Paleolimnological Analysis of Metals Contamination and Eutrophication in the Great Salt Lake

Wayne Wurtsbaugh

Utah State University, USA

Peter Leavitt & Linda Bunting

University of Regina, Canada

Katrina Moser & Craig Woodward

Univ. Western Ontario, Canada

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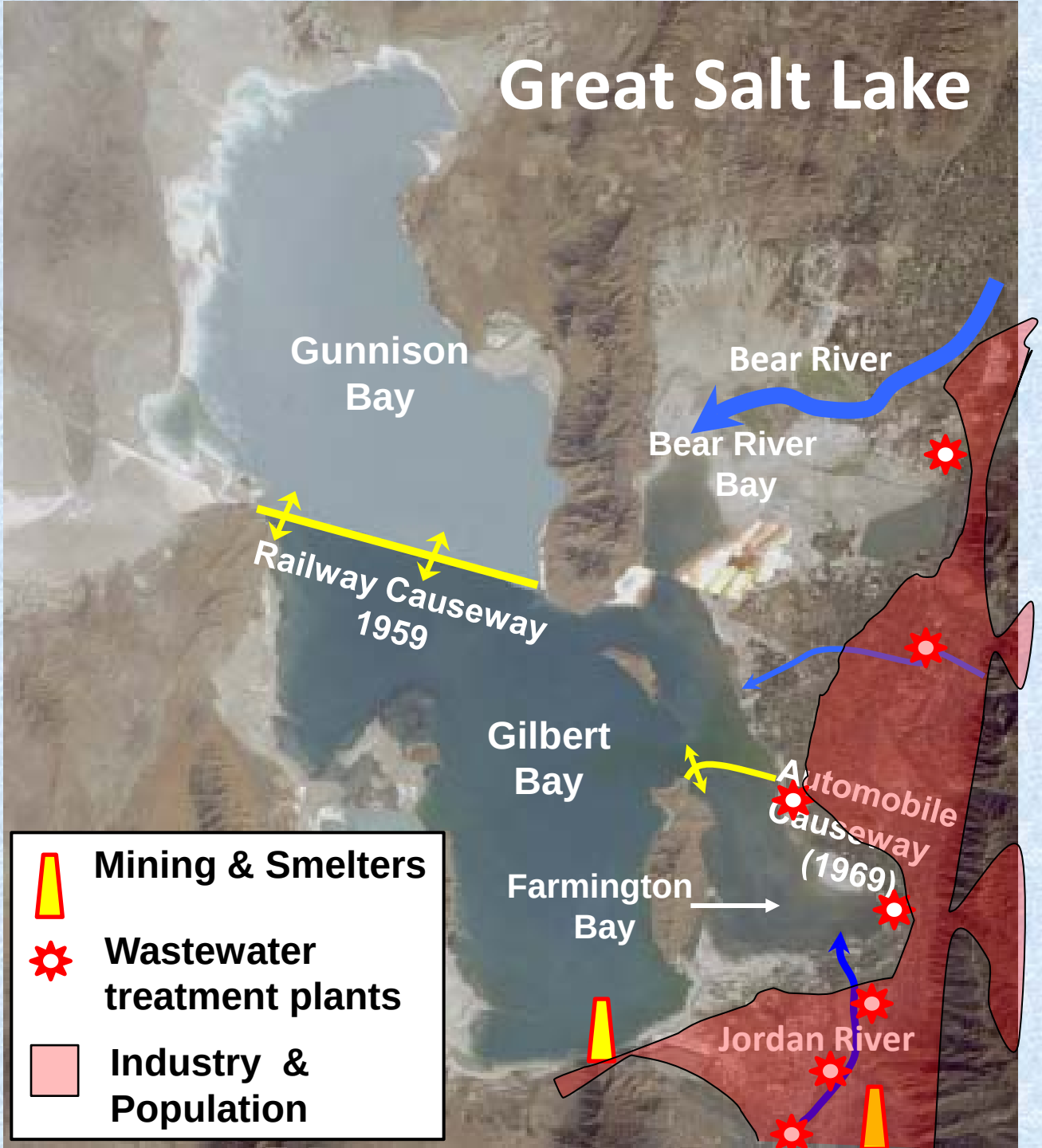
Utah Chapter of the AFS
Bullfrog, March 2012

Paleolimnology

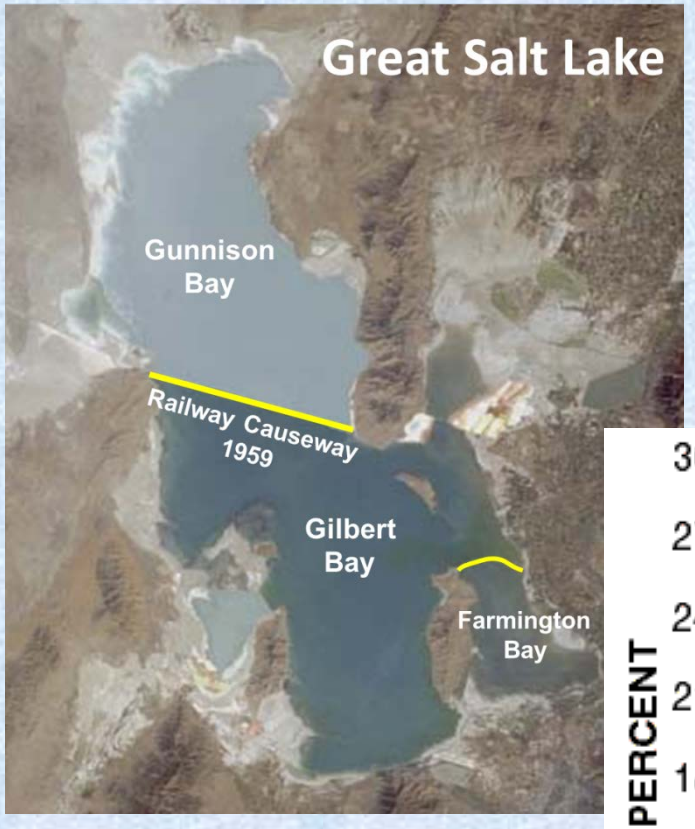
- **Paleolimnology – Reconstruction of the historical record in lakes, wetlands, oceans and rivers utilizing "fossils" buried in the sediments**
  - **Long-term paleo-climates (100,000 yr records)**
  - **Short-term anthropogenic impacts (e.g. 100 – 1,000 years)**

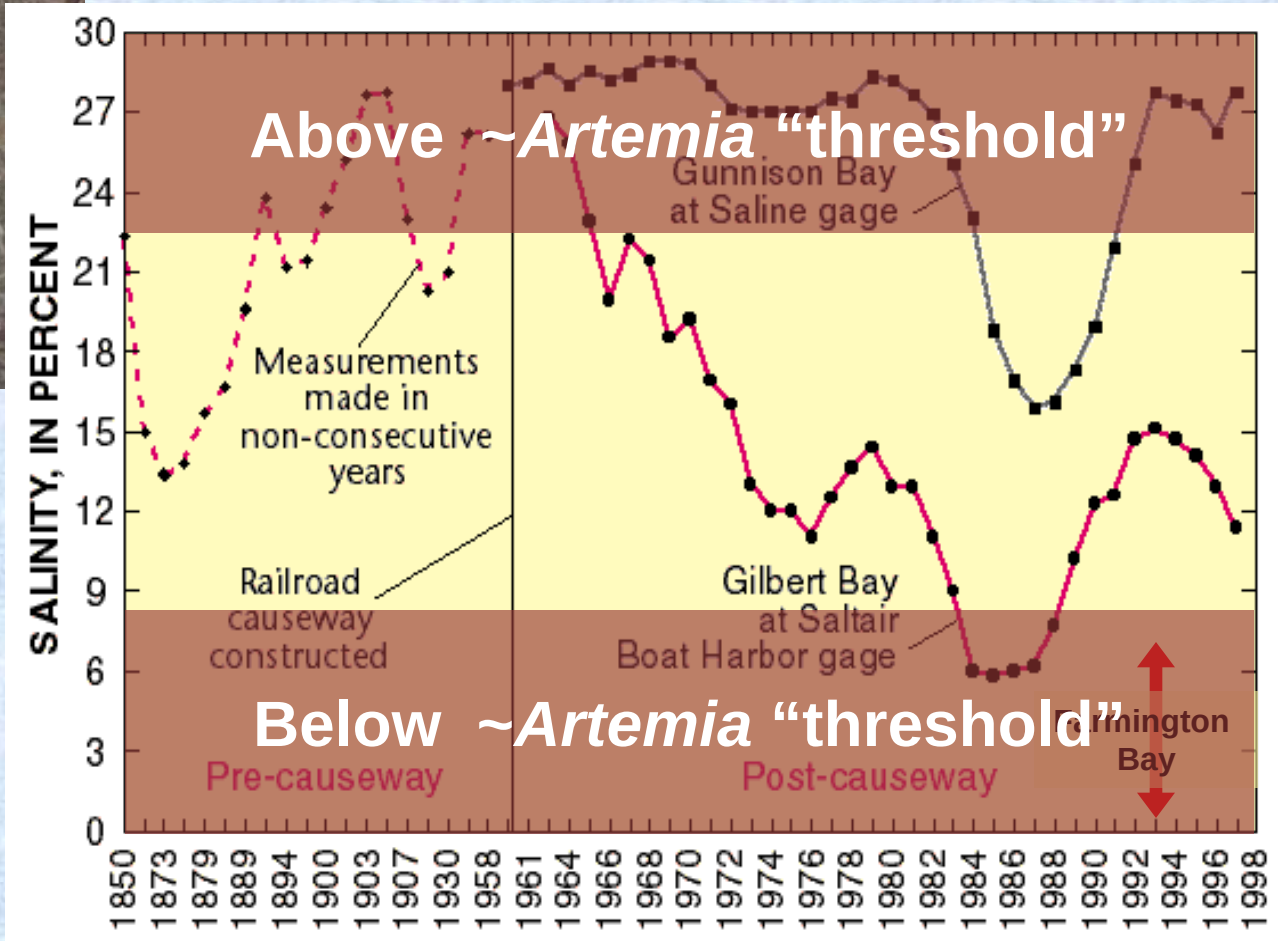

Great Salt Lake
Gunnison Bay
Bear River
Bear River Bay
Railway Causeway 1959
Gilbert Bay
Automobile Causeway (1969)
Farmington Bay
Jordan River
Mining & Smelters
Wastewater treatment plants
Industry & Population

Refineries and the
Northwest Oil Drain
EPA Superfund Site

Kennecott
(Rio Tinto)
metal refinery

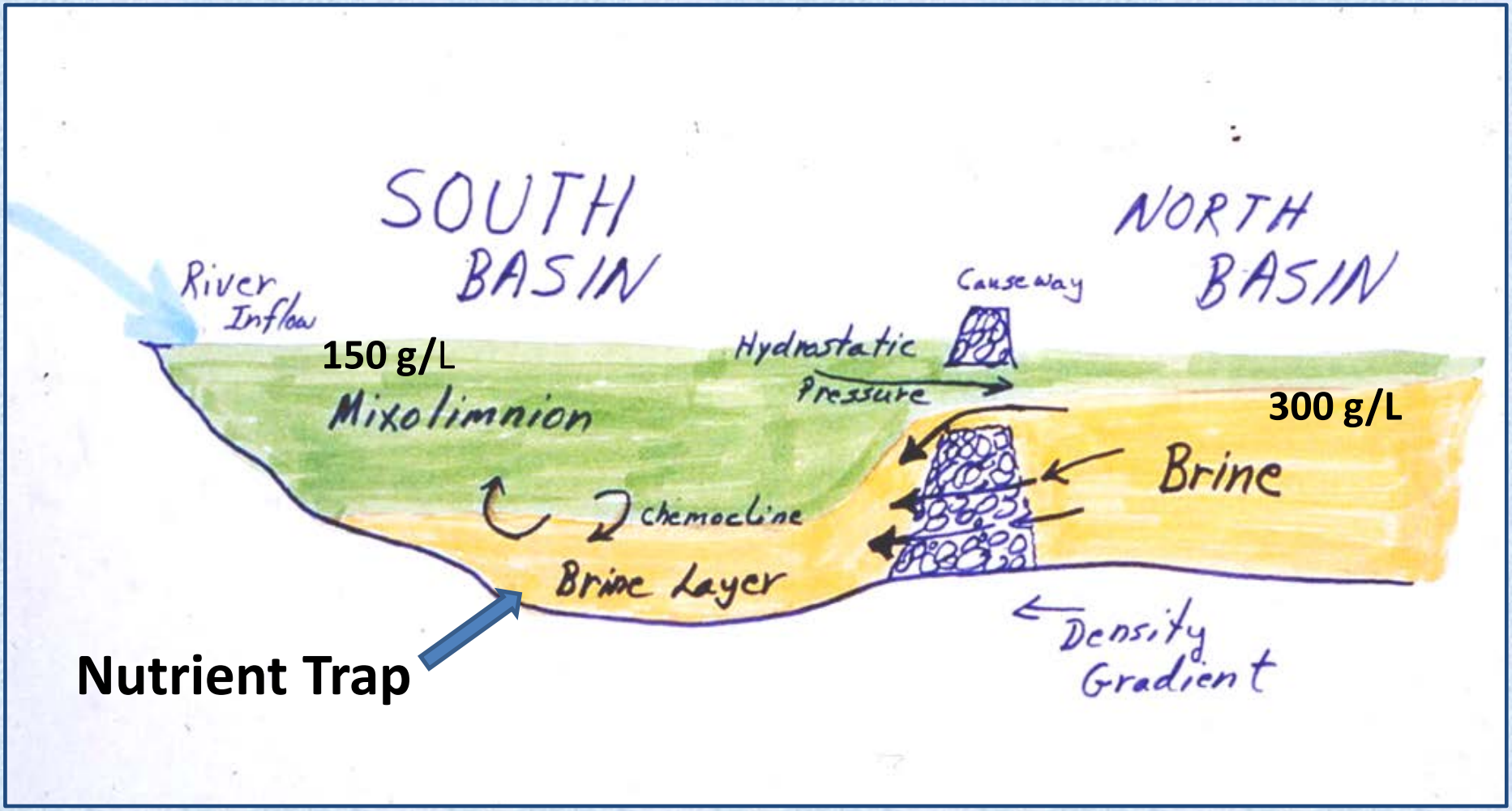
Salinity Changes in Gunnison, Gilbert and Farmington Bays





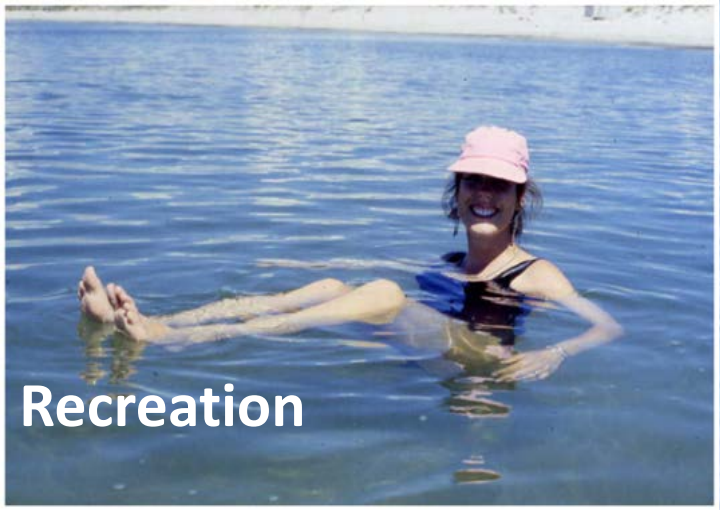
Source: US Geological Survey

Deep Brine Layer (monimolimnion) formed in Gilbert Bay after construction of SP Railroad Causeway



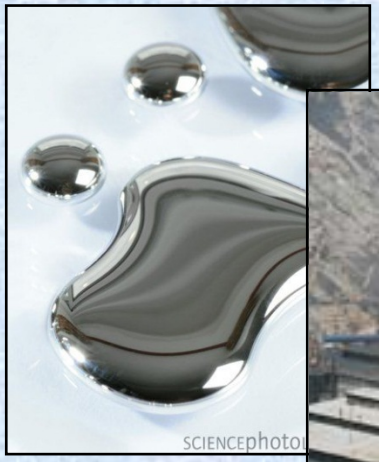
Lake Management Issues

Eutrophication



Lake Management Issues

- **Metal Pollution**
  - Mercury
  - Selenium
- Others (Cd, Cu, Pb, etc.)



