Selenium in Marine Birds

PREPARED FOR: Great Salt Lake Science Panel

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During the Science Panel meeting on March 21-22, 2007, the Panel asked CH2M HILL to create summary tables of selenium concentrations in livers, blood and eggs of marine-type birds from the literature to compare against what has been observed at the Great Salt Lake. Table 1 provides a summary of the data from our sampling in the Great Salt Lake (GSL) in 2006, along with information we have compiled for selenium (and also for mercury when results were reported in the same papers). The results are reported in the table as given in the reference (i.e., either arithmetic or geometric mean); however, when individual values were given, we calculated a geometric mean. When results were reported on wet-weight (ww) basis, we converted them to dry-weight (dw) basis using the study-specific percent moisture if it was provided in the reference. For conversion of plasma samples from µg Se/L ww to µg Se/g dw the percent moisture used was 92 percent. For conversion of whole blood selenium where percent moisture was not provided, 80 percent moisture was used. The text below provides a brief summary of some of the more relevant findings.

Selenium in Blood

We found only five studies that provided blood selenium concentrations in marine birds. Goede (1993a, b) reported selenium concentrations separately for plasma and red blood cells (RBCs), and Goede and Wolterbeek (1994) reported concentrations in RBCs. Grand et al. (2002) and Wayland et al. (2001) reported concentrations in blood as wet weight and did not give percent moisture for the samples.

The range of means found for selenium in blood of marine birds was 3.5 µg Se/g in oystercatchers (plasma conversion; Goede 1993b) to 96.3 µg Se/g in spectacled eiders from the Yukon-Kuskokwim Delta, AK (Grand et al. 2002). Geometric mean selenium in blood samples from the birds collected from GSL ranged from 12.6 to 34.1 µg Se/g, which fall within the range found in the marine bird studies.

Selenium in Livers

Mean selenium concentrations in livers ranged from 3.2 to 133 µg Se/g in the studies that we found (Elliott et al. 1992; Renzoni et al. 1986). This encompasses the range of geometric means from the birds collected from GSL (7.5 to 22.5 µg Se/g). Only two studies provided both liver and blood selenium concentrations. In oystercatchers (Goede 1993a), RBC concentrations (23 µg Se/g dw) were slightly higher and less variable (21-25 µg Se/g dw) than liver concentrations (19 µg Se/g dw; 15-21 µg Se/g dw). In common eiders (Wayland et al. 2001), blood and liver selenium concentrations also were similar to each other; in 1997 the values were 17.6 µg Se/g dw in blood and 20.1 µg Se/g dw in livers, and in 1998 they were 23.0 µg Se/g dw in blood and 18.5 µg Se/g dw in livers. For both blood and livers in both years, selenium concentrations in the eiders were more variable than those found in the oystercatchers mentioned above.

Selenium in Eggs

Mean concentrations in eggs ranged from 0.121 to 6.07 µg Se/g in the studies that we found (Burger and Gochfeld 1995; Ohlendorf and Harrison 1986). This encompasses the range of geometric means for the birds collected from GSL (1.93 to 4.73 µg Se/g). In female spectacled eiders, mean blood selenium (64 µg Se/g dw) was over 80 times the mean egg concentration (0.78 µg Se/g dw; Grand et al. [2001]). Henny et al. (1995) predicted egg concentrations (21.3 or 29.2 µg Se/g dw, based on different regressions) from liver concentrations in white-winged scoters (mean of 54 µg Se/g dw for combined males and females; concentration not given separately for females) based on established fresh water liver-egg relationships. However, they found that selenium concentrations in eggs were only about 10 percent of the predicted concentrations. In the study by Renzoni et al. (1986), mean selenium concentrations in livers of Corey's shearwaters were from 10 to over 22 times those found in eggs.

References

Burger, J., and M. Gochfeld. 1995. Heavy metal and selenium concentrations in eggs of herring gulls (*Larus argentatus*): Temporal differences from 1989 to 1994. Arch. Environ. Contam. Toxicol. 29:192-197.

Furness, R., and M. Hutton. 1979. Pollutant levels in the great skua *Catharacta skua.* Environ. Pollut. 19:261-268.

Goede, A.A. 1993a. Selenium status in Charadriiformes. Tissue distribution and seasonal, geographical, and species variation. Biol. Trace Elem. Res. 39:177-190.

Goede, A.A. 1993b. Selenium in eggs and parental blood of a Dutch wader. Arch. Environ. Contam. Toxicol. 25:79-84.

Goede, A.A., and H.T. Wolterbeek. 1994. Have high selenium concentration in wading birds their origin in mercury? Sci. Total Environ. 144:247-253.

Grand, J.B., J.C. Franson, P.L. Flint, and M.R. Petersen. 2002. Concentrations of trace elements in eggs and blood of spectacled and common eiders on the Yukon-Kuskokwim Delta, Alaska, USA. Environ. Toxicol. Chem. 21:1673-1678.

Henny, C.J., L.J. Blus, S.P. Thompson, and U.W. Wilson. 1989. Environmental contaminants, human disturbance and nesting of double-crested cormorants in Northwestern Washington. Colonial Waterbirds 12:198-206.

Henny, C. J., D. D. Rudis, T. J. Roffe, and E. Robinson-Wilson. 1995. Contaminants and sea ducks in Alaska and the circumpolar region. Environ. Health Perspect. 103:41-49.

Hutton, M. 1981. Accumulation of heavy metals and selenium in three seabird species from the United Kingdom. Environ. Pollut. Series A 26:129-145.

Kim, E.Y., K. Saeki, S. Tanabe, H. Tanaka, and R. Tatsukawa. 1996. Specific accumulation of mercury and selenium in seabirds. Environ. Pollut. 94:261-265.

Koeman, J.H., W.S.M. van de Ven, J.J.M. de Goeij, and P.S. Tjioe. 1975. Mercury and selenium in marine mammals and birds. Sci. Total Environ. 3:279-287.

Ohlendorf, H.M., and C.S. Harrison. 1986. Mercury, selenium, cadmium and organochlorines in eggs of three Hawaiian seabird species. Environ. Pollut. (Series B) 11:169-191.

Renzoni, A., S. Focardi, C. Fossi, C. Leonzio, and J. Mayol. 1986. Comparison between concentrations of mercury and other contaminants in eggs and tissues of Cory's shearwater *Calonectris diomedea* collected on Atlantic and Mediterranean islnds. Environ. Pollut. (Series A) 40:17-35.

Sanpera, C., M. Morera, X. Ruiz, and L. Jover. 2000. Variability of mercury and selenium levels in clutches of Audouin's gulls (*Larus audouinii*) breeding at the Chafarinas Islands, Southwest Mediterranean. Arch. Environ. Contam. Toxicol. 39:119-123.

Savinov, V.M., G.W. Gabrielsen, and T.N. Savinova. 2003. Cadmium, zinc, copper, arsenic, selenium and mercury in seabirds from the Barents Sea: levels, inter-specific and geographical differences. Sci. Total Environ. 306:133-158.

Wayland, M., A.J. Garcia-Fernandez, E. Neugebauer, and H.G. Gilchrist. 2001. Concentrations of cadmium, mercury and selenium in blood, liver and kidney of common eider ducks from the Canadian Arctic. Environ. Monit. Assess. 71:255-267.

TABLE 1
Selenium and Mercury Concentrations (µg/g dry weight) in Livers, Blood, and Eggs from the Great Salt Lake and Marine Birds from Elsewhere

