Appendix V6-5E

Food Chain Model and Predicted Concentrations of Contaminants of Potential Concern in the Tissues of Country Food Species and Wildlife Species

TMAC RESOURCES

Appendix V6-5E. Food Chain Model and Predicted Concentrations of Contaminants of Potential Concern in the Tissues of Country Food Species and Wildlife Species

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1. Introduction

Concentrations of contaminants of potential concern (COPCs) in the tissues of country food species and wildlife valued ecosystem components (VECs) were estimated using a food chain model. The country food species include: caribou (*Rangifer tarandus*), Arctic ground squirrel (*Spermophilus parryii*), and Canada goose (*Branta canadensis*). The wildlife VECs (or species selected to represent a VEC) include: caribou, muskox (*Ovibos moschatus*), wolverine (*Gulo gulo*), grizzly bear (*Ursus arctos horribilis*), wolf (*Canis lupus arctos*), Arctic ground squirrel, Arctic shrew (*Sorex arcticus*), northern red-backed vole (*Myodes rutilus*), willow ptarmigan (*Lagopus lagopus*), American tree sparrow (*Spizella arborea*), peregrine falcon (*Falco peregrinus*), Canada goose, red-breasted merganser (*Mergus serrator*), least sandpiper (*Calidris minutilla*), long-tailed duck (*Clangula hyemalis*), herring gull (*Larus smithsonianus*), yellow warbler (*Setophaga petechia*), brant (*Branta bernicla*), and ringed seal (*Phoca hispida*).

The food chain model predicts COPC concentrations in animal tissue by estimating the fraction of COPCs that are retained in the tissues when wildlife ingests environmental media such as vegetation, prey, soil, sediment, and surface water. The food chain model followed the methodology described in Golder Associates Ltd. (2005), which is recommended by Health Canada (2010) and is the same type of model recommended by Environment Canada (2012a). The modeled baseline COPC concentrations in tissue were used in the existing conditions human health risk assessment (HHRA) and the existing conditions environmental risk assessment (ERA) to assess the potential for the country foods to affect human health and the prey species to affect wildlife health prior to Phase 2 Project development.

2. Methods

The following equation was used to predict COPC concentrations in animal tissue (C_{total} in mg/kg):

$$C_{total} = C_{m[soil\ or\ sediment]} + C_{m[water]} + C_{m[veg]} + C_{m[prey]} \qquad \text{[Equation 1]}$$

where:

$C_{m[soil]}$ = concentration in meat from exposure to COPCs in soil
$C_{m[sediment]}$ = concentration in meat from exposure to COPCs in sediment
$C_{m[water]}$ = concentration in meat from exposure to COPCs in water
$C_{m[veg]}$ = concentration in meat from exposure to COPCs in vegetation
$C_{m[prey]}$ = concentration in meat from exposure to COPCs in prey

The wildlife uptake equations used to estimate the concentrations in animal tissue (meat) from exposure to soil or sediment, vegetation, prey, and water are presented in Table V6-5E1.

2.1 BIOTRANSFER FACTORS

The tissue uptake calculations were based, in part, on COPC specific biotransfer factors (BTFs), which are rates at which COPCs are taken up and absorbed into wildlife tissue from their food. Food-to-tissue BTFs are used for water, sediment, and soil transfer calculations in the absence of BTFs for these media, as recommended by Golder Associates Ltd. (2005). No species-specific BTFs for the country food or wildlife species were available, therefore beef BTFs were used for mammals (Table V6-5E2; US EPA 2005; RAIS 2010). The use of beef BTFs for wild mammals is considered to be a conservative approach (RAIS 2010). There were no BTFs specifically for the avian wildlife species; therefore, chicken BTFs were used for bird species (RAIS 2010). The chicken BTFs were obtained from the Pacific Northwest National Laboratory's (PNNL) report and the US EPA (Staven et al. 2003; US EPA 2005).

Table V6-5E1. Wildlife Uptake Equations for Contaminants of Potential Concern

Pathway	Equation and Parameters
Generic Equation	$C_{m[media]}$ = BTF x C x IR x ET x fw
Ingestion Equations	
Soil Ingestion	$C_{m[soil]} = BTF_{tissue\text{-}food} \times C_{soil} \times IR_{soil} \times ET \times fw$
Sediment Ingestion	$C_{m[sediment]} = BTF_{tissue\text{-}food} \times C_{sediment} \times IR_{sediment} \times ET \times fw$
Vegetation Ingestion	$C_{m[veg]} = BTF_{tissue\text{-}food} \times C_{veg} \times IR_{veg} \times ET \times fw$
Prey Ingestion	$C_{m[prey]} = BTF_{tissue\text{-}food} \times C_{prey} \times IR_{prey} \times ET \times fw$
Water Ingestion	$C_{m[water]} = BTF_{tissue\text{-}food} \times C_{water} \times IR_{water} \times ET \times fw$

Notes:
$C_{m[media]}$ = concentration of COPCs in wildlife tissue (mg/kg wet weight) from ingestion of environmental media (e.g., soil, sediment, vegetation, prey, water)
$BTF_{tissue\text{-}food}$ = biotransfer factor for the wildlife species and COPC (day/kg)
$C_{[media]}$ = COPC concentration in soil, sediment, vegetation, prey, or water (mg/kg or mg/L)
$IR_{soil/sediment/veg/prey/water}$ = daily ingestion rate of environmental media for wildlife species (kg/day or L/day)
ET = exposure time spent in the area for wildlife species (unitless)
fw = fraction of daily consumption for wildlife species (assumed 1; unitless)

Table V6-5E2. Biotransfer Factors Used to Predict Uptake of Contaminants of Potential Concern into Wildlife Tissue

	BTF_{beef}		$BTF_{chicken}$	
COPC	**day/kg**	**Reference**	**day/kg**	**Reference**
Aluminum	0.0015	1	0.8	2, 3
Arsenic	0.002	1	0.83	2
Cadmium	0.00055	1	0.106	4
Chromium	0.0055	1	0.2	2
Copper	0.01	1	0.5	2
Lead	0.0003	2	0.8	2
Manganese	0.0004	1	0.05	2
Mercury	0.25	1	0.03	2
Nickel	0.006	1	0.001	2
Selenium	0.00227	4	1.13	4
Thallium	0.04	4	10.8	2
Zinc	0.00009	4	0.00875	4

Notes:
COPC = contaminant of potential concern
BTFbeef = biotransfer factor for beef; BTFchicken = biotransfer factor for chicken
References: 1. RAIS (2010).
2. Staven et al. (2003).
3. BTFchicken for aluminum is based on BTFchicken for gallium.
4. US EPA (2005).

When BTF values were not available for specific COPCs, the BTF for a COPC with similar physicochemical characteristics was substituted. Metal COPCs were considered similar in their physicochemical characteristics if they were immediately above or below each other on the periodic table of elements. For example, the $BTF_{chicken}$ for aluminum was not available; therefore, the $BTF_{chicken}$ value for gallium was substituted because gallium is below aluminum on the periodic table of the elements.

Food chain models can over- or under-predict contaminant concentrations in the tissues of wildlife species, and the concentrations predicted with the Golder Associates Ltd. (2005) food chain model are for the whole-body and are not tissue specific. However, Inuit frequently consume the liver and kidney of caribou, which may have much higher metal concentrations than other tissues. Therefore, to obtain liver and kidney tissue concentrations for caribou, tissue distribution ratios were applied to the predicted whole-body tissue concentrations based on muscle, liver, and kidney concentrations in caribou tissue reported in peer reviewed literature. Tissue distribution ratios were calculated based on Canadian studies the data provided in the following studies:

- Crete et al. (1989): cadmium concentrations reported in muscle, kidney, and liver tissue of caribou from Quebec;
- Elkin and Bethke (1995): metal concentrations (i.e., aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc) reported in kidney and liver tissue of caribou from the Northwest Territories;
- Gamberg (2000): metal concentrations (i.e., arsenic, cadmium, copper, lead, mercury, and zinc) reported in muscle, kidney, and liver tissue of caribou from the Yukon;
- Gamberg (2004): metal concentrations (i.e., aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, uranium, vanadium, and zinc) reported in kidney tissue of caribou from the Yukon;
- Gamberg et al. (2005): metal concentrations (i.e., aluminum, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, selenium, and zinc) reported in kidney tissue of caribou from Alaska and the Yukon;
- Gamberg (2010): metal concentrations (i.e., arsenic, cadmium, copper, lead, mercury, selenium, and zinc) reported in kidney tissue of caribou from the Yukon and Northwest Territories;
- Gamberg and Scheuhammer (1994): cadmium concentrations reported in kidney and liver tissue of caribou from the Yukon and Northwest Territories;
- Kim, Chan, and Receuver (1998): cadmium concentrations reported in muscle, kidney, and liver tissue of caribou from the Northwest Territories;
- Larter et al. (2010): metal concentrations (i.e., aluminum, cadmium, copper, lead, mercury, nickel, selenium, and zinc) reported in kidney tissue of caribou from the Northwest Territories;
- Macdonald et al. (2002): metal concentrations (i.e., aluminum, cadmium, chromium, copper, lead, mercury, and zinc) reported in muscle, kidney, and liver tissue of caribou from the Northwest Territories and Nunavut;
- Pollock et al. (2009): metal concentrations (i.e., cadmium, lead, mercury, and selenium) reported in kidney tissue of caribou from Labrador; and
- Robillard et al. (2002): metal concentrations (i.e., cadmium, lead, and mercury) reported in muscle, kidney, and liver tissue in caribou from Northern Quebec.

Tissue distribution ratios for liver and kidney tissue were obtained by dividing the measured median liver or kidney concentrations by the measured median muscle concentration. The liver and kidney tissue calibration factors were then multiplied by the caribou whole body tissue concentration to obtain liver and kidney tissue concentrations. Calibration factors for organs could not be calculated for COPCs that were not measured in both muscle and kidney or liver; therefore, those COPCs were assumed to have a tissue distribution ratio of one, based on a lack of data to determine appropriate distribution ratios for organs compared to muscle. The tissue distribution ratios presented in Table V6-5E3 were used to estimate organ meat (i.e., liver and kidney tissue) concentrations based on predicted whole-body concentrations.

