Development of a Site-specific Standard for Selenium in Open Waters of Great Salt Lake, Utah

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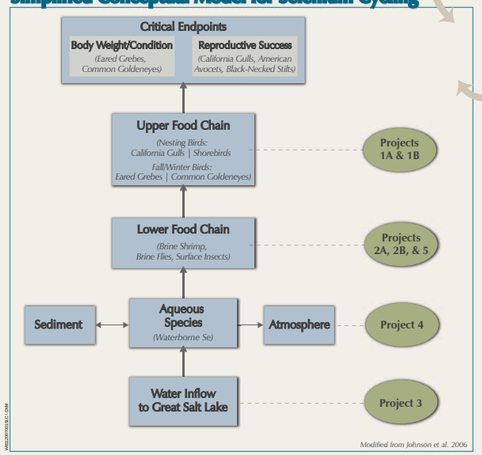
Selenium Program Objectives

Background:
Great Salt Lake (GSL) is a unique terminal lake located adjacent to a rapidly growing metropolitan area in the western United States. The lake is a critical ecological resource as well as an important recreational and mineral resource. The open water of GSL is protected for its current beneficial uses of primary and secondary recreation, aquatic wildlife, and mineral extraction through the application of a narrative criteria clause in the state water quality standards. The Utah Department of Environmental Quality (DEQ), Division of Water Quality (DWQ) initiated a process in 2004 to develop a site-specific numeric water quality standard for selenium for the open waters of GSL to balance protection of GSL's unique ecology and beneficial uses with burgeoning development.

Principal Program Question:
What is the acceptable waterborne concentration of selenium that will be appropriately protective of beneficial uses of GSL water?

Specific Program Questions:
1. What are the transfer factors that describe relationships between selenium concentrations in bird diets and the concentration found in bird eggs?
2. What is the relative importance (based on selenium concentrations and their availability) of various food-chain exposure pathways for aquatic wildlife?
3. Are significant ecological effects occurring in aquatic wildlife? If so, to which ones and at which locations? What are the associated selenium concentrations in tissues (including bird blood, liver and eggs)?
4. What are the sources of waterborne selenium entering GSL, and what is the relative significance of each of the various sources?
5. What are the most important processes that affect the partitioning, cycling, and release of selenium in GSL open waters?

Simplified Conceptual Model for Selenium Cycling



- Reviews objectives
- Determines final scope of project
- Agrees on sampling and analytical methodology
- Reviews existing data
- Develops water quality standard methodology for GSL
- Recommends additional research
- Forwards recommendations to Steering Committee

Steering Committee

- Develops draft objectives
- Develops draft process chart
- Develops draft organizational chart
- Works by consensus
- Forms the Science Panel

Aug 2004

Science Panel

- Contracts with outside private entities to complete data collection and analysis
- Periodically updates Water Quality Board on progress

Steering Committee

- Evaluates Science Panel recommendations
- Forwards Science Panel research requests and recommendations to DWQ
- Secures funding to support research

Dec 2005

Division of Water Quality

Mar 2006

CH2M HILL/ CWECS

- Performs additional research/monitoring, literature search and review
- Presents results to UDWQ/Science Panel

Science Panel evaluates new data/old data and provides recommendations for numeric standards

Science Panel

Nov 2007

Steering Committee

- Steering Committee evaluates Science Panel recommendations
- Forwards final recommendations to DWQ

Feb 2008

UDWQ prepares recommendations to go to Board

Division of Water Quality

Division of Water Quality

- Board approves/disapproves recommendations
- Approved recommendations forwarded to EPA

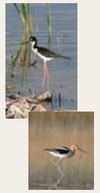
EPA approves final numeric standards

EPA

Dec 31, 2008

Great Salt Lake Selenium Projects

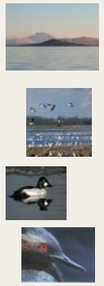
PROJECT 1A
Concentration and Effects of Selenium in Shorebirds



Principal Investigator: *Dr. John Cavitt/Weber State University*
Technical Advisor: *Gary Santolo/CH2M HILL*

Project-Specific Questions:
1. What is the diet of American avocets and black-necked stilts at GSL?
2. What is the ambient concentration of selenium in the water and macro-invertebrates consumed by shorebirds?
3. What is the concentration of selenium within the liver and blood of American avocets and black-necked stilts?
4. What is the concentration of selenium within the eggs of American avocets and black-necked stilts?
5. What is the hatching success of American avocet and black-necked stilt eggs?