		Selenium						Mercury						
		Liver		Blood		Egg		Liver		Blood		Egg		
Species	Location	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Reference
Great Salt Lake Birds														
American avocet	Antelope Island	11.9	5; 8.3-16	19.5	4; 16-23	2.22	21; 1.6-2.9							GSL Database
American avocet	Ogden Bay	16.2	5; 11-28	32.1	5; 21-60	1.93	19; 1.2-3.2							GSL Database
American avocet	Saltaire	22.5	5; 15-38	22.1	5; 12-35	4.73	7; 2.9-8.2							GSL Database
American avocet	West Carrington					2.5	1; NA							GSL Database
Black-necked stilt	Ogden Bay	22.0	5; 11-40	34.1	5; 20-68	2.47	21; 1.3-3.6							GSL Database
California gull	Antelope Island	6.98	12; 4-13	12.6	12; 6.4-25	2.75	12; 2.1-4.1							GSL Database
California gull	Hat Island	7.51	13; 5.6-13	14.8	11; 6.3-29	2.76	11; 2.0-3.4							GSL Database
California gull	Great Salt Lake Minerals	8.75	11; 3.9-13	21.0	12; 5.0-37	3.33	12; 2.6-4.3							GSL Database
Marine Birds														
Black guillemot	Canadian Arctic, Green I, Digges Sound	9.07	10; NA					3.75	10; NA					Braune, unpublished[e]
Black guillemot	Canadian Arctic, Prince Leopold I	10.8	5; NA					3.97	5; NA					Braune, unpublished[e]
Fulmar	Canadian Arctic, Prince Leopold I	34.4	10; NA					8.12	10; NA					Braune, unpublished[e]
Glaucous gull	Canadian Arctic, Coats I	9.2	2; NA					6.78	2; NA					Braune, unpublished[e]
Kittiwake	Canadian Arctic, Prince Leopold I	36.2	10; NA					3.05	10; NA					Braune, unpublished[e]
Herring gull (1989)	Long Island, NY					1.92	20; NA					0.172	20; NA	Burger and Gochfeld 1995
Herring gull (1991)	Long Island, NY					2.13	20; NA					0.370	20; NA	Burger and Gochfeld 1995
Herring gull (1992)	Long Island, NY					1.74	20; NA					0.121	20; NA	Burger and Gochfeld 1995
Herring gull (1993)	Long Island, NY					1.41	20; NA					0.248	20; NA	Burger and Gochfeld 1995
Herring gull (1994)	Long Island, NY					1.01	20; NA					0.458	20; NA	Burger and Gochfeld 1995
Puffin	Canadian Atlantic, Gull I	11.7	6; NA					2.6	6; NA					Elliott et al. 1992[e]
Puffin	Canadian Atlantic, Ille St Marie	8.29	6; NA					1.4	6; NA					Elliott et al. 1992[e]
Herring gull	Canadian Atlantic, Gull I	3.21	6; NA					1.7	6; NA					Elliott et al. 1992[e]
Herring gull	Canadian Atlantic, Kent I	3.36	6; NA					1.5	6; NA					Elliott et al. 1992[d]
Herring gull	Canadian Atlantic, Manawagonish I	3.2	6; NA					0.69	6; NA					Elliott et al. 1992[e]
Great skua	North Atlantic	17.7	13; 6.7-35					7.7	13; 3.2-30					Furness and Hutton 1979
Oystercatcher (Plasma conversion)	Frisian coast Dutch Wadden Sea, Paesenser Polder			5.1	5; 4.2-6.5									Goede 1993a
Oystercatcher	Frisian coast Dutch Wadden Sea, Paesenser Polder	19	5; 15.3-21.2	23	5; 21-25									Goede 1993a

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		Selenium						Mercury						
		Liver		Blood		Egg		Liver		Blood		Egg		
Species	Location	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Reference
Oystercatcher (Plasma)	Dutch Wadden Sea, Coast			4.2	38; NA									Goede 1993b
Oystercatcher (Plasma)	Dutch Wadden Sea, Inland			3.5	23; NA									Goede 1993b
Oystercatcher (Plasma)	Norway, Coast			5.2	10; NA									Goede 1993b
Oystercatcher (Plasma)	Norway, Inland			4.0	10; NA									Goede 1993b
Oystercatcher (RBC)	Dutch Wadden Sea, Coast			20.5	37; NA	2.3	54; NA							Goede 1993b
Oystercatcher (RBC)	Dutch Wadden Sea, Inland			6.4	22; NA	2.2	29; NA							Goede 1993b
Oystercatcher (RBC)	Norway, Coast			28.5	15; NA									Goede 1993b
Oystercatcher (RBC)	Norway, Inland			8.4	10; NA									Goede 1993b
Oystercatcher (F; RBC)	Dutch Wadden Sea, Coast			22.1	20; NA					1.9	20; NA			Goede and Wolterbeek 1994
Oystercatcher (M; RBC)	Dutch Wadden Sea, Coast			18.8	17; NA					2.5	17; NA			Goede and Wolterbeek 1994
Oystercatcher (F; RBC)	Dutch Wadden Sea, Inland									1.4	11; NA			Goede and Wolterbeek 1994
Oystercatcher (M; RBC)	Dutch Wadden Sea, Inland									2.0	11; NA			Goede and Wolterbeek 1994
Spectacled eider (M; Incubating)	Yukon-Kuskokwim Delta, Alaska			96.3	10; NA									Grand et al. 2002
Spectacled eider (F; Incubating)	Yukon-Kuskokwim Delta, Alaska			64	46; NA									Grand et al. 2002
Spectacled eider (1995 viable eggs)	Yukon-Kuskokwim Delta, Alaska					0.76	8; NA					0.21	8; NA	Grand et al. 2002[f]
Spectacled eider (1995 inviable eggs)	Yukon-Kuskokwim Delta, Alaska					0.74	10; NA					0.21	10; NA	Grand et al. 2002[f]
Spectacled eider (1996 viable eggs)	Yukon-Kuskokwim Delta, Alaska			67	38; NA	4.2	19; NA			0.70	38; NA	0.18	15; NA	Grand et al. 2002
Spectacled eider (1996 inviable eggs)	Yukon-Kuskokwim Delta, Alaska			52	8; NA	3.5	31; NA			0.50	8; NA	0.18	26; NA	Grand et al. 2002
Common eider (F; Hatch)	Yukon-Kuskokwim Delta, Alaska			36.5	11; NA					1.9	11; NA			Grand et al. 2002
Spectacled eider (F; Hatch)	Yukon-Kuskokwim Delta, Alaska			45.1	29; NA					1.7	29; NA			Grand et al. 2002
Spectacled eider (F; Brood rearing)	Yukon-Kuskokwim Delta, Alaska			21.6	4; NA					1.9	4; NA			Grand et al. 2002
Spectacled eider (Duckling)	Yukon-Kuskokwim Delta, Alaska			9.8	10; NA					1.9	10; NA			Grand et al. 2002
Double-crested cormorant (WA)	NW Washington, San Juan Islands	19.4	3; 17-21					38	3; 29-60					Henny et al. 1989
Double-crested cormorant	Colville Island					1.6						1.4		Henny et al. 1989
Double-crested cormorant	Protection Island NWR					1.4						1.3		Henny et al. 1989
Scoter (white-winged, black, surf)	Cape Yakataga, AK 1991	24.4	5; 14-45					3.5	5; 2.3-7.2					Henny et al. 1995
White-winged Scoter	Cape Suckling, AK 1991	22.8	5; 12-39					2.5	5; 1.2-12					Henny et al. 1995
White-winged Scoter	Cape Yakataga, AK 1992	18.7	4; 12-53					2.4	4; 1.6-4.9					Henny et al. 1995
Spectacled eider	St. Lawrence I, AK	23.8	3; 5-77					0.6	3; 0.4-1.1					Henny et al. 1995