Table V6-5E3. Literature Derived Muscle Tissue Metal Concentrations in Caribou and Tissue Distribution Ratios used to Predict Kidney and Liver Tissue Metal Concentrations in Caribou

Metal	Median Muscle Tissue Concentration (mg/kg wet weight)	Median Liver Tissue Concentration (mg/kg wet weight)	Median Kidney Tissue Concentration (mg/kg wet weight)	Tissue Distribution Ratio for Liver	Tissue Distribution Ratio for Kidney
Arsenic	0.129	0.174	0.146	1.35	1.13
Cadmium	0.0382	5.33	46.1	140	1207
Copper	2.83	130	20.7	46.0	7.30
Lead	0.0540	9.77	1.18	181	21.8
Mercury	0.0186	2.02	9.63	109	518
Zinc	47.0	74.0	88.9	1.57	1.89

2.2 CONCENTRATIONS OF CONTAMINANTS OF POTENTIAL CONCERN IN ENVIRONMENTAL MEDIA AND BIOTA

A summary of the data used as inputs into the food chain model for vegetation, soil, water, sediment, fish tissue, and mussel tissue quality is presented in Table V6-5E4.

The vegetation baseline sampling programs included the collection of tissue metal samples from within the human health LSA. The species sampled included: crowberries (*Empetrum nigrum*), bog blueberry (*Vaccinium uliginosum*), bearberry (*Arctostaphylos alpina*), and lichen (*Flavocetraria nivas* and *F. cucullata*). The vegetation tissue metal samples were used to support food chain modeling of country food species and wildlife species. Overall, 36 crowberry, 10 bearberry, 1 bog blueberry, 17 mixed berries (species unidentified), and 81 lichen tissue metal samples from two species were included in the food chain model. For berry producing plants, the berries were submitted for analysis. For lichens, the entire plant was collected and analyzed. The vegetation value (diet) used in the food chain model was the mean of the 95th percentile concentration of COPCs in the berries and lichen collected.

The vegetation diet items for the wildlife species that required food chain modeling were limited to the vegetation species that were available for collection at the time of sampling; thus, they may not entirely represent the actual diet of these wildlife species. Furthermore, diets shift during the year (e.g., due plant abundance during the growing season versus winter) whereas the model uses a generalized diet for the year. Therefore, there are several assumptions for the diet composition of the country food and wildlife species modeled and best professional judgement was used in the diet determination. Uncertainties with the use of the vegetation data are presented in Sections 5.3.6 and 5.5.5 of the existing conditions HHRA and ERA.

Table V6-5E4. Summary of the 95th Percentile Concentrations of Contaminants of Potential Concern in Vegetation, Soil, Sediment, Marine Water, Freshwater, Fish Tissue, and Mussel Tissue Samples

COPC	95th Percentile Baseline Berry Species Concentration (mg/kg ww; n=59)	95th Percentile Baseline Lichen Species Concentration (mg/kg ww; n=78)	Mean of 95th Percentiles of Berries and Lichen C_{veg}	95th Percentile Baseline Soil Concentration (mg/kg dw; n=100) C_{soil}	95th Percentile Baseline Freshwater Sediment Concentration [a] (mg/kg; n=271) $C_{f\text{-}sediment}$	95th Percentile Baseline Marine Sediment Concentration (mg/kg; n=84) $C_{m\text{-}sediment}$	95th Percentile Baseline Freshwater Concentration (mg/L; n=12 modelling nodes) $C_{f\text{-}water}$	95th Percentile Baseline Marine Water Concentration (mg/L; n=214) $C_{m\text{-}water}$	95th Percentile Arctic Char Tissue Concentration (mg/kg, n=5) $C_{arcticchar}$	95th Percentile Lake Trout Tissue Concentration (mg/kg, n=69) $C_{laketrout}$	95th Percentile Whitefish Tissue Concentration (mg/kg, n =7) $C_{whitefish}$	95th Percentile Stickleback Tissue Concentration (mg/kg, n =134) $C_{stickleback}$	95th Percentile Bay Mussel Tissue Concentration (mg/kg, n =24) C_{mussel}
Aluminum	5.48	354	180	21330	29407	19245	0.0605	0.134	0.518	4.24	3.05	57.3	113
Arsenic	0.00362	0.207	0.105	3.78	16.8	4.32	0.000266	0.00130	3.71	0.144	0.175	0.105	2.77
Cadmium	0.00380	0.150	0.0771	0.250	0.171	0.0960	0.00000631	0.0000600	0.0447	0.00250	0.00250	0.0447	0.741
Chromium	9.33	5.79	7.56	65.6	78.9	52.7	0.000437	0.00169	0.957	0.326	0.110	0.333	19.5
Copper	1.33	2.75	2.04	38.3	52.3	26.2	0.00143	0.00119	0.396	0.333	0.301	2.05	1.58
Lead	0.0133	0.797	0.405	15.0	12.9	7.46	0.0000543	0.000500	0.00276	0.0752	0.116	0.0738	0.191
Manganese	23.5	113	68.3	370	2477	308	0.0220	0.00825	0.0662	0.263	0.769	20.2	3.42
Mercury	0.000500	0.0897	0.0451	0.0506	0.0632	0.0108	0.00000133	0.00000500	0.00903	1.08	0.311	0.118	0.0206
Nickel	5.25	2.72	3.98	34.7	48.0	25.8	0.000576	0.000829	0.0414	0.196	0.274	0.265	10.5
Selenium	0.0100	0.100	0.0550	0.250	0.650	0.250	0.000250	0.00100	0.496	0.600	0.277	0.460	0.937
Thallium	0.000200	0.0138	0.00702	0.500	0.305	0.250	0.00000407	0.00500	0.00724	0.0110	0.00500	0.0150	0.00231
Zinc	2.15	28.4	15.3	59.1	105	57.3	0.00320	0.00258	2.77	4.75	3.90	76.9	20.4

Notes:
COPC = contaminant of potential concern
ww = wet weight
dw = dry weight
(-) = not calculated because that parameter was not measured in environmental media.
Cadmium was not measured in Arctic Char thus the concentration in Stickleback was adopted to be conservative.
[a] *The freshwater sediment concentration is the higher 95th percentile concentration of either lake or stream samples.*

Data used from the soil sampling program included 100 soil samples collected from depths ranging from 0 to 20 cm below ground surface (US EPA 2012). The 95th percentile soil concentration of COPCs were used in the incidental soil ingestion pathway to predict the tissue concentrations of COPCs in caribou, Arctic ground squirrel, muskox, wolverine, grizzly bear, wolf, Arctic shrew, northern red-backed vole, willow ptarmigan, American tree sparrow, peregrine falcon, and yellow warbler.

The data used for freshwater quality was from the base case baseline surface water quality model from 14 surface water quality model nodes (see Section 5.3.2.3 in Volume 6 for more information).

Data used from the freshwater sediment sampling program (stream and lake samples) included 271 samples collected between 2007 and 2015. The higher of the stream or lake sediment concentrations were used in the incidental freshwater sediment ingestion pathway to predict the tissue concentrations of COPCs in Canada goose, red-breasted merganser, least sandpiper, and long-tailed duck.

Data used from the marine sediment sampling program (i.e., Roberts Bay) included 84 samples collected between 2007 and 2015. The 95th percentile concentrations of COPCs were used in the incidental marine sediment ingestion pathway to predict the tissue concentrations of COPCs in herring gull, brant, and ringed seal.

Fish tissue samples included five samples of marine Arctic Char (*Salvelinus alpinus*) collected in 2006 and 2007; 69 samples of Lake Trout (*S. namaycush*) collected in 2009 and 2010; seven samples of Whitefish (*Coregonus* spp.) collected in 2009; 134 samples of Ninespine Stickleback (*Pungitius pungitius*) collected in 2010. There were also 28 samples of bay mussel (*Mytilus trossulus*) collected in 2010. The 95th percentile of COPC concentrations in fish and bay mussel tissue were used in the food chain model.

2.3 INVERTEBRATE TISSUE CONCENTRATIONS

Several of the wildlife species included in the food chain model consume invertebrates; however, invertebrate tissue was not analyzed for COPC concentrations during the baseline sampling program, except for marine bay mussels. Therefore, COPC concentrations in tissue of freshwater invertebrates and soil invertebrates were calculated using published bioconcentration factors (BCFs). To calculate COPC concentrations in invertebrate tissue, the 95th percentile COPC concentration in environmental media (i.e., freshwater and soil) was multiplied by the applicable BCF to obtain the COPC concentration in invertebrate tissue. The 95th percentile COPC concentrations in the environmental media, the invertebrate BCFs, and the calculated COPC concentrations in invertebrate tissue are presented in Tables V6-5E5 and V6-5E6.

Table V6-5E5. Calculated Concentration of Contaminants of Potential Concern in Freshwater Aquatic Invertebrate Tissue

Parameter	95th Percentile Surface Water Concentration (mg/L)	BCF Water-to-Aquatic Invertebrates	BCF Source	Aquatic Invertebrate Tissue Concentration (mg/kg ww)
Aluminum	0.0605	231	US EPA (1988) in Sample et al. (1996)	14.0
Arsenic	0.000266	73	US EPA (1999)	0.0194
Cadmium	0.00000631	3461	US EPA (1999)	0.0218
Chromium	0.000437	3000	US EPA (1999)	1.31
Copper	0.00143	3718	US EPA (1999)	5.32
Lead	0.0000543	5059	US EPA (1999)	0.275

Parameter	95th Percentile Surface Water Concentration (mg/L)	BCF Water-to-Aquatic Invertebrates	BCF Source	Aquatic Invertebrate Tissue Concentration (mg/kg ww)
Manganese	0.0220	4066	US EPA (1999)	89.6
Mercury	0.00000133	20184	US EPA (1999)	0.0269
Methylmercury	0.00000133	550000	US EPA (1999)	0.734
Nickel	0.000576	28	US EPA (1999)	0.0161
Selenium	0.000250	1262	US EPA (1999)	0.316
Thallium	0.00000407	15000	US EPA (1999)	0.0611
Zinc	0.00320	4578	US EPA (1999)	14.6

Notes:
BCF = bioconcentration factor (unitless; BCF = $C_{invertebrate}$ (in mg/kg ww)/C_{water} (in mg/L))
ww = wet weight
Freshwater aquatic invertebrates are trophic level 2.
** Dissolved concentrations are typically applied in BCF calculations. In the absence of the dissolved concentrations for metals, total metals were conservatively used in the calculations.*

Table V6-5E6. Calculated Concentration of Contaminants of Potential Concern in Terrestrial Invertebrate Tissue

Parameter	95th Percentile Soil Concentration (mg/kg)	BCF Soil-to-Terrestrial Invertebrates	BCF Source	Terrestrial Invertebrate Tissue Concentration (mg/kg ww)
Aluminum	21330	0.22	US EPA (1999)	4693
Arsenic	3.78	0.11	US EPA (1999)	0.416
Cadmium	0.250	0.96	US EPA (1999)	0.240
Chromium	65.6	0.01	US EPA (1999)	0.656
Copper	38.3	0.04	US EPA (1999)	1.53
Lead	15.0	0.03	US EPA (1999)	0.450
Manganese	370	0.054	CHPPM (2004)	20.0
Mercury	0.0506	0.04	US EPA (1999)	0.00202
Nickel	34.7	0.02	US EPA (1999)	0.694
Selenium	0.250	0.22	US EPA (1999)	0.0550
Thallium	0.500	0.22	US EPA (1999)	0.110
Zinc	59.1	0.56	US EPA (1999)	33.1

Notes:
BCF = bioconcentration factor (unitless; BCF = Cinvertebrate (in mg/kg ww)/Csoil (in mg/kg))
ww = wet weight
Terrestrial invertebrates are trophic level 2.

