SELENIUM AND MERCURY CONCENTRATIONS OF SHOREBIRD EGGS AT GREAT SALT LAKE, UTAH 2012 REPORT

John F. Cavitt, Josh Hall, Lessie Swenson and Nacole Wilson
Avian Ecology Laboratory,
Department of Zoology,
Weber State University
Ogden, UT 84408-2505

INTRODUCTION

The Avian Ecology Laboratory (AEL) located at Weber State University, collected American Avocet (*Recurvirostra americana*, AMAV) eggs, Black-necked Stilt (*Himantopus mexicanus, BNST*) eggs, and samples of water, sediment and invertebrates from each study site during June, 2012. Sediment samples were analyzed for total selenium (Se) and all other samples were analyzed for both total mercury (Hg) and Se. All analyses were conducted as part of the Utah Division of Water Quality's (UDWQ) ongoing water quality monitoring for the Great Salt Lake (GSL), Utah. Selenium is a target analyte because avian reproduction is the most sensitive ecosystem response identified for Se exposures (UDWQ, 2008). Hg is a target analyte because it biomagnifies through the food web. Shorebirds forage primarily on macroinvertebrates and are expected to be sensitive to exposures of these contaminants. Hg and Se can affect bird populations by reducing egg hatchability, increasing young mortality and the incidence of developmental deformities (Ohlendorf et al., 1989; Burger and Gochfeld, 1997). Gilbert Bay of the GSL has a water quality standard for Se that is based on egg concentrations. No water quality standard for Hg is currently available. These analyses are being conducted to determine if Se concentrations in Gilbert Bay meet the Se water quality standard. In addition, these data will provide information necessary to monitor for trends in Hg and Se concentrations over time.

OBJECTIVE

The objectives of this study were:

1. Collect AMAV and BNST eggs from at least two study sites at GSL, Utah.
2. Collect water, sediment and invertebrate food items from each site.
3. Examine collected eggs for malpositions and malformations.
4. Determine total Hg and Se levels in collected samples.

The objective of this study was to collect shorebird eggs from Gilbert Bay at the GSL 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. There are two overarching aims of these tiered regulatory responses. First, scientific uncertainties remain regarding the protectiveness of the selenium water quality standard and the triggers are intended to reduce some of these uncertainties as lake concentrations increase and approach the standard.

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. The 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 standard. The threshold or "trigger" values represent scientifically defensible values that were lower than the 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, Hg concentrations were also determined as well as the physical condition of each embryo.

METHODS

All samples were collected in June 2012.

Study Sites

Targeted sites for this study were within Gilbert Bay and included the north side of the Antelope Island Causeway, Ogden Bay, Bridger Bay of Antelope Island, and Saltair Beach. Each of these sites was searched for nesting AMAV and BNST several times over the breeding season. Bridger Bay as well as other previous nesting sites at Antelope Island were searched three times during June 2012 but no nesting activity was observed. Saltair Beach was searched weekly from May – July but no nests were ever located at this site. Nests were located at both the Antelope Island Causeway and Ogden Bay.

Antelope Island Causeway (ANTI)

The Antelope Island site is located west of Syracuse, Utah and north of the 7.2 mile causeway to the island. This study site is located near Howard's Slough and is within Gilbert Bay (41°5'32.13"N, 112°8'30.78"W; Figure 1). Eggs were also collected for Se and Hg monitoring at this location in 2011.

Ogden Bay (OGBA)

This study site is located at the Ogden Bay Waterfowl Management Area along the eastern shore of the Great Salt Lake. AMAV and BNST were observed in large numbers during the surveys. Freshwater from the Weber River flows into the bay at this location and attracts large numbers of shorebirds and waterfowl. The study site is located at 41˚12.038' N 112˚14.597'W. Eggs were collected at this location and examined for Se in 2006 as part of the research to establish a water quality standard for Se (Cavitt 2007).

Species

AMAV and BNST were chosen as the target species for this study by the Great Salt Lake Selenium Science Panel and the Utah Division of Water Quality. The eggs of these species are easily collected and their population sizes are large enough so as not to be affected by egg collections. The modal clutch size of both species is four eggs. Both of these species feed on aquatic invertebrates which 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 have contained breeding bird colonies over the last several years. A single egg was collected randomly from each of 19 nests. In order to randomly select an egg from each nest, eggs within the nest were assigned a number and then one of those eggs was collected after consulting a random number table. Every effort was made to minimize disturbance to the nest and any birds in the vicinity. Eggs were transferred to the laboratory on ice and stored within a refrigerator (1.7 – 3 °C) until they were dissected.

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 (Hoyt 1979):

$$IEM = Kw \bullet L \bullet W^2$$

Kw: weight coefficient for individual species
L: length
W:width

Volumes of the eggs were estimated by the "length-width technique" (Hoyt, 1979):

$$Volume = Kv \bullet L \bullet W^2$$

Kv: volume coefficient for individual species

Eggs were dissected in the laboratory within seven days of collection 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 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. Photographs were taken of each egg and are presented in Appendix 1.

After measurements were taken and eggs dissected, the content of each egg was frozen and shipped with dry ice to an environmental testing laboratory (Brooks Rand Labs, Seattle, Washington; BRL) for total Hg and Se analysis. Following dissection, shells were dried at 21 °C for at least 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 (g) / length (mm) x width (mm)

All egg data including measurements, coordinates and site locations are presented in Table 1.

Water, Sediment, and Invertebrates

Collection sites for environmental samples were located within AMAV and BNST foraging areas. A transect was established within a foraging area and water and sediment collections were made at random points along this transect. Invertebrates were collected opportunistically within the foraging area.