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		Liver		Blood		Egg		Liver		Blood		Egg		
Species	Location	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Reference
Steller's eider	Togiak NWR, AK	14	1; NA					1.1	1; NA					Henny et al. 1995
White-winged Scoter	Yukon Flats NWR, AK	54	37; 24-85				6; 2.7-4.7[b]	0.99	37; 0.28-4.02					Henny et al. 1995
Spectacled eider	Yukon Delta, AK 1992					3.3	19; 1.8-5.3					0.07	19; <0.03-0.41	Henny et al. 1995
Oystercatcher	Burry Inlet, Dyfed, Isle of May, Fife							0.73	9; 0.42-0.86					Hutton 1981
Herring gull	Burry Inlet, Dyfed, Isle of May, Fife							4.08	23; 0.52-11.1					Hutton 1981
Great skua	Burry Inlet, Dyfed, Isle of May, Fife							10.4	12; 3.2-30.4					Hutton 1981
Black-footed albatross	Northern Pacific	113	18; 39.0-311					25.5	18; 10.6-70.8					Kim et al. 1996
Northern fulmar	Northern Pacific	32	18; 12.2-56.7					2.83	18; 0.24-6.21					Kim et al. 1996
Brown booby	SW Ryukyu Islands	13.4	14; 4.54-26.6					3.66	14; 0.5-21.1					Kim et al. 1996
Grey petrel	Southern Indian Ocean	100	5; 49.0-194					7.42	5; 5.14-9.68					Kim et al. 1996
Light-mantled sooty albatross	Southern Indian Ocean	74.2	4; 47.9-94.9					12.2	4; 5.44-17.4					Kim et al. 1996
Northern giant petrel	Southern Indian Ocean	76.5	6; 35.6-154					14.5	6; 2.29-23.2					Kim et al. 1996
White-capped albatross	Southern Indian Ocean	41	3; 30.6-56.4					14.5	3; 13.4-15.9					Kim et al. 1996
Yellow-nosed albatross	Southern Indian Ocean	44.4	4; 26.0-61.6					4.24	4; 2.94-5.19					Kim et al. 1996
Royal albatross	Southern Indian Ocean	16.8	3; 14.8-18.5					8.94	3; 4.40-15.1					Kim et al. 1996
White-chinned petrel	Southern Indian Ocean	47.7	3; 28.0-85.5					8.83	3; 7.60-10.6					Kim et al. 1996
Alcids (guillemot [murre] & razorbill)	Dutch Coast	3.4	4; 2.4-4.6					2.1	4; 1.8-2.4					Koeman et al. 1975
Little auk	Greenland	19.7	13; NA					1.61	13; NA					Nielsen and Dietz 1989[e]
Black guillemot	Greenland	8.72	42; NA					2.2	42; NA					Nielsen and Dietz 1989[e]
Brünnich's guillemot	Greenland	7.58	20; NA					2.63	20; NA					Nielsen and Dietz 1989[e]
Common eider	Greenland	27.4	21; NA					3.09	21; NA					Nielsen and Dietz 1989[e]
King eider	Greenland	27.1	21; NA					2.07	21; NA					Nielsen and Dietz 1989[e]
Fulmar	Greenland	28.7	17; NA					0.92	17; NA					Nielsen and Dietz 1989[e]
Glaucous gull	Greenland	16.4	15; NA					8.72	15: NA					Nielsen and Dietz 1989[e]
Kittiwake	Greenland	32	15; NA					2.1	15; NA					Nielsen and Dietz 1989[e]
Brünnich's guillemot	Nordenskiöld Land, Svalbard	27.6	9; 3.7-8.74					2.02	9; 1.01-3.02					Norheim 1987[e]
Common eider	Nordenskiöld Land, Svalbard	29.9	9; 11.4-84					3.36	6; 1.68-5.71					Norheim 1987[e]
Fulmar	Nordenskiöld Land, Svalbard	10.1	10; 4.70-21.5					7.06	10; 2.02-14.1					Norheim 1987[e]
Glaucous gull	Nordenskiöld Land, Svalbard	7.39	11; 4.37-12.1					5.38	11; 2.69-7.73					Norheim 1987[e]
Little auk	Nordenskiöld Land, Svalbard	8.74	9; 5.04-15.1					1.68	9; 1.34-2.35					Norheim 1987[e]

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		Liver		Blood		Egg		Liver		Blood		Egg		
Species	Location	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Reference
Wedge-tailed shearwater	Oahu, HI					5.33	6; NA					0.837	6; NA	Ohlendorf and Harrison 1986
Red-fooetd booby	Oahu, HI					6.07	6; NA					1.2	6; NA	Ohlendorf and Harrison 1986
Sooty tern	Oahu, HI					4.74	4; NA					0.507	4; NA	Ohlendorf and Harrison 1986
Wedge-tailed shearwater	French Frigate Shoals, HI					4.42	7; NA					0.557	7; NA	Ohlendorf and Harrison 1986
Red-footed booby	French Frigate Shoals, HI					5.02	7; NA					1.3	7; NA	Ohlendorf and Harrison 1986
Sooty tern	French Frigate Shoals, HI					4.81	7; NA					0.474	7; NA	Ohlendorf and Harrison 1986
Wedge-tailed shearwater	Laysan, HI					4.46	6; NA					0.482	6; NA	Ohlendorf and Harrison 1986
Red-footed booby	Laysan, HI					5.36	6; NA					1.56	6; NA	Ohlendorf and Harrison 1986
Sooty tern	Laysan, HI					5.15	6; NA					0.634	6; NA	Ohlendorf and Harrison 1986
Wedge-tailed shearwater	Midway, HI					5.14	6; NA					0.553	6; NA	Ohlendorf and Harrison 1986
Red-footed booby	Midway, HI					5.97	6; NA					2.36	6; NA	Ohlendorf and Harrison 1986
Sooty tern	Midway, HI					4.07	6; NA					0.642	6; NA	Ohlendorf and Harrison 1986
Corey's shearwater (Station 1)	Atlantic and Mediterranean Islands	33.6	3; NA			3.4	20; NA	4.6	3; NA			2.1	20; NA	Renzoni et al. 1986
Corey's shearwater (Station 2)	Atlantic and Mediterranean Islands	81.9	5; NA			5.5	10; NA	14.9	5; NA			7.3	10; NA	Renzoni et al. 1986
Corey's shearwater (Station 3)	Atlantic and Mediterranean Islands	132.7	5;NA			5.9	11; NA	17.8	5;NA			5.9	11; NA	Renzoni et al. 1986
Corey's shearwater (Station 4)	Atlantic and Mediterranean Islands	32.9	5; NA			3.3	1; NA	18.9	5; NA			4.8	1; NA	Renzoni et al. 1986
Audouin's gull (1 of 2) [c]	Chafarinas Islands, SW Mediterranean					3.76	4; NA					5.69	4; NA	Sanpera et al. 2000
Audouin's gull (2 of 2) [c]	Chafarinas Islands, SW Mediterranean					3.82	4; NA					4.66	4; NA	Sanpera et al. 2000
Audouin's gull (1 of 3) [d]	Chafarinas Islands, SW Mediterranean					2.82	10; NA					6.57	10; NA	Sanpera et al. 2000
Audouin's gull (2 of 3) [d]	Chafarinas Islands, SW Mediterranean					2.57	10; NA					5.88	10; NA	Sanpera et al. 2000
Audouin's gull (3 of 3) [d]	Chafarinas Islands, SW Mediterranean					2.71	9; NA					5.5	9; NA	Sanpera et al. 2000
Puffin	Barents Sea	>10<15	17; NA					>1<2	17; NA					Savinov et al. 2003
Black guillemot	Barents Sea	>5<10	13; NA					<1	13; NA					Savinov et al. 2003
Glaucous gull	Barents Sea	>5<10	15; NA					>1<2	15; NA					Savinov et al. 2003
Little auk	Barents Sea	<5	25; NA					<1	25; NA					Savinov et al. 2003
Common eider	Barents Sea	>10<15	3; NA					~1	3; NA					Savinov et al. 2003
King eider	Barents Sea	>10<15	9; NA					<1	9; NA					Savinov et al. 2003
Herring gull	Barents Sea	>5<10	5; NA					~1	5; NA					Savinov et al. 2003
Black-legged kittiwake	Barents Sea	>10<15	46; NA					<1	46; NA					Savinov et al. 2003
Northern fulmar	Barents Sea	>15	15; NA					>3<4	15; NA					Savinov et al. 2003

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		Liver		Blood		Egg		Liver		Blood		Egg		
Species	Location	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Mean[a]	n; Range	Reference
Arctic tern	Barents Sea	>5<10	5; NA					>1<2	5; NA					Savinov et al. 2003
Brunnich's guillemot	Barents Sea	>5<10	5; NA					<1	5; NA					Savinov et al. 2003
Razorbill	Barents Sea	>15	5; NA					>1<2	5; NA					Savinov et al. 2003
Common eider (1997)	Canadian Arctic	20.1	12; 11-32	17.6	12; 4.9-39			1.8	11; 1.1-3.7	1.1	11; 0.8-1.4			Wayland et al. 2001
Common eider (1998)	Canadian Arctic	18.5	15; 11-47	23	15; 13-44			3.9	15; 2.5-5.8	1.1	15; 0.7-1.9			Wayland et al. 2001
Common eider (F)	Canadian Arctic	16.2	21; 6.5-47					3.3	21; 1.5-9.8					Wayland et al. 2003
Brünnich's guillemot	Barents Sea, Hormøya	7.05	14; NA					1.11	14; NA					Wenzel and Gabrielsen 1995[e]
Common guillemot	Barents Sea, Hormøya	17.6	10; NA					1.88	10; NA					Wenzel and Gabrielsen 1995[e]
Kittiwake	Barents Sea, Hormøya	16.9	22; NA					2.85	22; NA					Wenzel and Gabrielsen 1995[e]

[a] As reported in references (arithmetic or geometric mean), or calculated from individual values when available (geometric mean).

[b] Eggs from oviducts (2.7 and 3.0 µg/g dw) or less well-developed (2.8, 3.0, 3.4, 4.7 µg/g dw) in females shot. Predicted 21.3 or 29.2 µg/g dw in eggs based on livers and other species/area.