2.4 WILDLIFE CHARACTERISTICS

Wildlife characteristics are species-specific parameters that were used to estimate the amount of time an animal would spend in the wildlife RSA and the amount of environmental media that each species would be exposed to during that time. Tables V6-5E7 and V6-5E8 presents the species-specific characteristics that were used to predict country food and wildlife tissue concentrations of COPCs.

Table V6-5E7. Wildlife Diet Items and Proportions

Wildlife Species	Diet Item	% of Diet	Diet Reference	% Moisture of Diet Item	% Moisture Reference
Caribou	Vegetation	100	Environment Yukon (2016)	50.3	Baseline data
Muskox	Vegetation	100	Barboza, Peltier, and Forster (2006)	50.3	Baseline data
Wolverine	Caribou	8.33	State of Alaska (2015e)	70	Willmer, Stone, and Johnston (2009)
	Muskox	8.33			
	Arctic Ground Squirrel	8.33			
	Arctic Shrew	8.33			
	Northern Red-backed Vole	8.33			
	Willow Ptarmigan	8.33			
	Canada Goose	8.33			
	Red-breasted Merganser	8.33			
	Least sandpiper	8.33			
	American golden-plover	8.33			
	Yellow Warbler	8.33			
	American Tree Sparrow	8.33			
Grizzly Bear	Caribou	35.3	Gau et al. (2002)	70	Willmer, Stone, and Johnston (2009)
	Muskox	7.56			
	Arctic Ground Squirrel	7.56			
	Canada Goose	0.93			
	Willow Ptarmigan	0.93			
	Vegetation	46.8	Gau et al. (2002)	50.3	Baseline data
	Fish (all species)	0.93		77.0	Baseline data
Wolf	Muskox	20.0	Mech (2007)	70	Willmer, Stone, and Johnston (2009)
	Caribou	20.0			
	Arctic Ground Squirrel	20.0			
	Arctic Shrew	20.0			
	Northern Red-backed Vole	20.0			
Arctic Ground Squirrel	Vegetation	100	State of Alaska (2015a)	50.3	Baseline data
Arctic Shrew	Terrestrial Invertebrates	100	Environment Canada (2012b)	71.3	ORNL (1997)
Northern Red-backed Vole	Vegetation	80	Linzey et al. (2008)	50.3	Baseline data
	Terrestrial Invertebrates	20		71.3	ORNL (1997)
Willow Ptarmigan	Vegetation	100	Cornell Lab of Ornithology (2015i)	50.3	Baseline data
American Tree Sparrow	Vegetation	50	Cornell Lab of Ornithology (2015a)	50.3	Baseline data
	Terrestrial Invertebrates	50		71.3	ORNL (1997)

Wildlife Species	Diet Item	% of Diet	Diet Reference	% Moisture of Diet Item	% Moisture Reference
Peregrine Falcon	Arctic Ground Squirrel	2.5	Cornell Lab of Ornithology (2015g)	70	Willmer, Stone, and Johnston (2009)
	Arctic Shrew	2.5			
	Northern Red-backed Vole	2.5			
	Canada Goose	10			
	King Eider	10			
	Red-breasted Merganser	10			
	Least Sandpiper	10			
	American Golden Plover	10			
	Red-throated Loon	10			
	Herring Gull	10			
	Yellow Warbler	10			
	Brant	10			
	Fish (all species)	2.5	Cornell Lab of Ornithology (2015g)	77.0	Baseline data
Canada Goose	Vegetation	100	Cornell Lab of Ornithology (2015c)	50.3	Baseline data
Red-breasted Merganser	Fish (freshwater)	100	Cornell Lab of Ornithology (2015h)	80.0	Baseline data
Least Sandpiper	Freshwater Invertebrates	100	Cornell Lab of Ornithology (2015e)	78.5	ORNL (1997)
Long-tailed Duck	Vegetation	5	Cornell Lab of Ornithology (2015f)	50.3	Baseline data
	Freshwater Invertebrates	90		78.5	ORNL (1997)
	Fish (freshwater)	5		80.0	Baseline data
Herring Gull	Bay Mussel	50	(Cornell Lab of Ornithology 2015d)	87.9	Baseline data
	Fish (marine)	50		80.0	Baseline data
Yellow Warbler	Terrestrial Invertebrates	100	Cornell Lab of Ornithology (2015j)	71.3	ORNL (1997)
Brant	Vegetation	100	Cornell Lab of Ornithology (2015b)	50.3	Baseline data
Ringed Seal	Fish (marine)	80	NOAA (2014)	80.0	Baseline data
	Bay Mussel	20		87.9	Baseline data

Notes:
Diet items were specified in the references listed but the percent of the item in the diet was typically not provided and instead best professional judgement was used.

Concentrations of COPCs in tissue were not measured in prey species (except for fish and bay mussels); thus, tissue concentrations in prey species were modeled and used as diet items for carnivores and omnivores. Only the wildlife VECs were considered as prey species which is a simplification of the food chain. The diet items of the species included in the assessment is provided in Table V6-5E7.

Many of the ingestion rates for different wildlife species were not available in the literature, thus were calculated from equations provided in ORNL (1997). The calculations required the percent moisture of the food items, which are presented in Table V6-5E8.

Table V6-5E8. Wildlife Characteristics

Wildlife Species	Mean Body Weight (kg)	Body Weight Reference	Diet Items	Food Ingestion Rate (IR_{food}; kg-ww/day)	Soil/Sediment Ingestion Rate (IR_{soil}; kg-dw/day)	Soil/Sediment Ingestion Rate Reference	Water Ingestion Rate (IR_{water}; L/day)	Exposure Time in Area (ET)	Fraction of Daily Consumption (fw)
Caribou	150	Environment Yukon (2016)	Vegetation	6.72	0.134	Beyer and Fries (2003)	9.00	0.00356	1
Muskox	273	State of Alaska (2015c)	Vegetation	10.4	0.208	Beyer and Fries (2003)	15.4	1	1
Wolverine	12.0	State of Alaska (2015e)	Caribou	0.147	0.0353	Beyer and Fries (2003)	0.93	1	1
			Muskox	0.147					
			Arctic Ground Squirrel	0.147					
			Arctic Shrew	0.147					
			Northern Red-backed Vole	0.147					
			Willow Ptarmigan	0.147					
			Canada Goose	0.147					
			Red-breasted Merganser	0.147					
			Least sandpiper	0.147					
			Long-tailed duck	0.147					
			Herring Gull	0.147					
			Brant	0.147					
Grizzly Bear	450	State of Alaska (2015b)	Caribou	12.3	1.27	Gau et al. (2002)	24.2	0.458	1
			Muskox	2.63					
			Arctic Ground Squirrel	2.63					
			Canada Goose	3.23					
			Willow Ptarmigan	10.7					
			Vegetation	9.80					
			Fish (all species)	4.22					

Wildlife Species	Mean Body Weight (kg)	Body Weight Reference	Diet Items	Food Ingestion Rate (IR_{food}; kg-ww/day)	Soil/Sediment Ingestion Rate (IR_{soil}; kg-dw/day)	Soil/Sediment Ingestion Rate Reference	Water Ingestion Rate (IR_{water}; L/day)	Exposure Time in Area (ET)	Fraction of Daily Consumption (fw)
Wolf	49.5	State of Alaska (2015d)	Caribou	1.13	0.113	Beyer and Fries (2003)	3.32	1	1
			Muskox	1.13					
			Arctic Ground Squirrel	1.13					
			Arctic Shrew	1.13					
			Northern Red-backed Vole	1.13					
Arctic Ground Squirrel	1.01	State of Alaska (2015a)	Vegetation	0.0620	0.00434	Beyer and Fries (2003)	0.100	0.417	1
Arctic Shrew	0.00410	Environment Canada (2012b)	Terrestrial Invertebrates	0.00116	0.0000815	Beyer and Fries (2003)	0.000703	1	1
Northern Red-backed Vole	0.0300	Smithsonian National Museum of Natural History (2015)	Vegetation	0.00344	0.000660	Beyer and Fries (2003)	0.00422	1	1
			Terrestrial Invertebrates	0.00598					
Willow Ptarmigan	0.620	Cornell Lab of Ornithology (2015i)	Vegetation	0.0857	0.00171	Beyer and Fries (2003)	0.0428	1	1
American Tree Sparrow	0.0285	Cornell Lab of Ornithology (2015a)	Vegetation	0.0115	0.000631	Beyer and Fries (2003)	0.00544	0.417	1
			Terrestrial Invertebrates	0.0200					

Wildlife Species	Mean Body Weight (kg)	Body Weight Reference	Diet Items	Food Ingestion Rate (IR_{food}; kg-ww/day)	Soil/Sediment Ingestion Rate (IR_{soil}; kg-dw/day)	Soil/Sediment Ingestion Rate Reference	Water Ingestion Rate (IR_{water}; L/day)	Exposure Time in Area (ET)	Fraction of Daily Consumption (fw)
Peregrine Falcon	0.815	Environment Canada (2012b)	Arctic Ground Squirrel	0.00425	0.00684	Environment Canada (2012b)	0.0514	0.417	1
			Arctic Shrew	0.00425					
			Northern Red-backed Vole	0.00425					
			Willow Ptarmigan	0.0170					
			American Tree Sparrow	0.0170					
			Canada Goose	0.0170					
			Red-breasted Merganser	0.0170					
			Least Sandpiper	0.0170					
			Long-tailed duck	0.0170					
			Herring Gull	0.0170					
			Yellow Warbler	0.0170					
			Brant	0.0170					
			Fish (all species)	0.00554					
Canada Goose	3.16	US EPA (1993)	Vegetation	0.247	0.0198	Beyer and Fries (2003)	0.128	0.417	1
Red-breasted Merganser	1.08	Cornell Lab of Ornithology (2015h)	Fish (freshwater)	0.306	0.00612	Beyer and Fries (2003)	0.0621	0.417	1
Least Sandpiper	0.0245	Cornell Lab of Ornithology (2015e)	Freshwater Invertebrates	0.0242	0.000484	Beyer and Fries (2003)	0.00492	0.417	1
Long-tailed Duck	0.800	Cornell Lab of Ornithology (2015f)	Vegetation	0.00506	0.00457	Beyer and Fries (2003)	0.0508	0.417	1
			Freshwater Invertebrates	0.211					
			Fish (freshwater)	0.0126					

