Bioaccumulation and Bioadvection of Mercury in Great Salt Lake Ecosystems

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Jeff Collins

Heidi Saxton

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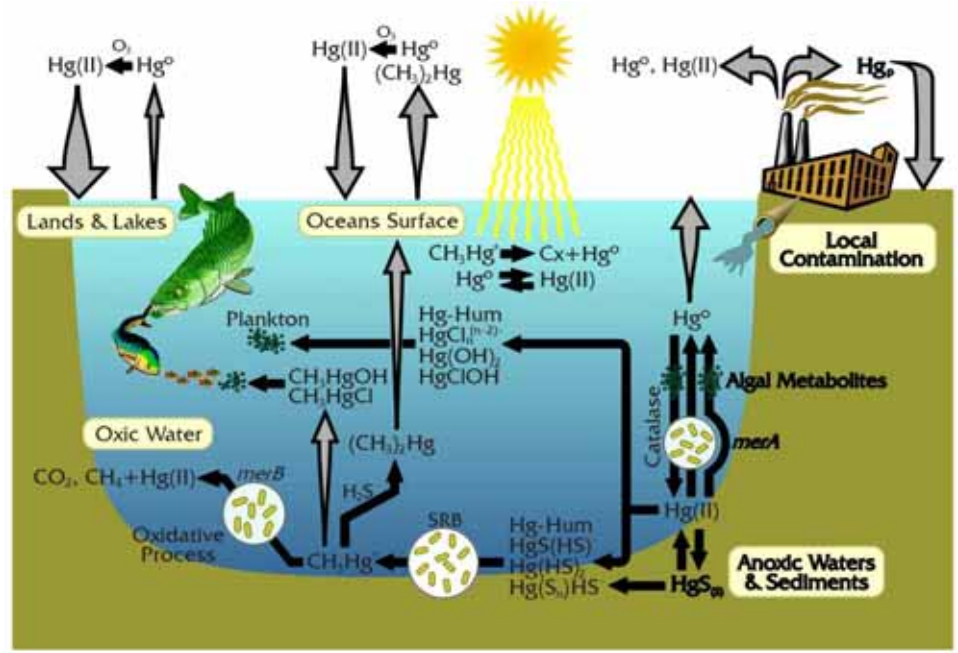
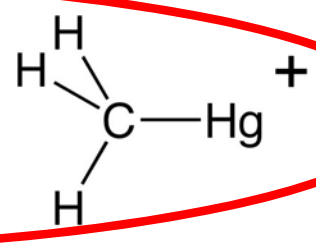
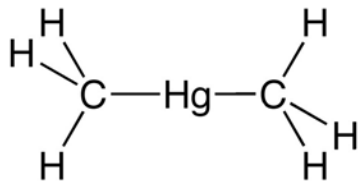
Outline



- **Short Hg Background**

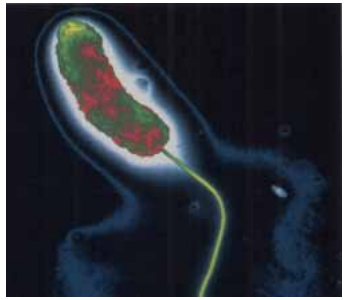
- **Mercury in Great Salt Lake Ecosystems**
  - HgT and MMHg in water
  - Bioadvection of Hg and MMHg by brine flies
  - Bioaccumulation of Hg and MMHg by spiders
  - Bioaccumulation of Hg in song birds

The various forms of Hg differ in their cycling and toxicity

- Elemental mercury - Hg(0) Hg^{0}
- Inorganic mercury - Hg(II) Hg^{2+}
- Monomethylmercury - MMHg 
- Dimethylmercury - DMHg 

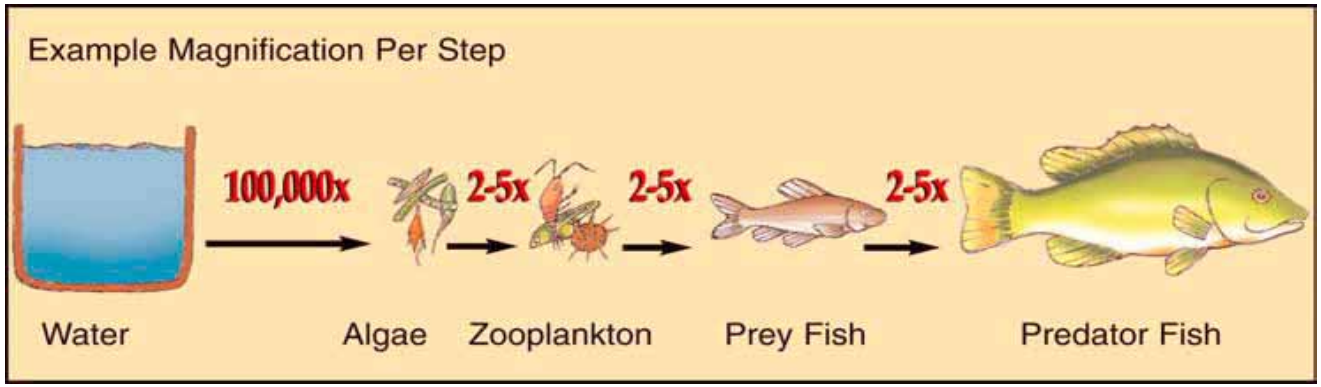
Methylation and biomagnification of mercury

Hg(II)
Inorganic
mercury



MMHg
Methyl
mercury

Sulfate/iron reducing bacteria

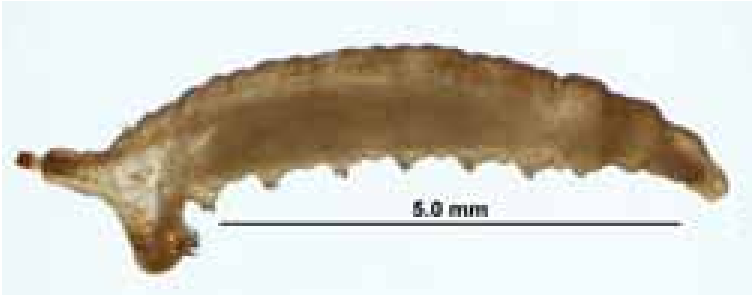


Pathways for Hg exposure from the GSL

Brine Fly Life Stages

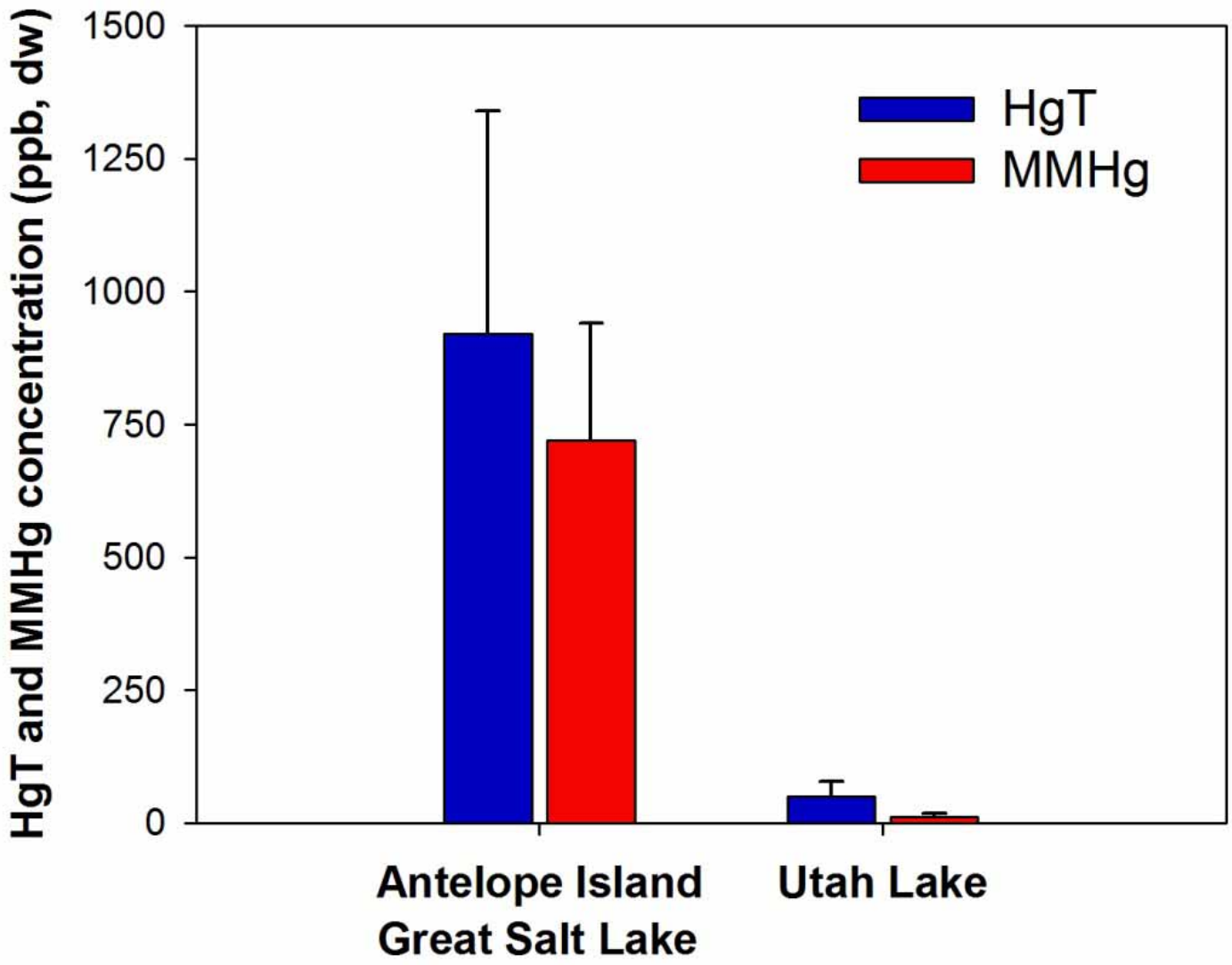
Adult

Pupa



Larva

www.watermonitoring.uwex.edu
www.bugguide.net
www.dududiaries.wildlifedirect.org



Spiders
Fall 2011

Spiders at GSL have 60 fold higher Hg than at Utah Lake.
Larger % of the Hg in spiders is MMHg at GSL.

Major Research Questions

- Do brine flies act as vectors to transfer Hg from the GSL to adjacent terrestrial ecosystems?
- As predators, do spiders accumulate high levels of Hg because they feed on brine flies?
- Are there temporal or spatial differences in Hg concentrations in water, brine flies, or spiders at the GSL?
- Are there song birds that are at risk of mercury toxicity because they eat spiders and feed them to their nestlings?

