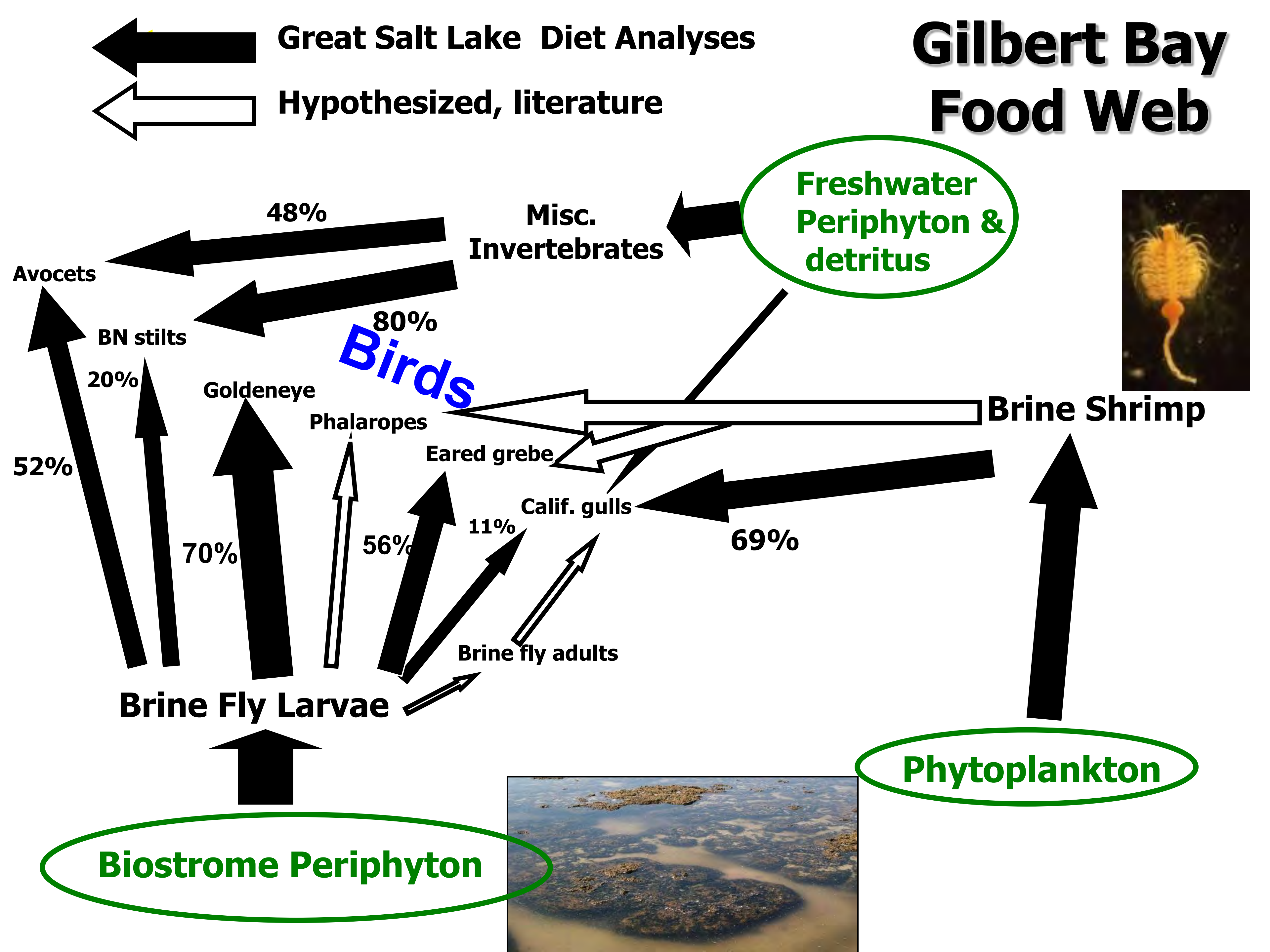
Mercury in the Pelagic and Benthic Food Webs of the Great Salt Lake

Wayne Wurtsbaugh, Erin Fleming & Caleb Izdepski
Dept. Watershed Sciences, Utah State Univ.

Jodi Gardberg
Utah Division of Water Quality

Great Salt Lake Technical Team – July 20, 2011


Gilbert Bay
Food Web
Great Salt Lake Diet Analyses
Hypothesized, literature
Freshwater Periphyton & detritus
Misc. Invertebrates
48%
80%
Avocets
BN stilts
20%
52%
Goldeneye
Birds
Phalaropes
Eared grebe
Calif. gulls
70%
56%
11%
69%
Brine Shrimp
Brine fly adults
Brine Fly Larvae
Biostrome Periphyton
Phytoplankton

Draft report with provisional data: do not cite.

Do Brine Shrimp Bioaccumulate Methylmercury From the Deep Brine Layer of the Great Salt Lake?

Erin Fleming and Wayne Wurtsbaugh

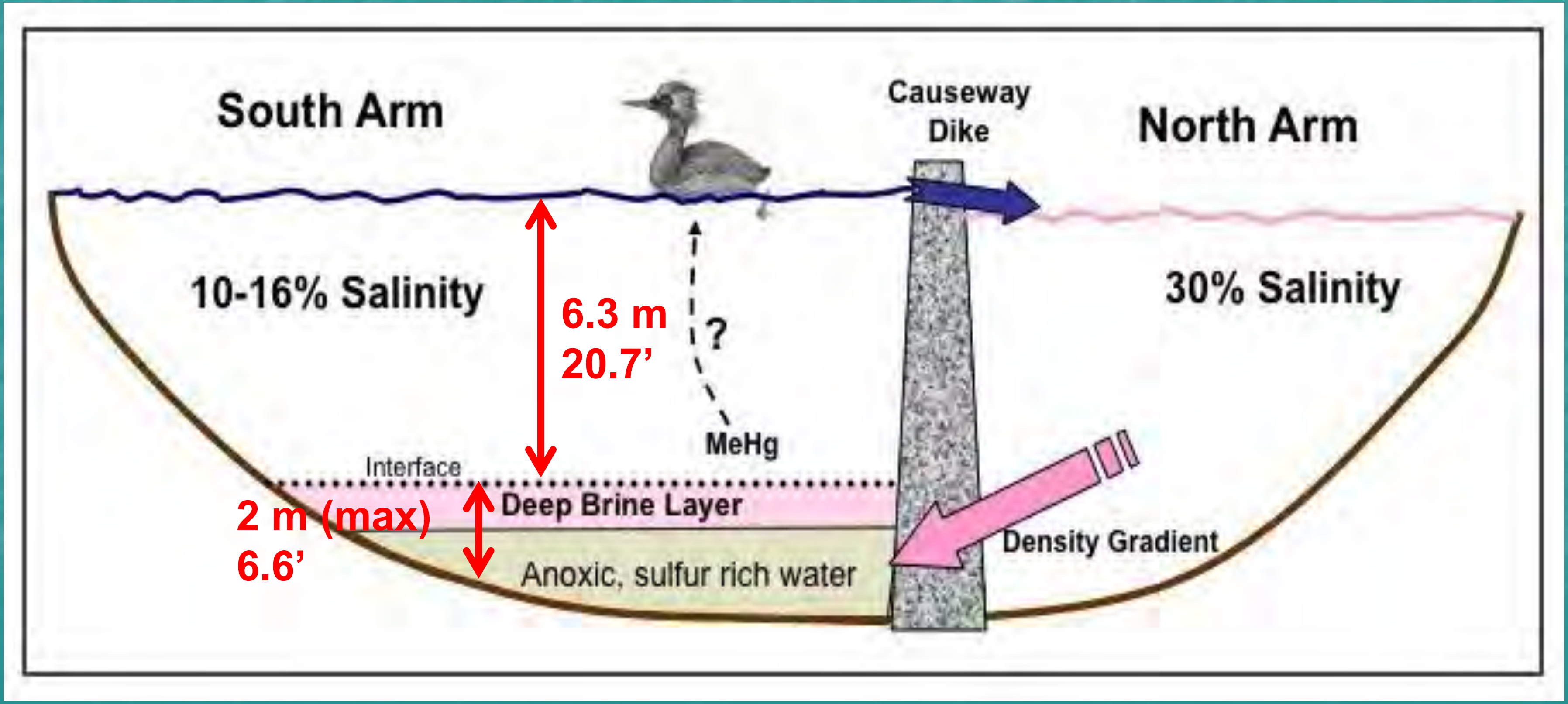
Department of Watershed Sciences

Utah State University

Project Funded by

The Division of Forestry, Fire & State Lands

Formation of the Deep brine layer (Monimolimnion)



Distinctive microbial community in anoxic, sulfide-rich waters

Photosynthetic purple-sulfur bacteria from 6.5 m
(not present in recent years)

Photo, April 1987

• Background

- Although there is normally insufficient light for photosynthesis, the deep brine layer is extremely rich in sedimenting organic material
- Total mercury, and especially methyl mercury, is extremely high in deep-brine layer (Naftz et al. 2008)
- Because of the high density water, the deep-brine layer has limited ability to mix into the upper mixed layer. However, some limited mixing is expected, but the amount is unknown.

- **Objectives**

- **Determine if brine shrimp graze at the interface of the deep brine layer and take up mercury from that layer**

- **Determine whether mercury uptake by shrimp is enhanced if deep brine layer is mixed into the upper layer**

Study Design

- Measure profiles of mercury and relevant limnological parameters in an area of Gilbert Bay underlain by the deep brine layer

- Measure mercury uptake of brine shrimp in mesocosms that simulated a water column with, and without, a deep brine layer

- Measure mercury uptake in brine shrimp when deep brine layer water is mixed with surface water

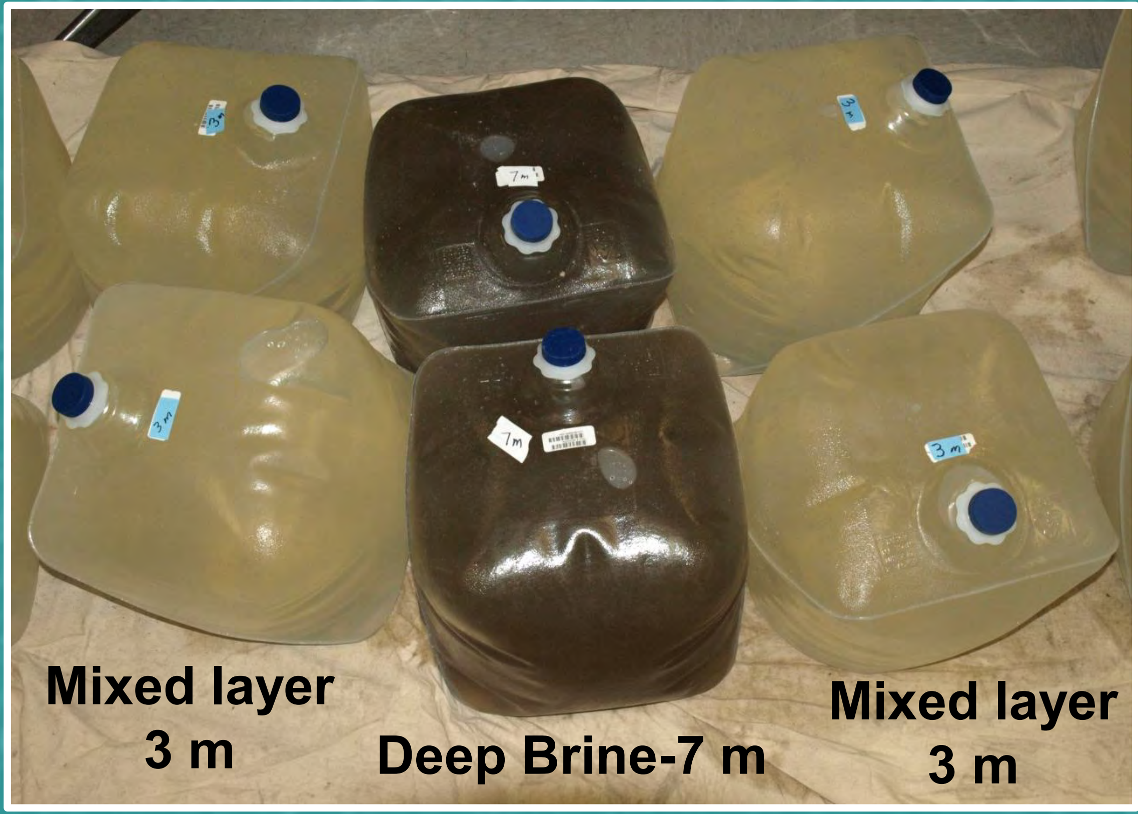
- Preliminary measurements & experiments in 2009, more detailed ones in 2010

Field study (2010)