Wildlife Species	Mean Body Weight (kg)	Body Weight Reference	Diet Items	Food Ingestion Rate (IR_{food}; kg-ww/day)	Soil/Sediment Ingestion Rate (IR_{soil}; kg-dw/day)	Soil/Sediment Ingestion Rate Reference	Water Ingestion Rate (IR_{water}; L/day)	Exposure Time in Area (ET)	Fraction of Daily Consumption (fw)
Herring Gull	1.03	(Cornell Lab of Ornithology 2015d)	Bay Mussel Fish (marine)	0.245 0.148	0.00786	(Beyer and Fries 2003)	0.0602	0.417	1
Yellow Warbler	0.0100	Cornell Lab of Ornithology (2015j)	Terrestrial Invertebrates	0.0101	0.000203	Beyer and Fries (2003)	0.00270	0.417	1
Brant	1.50	Cornell Lab of Ornithology (2015b)	Vegetation	0.152	0.00305	Beyer and Fries (2003)	0.07742	0.417	1
Ringed Seal	54.4	NOAA (2014)	Fish (marine) Bay Mussel	7.34 3.03	0.207	Environment Canada (2012b)	N/A	1	1

Notes:
ww = wet weight
dw = dry weight
N/A = not applicable
The food and water ingestion rates were obtained from ORNL (1997) and are based on equations for mammals and birds.
Many of the wildlife species were assumed to be similar to closely related species if species specific information was not available (e.g., assumed that soil ingestion by muskox was similar to that for moose).

The exposure time (ET) in the wildlife LSA for the different wildlife species was determined using information previously collected (e.g., collared caribou data), information available in the literature, and best professional judgement. A description of the ETs used for the different wildlife species are described in the sections below.

2.4.1 Caribou

The Phase 2 Project area lies within the seasonal ranges of the Ahiak and Dolphin-Union caribou herds. The calving range of the Ahiak herd (previously the Queen Maud Gulf herd) calves and spends the summer to the east of the Phase 2 Project area in the Queen Maud Gulf Migratory Bird Sanctuary. This herd winters to the south, near the treeline. The Dolphin-Union herd winters on the coast and migrates north at the end of April and May to Victoria Island to calve and spend the summer, returning to the mainland during the fall when the sea ice has frozen (typically in early November). The range of the Dolphin-Union caribou herd overlaps with the wildlife RSA during winter and the range of the Beverly/Ahiak caribou herd overlaps with the wildlife RSA during the summer (Rescan 2011b). More information on the caribou herds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.6.

The Dolphin-Union herd was in decline throughout the 1900s and is thought to have stabilized recently. The Dolphin-Union caribou herd is listed by as Special Concern by COSEWIC (2016) and is federally listed as Special Concern on Schedule 1 of the SARA (Government of Canada 2015).

The other principal caribou herd in this region of Nunavut is the Bathurst herd. However, this herd is outside of the Phase 2 Project area, calving west of Bathurst Inlet and spending the summer south-east of Bathurst Inlet. The southern tip of Bathurst Inlet is approximately 200 km south of the Doris North site. Gunn, Dragon, and Boulanger (2001) reported summer and fall ranges in the order of 46,000 to 58,000 km^2 for cumulative ranges for collared individuals of the Bathurst herd.

An analysis of the occurrence of caribou in relation to Windy Camp was performed for the post-calving period from 1996 to 2005 using presence-absence data. Comparatively few caribou have been observed during surveys conducted since 2006 (Rescan 2011a). One thousand and thirty-three caribou incidental observations were made during 2010, approximately twice as many as were recorded in 2009. Most of these observations were made in the Boston Camp area.

Estimation of occurrence of caribou in the Phase 2 Project area is based on baseline collar data, for details of this program see Volume 4, Section 9.2.6. From 1999 to 2004 there were 8 to 22 caribou per year collared from the Dolphin-Union herd and from 1996 to 2014 there were 3 to 57 caribou per year collared from the Ahiak herd. It was determined that the highest average number of days spent within the wildlife LSA was 1.3 days by the Dolphin-Union herd. Thus, for the purposes of this assessment it was assumed that caribou spend 1.3 days per year (ET = 0.00356) in the wildlife LSA.

A key observation from elders and harvesters at the caribou workshop held in September 2016 (ERM and EDI 2016) was that there was little to no information mapped specifically for the Phase 2 Project area or the proposed all-weather road development from Madrid to the Boston site. However, it was stated that caribou use the whole Phase 2 Project road area (ERM and EDI 2016). Workshop participants also indicated that they were concerned that caribou could consume contaminated tailings water. Potential disturbance effects on caribou which were raised at the workshop (ERM and EDI 2016) were addressed in Volume 4, Chapter 10: Terrestrial Wildlife and Wildlife Habitat. However, concerns relating to pollution (land or water; ERM and EDI 2016) affecting caribou is addressed with the Phase 2 Project-related ERA.

2.4.2 Muskox

Muskoxen do not migrate and spend their entire lives in the Arctic (State of Alaska 2015c). The winter home range for muskox is 27 to 70 km^2, while the summer home range is 223 km^2 (Volume 4, Section 9.2.6.1). Thus, they could be present year round (ET = 1) in the terrestrial wildlife LSA (563 km^2). More information on muskoxen that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.6.

2.4.3 Arctic Ground Squirrel

The study area is large enough that it could overlap with the entire home range of an individual Arctic ground squirrel (less than 3 ha; Hubbs and Boonstra 1998). Arctic ground squirrels hibernate over winter from early-September to late-April and would not be exposed to COPCs during that time. Therefore, the residency time in the study area was assumed to be five months of the year (ET = 0.417). Ecological Risk Assessment guidance (Environment Canada 2012a) indicates that certain terrestrial receptor types require assessment in an ERA. Therefore, Arctic ground squirrel was selected to represent small herbivorous mammals and they were also selected to represent the wildlife VEC “less conspicuous species that may be maximally exposed to contaminants”.

2.4.4 Canada Goose

Canada geese arrive on the central Canadian Arctic barrens in early to mid-May, and generally depart by mid-September (Cornell Lab of Ornithology 2015c). If a pair of geese were to nest and raise young in the study area, it is conceivable that residency in the Phase 2 Project area would be for the entire time that they are in the Arctic. Therefore, the residency of Canada goose in the study area is at most five months of the year (ET = 0.417). Freshwater sediment concentrations were used in predicting the Canada goose tissue concentrations of COPCs as Canada goose may ingest freshwater sediments while grazing. More information on the waterbirds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.11.

2.4.5 Wolverine

Wolverines (*Gulo gulo*) are members of the mustelid family, which includes weasels, badgers, and marten. Very large home ranges and low population densities are characteristics of this solitary species. Females have a home range of 100 km^2, and males 600 km^2 (Volume 4, Section 9.2.8.1); thus and they could be present in the terrestrial wildlife LSA (563 km^2) during the entire year. The wolverine is listed as being of Special Concern by COSEWIC (2016). Wolverines do not migrate or hibernate and spend their entire lives in the Arctic (State of Alaska 2015e). Thus, they could be present year round in the wildlife LSA (ET = 1). More information on wolverines that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.8.

2.4.6 Grizzly Bear

Barren-ground grizzly bears (*Ursus arctos horribilis*) inhabit the northern extent of the grizzly bear range in North America and are known to occur in the baseline wildlife LSA and RSA from satellite-collar data and observations made during baseline studies (Rescan 2011b). Average annual ranges of male and female grizzly bears are approximately 7,245 km^2 and 2,100 km^2, respectively, and home range overlap is relatively high (McLoughlin, Ferguson, and Messier 2000). These home ranges are much larger than the terrestrial wildlife LSA (563 km^2), thus a dose adjustment factor (DAF) was applied to the estimated daily intake of COPCs for grizzly bears. The DAF was calculated by dividing the area of the terrestrial wildlife LSA by the home range for females (DAF = 0.268).

In the Canadian Arctic typically emerge from hibernation in early to mid-May and resume hibernation in mid to late-October (Gau et al. 2002). Thus the maximum amount of time that a grizzly bear could possibly spend in the wildlife LSA is five and a half months of the year (ET = 0.458).

Barren-ground grizzly bears are listed by COSEWIC (2016) as being of Special Concern but they are not listed under SARA. More information on barren-ground grizzly bears that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.8.

2.4.7 Wolf

The grey wolf (*Canis lupis*) is the largest member of the *Canis* genus and is widespread throughout much of northern Canada, including the West Kitikmeot region of Nunavut. Three subspecies of grey wolf occur in Nunavut, all of which may be found within the wildlife RSA (Chambers et al. 2012): the northern timber wolf (*Canis lupis occidentalis*), the plains wolf (*Canis lupis nubilus*), and the Arctic wolf (*Canis lupis arctos*). The northern timber wolf and plains wolf subspecies are listed by COSEWIC (2016) as Not at Risk, while the Arctic wolf subspecies is listed as Data Deficient.

Wolves do not migrate or hibernate and spend their entire lives in the Arctic (State of Alaska 2015d). Thus, they could be present year round in the wildlife LSA (ET = 1). However, the home range for female wolves is 45,000 km^2, while that for males is 63,000 km^2 (Volume 4, Section 9.2.8.1), both of which are much larger than the terrestrial wildlife LSA (563 km^2). Thus a DAF was applied to the estimated daily intake of COPCs for wolves. The DAF was calculated by dividing the area of the terrestrial wildlife LSA by the home range for females (DAF = 0.0125). More information on wolves that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.8.

2.4.8 Arctic Shrew

The study area is large enough that it could overlap with the entire home range of the Arctic shrew (0.1 ha; Hammerson 2008). Arctic shrews do not hibernate over winter; therefore, the residency time in the study area was assumed to be the entire year (ET = 1). Ecological Risk Assessment guidance (Environment Canada 2012a) indicates that certain terrestrial receptor types require assessment in an ERA. Therefore, Arctic shrew was selected to represent insectivorous mammals and they were also selected to represent the wildlife VEC “less conspicuous species that may be maximally exposed to contaminants”.