[c] Eggs from two-egg clutches

[d] Eggs from three-egg clutches

[e] As reported in Savinov et al. 2003

[f.] As reported in Grand et al 2002, 66% moisture used for egg wet weight to dry weight conversion

F = Females

M = Males

RBC = Red Blood Cells

Avian Blood Sample Analysis

PREPARED FOR: Utah Department of Environmental Quality, Division of Water Quality; Great Salt Lake Science Panel; Dr. John Cavitt; and Dr. Mike Conover

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DATE: March 15, 2007

Background

The concensus of the Science Panel at their November 30-31, 2006 meeting was that the reported selenium (Se) concentrations in blood from nesting birds were higher than expected given the concentrations found in eggs. CH2M HILL reviewed the datasets and analytical methods and reported findings to the Science Panel during their January 4, 2007 conference call. CH2M HILL, the PIs, and Science Panel have since discussed the issue extensively.

Purpose

The purpose of this memorandum is to address a number of questions raised at the Science Panel's conference call on January 4, 2007, pertaining to methods used in analyzing blood samples collected from the Great Salt Lake and present the recommended plan for further analysis of available blood samples developed since that conference call.

Why was avian blood analyzed as freeze-dried samples vs. direct analysis of whole blood?

Chemists from the California Animal Food Health Service Laboratory at UC Davis (who have analyzed samples for us on some of our other projects) stated that they had run spiked blood samples that had been dried and that they would not expect freeze-drying to affect the Se results. Only volatile forms would be lost if there was any loss, and freeze-drying the blood would minimize that loss. Ed Hinderberger (at LET) does not believe that the freeze-drying process will have a discernable impact on the Se results in blood and this premise is supported by the acceptable data quality indicator results. Ed mentioned that several years ago LET evaluated several sample digestion procedures and found that the current sample preparation process (see LET sample preparation SOP in the Quality Assurance Project Plan) generated the most accurate sample data.

Although all of the laboratory chemists that we spoke to from UC Davis, LET, and USFWS indicated that freeze-drying the samples is appropriate, the most relevant remarks were from Brenda Bischoff, who is the Analytical Control Facility Branch Chief for the U.S. Fish and Wildlife Service. The Analytical Control Facility (http://www.fws.gov/chemistry/) does analyses of samples for the USFWS and also handles contracting of analytical services by other labs for the USFWS. Brenda said that if they were analyzing blood in their own lab, they would freeze-dry the samples for analysis, and both of the labs they have under contract (LET, and the Trace Element Research Laboratory at Texas A&M University) also freeze-dry blood samples for analysis. She also said that Ed Hinderberger's (LET) Se analyses are top-quality, which agrees with our experience over many years of our having used his lab.

Is bias introduced?

Chemists at UC Davis did not think that there would be a bias from freeze-drying. However, if there was a bias it would be a negative bias through loss of volatile forms.

Why were blood sample results reported as dry-weight values vs. wet-weight values?

CH2M HILL directed LET to analyze avian blood and report on dry-weight basis plus percent moisture based upon prior experience, the prevailing reporting found in the literature, as well as consistency with the QAPP. Most of the literature on blood Se in wildlife expresses Se as either µg Se/g or ppm on a wet- or dry-weight basis (El-Begearmi et al. 1977, Moksnes and Norheim 1986, Heinz et al. 1990, Heinz and Fitzgerald 1993, Goede and Wolterbeek 1994, Hoffman and Heinz 1998, NIWQP 1998, Yamamoto et al. 1998, Caldwell et al. 1999, Santolo and Yamamoto 1999, Santolo et al. 1999, Osofsky et al. 2001, Franson et al. 2002, Grand et al. 2002, Henny et al. 2002, Hopkins et al. 2005, Weech et al. 2006). Diagnostic values for Se in poultry blood also are given as ppm values (e.g., Puls 1988). Occasionally (e.g., Wayland et al. 2001), blood Se concentrations in birds are reported as µg Se/dl of blood, but this is not a common practice.

Under uniform conditions of sampling blood, the moisture content of blood is fairly uniform, but under field conditions the moisture content can vary substantially. For example, when mallard blood was sampled over a period of about 3 months by exsanguination in a laboratory study, the dry-weight content of blood averaged 21.70±0.21 percent (mean ± SE) (Scanlon 1982). In a laboratory study with kestrels (Yamamoto et al. 1998, Santolo et al. 1999), the dry-weight content of blood averaged 21.40±0.11 percent (mean ± SE) with a range from 14 to 25 percent. However, when kestrels and other raptors were sampled in the field (Santolo and Yamamoto 1999), the dry-weight content of blood averaged 19.30±0.14 percent (mean ± SE) with a range from 9 to 32 percent. In both the laboratory and field studies of kestrels (and other raptors), blood samples were taken in a consistent manner from the birds by the same investigators. However, there was much greater variability in moisture content of birds collected in the field (Variance = 8.3) and than in the lab (Variance = 2.2).

For the birds sampled at the Great Salt Lake, it was not possible to take blood from a vein in the same manner as blood is collected in most studies (because those birds had been shot). Instead, blood was collected from the thoracic cavity of the birds soon after they were shot. Although the collection method may have resulted in more variablity in moisture content of the sample collected, the range and average moisture content does not seem remarkably different than found in the sampling of raptor blood under field conditions (Santolo and Yamamoto 1999), though we did not compare those statistically. It is unlikely that the moisture content of the blood samples would change much after collection because they were stored in air-tight containers.

For the reasons given above, and discussed in the December 21, 2006, technical memorandum, "Evaluation of Avian Blood Sample Data from Great Salt Lake, 2006," we believe that it is more appropriate to use dry-weight concentrations because those values generally reduce the variability among blood samples and also normalize the Se concentrations among various tissues and the dietary concentration (i.e., all are on the same dry-weight basis). If it is desirable to estimate wet-weight concentrations (other than using the reported values provided by the lab), that is probably done best by using "normal" moisture content of about 80 percent and dividing the dry-weight concentrations by 5 to get an approximate wet-weight concentration.

What are the results for analyses of reference materials, spiked samples, etc. that are associated with Great Salt Lake avian blood samples?

The Science Panel requested that reference samples, spike values, and other QC data be provided for review. Attached to the memorandum is a table (Attachment A) including the blood and liver data reported as dry-weight and wet-weight concentrations including the standard reference material measurements, reference spikes, and the laboratory duplicate data.

Can blood samples be split to allow for comparison with a different lab? If so, how should that be done?

There is no available material from gull, avocet, or stilt blood samples collected from the Great Salt Lake in 2006.

Blood samples collected from eared grebes in September and November 2006 were frozen and have not been freeze-dried or split. Although it is theoretically possible to split those samples for analysis at two different labs, there is concern that thawing and splitting the samples before freeze-drying them would raise many issues about the lack of comparability (homogeneity) of the split samples (i.e., the previously-frozen blood can't be split with certainty that the samples are comparable) for comparison between labs. Thus, the grebe samples should be freeze-dried for analysis of Se because that is now standard practice and would increase our chances of getting homogeneous samples to split.

The quantity of grebe blood in each sample is small but adequate for the Se analyses the project was designed for. The quantity of grebe blood in each sample is not adequate, however, to facilitate an inter-lab comparison and other potential analyses (e.g., for mercury [Hg]) of the blood. Compositing of some of the blood samples will be required to enable those comparisons and additional analyses.

In addition to the 10 grebes collected during the early and late time period from each of the two locations (Hat Island and Antelope Island), blood (and liver) samples are available from 5 extra grebes collected from the vicinity of Hat Island in the early collection period, 5 extra grebes from Hat Island in the late collection, and 5 extra grebes from Antelope Island in the late collection. The proposed approach for compositing and splitting the samples for inter-lab comparison is as follows:

- Gary Santolo and Mike Conover will determine which extra grebe blood samples will be used to make the composite samples (using "spare" samples other than those that would give us the most representative sample using the remaining grebes) and we provide that list of samples to LET and to Tom May at the USGS Columbia Environmental Research Center in Columbia, MO, who would do analyses for inter-lab comparison.
- LET will then provide the identified blood samples to Tom May, who will create 3 freeze-dried composites with 5 blood samples combined in each. Tom will split the 3 composites and provide half of each freeze-dried, homogenized sample to LET.

How will the inter-laboratory comparison of Se analyses be completed?

Tom May and LET will each use part of each of the three composited samples to do duplicate analyses for Se using hydride generation AA (the same method used by LET for the gull and shorebird samples previously). In addition, they will also do duplicate analyses of the samples for both Se + Hg, with LET using the proposed approach described below.

The main advantage of using the composited samples for the interlaboratory comparison is that more mass would be available for each lab to work with (1 to 1.5 grams of dried blood in each of the 3 samples – still pretty small, but should be adequate and much preferred over trying to split individual bird blood samples). In addition, we can get inter-lab comparison for both the Se analyses and the Se + Hg analyses on the same 3 samples.

