = 0.16; liver = 3.39; kidney = 0.83 mg/kg **MAX 3.39 mg/kg**

Alaskan phocids: Bearded seal 4.35-5.09 mg/kg Kivalina (Quakenbush and Citta 2009)

Kotzebue spotted seal: n=5 mean blubber 0.0384 mg/kg, muscle 0.169 mg/kg, liver 5.306 mg/kg, kidney 1.066 mg/kg (Moses et al 2008)

Other values

3 Swedish seal spp (Harbor, Grey, Ringed) n= 109. Manganese range for all species, all tissues (blubber, liver, kidney) 0.3 – 3.7 mg/kg (Frank et al 1992)

**Mercury (Hg)** Hawk Point – fat = 0.057; muscle = 2.18; liver = 222; kidney = 6.3 mg/kg **MAX 222 mg/kg**

Alaskan values:

Prince Wm Sound/Kodiak Harbor seal liver n = 98 mean 13.4 mg/kg; range 0.61-106 mg/kg (Morino et al 2-11)

Pribilof Harbor seal liver (n=3) 0.6 – 8.9 mg/kg (Anas 1974)

Alaskan phocids: Bearded seal mean 1.25 – 3.93 mg/kg; max 28.31 (Quakenbush and Citta 2009)

Alaska Bearded Seal liver mean 2.8 mg/kg; n=7 (Alaska DSHS 1997)

Alaska ringed seal liver n=13, mean 1.8 mg/kg (Alaska DSHS 1997)

Kotzebue spotted seal: n=5 mean muscle 0.196 mg/kg, liver 1.991mg/kg, kidney 0.437mg/kg (Moses et al 2008)

Barrow Bearded Seal kidney n=26 mean 0.58 mg/kg range 0.21 – 1.5 mg/kg (Dehn et al 2006)

Barrow Bearded Seal liver n=34 mean 3.84 mg/kg range 0.64-20.44 mg/kg (Dehn et al 2006)

Barrow Ringed Seal kidney n = 64 mean 1.94 mg/kg 0.79-3.71 mg/kg (Dehn et al 2006) Barrow

Ringed Seal liver n = 64 mean 2.47 mg/kg; range 0.06-16.55 mg/kg (Dehn et al 2006) Diomede

Spotted Seal kidney n=34 mean 0.31 mg/kg; range 0.08-0.9 mg/kg (Dehn et al 2006) Diomede

Spotted Seal liver n=34 mean 0.68 mg/kg; range 0.10-2.62 mg/kg (Dehn et al 2006) Diomede

Ribbon Seal kidney n=40 mean 0.5 mg/kg; range 0.13-1.61 mg/kg (Dehn et al 2006) Diomede

Ribbon Seal liver n=40 mean 1.17 mg/kg; range 0.18-8.52 mg/kg (Dehn et al 2006)

Other values

Canada/Greenland Ringed Seal Liver/Muscle mean range 0.32-25.5 mg/kg; n=445 (Alaska DSHS 1997)

Canada/Greenland Bearded Seal liver mean range 1.9-143 (mean 37.5 mg/kg); n=62 (Alaska DSHS 1997)

California harbor seal liver N = 40 Range 0.151 – 162.817 mg/kg (Brookens et al 2007)

California harbor seal n = 26 liver mean 1.8 mg/kg, range 0.075 – 6.392 mg/kg; kidney mean 1.611 mg/kg, range 0.27 – 6.082 mg/kg; muscle mean 0.7552 mg/kg; range 0.108 – 2.246 mg/kg; blubber mean 0.107 mg/kg; range 0.007 – 0.284 mg/kg (Brookens et al 2008)

California Harbor Seal blood range 0.057 to 1.19 mg/kg (McHuron et al 2014)

San Miguel Island California (1971) n=4 Thg Harbor seal liver 81-700 mg/kg (Anas 1974)

Oregon-Washington Harbor Seal liver n=6 THg Harbor seal liver 0.3-81 mg/kg (Anas 1974)

North Sea Phocid seals n=80 THg in blood 0.02 – 0.56 mg/kg (Das et al 2008)

Northeast US Coast Harbor Seal liver n = 34, mean 64.8 mg/kg (<60 level of concern) (Shaw 2002)