2.4.9 Northern Red-backed Vole

The study area is large enough that it could overlap with the entire home range of the northern red-backed vole (0.5 ha; Batzli 1999). Northern red-backed voles do not hibernate over winter; therefore, the residency time in the study area was assumed to be the entire year (ET = 1). Ecological Risk Assessment guidance (Environment Canada 2012a) indicates that certain terrestrial receptor types require assessment in an ERA. Therefore, northern red-backed vole was selected to represent small omnivorous mammals and they were also selected to represent the wildlife VEC “less conspicuous species that may be maximally exposed to contaminants”.

2.4.10 Willow Ptarmigan

Willow ptarmigans make short local migrations depending on weather conditions, but are otherwise resident species that overwinter on the tundra. Willow ptarmigan migrate between summer and winter ranges that can be separated by a few kilometers to over a 100 kilometers (State of Alaska 2016). To provide a conservative risk estimate it was assumed that willow ptarmigan could be in the study area the entire year (ET = 1). More information on the upland birds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.12.

2.4.11 American Tree Sparrow

American tree sparrows have a medium distance migration, with breeding occurring in the far north of North America and wintering occurring in north and central North America (Cornell Lab of Ornithology 2015a). If a pair of sparrows were to nest and raise young in the study area, it is conceivable that residency in the Phase 2 Project area would be for the entire time that they are in the Arctic. Therefore, the residency of American tree sparrow in the study area is at most five months of the year (ET = 0.417). More information on the upland birds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.12.

2.4.12 Peregrine Falcon

Peregrine falcons (*Falco peregrinus*) are cliff-nesting raptors and have the potential to breed in the wildlife RSA. There are three subspecies of peregrine falcon in Canada, and the tundra peregrine falcon (*Falco peregrinus tundrius*) is highly migratory and breeds in the Canadian Arctic, Alaska, and Greenland (Rescan 2011b). They have the greatest distance migration of any North American bird, with some falcons nesting in the Arctic tundra and wintering as far south as Argentina and Chile (Cornell Lab of Ornithology 2015g). Thus, they could be present for five months of the year in the study area due to migration (ET = 0.417). The tundra peregrine falcon is ranked as of Special Concern by (COSEWIC 2016) and is federally listed on Schedule 1 as a population of Special Concern under SARA (Government of Canada 2015). More information on the raptors that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.10.

2.4.13 Red-breasted Merganser

Red-breasted mergansers spend the summer breeding season at northern latitudes and winter along the coast at locations further south (Cornell Lab of Ornithology 2015h). Thus, they could be present for five months of the year in the study area due to migration (ET = 0.417). Freshwater sediment concentrations were used in predicting the red-breasted merganser tissue concentrations of COPCs as they may ingest freshwater sediments while foraging. More information on the waterbirds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.11.

2.4.14 Least Sandpiper

Least sandpipers have long distance migrations that can range from the far north of North America to South America (Cornell Lab of Ornithology 2015e). Thus, they could be present for five months of the year in the study area due to migration (ET = 0.417). Freshwater sediment concentrations were used in predicting the least sandpiper tissue concentrations of COPCs as they may ingest freshwater sediments while foraging. More information on the waterbirds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.11.

2.4.15 Long-tailed Duck

North American long-tailed ducks breed in the Arctic and migrate to wintering grounds along the Pacific coast from the Bering Sea to California and as far west as Russia (Sea Duck Joint Venture 2003). Waterbirds can spend up to 50% of the year migrating between wintering and breeding areas, and up to 95% of that time staging in areas prior to and following breeding. Thus, they could be present for five months of the year in the study area due to migration (ET = 0.417). Freshwater sediment concentrations were used in predicting the long-tailed duck tissue concentrations of COPCs as they may ingest freshwater sediments while foraging. More information on the waterbirds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.11.

2.4.16 Herring Gull

Herring gulls have a short to medium distance migration and birds that breed in the far north of North America tend to move south or out to sea for the winter (Cornell Lab of Ornithology 2015d). Thus, herring gulls could be present for five months of the year in the study area due to migration (ET = 0.417). Marine sediment concentrations were used in predicting the herring gull tissue concentrations of COPCs as they may ingest marine sediments while foraging. Seabirds have the ability to drink salt water while at sea (National Audubon Society 2013), thus to be conservative the highest 95th percentile COPC concentration from either freshwater or marine water was used as the drinking water input in the food chain model. More information on the seabirds that can be found in the Phase 2 Project area can be found in Volume 5, Section 12.2.7.

2.4.17 Yellow Warbler

Yellow warblers have a long migration from breeding grounds in North America to wintering grounds in Central America and northern South America (Cornell Lab of Ornithology 2015j). Thus, yellow warblers could be present for five months of the year in the study area due to migration (ET = 0.417). More information on the upland birds that can be found in the Phase 2 Project area can be found in Volume 4, Section 9.2.12.

2.4.18 Brant

The breeding ground of brants is in the high Arctic tundra and wintering grounds are along the coasts of the Pacific and Atlantic oceans of the US. Thus, brants could be present for five months of the year in the study area due to migration (ET = 0.417). Marine sediment concentrations were used in predicting the brant tissue concentrations of COPCs as they may ingest marine sediments while foraging. Seabirds have the ability to drink salt water while at sea (National Audubon Society 2013), thus to be conservative the highest 95th percentile COPC concentration from either freshwater or marine water was used as the drinking water input in the food chain model. More information on the seabirds that can be found in the Phase 2 Project area can be found in Volume 5, Section 12.2.7.

2.4.19 Ringed Seal

Ringed seals inhabit Arctic waters and are often found near ice floes and pack ice as they use ice to haul out on (NOAA 2014). To provide a conservative risk estimate it was assumed that ringed seals could be in the study area the entire year (ET = 1). Marine sediment concentrations were used in predicting the ringed seal tissue concentrations of COPCs as they may ingest marine sediments while foraging. Ringed seal are listed by COSEWIC (2016) as being Not at Risk. More information on the marine mammals that can be found in the Phase 2 Project area can be found in Volume 5, Section 12.2.6.

2.5 SAMPLE CALCULATION AND COMPLETE MODEL RESULTS

To calculate the amount of COPCs that each ingestion pathway contributes, an equation for all ingestion routes is presented in Table V6-5E9, followed by media specific equations. Table V6-5E9 also provides a sample calculation for the copper concentration in caribou tissue resulting from ingesting soil, water, and vegetation during existing conditions conditions. As described in Section 2.1, the food chain model predicts whole-body tissue concentrations; therefore, Table V6-5E9 also provides a sample calculation for the calibrated muscle, liver, and kidney tissue copper concentration in caribou.

Table V6-5E9. Sample Calculation of Copper Concentration in Caribou Tissue due to Uptake from Soil, Surface Water, and Vegetation

Overall equation:	
$C_{total} = C_{m[veg]} + C_{m[soil]} + C_{m[water]}$	
where: $C_{m[veg]} = BTF_{tissue\text{-}food} \times C_{veg} \times IR_{veg} \times ET \times fw$	
$C_{m[soil]} = BTF_{tissue\text{-}food} \times C_{soil} \times IR_{soil} \times ET \times fw$	
$C_{m[water]} = BTF_{tissue\text{-}food} \times C_{water} \times IR_{water} \times ET \times fw$	
Parameters:	
C_{total}	= Total concentration of COPC (copper) in animal tissue (caribou) from all ingestion pathways (mg/kg)
$C_{m[veg]}$	= Total concentration of COPC (copper) in animal tissue (caribou) from vegetation ingestion (mg/kg)
$C_{m[soil]}$	= Total concentration of COPC (copper) in animal tissue (caribou) from soil ingestion (mg/kg)
$C_{m[water]}$	= Total concentration of COPC (copper) in animal tissue (caribou) from water ingestion (mg/kg)
$BTF_{tissue\text{-}food}$	= Biotransfer factor from food consumption to tissues for a selected COPC (mg/kg)
$C_{m[media]}$	= 95th percentile COPC concentration in media (mg/kg)
$IR_{soil/veg/water}$	= Ingestion rate of media (i.e., soil, vegetation, or water; kg/day or L/day)
ET	= Exposure time in the Project area (unitless)
fw	= Fraction of daily consumption for animal (assumed 1; unitless)
Sample calculation for whole-body concentration:	
$C_{m[veg]}$	= (0.01 day/kg) x (2.04 mg/kg ww) x (6.72 kg/day) x 0.00356 x 1 = 0.000488 mg/kg
$C_{m[soil]}$	= (0.01 day/kg) x (38.3 mg/kg dw) x (0.134 kg/day) x 0.00356 x 1 = 0.000183 mg/kg
$C_{m[water]}$	= (0.01 day/kg) x (0.00145 mg/L) x (9 L/day) x 0.00356 x 1 = 0.000000458 mg/kg
C_{total}	= 0.000488 mg/kg + 0.000183 mg/kg + 0.000000464 mg/kg = 0.000672 mg/kg
Sample calculation for concentrations in liver and kidney tissue using the tissue distribution ratio:	
C_{liver}	= C_{total} x liver distribution ratio = 0.000672 mg/kg x 46.0 = 0.0309 mg/kg
C_{kidney}	= C_{total} x kidney distribution ratio = 0.000672 mg/kg x 7.30 = 0.00490 mg/kg

Table V6-5E10 presents the modeled concentrations of COPCs in tissue of country food species (caribou, Arctic ground squirrel, and Canada goose) and wildlife species (caribou, muskox, wolverine, grizzly bear, wolf, Arctic ground squirrel, Arctic shrew, northern red-backed vole, willow ptarmigan, American tree sparrow, peregrine falcon, Canada goose, red-breasted merganser, least sandpiper, long-tailed duck, herring gull, yellow warbler, brant, and ringed seal) for the existing conditions HHRA and ERA. Each ingestion pathway (i.e., soil or sediment, water, prey, and vegetation) contributes to the total concentration of COPCs in these species.

The existing conditions concentrations of COPCs modeled in country food tissue (caribou, Arctic ground squirrel, and Canada goose) were used in the existing conditions HHRA to calculate the estimated daily intake of COPCs for people who eat these foods from within the human health RSA. The existing conditions concentrations of COPCs modeled in wildlife species were used in the existing conditions ERA to calculate the estimated daily intake (EDI) of COPCs from ingestion of prey items for carnivores and omnivores who eat these prey items from within the wildlife RSA.