Standard reference materials will be analyzed for Se and Hg by each of the labs.

Why and how will bird livers and blood be analyzed for Hg?

The technical memorandum submitted to the Science Panel on December 21, 2006, raised the hypothesis that elevated Se in avian blood may be in part a result of elevated Hg exposure of the sampled birds. A total of 56 eared grebes were collected by Mike Conover in 2006; 40 livers and 40 blood samples were originally planned for Se analyses, and some of them also will be analyzed for both Se and Hg. The remaining livers will be kept in storage, whereas most of the extra blood samples will be used for compositing and inter-lab confirmation of analytical results. The benefit of analyzing livers and blood of those grebes for Hg is that the results should help the project team understand how Se concentrations in liver and blood change with period of residence of the grebes on the lake and also the possible influence of Hg on the Se concentrations in blood, if any.

The Science Panel decided at its conference call on February 22, 2007 to complete Se + Hg analyses of blood and liver for the following:

- 10 eared grebes from early season and 10 of those grebes from late season (total of 20 birds from one location [Mike Conover has suggested using birds from near Hat Island]);
- 10 goldeneyes from the late season (with caveat that these birds may be feeding off-lake); and
- An undetermined number of nesting birds from the Great Salt Lake in May/June 2007 (the number and species to be determined at the March 21-23, 2007 Science Panel meeting).

The analyses of liver samples are under way, and blood analyses will be done once the method for Se + Hg analyses has been subjected to inter-laboratory comparison. Tom May and LET will complete duplicate analyses of the composited blood samples (described above) for both Se + Hg, with LET using the proposed approach described below. Tom's method for Hg is somewhat different, but the expectation is that results should be comparable. Instead of the microwave digestion of a liquid sample, he uses 10-50 mg of the freeze-dried sample that is then thermally combusted in pure oxygen at high temperature, and Hg is then captured in a gold trap, with concentration determined in an AA cell using a mercury autoanalyzer (a DMA 80).

For LET to do the Se + Hg analyses of blood samples (which require different analytical methods), the lab has suggested a change in the procedure for preparation of those samples. Two preparation procedures are summarized below, including the one used previously and the proposed approach (the only real difference is the microwave digestion step) that will facilitate completion of the additional Hg analyses. LET has used this method of sample preparation on other samples and reports good results.

Blood sample preparation used for California gulls and shorebirds:

1) Freeze-dry the samples

2) Perform dry-ash digestion for Se analysis

Proposed procedure for preparation of blood from eared grebes and ducks to be analyzed for Se + Hg:

1) Freeze-dry the samples

2) Perform microwave digestion using a nitric/peroxide solution

3) Split digestate - 25 ml for Hg analysis and 25 ml for Se analysis

4) Perform dry-ash digestion for Se analysis

After the inter-laboratory comparison of analyses of blood for Se and for Se + Hg is completed (with satisfactory results), LET will analyze 20 grebe blood samples (not identified for Se + Hg analysis) for Se using the same methods as for gulls and shorebirds and the other 20 grebe blood samples for Se + Hg using the proposed preparation procedure.

Where to from here?

CH2M HILL will coordinate the above analyses upon approval by the Science Panel.

The following items will be on the agenda for the March 21-23, 2007 Science Panel meeting:

1. Identify the number and species of nesting birds to be sampled for Se + Hg analyses in May/June 2007.
2. Determine path forward given different potential results from laboratories, i.e., If we confirm high Se and Hg, what then?; If high Se and low Hg, what then?; If we show low Se, what then? A decision should be made as to how to proceed with available data. Funding may not be available for further study.
3. Discuss approval of bird reports for publication.

References

Caldwell, C. A., M. A. Arnold, and W. R. Gould. 1999. Mercury distribution in blood, tissues, and feathers of double-crested cormorant nestlings from arid-lands reservoirs in South Central New Mexico. *Archives of Environmental Contamination and Toxicology* 36:451-461.

El-Begearmi, M., M. Sunde, and H. Ganther. 1977. A mutual protective effect of mercury and selenium in Japanese quail. *Poultry Science* 56:313-322.

Franson, J. C., D. J. Hoffman, and J. A. Schmutz. 2002. Blood selenium concentrations and enzyme activities related to Glutathione metabolism in wild emperor geese. *Environmental Toxicology and Chemistry* 21:2179-2184.

Goede, A. A., and H. T. Wolterbeek. 1994. The possible role of selenium in antioxidation in marine waders; a preliminary study. *The Science of the Total Environment* 144:241-246.

Grand, J. B., J. C. Franson, P. L. Flint, and M. R. Petersen. 2002. Concentrations of trace elements in eggs and blood of spectacled and common eiders on the Yukon-Kuskokwim Delta, Alaska, USA. *Environmental Toxicology and Chemistry* 21:1673-1678.

Heinz, G. H., and M. A. Fitzgerald. 1993. Overwinter survival of mallards fed selenium. *Archives of Environmental Contamination and Toxicology* 25:90 - 94.

Heinz, G. H., G. W. Pendleton, A. J. Krynitsky, and L. G. Gold. 1990. Selenium accumulation and elimination in mallards. *Archives of Environmental Contamination and Toxicology* 19:374-379.

Henny, C. J., E. F. Hill, D. J. Hoffman, M. G. Spalding, and R. A. Grove. 2002. Nineteenth century mercury: hazard to wading birds and cormorants of the Carson River, Nevada. *Ecotoxicology* 11:213-231.

Hoffman, D. J., and G. H. Heinz. 1998. Effects of mercury and selenium on glutathione metabolism and oxidative stress in mallard ducks. *Environmental Toxicology and Chemistry* 17:161-166.

Hopkins, W. A., J. W. Snodgrass, J. A. Baionno, J. H. Roe, B. P. Staub, and B. P. Jackson. 2005. Functional relationships among selenium concentrations in the diet, target tissues, and nondestructive tissue samples of two species of snakes. *Environmental Toxicology and Chemistry* 24:344-351.

Moksnes, K., and G. Norheim. 1986. A comparison of selenomethionine and sodium selenite as a supplement in chicken feeds. *Acta Veterinaria Scandinavica* 27:103-114.

National Irrigation Water Quality Program (NIWQP). 1998. Guidelines for the Interpretation of Biological Effects of Selected Constituents in Biota, Water, and Sediment. National Irrigation Water Quality Program, Department of the Interior. Denver, CO.

Osofsky, A., P. L. H. Jowett, G. Hosgood, and T. N. Tully. 2001. Determination of normal blood concentrations of lead, zinc, copper, and iron in Hispaniolan Amazon parrots (*Amazona ventralis*). *Journal of Avian Medicine and Surgery* 15:31-36.

Puls, R. 1988. Mineral Levels in Animal Health: Diagnostic Data. Sherpa International, Clearbrook, British Columbia, CAN.

Santolo, G. M., and J. T. Yamamoto. 1999. Selenium in blood of predatory birds from Kesterson Reservoir and other areas of California. *Journal of Wildlife Management* 63:1273-1281.

Santolo, G. M., J. T. Yamamoto, J. M. Pisenti, and B. W. Wilson. 1999. Selenium accumulation and effects on reproduction in captive American kestrels fed selenomethionine. *Journal of Wildlife Management* 63:502-511.

Scanlon, P. F. 1982. Wet and dry weight relationships of mallard (*Anas platyrhynchos*) tissues. *Bulletin of Environmental Contamination & Toxicology* 29:615-617.

Wayland, M., A. J. Garcia-Fernandez, E. Neugebauer, and H. G. Gilchrist. 2001. Concentrations of cadmium, mercury and selenium in blood, liver and kidney of common eider ducks from the Canadian Arctic. *Environmental Monitoring and Assessment* 71:255-267.

Weech, S. A., A. M. Scheuhammer, and J. E. Elliott. 2006. Mercury exposure and reproduction in fish-eating birds breeding in the Pinchi Lake Region, British Columbia, Canada. *Environmental Toxicology and Chemistry* 25:1433-1440.

Yamamoto, J. T., G. M. Santolo, and B. W. Wilson. 1998. American kestrels (*Falco sparverius*) fed selenomethionine and naturally incorporated selenium. *Environmental Toxicology and Chemistry* 17:2494-2497.