Pumped water from specific depths For chemical analyses & brine shrimp counts

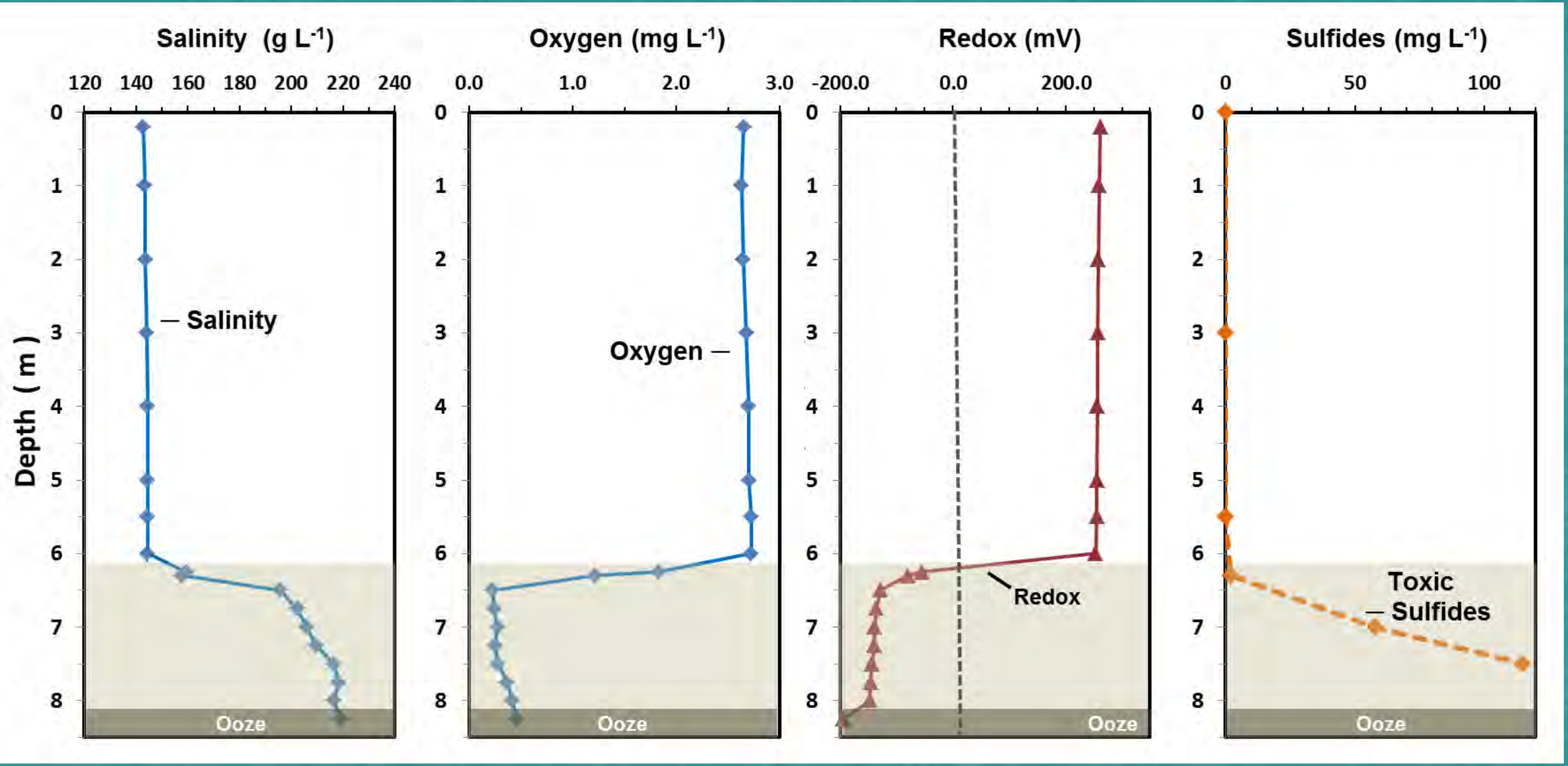
Collected water for laboratory experiments

Deep Brine Water Characteristics

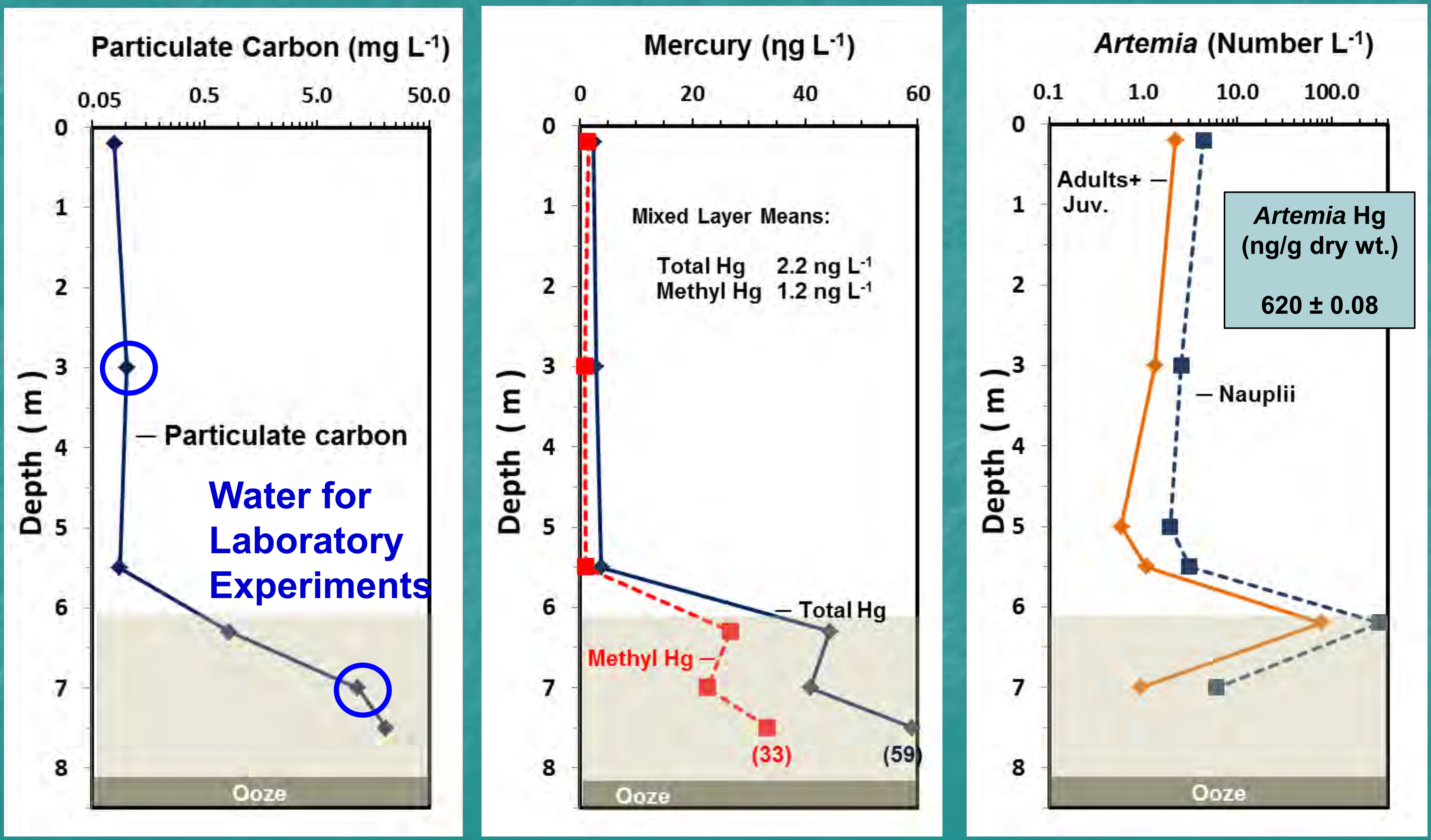


- High organic matter
  - Particulate
  - Dissolved organic carbon (DOC)
    3 m – 42 mg C/L
    7 m – 53 mg C/L
  - DOC binds with and maintains mercury in solution
- Anoxic
- H_2S – rich (toxic)
  - Sulfide reduction linked to production of methyl mercury
- High mercury, especially methyl mercury

Field study (August 3, 2010)



Field study (August 3, 2010)

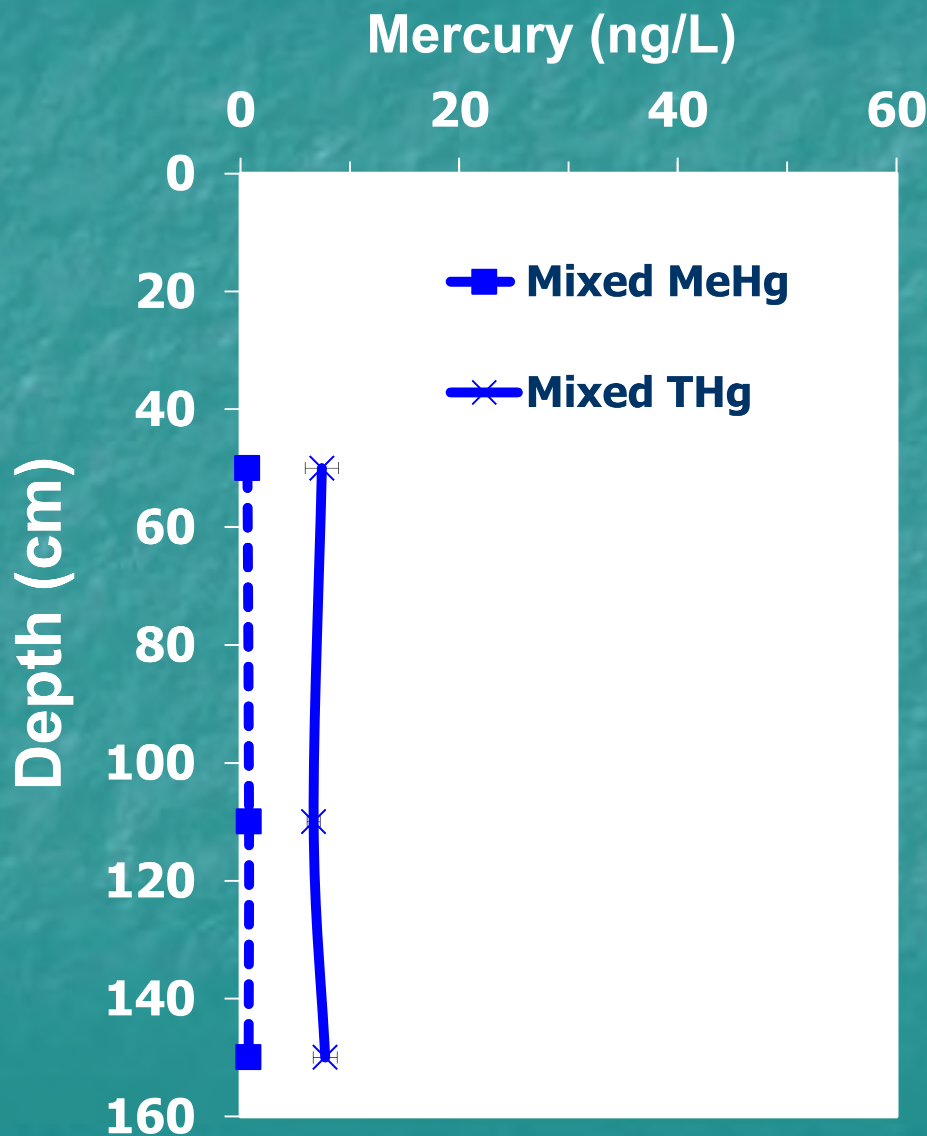


Vertical stratification simulation Experimental Design:

- Six, 46-L columns
- 3 columns with deep brine water, 3 without
- 18:16 light:dark regime to promote photosynthesis
- 27°C
- 10 *Artemia* nauplii/L
- 14 day-long experiment
  Artemia grew from 1-mm to maturity (~9 mm)

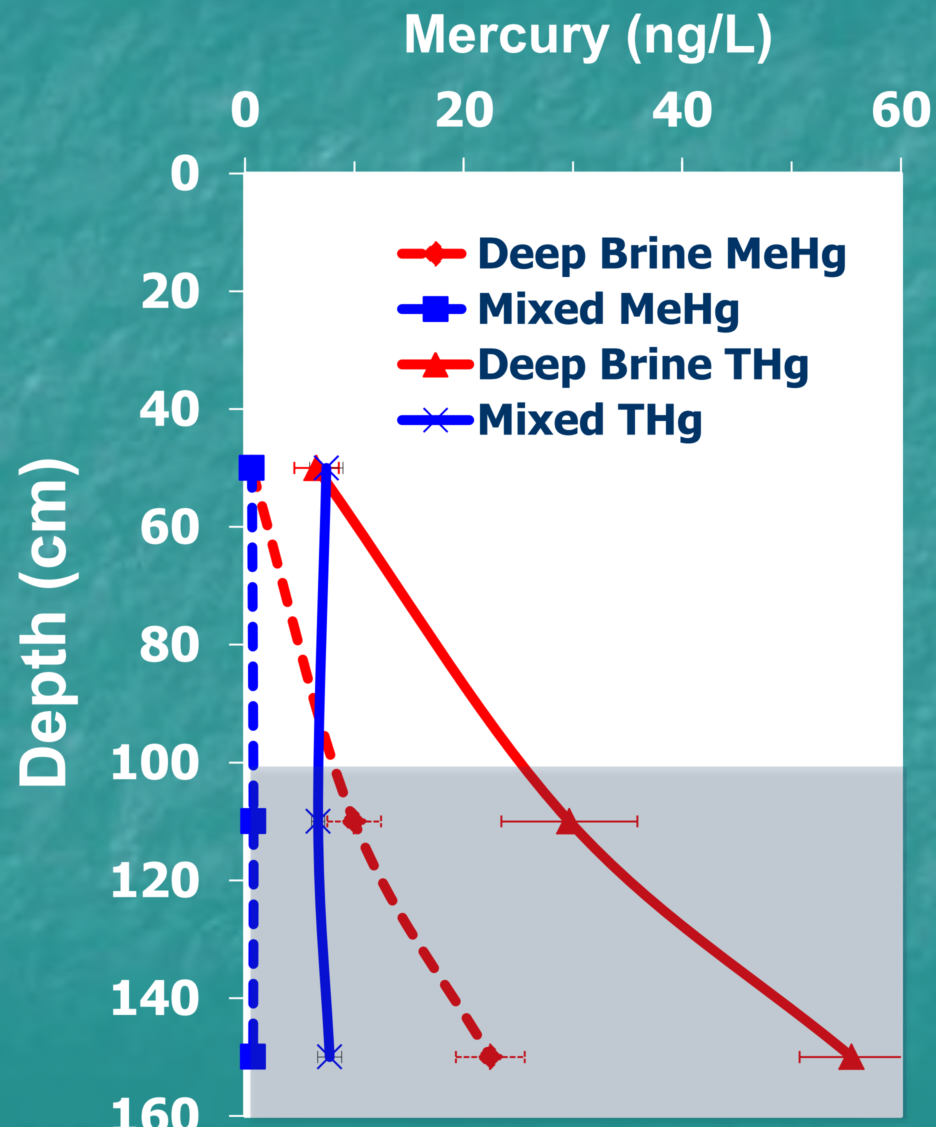
Mercury concentrations in columns

- **Mixed columns**
  - **Uniform Concentrations**
  - **Methyl Hg – 0.7 ng/L**
  - **Total Hg – 7.3 ng/L**

