Tri-Service Infrastructure Conference

Water Quality Management

San Francisco Bay Mercury TMDL – Implications for Constructed Wetlands

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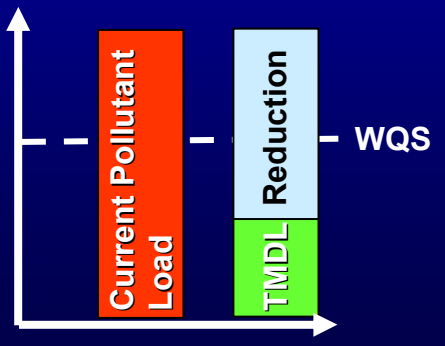
Total Maximum Daily Load (TMDL)

Definition

- **1972 Federal Clean Water Act [§ 303(d)]** – essentially requires USEPA to manage the nation's water quality on a watershed basis.
- Calculation of the maximum amount of a specific pollutant that a water body can receive and still meet Water Quality Standards
- Allocation of that (maximum) amount to the various pollutant's sources

$$TMDL = \Sigma WLA + \Sigma LA + \Sigma MOS$$



(from Steve Silva, EPA Region 1)

Total Maximum Daily Load (TMDL)

Process

1. Identify impaired water – “303(d) List”.
2. Determine maximum quantity of a pollutant that a water body can assimilate without exceeding a Water Quality Standard.
3. Quantify current sources of pollutant.
4. Determine necessary load reductions.
5. Allocate maximum pollutant loads to each source.

(from Steve Silva, EPA Region 1)

Mercury – an Environmental Pollutant

Human Exposure

http:www.nih.gov/od/prs/ds/nomercury/health.htm

- Neural impairment – chidren most susceptible
- Level of Concern in Blood = 5.8 THg µg per L
- 6% of U.S.A. childbearing-aged women, blood levels at/above 5.8 (1999-2002)
- Hair Hg levels 20% of U.S.A. childbearing-aged women greater than Federal health standards (UNC Asheville)
- 60,000 U.S.A. births per year Hg impaired (NAS, July 2001)
- Methylmercury (MeHg) is bioavailable form

Mercury – an Environmental Pollutant

Human Exposure Route - Mainly through eating fish

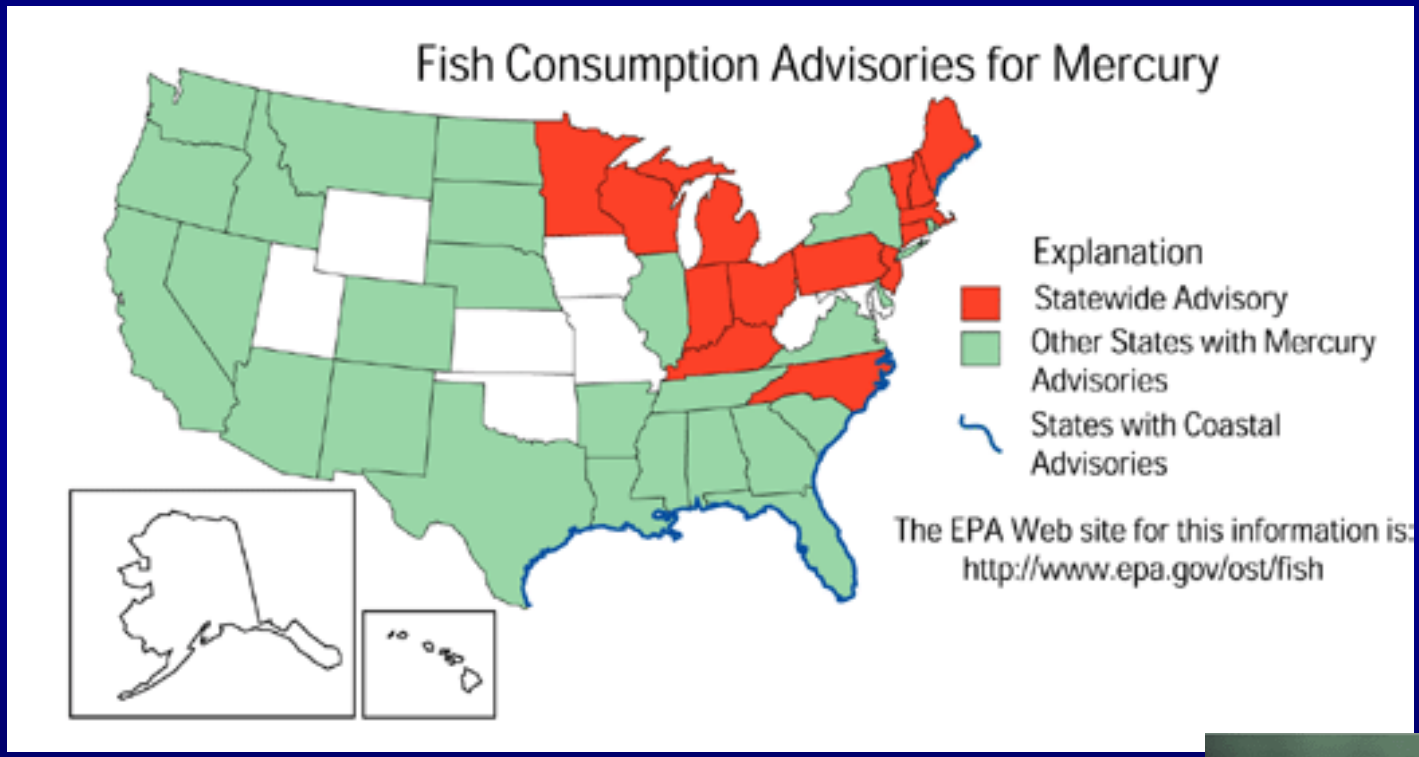
Fish Consumption Frequency	Average Hg Hair Concentration (µg/g of hair)
None	2.0
Less than 1 fish meal/month	1.4 (range 0.1 to 6.2)
Fish meals twice/month	1.9 (range 0.2 to 9.2
One fish meal/week	2.5 (range0.2 to 16.2)
One fish meal/day	11.6 (range 3.6 to 24.0)

World Health Organization Programme for Chemical Safety

Cited in EPA's Mercury Study Report to Congress December 1977

Mercury – an Environmental Pollutant

Environmental Effects



- MeHg accounts for 75% of USA fish advisories
- 2073 MeHg fish advisories in 41 states

SF Bay Mercury Total Maximum Daily Load (TMDL)

GOALS:

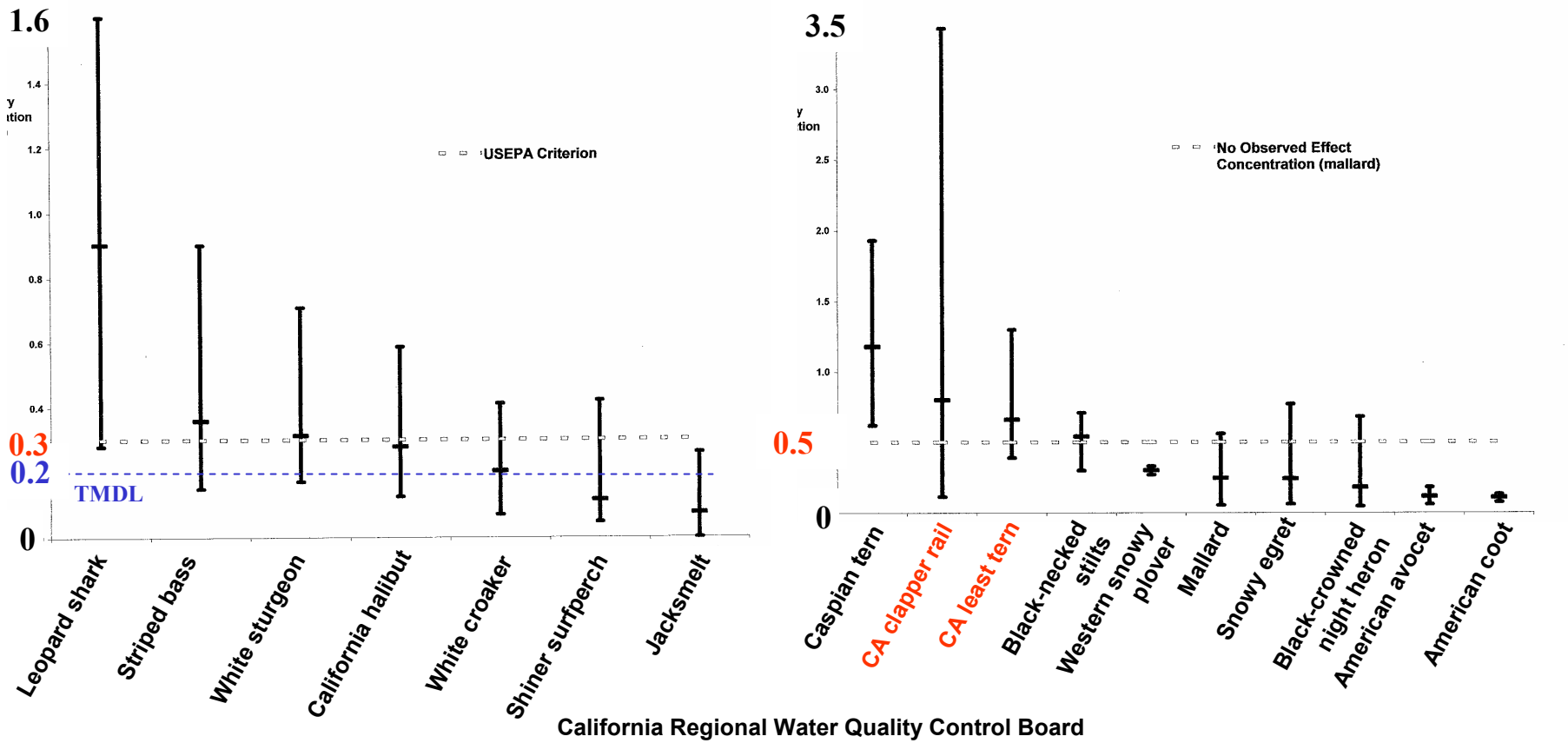
1. Reduce total mercury loads into the bay.
2. Reduce methylmercury production.
3. Monitor and focus studies on understanding Bay system.
4. Encourage actions that address multiple contaminants.

Mercury Total Maximum Daily Load (TMDL)

303(d) Impairment – Sports fishery, Endangered species, Habitat

SF Bay Fish Tissue THg Concentration Compared to US EPA Criterion

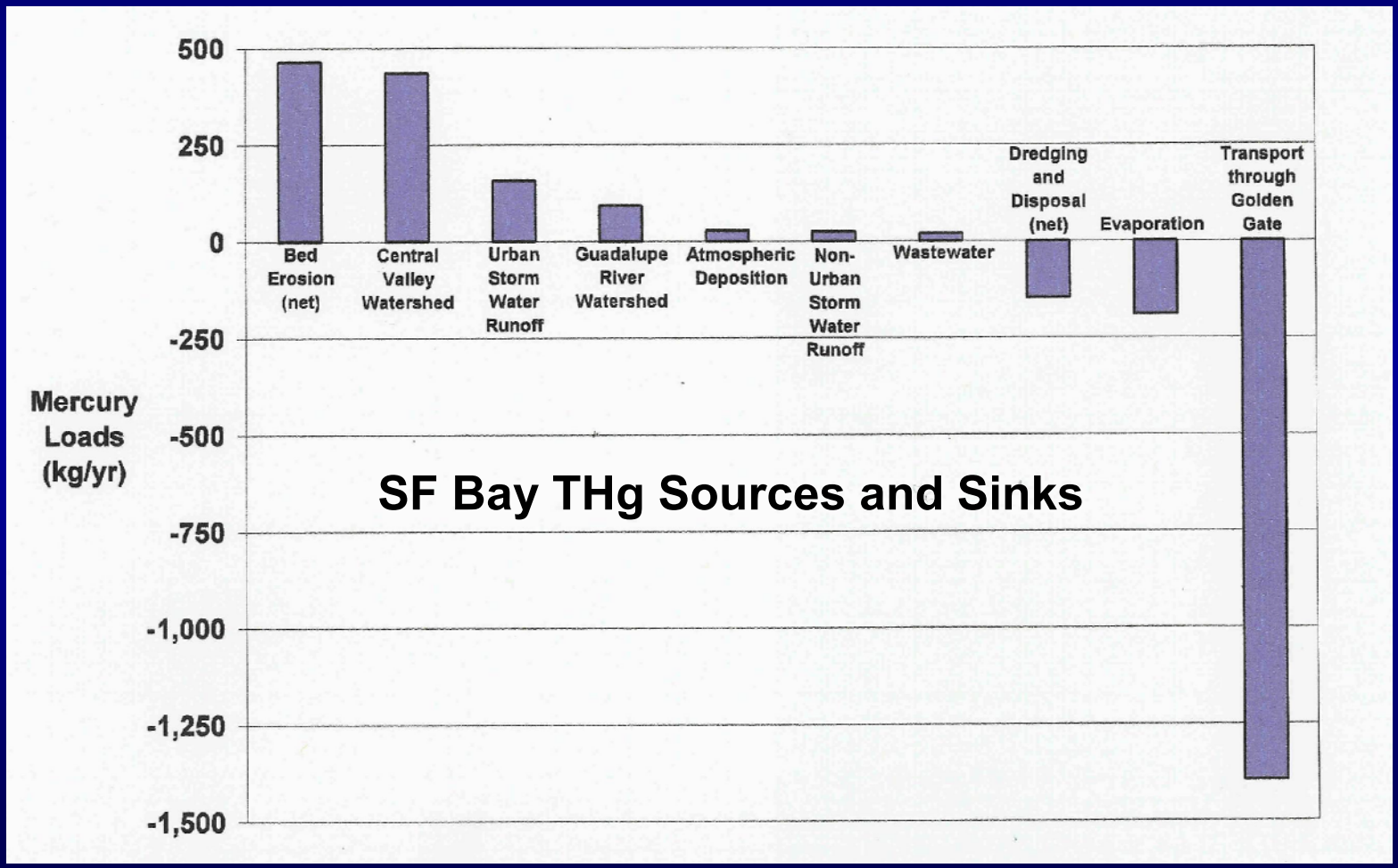
SF Bay Bird Egg THg Concentration Compared to No Effect Level



California Regional Water Quality Control Board
http://www.swrcb.ca.gov/rwqcb2/sfbaymercurytmdl.htm

Mercury Total Maximum Daily Load (TMDL)