PROJECT 1B
Concentration and Effects of Selenium in Gulls, Grebes, and Ducks



Principal Investigators: *Dr. Mike Conover/Utah State University, Clay Perschon/Utah Division of Wildlife Resources*
Technical Advisor: *Gary Santolo/CH2M HILL*

Project-Specific Questions:
1. Where do California gulls nest and forage within GSL?
2. What is the diet of nesting California gulls?
3. What are the ambient selenium concentrations in the water, sediment, and diet items at the foraging sites of nesting California gulls in GSL?
4. What are the associated selenium concentrations in nesting California gulls (blood and liver), a random sample of gull eggs, gull eggs with dead or abnormal embryos, and deformed gull chicks?
5. What are selenium concentrations in adult eared grebes staging on GSL when they first arrive and right before they leave, and how does body condition of grebes relate to selenium concentrations in their tissues?
6. What are selenium concentrations in overwintering ducks (adult male common goldeneye), and how does body condition of ducks relate to selenium concentrations in their tissues?
7. At which locations in GSL are high selenium concentrations in tissues associated with high ambient selenium concentrations?

PROJECT 2A
Synoptic Survey of Selenium in Periphyton and Brine Fly Larvae from the Benthic Zone of Great Salt Lake

Principal Investigators: *Dr. Wayne Wurtsbaugh/Utah State University*
Technical Advisor: *Dr. Earl Byron/CH2M HILL*

Project-Specific Questions:
1. What the respective larval and pupal brine fly densities on mud, sand, and stromatolite substrates?
2. What are the ambient selenium concentrations in the water and sediment at the selected sampling sites in the GSL?
3. What are the associated concentrations of selenium in the periphyton/detrital material and in the brine flies?

PROJECT 2B
Synoptic Survey of Selenium in Water, Seston, and Artemia

Principal Investigator: *Brad Marden/Parliament Fisheries*
Technical Advisor: *Dr. Earl Byron/CH2M HILL*

Project-Specific Questions:
1. What are the concentrations of selenium in GSL water, seston, and Artemia tissue?
   a) What is the correlation between waterborne concentrations of selenium and levels found in seston and Artemia?
   b) What is the potential dietary selenium risk to avian species from consuming Artemia?
2. What are the temporal and spatial patterns of isotopic carbon (^{13}C) and nitrogen (^{15}N) in particulate organic matter (POM) and Artemia tissue?
   a) Do ^{13}C and ^{15}N correlate with selenium concentrations in POM and Artemia?
   b) Do selenium, ^{13}C, and ^{15}N in Artemia correlate with seston (i.e., phytoplankton abundance)?
   c) Do the stable isotope fractions in diet indicate discrete sources of selenium that account for Artemia tissue levels of selenium? Do the sources supporting the Artemia body-burdens of selenium vary seasonally?
3. What are the population size, age-structure, and biomass of Artemia in GSL?
   a) What is the total selenium load in GSL Artemia population?
   b) How do changing Artemia tissue concentrations of selenium and the abundance of adults or cysts correlate with avian consumers and avian seasonality and nesting at GSL?

PROJECT 3
Measurement and Modeling of Selenium Loads to Great Salt Lake

Principal Investigators: *Dr. David Naftz/U.S. Geological Survey, Dr. Bill Johnson/University of Utah*
Technical Advisor: *Dr. Earl Byron/CH2M HILL*

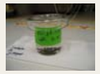
Project-Specific Questions:
1. What are the selenium loads to GSL from inflows to the lake?
2. What is the quantity of water inflow and selenium concentration from the following sources of inflow to GSL: North Arm of GSL, Bear River, Weber River, Farmington Bay, Lee Creek, Goggin Drain, and KUCC Outfall? Flow gages to be installed at all locations.
3. In combination with Project 4, what is the selenium budget for GSL?

PROJECT 4
Measurement of Selenium Flux in Great Salt Lake

Principal Investigators: *Dr. David Naftz/U.S. Geological Survey, Dr. Bill Johnson/University of Utah*
Technical Advisor: *Dr. Earl Byron/CH2M HILL*

Project-Specific Questions:
1. What are the rates of volatilization and ebullition for selenium from GSL?
2. What is the rate of permanent sequestration of selenium via sedimentation?
3. Do transient suspension events re-suspend and re-solubilize selenium into the water column to an extent that has biological significance?
4. Do lake level rises re-introduce selenium into the water column to an extent that has biological significance?

PROJECT 5
Predictions of Selenium Accumulation in Artemia franciscana under Conditions Realistic for the Populations Residing in Great Salt Lake

Principal Investigators: *Dr. Martin Grosell/University of Miami*
Technical Advisor: *Dr. David Buchwalter/North Carolina State University*

Project-Specific Questions:
1. What are the transfer factors for selenium from water and algae to the brine shrimp component of the food web as determined under laboratory conditions?
2. What is the influence of salinity on selenium uptake and feeding rate by brine shrimp?
3. What are the uptake kinetics, assimilation efficiencies, and elimination rates for brine shrimp in artificial GSL water and shrimp fed a diet of selenium-loaded algae cells?
4. What is the "knee" of the dissolved selenium accumulation rate curve in brine shrimp?
5. How can we predict how selenium will accumulate in brine shrimp during realistic exposure scenarios?

Great Salt Lake Sampling Locations and Study Area