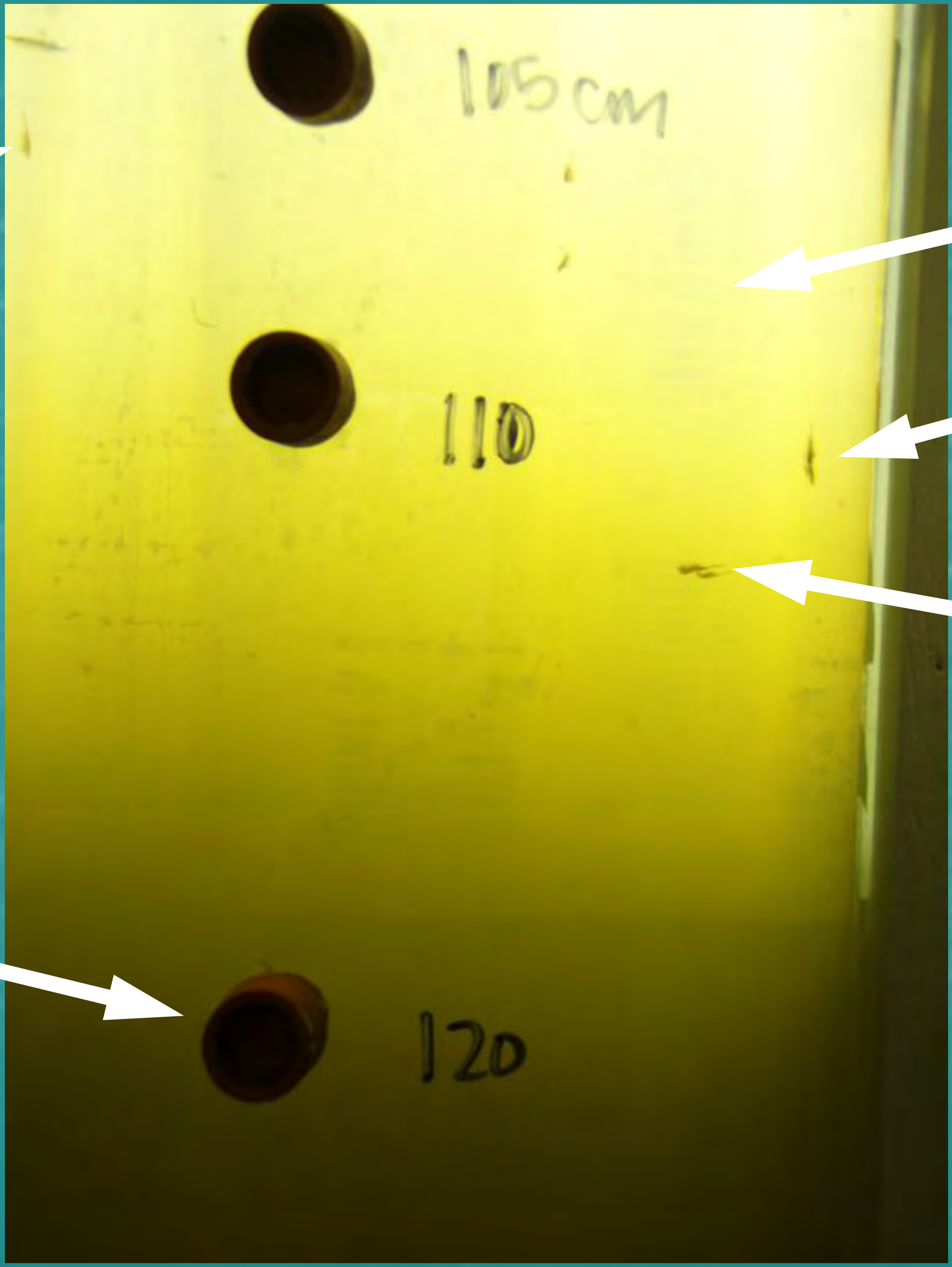


Mercury concentrations in columns

- **Mixed columns**
  - **Uniform Concentrations**
  -
- **Deep-brine columns: High Hg in deeper water**
  - **Methyl Hg**
    - **1-22 ng/L**
  - **Total Hg**
    - **6-56 ng/L**



Brine shrimp feeding in the deep-brine interface



Shrimp

Interface

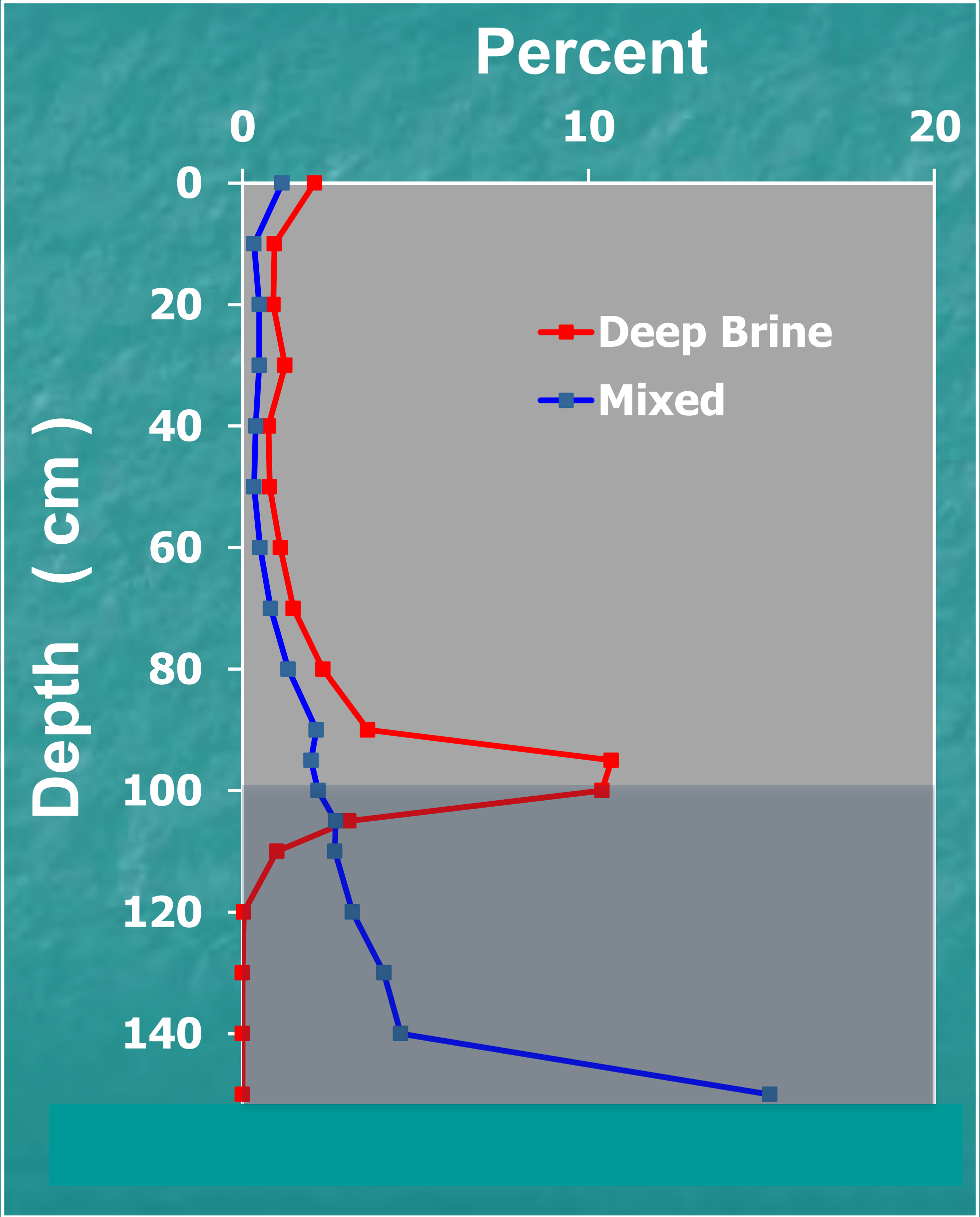
Shrimp

Mating shrimp pair

Sampling Port

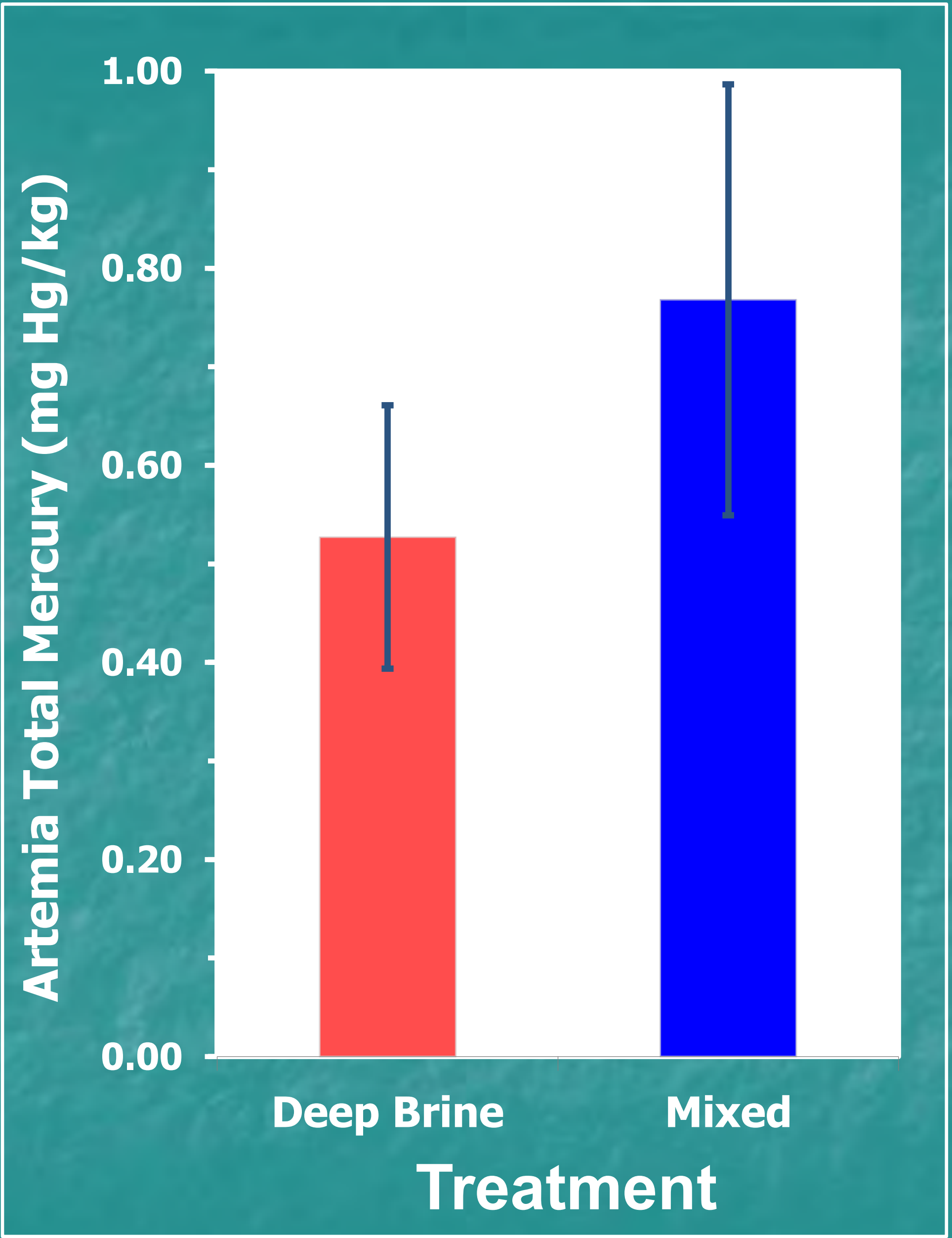
Artemia Distribution in columns

- **Shrimp concentrated at top and bottom in mixed-layer treatments**
- **They concentrated at deep-brine interface in the stratified columns**