Humans

Shoveler

Cinnamon teal

Goldeneye

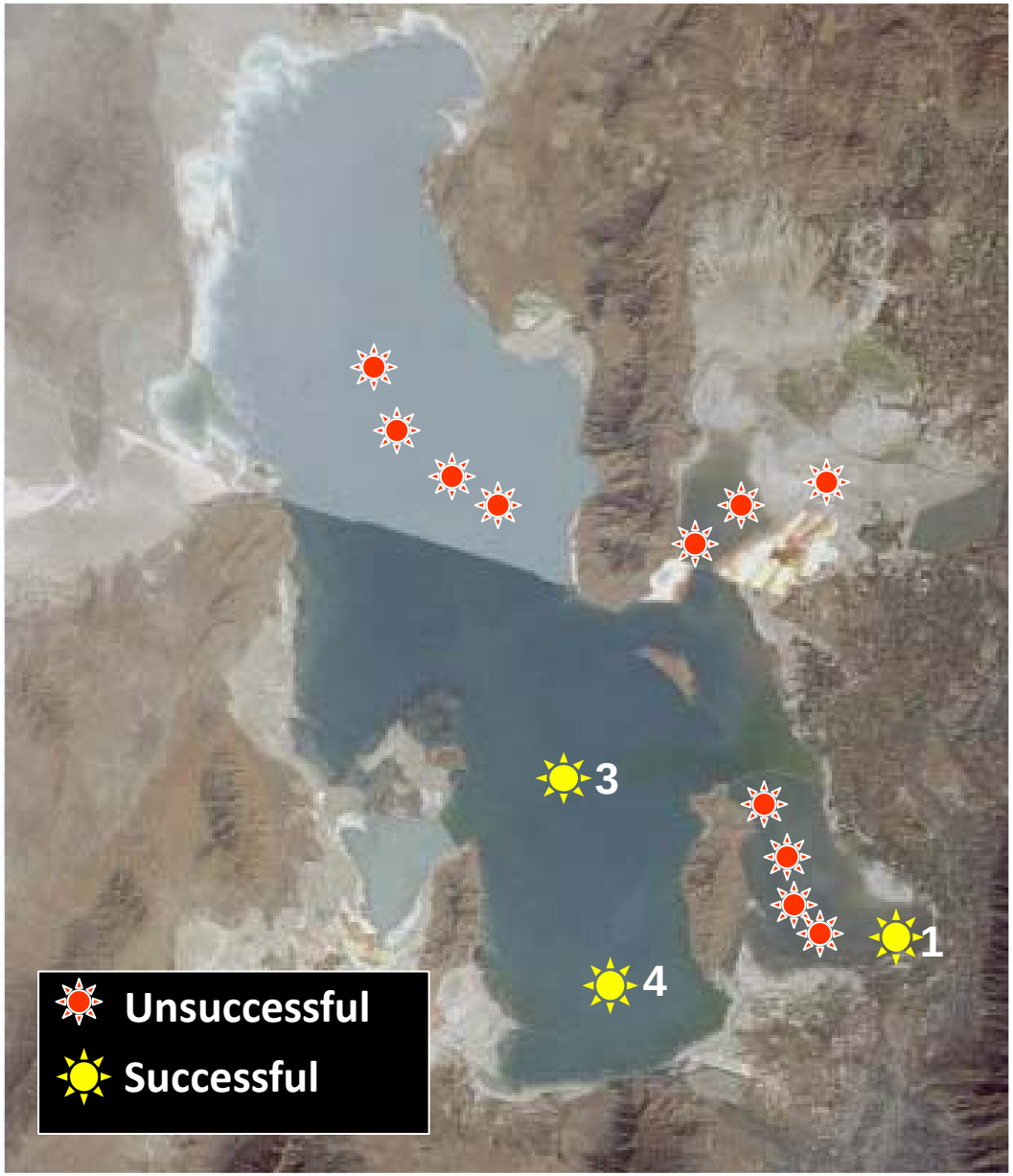
Questions

- **How have concentrations of mercury, lead, copper and other metals changed since Anglo settlement in the 1850s? Can we trace metal contamination to historical events?**

- **How much eutrophication has occurred in the bays of the Great Salt Lake?**

- **Are there useful records of brine shrimp buried in the sediments?**
  - **How long are brine shrimp cysts viable when buried in sediments?**

Coring Sites



Gravity Corer—

Parameters

- Lead-*210* dating
- Metals (30 w/ ICP Mass-Spec.)

Eutrophication Parameters

- Total N , Total P
- N, C isotopes
- Algal pigments
- *Artemia* cyst densities
  - *Artemia* hatching
- Algal microfossils
- Invertebrate fossils

Only Successful Farmington Bay Coring Site

Coring in Bear River Bay

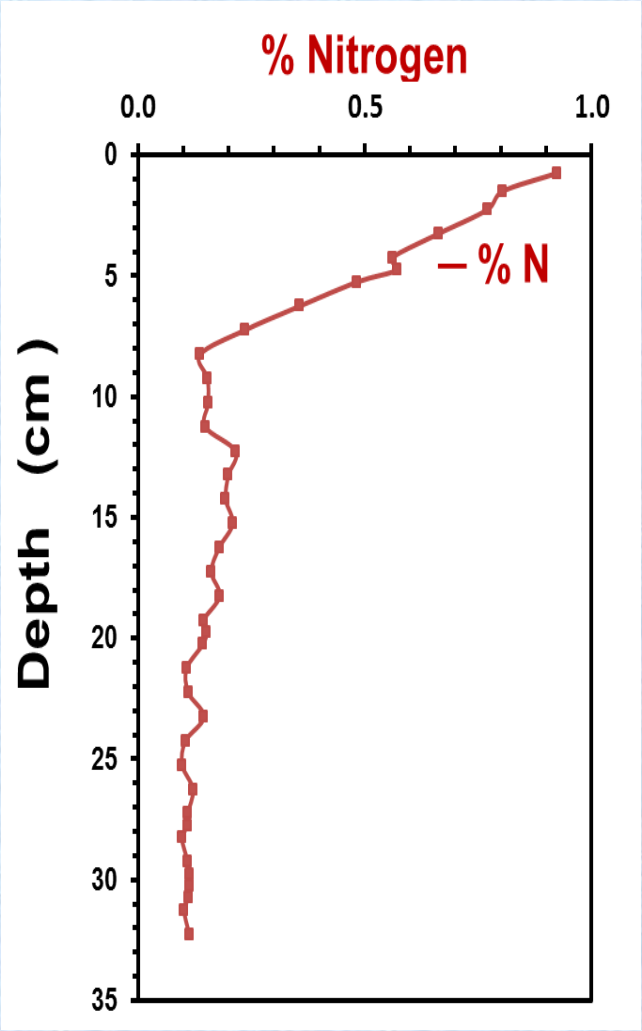
Gilbert Bay
Site 4 Core

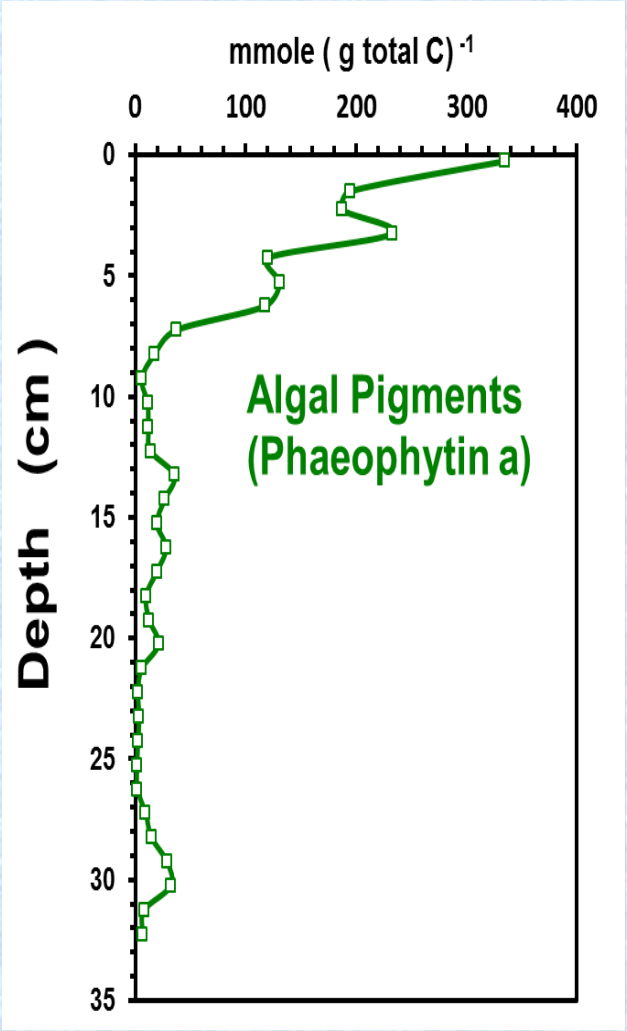
Gunnison Bay
Coring Attempts

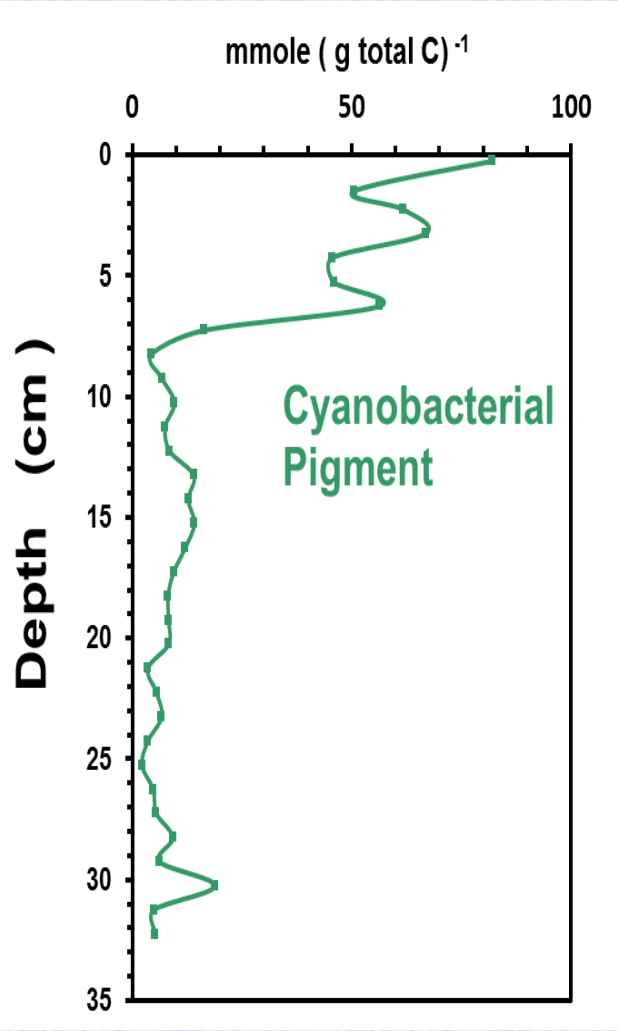
Core Sectioning
0.5 or 1-cm intervals

Multiple cores at each site

Eutrophication in Farmington Bay

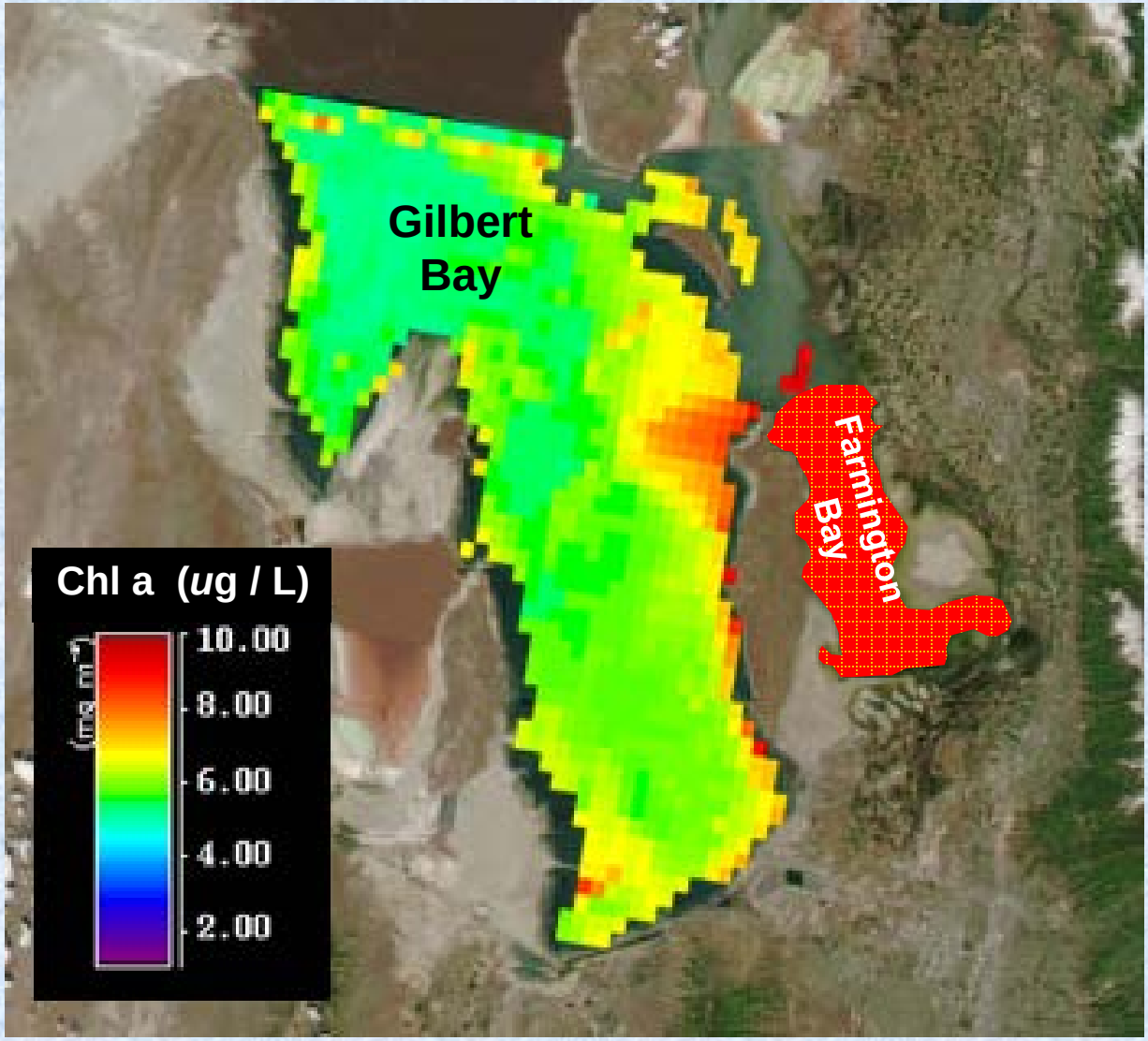






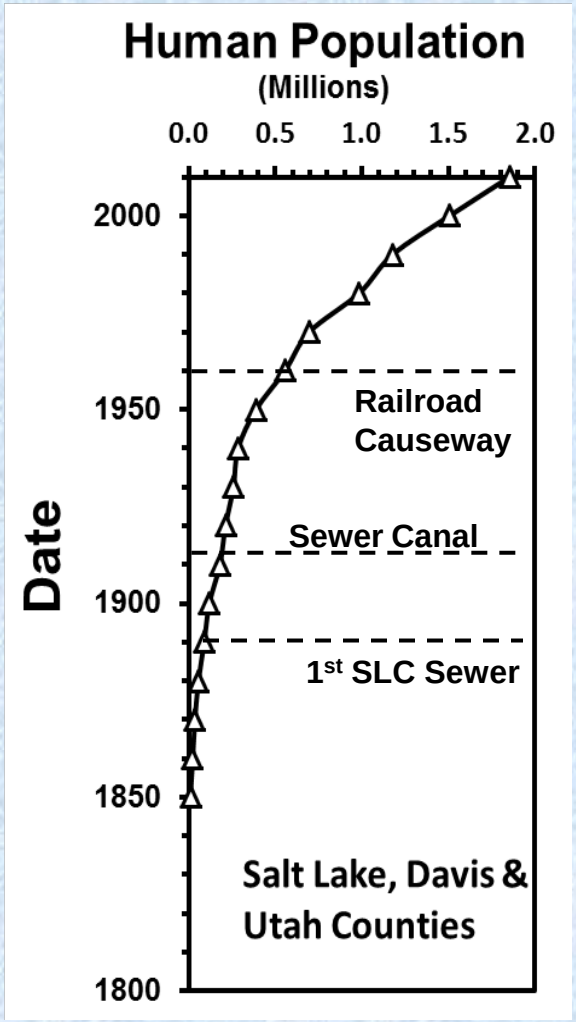
Large increases in all eutrophication parameters