Swedish Harbor, Grey, Ringed n= 92. Mercury range for all species, liver and kidney was 0.72-66 mg/kg. Values reported separately for grey seal liver in the polluted Baltic region (n=15) had a mean range of 77-110 mg/kg and two individual highest values of 357 and 730 mg/kg (Frank et al 1992)

Arctic Canada ringed seal liver mean 32.9-8.34 mg/kg range 0.23 – 219 mg/kg n = 260 (Dehn et al 2006)

Arctic Canada ringed seal kidney mean 1.49-2.05 mg/kg range 0.25-2.88 mg/kg n=177 (Dehn et al 2006)

**Nickel (Ni)** Hawk Point – fat = 0.7 mg/kg; muscle = 0.2 mg/kg; liver =0.2; kidney = 0.2 mg/kg **MAX 0.7 mg/kg**

Alaskan phocids: Bearded seal mean 0.06-0.08 mg/kg, n=24 (Quakenbush and Citta 2009)

Other values

Swedish Harbor, Grey and Ringed Seal n= 109. Nickel range for all species, all tissues (blubber, liver, kidney) $\leq$0.006 - 0.078 mg/kg (Frank et al 1992)

**Selenium (Se)** Hawk Point – fat = 1 ; muscle = 1; liver =82; kidney = 3 mg/kg **MAX 82 mg/kg**

Alaskan values: Alaska Harbor Seal Liver mean 1.6 mg/kg n = 23 (Alaska DSHS 1997)

Alaskan phocids: Bearded seal 3.19 – 4.79 mg/kg n=24 Kivalina (Quakenbush and Citta 2009)

Kotzebue spotted seal: n=5 mean blubber 0.138 mg/kg, muscle 0.649 mg/kg, liver 2.992 mg/kg, kidney 0.437 mg/kg (Moses et al 2008)

Bearded Seal 3.07 mg/kg n = 3 (Alaska DSHS 1997)

Ringed Seal 3.12 mg/kg n = 2 (Alaska DSHS 1997)

Other values: California harbor seal liver N = 40 Selenium 0.4-57.9 mg/kg (Brookens 2007)

Canada bearded seal mean 2.59 mg/kg n = 16 (Alaska DSHS 1997)

Canada ringed seal mean 1.09 mg/kg n = 14 (Alaska DSHS 1997)

California Harbor Seal blood n=73 range 0.48 to 1.44 mg/kg (McHuron et al 2014)

Swedish Harbor, Grey and Ringed Seal n = 92. Selenium range for all species, liver and kidney 0.69 – 52.0 mg/kg. Higher levels reported for grey seal in the contaminated Baltic region n = 15, 9.9 – 332 mg/kg (Frank et al 1992)

**Silver (Ag)** Hawk Point – fat = 0.06; muscle = 0.06; liver = 0.45; kidney = 0.06 mg/kg **MAX 0.45 mg/kg**

Alaska Harbor Seal Kodiak mean 0.21 mg/kg n=58 (Dehn et al 2006)8

Kotzebue spotted seal: n=5 mean, liver 0.043 mg/kg (Moses et al 2008)

Bearded Seal Barrow n = 38 mean Ag 0.34 mg/kg range 0.01 – 1.13 mg/kg (Dehn et al 2006)

Ringed Seal Barrow n = 66 mean 0.11 mg/kg range <0.01 – 0.69 mg/kg (Dehn et al 2006)

Spotted Seal n = 17 mean 0.08 mg/kg, range 0.01 – 0.13 mg/kg (Dehn et al 2006)

Other values: Global marine mammal max 1.5 mg/kg dw (WHO 2002)

**Zinc (Zn)** Hawk Point – fat = 8.4; muscle = 21.1 ; liver = 58.9 mg/kg; kidney = 38.6 mg/kg **MAX 58.9 mg/kg**

Alaskan phocids: Kivalina bearded seal 59.19-65.45 mg/kg (Quakenbush and Citta 2009)

Kotzebue spotted seal: n=5 mean blubber 3.3 mg/kg, muscle 19.6 mg/kg, liver 42.1 mg/kg, kidney 26.2 mg/kg (Moses et al 2008)

Other values:

Swedish Harbor, Grey and Ringed Seal n= 109. Lead range for all species, all tissues (blubber, liver, kidney) 15 – 76 mg/kg (Frank et al 1992)