One Box Mercury Mass Balance Model



California Regional Water Quality Control Board

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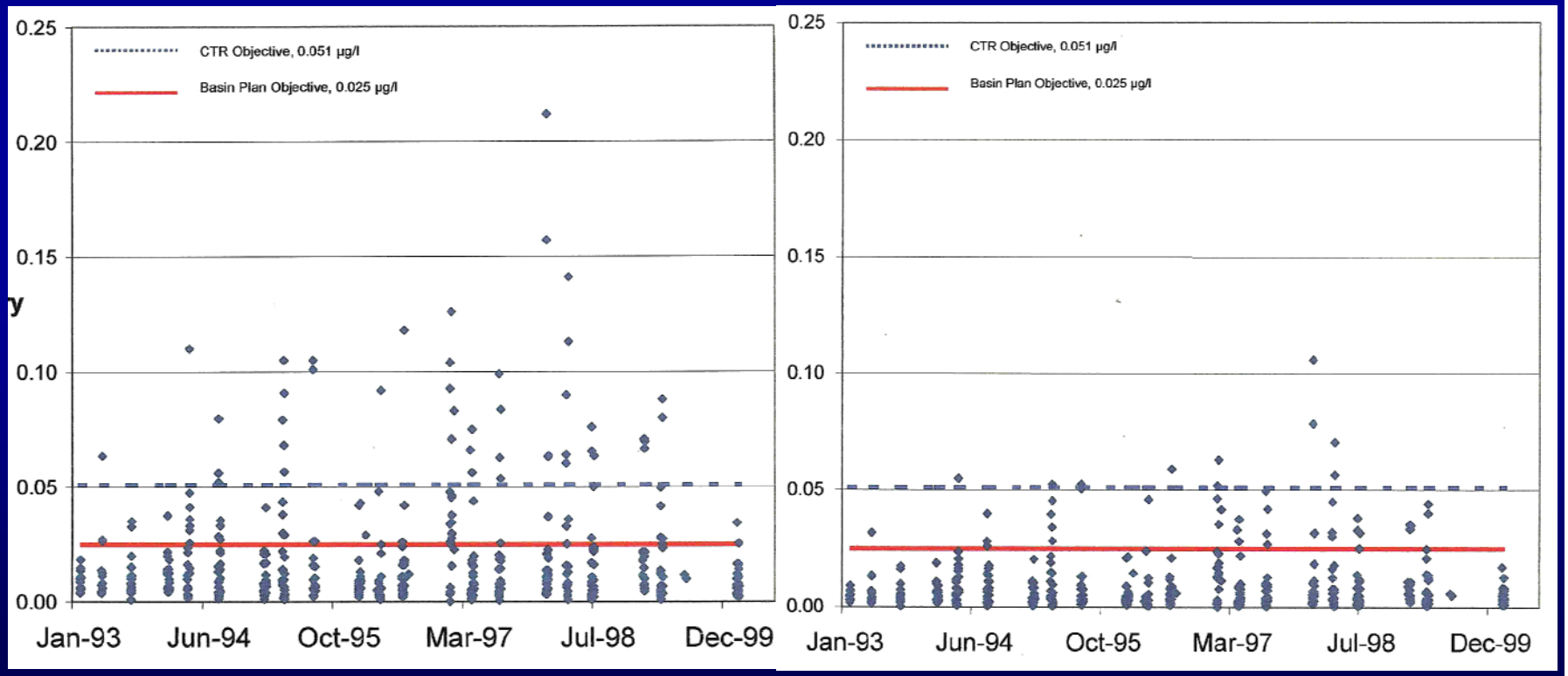
Mercury Total Maximum Daily Load (TMDL)

Levels of Particulate Total Mercury in the Water Column

Measured THg Levels

Predicted aqueous THg Levels by reducing sediments by 50%



California Regional Water Quality Control Board

http://www.swrcb.ca.gov/rwqcb2/sfbaymercurytmdl.htm

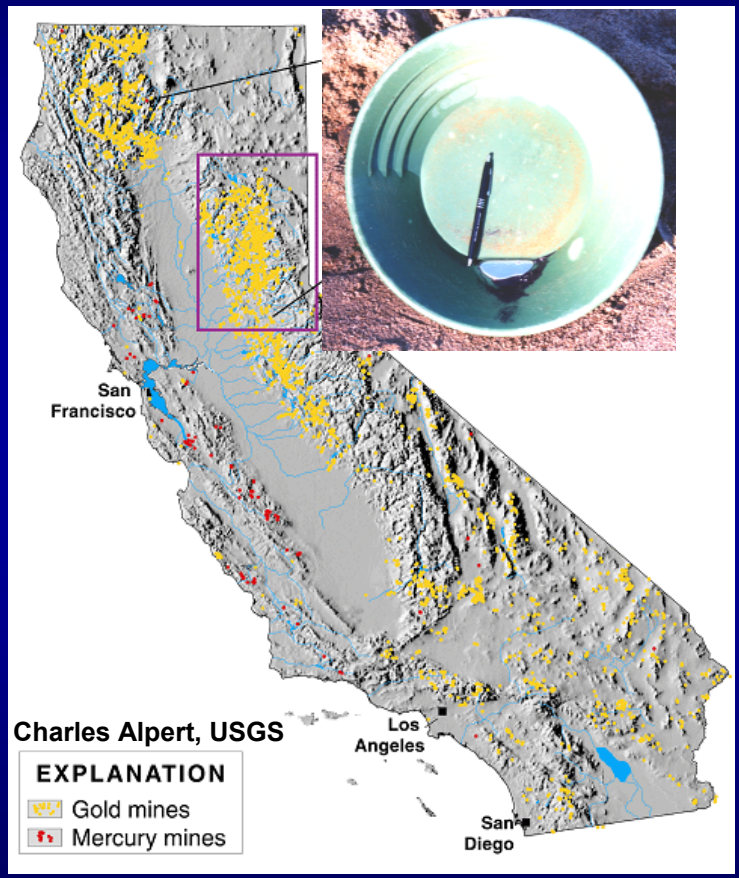
Mercury Total Maximum Daily Load (TMDL)

Mining Legacy *vs* Contemporary Atmospheric Loading

Current Mercury Loads /Proposed Allocations

SOURCE	Existing kg/yr	Allocation kg/yr	Per Cent Reduction
Sediments	460	220	53%
Upstream Sources (Central Valley)	440	330	25%
Urban Runoff	160	82	49%
Rural Runoff	25	25	0%
Historic Mercury Mine Drainage (Guadalupe River)	92	2	98%
Atmosphere	27	27	0%
Wastewater	16	16	0%
TOTAL	**1,220**	**702**	**42%**

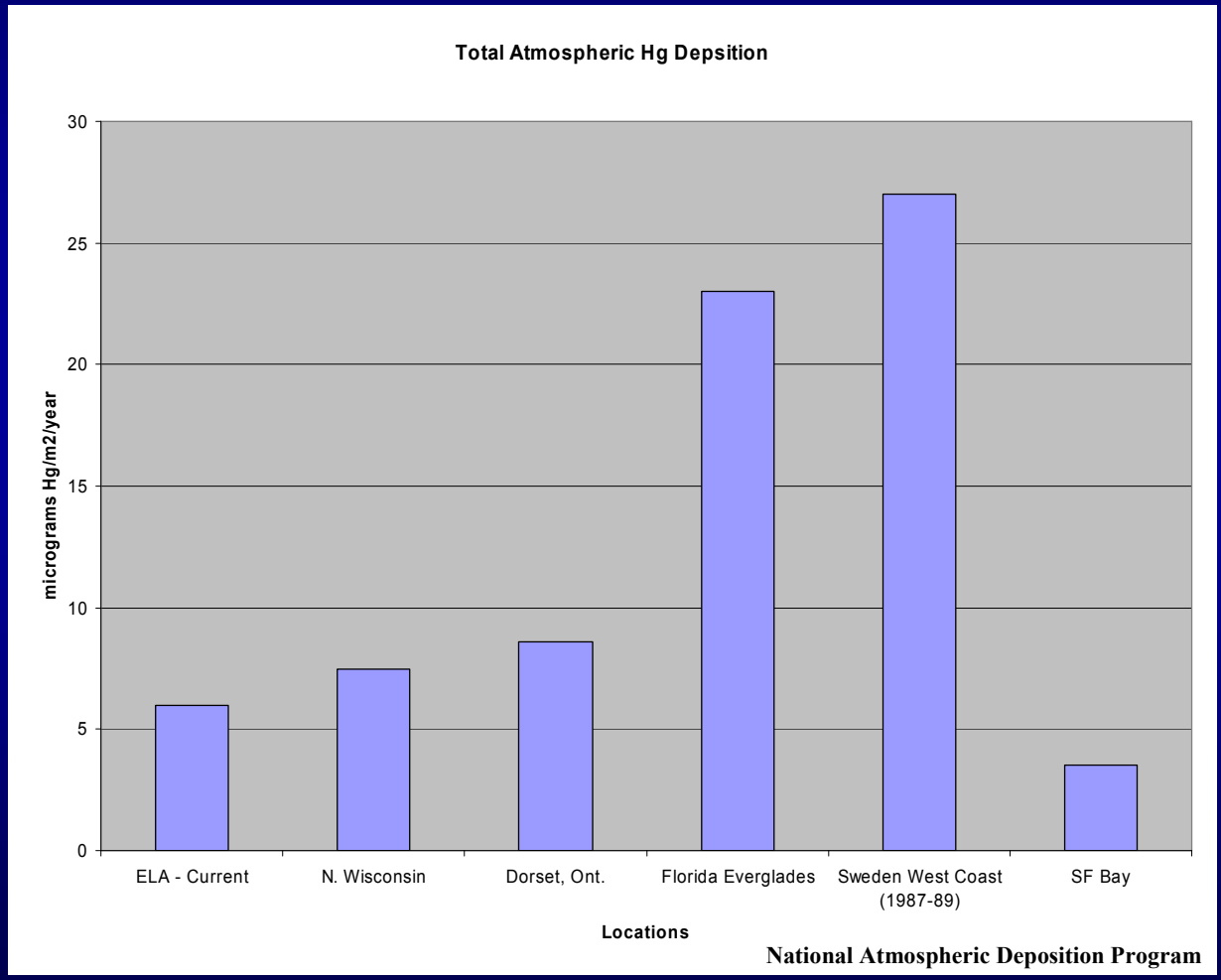
http://www.swrcb.ca.gov/rwqcb2/sfbaymercurytmdl.htm