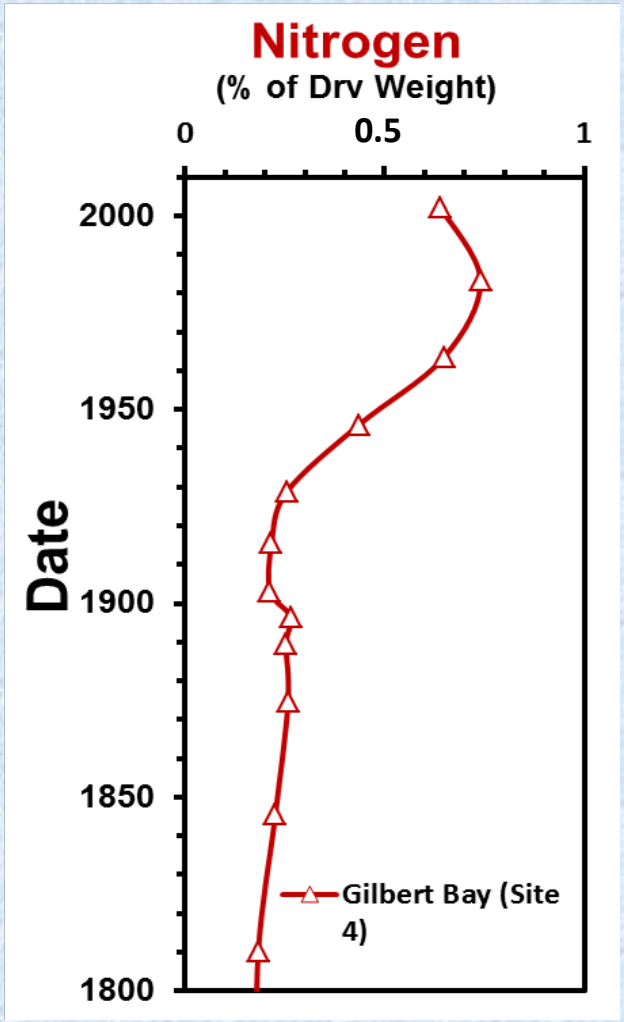
Algae and nutrients are exported from Farmington Bay to Gilbert Bay

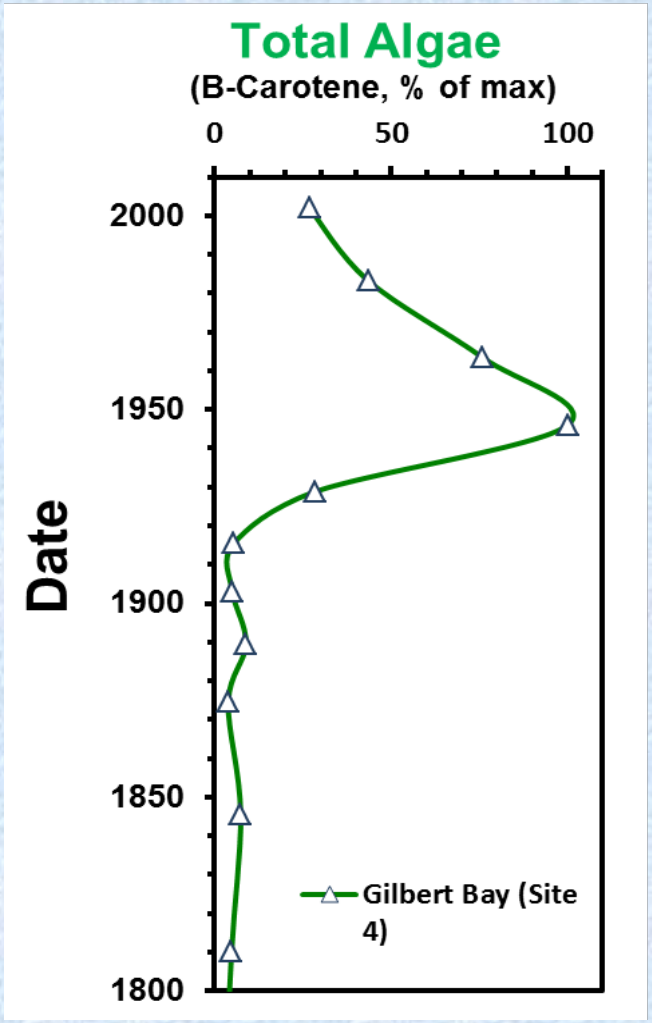


MODIS Satellite
30 May 2006

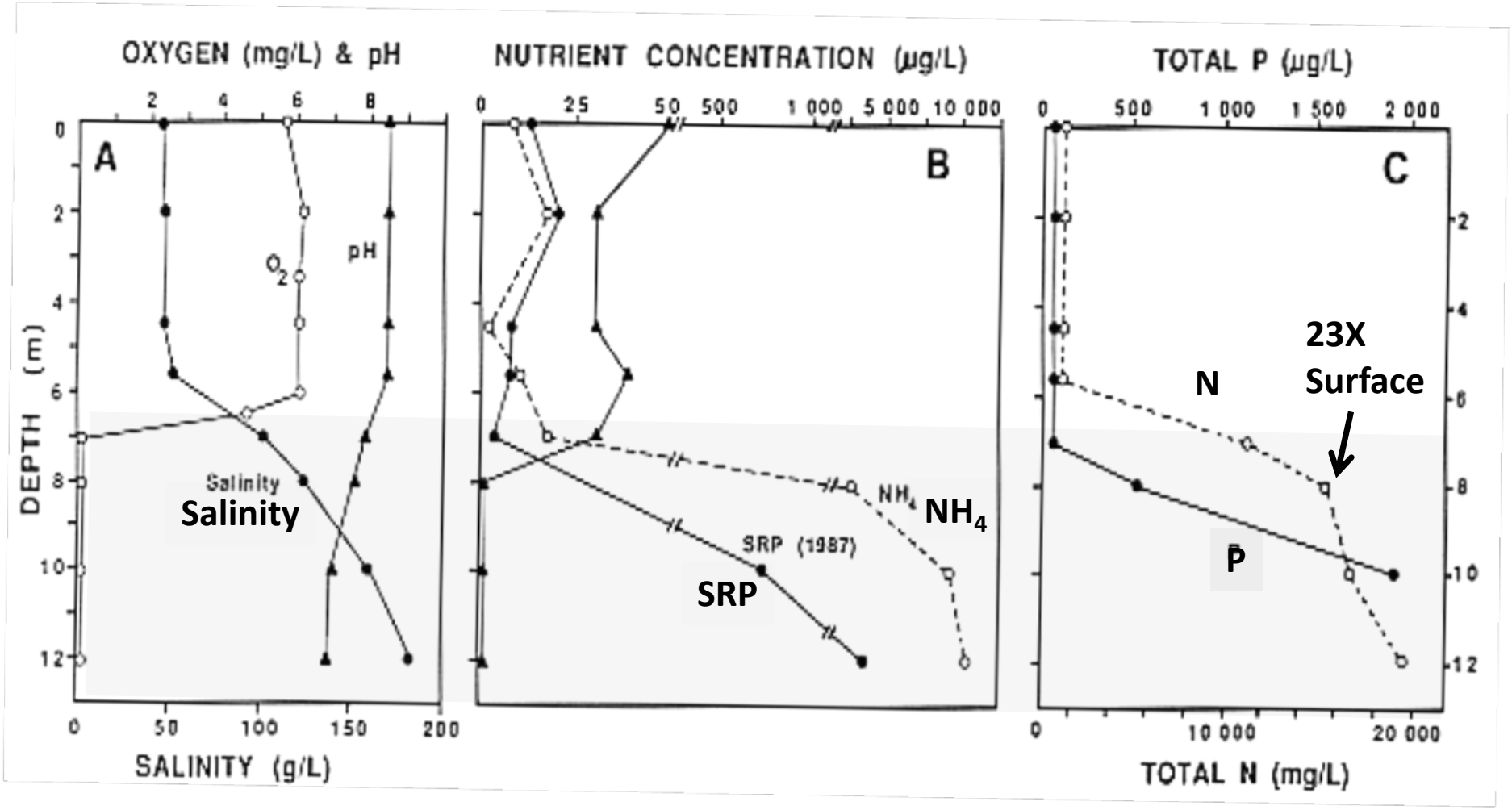
Eutrophication (Gilbert Bay)







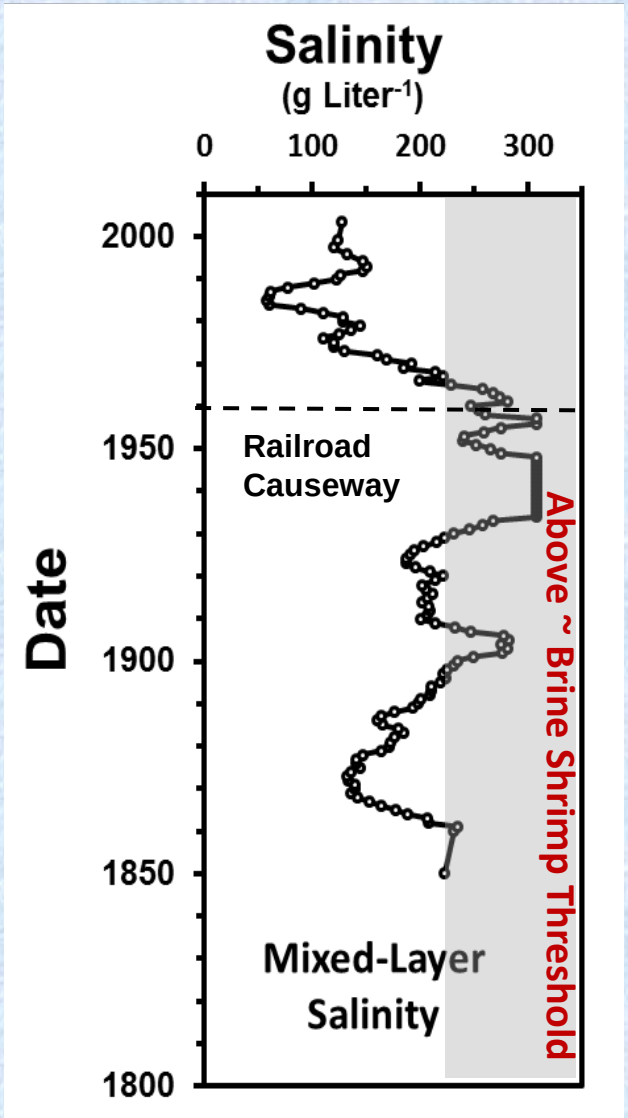
Nutrient Storage in Deep Brine Layer May Explain Reduction in Eutrophication in Gilbert Bay Since RR Construction.

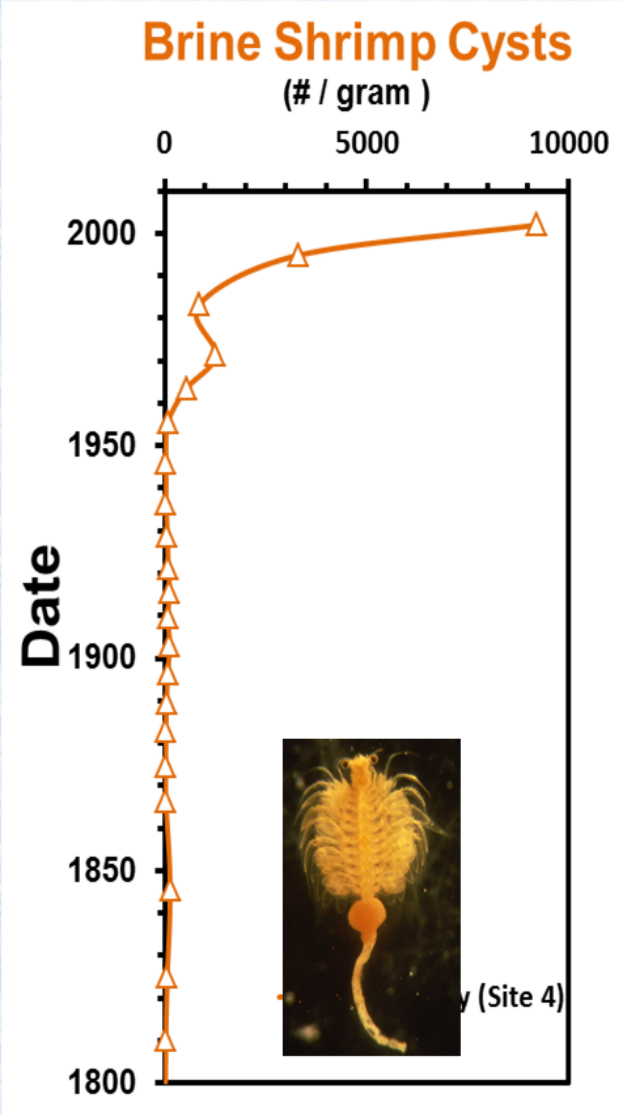


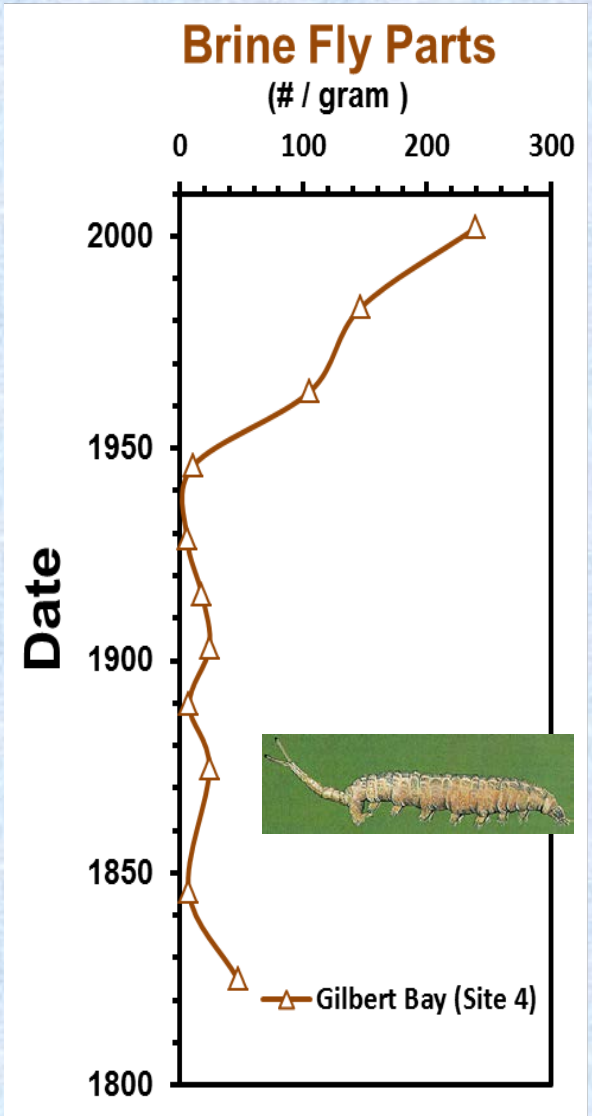
Closure of AI automobile causeway might have contributed too.