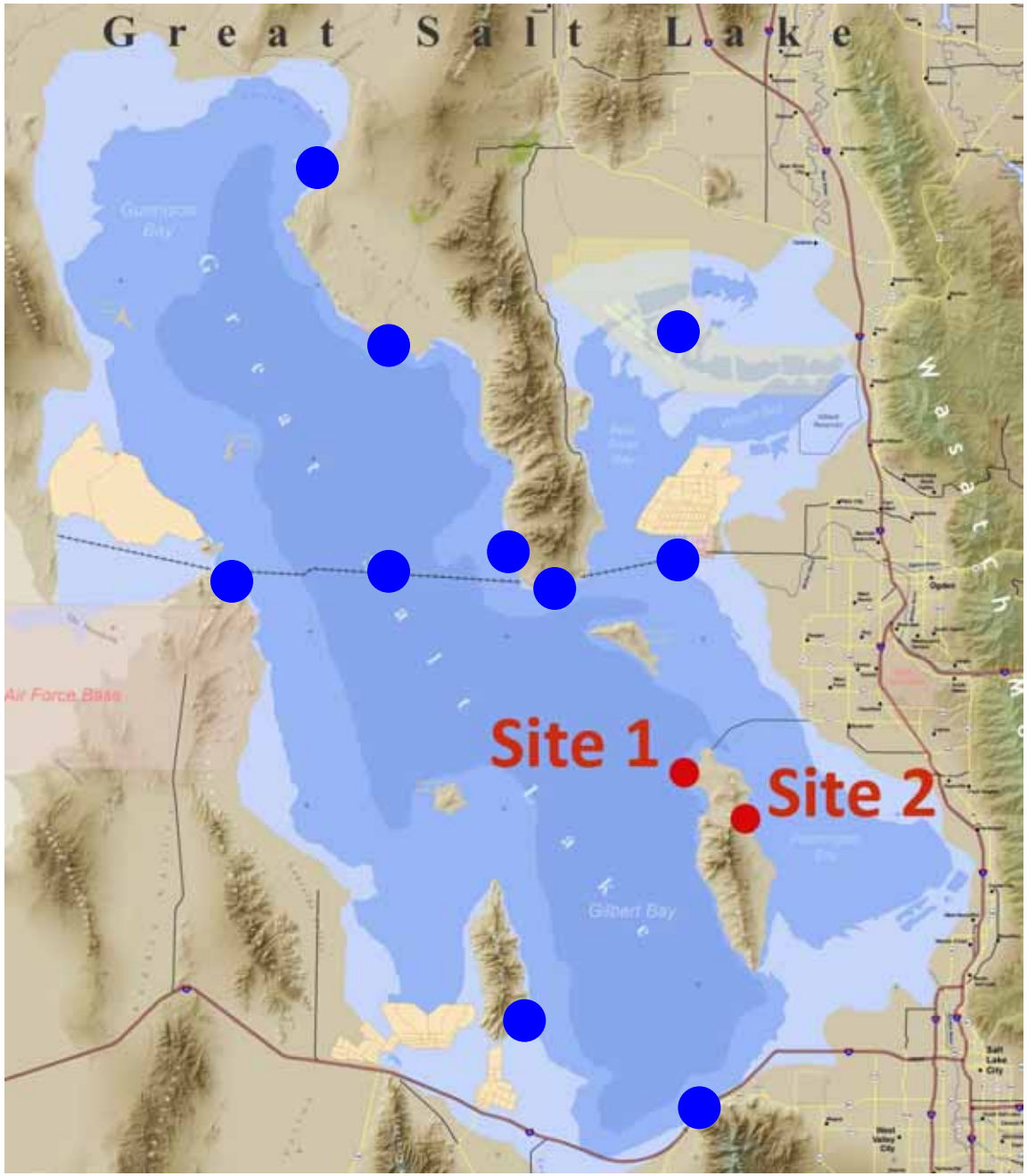
Sample collection

Water, brine flies, spiders

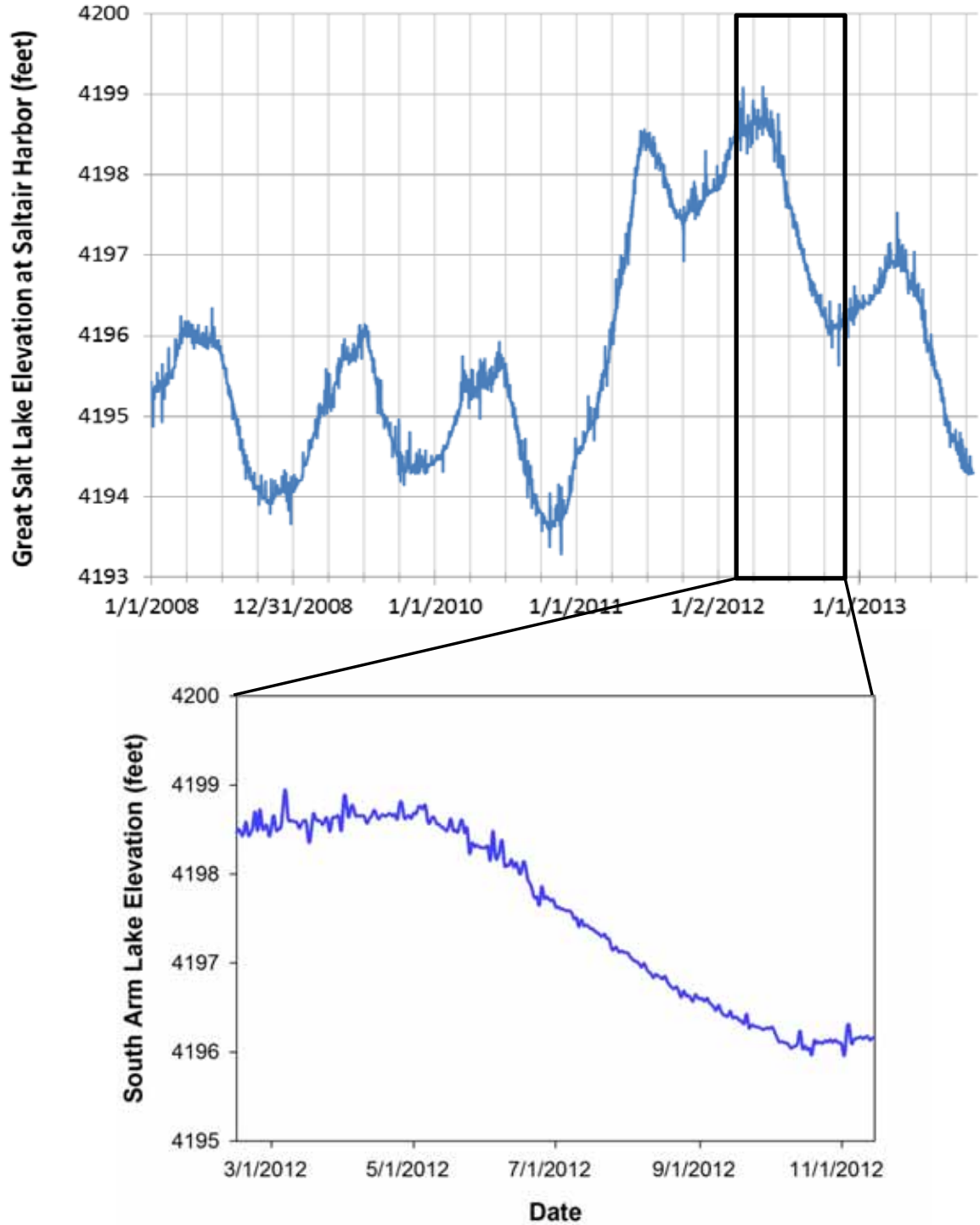
2 sites once monthly: February to November

12 sites once August, 2012

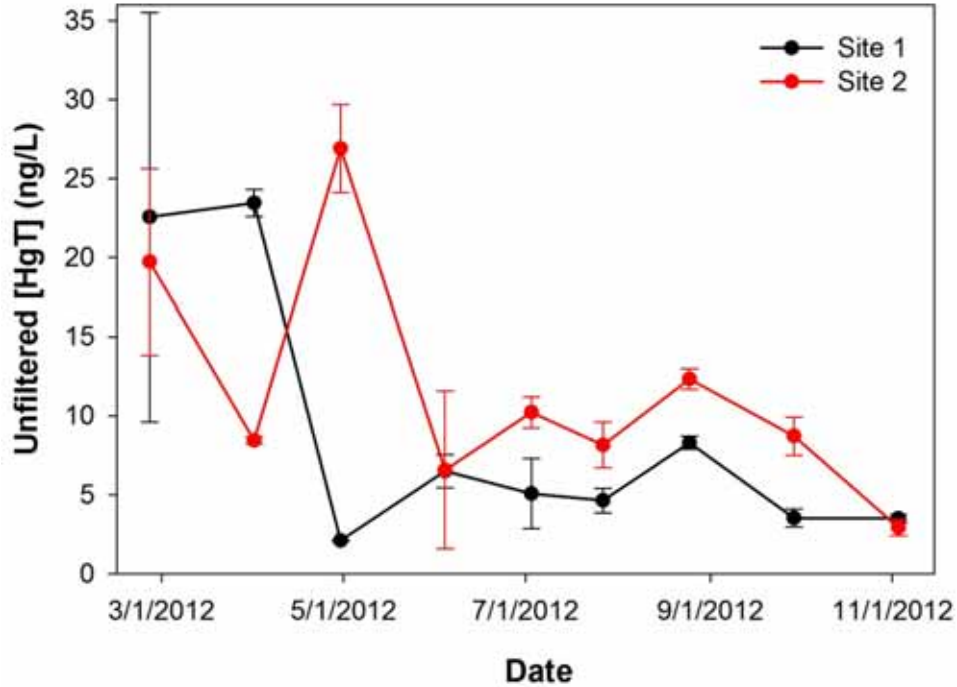
>1000 spider and brine fly samples collected

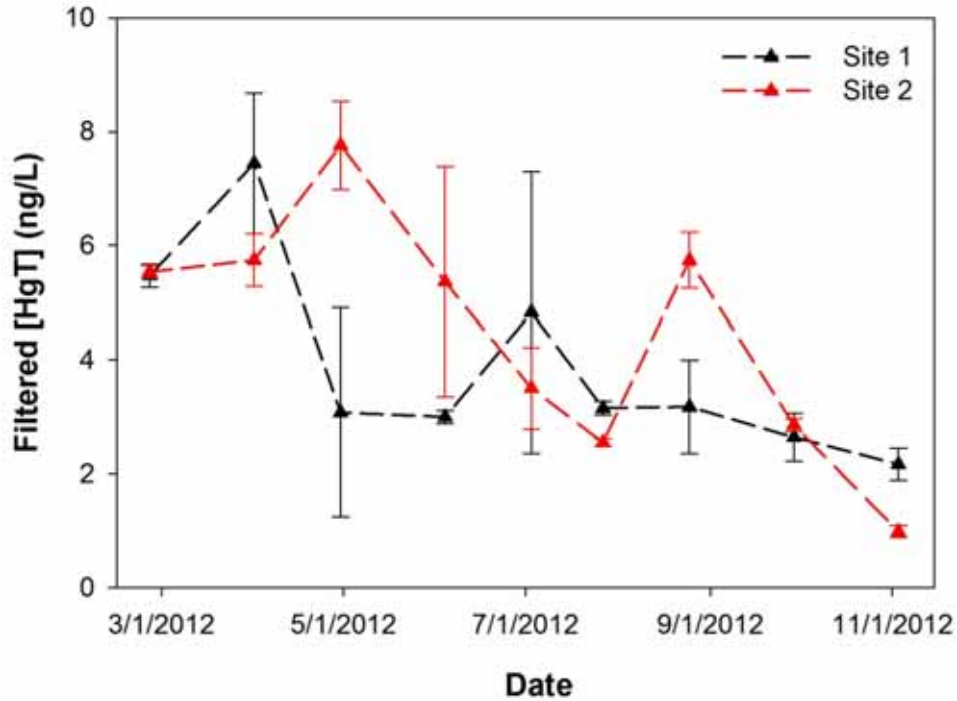


Lake Elevation in South Arm



HgT in water





% of HgT in dissolved (filtered) phase

Site 1: 60 ± 27 % (32-95%)

Site 2: 43 ± 19 % (28-82%)