All water samples were collected following the protocol described in EPA's Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Criteria Levels, EPA- 821-R-96-011. Five sediment samples were collected and composited into one sample at both sites. Samples were refrigerated until they were shipped with dry ice to BRL for Se analysis. Mercury was not analyzed in sediment samples.

Invertebrate sweeps were made opportunistically within the foraging area to include the benthos and water column. Invertebrates found in the sweep samples were sorted and their mass recorded in the laboratory following collection. After weighing, invertebrate samples were immediately frozen until they were shipped with dry ice to BRL for total Se and Hg analysis. All data forms can be found in Appendix 2.

Sample Shipping for Laboratory Analysis

Nacole Wilson, from the Avian Ecology Lab, contacted Tiffany Stillwater of BRL to request the delivery address for shipment of all samples. Tiffany inadvertently provided her home address. Consequently, FedEx attempted to deliver seven invertebrate samples, 18 shorebird eggs, and two sediment samples to the residential address when no one was present to accept the shipment. On August 3, 2012 at 2:05 P.M. the samples were finally received but the temperature had warmed to ambient. BRL immediately notified the AEL and UDWQ of the problem and it was decided to re-sample the sediments. The biota samples were irreplaceable and in consultation with UDWQ, it was agreed to proceed with the analyses because both total mercury (Hg) and selenium (Se), are extremely stable in tissue samples at elevated temperatures. The results were none-the-less qualified as estimates in accordance with EPA methodology since the holding time and/or preservation requirements were not met.

RESULTS AND DISCUSSION

We were successful in finding both AMAV and BNST nests during the 2012 season. Five AMAV and four BNST eggs were collected from June 8-28, 2012 at OGBA (Figure 1). On June 11, and 22, 2012 invertebrate sweeps were collected and on June 11, 2012, four water samples and five sediment samples were collected from this site.

Five AMAV and five BNST eggs were collected on June 20, 2012 at ANTI (Figure 1). Invertebrate sweeps were collected on June 20, 29, and July 24, 2012 invertebrate sweeps were collected and on June 20, 2012, four water samples were collected at this site. Five sediment samples were collected on June 29, 2012 from ANTI. The locations of each egg collected are provided in Table 1. Locations for the remaining samples can be found in Appendix 2.

Due to the late nesting of the target species, variable water levels, and high rates of nest predation eggs were occasionally collected from nests before clutches were complete. All of the nine eggs collected from OGBA were from nests with less than 4 eggs. All of the eggs collected from AIC were from nests with the modal clutch size of four.

Egg Breakouts

All eggs were determined to be less than 9 days of age and the stages of development observed were normal. Eleven of the 19 eggs were determined to be viable. Photographs of each egg during dissection are provided in Appendix 1.

Total Egg Selenium and Mercury

Laboratory results for total egg Se showed a mean concentration of 1.46 *µg/g dw* (standard error = 0.110; median = 1.35) at OGBA and 1.51 *µg/g dw* (standard error = 0.152; median = 1.36) at ANTI. These levels are well below the established Se standard of 12.5 *µg/g* dw. In addition, these results are lower than the 4.43 *µg/g* dw Se content reported for AMAV in 2010 at Great Salt Lake (Cavitt et al. 2011), and the 1.56 *µg/g dw* reported at the ANTI site in 2011 (Cavitt and Wilson 2012).

Mean egg Hg concentrations were 0.516 *µg/g dw* (standard error = 0.116; median = 0.415) at OGBA and 0.439 *µg/g dw* (standard error = 0.090; median = 0.30) at ANTI. Table 2 provides Se and Hg concentrations for each egg sampled. Laboratory results are provided in Appendix 2. These values are below the concentrations found within eggs collected at ANTI (0.81 *µg/g dw*) in 2011 (Cavitt and Wilson 2012)

Sediment and Water

Selenium analysis for both ANTI and OGBA sediment samples resulted in concentrations greater than the method detection limit but less than the method reporting limit. Consequently, these results are considered estimates. Sediments collected at the ANTI site were estimated to contain 0.90 *µg/g dw* selenium (% total solids = 53.02) and 0.83 *µg/g dw* selenium at OGBA (% total solids = 66.76).

Two water samples were collected from the ANTI site (41°5'31.43"N, 112°8'3.122"W) in chemically cleaned jars. Samples were collected from water that was approximately 25 cm deep. Water samples for Se analysis resulted in concentrations greater than the method detection limit but less than the method reporting limit. Consequently, these results are considered estimates. The estimated Se content of ANTI water samples were 0.70 *µg/L* and 0.64 *µg/L*. Total Hg for these samples were 0.0611 *µg/L* and 0.0498 *µg/L*.

Two water samples were also collected from the OGBA site in chemically cleaned jars at (41°12'14.02"N, 112°15'0.842"W). The Se analysis resulted in concentrations less than or equal to the method detection limit. Consequently, the result is reported as the method detection limit of 0.349 *µg/L* for both samples. OGBA Hg concentrations were 0.0363 *µg/L* at the sheet-flow and 0.0395 *µg/L* at the second site. Results of all chemical analyses, including field and equipment blanks are found in Appendix 2.

All water samples collected were low and within reported average background levels (USDI 1998). At Kesterson National Wildlife Refuge, where Se toxicity produced high egg mortality and deformities within shorebirds and waterfowl, water Se levels ranged from 15 – 350 *µg/L* (Ohlendorf et al. 1986, Ohlendorf et al. 1988).