Mercury in brine shrimp adults

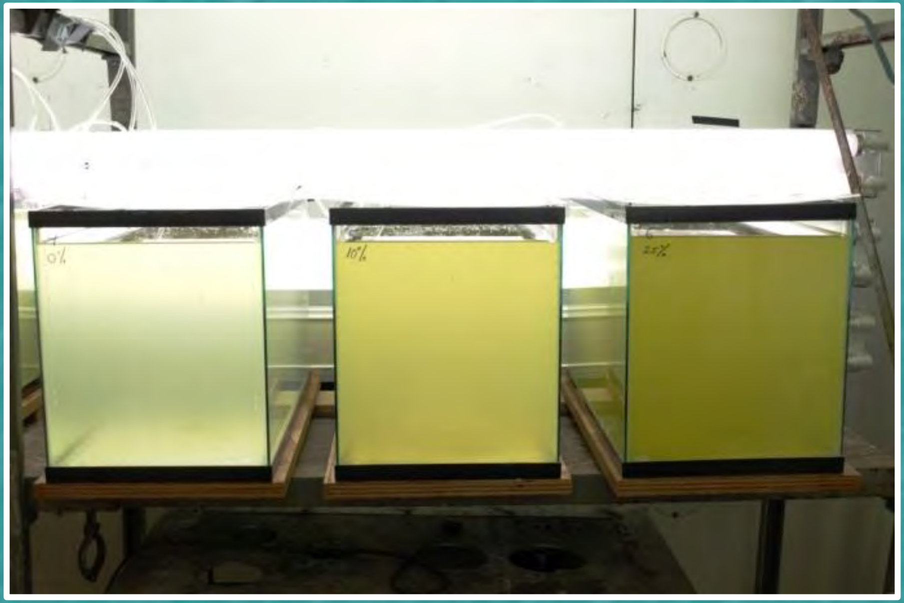
- **At end of experiment brine shrimp in deep brine treatment had significantly lower levels of mercury, despite exposure to higher mercury levels!**



(t-test, p=0.05)

Mixing simulation experiment in 34-L aquaria

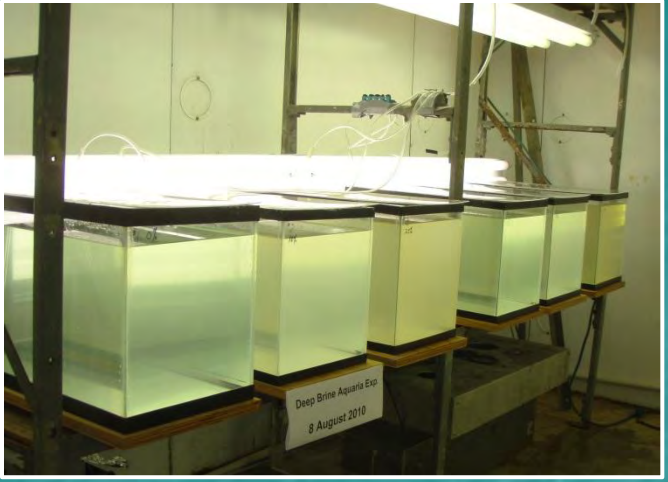
- Three treatments (2 replicates each)
  - 0% deep brine; 100% mixed-layer
  - 10% deep brine; 90% mixed
  - 25% deep brine; 75% mixed



0% 10% 25%
Deep Brine Water

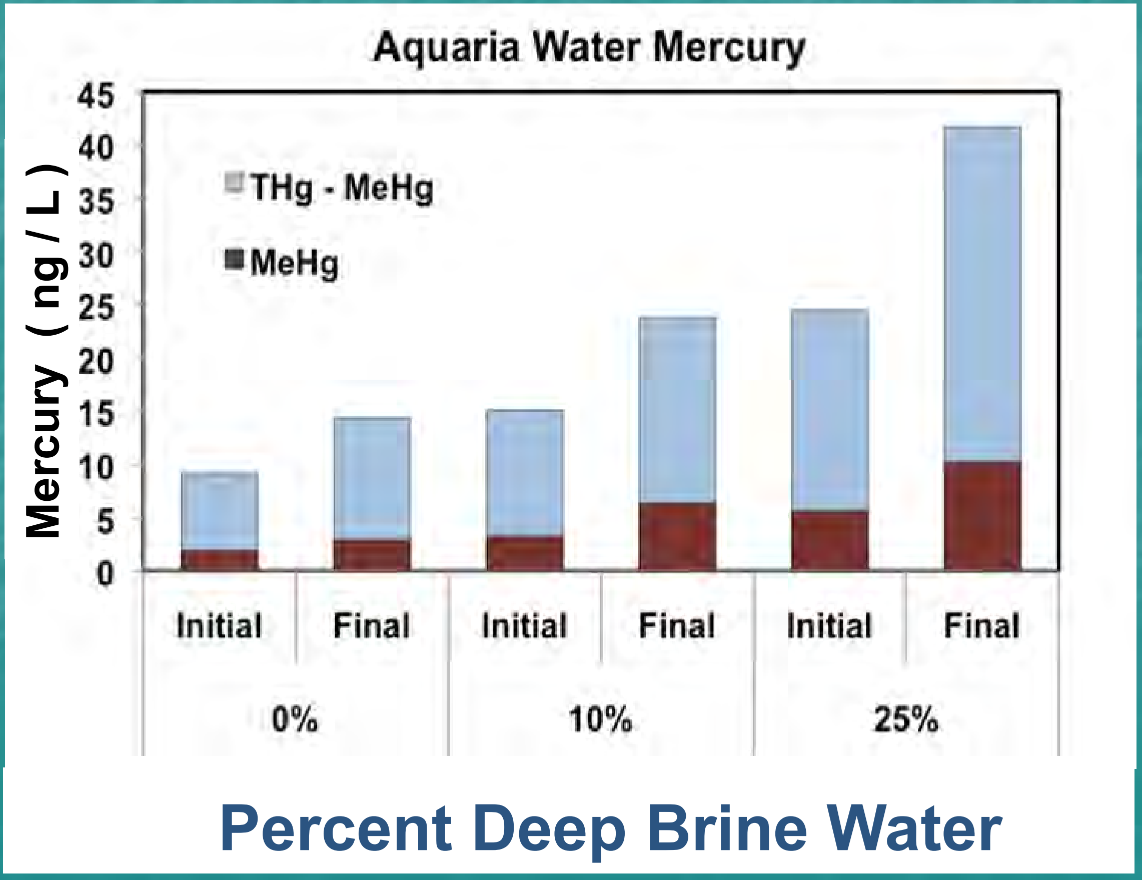
- 18:16 light:dark
- 27°C
- 10 *Artemia* nauplii/L
- 14 day-long experiment (*Artemia* grew to maturity)
- Aerated initially for 1 day to remove H_2S; 1 hr/day subsequently

Mixing simulation



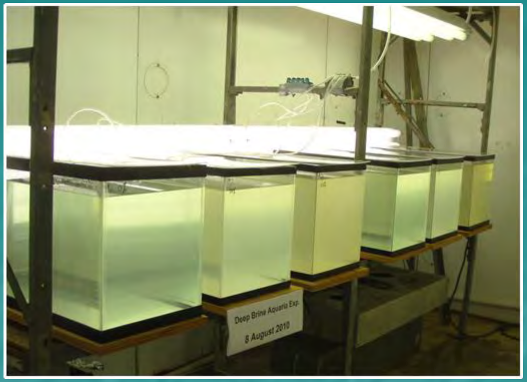
- Significantly higher mercury in treatments with more deep brine water

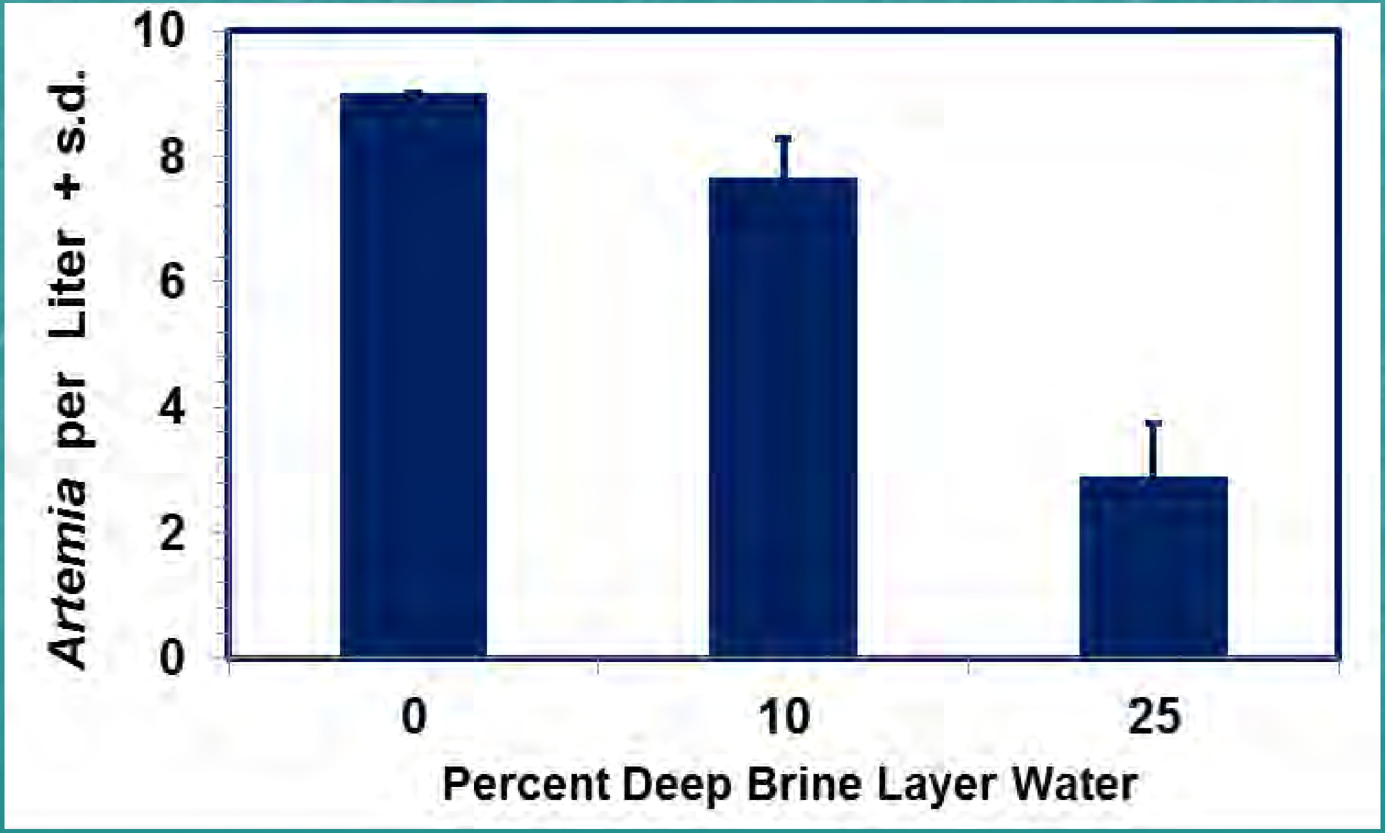
- Increasing mercury from beginning to end of experiment
- (due to contamination from aeration?)



Poor *Artemia* survival after 14 d in treatments with higher proportions of deep-brine water. Toxic factor unknown

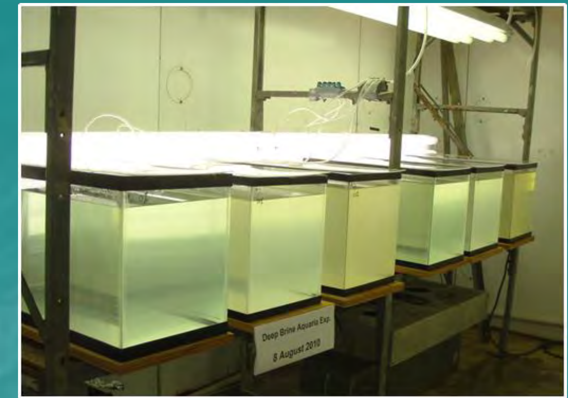
(Hg?, Other metals? Organic compounds?)