SF Bay Catchment - ~40% area of CA; 47% of CA runoff

Mercury Total Maximum Daily Load (TMDL)

Comparison of Rates of Atmospheric Mercury Deposition

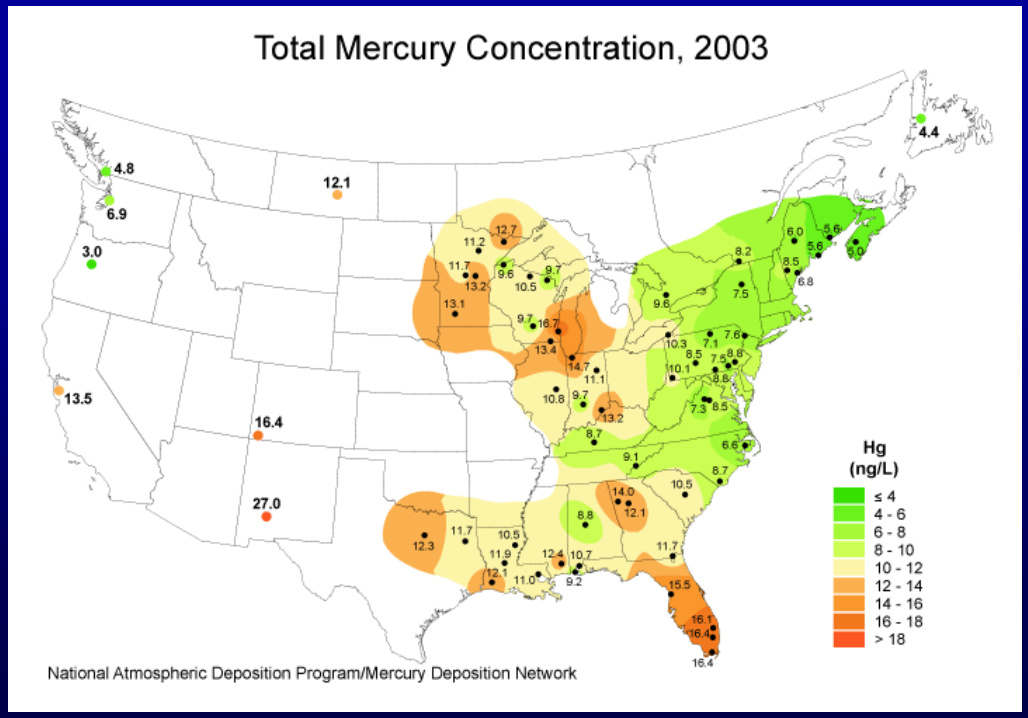


Newly deposited Hg more bioavailable than that in sediment (Benoit et al, 2003)

Mercury Total Maximum Daily Load (TMDL)

Mercury TMDL Compliance Issue #1

- Atmospheric deposition of mercury is an important source.
- States lack interstate regulatory jurisdiction



Mercury TMDL Compliance Issue #2

- Linkages between particulate THg and MeHg and fish body burdens are not clear.
- Net MeHg production is site specific
- MeHg uptake and biomagnification is foodweb specific.

San Francisco Bay Wetland Reconstruction

"… the restored wetland be designed and operated to minimize methylmercury production and biological uptake, and result in no net increase in mercury or methylmercury loads to the Bay."

California Regional Water Quality Control Board
Basin Plan Amendment – Resolution R2-2004-008

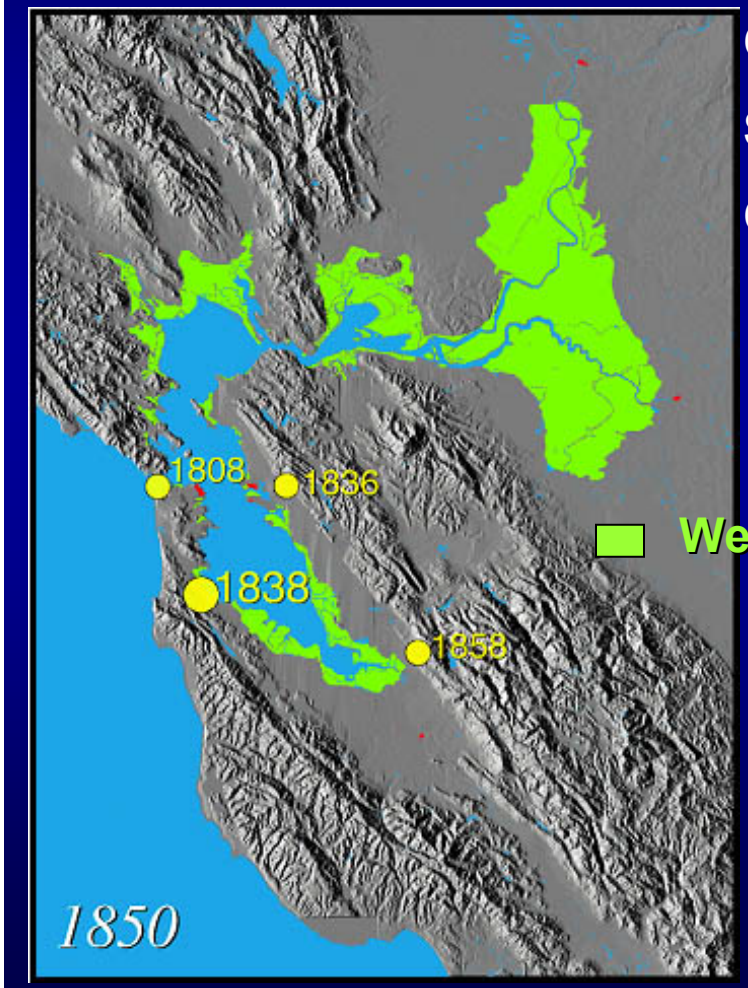
San Francisco Bay Wetlands- Ecological Importance

- Loss >90% of marsh wetlands since 1900
- West coast flyway
- Critical habitat for endangered species