Invertebrates

One species of invertebrate, commonly found in the diet of shorebirds (Cavitt 2006) was collected in testable amounts; brine fly larvae (genus *Ephydra*). Brine fly larvae collected at ANTI had Se concentration of 0.83 *µg/g dw* and Hg concentration of 0.14 *µg/g dw.* Brine fly larvae collected OGBA had Se concentration of 0.78 *µg/g dw* and Hg concentration of .157 *µg/g dw.*

Invertebrate Se concentrations are at, or slightly below reported background concentrations. Cavitt (2007) reported concentrations of Se within brine fly larvae at Great Salt Lake from 0.8 to 3.8 *µg/g dw*. Maier and Knight (1994) reported a range of ambient selenium concentrations of 0.5 to 2.0 *µg/g dw* in invertebrates. Lemly (1996a, 1996b) suggests that Se concentrations in bird diets that are greater than 3 *µg/g dw* are above the toxicity threshold for sensitive species.

Figure 1. Map showing the Antelope Island study site in relation to the causeway (ArcGIS Desktop 10, 2010).

Table 1. Egg breakout datasheet for collected AMAV AND BNST eggs including lab ID, site name, coordinates, date collected, number of eggs in the clutch, initial egg mass, egg weight, length and width (breadth), fresh egg mass, egg volume, density, Ratcliff index, shell thickness, dry shell weight, stage of development, and sample weight.

Laboratory ID #	Site Name	LAT (N) DMS	LONG (W) DMS	Date Collected	#of Eggs Clutch	IEM HOYT	Egg Wt (g)	Measurements L & W (mm)		FEM Calc	Egg Vol	Density	Ratcliff Index Wt/(LxW)	Shell (mm)	Dry Shell Wt (mg)	Embryo Stage[a]	Sample wt. (g)
HC-001-12	OGBA	41.20503	-112.252	6/1/2012	2	22.732	21.13	42.97	31.07	19.32	21.16	0.9988	0.015827	14.512	1430	D1/HH3	16.12
AEL-001-12	OGBA	41.19252	-112.259	6/11/2012	1	32.385	30.36	48.05	35.07	27.53	30.14	1.0073	0.018017	18.752	1872	D1/HH3	26.45
AEL-002-12	OGBA	41.20325	-112.253	6/11/2012	1	20.804	19.47	42.98	29.72	17.68	19.36	1.0056	0.015242	13.557	1397	D0	16.83
AEL-003-12	OGBA	41.20342	-112.253	6/11/2012	2	24.059	22.99	44.33	31.47	20.45	22.39	1.0268	0.016480	15.071	1505	D2/HH6	20.28
AEL-004-12	OGBA	41.20352	-112.25	6/11/2012	2	33.588	30.35	47.53	35.91	28.55	31.26	0.9709	0.017782	19.341	1792	D1/HH3	26.45
AEL-005-12	OGBA	41.20365	-112.249	6/11/2012	1	28.200	26.73	46.8	33.16	23.97	26.24	1.0185	0.017224	16.882	2251	D3	23.35
AEL-006-12	OGBA	41.2038	-112.249	6/11/2012	1	34.936	33.41	47.41	36.67	29.70	32.51	1.0276	0.019217	19.985	2084	D0	16.83
AEL-007-12	OGBA	41.20406	-112.249	6/11/2012	1	33.243	30.97	50.79	34.56	28.26	30.94	1.0010	0.017644	18.955	2204	D0+	27.13
AEL-018-12	OGBA	41.19161	-112.258	6/22/2012	1	22.821	20.82	45.12	30.38	19.40	21.24	0.9803	0.015189	14.402	1225	D1/HH3	18.85
AEL-008-12	AIC	41.09212	-112.132	6/20/2012	4	32.858	30.77	48.31	35.23	27.93	30.58	1.0062	0.018079	18.953	2108	D3/HH8	27.53
AEL-009-12	AIC	41.09234	-112.132	6/20/2012	4	21.678	20.58	45.21	29.58	18.43	20.17	1.0201	0.015389	13.843	1373	D7/HH23+	17.53
AEL-010-12	AIC	41.0915	-112.133	6/20/2012	4	21.353	20.18	43.82	29.82	18.15	19.87	1.0155	0.015443	13.775	1382	D5/HH18	17.85
AEL-011-12	AIC	41.09253	-112.134	6/20/2012	4	33.740	29.78	53.23	34.01	28.68	31.40	0.9484	0.016450	19.011	1914	UNK	26
AEL-012-12	AIC	41.09267	-112.135	6/20/2012	4	29.923	27.15	44.6	34.99	25.43	27.85	0.9749	0.017398	17.853	1895	D8/HH25	24.3
AEL-013-12	AIC	41.09307	-112.136	6/20/2012	4	22.227	20.58	44.12	30.32	18.89	20.69	0.9949	0.015384	14.182	1492	UNK	18.47
AEL-014-12	AIC	41.09343	-112.133	6/20/2012	4	22.311	20.1	44.17	30.36	18.96	20.76	0.9680	0.014989	14.214	1238	D6/HH19	18.12
AEL-015-12	AIC	41.09336	-112.132	6/20/2012	4	20.851	19.45	41.28	30.36	17.72	19.40	1.0023	0.015520	13.701	1199	D4+/HH13	17.21
AEL-016-12	AIC	41.09141	-112.133	6/20/2012	4	30.911	27.93	49.52	33.75	26.27	28.77	0.9709	0.016712	17.956	1861	D5+/HH18	25.12
AEL-017-12	AIC	41.09227	-112.133	6/20/2012	4	29.408	26.42	49.85	32.81	25.00	27.37	0.9654	0.016153	17.231	1718	D7/HH23+	24.04

Table 2. Selenium and mercury analysis for Black-necked Stilt egg samples collected in 2012.