MMHg in water

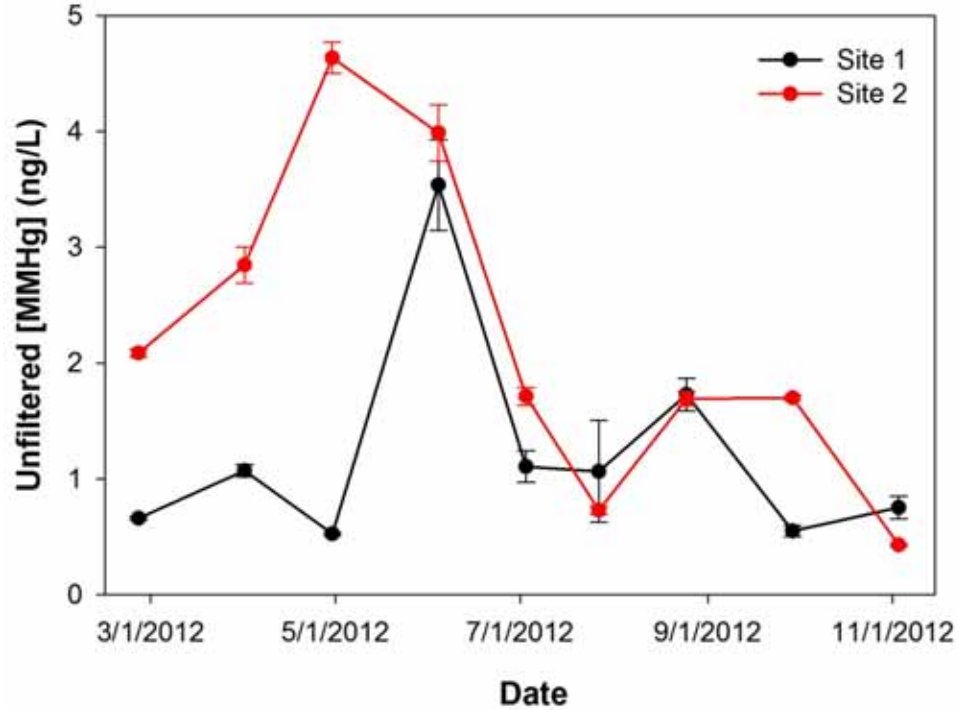
% of MMHg in dissolved (filtered) phase

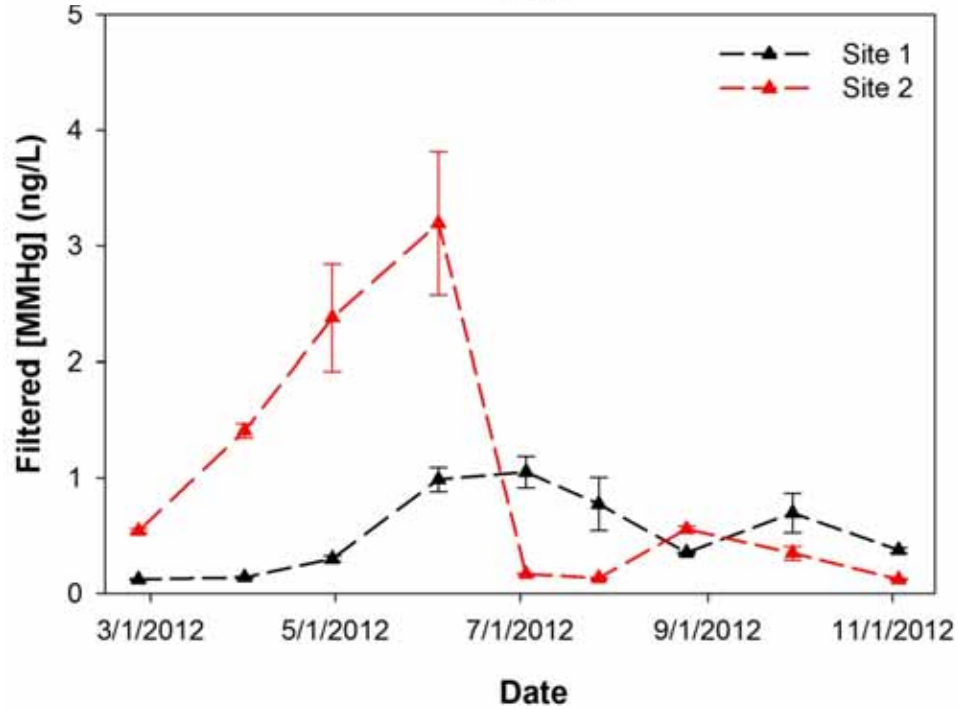
Site 1: 51 ± 33 % (13-95%)
Site 2: 35 ± 22 % (10-80%)

% of HgT that is MMHg in dissolved (filtered) fraction

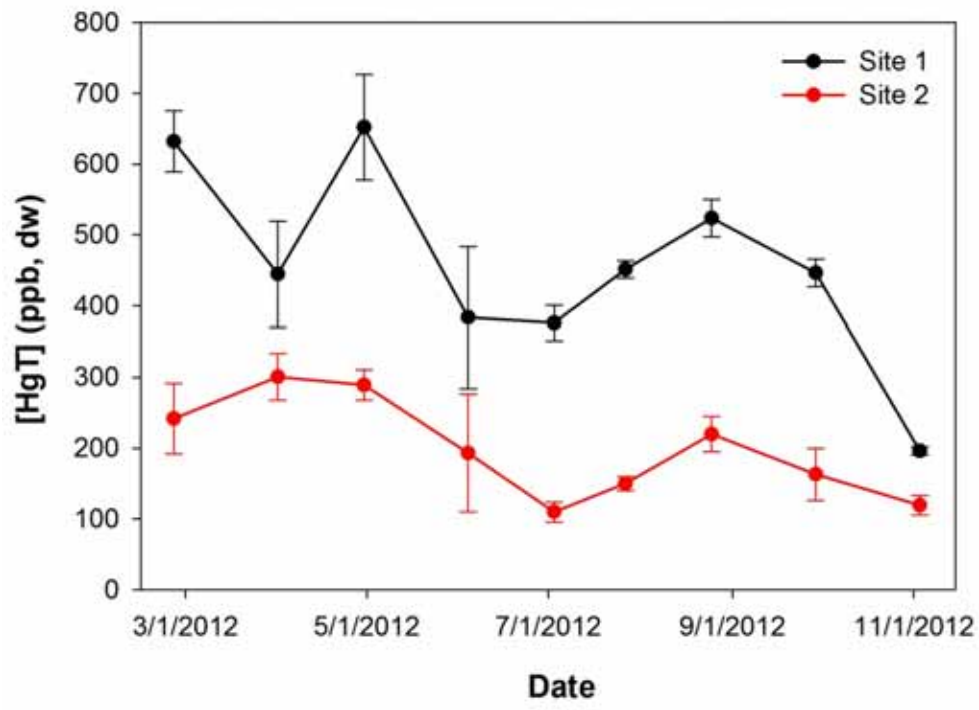
Site 1: 16 ± 11 % (2-33%)
Site 2: 19 ± 18 % (5-60%)

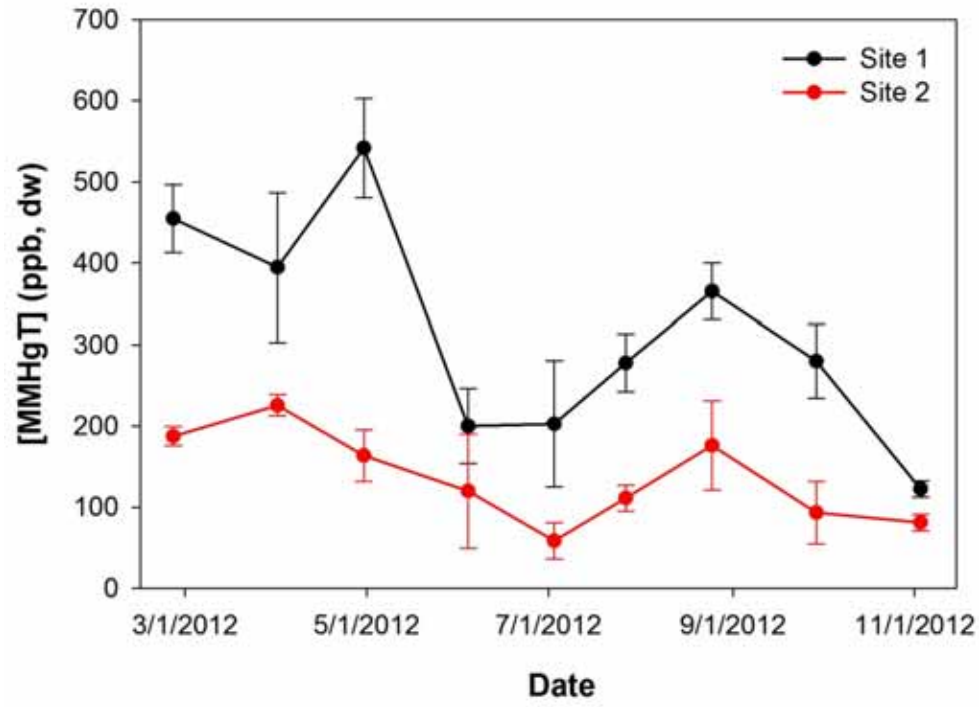
% of HgT that is MMHg in unfiltered fraction
Site 1: 21 ± 15 % (3-54%)
Site 2: 22 ± 16 % (9-61%)