California Clapper Rail

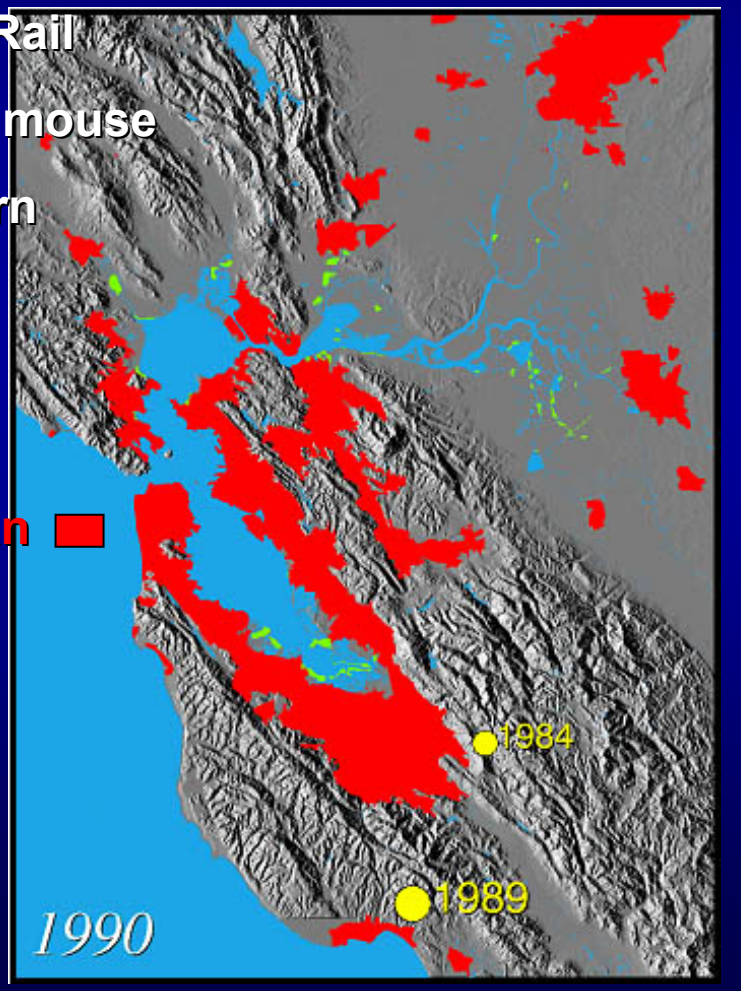
Salt marsh harvest mouse

California Least Tern



Wetlands

Urban

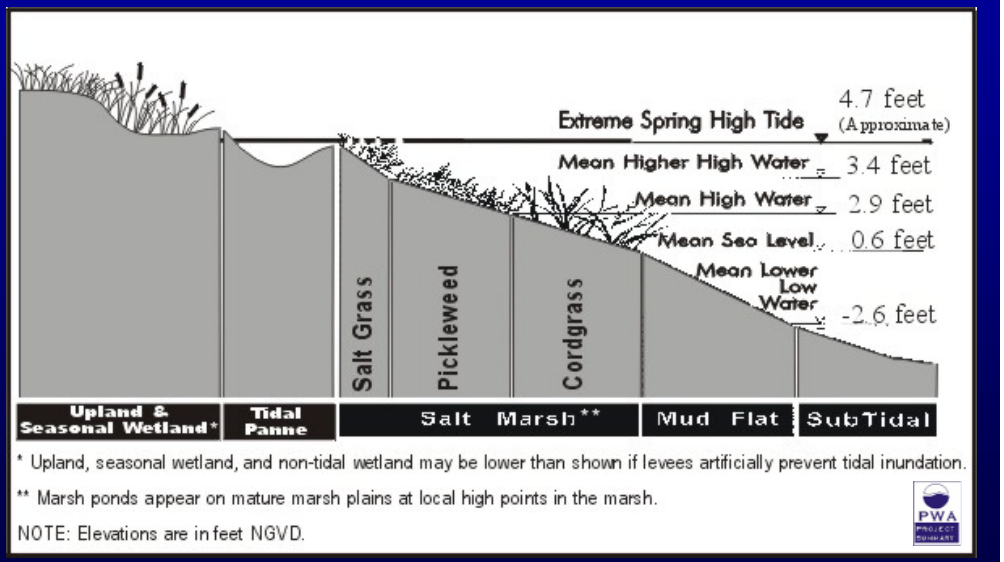


URL: http://sfbay.wr.usgs.gov/access/IntegratedScience/IntSci.html

Cumulative Effects of SF Bay Wetland Restorations

San Francisco Bay Area Wetlands Ecosystem Goals Project

- HAAF represents only 203 hectares (0.8 %) of 26,300 hectares to be restored by 2055
- Many restoration sites will require fill material
- Intertidal wetlands are potential source of MeHg



Port of Oakland - Commercial Importance

Most important on west coast ($30 B pa)

Deep Ocean Disposal Site

Potential Win – Win

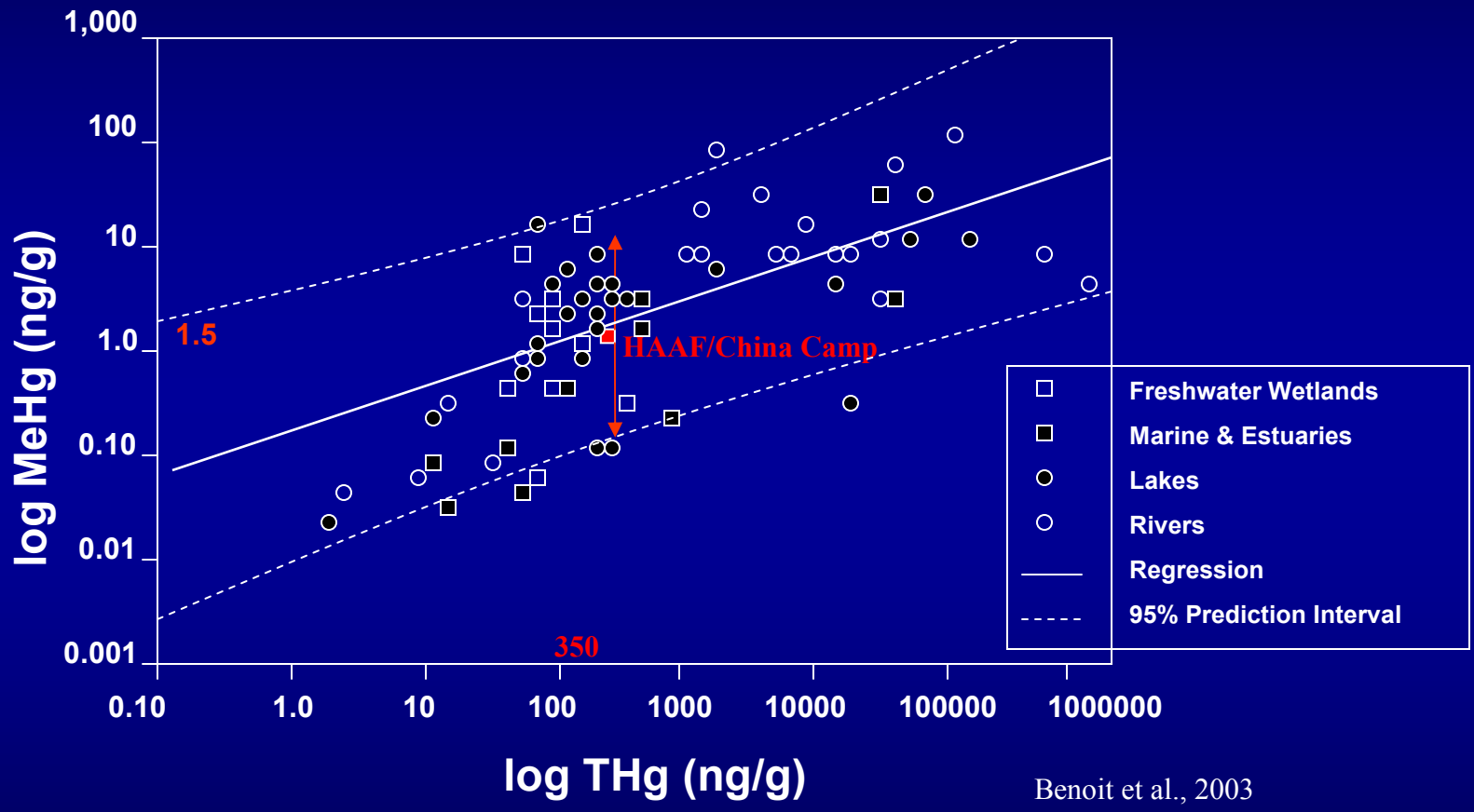
1. **Reduce DM disposal costs.**
2. **Avoid material & transport cost.**

Hamilton Army Airfield – FUDS Site

China Camp State Park – Reference Site

Aquatic Systems Produce Methylmercury

THg and MeHg in surface (0-4 cm) sediments from various wetlands



Benoit et al., 2003

- Only a loose relationship between THg and MeHg levels (log – log plot).
- Despite history of mining level of THg and MeHg are median among contaminated sites.
- However, potential for a 10X increase/decrease in MeHg levels.