**APPENDIX B Laboratory Data Report for Hawk Inlet Seal Tissue Analysis**

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS
Page 1 of 1

Sample ID: LCN-TIS-54-ST
Fat

Lab Sample ID: AGS2A
LIMS ID: 15-10094
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

| Prep Meth | Prep Date | Analysis Method | Analysis Date | CAS Number | Analyte | LOQ | mg/kg-as-rec | Q |
|---|---|---|---|---|---|---|---|---|
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-38-2** | **Arsenic** | 1 | **1** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-43-9 | Cadmium | 0.04 | 0.04 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-47-3** | **Chromium** | 0.1 | **1.5** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-50-8** | **Copper** | 0.04 | **9.29** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-92-1** | **Lead** | 0.4 | **0.9** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-96-5** | **Manganese** | 0.02 | **0.60** | |
| CLP-M | 06/02/15 | 7471A | 06/05/15 | **7439-97-6** | **Mercury** | 0.005 | **0.057** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-02-0** | **Nickel** | 0.2 | **0.7** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7782-49-2 | Selenium | 1 | 1 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-22-4 | Silver | 0.06 | 0.06 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-66-6** | **Zinc** | 0.2 | **8.4** | |

U-Analyte undetected at given LOQ
LOQ-Limit of Quantitation

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ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS
Page 1 of 1

Sample ID: LCN-TIS-54-ST
Fat

Lab Sample ID: AGS2A
LIMS ID: 15-10094
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

MATRIX DUPLICATE QUALITY CONTROL REPORT

| Analyte | Analysis Method | Sample | Duplicate | RPD | Control Limit | Q |
|---|---|---|---|---|---|---|
| Arsenic | 6010C | 1 | 1 | 0.0% | +/- 1 | L |
| Cadmium | 6010C | 0.04 U | 0.04 U | 0.0% | +/- 0.04 | L |
| Chromium | 6010C | 1.5 | 1.4 | 6.9% | +/- 20% | |
| Copper | 6010C | 9.29 | 12.0 | 25.5% | +/- 20% | * |
| Lead | 6010C | 0.9 | 1.3 | 36.4% | +/- 0.4 | L |
| Manganese | 6010C | 0.60 | 0.64 | 6.5% | +/- 20% | |
| Mercury | 7471A | 0.057 | 0.045 | 23.5% | +/- 20% | * |
| Nickel | 6010C | 0.7 | 0.8 | 13.3% | +/- 0.2 | L |
| Selenium | 6010C | 1 U | 1 U | 0.0% | +/- 1 | L |
| Silver | 6010C | 0.06 U | 0.06 U | 0.0% | +/- 0.06 | L |
| Zinc | 6010C | 8.4 | 10.4 | 21.3% | +/- 20% | * |

Reported in mg/kg-as-rec

*-Control Limit Not Met
L-RPD Invalid, Limit = Detection Limit

ANALYTICAL RESOURCES INCORPORATED

**INORGANICS ANALYSIS DATA SHEET**
**TOTAL METALS**
Page 1 of 1

**Sample ID: LCN-TIS-54-ST**
**Fat**

Lab Sample ID: AGS2A
LIMS ID: 15-10094
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

**MATRIX SPIKE QUALITY CONTROL REPORT**

| Analyte | Analysis Method | Sample | Spike | Spike Added | % Recovery | Q |
|---|---|---|---|---|---|---|
| Arsenic | 6010C | 1 | 91 | 77.5 | 116% | |
| Cadmium | 6010C | 0.04 U | 19.7 | 19.4 | 102% | |
| Chromium | 6010C | 1.5 | 23.2 | 19.4 | 112% | |
| Copper | 6010C | 9.29 | 30.7 | 19.4 | 110% | |
| Lead | 6010C | 0.9 | 74.8 | 77.5 | 95.4% | |
| Manganese | 6010C | 0.60 | 21.3 | 19.4 | 107% | |
| Mercury | 7471A | 0.057 | 0.086 | 0.0485 | 59.8% | N |
| Nickel | 6010C | 0.7 | 21.4 | 19.4 | 107% | |
| Selenium | 6010C | 1 U | 101 | 77.5 | 130% | N |
| Silver | 6010C | 0.06 U | 19.1 | 19.4 | 98.5% | |
| Zinc | 6010C | 8.4 | 29.7 | 19.4 | 110% | |