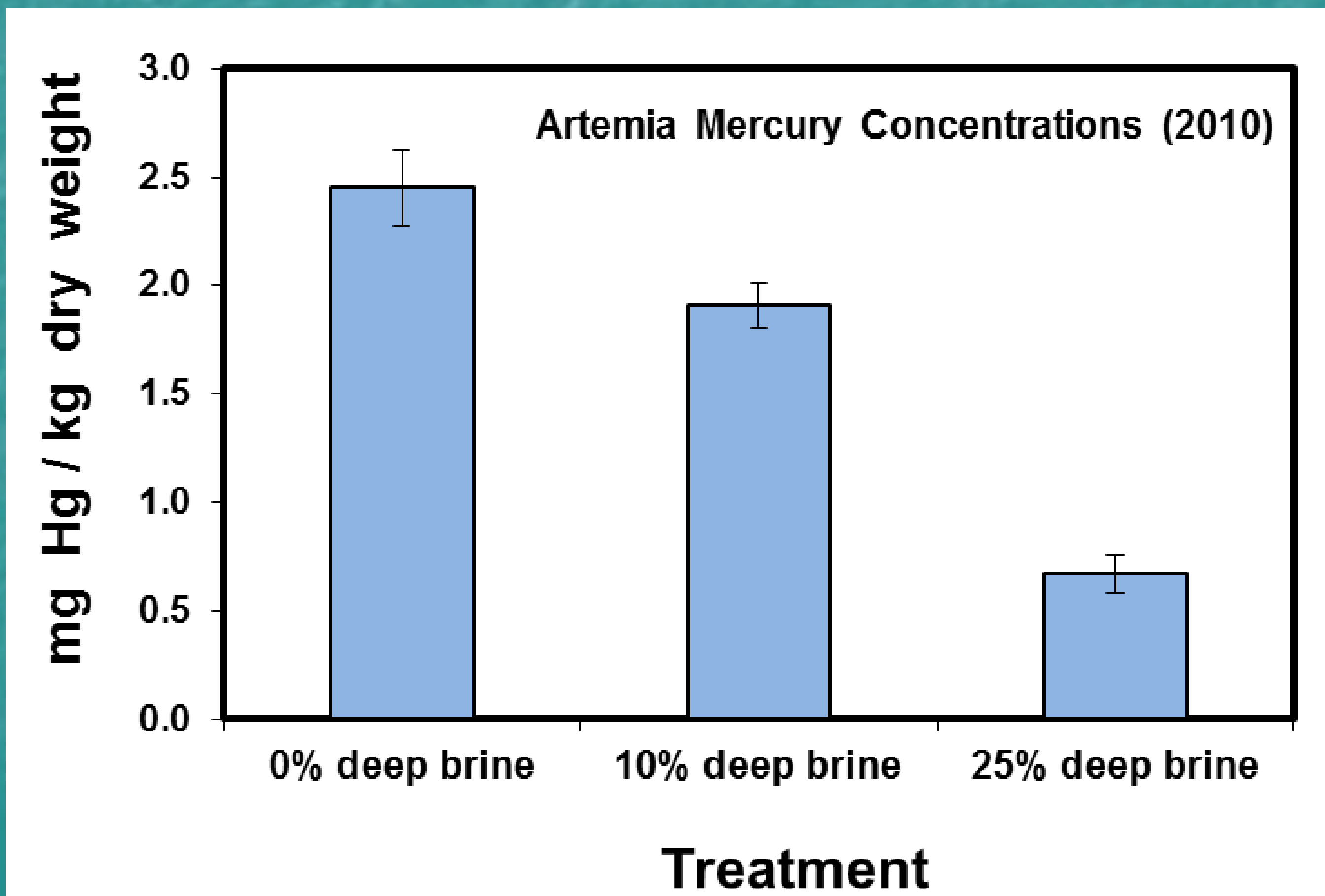




ANOVA: p = 0.002

But, <u>lower</u> mercury levels in *Artemia* in treatments with more deep-brine water (higher mercury concentrations)!





ANOVA; $p < 0.000$

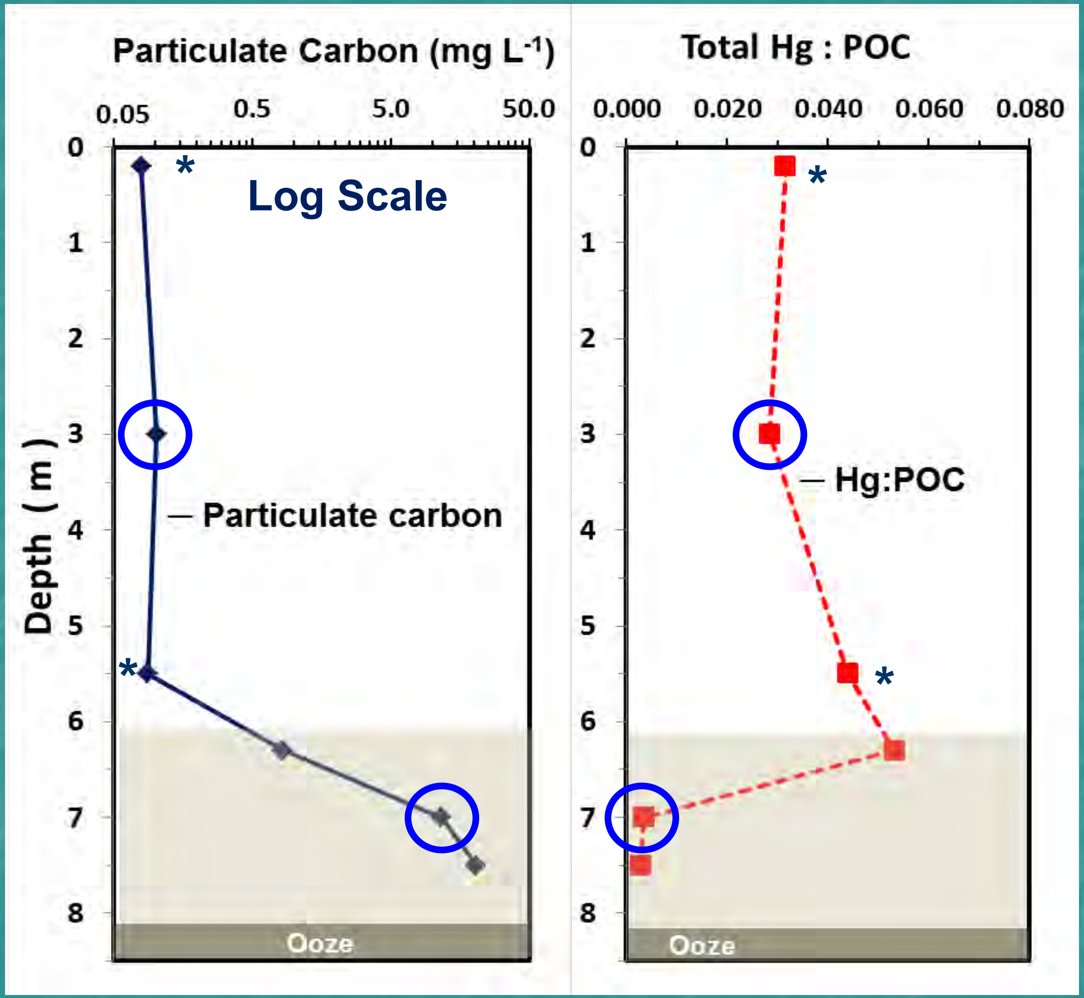
Conclusions for Deep Brine Layer Experiments

- *Artemia* enter upper layer of deep brine layer, but do not penetrate far
- In Column Experiment, growth and survival unaffected by presence of deep brine layer
- In Aquaria Mixing Experiment, survival much lower in treatments with deep brine layer water: toxic component unknown

Conclusions for Deep Brine Layer Experiments

In both experiments mercury concentrations in *Artemia* were significantly lower when exposed to deep brine layer water with high methyl and total mercury concentrations

Likely explanation:
High particulate carbon concentrations in deep brine layer dilutes the mercury shrimp are consuming

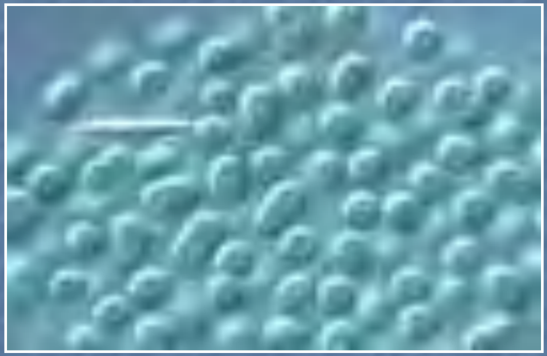


* 0.2 and 5.5 m values estimated based on chlorophyll a and Chl a:POC ratios

○ Depths of water used in lab experiments

Mercury and selenium bioaccumulation in the stromatolite community of the Great Salt Lake, Utah, USA

Wayne Wurtsbaugh[1], Jodi Gardberg[2], Caleb Izdepski[1]
[1]Utah State University; Utah DWQ[2]



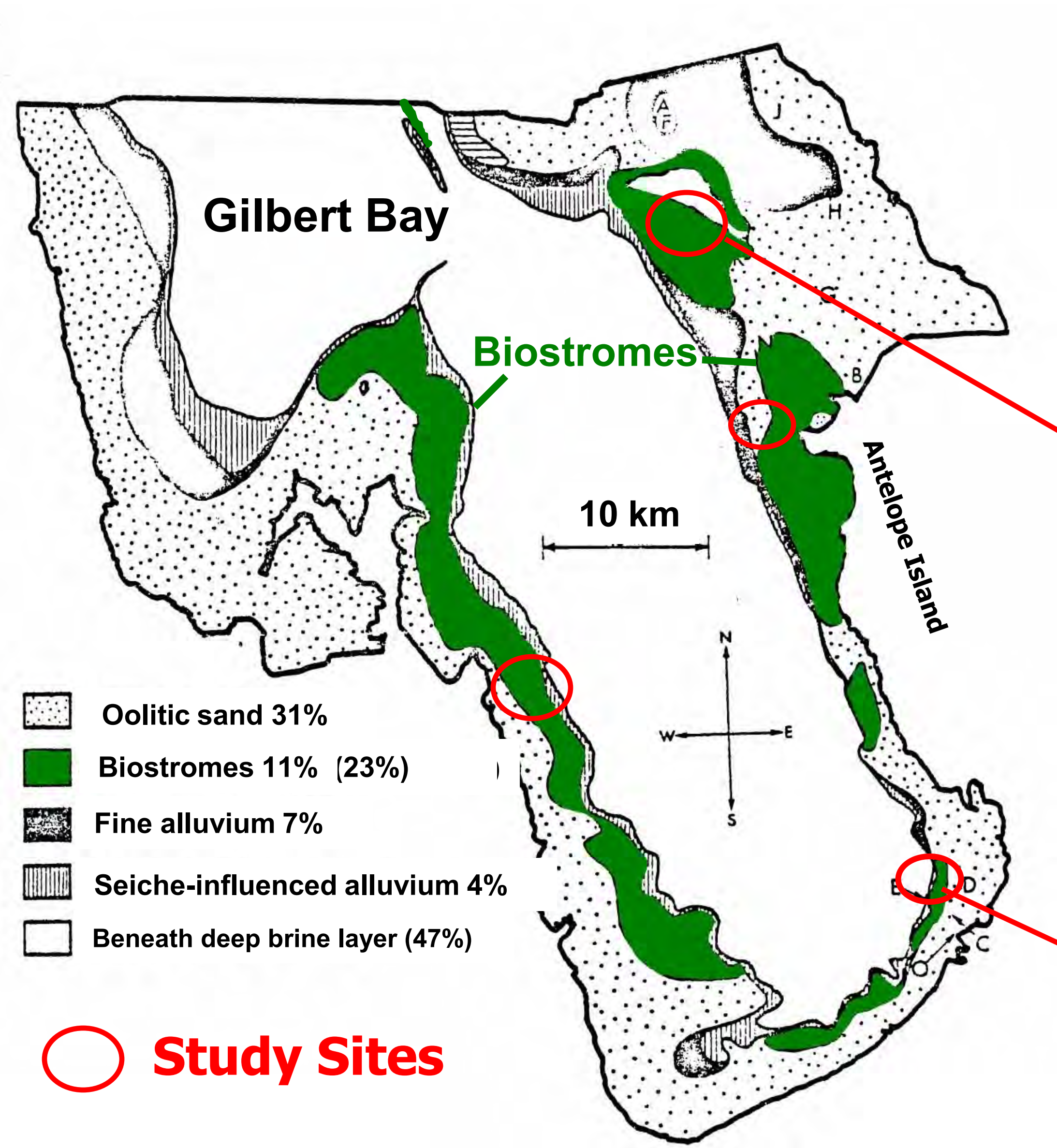
Funding from the Utah Division of Water Quality

- **Reference for this biostrome research:**

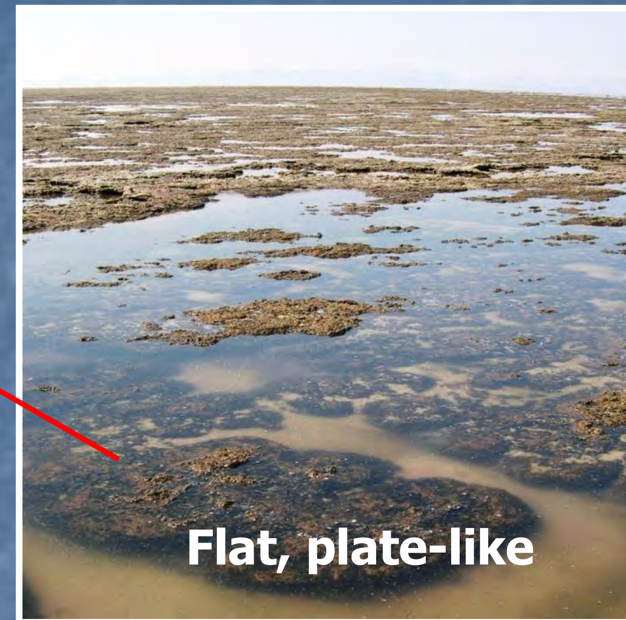
Wurtsbaugh, W.A., J. Gardberg and C. Izdepski. In Press. Biostrome communities and mercury and selenium bioaccumulation in the Great Salt Lake (Utah, USA). Science of the Total Environment.