Wurtsbaugh & Berry Can J. Fish. Aquatic Sci. (1990)

Changes in Invertebrate Fossils in Sediments







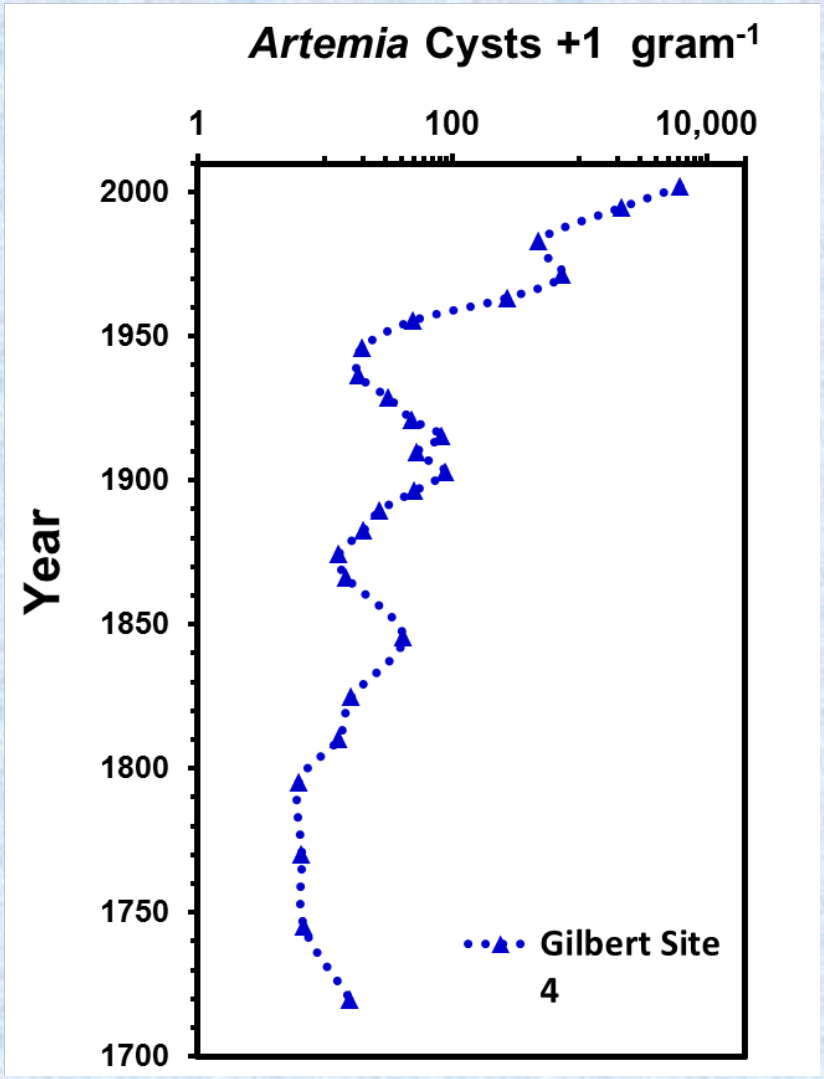
Changes are consistent with changes in nutrient loading and with salinity decreases that have occurred as a result of the railway causeway

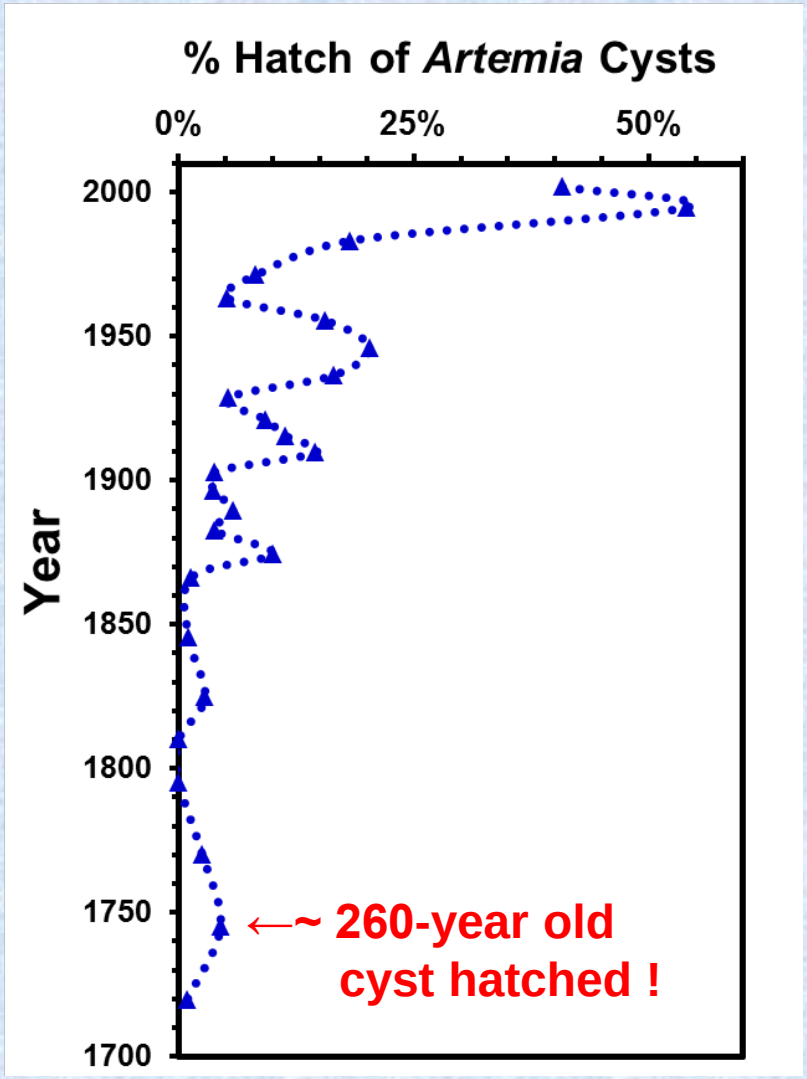
Artemia Cryptobiology

- Cysts extracted from sediments with brine & counted. Then frozen to break diapause.

- Hatched in 28 g/L salt solution & counted after 3-4 d

Resurrection Ecology



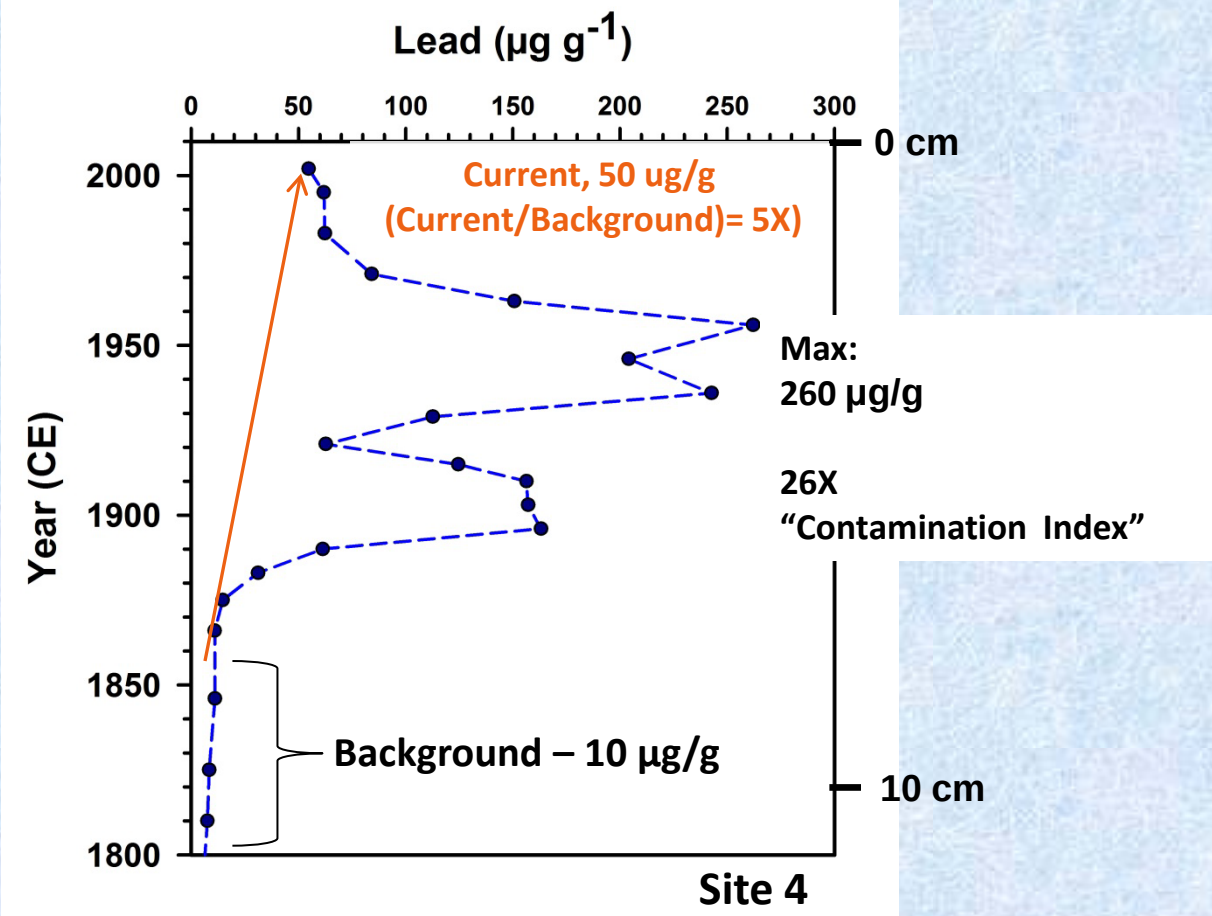


Provides opportunity to study *Artemia* genotypes exposed to very different environmental histories.

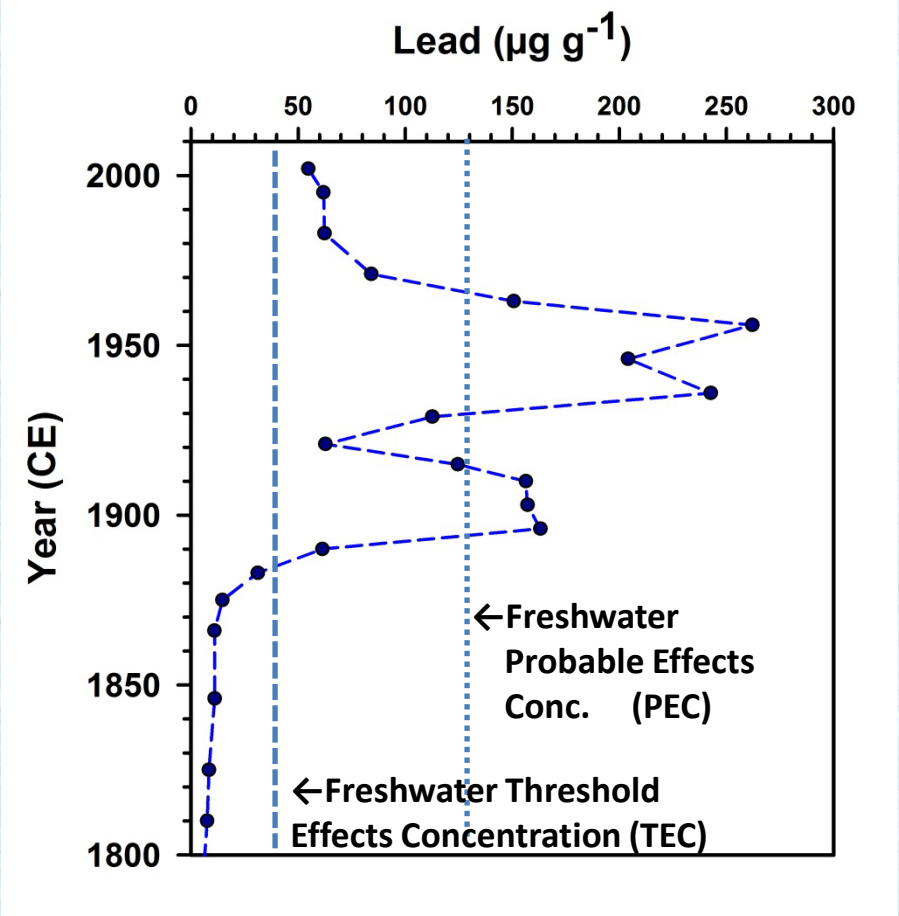
Metal Contamination and Recovery in the Great Salt Lake

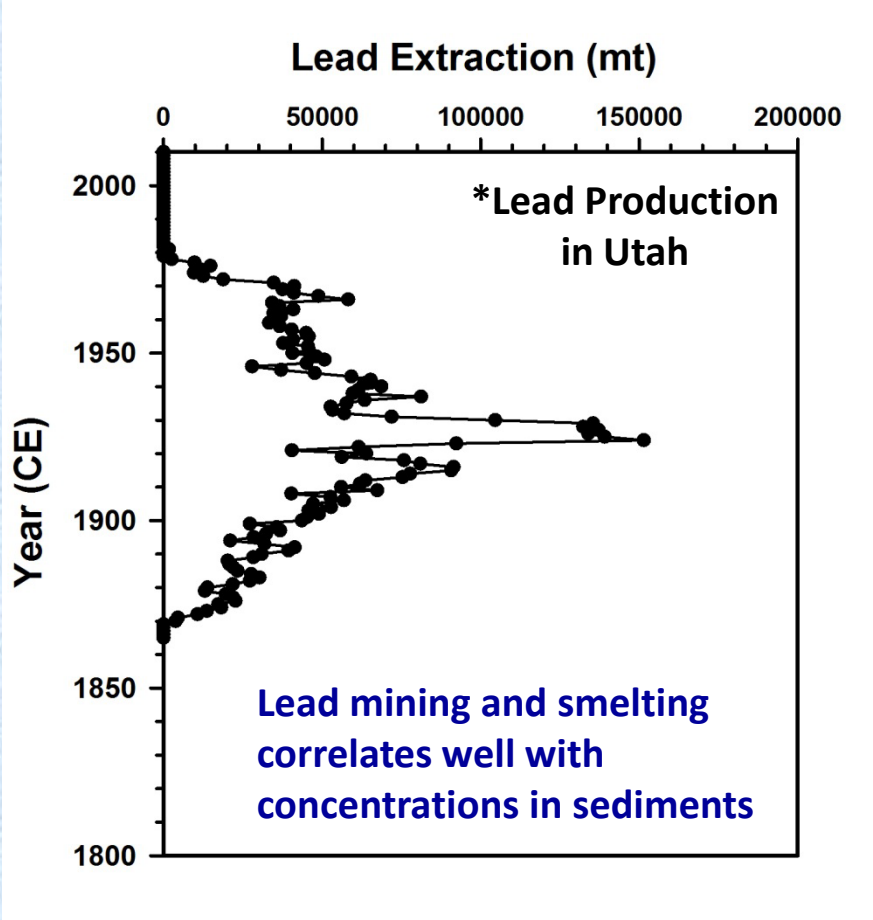
- **Metal Pollution**
  - Mercury
  - Selenium
- Others
  - Arsenic
  - Copper
  - Lead
  - Zinc
  - Many others