HgT and MMHg in adult brine flies



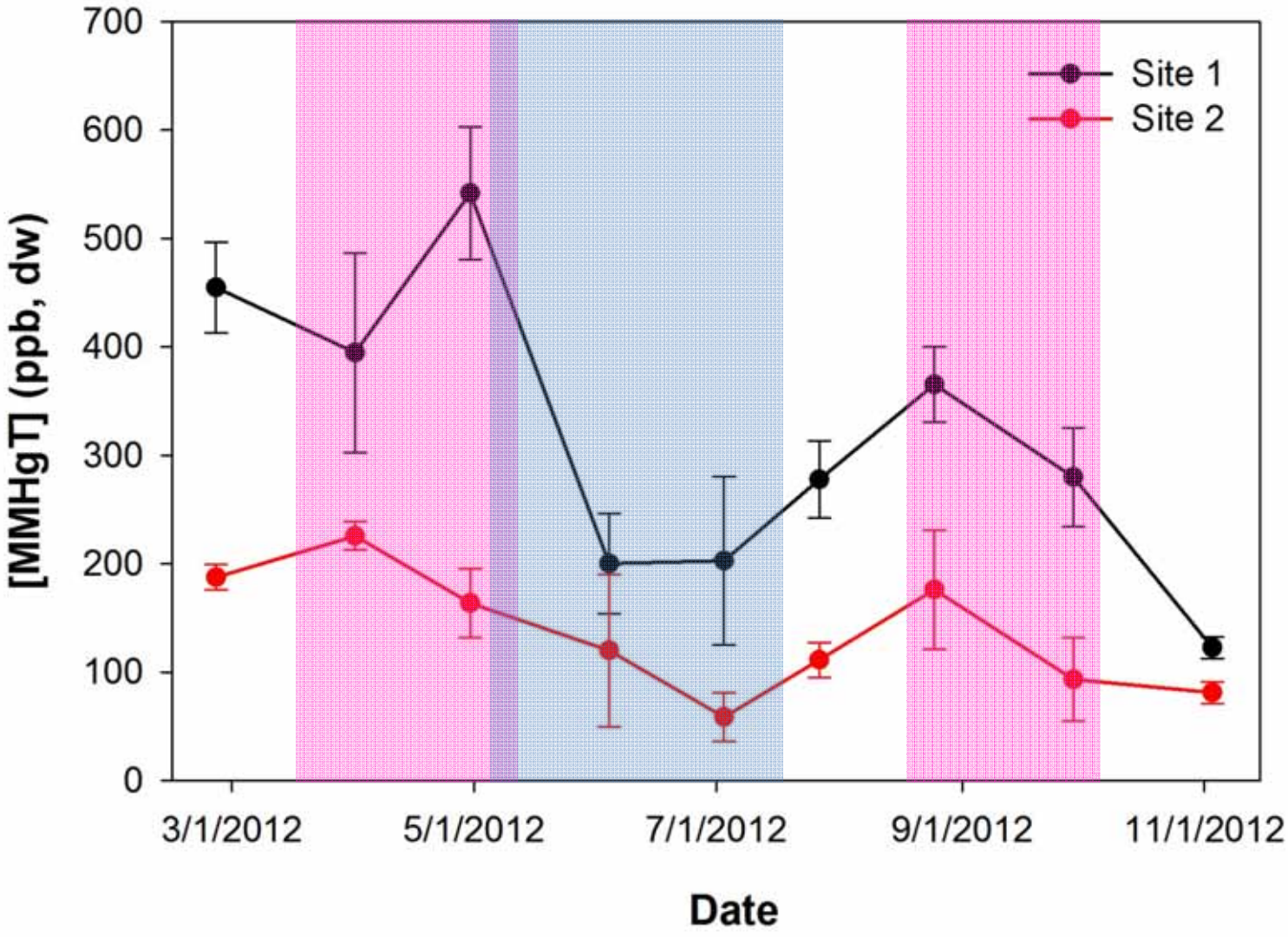


% MMHg

Site 1: 68 ± 15 %

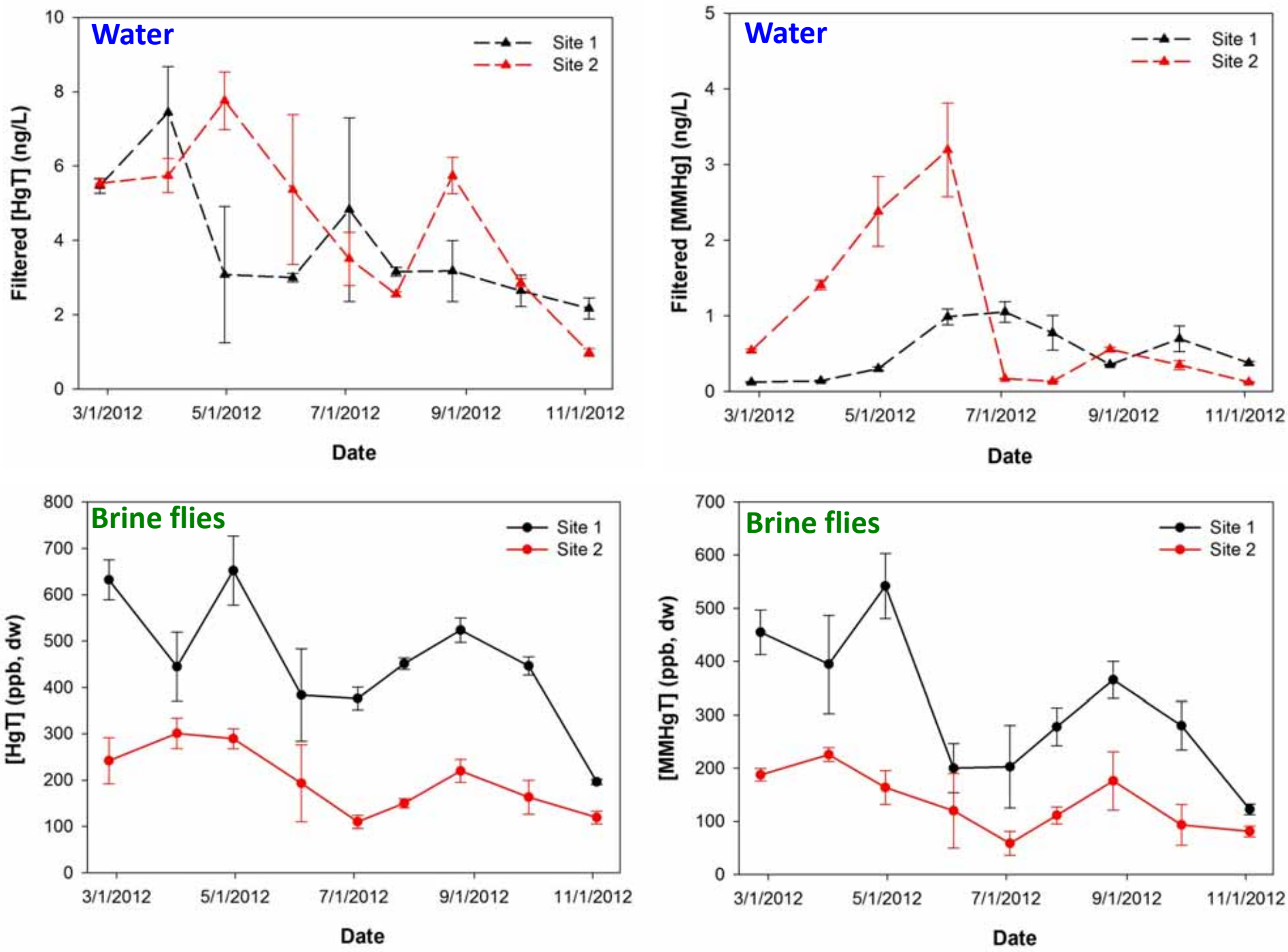
Site 2: 70 ± 15 %

Implications of temporal trends in brine flies



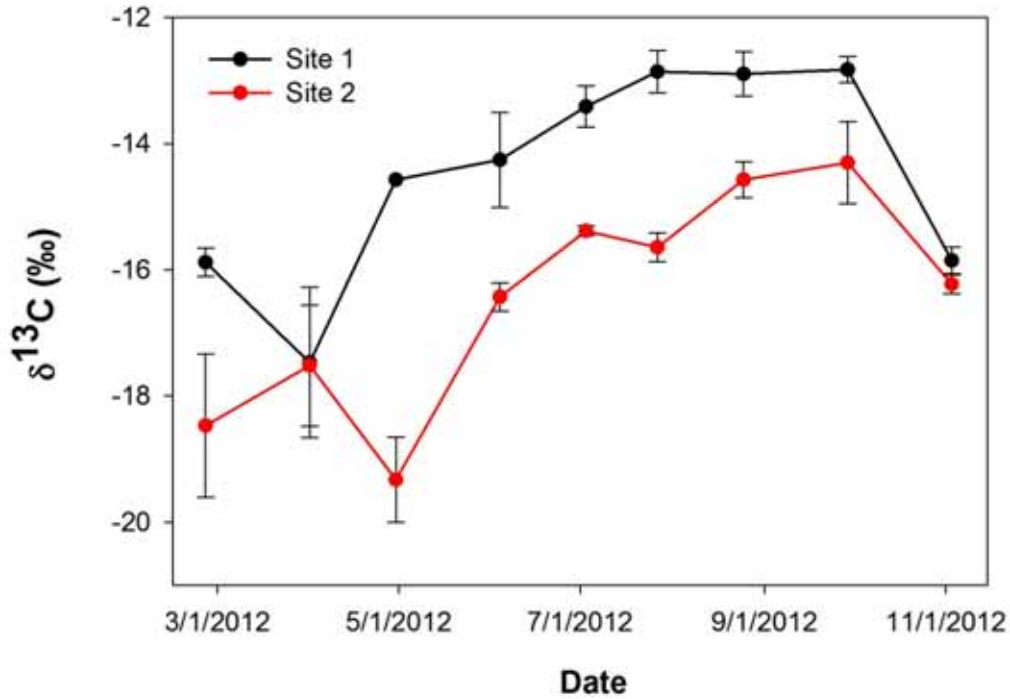
Spring and fall migration stopover

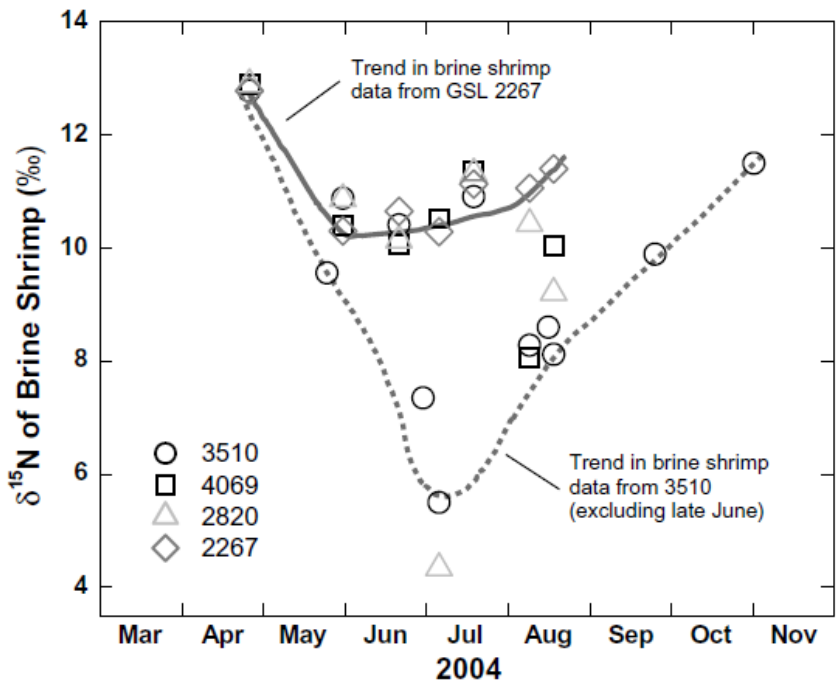
Nesting and fledging by local birds


Water
Site 1
Site 2
Filtered [HgT] (ng/L)
Date
3/1/2012
5/1/2012
7/1/2012
9/1/2012
11/1/2012
Water
Filtered [MMHg] (ng/L)
Brine flies
[HgT] (ppb, dw)
Brine flies
[MMHgT] (ppb, dw)

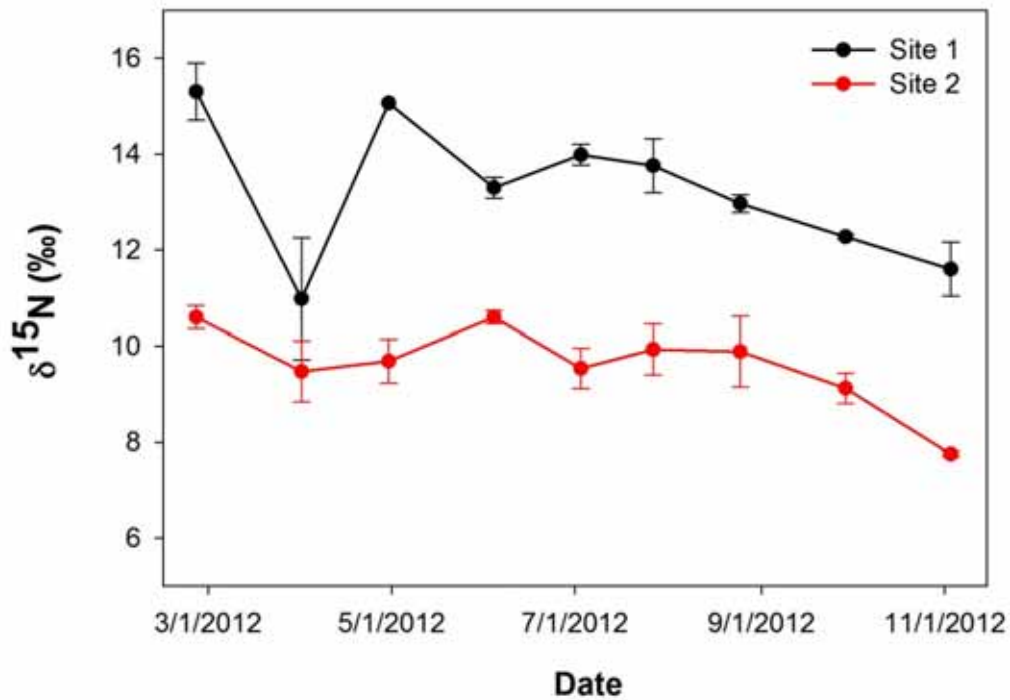
Carbon and nitrogen isotopic ratios in brine flies

$$\delta^{13}C_{Sample} = \left\{ \frac{\left(\frac{^{13}C}{^{12}C}\right)_{Sample}}{\left(\frac{^{13}C}{^{12}C}\right)_{Reference}} - 1 \right\} * 1000$$

