SELENIUM CONCENTRATION IN SHOREBIRD EGGS AT
GREAT SALT LAKE UTAH
2010 REPORT

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INTRODUCTION

The Avian Ecology Laboratory (AEL) located at Weber State University, collected American Avocet (Recurvirostra americana, AMAV) and Black-necked Stilt (Himantopus mexicanus, BNST) eggs, in June, 2010, for Se analysis as part of the ongoing protective program of site-specific standards for water quality at Great Salt Lake, Utah. Since shorebirds forage primarily on macroinvertebrates, it is expected that these birds will respond negatively to reductions in water quality. In addition, contaminants can also affect bird populations by reducing hatchability of eggs, increasing young mortality and the incidence of developmental deformities (Ohlendorf et al. 1989). Because of the response of birds to water quality, standards are based on tissue concentrations and designed to be protective of birds (UDWQ, 2008).

OBJECTIVE

The objective of this study was to collect shorebird eggs at Great Salt Lake to assess trends in selenium concentrations and determine whether they are approaching or exceeding the established egg-tissue standards.

Thresholds of selenium concentrations in the eggs of aquatic-dependent birds were established and "trigger" specific regulatory responses as selenium concentration in eggs increase in the lake. Each trigger value represents a scientifically defensible point, as recognized by the Great Salt Lake Selenium Science Panel. There are two overarching aims of these tiered regulatory responses. First, the triggers are intended to ensure that scientific uncertainties do not result in degradation of beneficial uses. Second, the proactive, adaptive management process established by these procedures allows steps to be taken to avoid selenium-related impairments to the Great Salt Lake by preventing the standard from being exceeded. (Table 1.)

The proposed trigger values and associated regulatory responses were developed using various scientific arguments and by evaluating all existing data. Due to uncertainty inherent in all scientific inquiry and the desired level of protection, it was difficult to derive a single value from these analyses as a recommended standard. Instead, a range of numbers was generated from different inquiries that were both higher and lower than the proposed standard. The proposed threshold or "trigger" values proposed represent scientifically defensible values that were lower than the proposed standard. For additional details, see *Developing a Selenium Standard for the Open Waters of the Great Salt Lake* and associated supporting literature at: http://www.deq.utah.gov/Issues/GSL_WQSC/index.htm.

In addition to determining Se concentrations, the physical condition of each egg was qualitatively examined.

METHODS
Eggs were collected in June 2010.

Study Sites

Ogden Bay

Ogden Bay Waterfowl Management Area is located along the eastern shore of the GSL. Freshwater from the Weber River flows into the bay at this location (41°12.038' N, 112°14.597'W) and attracts large numbers of shorebirds and waterfowl.

A preliminary study conducted in 2006 found Ogden Bay (OGBA) to have high levels of Se within both blood and liver of AMAV (Cavitt, 2007). Consequently, every effort was made to collect eggs from this site. However, persistent rain early in the breeding season causing impassable mud-covered areas prevented access to the site. Several attempts were made in June to survey the site on foot and all observed nests were flooded. When the area dried enough to gain access later in the season (July), no active nests were located.

Saltair

Saltair is located along the south shore of the GSL (40°46.116' N, 112°10.466'W). The site receives freshwater inflows from the Kennecott wastewater discharge.
All of the 11 eggs collected were from this site. (Figure 1.)

Species

American Avocet and Black-necked Stilts were chosen as the target species. As ground nesting species, the eggs are easily collected and the population sizes of these birds are large enough so as not to be affected by egg collections. The modal clutch size of both species is four eggs and only one of the four eggs was collected. Both of these species feed on invertebrates gathered from the water. These invertebrates are suspected to be the food-chain link in the transfer of Se to shorebirds.

PROCEDURES

Shorebird nests were located by systematic search of areas known to contain breeding bird colonies. A single egg was collected randomly from each of 11 nests. Every effort was made to minimize disturbance to the nest and any birds in the vicinity.

In the laboratory, measurements of length, width, mass, volume, density and shell thickness were taken.

Initial egg mass, (IEM) was calculated by the following formula:

$IEM=K_w \bullet LB^2$ (Hoyt, 1979).
K_w: weight coefficient for individual species
L: length
B: breadth

Eggs were examined by "candling" to determine if the shell was intact. Egg volume of intact shells was determined by water displacement. Volume of eggs with cracked shells was estimated by the "length-breadth technique" (Hoyt, 1979):

$Volume = K_v \bullet L \bullet B^2$
K_v: volume coefficient for individual species
L: length
B: breadth

Following dissection of each egg, shells were dried for 30 days. The mass of the dried shells was then recorded. Thickness was measured to the nearest 0.001mm with a Starrett micrometer. The Ratcliffe index (Ratcliffe, 1967) was calculated with the following formula:

Index= shell mass (mg)/
length(mm) x width (mm)

Egg measurements are presented in Table 2.