Metal Contamination & Recovery: Gilbert Bay



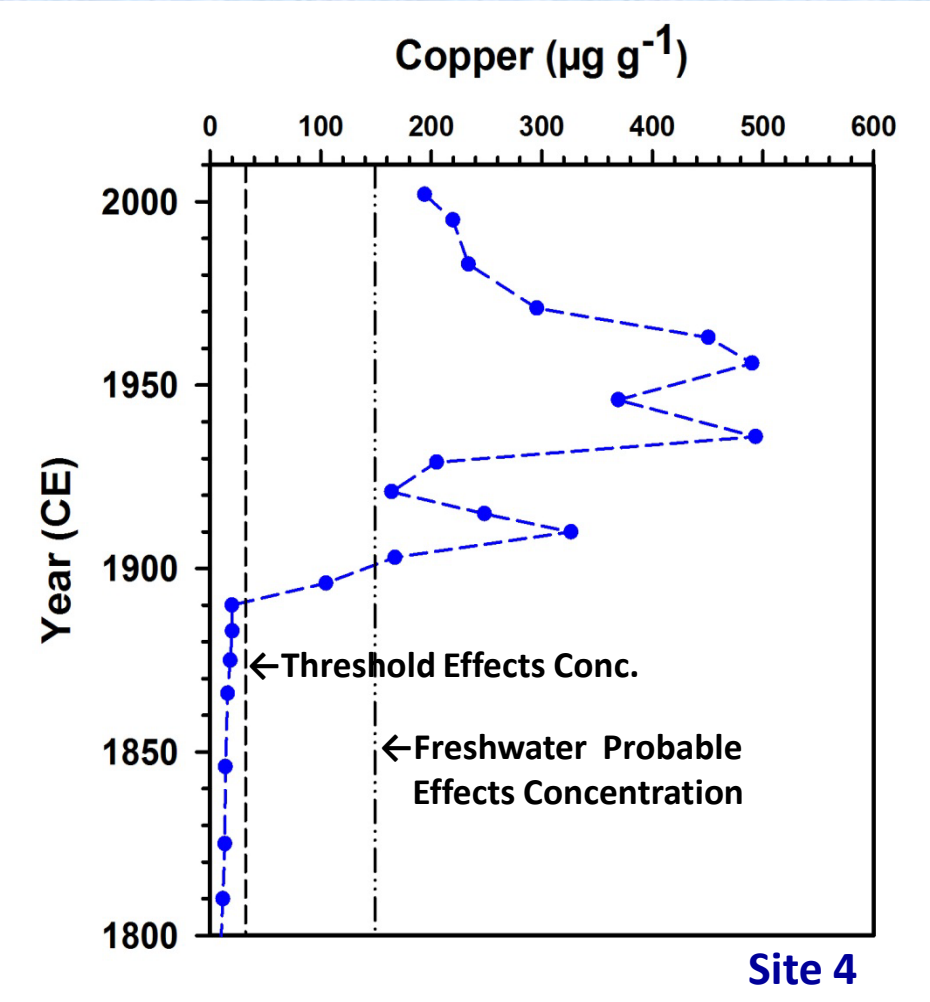
Metal Contamination & Recovery: Gilbert Bay

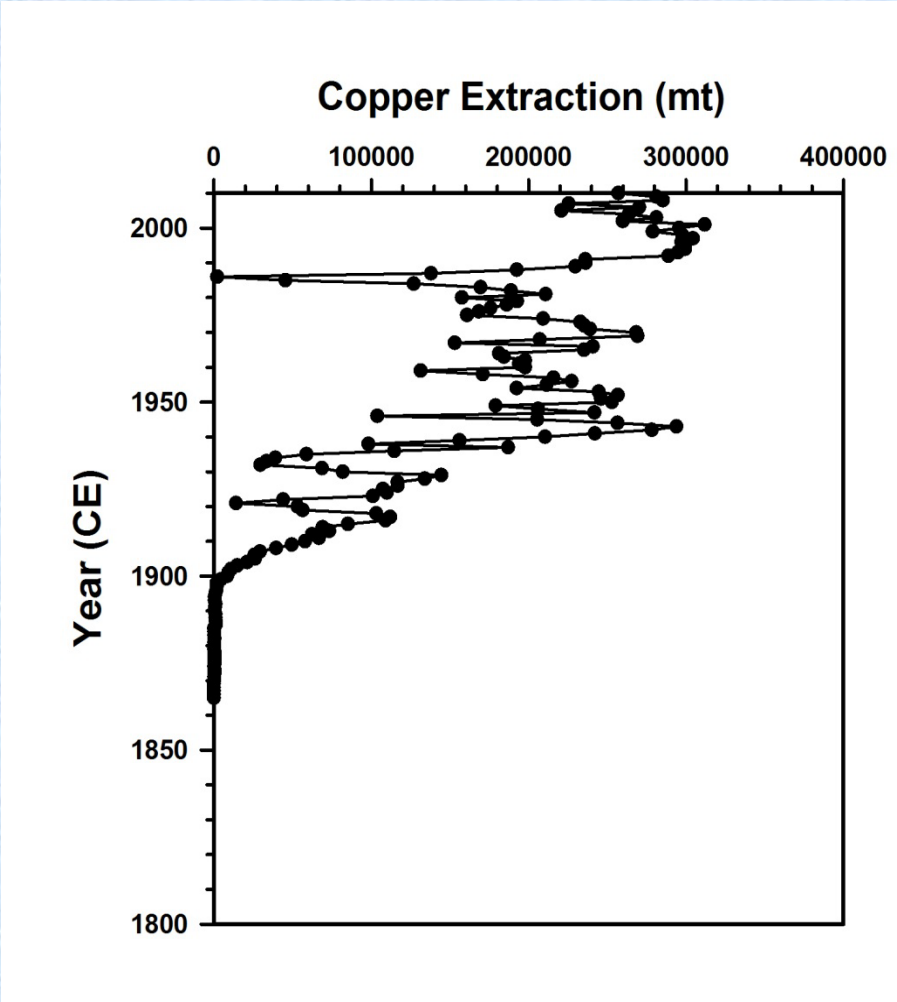




*Source: Utah Geological Survey (2011)

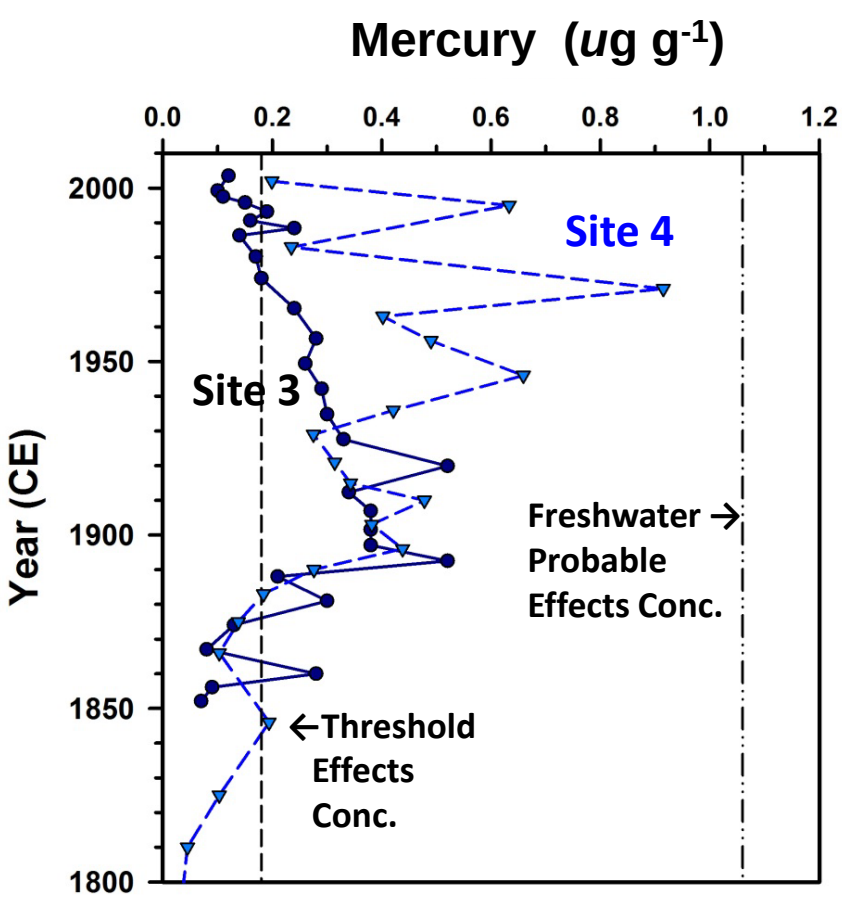
Copper

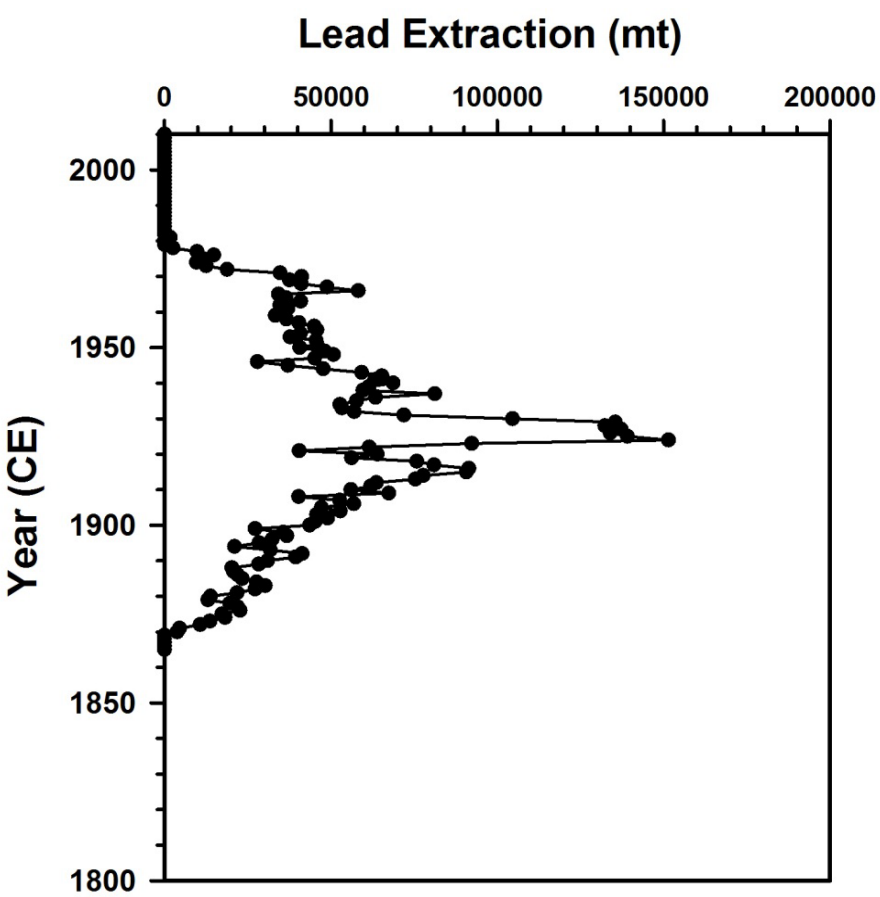




Rise in sediment contamination followed rise in smelting of copper. However--large decrease in sediment contamination despite recent increases in Cu production: Significant technological improvements.

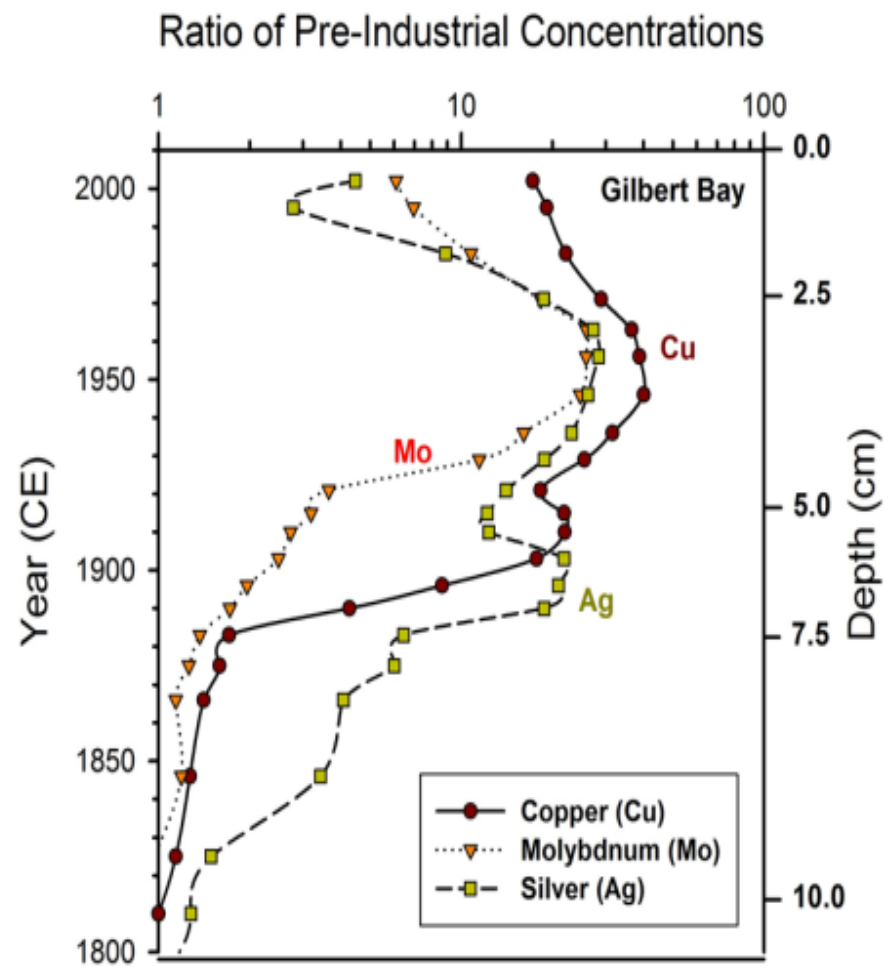
Metal Contamination & Recovery

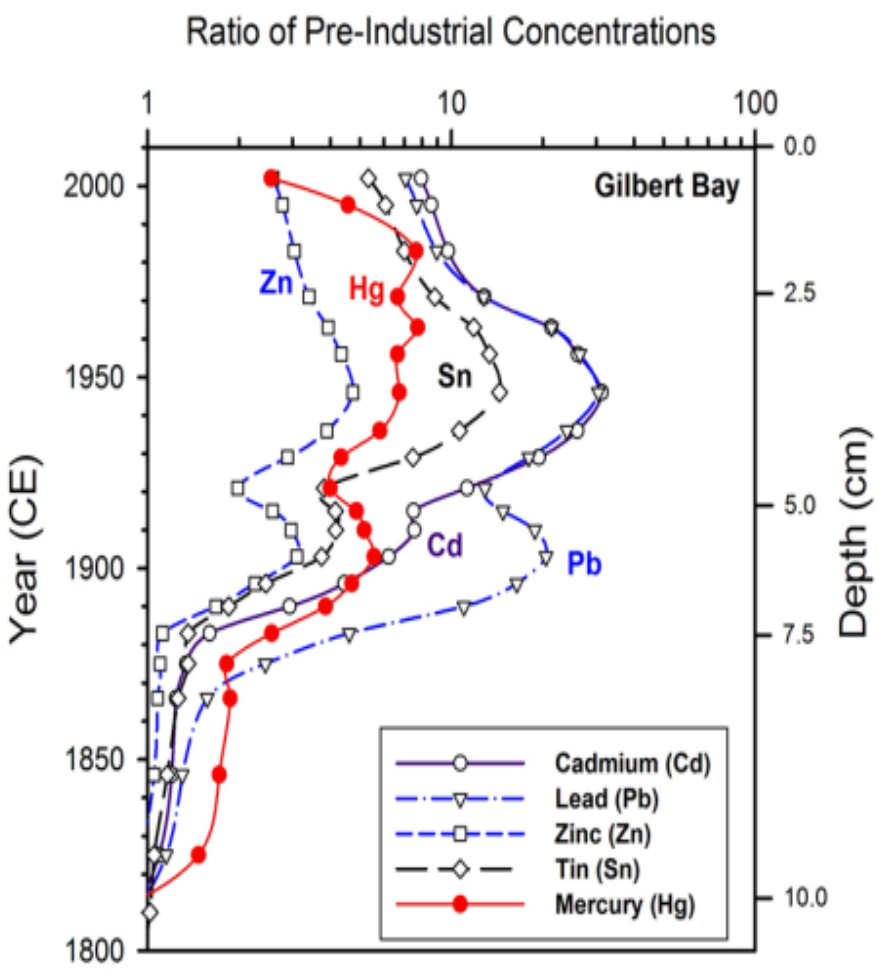




Rise in contamination correlated with lead (and zinc) that co-occurs in the same ore bodies. Other sources of Hg: coal, batteries, gasoline