Biostrome Structures

Biostrome Distribution in Gilbert Bay



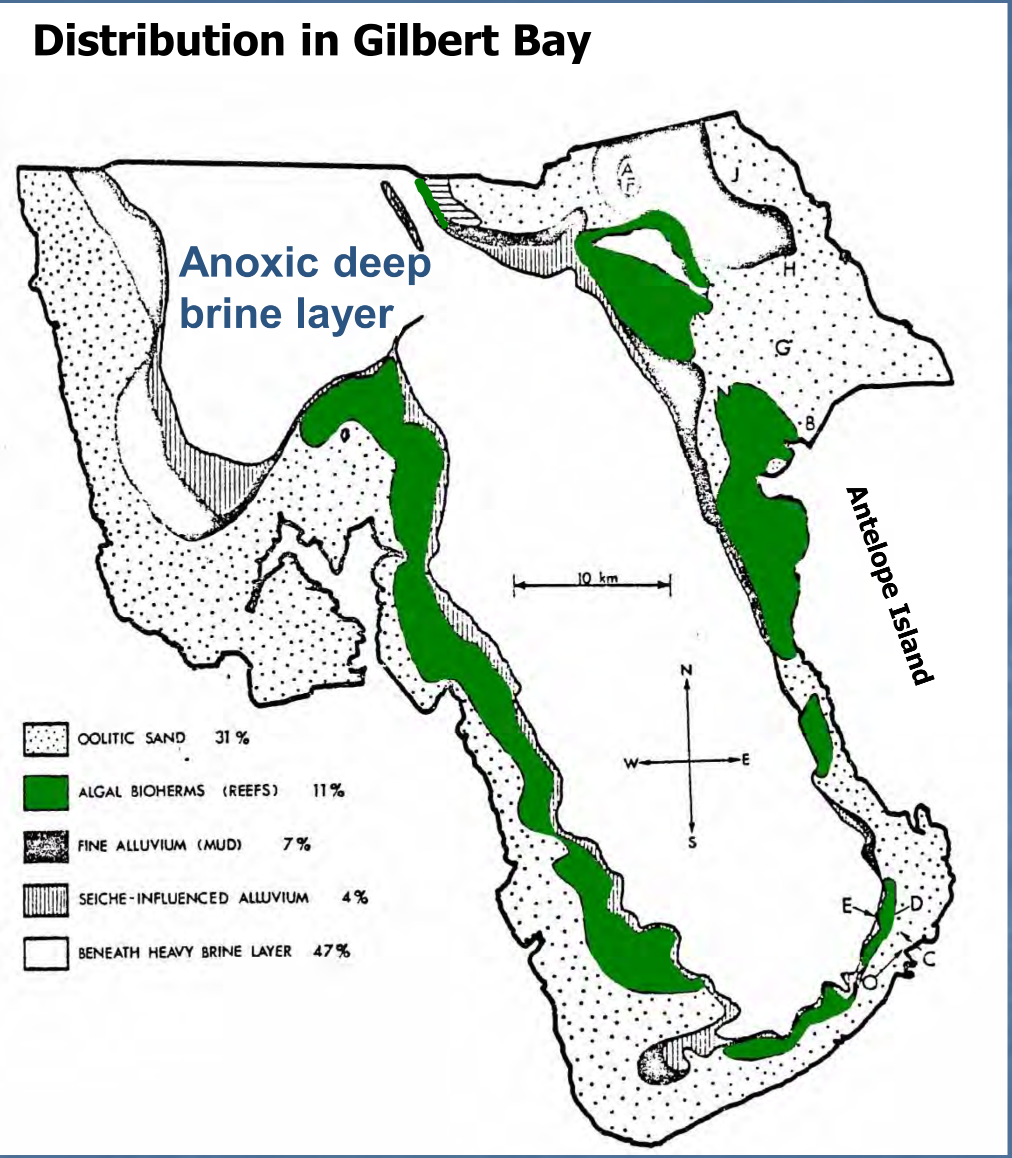
After Eardley (1938)



Mounds, ca. 1-m high

Stromatolites (Biostromes)

Dominant hard substrate for periphyton, brine fly larvae & pupae



Aphanothece **sp. (cyanobacteria)**

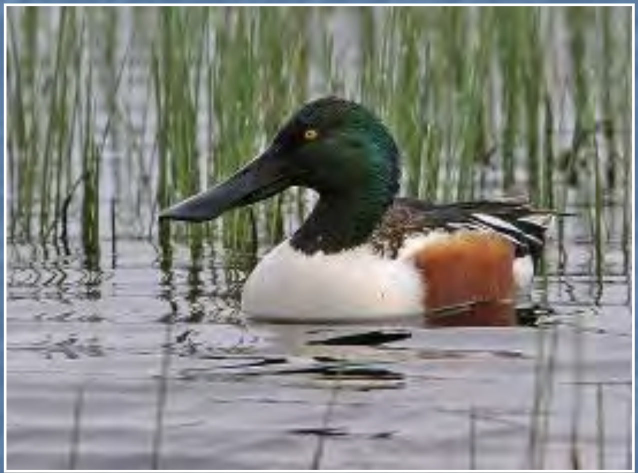
Food Web Importance: Principal Brine Fly Habitat

Ephydra cinerea

Simple Food Web

Cyanobacteria → Brine fly larvae → Goldeneye, grebes,
(*Aphanothece* sp.) and adults avocets, gulls, etc.

Consumption Advisories
on Three Species of Ducks

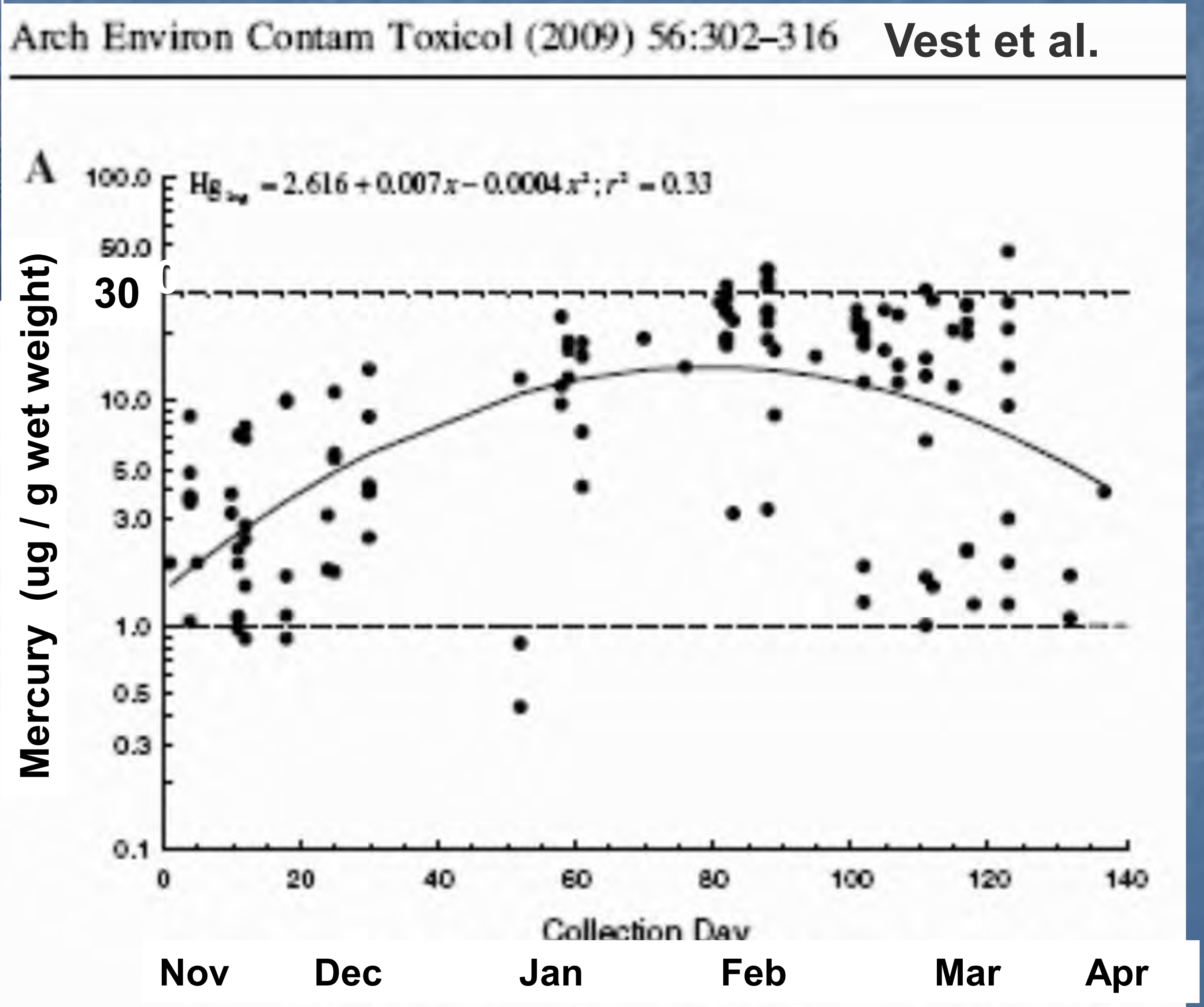


Northern shoveler

Cinnamon teal

Goldeneye
(Diet: 70% brine fly larvae)

Goldeneye increase Hg levels ~8X after arriving at Great Salt Lake and feeding on brine fly larvae.



Could be due to feeding on contaminated food in GSL, or because later-arriving birds have more mercury.

Questions

- **How important are the stromatolite communities for algal and invertebrate production in the Great Salt Lake?**
- **Do mercury and selenium bioaccumulate in the stromatolite communities and contribute to the high mercury loads in ducks that feed in the lake?**

Stromatolite Sampling Methods

- Brine fly larvae & pupae:
  Bucket Sampler & SCUBA
  Scrub stromatolite
  surface with brush

Sample pumped
to boat & sieved

Mercury – 2008 (3 stations, 5 times, June – Dec)

Cold vapor atomic fluorescence spectrometry (USGS Lab)

Selenium – 2006-07 (2 stations, June)

Hydride generation & atomic fluorescence spectrometry – Frontier Geosci.

Biostrome Sampling Methods

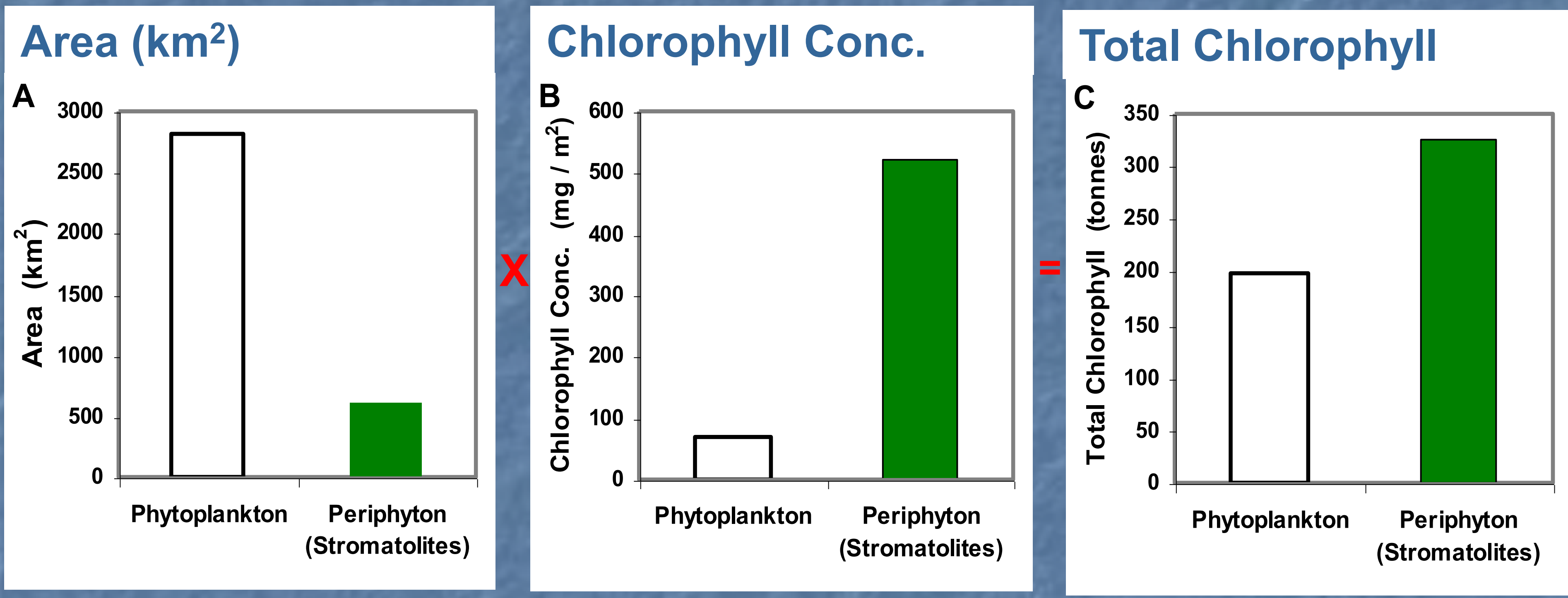
Stromatolite chunks broken off underwater