Mercury magnification in aquatic food webs
Biogeochemistry – Microbial Ecology

Question:

How do ppb levels of Hg in soil, water and sediment become ppm levels in top aquatic predators? (Benoit et al., 2003)

Gray et al., 2004 EST

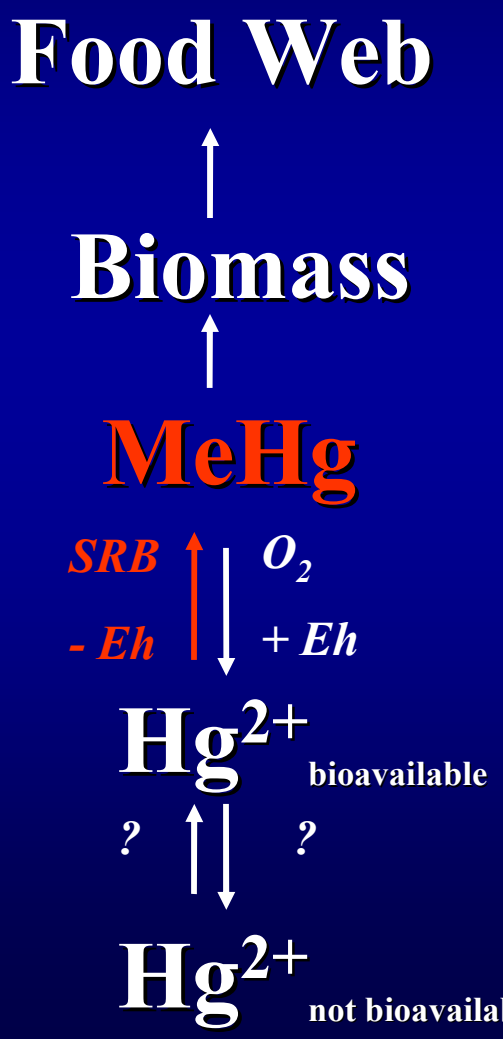
Clues:

MeHg generally comprises <1% of the THg in soils and sediments, but comprises 99% of the total Hg in fish biomass.

Sulfate-reducing bacteria methylate mercury.

How Can We Minimize MeHg production?

Methylmercury is the species of highest concern

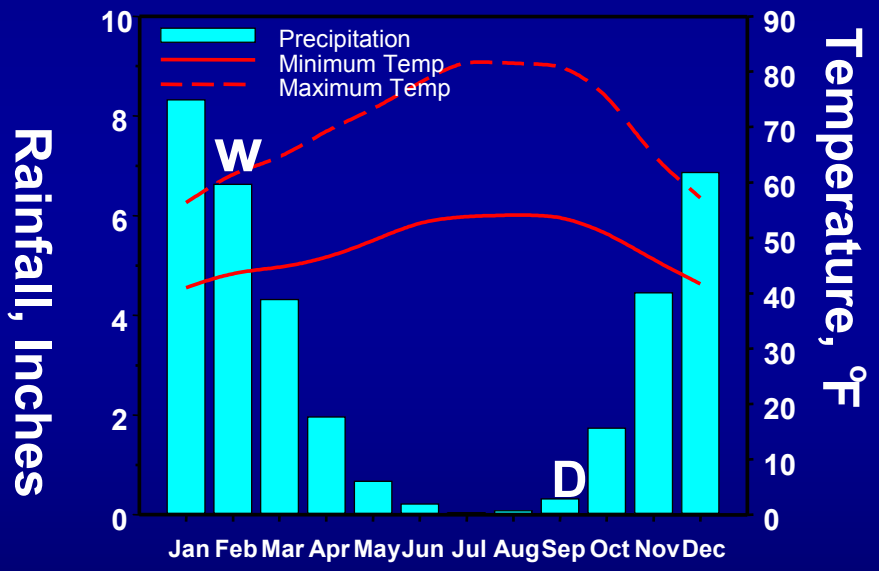


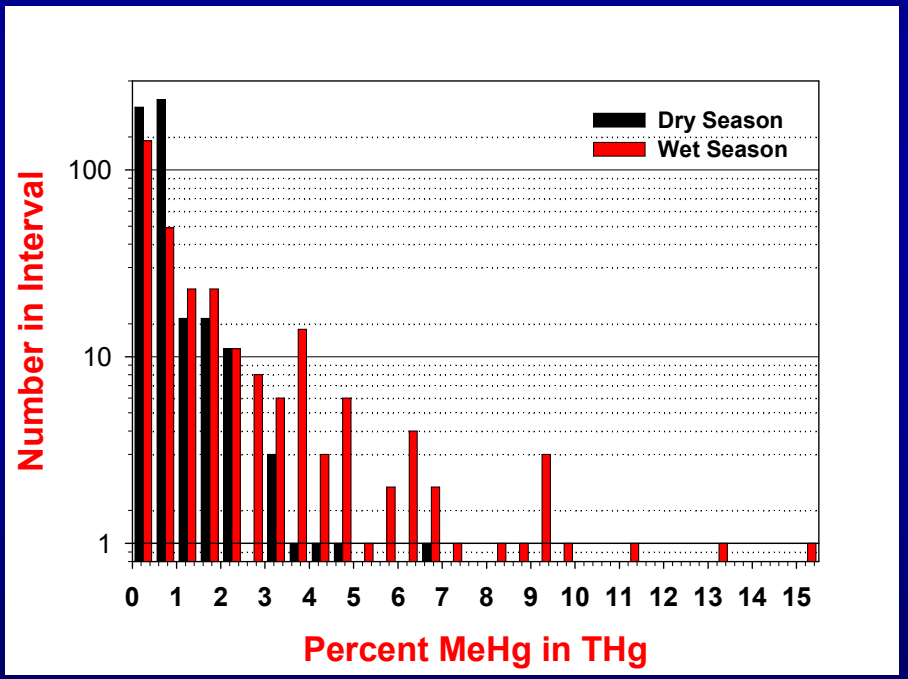
- Bacteria in sediment catalyze antagonistic methylation and demethylation reactions.
- These reactions are very rapid.
- The availability of mercury to methylating bacteria limits MeHg production.
- Extent of biomagnification is foodweb specific.

Macro Drivers of Net Methylation

Wet Season *vs* Dry Season

San Rafael Average Temperature and Rainfall





❖ Relative MeHg levels (% THg) are 3X greater on average in the wet season.