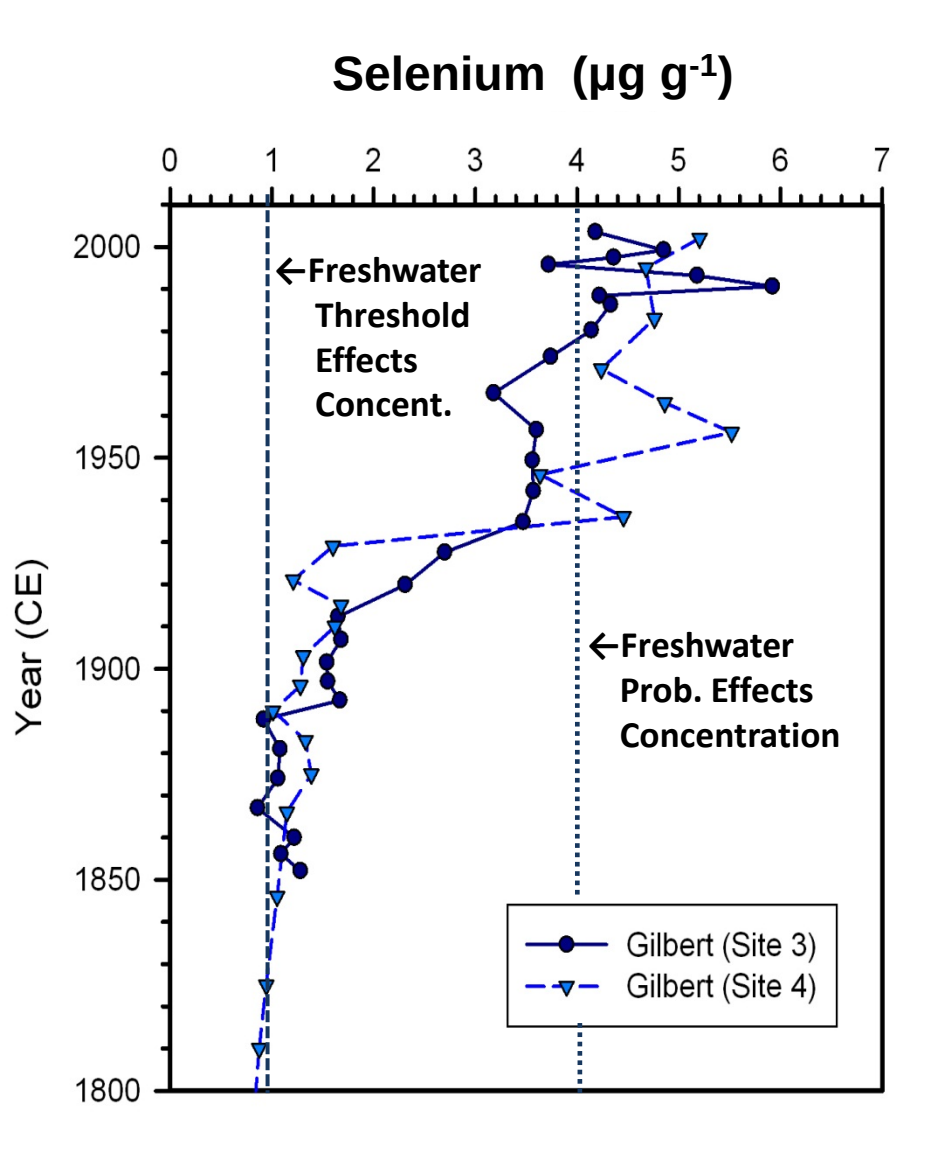
Contamination Index (measured/background)