Eggs were dissected in the laboratory and examined for malpositions and malformations. Malpositions were characterized as follows:

I. Head between thighs
II. Head in small end of egg
III. Head under left wing
IV. Embryo rotated so that bill is not directed toward the air cell.
V. Feet over head
VI. Bill over right wing

Embryonic age was estimated according to "Lillie's development of the Chick" (Hamilton 1952). If no embryo was found, the egg was examined for the presence of a blastodisc. For eggs containing embryos, presence or absence of eyes, limbs or limb buds, presence and number of digits on the feet, and length of tarsus and upper mandible were also recorded.

After measurements were taken and eggs dissected, the content of each egg was frozen and shipped overnight in dry ice to an environmental testing laboratory (LET Laboratories, Columbia, Missouri) for total Se analysis.

RESULTS AND DISCUSSION

Egg Breakouts

Egg breakout procedures revealed a potential Type IV malposition in egg #SWR-200-10. A malformation was observed in egg #SWR-203-10. This embryo only developed a single eye.

In egg #SWR-207-10 and #SWR-203- 10, the bills were in unusual positions, tucked parallel to the head. However, given the age of the embryo this cannot be considered a malposition.

A majority of eggs were determined to be viable, however the presence of a potential malposition, and one malformation is of concern.

Total Selenium

Laboratory results for total Se in AMAV and BNST eggs showed a mean Se concentration of 4.32 μg/g dw for both species combined. Taken separately, AMAV had a mean total Se concentration of 4.43 μg/g dw and BNST had a mean of 4.16 μg/g dw. (Table 3.)

These levels are well below the established standard of between 6 and 16mg Se/kg dw (Fig 2).

CONCLUSION

Analysis of Se concentration from shorebird eggs gathered at Saltair, GSL, Utah, showed levels well below Se standards set by the Science Panel. Examinations of egg development raise questions of viability in some of the eggs collected. Ongoing study of Se levels and egg condition, as well as examination of hatchability, and nesting success of shorebirds at GSL is recommended for further understanding of water quality issues at Great Salt Lake.

Figure 1. Map showing egg collection study site. Saltair is shown in the main map with its position southeast of Antelope Island shown lower left. Species and the location of individual nests are indicated by red and yellow diamonds.