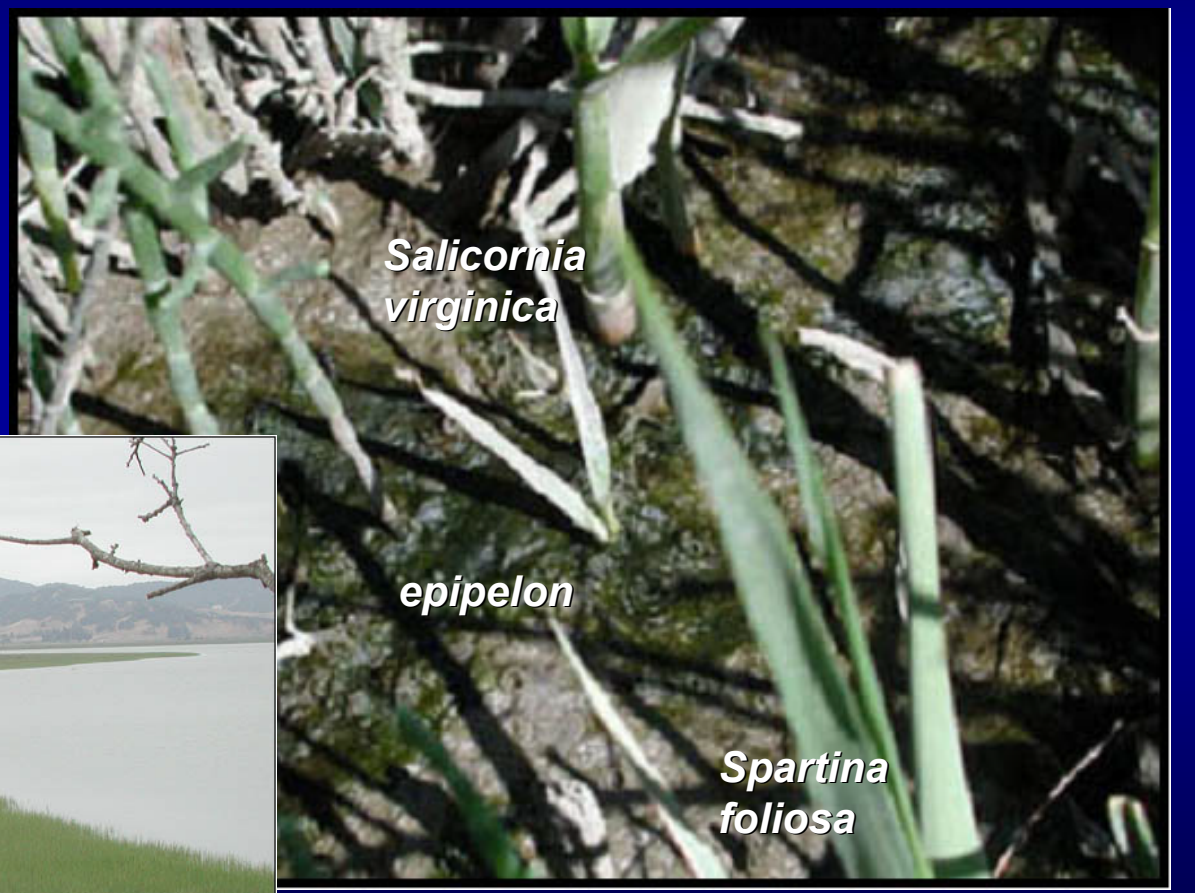
Macro Drivers of Net Methylation

Position in Salinity Gradient

Site	THg	MeHg	Meth.rate	Dem.rate	M/D
Jul-04	(ng/gDW)	(ng/g DW)	(ng/gDW/d))	(ng/gDW/d)	
Petaluma River Mud	397 (2)	1.33 (0.32)	7.74 (2.21)	1.26 (0.39)	6.19 (0.99)
Sonoma Fringe Marsh Mud	358 (10)	0.49 (0.07)	2.80 (0.28)	0.42 (0.14)	7.36 (3.34)
Sonoma Baylands Mud	296 (10)	2.75 (0.16)	13.21 (3.18)	2.64 (0.14)	5.03 (1.33)
HAAF Fringe Marsh Mud	299 (117)	1.97 (0.89)	6.59 (4.87)	1.60 (0.91)	4.18 (1.44)
China Camp Mud	362 (35)	3.71 (0.59)	9.43 (0.19)	3.27 (0.71)	3.00 (0.81)

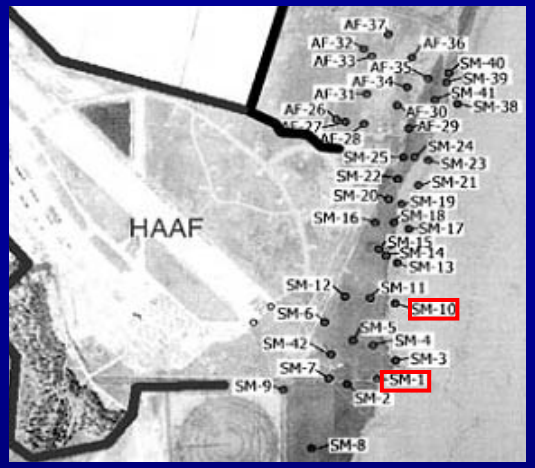
San Pablo Bay Wetland Trophic Structure

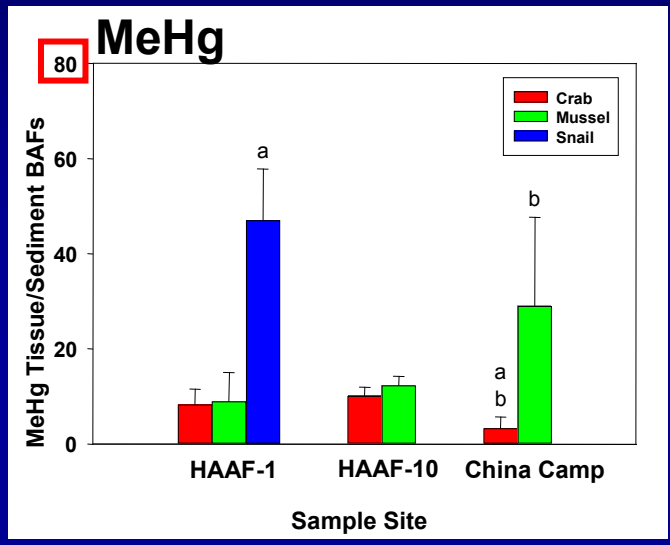
High Primary Production – Hallmark of Intertidal Wetlands

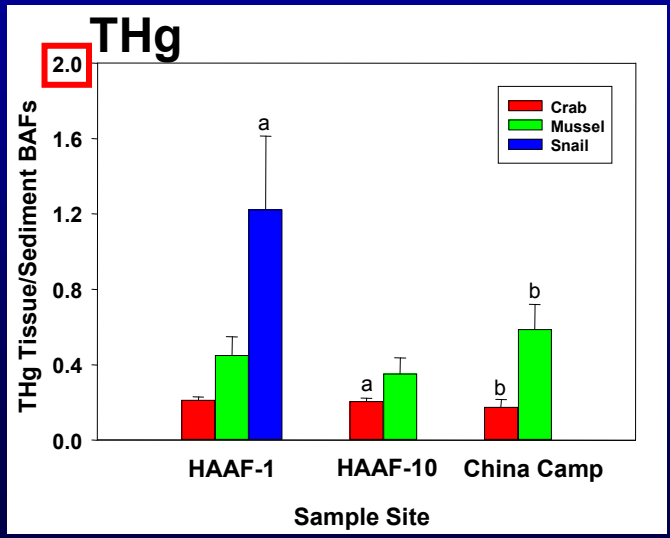


MeHg Biomagnification at the Base of the Foodweb

Mercury Bioaccumulation Factors (BAF)



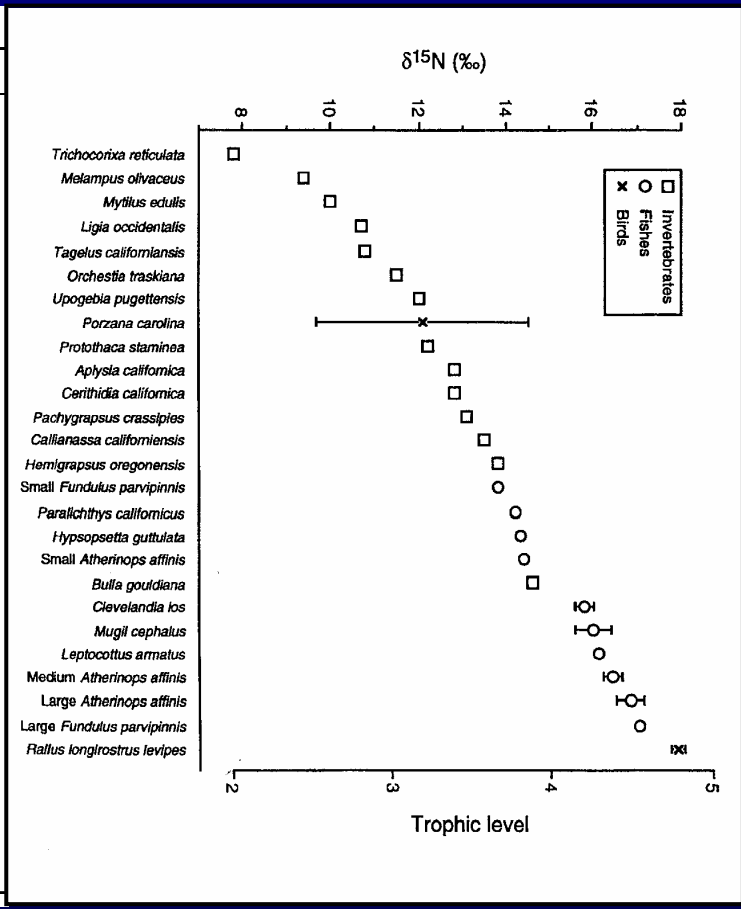




Use of Isotopic Ratios of C, N and S to Unravel San Pablo Bay Wetland Foodwebs?