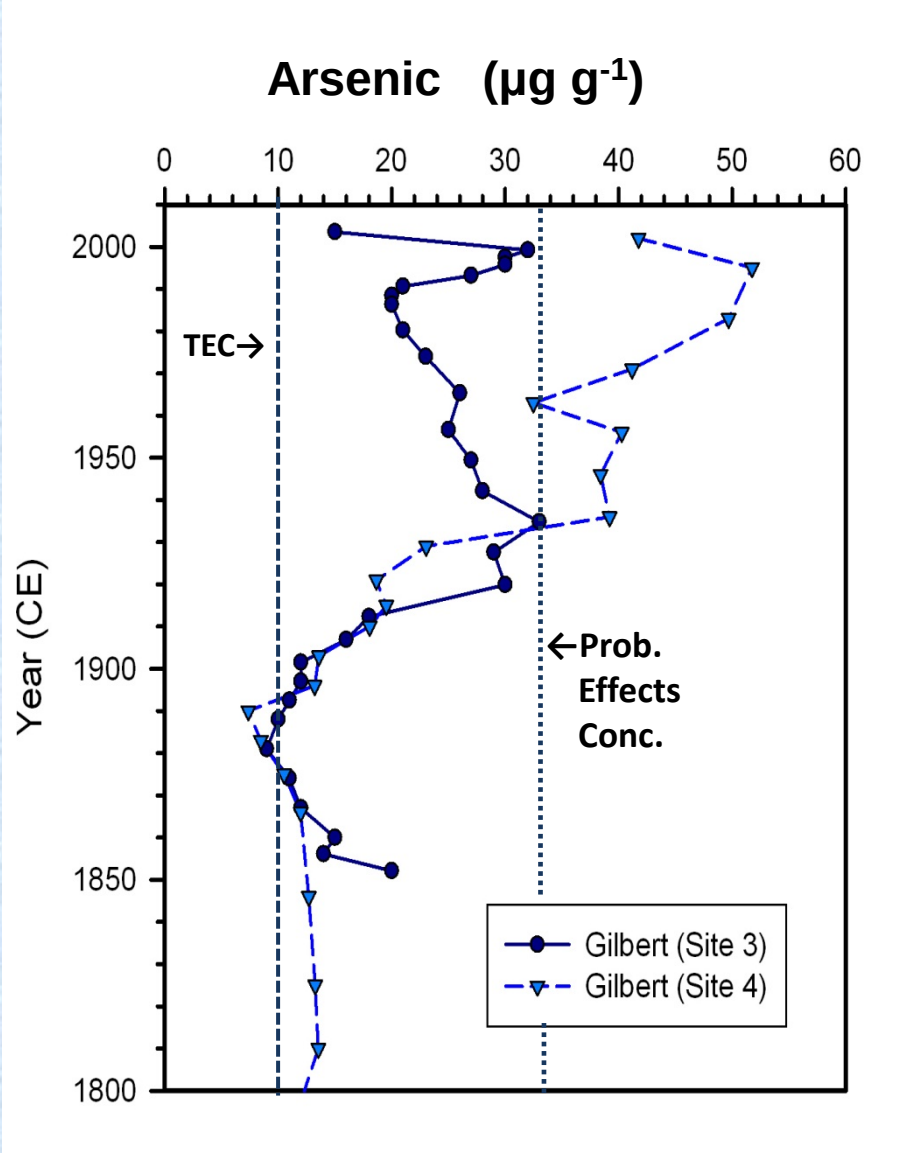




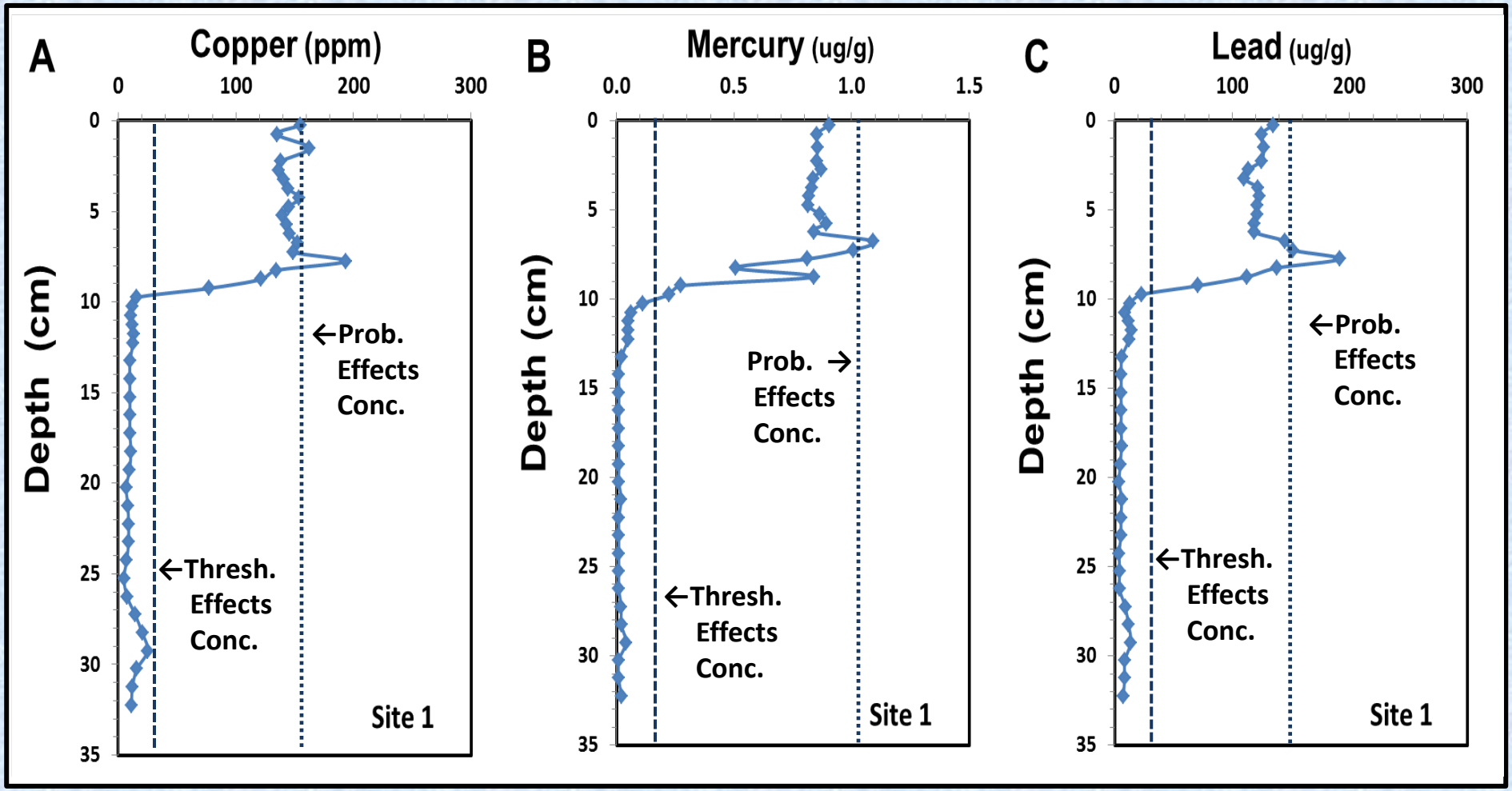
3-point running means

It's not all rosy

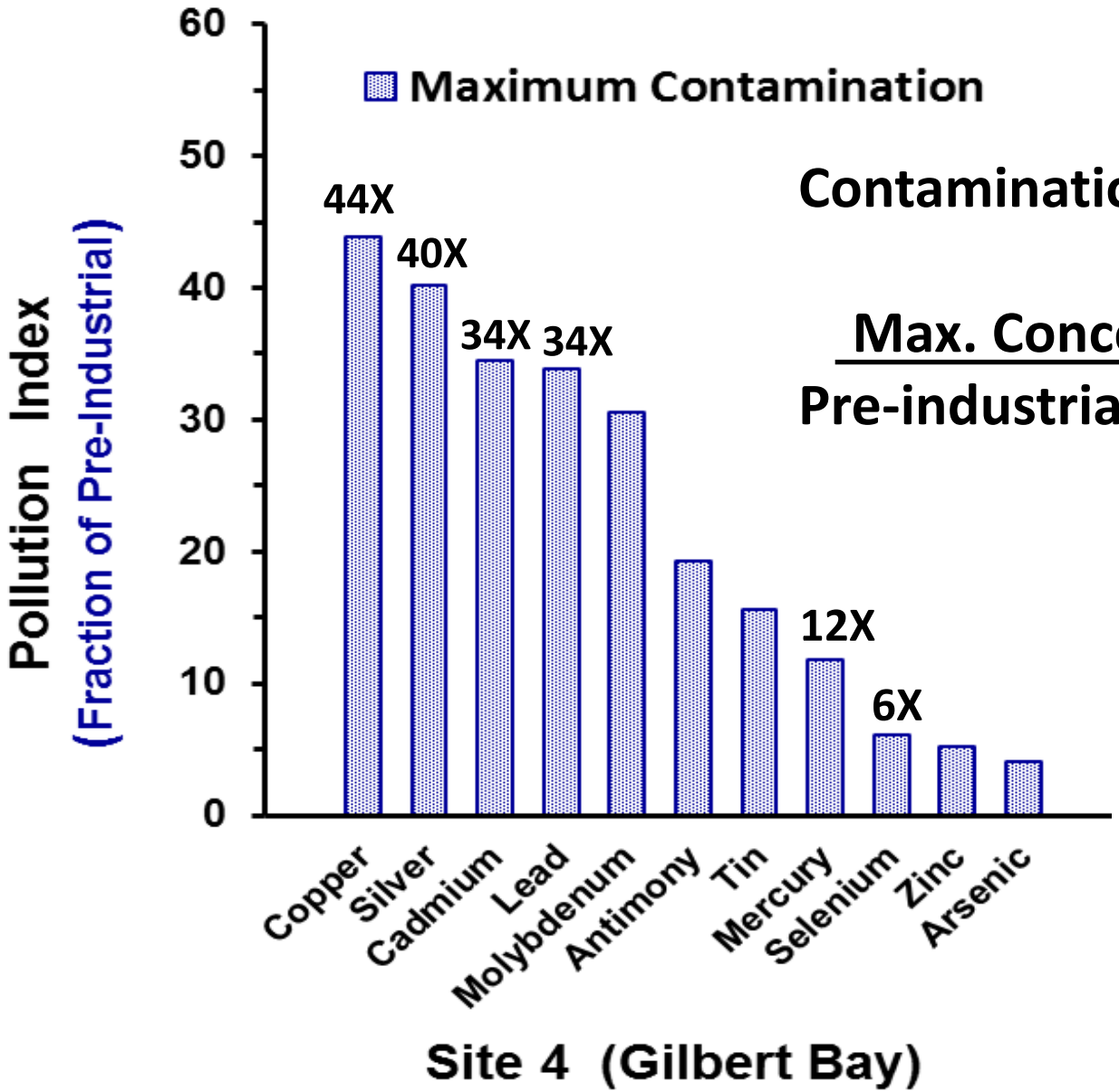




Farmington Bay

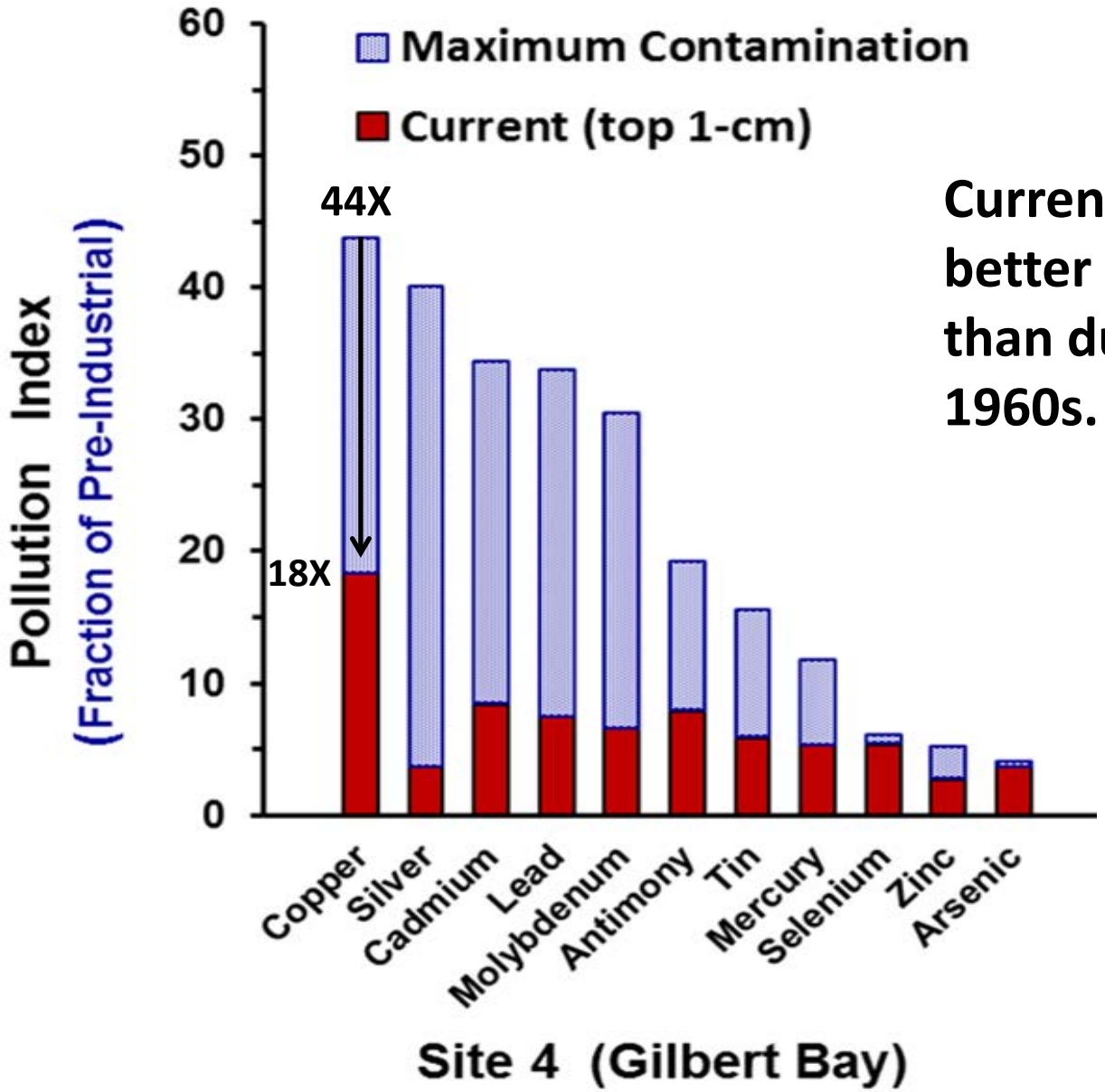


Large, sudden increases, with little or no decline in concentrations of most metals.



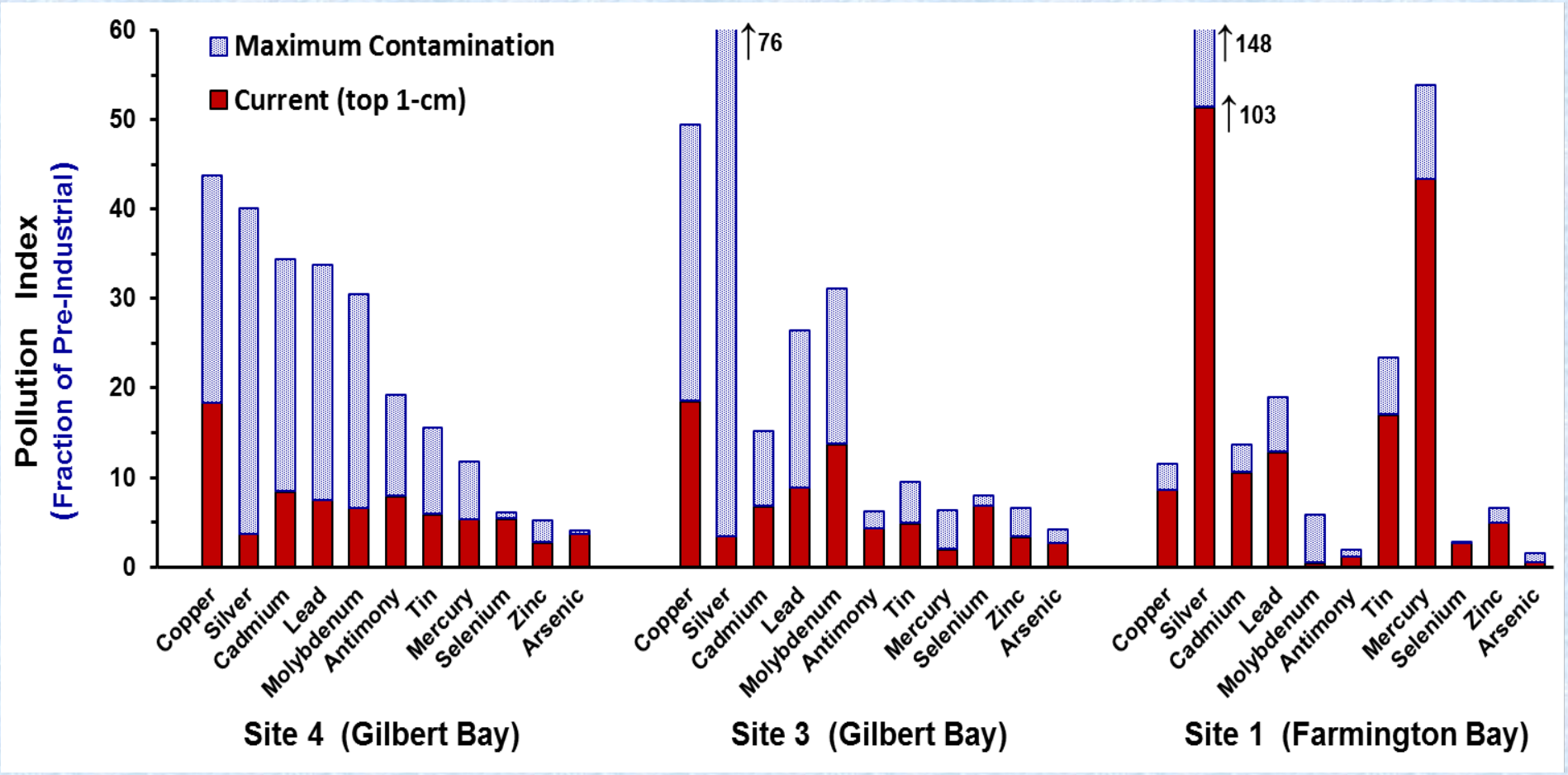
Contamination Index =

$$\frac{\text{Max. Concentration in Core}}{\text{Pre-industrial Conc. (before 1860)}}$$



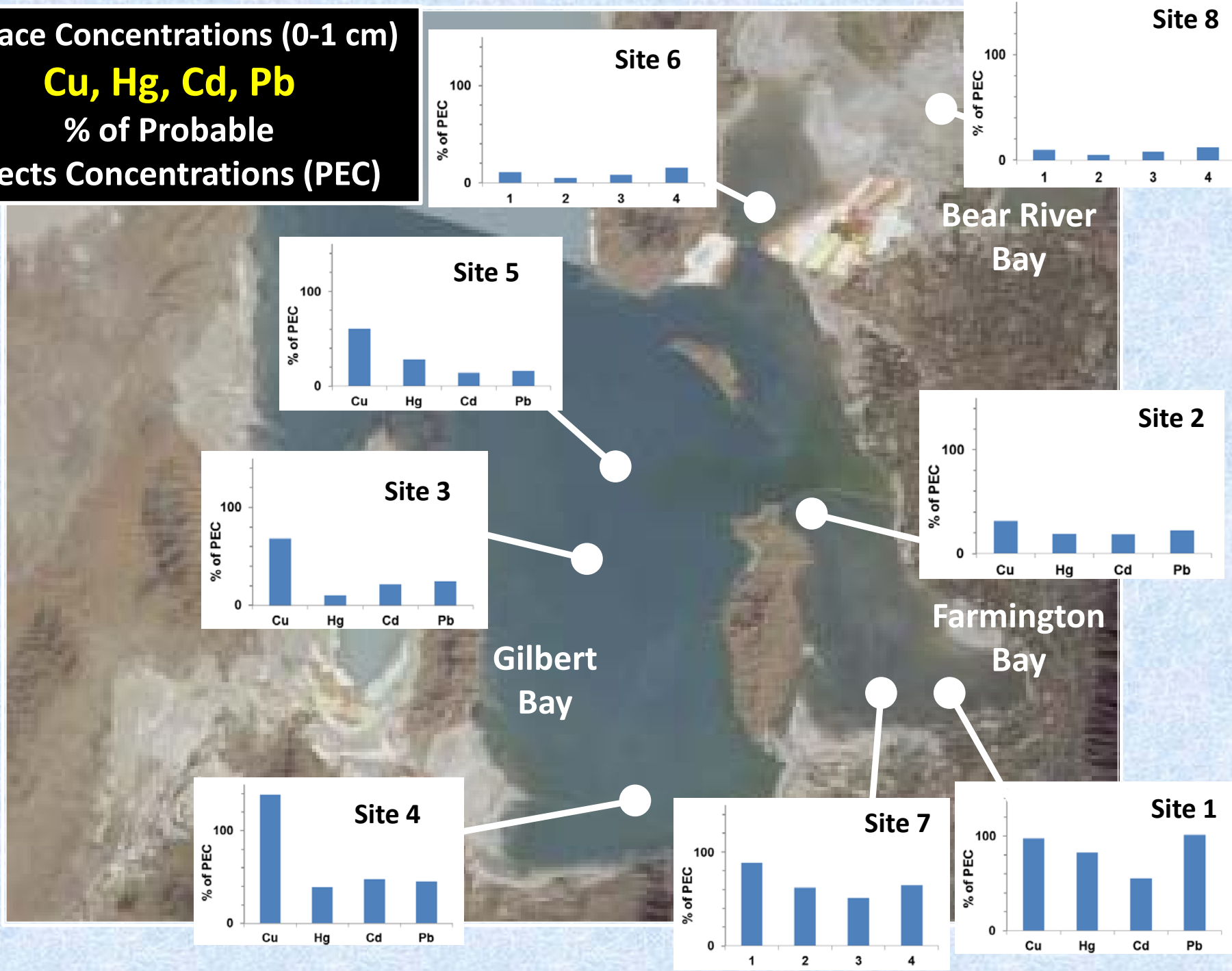
Current situation is much better for most metals than during the 1950s and 1960s.

In Gilbert Bay, metals (except Se, As) have dropped to much lower levels than the worst situations in the 1950-60's

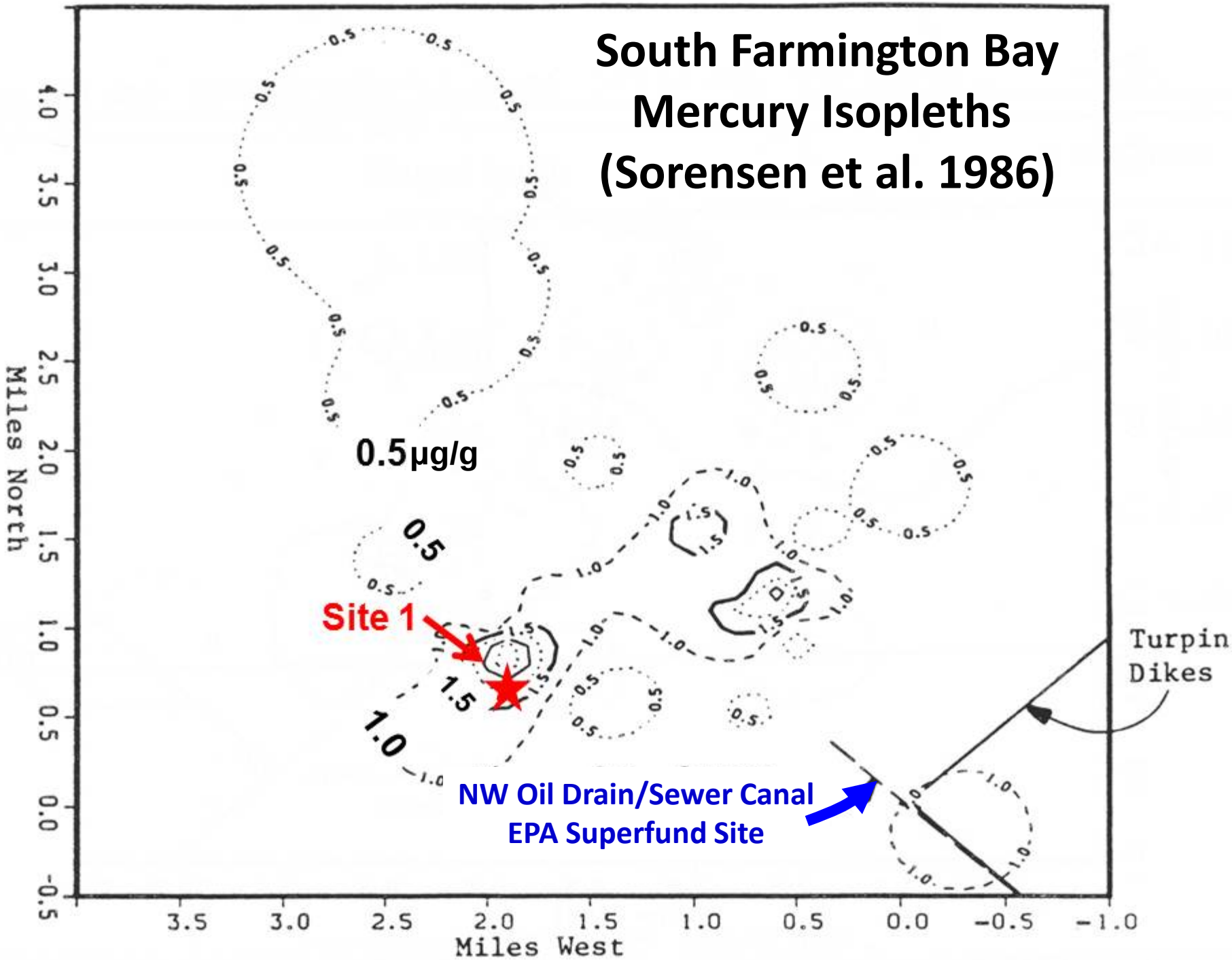


In Farmington Bay, most metals are near their all-time high concentrations (little or no drop)