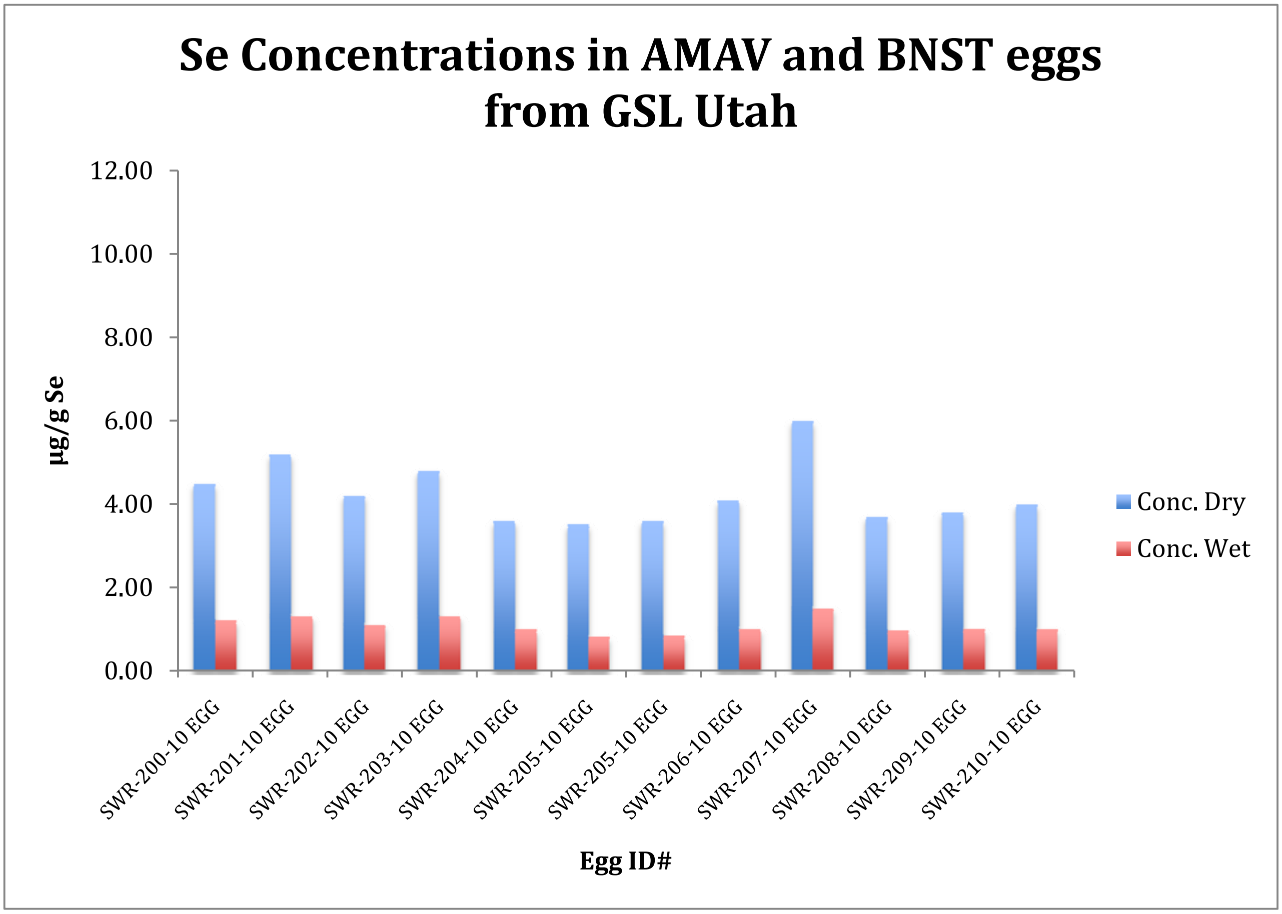

Figure 2. Se concentrations in AMAV and BNST eggs taken from Saltair, Great Salt Lake, Utah.

Table 1. The water quality standard for selenium is as follows:

Selenium (14)
Gilbert Bay (Class 5A)
Great Salt Lake
Geometric mean of egg concentrations
over the nesting season (mg/kg dry wt) 12.5

(14) The selenium water quality standard of 12.5 mg/kg (dry weight) for Gilbert Bay is a tissue-based standard using the complete egg/embryo of aquatic-dependent birds that use the waters of Gilbert Bay based upon a minimum of five samples over the nesting season. Increasing bird egg concentrations and Division of Water Quality responses are indicated below: ***SELENIUM TRIGGERS AND REGULATORY RESPONSES TO OBSERVED INCREASES OF SELENIUM IN AQUATIC BIRDS OF GREAT SALT LAKE.***

Egg Concentration Trigger	DWQ Responses
5.0 mg/kg and below	Routine monitoring with sufficient intensity to evaluate whether selenium concentrations within the Great Salt Lake ecosystem are increasing
5.0 mg/kg	Increased monitoring to address data gaps and areas of uncertainty identified from initial Great Salt Lake selenium studies
6.4 mg/kg	Initiation of Level II Antidegradation reviews for all permit renewals or new permits to Great Salt Lake
9.8 mg/kg	Initiation of preliminary TMDL studies to evaluate all selenium loading sources
12.5 mg/kg and above	Declare impairment;.formalize and implement the TMDL

Table 2. Measurements of AMAV and BNST eggs collected from Saltair, at Great Lake Utah, showing ID#, species, initial egg mass, total weight, length, width (breadth), fresh egg mass, volume, density, Ratcliffe Index, shell thickness, shell calc, dry weight, and sample weight.

Laboratory ID #	Sp. ID	IEM HOYT	Egg Wt	L (mm)	W (mm)	FEM Calc	Egg Vol	Egg Density	Ratcliff mg/(LxW)	Shell (mm)	Shell Calc	Dry Shell Weight (g)	Sample wt.
SWR-210-10	AMAV	33.13	28.60	52.60	33.90	28.16	30.83	0.93	1205.19	0.20	0.27	1.87	25.46
SWR-209-10	BNST	24.82	21.50	42.10	32.80	21.10	23.10	0.93	1129.69	0.21	0.27	1.45	19.32
SWR-208-10	AMAV	24.34	22.90	44.20	31.70	20.69	22.65	1.01	1176.20	0.23	0.26	1.64	20.09
SWR-207-10	AMAV	29.48	26.30	48.80	33.20	25.06	27.43	0.96	1326.64	0.25	0.27	1.95	22.99
SWR-206-10	BNST	19.45	17.90	42.20	29.00	16.53	18.10	0.99	879.62	0.24	0.24	1.28	15.78
SWR-205-10	AMAV	34.89	32.70	49.40	35.90	29.66	32.47	1.01	1395.30	0.22	0.29	1.92	29.07
SWR-204-10	BNST	24.48	20.80	43.90	31.90	20.81	22.78	0.91	1148.11	0.23	0.26	1.58	17.34
SWR-203-10	BNST	19.56	16.40	39.40	30.10	16.63	18.21	0.90	924.39	0.20	0.25	1.21	14.38
SWR-202-10	AMAV	30.30	26.80	54.00	32.00	25.76	28.20	0.95	1096.30	0.22	0.26	1.85	23.85
SWR-201-10	AMAV	30.69	28.50	49.90	33.50	26.08	28.56	1.00	1389.68	0.25	0.27	2.07	23.63
SWR-200-10	BNST	18.92	15.40	42.20	28.60	16.08	17.60	0.87	853.93	0.17	0.23	1.26	13.36