Laboratory ID #	Site Name	Se dry (µg/g)	Hg dry (µg/g)	Date Collected	Sample wt. (g)
AEL-002-12	OGBA	2.03	0.747	6/11/2012	16.83
AEL-003-12	OGBA	1.75	0.546	6/11/2012	20.28
AEL-018-12	OGBA	1.47	0.134	6/22/2012	18.85
HC-001-12	OGBA	1.35	0.427	6/1/2012	16.12
AEL-009-12	AIC	1.32	0.328	6/20/2012	17.53
AEL-010-12	AIC	1.31	0.271	6/20/2012	17.85
AEL-013-12	AIC	1.47	0.765	6/20/2012	18.47
AEL-014-12	AIC	1.61	0.7	6/20/2012	18.12
AEL-015-12	AIC	1.43	0.947	6/20/2012	17.21

Table 3. Selenium and mercury analysis for American Avocet egg samples collected in 2012.

Laboratory ID #	Site Name	Se dry (µg/g)	Hg dry (µg/g)	Date Collected	Sample wt. (g)
AEL-001-12	OGBA	1.13	0.295	6/11/2012	26.45
AEL-004-12	OGBA	1.13	0.358	6/11/2012	26.45
AEL-005-12	OGBA	1.29	0.216	6/11/2012	23.35
AEL-006-12	OGBA	1.19	0.297	6/11/2012	16.83
AEL-007-12	OGBA	1.82	0.415	6/11/2012	27.13
AEL-008-12	AIC	1.21	0.197	6/20/2012	27.53
AEL-011-12	AIC	1.29	0.157	6/20/2012	26
AEL-012-12	AIC	2.84	0.589	6/20/2012	24.3
AEL-016-12	AIC	1.4	0.206	6/20/2012	25.12
AEL-017-12	AIC	1.23	0.227	6/20/2012	24.04

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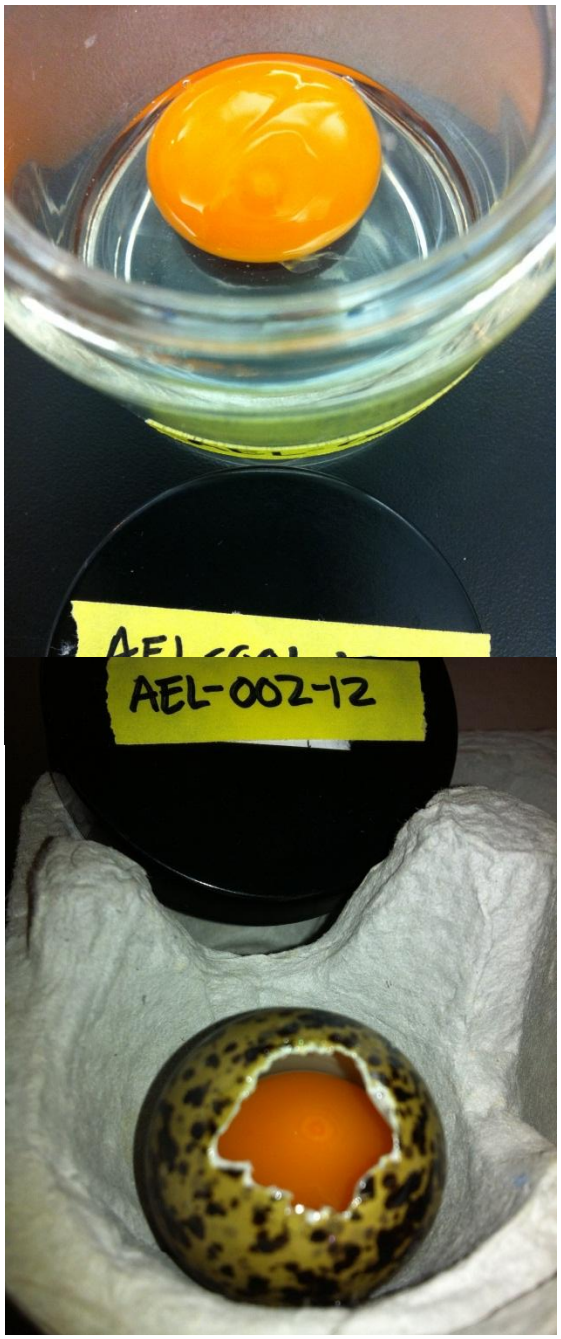
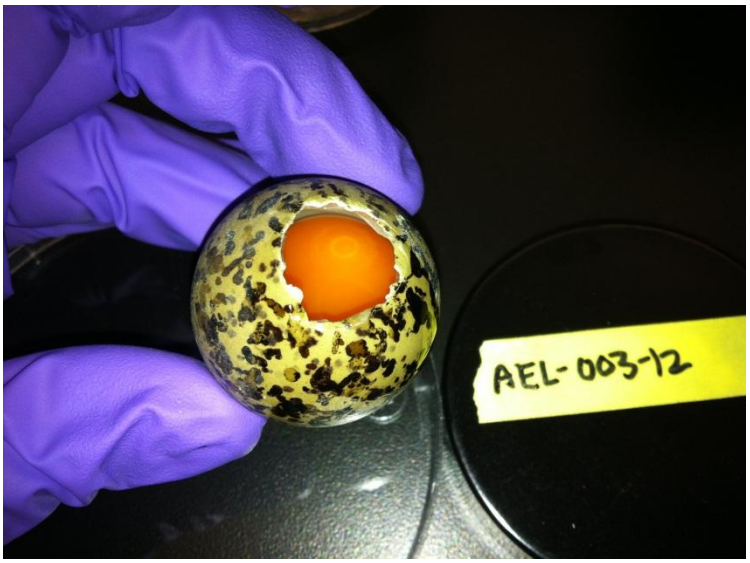
Appendix 1. Egg-breakout photographs of the eggs collected and analyzed for Se and Hg (see text for study sites and descriptions).