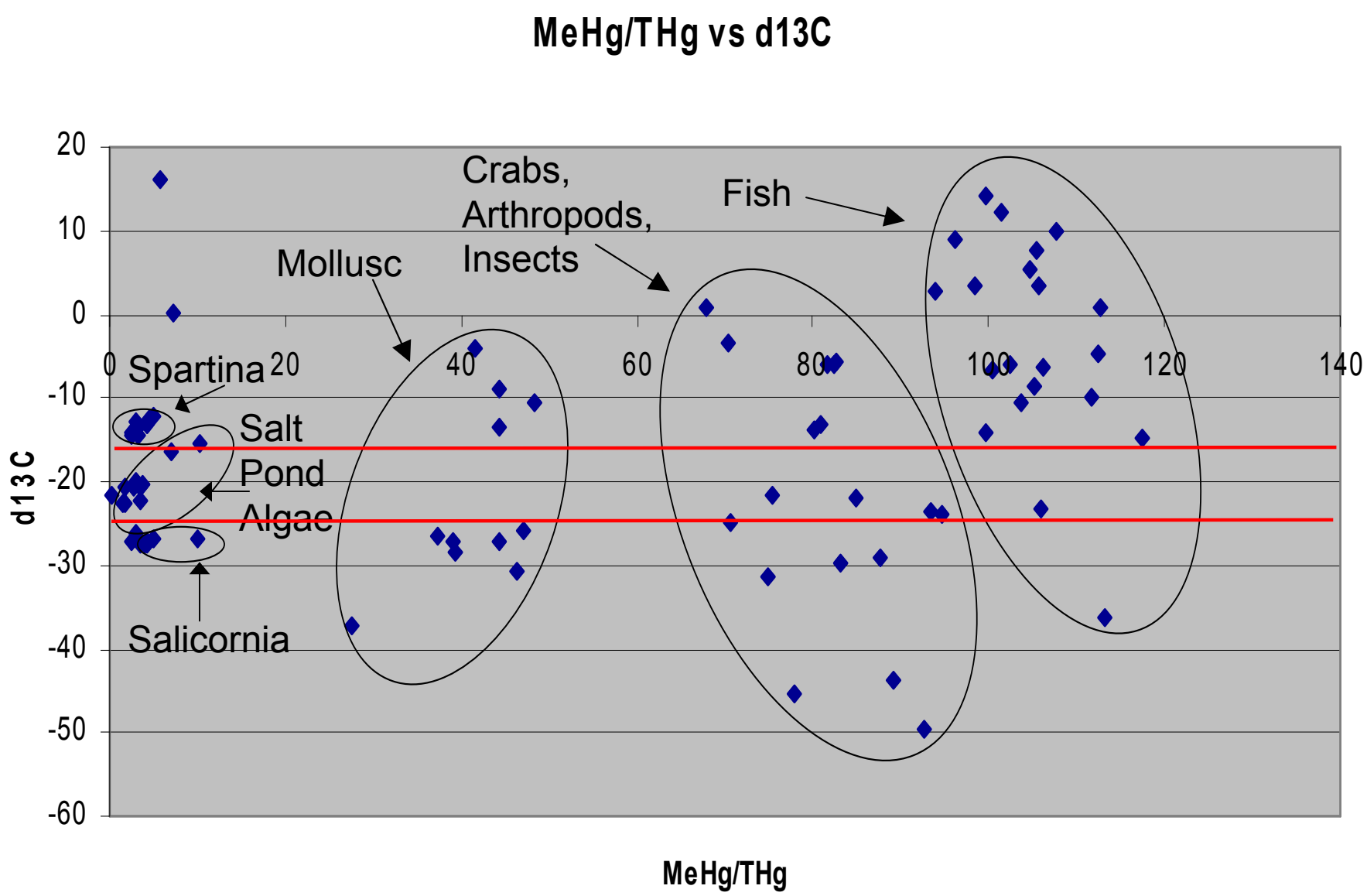
You are what you eat

Species	Marsh Habitat	$\delta^{13}C \pm SD$	$\delta^{15}N \pm SD$	$\delta^{34}S \pm SD$
Primary producers				
Macrophytes				
Spartina foliosa	Low marsh	-15.1 ± 0.2	10.3 ± 0.3	11.5 ± 0.5
Salicornia virginica	High marsh	-26.7 ± 0.2	11.0 ± 1.2	12.3 ± 2.2
Microalgae				
Microcystis sp.	Marsh pool	-17.7	5.1	9.5
Macroalgae				
Rhizoclonium sp.	Mid marsh	-20.2	9.6	17.5
Consumers				
Birds				
L-F Clapper rail	Low marsh	-18.4 ± 0.2	17.9 ± 0.1	14.6 ± 1.2
Fish				
Arrow goby	Channel	-18.4 ± 0.2	17.9 ± 0.1	14.6 ± 1.2
Striped mullet	Channel	-16.1 ± 0.2	16.0 ± 0.2	7.4 ± 0.2
Invertebrates				
Mytilus edulis	Channel	-18.0	10.0	13.7
Orchestia traskiana	Mid marsh	-21.5	11.5	14.1



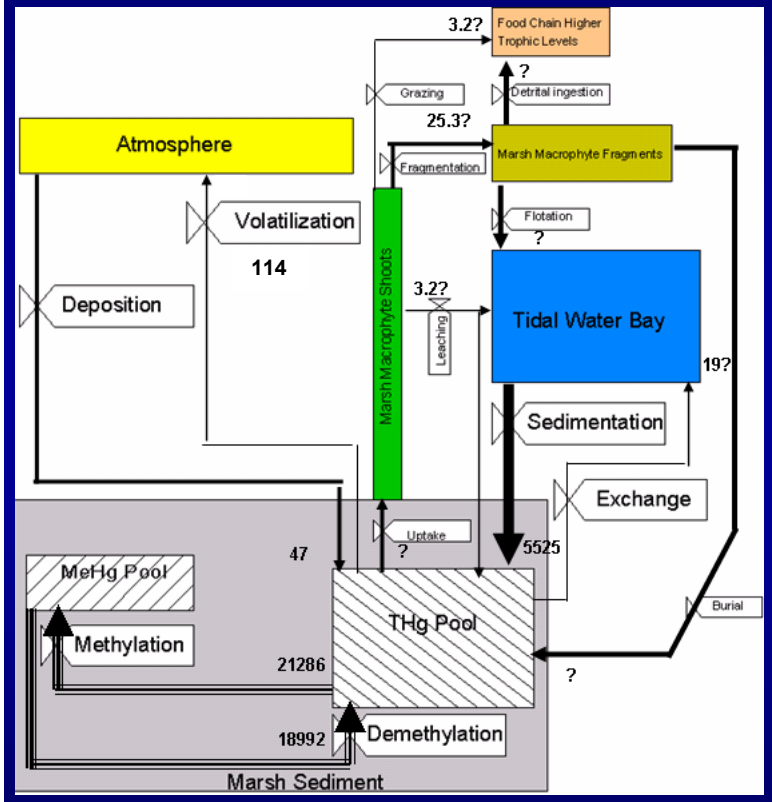
Dr. Joy Zedler's Study (1997) of Tijuana Estuary

Fish are trophically linked to *Spartina* derived carbon in the low marsh



SUMMARY

HAAF Mercury Mass Balance



- Marshes may become net Hg exporters as they mature
- Linkage between particulate THg and fish/egg burdens tenuous
- Antagonistic microbial methlyation/ demethylation rates are both fast (net MeHg)
  - Large temporal and spatial variability
- Macro drivers of net methylation
  - Wet season
  - Marsh position in salinity gradient
- Uncertainty due to lack of knowledge
  - Availability for methylation
  - Trophic structure and biomagnification
- Adaptive management is essential

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Questions?

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