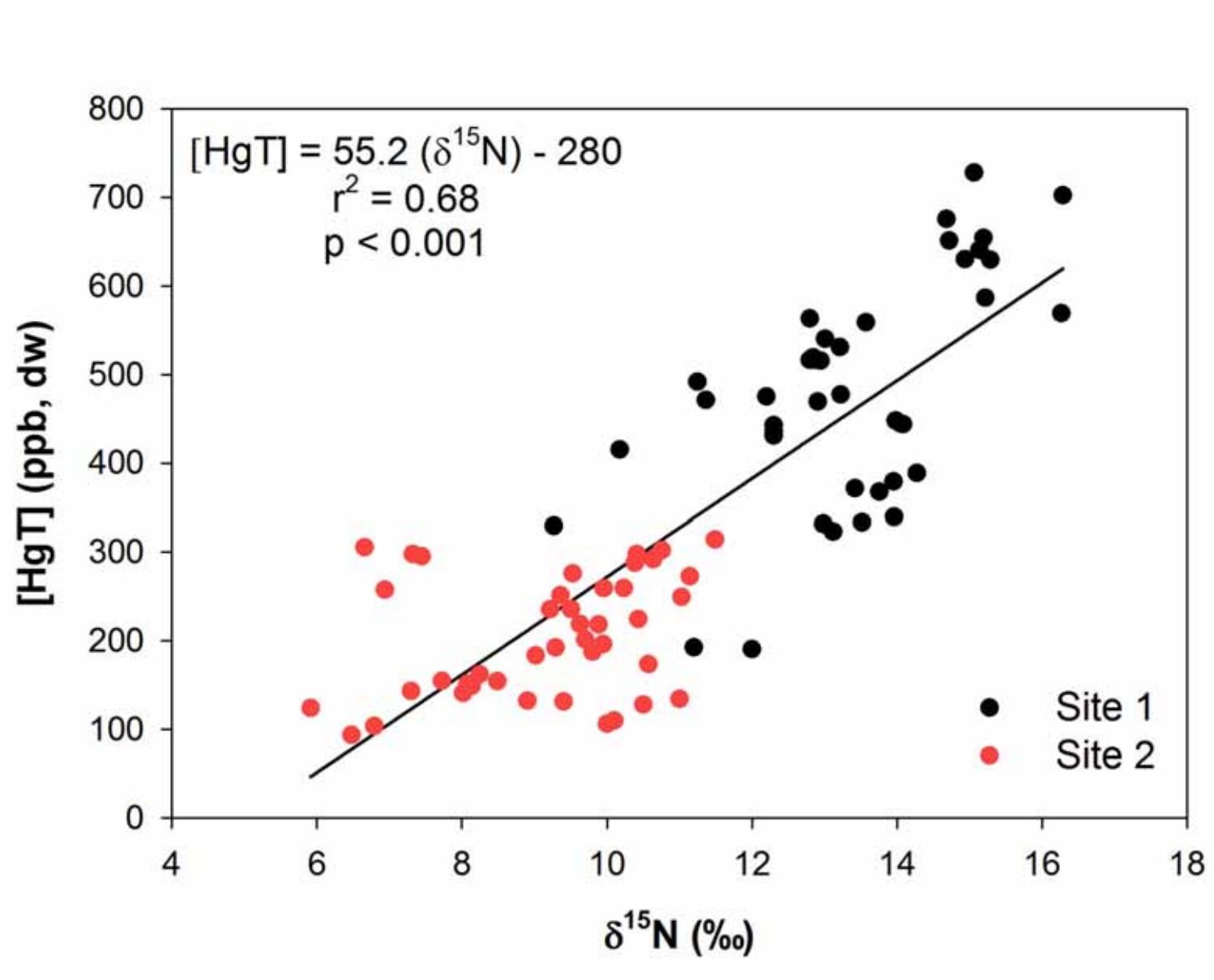


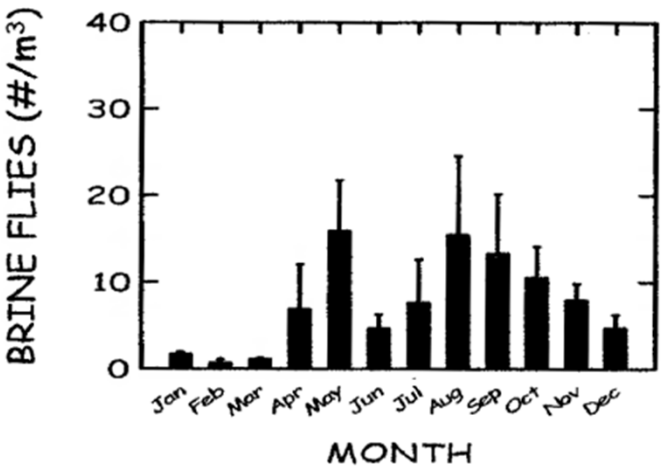


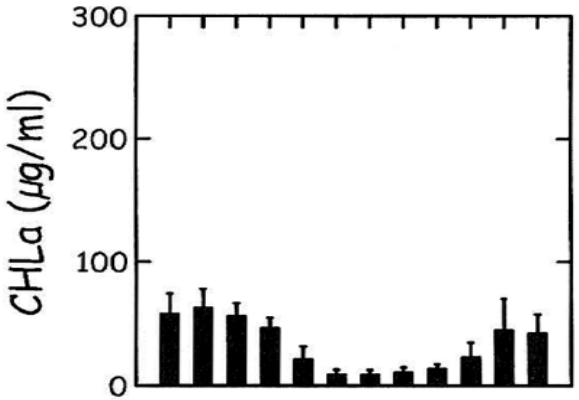
Naftz et al., 2008, Applied Geochemistry

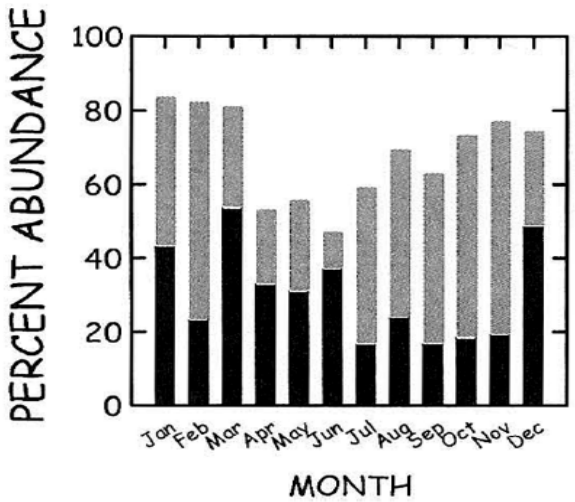


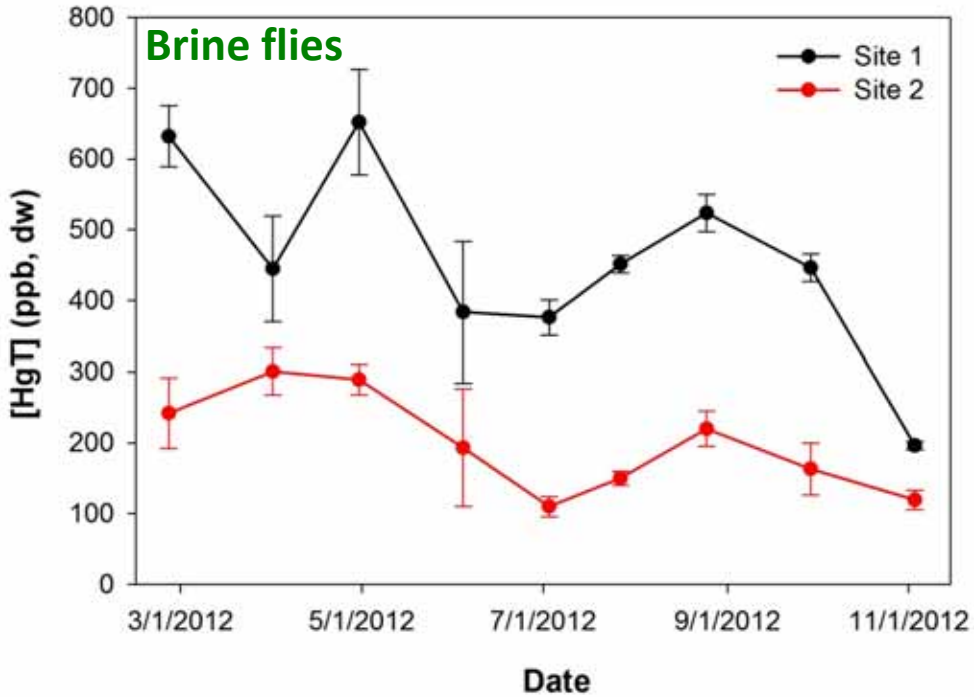
Nitrogen isotopic ratio vs. [HgT] in adult brine flies