Reported in mg/kg-as-rec

N-Control Limit Not Met
H-% Recovery Not Applicable, Sample Concentration Too High
NA-Not Applicable, Analyte Not Spiked

Percent Recovery Limits: 75-125%

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS
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Sample ID: LCN-TIS-55-ST
Muscle

Lab Sample ID: AGS2B
LIMS ID: 15-10095
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

| Prep Meth | Prep Date | Analysis Method | Analysis Date | CAS Number | Analyte | LOQ | mg/kg-as-rec | Q |
|---|---|---|---|---|---|---|---|---|
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-38-2 | Arsenic | 1 | 1 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-43-9 | Cadmium | 0.04 | 0.04 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-47-3** | **Chromium** | 0.1 | **0.1** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-50-8** | **Copper** | 0.04 | **2.08** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7439-92-1 | Lead | 0.4 | 0.4 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-96-5** | **Manganese** | 0.02 | **0.16** | |
| CLP-M | 06/02/15 | 7471A | 06/05/15 | **7439-97-6** | **Mercury** | 0.02 | **2.18** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-02-0 | Nickel | 0.2 | 0.2 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7782-49-2 | Selenium | 1 | 1 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-22-4 | Silver | 0.06 | 0.06 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-66-6** | **Zinc** | 0.2 | **21.1** | |

U-Analyte undetected at given LOQ
LOQ-Limit of Quantitation

ANALYTICAL RESOURCES INCORPORATED

**INORGANICS ANALYSIS DATA SHEET**
**TOTAL METALS**
Page 1 of 1

**Sample ID: LCN-TIS-57-ST**
**Liver**

Lab Sample ID: AGS2C
LIMS ID: 15-10096
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

| Prep Meth | Prep Date | Analysis Method | Analysis Date | CAS Number | Analyte | LOQ | mg/kg-as-rec | Q |
|---|---|---|---|---|---|---|---|---|
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-38-2 | Arsenic | 1 | 1 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-43-9** | **Cadmium** | 0.04 | **4.31** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-47-3** | **Chromium** | 0.1 | **0.1** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-50-8** | **Copper** | 0.04 | **19.2** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7439-92-1 | Lead | 0.4 | 0.4 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-96-5** | **Manganese** | 0.02 | **3.39** | |
| CLP-M | 06/02/15 | 7471A | 06/05/15 | **7439-97-6** | **Mercury** | 5 | **222** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-02-0 | Nickel | 0.2 | 0.2 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7782-49-2** | **Selenium** | 1 | **82** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-22-4** | **Silver** | 0.06 | **0.45** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-66-6** | **Zinc** | 0.2 | **58.9** | |

U-Analyte undetected at given LOQ
LOQ-Limit of Quantitation

ANALYTICAL RESOURCES INCORPORATED

INORGANICS ANALYSIS DATA SHEET
TOTAL METALS
Page 1 of 1

Sample ID: LCN-TIS-59-ST
Kidney

Lab Sample ID: AGS2D
LIMS ID: 15-10097
Matrix: Tissue
Data Release Authorized:
Reported: 06/08/15

QC Report No: AGS2-Oceanus Alaska
Project: Legacy Cove North

Date Sampled: 05/17/15
Date Received: 05/27/15

| Prep Meth | Prep Date | Analysis Method | Analysis Date | CAS Number | Analyte | LOQ | mg/kg-as-rec | Q |
|---|---|---|---|---|---|---|---|---|
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-38-2 | Arsenic | 1 | 1 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-43-9** | **Cadmium** | 0.04 | **12.3** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-47-3** | **Chromium** | 0.1 | **0.2** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-50-8** | **Copper** | 0.04 | **7.99** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-92-1** | **Lead** | 0.4 | **0.5** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7439-96-5** | **Manganese** | 0.02 | **0.83** | |
| CLP-M | 06/02/15 | 7471A | 06/05/15 | **7439-97-6** | **Mercury** | 0.1 | **6.3** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-02-0 | Nickel | 0.2 | 0.2 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7782-49-2** | **Selenium** | 1 | **3** | |
| 3050B | 06/02/15 | 6010C | 06/03/15 | 7440-22-4 | Silver | 0.06 | 0.06 | U |
| 3050B | 06/02/15 | 6010C | 06/03/15 | **7440-66-6** | **Zinc** | 0.2 | **38.6** | |

U-Analyte undetected at given LOQ
LOQ-Limit of Quantitation

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