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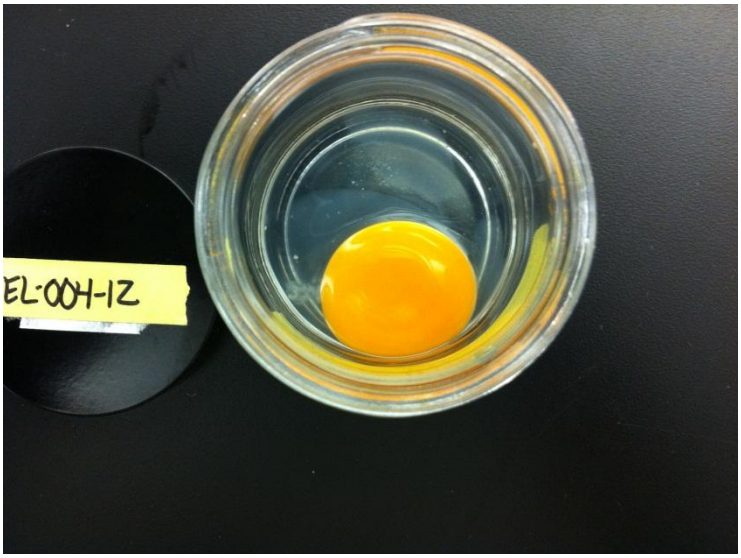
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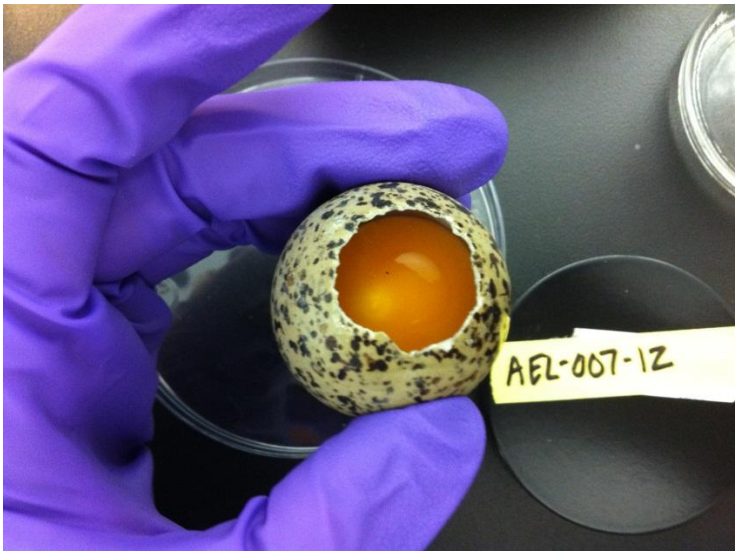
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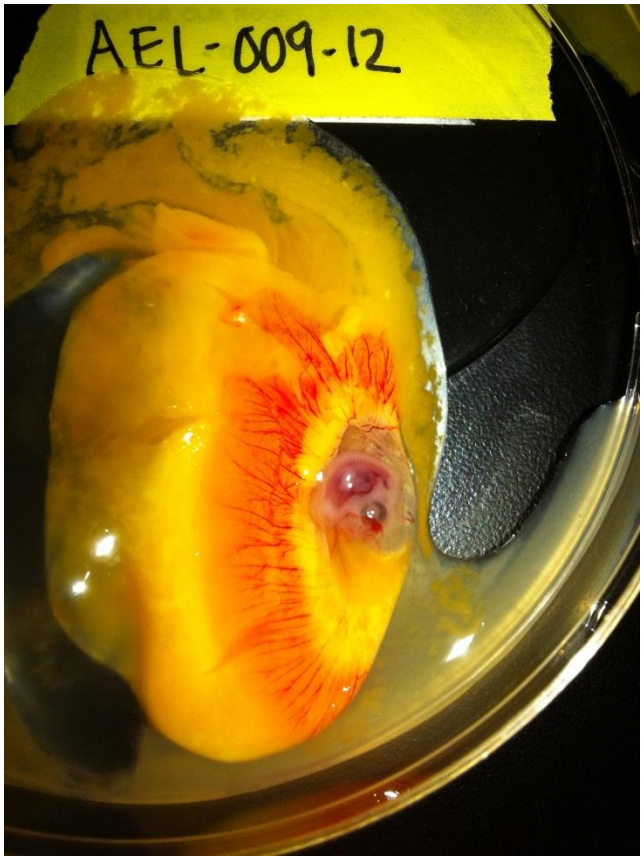

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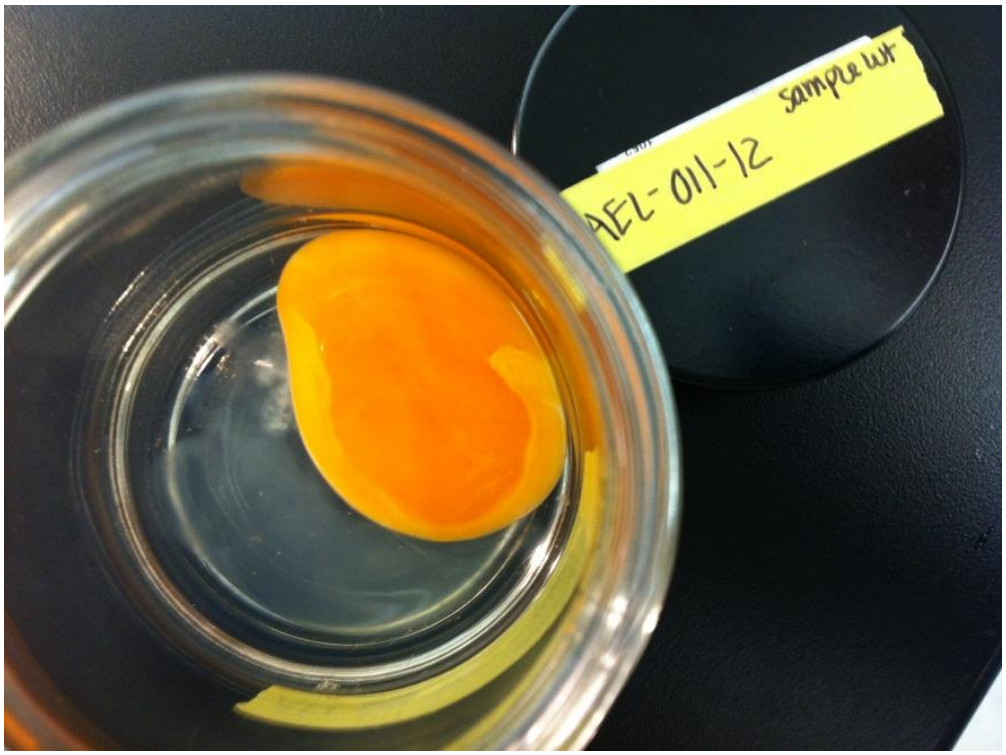