- Chl *a* extracted
- Periphyton removed
  - With & without acidification to remove carbonates
- Portions preserved for mercury analyses

Adult brine flies collected on shore with net

- All Hg analyses by cold vapor atomic fluorescence spectrometry at the U.S. Geological Survey Wisconsin Mercury Research Laboratory

Abundance of Periphyton on Stromatolites Compared to Phytoplankton

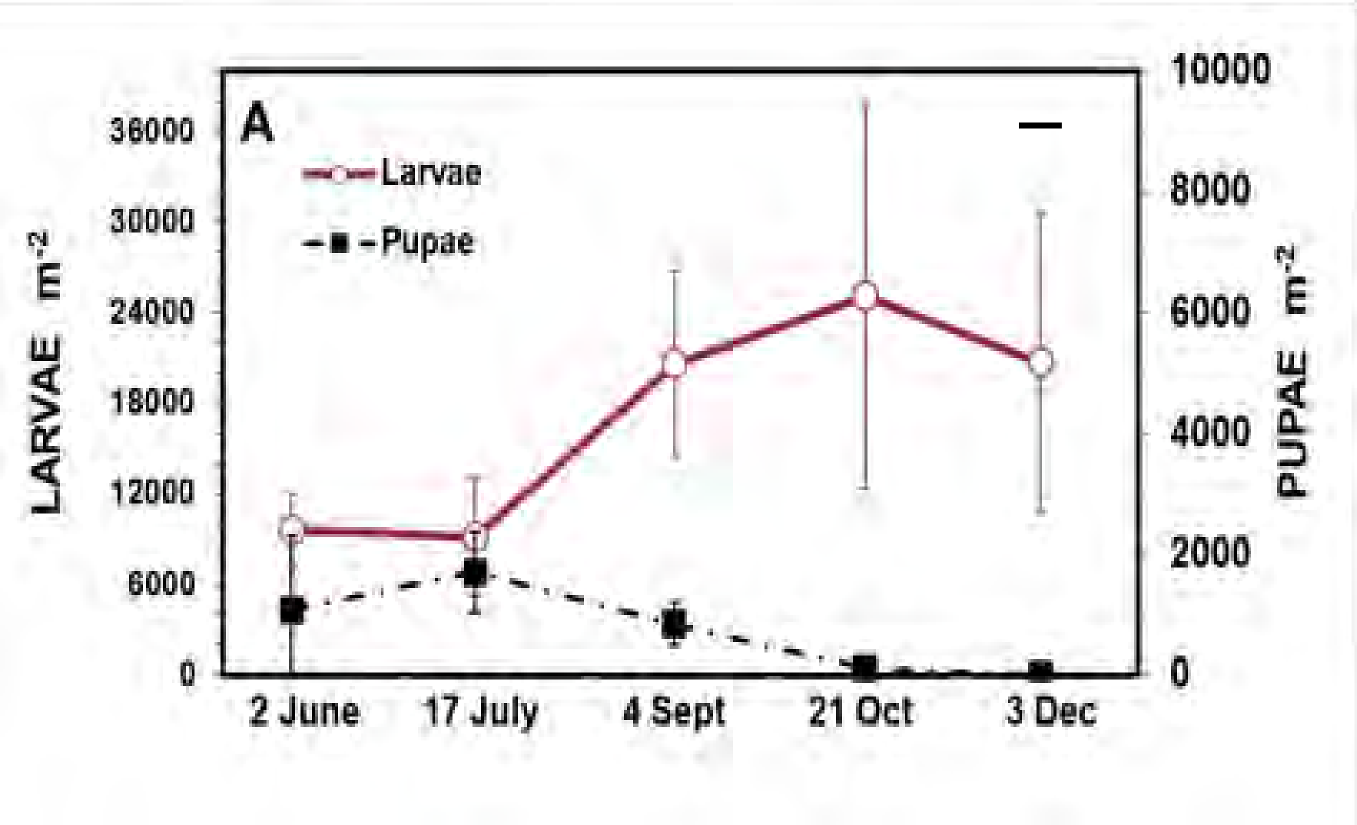


Periphyton on biostromes estimated to contribute 40% of the primary productivity in Gilbert Bay (60% phytoplankton)

*Based on May-October phytoplankton in Gilbert Bay (2002-2005), and summer periphyton values

Brine fly larvae very abundant on stromatolites

10 mm

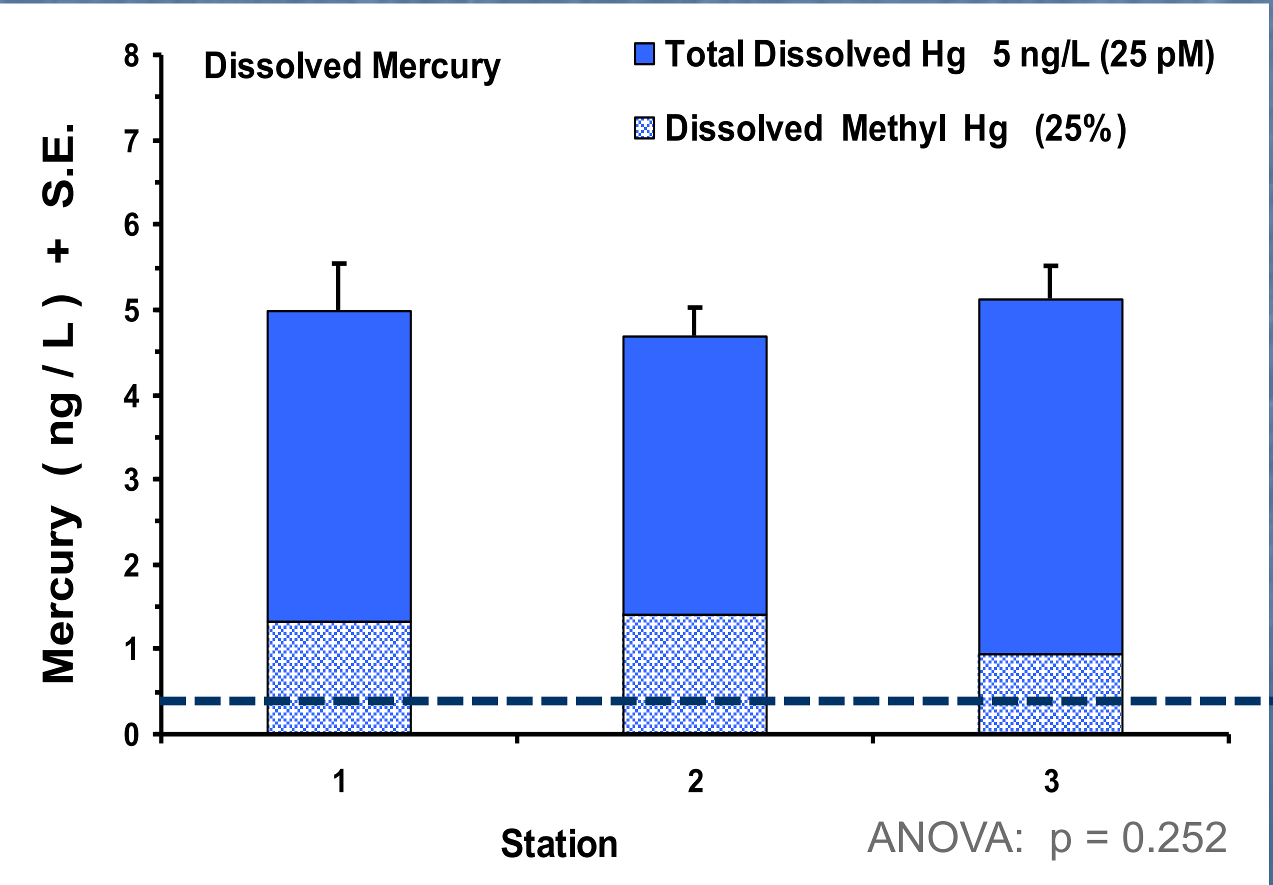


X = 15,500 larvae per square meter

Biomass per square meter comparable to that of brine shrimp

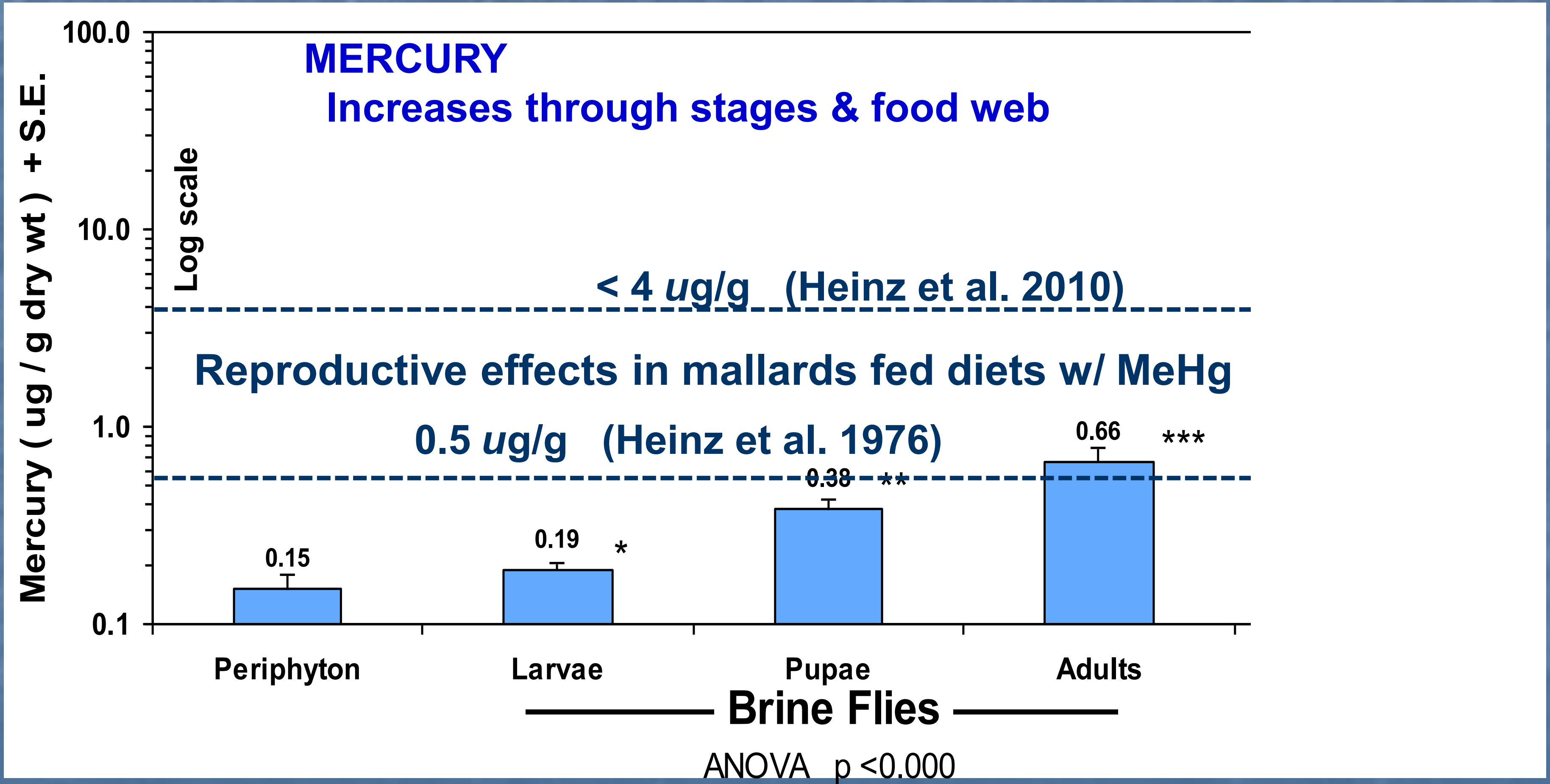
Moderate Total Dissolved Mercury Concentrations in Water Over Biostromes