Surface Concentrations (0-1 cm)
Cu, Hg, Cd, Pb
% of Probable Effects Concentrations (PEC)

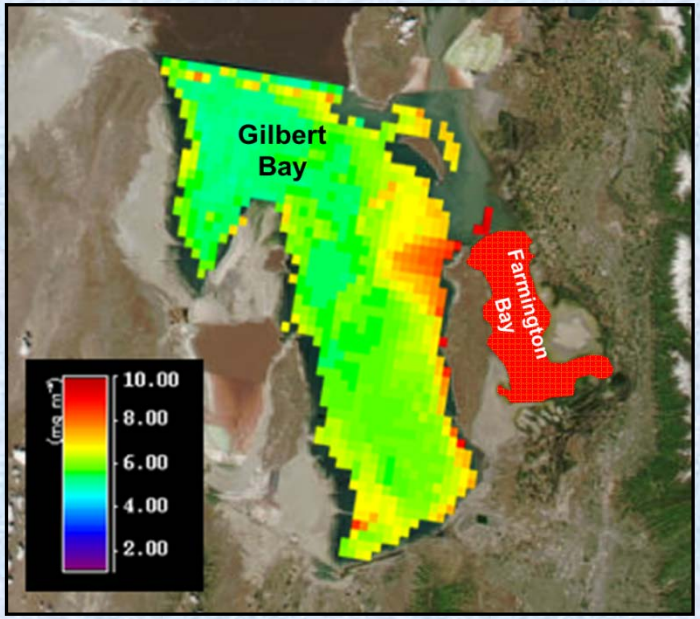


South Farmington Bay Mercury Isopleths (Sorensen et al. 1986)



Conclusions

- **Major temporal changes in production parameters in the Great Salt Lake during the last 150-270 yr.**
  - ***Great Salt Lake was likely oligo-mesotrophic prior to wastewater discharges***



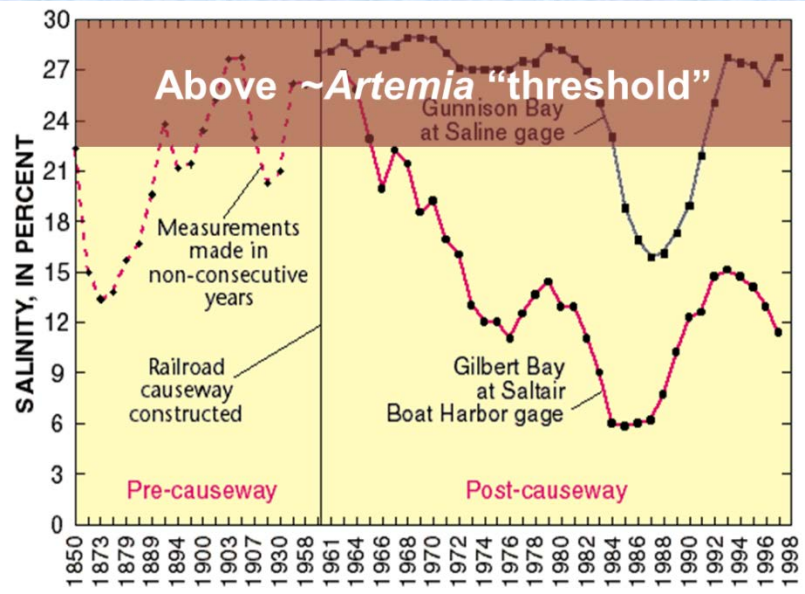
Chlorophyll plume from Farmington into Gilbert Bay

- **Most changes analyzed to date are coincident with railroad causeway construction that has altered salinities and nutrient loading that has increased productivity.**

Railroad Causeway

Conclusions

- **High salinities prior to causeway construction likely limited invertebrate production in many years.**



- **Brine shrimp cysts have an incredible ability to stay viable in anoxic sediments (oxygen is "toxic"). Preserved genotypes present opportunity for innovative studies**

Conclusions

- **Metals contamination extremely high in 1900-1950's, but situation is improving with cleaner smelting technologies and decreased mining of some metals.**

Photo G.A. Williams

- **Other industries (refineries, coal, gasoline, batteries) may have, and continue to contribute to high metal levels in the lake.**

NW Oil Drain & Refineries

Acknowledgements

Assistance -

- Michelle Kang
- Dave Powelson
- Erin Fleming
- Jeff Ostermiller
- Tim Walsworth
- Jodi Gardberg
- Wally Gwynn
- Ken Krahuleck
- Central Davis Sewer District

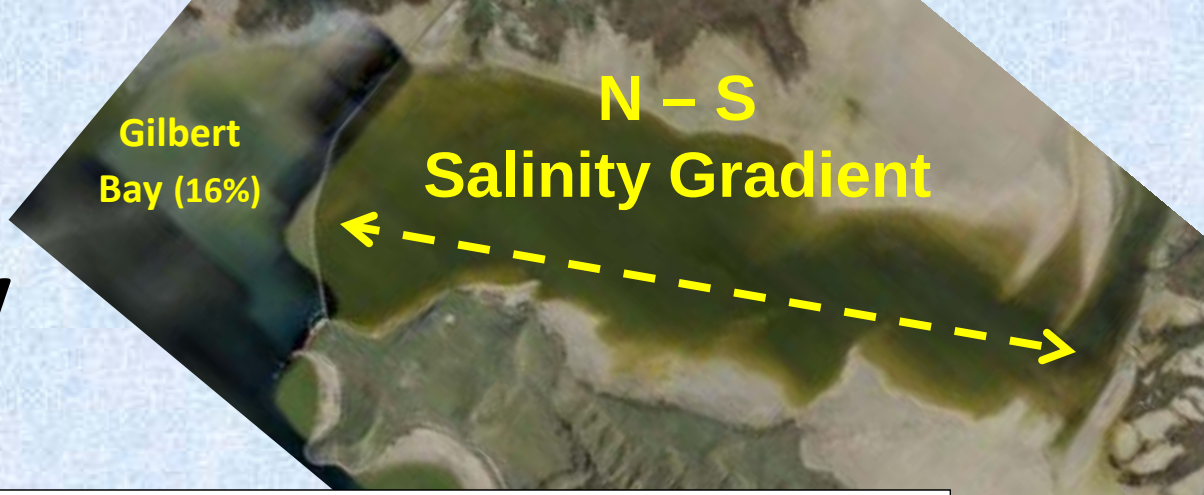
Funding -

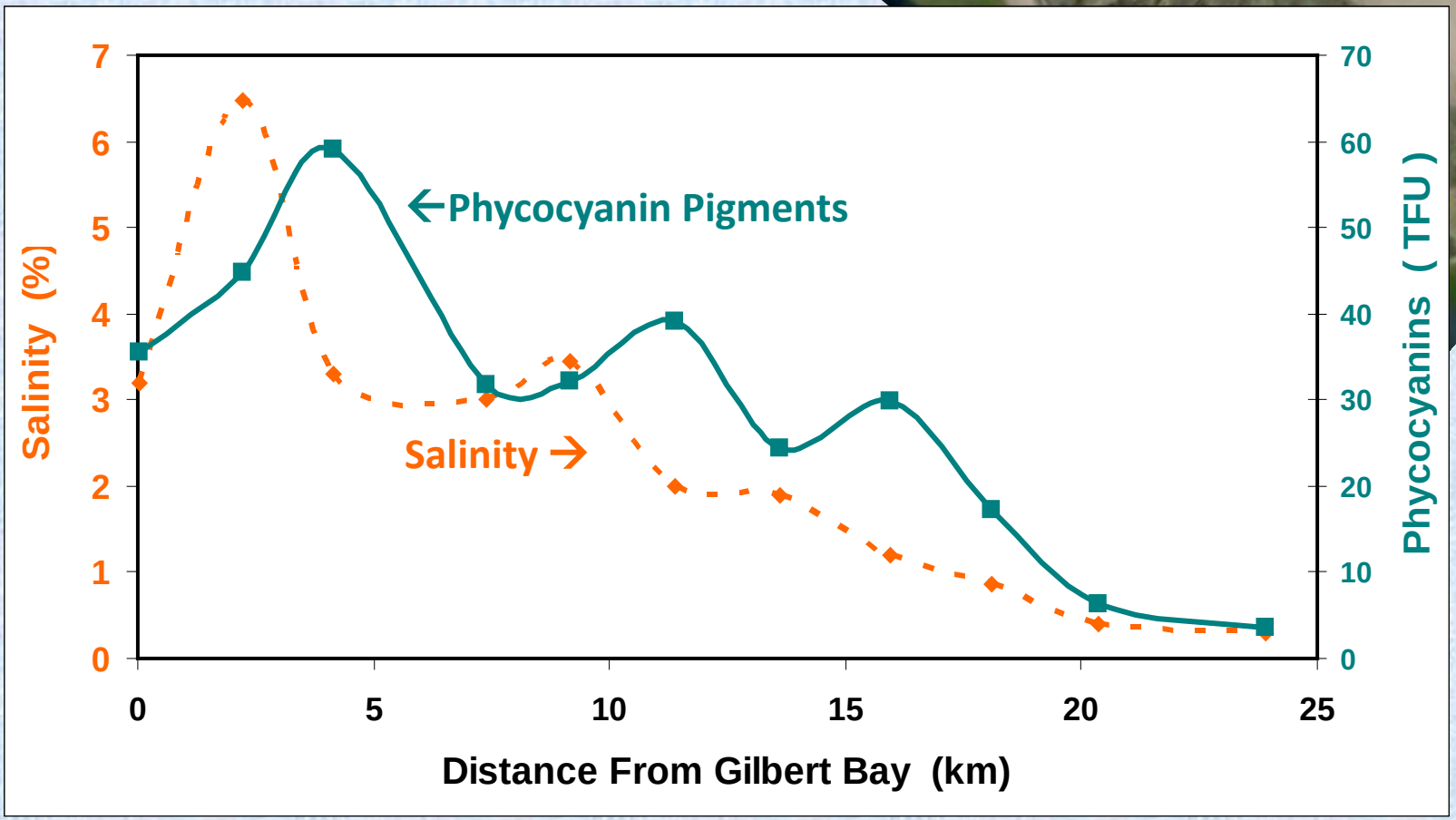
Utah Division of Water Quality

Questions?

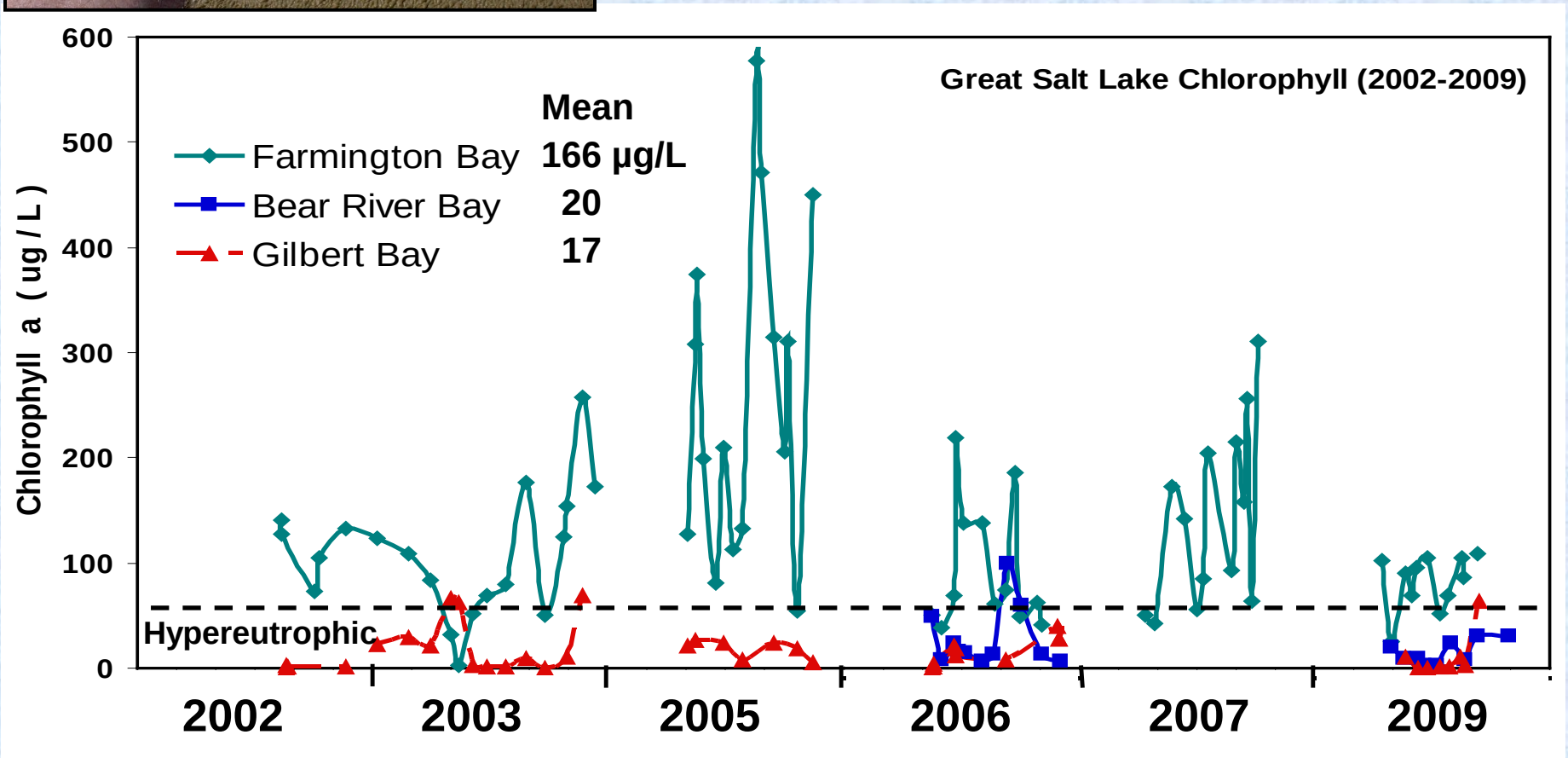
Farmington Bay

17-Aug-2009



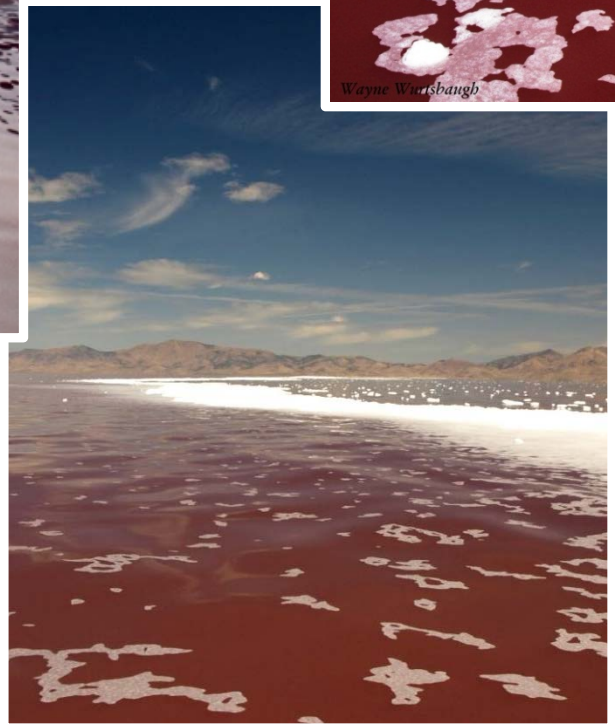


- **Extreme Chlorophyll Levels in Farmington Bay**
- **Moderate in other bays**



Bear River Bay and much of Farmington Bay:

Shallow sites + Large fetch = Disturbed Sediments

= No ^{210}Pb chronology

Could not penetrate salt barrier on bottom of Gunnison Bay, but we saw some wonderful foam patterns!