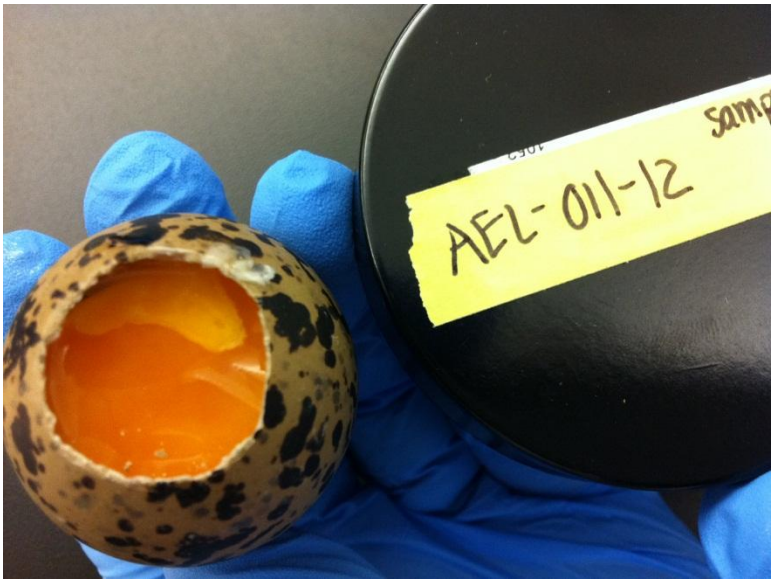
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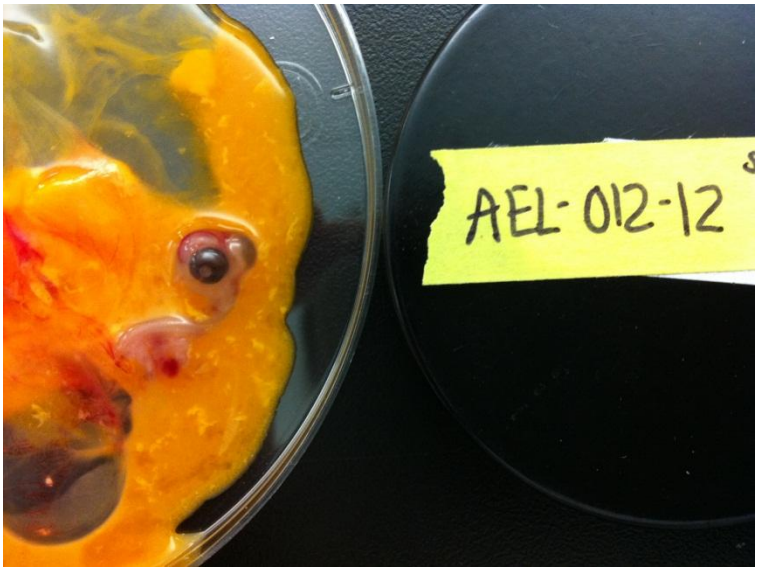
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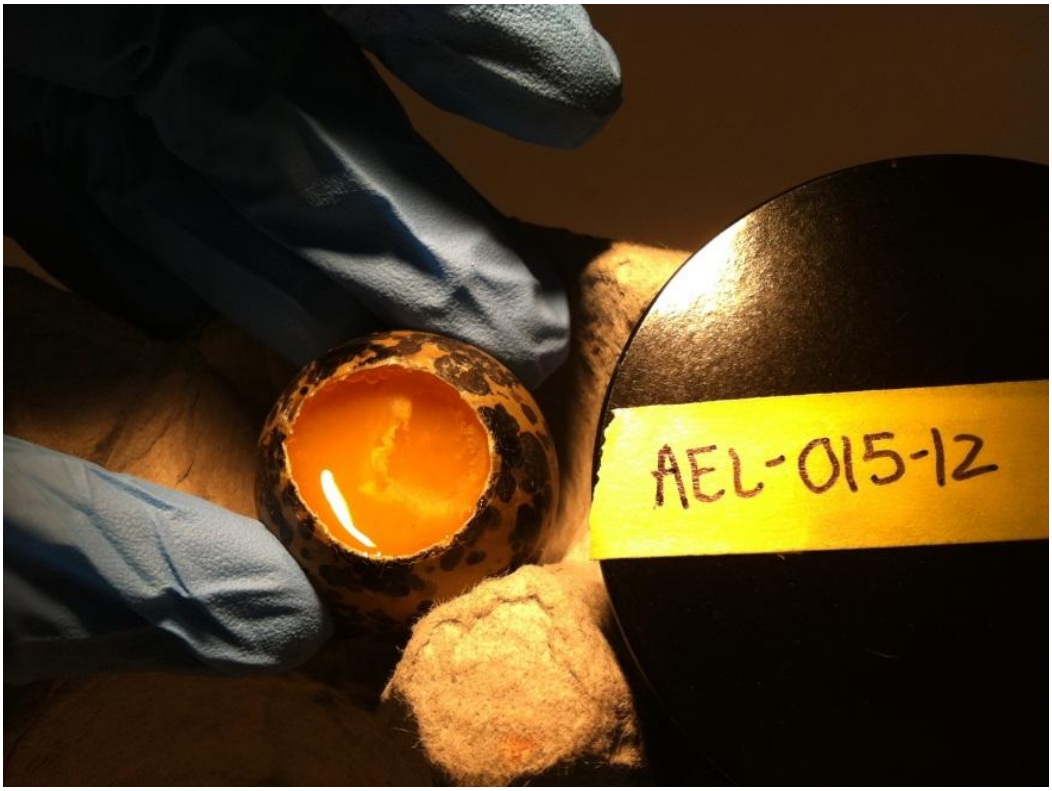
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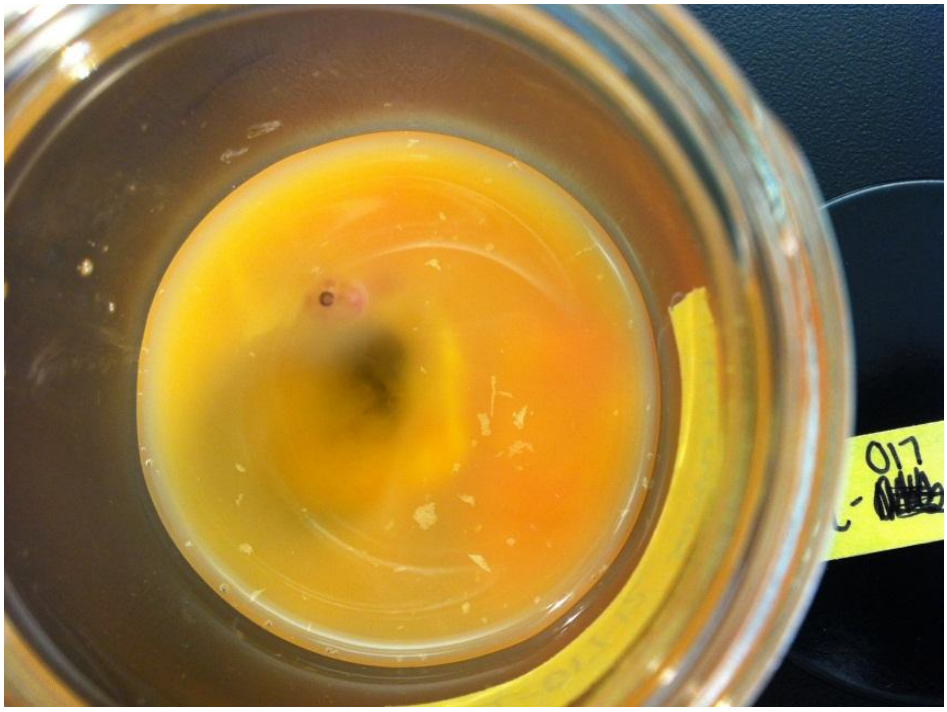