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
Antelope Island	Blood A-10	CA Gull	N	4-May-06	10:00	Blood	Selenium	8.8		0.2	1.7	0	ug/g					
Antelope Island	Blood A-11	CA Gull	N	4-May-06	10:00	Blood	Selenium	10		0.3	2.1	0.1	ug/g					
Antelope Island	Blood A-12	CA Gull	MS	4-May-06	10:00	Blood	Selenium	34		1	5.6	0.2	ug/g	33.3	103	wet recovery =101	80	120
Antelope Island	Blood A-12	CA Gull	N	4-May-06	10:00	Blood	Selenium	6.4		0.3	1.1	0.1	ug/g					
Antelope Island	Blood A-1	CA Gull	N	4-May-06	10:00	Blood	Selenium	7.7		0.2	1.9	0.1	ug/g					
Antelope Island	Blood A-2	CA Gull	N	4-May-06	10:00	Blood	Selenium	20		0.6	4.7	0.1	ug/g					
Antelope Island	Blood A-3	CA Gull	N	4-May-06	10:00	Blood	Selenium	19		0.6	4.3	0.1	ug/g					
Antelope Island	Blood A-4	CA Gull	N	4-May-06	10:00	Blood	Selenium	22		0.4	3	0.1	ug/g					
Antelope Island	Blood A-5	CA Gull	N	4-May-06	10:00	Blood	Selenium	14		0.3	2.7	0.1	ug/g					
Antelope Island	Blood A-6	CA Gull	N	4-May-06	10:00	Blood	Selenium	25		0.8	6.7	0.2	ug/g					
Antelope Island	Blood A-7	CA Gull	N	4-May-06	10:00	Blood	Selenium	13		0.3	3.1	0.1	ug/g					
Antelope Island	Blood A-8	CA Gull	N	4-May-06	10:00	Blood	Selenium	13		0.5	3.1	0.1	ug/g					
Antelope Island	Blood A-8	CA Gull	LR			Blood	Selenium	14		0.5	3.2	0.1	ug/g	13				
Antelope Island	Blood A-9	CA Gull	N	4-May-06	10:00	Blood	Selenium	7.7		0.2	1.5	0	ug/g					
Antelope Island	6106-1-AML a	AMAV	N	1-Jun-06	7:45	Liver	Selenium	14		0.2	4.4	0.1	ug/g					
Antelope Island	6106-1-AML b	AMAV	N	1-Jun-06	7:45	Blood	Selenium	23		0.2	5.6	0.1	ug/g					
Antelope Island	6106-2-AML a	AMAV	N	1-Jun-06	7:45	Liver	Selenium	16		0.2	5	0.1	ug/g					
Antelope Island	6106-2-AML b	AMAV	N	1-Jun-06	7:45	Blood	Selenium	23		0.3	6	0.1	ug/g					
Antelope Island	6106-3-AML a	AMAV	N	1-Jun-06	7:45	Liver	Selenium	8.3		0.2	2.8	0.1	ug/g					
Antelope Island	6106-3-AML b	AMAV	N	1-Jun-06	7:45	Blood	Selenium	17		1	4.7	0.3	ug/g					
Antelope Island	6106-4-AML a	AMAV	N	1-Jun-06	8:00	Liver	Selenium	10		0.2	3	0.1	ug/g					
Antelope Island	6106-5-AML a	AMAV	N	1-Jun-06	8:10	Liver	Selenium	13		0.2	4.1	0.1	ug/g					
Antelope Island	6106-5-AML b	AMAV	MS	1-Jun-06	8:10	Liver	Selenium	32		0.3	8.1	0.1	ug/g	30.8		Not Calculated	80	120
Antelope Island	6106-5-AML b	AMAV	N	1-Jun-06	8:10	Blood	Selenium	16		0.2	4.1	0.1	ug/g					
Antelope Island	Liver A-10	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.5		0.2	1.8	0.1	ug/g					
Antelope Island	Liver A-11	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.9		0.2	2	0.1	ug/g					
Antelope Island	Liver A-12	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.8		0.2	2	0.1	ug/g					
Antelope Island	Liver A-1	CA Gull	N	4-May-06	10:00	Liver	Selenium	5.3		0.2	1.5	0.1	ug/g					

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
Antelope Island	Liver A-2	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.9		0.2	2.1	0.1	ug/g					
Antelope Island	Liver A-2	CA Gull	LR			Liver	Selenium	6.9		0.2	2.1	0.1	ug/g	6.9				
Antelope Island	Liver A-3	CA Gull	N	4-May-06	10:00	Liver	Selenium	9.5		0.2	2.3	0.1	ug/g					
Antelope Island	Liver A-4	CA Gull	N	4-May-06	10:00	Liver	Selenium	13		0.4	3.3	0.1	ug/g					
Antelope Island	Liver A-5	CA Gull	MS	4-May-06	10:00	Liver	Selenium	16		0.4	4.3	0.1	ug/g	15.9	101	wet recovery =104	80	120
Antelope Island	Liver A-5	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.1		0.2	1.6	0.1	ug/g					
Antelope Island	Liver A-6	CA Gull	N	4-May-06	10:00	Liver	Selenium	9.9		0.4	2.8	0.1	ug/g					
Antelope Island	Liver A-7	CA Gull	N	4-May-06	10:00	Liver	Selenium	6		0.2	1.8	0.1	ug/g					
Antelope Island	Liver A-8	CA Gull	N	4-May-06	10:00	Liver	Selenium	6.7		0.2	1.8	0.1	ug/g					
Antelope Island	Liver A-8	CA Gull	LR			Liver	Selenium	6.8		0.2	1.8	0.1	ug/g	6.7				
Antelope Island	Liver A-9	CA Gull	N	4-May-06	10:00	Liver	Selenium	4		0.2	1.2	0.1	ug/g					
GSL Mineral Colony	Blood CG-01	CA Gull	N	2-May-06	10:00	Blood	Selenium	17		0.4	4.6	0.1	ug/g					
GSL Mineral Colony	Blood CG-02	CA Gull	N	2-May-06	10:00	Blood	Selenium	28		0.5	6	0.1	ug/g					
GSL Mineral Colony	Blood CG-03	CA Gull	N	2-May-06	10:00	Blood	Selenium	32		0.8	6.5	0.2	ug/g					
GSL Mineral Colony	Blood CG-03	CA Gull	LR			Blood	Selenium	32		0.8	6.6	0.2	ug/g	32				
GSL Mineral Colony	Blood CG-04	CA Gull	N	2-May-06	10:00	Blood	Selenium	37		1	10	0.3	ug/g					
GSL Mineral Colony	Blood CG-05	CA Gull	N	2-May-06	10:00	Blood	Selenium	13		0.4	2.3	0.1	ug/g					
GSL Mineral Colony	Blood CG-06	CA Gull	N	2-May-06	10:00	Blood	Selenium	18		0.6	3.7	0.1	ug/g					
GSL Mineral Colony	Blood CG-07	CA Gull	MS	2-May-06	10:00	Blood	Selenium	13		0.3	2.8	0.1	ug/g	12.4	107	wet recovery =107	80	120
GSL Mineral Colony	Blood CG-07	CA Gull	N	2-May-06	10:00	Blood	Selenium	5		0.2	1.1	0	ug/g					
GSL Mineral Colony	Blood CG-08	CA Gull	N	2-May-06	10:00	Blood	Selenium	33		0.7	7.4	0.2	ug/g					
GSL Mineral Colony	Blood CG-09	CA Gull	N	2-May-06	10:00	Blood	Selenium	31		1	6.2	0.2	ug/g					
GSL Mineral Colony	Blood CG-10	CA Gull	N	2-May-06	10:00	Blood	Selenium	25		0.8	5.3	0.2	ug/g					
GSL Mineral Colony	Blood CG-11	CA Gull	N	2-May-06	10:00	Blood	Selenium	37		1	8.7	0.2	ug/g					
GSL Mineral Colony	Liver CG-01	CA Gull	MS	2-May-06	10:00	Liver	Selenium	18		0.4	5.2	0.1	ug/g	16.6	115	wet recovery =110	80	120
GSL Mineral Colony	Liver CG-01	CA Gull	N	2-May-06	10:00	Liver	Selenium	6.7		0.2	2	0.1	ug/g					
GSL Mineral Colony	Liver CG-02	CA Gull	N	2-May-06	10:00	Liver	Selenium	12		0.4	3.5	0.1	ug/g					
GSL Mineral Colony	Liver CG-03	CA Gull	N	2-May-06	10:00	Liver	Selenium	9.9		0.4	3.1	0.1	ug/g					