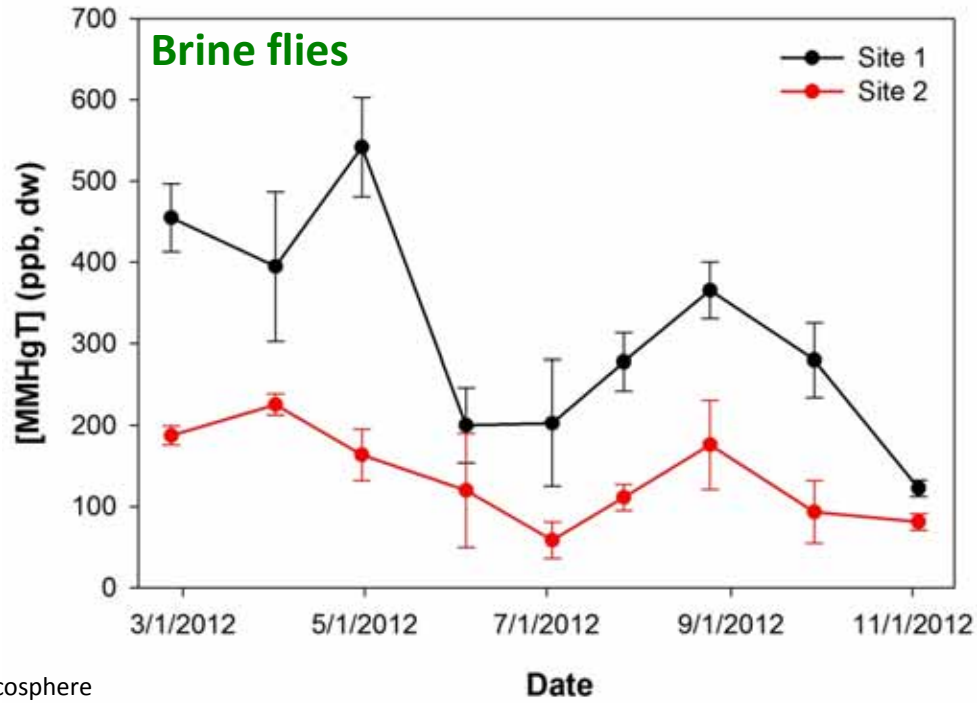






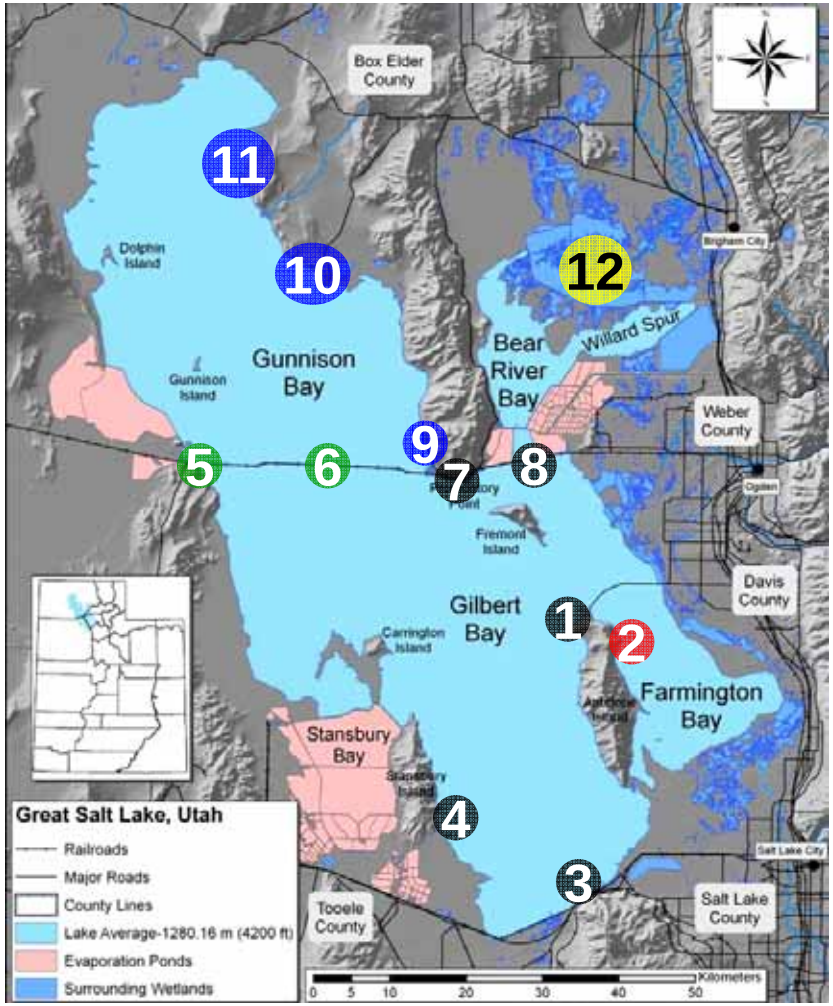


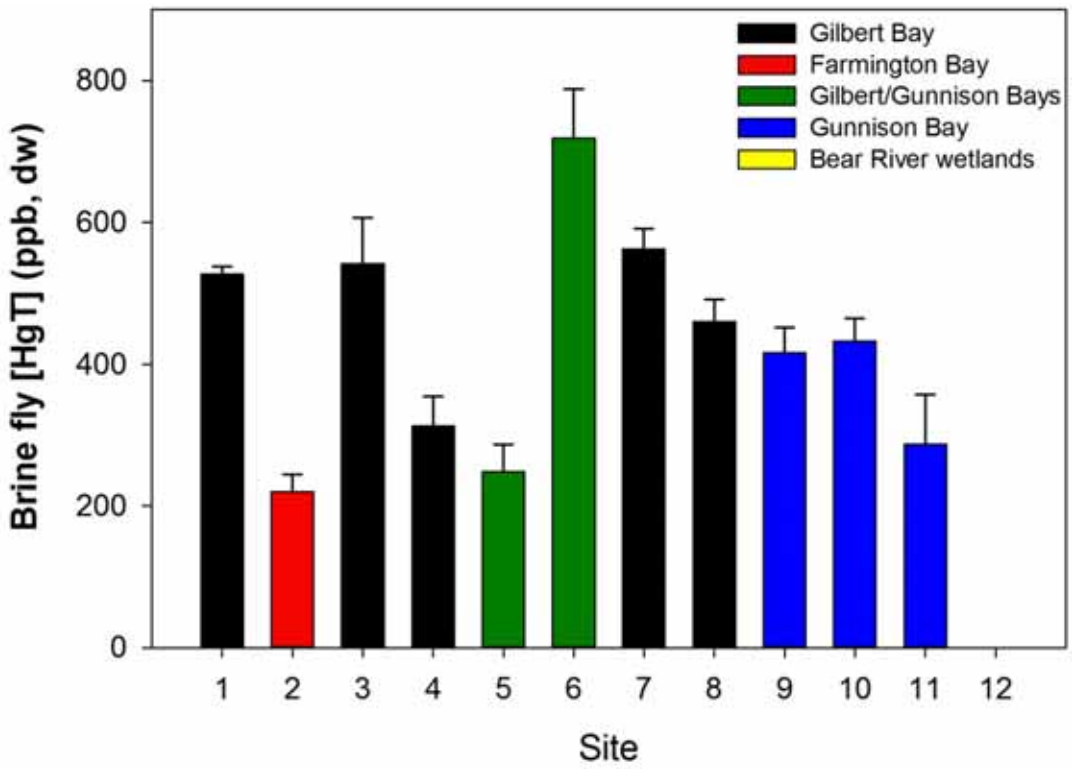




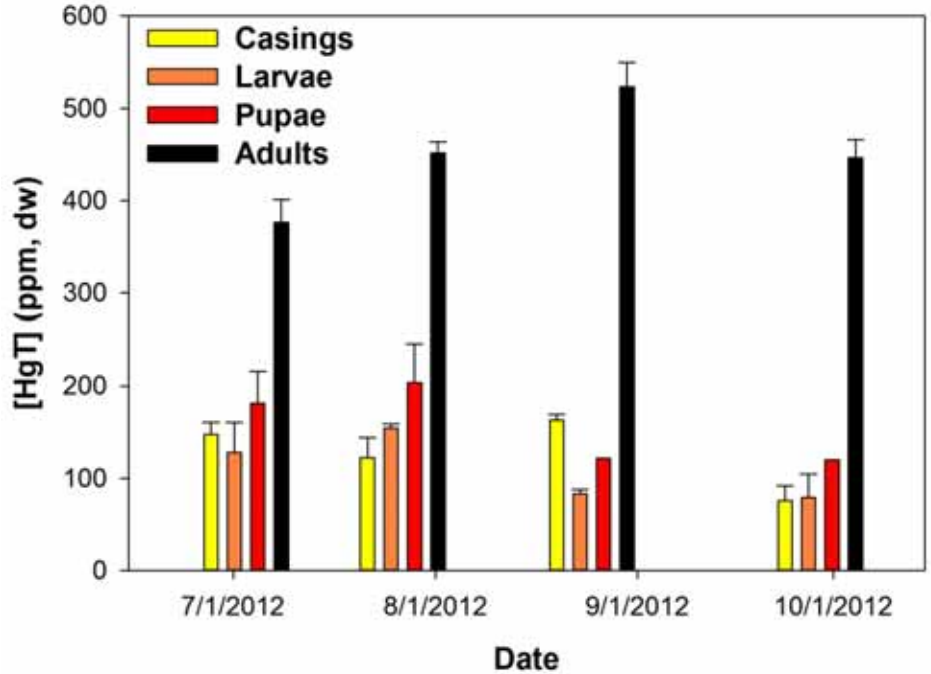
Belovsky et al., 2011, Ecosphere

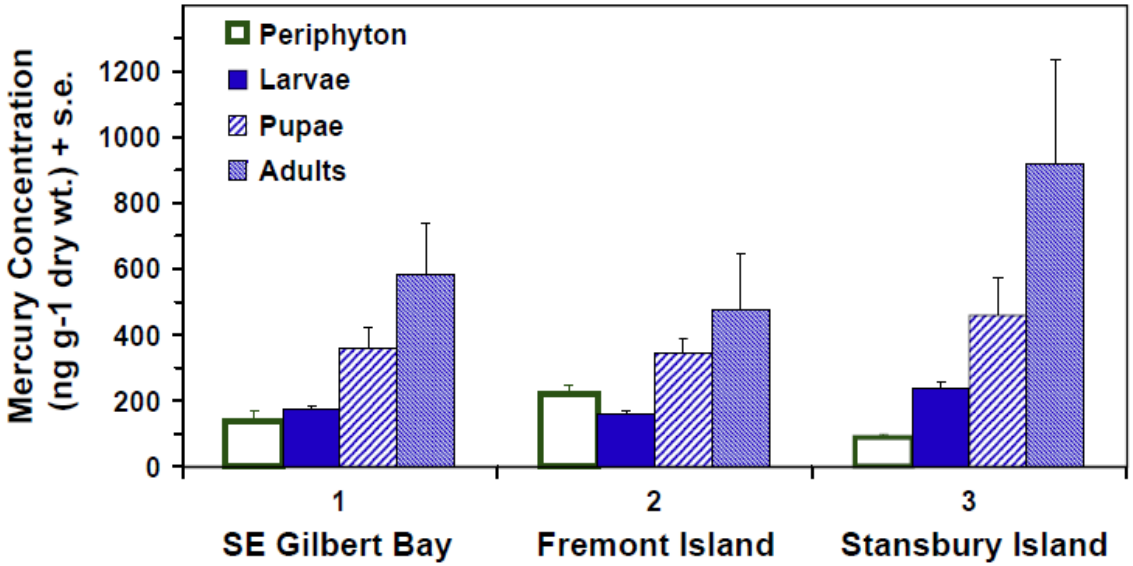
HgT in adult brine flies around the GSL, August 2012





HgT and % MMHg in brine fly life stages, Site 1





Wurtzbaugh et al., 2011, STOTEN

JOURNAL

OF THE

New York Entomological Society.

VOL. XX. JUNE, 1912. No. 2

THE BIOLOGY OF SOME WESTERN SPECIES OF THE DIPTEROUS GENUS EPHYDRA.[1]

BY J. M. ALDRICH,

again. They extended up the beach a few feet above the water also, so the average width of the mass was over 20 feet. I thought that there were more than 25 flies to the square inch; in fact, double that seems a small estimate. The minimum estimate would give about 370,000,000 flies to the mile of beach.

How much Hg leaves the GSL with brine flies annually?

- Lake average annual emerging adult brine flies ~50 g/m^2 (Collins, 1980)
- Summer 2012: Lake elevation of 4197 m and South Arm surface area of 1870 km^2 (Baskin, 2005)
- Brine flies ~70% water by mass
- Average brine fly adult dry weight [HgT] ≈ 350 ppb, [MMHg] ≈ 250 ppb

~ 10 kg HgT and ~ 7 kg MMHg leave GSL with emerging brine flies.

- Summer 2012: South Arm volume of 9.6×10^9 m^3 (Baskin, 2005)
- South Arm weighted average [HgT] ≈ 10 ng/L, [MMHg] ≈ 3 ng/L

~ 96 kg HgT and ~ 29 kg MMHg in South Arm water column

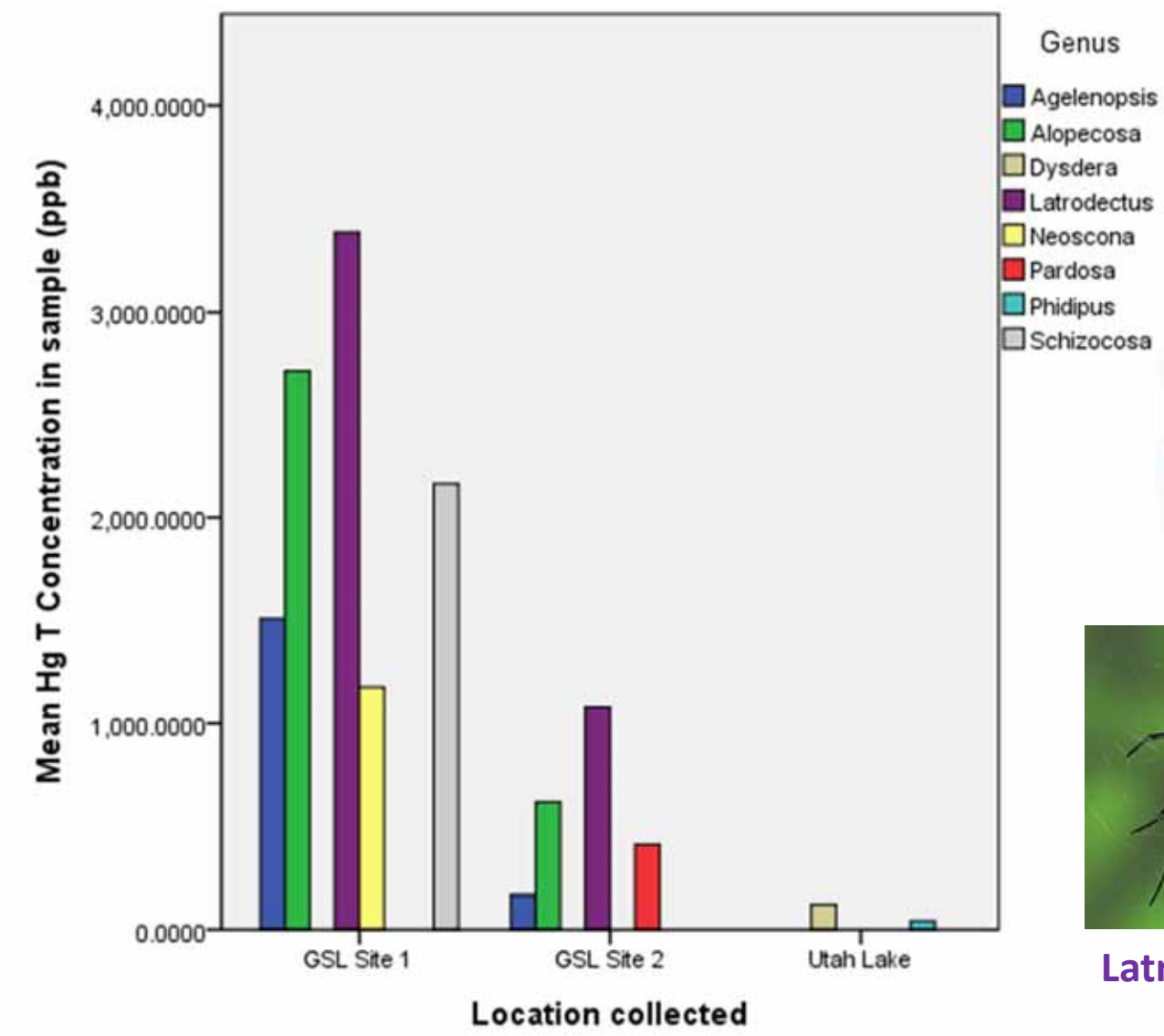
~ 10% of HgT, ~ 24% of MMHg in South Arm water fluxed out with brine flies.

Is the bioadvection of Hg by brine flies important?

If 10% of brine flies die on land or washed to shore, annual brine fly flux to terrestrial ecosystem is ~ 1 kg HgT and ~ 0.7 kg MMHg.

- **US EPA consumption limit for Hg of 1 ppm**
- **Average mallard duck mass ~1.2 kg**
- **1 kg of HgT is enough to contaminate > 830,000 mallards to 1 ppm Hg**