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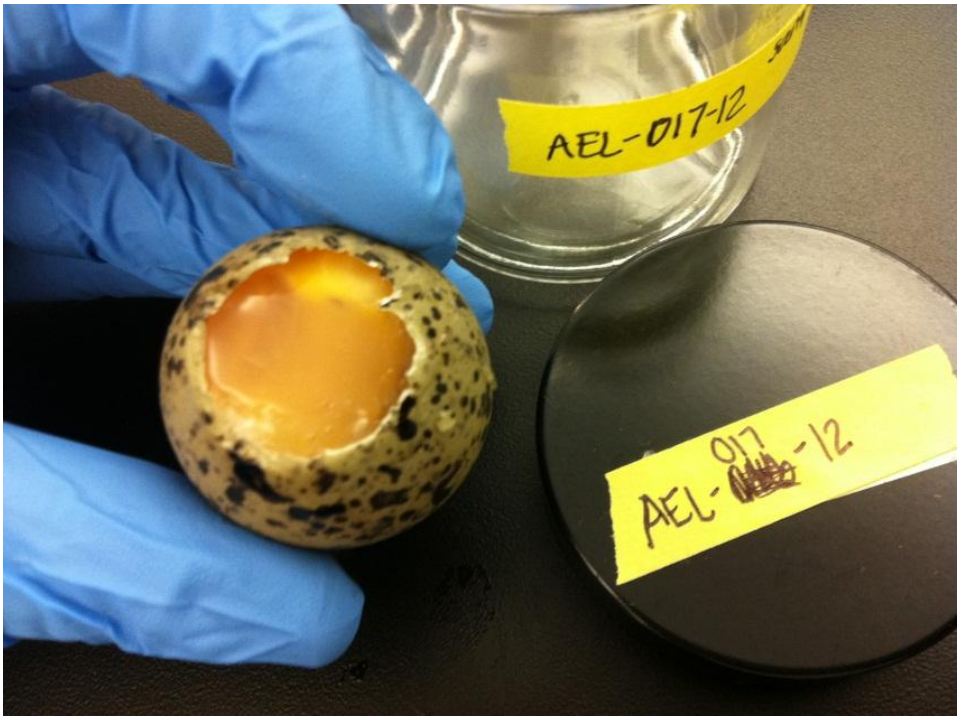