Table V6-5E10. Modeled Concentrations of Contaminants of Potential Concern in the Tissues of Country Food Species (Caribou, Arctic Ground Squirrel, and Canada Goose) and Wildlife Species (Muskox, Wolverine, Grizzly Bear, Wolf, Peregrine Falcon, Short-eared Owl, King/Common Eider, Red-breasted Merganser, and Ringed Seal)

	Caribou				Muskox				Wolverine				Grizzly Bear				
COPC	$C_{m[veg]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$
Aluminum	6.46E-03	1.53E-02	2.91E-06	**2.18E-02**	2.80E+00	6.64E+00	1.40E-03	**9.45E+00**	1.02E-01	1.13E+00	8.41E-05	**1.23E+00**	1.21E+00	8.36E-01	1.87E+01	1.01E-03	**2.07E+01**
Arsenic	5.04E-06	3.62E-06	1.70E-08	**8.67E-06**	2.19E-03	1.57E-03	8.21E-06	**3.76E-03**	1.97E-04	2.67E-04	4.93E-07	**4.64E-04**	9.46E-04	4.49E-03	4.41E-03	5.90E-06	**9.86E-03**
Cadmium	1.01E-06	6.58E-08	1.11E-10	**1.08E-06**	4.40E-04	2.86E-05	5.35E-08	**4.69E-04**	9.44E-07	4.85E-06	3.21E-09	**5.80E-06**	1.91E-04	2.82E-05	8.03E-05	3.85E-08	**2.99E-04**
Chromium	9.95E-04	1.73E-04	7.71E-08	**1.17E-03**	4.32E-01	7.49E-02	3.71E-05	**5.07E-01**	1.30E-03	1.27E-02	2.23E-06	**1.40E-02**	1.87E-01	1.44E-02	2.11E-01	2.67E-05	**4.12E-01**
Copper	4.88E-04	1.83E-04	4.58E-07	**6.72E-04**	2.12E-01	7.95E-02	2.21E-04	**2.91E-01**	2.05E-03	1.35E-02	1.33E-05	**1.56E-02**	9.16E-02	2.91E-02	2.24E-01	1.59E-04	**3.45E-01**
Lead	2.91E-06	2.15E-06	5.22E-10	**5.06E-06**	1.26E-03	9.34E-04	2.51E-07	**2.20E-03**	1.38E-05	1.59E-04	1.51E-08	**1.73E-04**	5.46E-04	1.64E-04	2.63E-03	1.81E-07	**3.34E-03**
Mercury	2.70E-04	7.09E-05	1.07E-08	**7.25E-04**	1.17E-01	3.08E-02	5.14E-06	**3.15E-01**	1.99E-04	5.23E-03	8.16E-06	**5.44E-03**	1.23E-01	5.73E-03	8.65E-02	9.77E-05	**2.15E-01**
Nickel	5.72E-04	9.97E-05	1.11E-07	**6.72E-04**	2.48E-01	4.33E-02	5.33E-05	**2.91E-01**	2.62E-04	7.35E-03	3.20E-06	**7.62E-03**	1.07E-01	4.40E-03	1.22E-01	3.83E-05	**2.33E-01**
Selenium	2.98E-06	2.71E-07	1.82E-08	**3.27E-06**	1.29E-03	1.18E-04	8.74E-06	**1.42E-03**	9.06E-05	2.00E-05	5.25E-07	**1.11E-04**	5.60E-04	2.12E-03	3.31E-04	6.28E-06	**3.01E-03**
Thallium	6.71E-06	9.57E-06	5.22E-09	**1.63E-05**	2.91E-03	4.15E-03	2.51E-06	**7.07E-03**	1.06E-03	7.06E-04	1.51E-07	**1.77E-03**	1.26E-03	6.26E-03	1.17E-02	1.80E-06	**1.92E-02**
Zinc	3.29E-05	2.55E-06	9.21E-09	**3.54E-05**	1.43E-02	1.10E-03	4.44E-06	**1.54E-02**	1.72E-06	1.88E-04	2.66E-07	**1.90E-04**	6.17E-03	3.85E-03	3.11E-03	3.19E-06	**1.31E-02**

	Wolf				Arctic Ground Squirrel				Arctic Shrew				Northern Red-backed Vole				
COPC	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$
Aluminum	1.63E-02	3.62E+00	3.01E-04	**3.64E+00**	6.97E-03	5.79E-02	3.78E-06	**6.48E-02**	8.20E-03	2.61E-03	6.39E-08	**1.08E-02**	9.30E-04	4.21E-02	2.11E-02	3.83E-07	**6.41E-02**
Arsenic	8.61E-06	8.55E-04	1.76E-06	**8.66E-04**	5.44E-06	1.37E-05	2.21E-08	**1.91E-05**	9.68E-07	6.16E-07	3.74E-10	**1.58E-06**	7.26E-07	4.97E-06	4.98E-06	2.24E-09	**1.07E-05**
Cadmium	2.94E-07	1.56E-05	1.15E-08	**1.59E-05**	1.10E-06	2.49E-07	1.44E-10	**1.34E-06**	1.54E-07	1.12E-08	2.44E-12	**1.65E-07**	1.46E-07	7.89E-07	9.07E-08	1.46E-11	**1.03E-06**
Chromium	3.17E-03	4.08E-02	7.98E-06	**4.40E-02**	1.07E-03	6.53E-04	1.00E-07	**1.73E-03**	4.20E-06	2.94E-05	1.69E-09	**3.36E-05**	1.43E-04	2.16E-05	2.38E-04	1.01E-08	**4.03E-04**
Copper	3.33E-03	4.34E-02	4.74E-05	**4.67E-02**	5.27E-04	6.93E-04	5.95E-07	**1.22E-03**	1.78E-05	3.12E-05	1.01E-08	**4.91E-05**	7.02E-05	9.16E-05	2.53E-04	6.03E-08	**4.15E-04**
Lead	7.53E-07	5.09E-04	5.40E-08	**5.10E-04**	3.14E-06	8.14E-06	6.78E-10	**1.13E-05**	1.57E-07	3.67E-07	1.15E-11	**5.24E-07**	4.19E-07	8.07E-07	2.97E-06	6.87E-11	**4.19E-06**
Mercury	1.43E-04	1.68E-02	2.92E-05	**1.69E-02**	7.06E-04	2.68E-04	3.67E-07	**9.74E-04**	9.31E-06	1.21E-05	6.20E-09	**2.14E-05**	9.41E-05	4.78E-05	9.77E-05	3.72E-08	**2.40E-04**
Nickel	1.99E-03	2.36E-02	1.15E-05	**2.56E-02**	6.18E-04	3.77E-04	1.44E-07	**9.94E-04**	4.85E-06	1.70E-05	2.43E-09	**2.18E-05**	8.23E-05	2.49E-05	1.37E-04	1.46E-08	**2.45E-04**
Selenium	3.66E-06	6.41E-05	1.88E-06	**6.96E-05**	3.22E-06	1.02E-06	2.36E-08	**4.27E-06**	1.45E-07	4.61E-08	3.99E-10	**1.92E-07**	4.29E-07	7.45E-07	3.73E-07	2.39E-09	**1.55E-06**
Thallium	3.25E-04	2.26E-03	5.40E-07	**2.59E-03**	7.25E-06	3.62E-05	6.78E-09	**4.34E-05**	5.12E-06	1.63E-06	1.14E-10	**6.75E-06**	9.67E-07	2.63E-05	1.32E-05	6.87E-10	**4.05E-05**
Zinc	1.58E-06	6.02E-04	9.54E-07	**6.05E-04**	3.55E-05	9.62E-06	1.20E-08	**4.51E-05**	3.47E-06	4.34E-07	2.02E-10	**3.90E-06**	4.73E-06	1.78E-05	3.51E-06	1.21E-09	**2.61E-05**

	Willow Ptarmigan				American Tree Sparrow					Peregrine Falcon				Canada Goose			
COPC	$C_{m[veg]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$
Aluminum	1.23E+01	2.92E+01	2.07E-03	**4.16E+01**	6.92E-01	3.13E+01	4.49E+00	1.10E-04	**3.65E+01**	2.89E+00	4.87E+01	1.04E-03	**5.16E+01**	1.48E+01	1.94E+02	2.57E-03	**2.09E+02**
Arsenic	7.49E-03	5.37E-03	9.46E-06	**1.29E-02**	4.20E-04	2.88E-03	8.25E-04	5.00E-07	**4.12E-03**	5.92E-03	8.94E-03	4.73E-06	**1.49E-02**	9.01E-03	1.15E-01	1.17E-05	**1.24E-01**
Cadmium	7.02E-04	4.55E-05	2.87E-08	**7.48E-04**	3.94E-05	2.13E-04	6.99E-06	1.52E-09	**2.59E-04**	1.45E-05	7.58E-05	1.44E-08	**9.02E-05**	8.45E-04	1.50E-04	3.56E-08	**9.95E-04**
Chromium	1.30E-01	2.25E-02	3.75E-06	**1.52E-01**	7.27E-03	1.10E-03	3.45E-03	1.98E-07	**1.18E-02**	1.78E-03	3.74E-02	1.87E-06	**3.92E-02**	1.56E-01	1.30E-01	4.65E-06	**2.86E-01**
Copper	8.73E-02	3.28E-02	3.06E-05	**1.20E-01**	4.90E-03	6.39E-03	5.04E-03	1.62E-06	**1.63E-02**	4.86E-03	5.46E-02	1.53E-05	**5.95E-02**	1.05E-01	2.16E-01	3.80E-05	**3.21E-01**
Lead	2.78E-02	2.06E-02	1.86E-06	**4.83E-02**	1.56E-03	3.00E-03	3.16E-03	9.85E-08	**7.72E-03**	1.94E-03	3.42E-02	9.31E-07	**3.62E-02**	3.34E-02	8.54E-02	2.31E-06	**1.19E-01**
Mercury	2.93E-01	3.17E-02	4.72E-05	**3.24E-01**	1.64E-02	8.34E-03	4.87E-03	2.50E-06	**2.96E-02**	1.71E-03	5.28E-02	2.36E-05	**5.45E-02**	3.52E-01	1.02E+00	5.85E-05	**1.37E+00**
Nickel	3.41E-04	5.95E-05	2.47E-08	**4.01E-04**	1.92E-05	5.79E-06	9.13E-06	1.31E-09	**3.41E-05**	4.71E-07	9.90E-05	1.23E-08	**9.95E-05**	4.11E-04	3.96E-04	3.06E-08	**8.06E-04**
Selenium	5.31E-03	4.83E-04	1.21E-05	**5.80E-03**	2.98E-04	5.17E-04	7.41E-05	6.39E-07	**8.90E-04**	3.36E-03	8.03E-04	6.04E-06	**4.17E-03**	6.39E-03	6.04E-03	1.50E-05	**1.24E-02**
Thallium	6.49E-03	9.26E-03	1.88E-06	**1.58E-02**	3.64E-04	9.91E-03	1.42E-03	9.96E-08	**1.17E-02**	1.48E-02	1.54E-02	9.42E-07	**3.02E-02**	7.81E-03	2.72E-02	2.34E-06	**3.50E-02**
Zinc	1.14E-02	8.87E-04	1.20E-06	**1.23E-02**	6.42E-04	2.42E-03	1.36E-04	6.34E-08	**3.20E-03**	4.53E-04	1.48E-03	5.99E-07	**1.93E-03**	1.38E-02	7.54E-03	1.49E-06	**2.13E-02**