← 12 ηg L^{-1}: EPA Freshwater Aquatic Life Standard

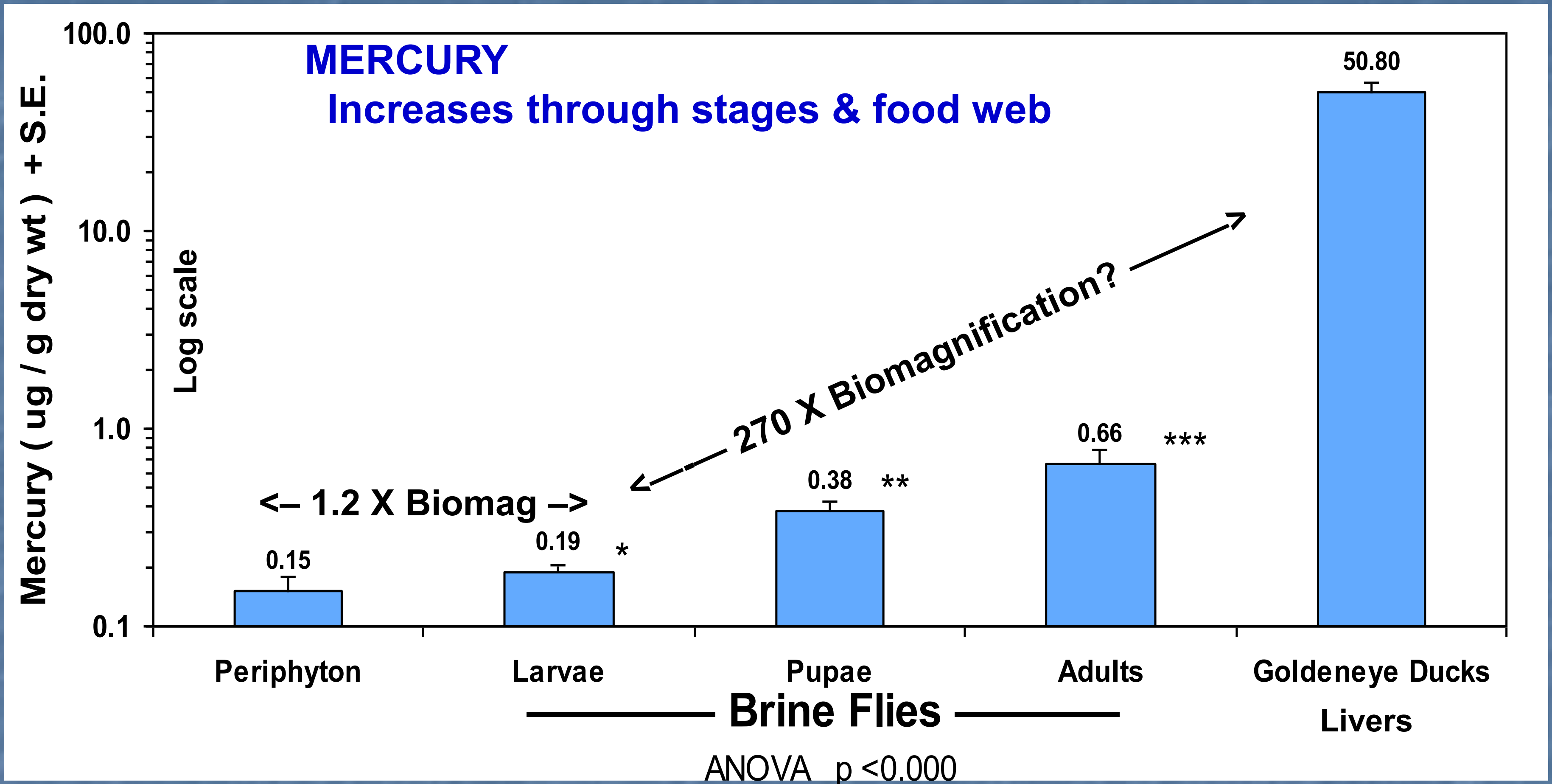


Uncontaminated Worldwide MeHg baseline (0.3 ηg L^{-1}) Gray and Hines (2009)

Mercury concentrations in brine flies are below, or at levels that have been shown to harm birds

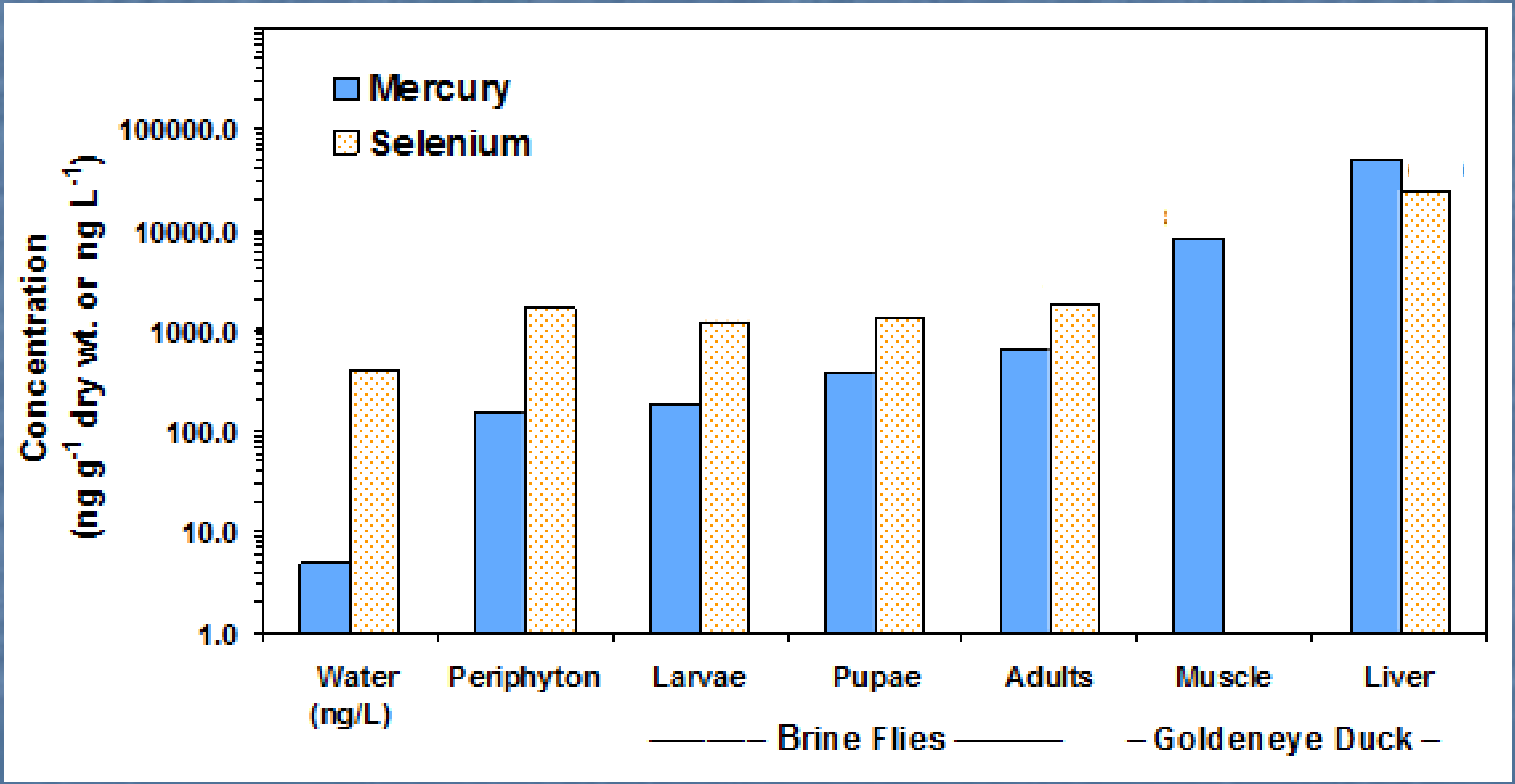


Biomagnification moderate, except for larvae to Goldeneye transfer



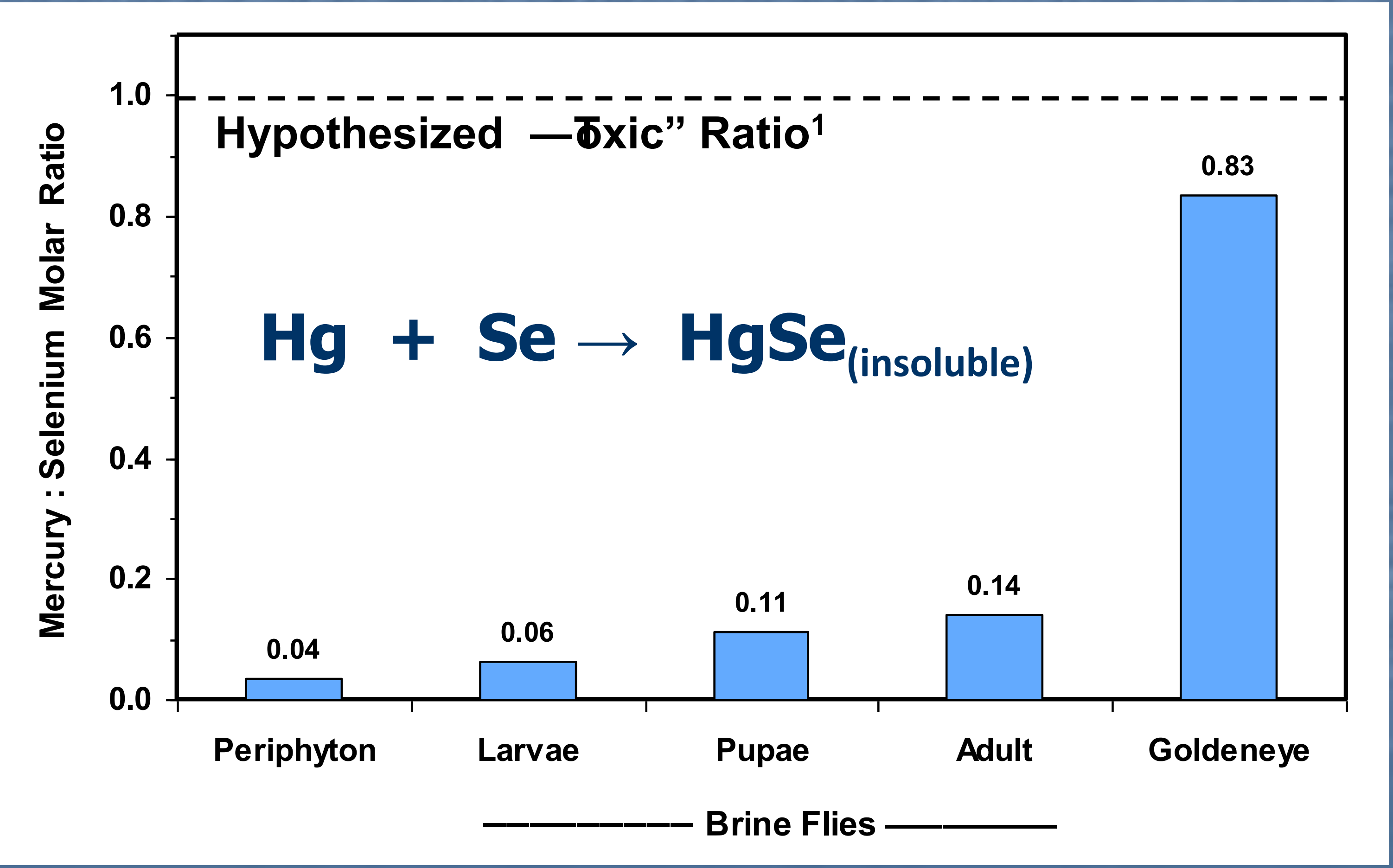
[1]Goldeneye Data from Vest et al. 2008

Selenium Concentrations Relative to Mercury Concentrations



Selenium data from: Wurtsbaugh, W.A. 2009. Biostromes, brine flies, birds and the bioaccumulation of selenium in Great Salt Lake, Utah. Pp. 1-15 In: Saline Lakes Around the World. URL: http://www.cnr.usu.edu/quinney/files/uploads/NREI2009online.pdf .

Low Hg:Se Molar ratios suggest that although Hg levels are high in the biota, toxicity may be minimized by sequestration



[1]Ganther et al. 1972; Ralston et al. 2007

Conclusions

- Stromatolites/periphyton and brine flies are important in the economy of the lake, and important in the diets of many bird species, likely rivaling the importance of brine shrimp as a food source.

- Mercury concentrations are moderate in biostromes and in brine flies, but biomagnification not important in the periphyton → brine fly larvae transfer.

- Goldeneye ducks have very high mercury concentrations: either there is very high biomagnification in the brine fly → duck transfer, the ducks are obtaining mercury from elsewhere, or they are sequestering it in livers & detoxifying with selenium.

- Hg:Se ratios < 1 suggest that even the high mercury levels may not be toxic to the biota

Source of High Mercury Unknown

- Natural sources in watershed?

  Mercury mine operated in Mercur, 25 miles (40 km) from the Great Salt Lake. Other abandoned mines even closer.

- Natural concentration in salt lake?

  Na and Cl concentrated 200-300 fold over river water. Mercury in the GSL (in mixed layer) is concentrated 2-3 fold (based on data from Naftz (in prep.).

Source of High Mercury Unknown

- Long-range atmospheric deposition ?
- Legacy mining contributions & recycling ?

• Current atmospheric Hg deposition to lake[1] 36 kg/yr
is not abnormally high

• Legacy gold/silver mining Hg use
in Utah[2] (1864-present) 19,900,000 kg
(136,000 kg/yr)

[1] Peterson & Gustin (2009)

[2] C.L. Ege, Selected Mining Districts of Utah, UGS Misc. Pub. 05-5 2005

Questions?

Acknowledgements:

- Caleb Izdepski, Ian Washbourn, Michelle Kang, Jodi Gardberg, John Whitehead, John DeWild, David Naftz, Josh Vest
- Funding provided by the Utah Division of Water Quality & the Utah Division of Forestry, Fire and State Lands