Differences in HgT in spiders by genus



Agelenopsis

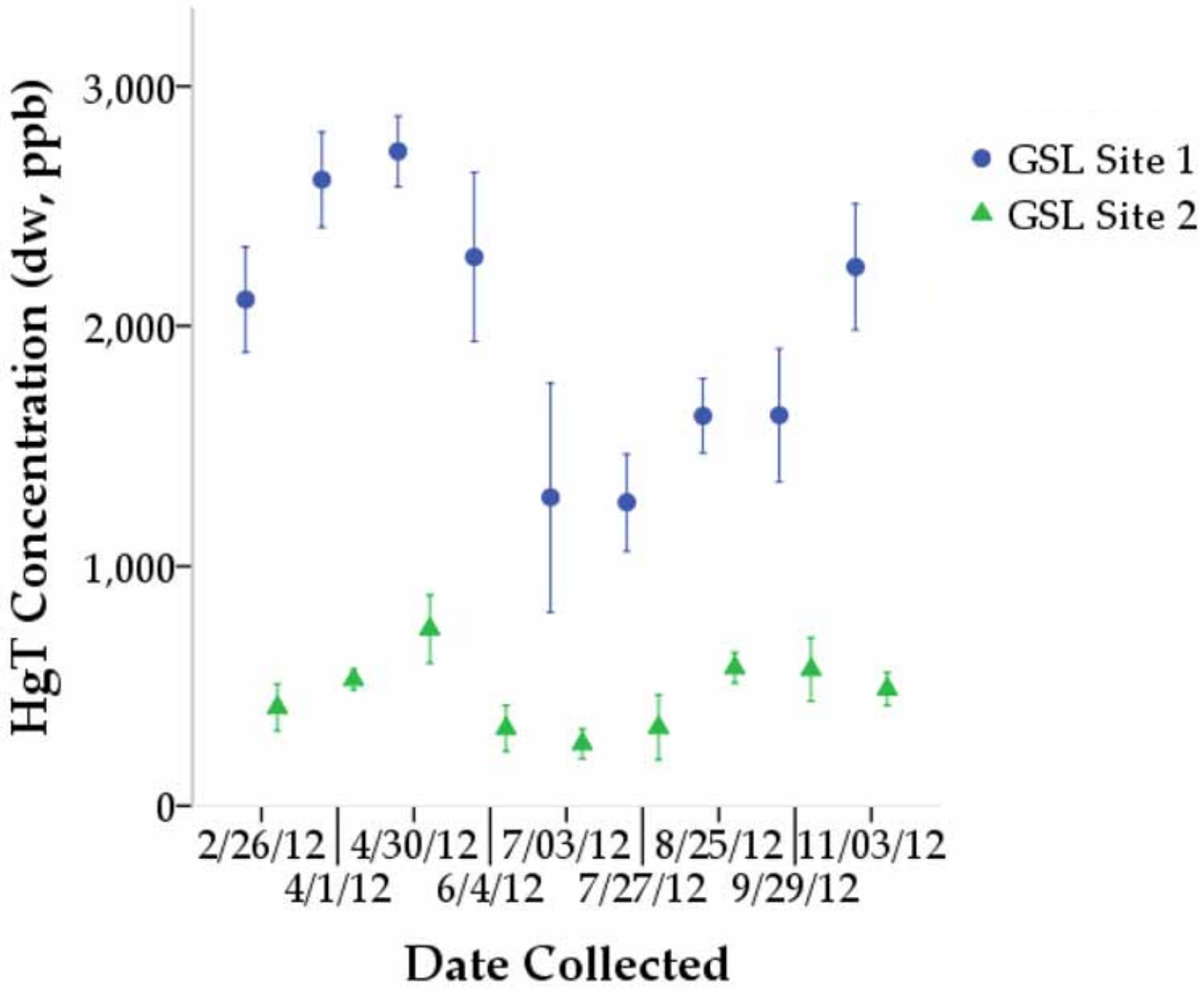
Alopecosa

Schizocosa

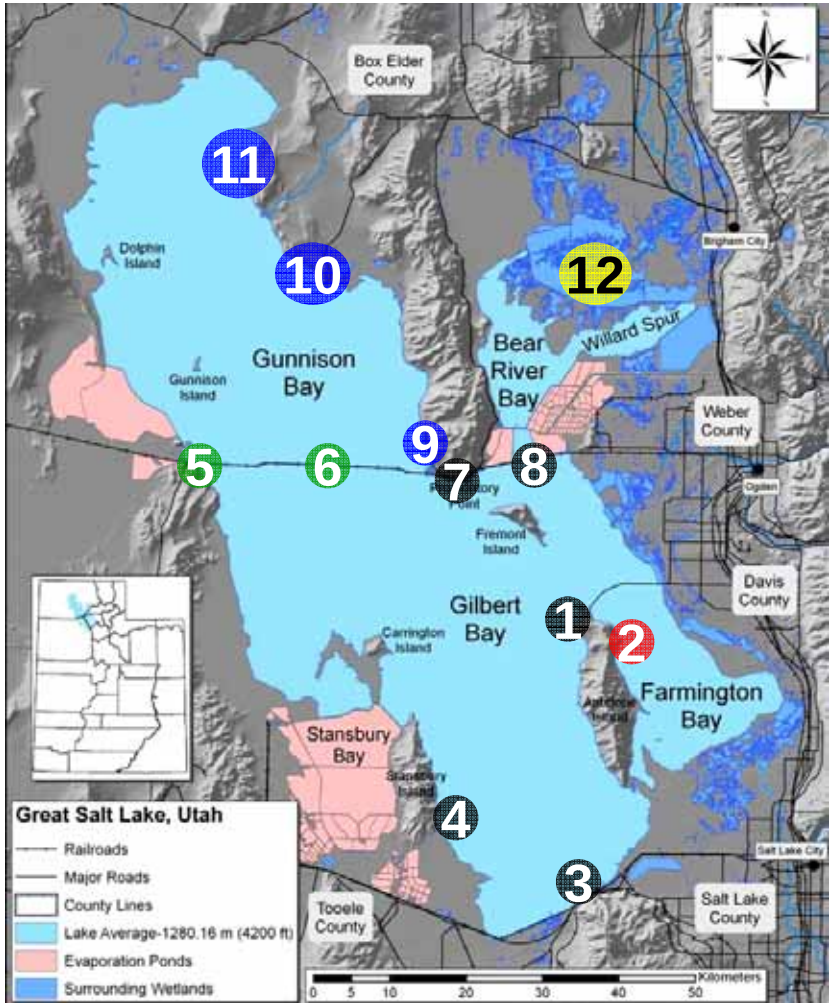
Latrodectus

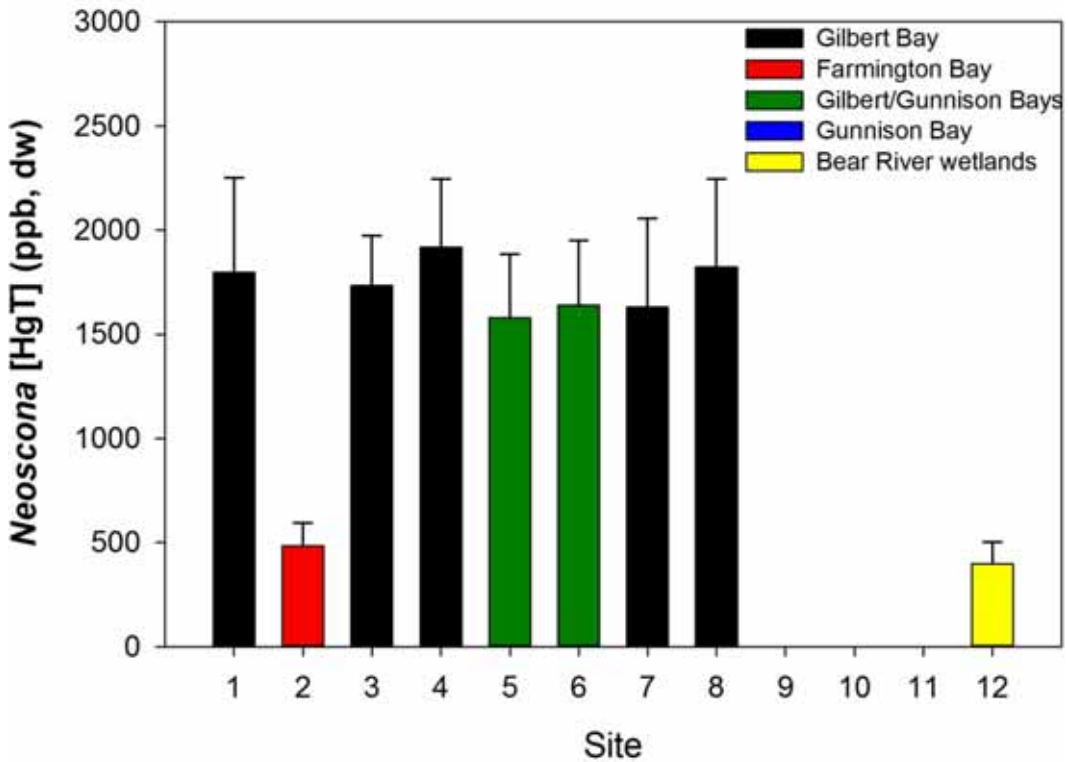
Neoscona

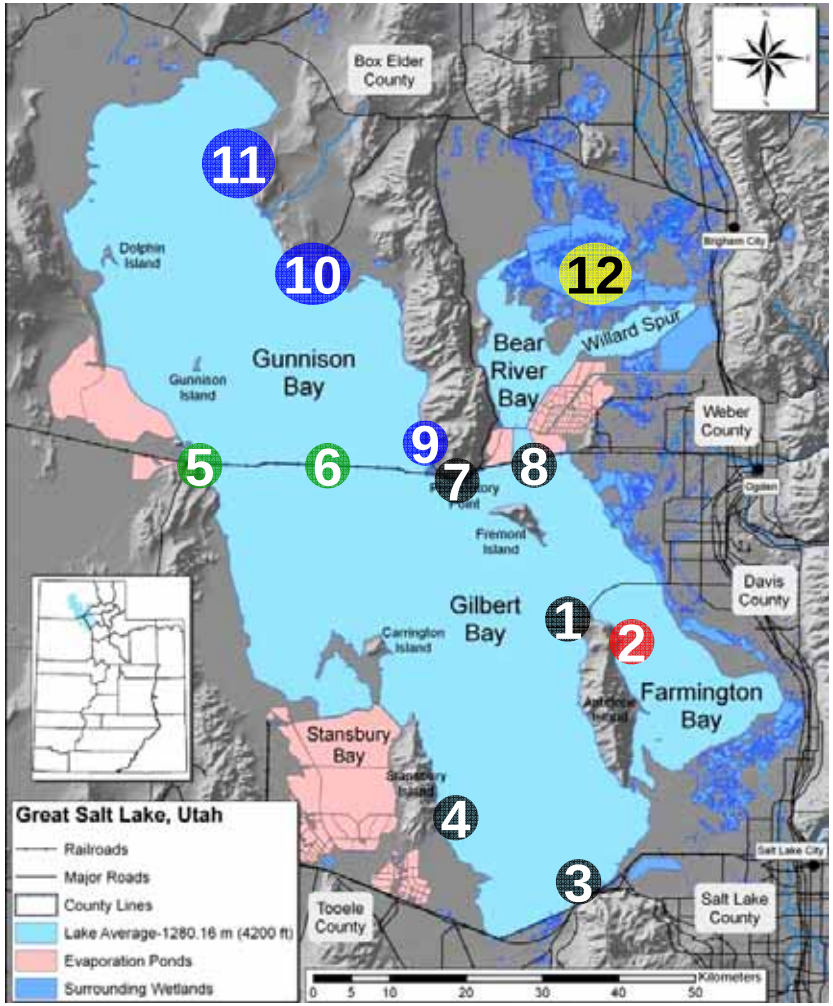
HgT in Spiders

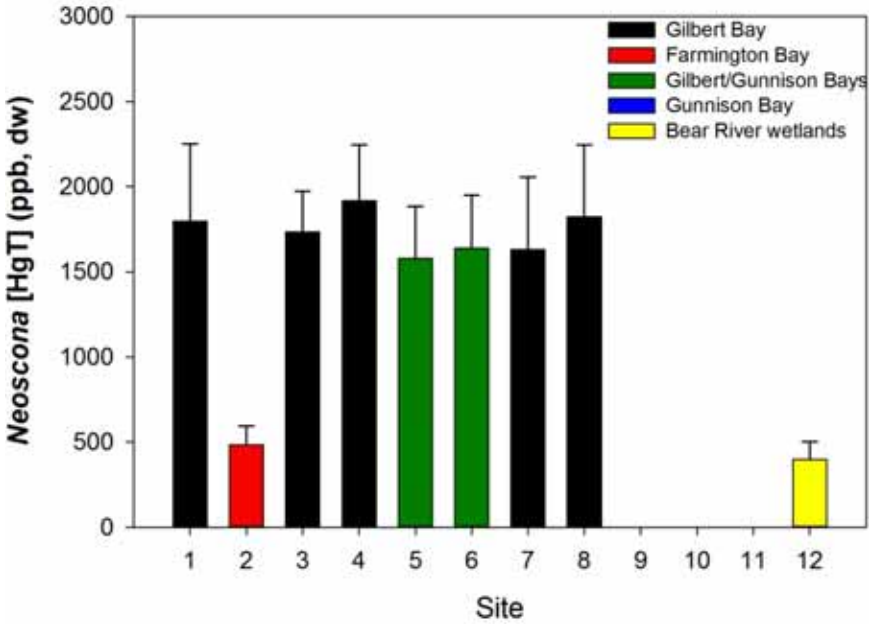


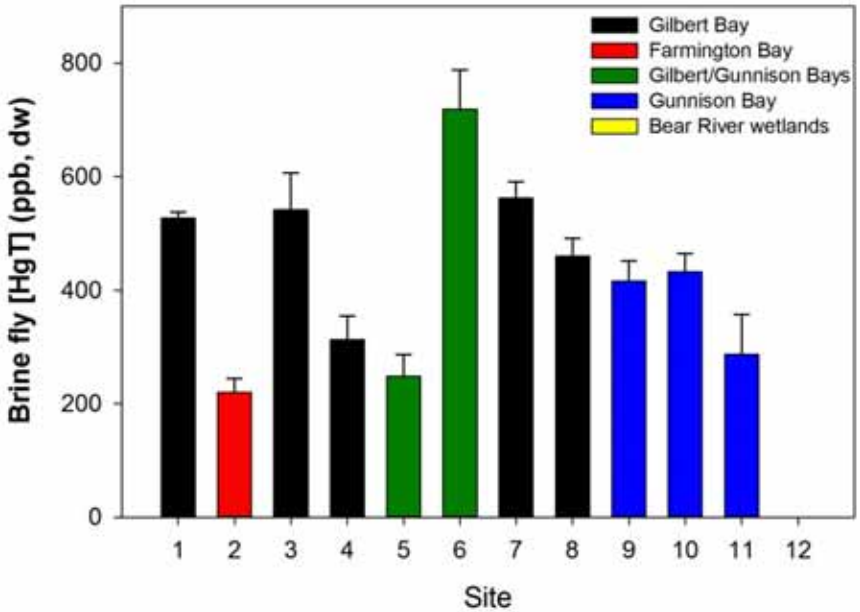
HgT in spiders of the genus *Neoscona* around the GSL, August 2012