Table V6-5E10. Modeled Concentrations of Contaminants of Potential Concern in the Tissues of Country Food Species (Caribou, Arctic Ground Squirrel, and Canada Goose) and Wildlife Species (Muskox, Wolverine, Grizzly Bear, Wolf, Peregrine Falcon, Short-eared Owl, King/Common Eider, Red-breasted Merganser, and Ringed Seal)

	Red-breasted Merganser				Least Sandpiper				Long-tailed Duck					Herring Gull			
COPC	$C_{m[prey]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[prey]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$
Aluminum	2.19E+00	6.00E+01	1.25E-03	**6.22E+01**	1.13E-01	4.74E+00	9.92E-05	**4.86E+00**	3.03E-01	1.07E+00	4.48E+01	1.03E-03	**4.61E+01**	9.22E+00	5.04E+01	2.69E-03	**5.96E+01**
Arsenic	1.50E-02	3.55E-02	5.71E-06	**5.04E-02**	1.63E-04	2.81E-03	4.52E-07	**2.97E-03**	1.84E-04	2.03E-03	2.65E-02	4.67E-06	**2.87E-02**	4.25E-01	1.18E-02	2.71E-05	**4.37E-01**
Cadmium	2.24E-04	4.64E-05	1.73E-08	**2.71E-04**	2.34E-05	3.67E-06	1.37E-09	**2.71E-05**	1.73E-05	2.13E-04	3.46E-05	1.42E-08	**2.65E-04**	8.32E-03	3.34E-05	1.60E-07	**8.35E-03**
Chromium	6.54E-03	4.02E-02	2.26E-06	**4.68E-02**	2.65E-03	3.18E-03	1.79E-07	**5.83E-03**	3.19E-03	2.33E-02	3.00E-02	1.85E-06	**5.65E-02**	4.10E-01	3.45E-02	8.45E-06	**4.44E-01**
Copper	5.70E-02	6.66E-02	1.85E-05	**1.24E-01**	2.68E-02	5.27E-03	1.46E-06	**3.21E-02**	2.15E-03	2.36E-01	4.97E-02	1.51E-05	**2.88E-01**	9.27E-02	4.30E-02	1.79E-05	**1.36E-01**
Lead	9.00E-03	2.64E-02	1.12E-06	**3.54E-02**	2.22E-03	2.09E-03	8.90E-08	**4.30E-03**	6.83E-04	1.97E-02	1.97E-02	9.20E-07	**4.00E-02**	1.57E-02	1.95E-02	1.00E-05	**3.53E-02**
Mercury	1.93E-03	4.84E-06	1.04E-09	**1.93E-03**	2.22E-04	3.83E-07	8.20E-11	**2.22E-04**	2.85E-06	2.01E-03	3.61E-06	8.47E-10	**2.02E-03**	7.99E-05	1.06E-06	3.76E-09	**8.09E-05**
Nickel	3.12E-05	1.22E-04	1.49E-08	**1.54E-04**	1.63E-07	9.67E-06	1.18E-09	**9.84E-06**	8.40E-06	2.70E-06	9.13E-05	1.22E-08	**1.02E-04**	1.07E-03	8.46E-05	2.08E-08	**1.15E-03**
Selenium	6.40E-02	1.87E-03	7.30E-06	**6.59E-02**	3.59E-03	1.48E-04	5.77E-07	**3.73E-03**	1.31E-04	3.39E-02	1.39E-03	5.97E-06	**3.54E-02**	1.42E-01	9.22E-04	2.82E-05	**1.43E-01**
Thallium	1.42E-02	8.41E-03	1.14E-06	**2.26E-02**	6.65E-03	6.65E-04	9.00E-08	**7.31E-03**	1.60E-04	5.85E-02	6.27E-03	9.31E-07	**6.49E-02**	7.37E-03	8.84E-03	1.35E-03	**1.76E-02**
Zinc	3.18E-02	2.33E-03	7.24E-07	**3.41E-02**	1.29E-03	1.84E-04	5.73E-08	**1.48E-03**	2.81E-04	1.25E-02	1.74E-03	5.92E-07	**1.46E-02**	1.97E-02	1.64E-03	7.01E-07	**2.13E-02**

	Yellow Warbler				Brant				Ringed Seal		
COPC	$C_{m[prey]}$	$C_{m[soil]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[veg]}$	$C_{m[sediment]}$	$C_{m[water]}$	$C_{m[total]}$	$C_{m[prey]}$	$C_{m[sediment]}$	$C_{m[total]}$
Aluminum	1.58E+01	1.44E+00	5.44E-05	**1.73E+01**	9.14E+00	1.95E+01	3.47E-03	**2.87E+01**	5.19E-01	5.99E+00	**6.51E+00**
Arsenic	1.46E-03	2.65E-04	2.48E-07	**1.72E-03**	5.55E-03	4.56E-03	3.49E-05	**1.01E-02**	7.12E-02	1.79E-03	**7.30E-02**
Cadmium	1.08E-04	2.24E-06	7.53E-10	**1.10E-04**	5.20E-04	1.29E-05	2.06E-07	**5.33E-04**	1.42E-03	1.10E-05	**1.43E-03**
Chromium	5.54E-04	1.11E-03	9.83E-08	**1.66E-03**	9.60E-02	1.34E-02	1.09E-05	**1.09E-01**	3.64E-01	6.01E-02	**4.24E-01**
Copper	3.23E-03	1.62E-03	8.03E-07	**4.85E-03**	6.47E-02	1.67E-02	2.31E-05	**8.14E-02**	7.69E-02	5.44E-02	**1.31E-01**
Lead	1.52E-03	1.01E-03	4.88E-08	**2.53E-03**	2.06E-02	7.58E-03	1.29E-05	**2.82E-02**	1.80E-04	4.64E-04	**6.44E-04**
Mercury	4.22E-03	1.56E-03	1.24E-06	**5.78E-03**	8.58E-05	4.10E-07	4.84E-09	**8.63E-05**	3.22E-02	5.59E-04	**3.28E-02**
Nickel	2.93E-06	2.93E-06	6.47E-10	**5.86E-06**	2.53E-04	3.28E-05	2.68E-08	**2.86E-04**	1.92E-01	3.21E-02	**2.25E-01**
Selenium	2.61E-04	2.38E-05	3.17E-07	**2.85E-04**	3.93E-03	3.57E-04	3.63E-05	**4.33E-03**	1.47E-02	1.17E-04	**1.48E-02**
Thallium	5.01E-03	4.56E-04	4.94E-08	**5.47E-03**	4.81E-03	3.43E-03	1.74E-03	**9.98E-03**	2.41E-03	2.07E-03	**4.48E-03**
Zinc	1.22E-03	4.37E-05	3.14E-08	**1.27E-03**	8.48E-03	6.36E-04	9.02E-07	**9.11E-03**	7.39E-03	1.07E-03	**8.46E-03**

Notes:

All concentrations in mg/kg wet weight.

COPC = contaminant of potential concern

$C_{m[veg]}$ *= concentration of COPC in meat tissue from vegetation consumption*

$C_{m[prey]}$ *= concentration of COPC in meat tissue from prey consumption*

$C_{m[soil]}$ *= concentration of COPC in meat tissue from soil consumption*

$C_{m[sediment]}$ *= concentration of COPC in meat tissue from sediment consumption*

$C_{m[water]}$ *= concentration of COPC in meat tissue from water consumption*

$C_{m[total]}$ *= total concentration of COPC in meat tissue from soil, vegetation, and water consumption*

References

Barboza, P. S., T. C. Peltier, and R. J. Forster. 2006. Ruminal fermentation and fill change with season in an Arctic grazer: responses to hyperphagia and hypophagia in muskoxen (*Ovibos moschatus*). *Physiological and Biochemical Zoology*, 79 (3): 497-513.

Batzli, G. 1999. Northern red-backed vole (*Clethrionomys rutilus*). In *The Smithosonian Book of North American Mammals*. Eds. D. Wilson and S. Ruff. pp. 616-17. Washington, D.C.: The Smithsonian Institution Press.

Beyer, W. N. and G. F. Fries. 2003. Toxicological Significance of Soil Ingestion by Wild and Domestic Animals. In *Handbook of Ecotoxicology, 2nd Edition*. Eds. D. J. Hoffman, B. A. Rattner, G. A. J. Burton, and J. J. Cairns. 151-66. Boca Raton, FL: Lewis Publishers.

Chambers, S. M., S. R. Fain, B. Fazio, and M. Amaral. 2012. An account of the taxonomy of North American wolves from morphological and genetic analyses. *North American Fauna*, 77: 1-67.

CHPPM. 2004. *Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)*. Contract Number DAAD050-00-P-8365. US Army Center for Health Promotion and Preventive Medicine (CHPPM): Aberdeen Proving Ground, MD.

Cornell Lab of Ornithology. 2015a. *All About Birds: American Tree Sparrow*. https://www.allaboutbirds.org/guide/American_Tree_Sparrow/lifehistory (accessed November 2016).

Cornell Lab of Ornithology. 2015b. *All About Birds: Brant*. https://www.allaboutbirds.org/guide/Brant/lifehistory (accessed November 2016).

Cornell Lab of Ornithology. 2015c. *All About Birds: Canada Goose*. http://www.allaboutbirds.org/guide/Canada_Goose/lifehistory (accessed September 2015).

Cornell Lab of Ornithology. 2015d. *All About Birds: Herring Gull*. https://www.allaboutbirds.org/guide/Herring_Gull/lifehistory (accessed November 2016).

Cornell Lab of Ornithology. 2015e. *All About Birds: Least Sandpiper*. https://www.allaboutbirds.org/guide/Least_Sandpiper/lifehistory (accessed November 2016).

Cornell Lab of Ornithology. 2015f. *All About Birds: Long-tailed Duck*. https://www.allaboutbirds.org/guide/Long-tailed_Duck/lifehistory (accessed December 2015).