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
GSL Mineral Colony	Liver CG-04	CA Gull	N	2-May-06	10:00	Liver	Selenium	13		0.4	3.7	0.1	ug/g					
GSL Mineral Colony	Liver CG-04	CA Gull	LR			Liver	Selenium	13		0.4	3.7	0.1	ug/g	13				
GSL Mineral Colony	Liver CG-05	CA Gull	N	2-May-06	10:00	Liver	Selenium	6.1		0.2	1.9	0.1	ug/g					
GSL Mineral Colony	Liver CG-06	CA Gull	N	2-May-06	10:00	Liver	Selenium	7.5		0.2	2.1	0.1	ug/g					
GSL Mineral Colony	Liver CG-07	CA Gull	N	2-May-06	10:00	Liver	Selenium	3.9		0.2	1	0.1	ug/g					
GSL Mineral Colony	Liver CG-08	CA Gull	MS	2-May-06	10:00	Liver	Selenium	21		0.4	6	0.1	ug/g	20.9		Not Calculated	80	120
GSL Mineral Colony	Liver CG-08	CA Gull	N	2-May-06	10:00	Liver	Selenium	11		0.4	3.1	0.1	ug/g					
GSL Mineral Colony	Liver CG-09	CA Gull	N	2-May-06	10:00	Liver	Selenium	11		0.4	2.9	0.1	ug/g					
GSL Mineral Colony	Liver CG-10	CA Gull	N	2-May-06	10:00	Liver	Selenium	8.6		0.2	2.4	0.1	ug/g					
GSL Mineral Colony	Liver CG-11	CA Gull	N	2-May-06	10:00	Liver	Selenium	12		0.4	3.6	0.1	ug/g					
Hat Island Colony	Blood H-10	CA Gull	N	9-May-06	10:00	Blood	Selenium	25		0.6	5.7	0.1	ug/g					
Hat Island Colony	Blood H-11	CA Gull	N	9-May-06	10:00	Blood	Selenium	8.1		0.2	1.3	0	ug/g					
Hat Island Colony	Blood H-11	CA Gull	LR			Blood	Selenium	8.1		0.2	1.3	0	ug/g	8.1				
Hat Island Colony	Blood H-12	CA Gull	N	9-May-06	10:00	Blood	Selenium	6.3		0.2	1.3	0	ug/g					
Hat Island Colony	Blood H-1	CA Gull	N	9-May-06	10:00	Blood	Selenium	12		0.2	1.6	0	ug/g					
Hat Island Colony	Blood H-2	CA Gull	N	9-May-06	10:00	Blood	Selenium	29		0.5	5.3	0.1	ug/g					
Hat Island Colony	Blood H-2	CA Gull	LR			Blood	Selenium	29		0.5	5.3	0.1	ug/g	29				
Hat Island Colony	Blood H-3	CA Gull	N	9-May-06	10:00	Blood	Selenium	8.5		0.6	2.1	0.1	ug/g					
Hat Island Colony	Blood H-4	CA Gull	N	9-May-06	10:00	Blood	Selenium	15		0.3	2.3	0.1	ug/g					
Hat Island Colony	Blood H-5	CA Gull	N	9-May-06	10:00	Blood	Selenium	15		0.4	3.9	0.1	ug/g					
Hat Island Colony	Blood H-6	CA Gull	N	9-May-06	10:00	Blood	Selenium	17		0.4	5.4	0.1	ug/g					
Hat Island Colony	Blood H-7	CA Gull	MS	9-May-06	10:00	Blood	Selenium	32		0.7	3.8	0.1	ug/g	32.6	96.4	wet recovery =89.7	80	120
Hat Island Colony	Blood H-7	CA Gull	N	9-May-06	10:00	Blood	Selenium	16		0.7	2	0.1	ug/g					
Hat Island Colony	Blood H-8	CA Gull	N	9-May-06	10:00	Blood	Selenium	22		1	6.6	0.3	ug/g					
Hat Island Colony	Blood H-9	CA Gull	N	9-May-06	10:00	Blood	Selenium	18		0.5	2.5	0.1	ug/g					
Hat Island Colony	Liver H-9	CA Gull	N	9-May-06	10:00	Liver	Selenium	8.6		0.4	2.5	0.1	ug/g					
Hat Island Colony	Liver H-10	CA Gull	N	9-May-06	10:00	Liver	Selenium	9.3		0.4	2.7	0.1	ug/g					
Hat Island Colony	Liver H-11	CA Gull	N	9-May-06	10:00	Liver	Selenium	5.7		0.2	1.6	0.1	ug/g					

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
Hat Island Colony	Liver H-12	CA Gull	N	9-May-06	10:00	Liver	Selenium	5.6		0.2	1.8	0.1	ug/g					
Hat Island Colony	Liver H-1	CA Gull	N	9-May-06	10:00	Liver	Selenium	6.3		0.2	1.8	0.1	ug/g					
Hat Island Colony	Liver H-2	CA Gull	N	9-May-06	10:00	Liver	Selenium	13		0.4	2.8	0.1	ug/g					
Hat Island Colony	Liver H-2	CA Gull	LR			Liver	Selenium	13		0.4	2.7	0.1	ug/g	13				
Hat Island Colony	Liver H-3	CA Gull	N	9-May-06	10:00	Liver	Selenium	5.9		0.2	1.8	0.1	ug/g					
Hat Island Colony	Liver H-4	CA Gull	N	9-May-06	10:00	Liver	Selenium	6.8		0.2	2.1	0.1	ug/g					
Hat Island Colony	Liver H-5	CA Gull	N	9-May-06	10:00	Liver	Selenium	6.1		0.2	1.8	0.1	ug/g					
Hat Island Colony	Liver H-6	CA Gull	N	9-May-06	10:00	Liver	Selenium	8.4		0.4	2.5	0.1	ug/g					
Hat Island Colony	Liver H-7	CA Gull	MS	9-May-06	10:00	Liver	Selenium	19		0.4	5.5	0.1	ug/g	19.2	98.2	wet recovery =99.0	80	120
Hat Island Colony	Liver H-7	CA Gull	N	9-May-06	10:00	Liver	Selenium	9.3		0.4	2.7	0.1	ug/g					
Hat Island Colony	Liver H-8	CA Gull	N	9-May-06	10:00	Liver	Selenium	8.6		0.4	2.6	0.1	ug/g					
LET QC	ANTI-DOLT-3	LET QC	SRM				Selenium	6.8		0.2	6.8	0.2	ug/g	7.06		NRCC DOLT-3	6.6	7.5
LET QC	BJO-DOLT-03	LET QC	SRM				Selenium	7		0.2	7	0.2	ug/g	7.06		NRCC DOLT-3	6.6	7.5
LET QC	Blood A-13	LET QC	SRM				Selenium	6.7		0.4	6.7	0.4	ug/g	7.06		NRCC DOLT-3	6.6	7.5
LET QC	Blood H-13	LET QC	SRM				Selenium	5.6		0.4	5.6	0.4	ug/g	5.63		NRCC TORT-2	5	6.3
LET QC	JFC-TORT-02	LET QC	SRM				Selenium	5.1		0.2	5.1	0.2	ug/g	5.63		NRCC TORT-2	5	6.3
LET QC	Liver H-13	LET QC	SRM				Selenium	7		0.4	7	0.4	ug/g	7.06		NRCC DOLT-3	6.6	7.5
LET QC	RefSpk-1	LET QC	BS				Selenium	5		0.2	5	0.2	ug	5	100			
LET QC	RefSpk-1	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefSpk-2	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
LET QC	RefSpk-2	LET QC	BS				Selenium	5.2		0.2	5.2	0.2	ug	5	104			
LET QC	RefSpk-3	LET QC	BS				Selenium	5		0.1	5	0.1	ug	5	100			
LET QC	RefSpk-3	LET QC	BS				Selenium	5.2		0.2	5.2	0.2	ug	5	104			
LET QC	RefSpk-4	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefSpk-4	LET QC	BS				Selenium	5.3		0.2	5.3	0.2	ug	5	106			
LET QC	RefSpk-5	LET QC	BS				Selenium	4.9		0.2	4.9	0.2	ug	5	98			
LET QC	RefSpk-6	LET QC	BS				Selenium	5.5		0.2	5.5	0.2	ug	5	110			
LET QC	RefSpk-6	LET QC	BS				Selenium	18		0.2	18	0.2	ug	20	90			