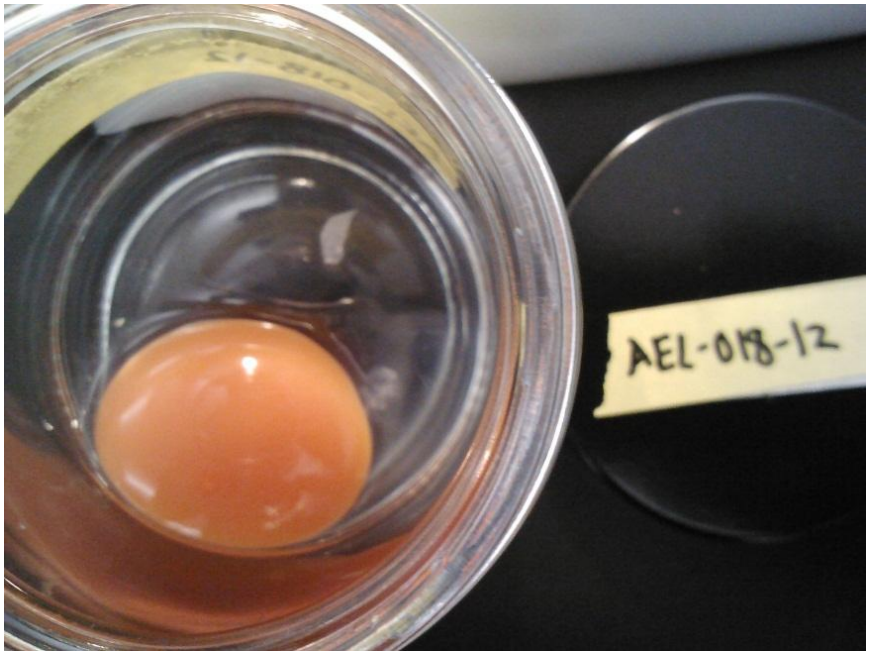
AEL-018-12

HC-001-12

HC-001-12

Appendix 2a Datasheet for water samples collected at OGBA and ANTI including alb ID, coordinates and notes.

Date Collected	Lab ID	Site	Lat (N) DMS	Long (W) DMS	Se (µg/L)	Hg (µg/L)	Notes
6/11/2012	OGBA-01-12	OGBA	41° 12' 14.008"	112° 15' 0.842" W	0.349	0.0363	Hg Sample
6/11/2012	OGBA-02-12	OGBA	41° 12' 14.008"	112° 15' 0.842" W	0.349	0.0395	Se Sample
6/11/2012	OGBA-FB02-12	OGBA	41° 12' 14.008"	112° 15' 0.842" W			Field Blank Se
6/11/2012	OGBA-FB01-12	OGBA	41° 12' 14.008"	112° 15' 0.842" W			Field Blank Hg
6/20/2012	AIC-Se-01-12	ANTI	41° 5' 31.430"	112° 8' 3.122" W	0.699	0.0611	Se Sample
6/20/2012	AIC-Hg-01-12	ANTI	41° 5' 31.430"	112° 8' 3.122" W	0.64	0.0498	Hg Sample
6/20/2012	AIC-Se-FB-12	ANTI	41° 5' 31.430"	112° 8' 3.122" W			Se Field Blank
6/20/2012	AIC-Hg-FB-12	ANTI	41° 5' 31.430"	112° 8' 3.122" W			Hg Field Blank

Appendix 2b Datasheet for sediment samples collected from both OGBA and ANTI including lab ID, coordinates and notes.

Date Collected	Lab ID	Site	UTM E	UTM N	Lat (N) DMS	Long (W) DMS	Notes
6/29/2012	AIC-Sed-01-12	AIC	404393	4549627	41° 5' 32.254"	112° 8' 18.181"	All five samples from ANTI were composited into one sample to be sent to
6/29/2012	AIC-Sed-02-12	AIC	404417	4549640	41° 5' 32.686"	112° 8' 17.160	
6/29/2012	AIC-Sed-03-12	AIC	404454	4549652	41° 5' 33.090"	112° 8' 15.581"	
6/29/2012	AIC-Sed-04-12	AIC	404495	4549667	41° 5' 33.594"	112° 8' 13.832"	
6/29/2012	AIC-Sed-05-12	AIC	404568	4549693	41° 5' 34.468"	112° 8' 10.718"	
6/11/2012	OGBA-Sed-01-12	OGBA	395160	4562138	41° 12' 13.773"	112° 15' 1.567"	All five samples from OGBA were composited into one sample
6/11/2012	OGBA-Sed-02-12	OGBA	395171	4562139	41° 12' 13.811"	112° 15' 1.095"	
6/11/2012	OGBA-Sed-03-12	OGBA	395191	4562139	41° 12' 13.820"	112° 15' 0.237"	
6/11/2012	OGBA-Sed-04-12	OGBA	395217	4562137	41° 12' 13.767"	112° 14' 59.120"	
6/11/2012	OGBA-Sed-05-12	OGBA	395260	4562137	41° 12' 13.788"	112° 14' 57.274"	

Appendix 2c Datasheet for invertebrate species sorted form sweep samples and sent to BRL for total Hg and Se analysis

Date Collected	Lab ID	Site	Content	Se dry wght (µg/g)	Hg dry wght (µg/g)	Mass (wet) g
06/20/2012	AIC-invert-001-12	ANTI	Ephydra Adult Brine Fly	0.83	0.118	34.29
06/29/2012	AIC-invert-002-12	ANTI	Ephydra Larvae	0.68	0.0225	13.69
06/29/2012	AIC-invert-003-12	ANTI	Ephydra Pupae/Casings	0.61	0.0441	3.68
07/24/2012	AIC-invert-12	ANTI	Ephydra Adult Brine Fly	1.2	0.356	198.3
06/22/2012	OGBA-invert-001-12	OGBA	Ephydra Adult Brine Fly	1.27	0.295	73.22
06/11/2012	OGBA-invert-005-12	OGBA	Ephydra Adult Brine Fly	0.28	0.0181	