Cornell Lab of Ornithology. 2015g. *All About Birds: Peregrine Falcon*. http://www.allaboutbirds.org/guide/Peregrine_Falcon/lifehistory (accessed September 2015).

Cornell Lab of Ornithology. 2015h. *All About Birds: Red-breasted Merganser*. http://www.allaboutbirds.org/guide/Red-breasted_Merganser/lifehistory (accessed September 2015).

Cornell Lab of Ornithology. 2015i. *All About Birds: Willow Ptarmigan*. https://www.allaboutbirds.org/guide/Willow_Ptarmigan/lifehistory (accessed December 2015).

Cornell Lab of Ornithology. 2015j. *All About Birds: Yellow Warbler*. https://www.allaboutbirds.org/guide/Yellow_Warbler/lifehistory (accessed November 2016).

COSEWIC. 2016. *Database of Wildlife Species Assessed by COSEWIC*. Committee on the Status of Endangered Species in Canada. http://www.cosewic.gc.ca/eng/sct5/index_e.cfm (accessed October 2016).

Crete, M., R. Nault, P. Walsh, J. L. Benedetti, M. A. Lefebvre, J. P. Weber, and J. Gagnon. 1989. Variation in cadmium content of caribou tissues from northern Quebec, Canada. *Science of the Total Environment*, 80: 103 - 12.

Elkin, B. T. and R. W. Bethke. 1995. Environmental contaminants in caribou in the Northwest Territories, Canada. *Science of the Total Environment*, 160-161: 307-21.

Environment Canada. 2012a. *Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance*. Government of Canada, Environment Canada: Gatineau, QC.

Environment Canada. 2012b. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Module 3: Standardization of Wildlife Receptor Characteristics. Gatineau, QC.

Environment Yukon. 2016. Barren-ground Caribou (*Rangifer tarandus grantii*). *Yukon Government*: http://www.env.gov.yk.ca/animals-habitat/mammals/barrengroundcaribou.php (accessed July 2016).

ERM and EDI. 2016. *Hope Bay Project: Caribou Workshop*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Vancouver, British Columbia and EDI Environmental Dynamics Inc: Whitehorse, YK: Vancouver, BC.

Gamberg, M. 2000. *Contaminants in Yukon Country Foods*. Prepared for Yukon Contaminants Committee and Department of Indian and Northern Affairs, Northern Contaminants Program by Gamberg Consulting: Whitehorse, YK.

Gamberg, M. 2004. *Contaminants in Yukon Moose and Caribou - 2003*. Prepared for Yukon Contaminants Committee and Department of Indian and Northern Affairs, Northern Contaminants Program by Gamberg Consulting: Whitehorse, YT.

Gamberg, M. 2010. Arctic moose and caribou contaminant monitoring program. Synopsis of research conducted under the 2009-2010 Northern Contaminants Program. Department of Indian Affairs and Northern Development: Ottawa, ON.

Gamberg, M., B. Braune, E. Davey, B. Elkin, P. F. Hoekstra, D. Kennedy, C. Macdonald, D. Muir, A. Nirwal, M. Wayland, and B. Zeeb. 2005. Spatial and temporal trends of contaminants in terrestrial biota from the Canadian arctic. *Science of the Total Environment*, 351-352: 148-64.

Gamberg, M. and A. M. Scheuhammer. 1994. Cadmium in caribou and muskoxen from the Canadian Yukon and Northwest Territories. *Science of the Total Environment*, 143 (2-3): 221-34.

Gau, R. J., R. Case, D. F. Penner, and P. D. McLoughlin. 2002. Feeding patterns of barren-ground grizzly bears in the central Canadian Arctic. *Arctic*, 55 (4): 339-44.

Golder Associates Ltd. 2005. Guidance for Including Country Foods in Human Health Risk Assessments for Federal Contaminated Sites. 04-1412-041. Prepared for Health Canada: Burnaby, BC.

Government of Canada. 2015. *Species at Risk Public Registry*. http://www.sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1 (accessed August 2015).

Gunn, A., J. Dragon, and J. Boulanger. 2001. *Seasonal Movements of Satellite-collared Caribou from the Bathurst herd*. Final report to the West Kitikmeot Slave Study Society: Yellowknife, NT.

Hammerson, G. 2008. NatureServe: Sorex arcticus. The IUCN Red List of Threatened Species 2008: e.T41385A10442058. http://www.iucnredlist.org/details/41385/0 (accessed October 2016).

Health Canada. 2010. Draft Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment for Country Foods ($HHRA_{FOODS}$). Version 1.2 (Draft). Contaminated Sites Division, Safe Environments Directorate: Ottawa, ON.

Hubbs, A. H. and R. Boonstra. 1998. Effects of food and predators on the home-range sizes of Arctic ground squirrels (*Spermophilus parryii*). *Canadian Journal of Zoology*, 76 (3): 592-96.

Kim, C., H. M. Chan, and O. Receuver. 1998. Risk assessment of cadmium exposure in Fort Resolution, Northwest Territories, Canada. *Food Additives and Contaminants*, 15 (3): 307–17.

Larter, N. C., J. A. Nagy, B. T. Elkin, and C. R. Macdonald. 2010. Differences in radionuclide and heavy metal concentrations found in the kidneys of barren-ground caribou from the western Northwest Territories 1994/95 to 2000/01. *Rangifer*, 30 (1): 61-66.

Linzey, A. V., H. Henttonen, B. Sheftel, and N. Batsaikhan. 2008. Myodes rutilus. The IUCN Red List of Threatened Species 2008: e.T4975A11106075. http://www.iucnredlist.org/details/4975/0 (accessed October 2016).

Macdonald, C. R., B. T. Elkin, P. Roach, M. Gamberg, and M. Palmer. 2002. Inorganic elements in caribou in the Yukon, NWT, and Nunavut from 1992 to 2000. Spatial and temporal trends and the effect of modifying factors. Environment Canada, unpublished report: n.p.

McLoughlin, P. D., S. H. Ferguson, and F. Messier. 2000. Interspecific variation in home range overlap with habitat quality: a comparison among brown bear populations. *Evolutionary Ecology*, 14: 39-60.

Mech, D. L. 2007. Arctic Wolves and their Prey. National Oceanic and Atmospheric Administration Arctic Theme Page. http://www.arctic.noaa.gov/essay_mech.html (accessed September 2015).

National Audubon Society. 2013. *What Happens When Seabirds Drink Saltwater?* https://www.audubon.org/news/what-happens-when-seabirds-drink-saltwater (accessed September 2015).

NOAA. 2014. *Ringed Seal (Phoca hispida)*. National Oceanic and Atmospheric Administration, Office of Protected Resources. http://www.nmfs.noaa.gov/pr/species/mammals/pinnipeds/ringedseal.htm (accessed September 2015).

ORNL. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*. Publication No. 4650. Prepared for the United States Department of Energy, Office of Environmental Policy and Assistance, Air, Water, and Radiation Division by Oak Ridge National Laboratory: Oak Ridge, TN.

Pollock, B., B. Penashue, M. Scott, J. Vanleeuwen, P. Y. Daoust, N. M. Burgess, and A. R. Tasker. 2009. Liver parasites and body condition in relation to environmental contaminants in caribou (Rangifer tarandus) from Labrador, Canada. *Arctic*, 62: 1-12.

RAIS. 2010. *Chemical Factors*. Risk Assessment Information System. http://rais.ornl.gov/index.html (accessed January 2012).

Rescan. 2011a. *Doris North Gold Mine Project: Wildlife Mitigation and Monitoring Program, 2010*. Prepared for Hope Bay Mining Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011b. *Hope Bay Belt Project: Wildlife Habitat Suitability Baseline, 2010*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Robillard, S., G. Beauchamp, G. Paillard, and D. Belanger. 2002. Levels of cadmium, lead, mercury and ^{137}caesium in Caribou (*Rangifer tarandus*) tissues from northern Québec. *Arctic*, 55 (1): 1-9.

Sea Duck Joint Venture. 2003. Sea Duck Information Series: Long-tailed Duck (*Clangula hyemalis*). Info Sheet #10 of 15. http://seaduckjv.org/wp-content/uploads/2015/01/ltdu_sppfactsheet.pdf (accessed October 2016).

Smithsonian National Museum of Natural History. 2015. North American Mammals: Northern Red-backed Vole, *Myodes rutilus*. http://www.mnh.si.edu/mna/image_info.cfm?species_id=44 (accessed December 2015).

State of Alaska. 2015a. Arctic Ground Squirrel (*Spermophilus parryii*). State of Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=arcticgroundsquirrel.printerfriendly (accessed September 2015).

State of Alaska. 2015b. *Brown/Grizzly Bear Hunting in Alaska*. State of Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=brownbearhunting.main (accessed September 2015).

State of Alaska. 2015c. *Muskox Hunting in Alaska*. State of Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=muskoxhunting.main (accessed September 2015).

State of Alaska. 2015d. *Wolf (Canis lupus) Species Profile*. State of Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=wolf.main (accessed September 2015).

State of Alaska. 2015e. *Wolverine (Gulo gulo) Species Profile*. State of Alaska Department of Fish and Game. http://www.adfg.alaska.gov/index.cfm?adfg=wolverine.main (accessed September 2015).

State of Alaska. 2016. *Small Game Hunting in Alaska: Small Game Species - Willow Ptarmigan.* http://www.adfg.alaska.gov/index.cfm?adfg=smallgamehunting.willowptarmigan (accessed October 2016).

Staven, L. H., K. Rhoads, B. A. Napier, and D. L. Strenge. 2003. *A Compendium of Transfer Factors for Agricultural and Animal Products*. PNNL-13421. Pacific Northwest National Laboratory US Department of Energy: Richland, WA.

US EPA. 1993. *Wildlife Exposure Factors Handbook*. EPA/600/R-93/187. United States Environmental Protection Agency, Office of Health and Environmental Assessment, Office of Research and Development: Washington, DC.

US EPA. 1999. *Screening Level Ecological Risk Assessment Protocol*. Appendix C: Media-to-Receptor Bioconcentration Factors (BCFs). United States Environmental Protection Agency, Office of Solid Waste: n.p.

US EPA. 2005. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. EPA520-R-05-006. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response: Washington, DC.

US EPA. 2012. *The Hazardous Waste Companion Database (ACCESS)*. http://www.epa.gov/osw/hazard/tsd/td/combust/riskvol.htm#volume2 (Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities, Final accessed March 2013).

Willmer, P., G. Stone, and I. Johnston. 2009. *Environmental Physiology of Animals*. 2nd ed. Oxford, UK: Blackwell Publishing.