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
LET QC	RefSpk-7	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefSpk-8	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
LET QC	RefSpk-8	LET QC	BS				Selenium	17		0.5	17	0.5	ug	20	85			
LET QC	RefSpk-9	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
LET QC	RefStd-1	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefStd-2	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
LET QC	RefStd-2	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefStd-3	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
LET QC	RefStd-3	LET QC	BS				Selenium	5.2		0.2	5.2	0.2	ug	5	104			
LET QC	RefStd-4	LET QC	BS				Selenium	3.8		0.2	3.8	0.2	ug	5	76			
LET QC	RefStd-4	LET QC	BS				Selenium	4.8		0.2	4.8	0.2	ug	5	96			
LET QC	RefStd-5	LET QC	BS				Selenium	5		0.2	5	0.2	ug	5	100			
LET QC	RefStd-6	LET QC	BS				Selenium	0.2	U	0.2	0.2	0.2	ug	5		Not spiked – Sample spikes ok-		
LET QC	RefStd-6	LET QC	BS				Selenium	21		0.2	21	0.2	ug	20	102			
LET QC	RefStd-7	LET QC	BS				Selenium	5.1		0.2	5.1	0.2	ug	5	102			
LET QC	RefStd-7	LET QC	BS				Selenium	19		0.5	19	0.5	ug	20	95			
LET QC	RefStd-8	LET QC	BS				Selenium	5.2		0.1	5.2	0.1	ug	5	104			
LET QC	RefStd-8	LET QC	BS				Selenium	16		0.5	16	0.5	ug	20	80			
LET QC	RefStd-9	LET QC	BS				Selenium	5.1		0.1	5.1	0.1	ug	5	102			
Ogden Bay	61306-1-AML a	BNST	N	13-Jun-06	7:30	Liver	Selenium	16		0.2	5.3	0.1	ug/g					
Ogden Bay	61306-1-AML b	BNST	N	13-Jun-06	7:30	Blood	Selenium	23		0.6	9.3	0.2	ug/g					
Ogden Bay	61306-2-AML a	BNST	N	13-Jun-06	7:30	Liver	Selenium	11		0.2	3.1	0.1	ug/g					
Ogden Bay	61306-2-AML b	BNST	N	13-Jun-06	7:30	Blood	Selenium	20		0.3	5.3	0.1	ug/g					
Ogden Bay	61306-3-AML a	BNST	N	13-Jun-06	7:30	Liver	Selenium	29		0.5	8.4	0.1	ug/g					
Ogden Bay	61306-3-AML b	BNST	N	13-Jun-06	7:30	Blood	Selenium	40		0.5	11	0.1	ug/g					
Ogden Bay	6606-1-JFC a	AMAV	N	6-Jun-06	7:30	Liver	Selenium	28		0.5	8.4	0.1	ug/g					
Ogden Bay	6606-1-JFC b	AMAV	N	6-Jun-06	7:30	Blood	Selenium	60		0.5	21	0.2	ug/g					
Ogden Bay	6606-2-JFC a	AMAV	N	6-Jun-06	7:30	Liver	Selenium	17		0.2	5.3	0.1	ug/g					

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Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
Ogden Bay	6606-2-JFC b	AMAV	N	6-Jun-06	7:30	Blood	Selenium	33		2	12	0.7	ug/g					
Ogden Bay	6606-3-JFC a	AMAV	N	6-Jun-06	7:45	Liver	Selenium	15		0.2	4.5	0.1	ug/g					
Ogden Bay	6606-3-JFC b	AMAV	N	6-Jun-06	7:45	Blood	Selenium	34		0.5	12	0.2	ug/g					
Ogden Bay	6606-4-JFC a	AMAV	N	6-Jun-06	7:45	Liver	Selenium	14		0.2	4.1	0.1	ug/g					
Ogden Bay	6606-4-JFC b	AMAV	N	6-Jun-06	7:45	Blood	Selenium	21		4	7.2	1	ug/g					
Ogden Bay	6606-5-JFC a	AMAV	MS	6-Jun-06	7:45		Selenium	21		0.4	6	0.1	ug/g	21		Not Calculated	80	120
Ogden Bay	6606-5-JFC a	AMAV	N	6-Jun-06	7:45	Liver	Selenium	11		0.2	3.3	0.1	ug/g					
Ogden Bay	6606-5-JFC b	AMAV	N	6-Jun-06	7:45	Blood	Selenium	24		0.6	13	0.3	ug/g					
Ogden Bay	6706-1-JFC a	BNST	N	7-Jun-06	7:30	Liver	Selenium	40		1	13	0.3	ug/g					
Ogden Bay	6706-1-JFC b	BNST	N	7-Jun-06	7:30	Blood	Selenium	68		1	26	0.4	ug/g					
Ogden Bay	6706-2-JFC a	BNST	N	7-Jun-06	7:30	Liver	Selenium	25		0.5	7.7	0.2	ug/g					
Ogden Bay	6706-2-JFC b	BNST	N	7-Jun-06	7:30	Blood	Selenium	37		0.9	12	0.3	ug/g					
Saltaire	6606-10-AML a	AMAV	MS	6-Jun-06	8:45	Liver	Selenium	31		0.5	9.8	0.2	ug/g	29.0		Not Calculated	80	120
Saltaire	6606-10-AML a	AMAV	N	6-Jun-06	8:45	Liver	Selenium	19		0.5	6	0.2	ug/g					
Saltaire	6606-10-AML b	AMAV	N	6-Jun-06	8:45	Blood	Selenium	28		0.3	6.2	0.1	ug/g					
Saltaire	6606-6-AML a	AMAV	N	6-Jun-06	8:45	Liver	Selenium	15		0.2	4	0.1	ug/g					
Saltaire	6606-6-AML b	AMAV	N	6-Jun-06	8:45	Blood	Selenium	18		0.3	4.1	0.1	ug/g					
Saltaire	6606-7-AML a	AMAV	N	6-Jun-06	8:45	Liver	Selenium	24		0.5	6.8	0.1	ug/g					
Saltaire	6606-7-AML b	AMAV	MS	6-Jun-06	8:45	Liver	Selenium	66		0.6	22	0.2	ug/g	65.6		Not Calculated	80	120
Saltaire	6606-7-AML b	AMAV	N	6-Jun-06	8:45	Blood	Selenium	35		0.3	12	0.1	ug/g					
Saltaire	6606-8-AML a	AMAV	N	6-Jun-06	8:45	Liver	Selenium	22		0.5	6.2	0.1	ug/g					
Saltaire	6606-8-AML b	AMAV	N	6-Jun-06	8:45	Blood	Selenium	12		0.3	2.6	0.1	ug/g					
Saltaire	6606-9-AML a	AMAV	N	6-Jun-06	8:45	Liver	Selenium	38		1	11	0.3	ug/g					
Saltaire	6606-9-AML b	AMAV	N	6-Jun-06	8:45	Blood	Selenium	25		0.4	7.4	0.1	ug/g					
LET QC	IAEA A-13	LET QC	SRM				Selenium	0.2		0.2	0.2	0.2	ug/g	0.24			0.16	0.32
LET QC	IAEA A-13-D	LET QC	SRM				Selenium	0.2		0.2	0.2	0.2	ug/g	0.24			0.16	0.32
LET QC	8841 ClinChek Blood 3	LET QC	SRM				Selenium	0.9		0.2	0.9	0.2	ug/g	0.952			0.7626	1.14
LET QC	8841 ClinChek Blood 3D	LET QC	SRM				Selenium	1.1		0.2	1.1	0.2	ug/g	0.952			0.7626	1.14

Attachment A – Validated Data with Laboratory Data Quality Indicator Data

Location	NativeID	Species	QA/QC Type	Sample Date	Sample Time	Matrix	Analyte	Dry Weight Result	Final Validation Flag	RL	Wet Weight Result	Wet Weight RL	Units	Dry Weight Expected Value	Dry Weight Recovery	Comments	LCL	UCL
LET QC	SERO 201705 Blood 3	LET QC	SRM				Selenium	1		0.2	1	0.2	ug/g	0.985			0.924	1.05
LET QC	SERO 201705 Blood 3D	LET QC	SRM				Selenium	1		0.2	1	0.2	ug/g	0.985			0.924	1.05
LET QC	SERO 201705 Blood 3	LET QC	MS				Selenium	27		0.5	27	0.5	ug/g	24.3	112		80	120
LET QC	NIST Oyster	LET QC	SRM				Selenium	2		0.1	2	0.1	ug/g	2.06			1.91	2.21

Notes:
QC types – N = Normal Investigative Sample, LR = Laboratory replicate sample, MS = Matrix Spike, BS= Laboratory Blank Spike, SRM = Standard Reference Material
Not Calculated – Spike concentration is not calculated when the sample result is greater than the spike concentration.
The dry weight expected value for sample with a QA/QC type of “LR” represents the Normal Investigative Sample concentration.
To calculate the MS percent recovery, divide the dry weight sample concentration by the dry weight expected value and multiply by 100.