Box Elder County
Dolphin Island
Gunnison Island
Gunnison Bay
Bear River Bay
Willard Spur
Brigham City
Weber County
Ogden
Fremont Island
Davis County
Gilbert Bay
Carrington Island
Farmington Bay
Antelope Island
Stansbury Bay
Stansbury Island
Salt Lake City
Salt Lake County
Tooele County
1
2
3
4
5
6
7
8
9
10
11
12
Great Salt Lake, Utah
Railroads
Major Roads
County Lines
Lake Average-1280.16 m (4200 ft)
Evaporation Ponds
Surrounding Wetlands
Kilometers
0 5 10 20 30 40 50


Neoscona [HgT] (ppb, dw)
3000
2500
2000
1500
1000
500
0
Gilbert Bay
Farmington Bay
Gilbert/Gunnison Bays
Gunnison Bay
Bear River wetlands
1 2 3 4 5 6 7 8 9 10 11 12
Site


Brine fly [HgT] (ppb, dw)
800
600
400
200
0
Gilbert Bay
Farmington Bay
Gilbert/Gunnison Bays
Gunnison Bay
Bear River wetlands
1 2 3 4 5 6 7 8 9 10 11 12
Site

Some effects of mercury in birds

- Reduction in hatching success
- Reduction in offspring care
- Potential increase in rates of infectious diseases
- Reduction in number of offspring produced
  - In white ibis reduction in offspring number due to male-male mating
    (Frederick and Jayasena, 2010, Proceedings of the Royal Society B)

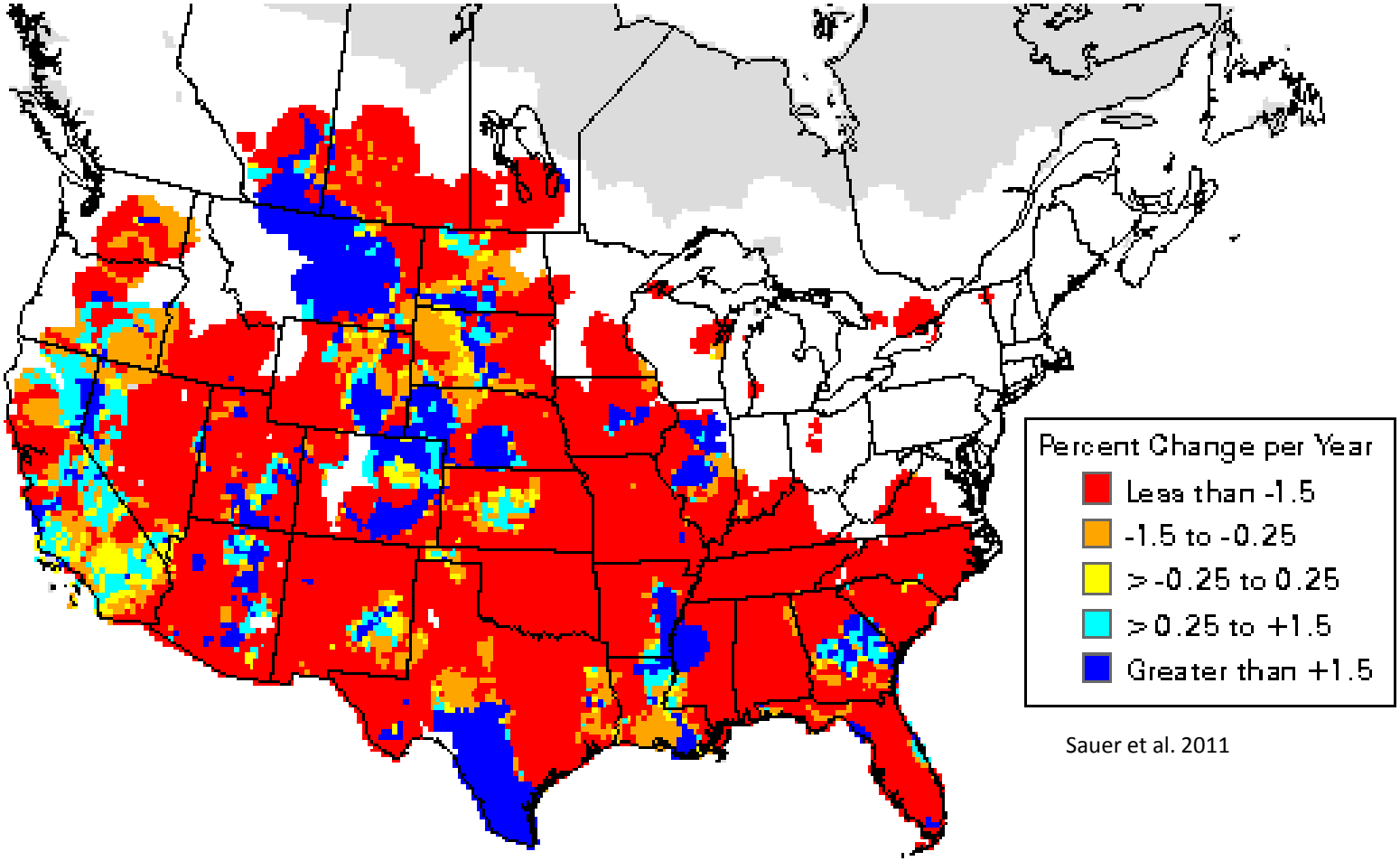
Hg in Loggerhead shrikes at the Great Salt Lake

Photos: R. Dudley

Study Species – Loggerhead Shrike ("Butcher bird")

Photo: Terry Ross

Study Species – Loggerhead Shrike



Sauer et al. 2011

Adult and nestling shrikes:

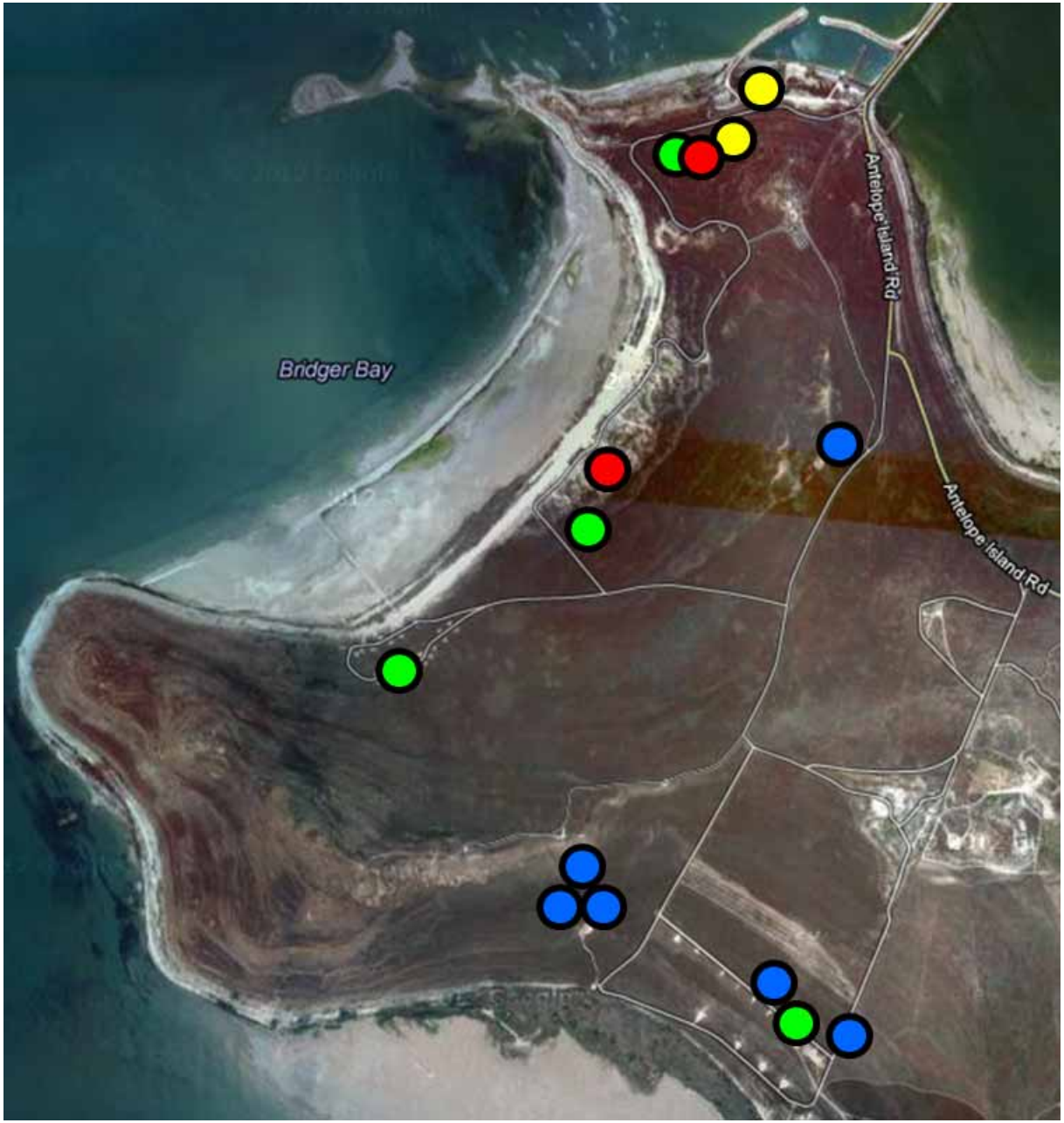
- Blood and feather sample
- Color band

Breeding success:

Monitor nests to determine fate

- How many eggs fail to hatch?
- How many nestlings make it out of the nest?
- What types of food are nestlings being fed?
- Correlation between blood Hg and breeding success?

2012: Only 15 adult and juvenile shrikes sampled



Shrike blood [HgT]

- 0.15-0.6 ppm
- 0.61-1.0 ppm
- 1.1-2.4 ppm
- 2.5+ ppm

Blood Hg > 3.7 ppm in 2 shrikes (13%)

Adverse effects in other avian species at ≥ 2.0 ppm

Lowest blood Hg in birds furthest from shore?

2013 shrike sampling

14 adult and juvenile shrikes, 100 nestlings in 22 nests

Does nestling diet correlate with blood Hg?

- Video cameras on nests
- Identify food types and percentage of diet

Does blood Hg correlate with nesting success?

- Number of eggs laid?
- Egg mass?
- How many eggs fail to hatch?
- How quickly do nestlings gain weight?
- How many nestlings make it out of the nest?

Average % MMHg at Site 1

Filtered surface water: 16%

Brine flies: 68%

Spiders: 79%

Brine Shrimp: 94%

Conclusions

- Any efforts to document long term changes in Hg in biotic or abiotic compartments at the GSL must account for seasonal changes and spatial differences.
- Biota along Gilbert Bay has higher Hg levels than along Farmington Bay, despite similar concentrations of HgT and MMHg in water. This appears due to differences in brine fly diet or food web structure.
- Peaks in HgT and MMHg concentrations in brine flies loosely coincide with peak spring and fall bird migration stopovers at GSL.
- Birds that breed and nest at the GSL benefit from a seasonal low in Hg in brine flies and spiders during nesting and fledging.
- Bioadvection by brine flies represents a significant flux of HgT and MMHg from the lake to surrounding terrestrial ecosystems.
- Some song birds have blood Hg concentrations that could result in sub-lethal toxicity. Additional studies are ongoing.

Questions?