Table 3. Laboratory analyses for total Se in AMAV and BNST eggs collected at Saltair, Utah 2010, showing ID#, analyte, Se concentrations in dry and wet samples, percent moisture, and sample spikes for controls.

Identification number	Analyte	Conc Dry	D L Dry	Conc Wet	D L Wet	% Moisture	Units	Sample Spike
Blank-1	Se-HY	<0.2	0.2	<0.05	0.05		mcg/g	
SWR-200-10 EGG	% M					73.1		
SWR-200-10 EGG	Se-HY	4.5	0.2	1.2	0.05		mcg/g	
SWR-201-10 EGG	% M					74		
SWR-201-10 EGG	Se-HY	5.2	0.2	1.3	0.05		mcg/g	
SWR-201-10 EGG	Se-HY	5.2	0.2	1.3	0.05		mcg/g	
SWR-202-10 EGG	% M					74.7		
SWR-202-10 EGG	Se-HY	4.2	0.2	1.1	0.05		mcg/g	
SWR-203-10 EGG	% M					71.9		
SWR-203-10 EGG	Se-HY	4.8	0.2	1.3	0.06		mcg/g	
SWR-203-10 EGG	Se-HY	15	0.2	4.3	0.06		mcg/g	9.84
SWR-204-10 EGG	% M					73		
SWR-204-10 EGG	Se-HY	3.6	0.2	0.98	0.05		mcg/g	
SWR-205-10 EGG	% M					76.8		
SWR-205-10 EGG	Se-HY	3.5	0.2	0.81	0.05		mcg/g	
SWR-205-10 EGG	Se-HY	3.6	0.2	0.83	0.05		mcg/g	
SWR-206-10 EGG	% M					75.5		
SWR-206-10 EGG	Se-HY	4.1	0.2	1	0.05		mcg/g	
SWR-207-10 EGG	% M					74.9		
SWR-207-10 EGG	Se-HY	6	0.2	1.5	0.05		mcg/g	
SWR-208-10 EGG	% M					74.3		
SWR-208-10 EGG	Se-HY	3.7	0.2	0.95	0.05		mcg/g	
SWR-209-10 EGG	% M					74		
SWR-209-10 EGG	Se-HY	3.8	0.2	0.98	0.05		mcg/g	
SWR-210-10 EGG	% M					73.7		
SWR-210-10 EGG	Se-HY	4	0.2	1	0.05		mcg/g	
SWR-210-10 EGG	Se-HY	14	0.2	3.7	0.05		mcg/g	9.84
QC-1	Se-HY	2.3	0.2	2.3	0.2		mcg/g	

Table 4. Mean Se concentrations in AMAV and BNST eggs collected from Saltair Utah, June 2010.

Spp. Combined	µg Se/g Dry	µg Se/g Wet
Mean	4.32	1.10
High	6.00	1.50
Low	3.50	0.81
AMAV		
Mean	4.43	1.10
High	6.00	1.50
Low	3.50	0.81
BNST		
Mean	4.16	0.85
High	4.80	1.30
Low	3.60	0.98

Table 5. Egg breakout results: date opened, ID#, species, embryonic stage, and sample weight.

Date Opened	Laboratory ID#	Sp. ID	Embryo Stage	Sample wt
7/27/10	SWR-210-10	AMAV	D8+/25-28	25.46
7/27/10	SWR-209-10	BNST	D11+/30-32	19.32
7/27/10	SWR-208-10	AMAV	D3+/8	20.09
7/27/10	SWR-207-10	AMAV	D9+/28	22.99
7/27/10	SWR-206-10	BNST	D6+/19	15.78
7/27/10	SWR-205-10	AMAV	D0+	29.07
7/27/10	SWR-204-10	BNST	Undetermined	17.34
7/27/10	SWR-203-10	BNST	D9+/28	14.38
7/27/10	SWR-202-10	AMAV	Undetermined	23.85
7/30/10	SWR-201-10	AMAV	D2+/6-8	23.63
7/30/10	SWR-200-10	BNST	D17+/37-38	13.36

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