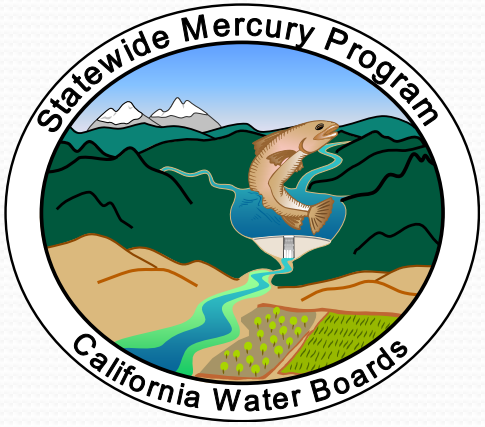
California Statewide Mercury Control Program for Reservoirs

California Lake Management Society

October 9, 2014



Multi-Region Team

Carrie Austin , Michelle Wood & many others

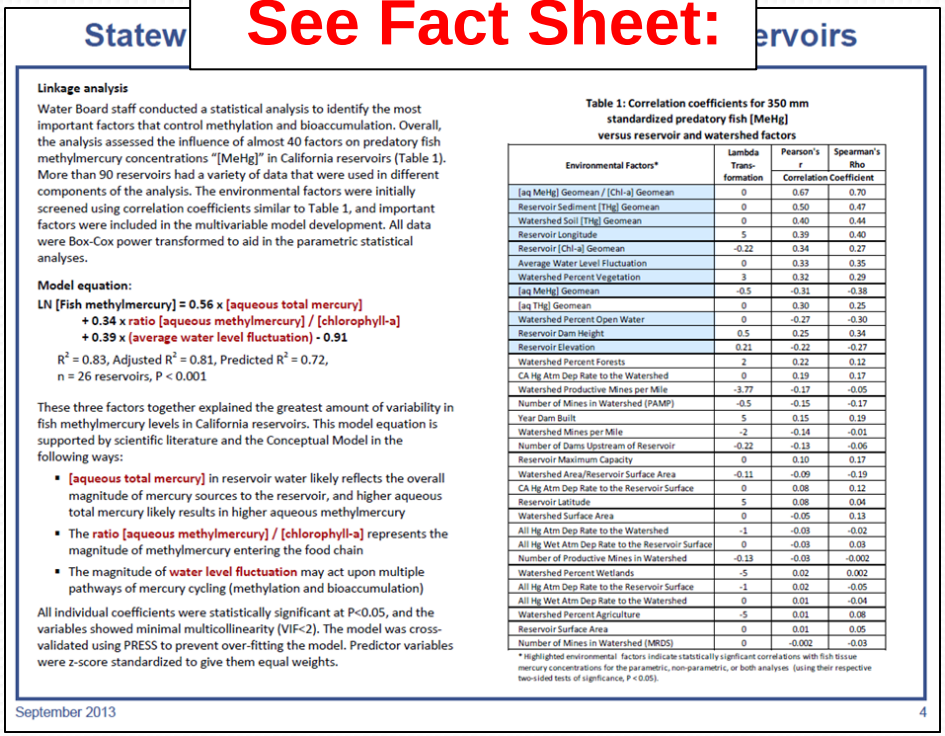
CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

California Statewide Mercury Control Program for Reservoirs

Goal:

Quickly, measurably reduce fish MeHg

See Fact Sheet:



Statew ervoirs

Linkage analysis

Water Board staff conducted a statistical analysis to identify the most important factors that control methylation and bioaccumulation. Overall, the analysis assessed the influence of almost 40 factors on predatory fish methylmercury concentrations "[MeHg]" in California reservoirs (Table 1). More than 90 reservoirs had a variety of data that were used in different components of the analysis. The environmental factors were initially screened using correlation coefficients similar to Table 1, and important factors were included in the multivariable model development. All data were Box-Cox power transformed to aid in the parametric statistical analyses.

Model equation:

LN [Fish methylmercury] = 0.56 x [aqueous total mercury]
+ 0.34 x ratio [aqueous methylmercury] / [chlorophyll-a]
+ 0.39 x (average water level fluctuation) - 0.91

R^2 = 0.83, Adjusted R^2 = 0.81, Predicted R^2 = 0.72,
n = 26 reservoirs, P < 0.001

These three factors together explained the greatest amount of variability in fish methylmercury levels in California reservoirs. This model equation is supported by scientific literature and the Conceptual Model in the following ways:

- **[aqueous total mercury]** in reservoir water likely reflects the overall magnitude of mercury sources to the reservoir, and higher aqueous total mercury likely results in higher aqueous methylmercury
- The **ratio [aqueous methylmercury] / [chlorophyll-a]** represents the magnitude of methylmercury entering the food chain
- The magnitude of **water level fluctuation** may act upon multiple pathways of mercury cycling (methylation and bioaccumulation)

All individual coefficients were statistically significant at P<0.05, and the variables showed minimal multicollinearity (VIF<2). The model was cross-validated using PRESS to prevent over-fitting the model. Predictor variables were z-score standardized to give them equal weights.

Table 1: Correlation coefficients for 350 mm standardized predatory fish [MeHg] versus reservoir and watershed factors

Environmental Factors*	Lambda Trans-formation	Pearson's r Correlation Coefficient	Spearman's Rho Correlation Coefficient
[aq MeHg] Geomean / [Chl-a] Geomean	0	0.67	0.70
Reservoir Sediment [THg] Geomean	0	0.50	0.47
Watershed Soil [THg] Geomean	0	0.40	0.44
Reservoir Longitude	5	0.39	0.40
Reservoir [Chl-a] Geomean	-0.22	0.34	0.27
Average Water Level Fluctuation	0	0.33	0.35
Watershed Percent Vegetation	3	0.32	0.29
[aq MeHg] Geomean	-0.5	-0.31	-0.38
[aq THg] Geomean	0	0.30	0.25
Watershed Percent Open Water	0	-0.27	-0.30
Reservoir Dam Height	0.5	0.25	0.34
Reservoir Elevation	0.21	-0.22	-0.27
Watershed Percent Forests	2	0.22	0.12
CA Hg Atm Dep Rate to the Watershed	0	0.19	0.17
Watershed Productive Mines per Mile	-3.77	-0.17	-0.05
Number of Mines in Watershed (PAMP)	-0.5	-0.15	-0.17
Year Dam Built	5	0.15	0.19
Watershed Mines per Mile	-2	-0.14	-0.01
Number of Dams Upstream of Reservoir	-0.22	-0.13	-0.06
Reservoir Maximum Capacity	0	0.10	0.17
Watershed Area/Reservoir Surface Area	-0.11	-0.09	-0.19
CA Hg Atm Dep Rate to the Reservoir Surface	0	0.08	0.12
Reservoir Latitude	5	0.08	0.04
Watershed Surface Area	0	-0.05	0.13
All Hg Atm Dep Rate to the Watershed	-1	-0.03	-0.02
All Hg Wet Atm Dep Rate to the Reservoir Surface	0	-0.03	0.03
Number of Productive Mines in Watershed	-0.13	-0.03	-0.002
Watershed Percent Wetlands	-5	0.02	0.002
All Hg Atm Dep Rate to the Reservoir Surface	-1	0.02	-0.05
All Hg Wet Atm Dep Rate to the Watershed	0	0.01	-0.04
Watershed Percent Agriculture	-5	0.01	0.08
Reservoir Surface Area	0	0.01	0.05
Number of Mines in Watershed (MRDS)	0	-0.002	-0.03

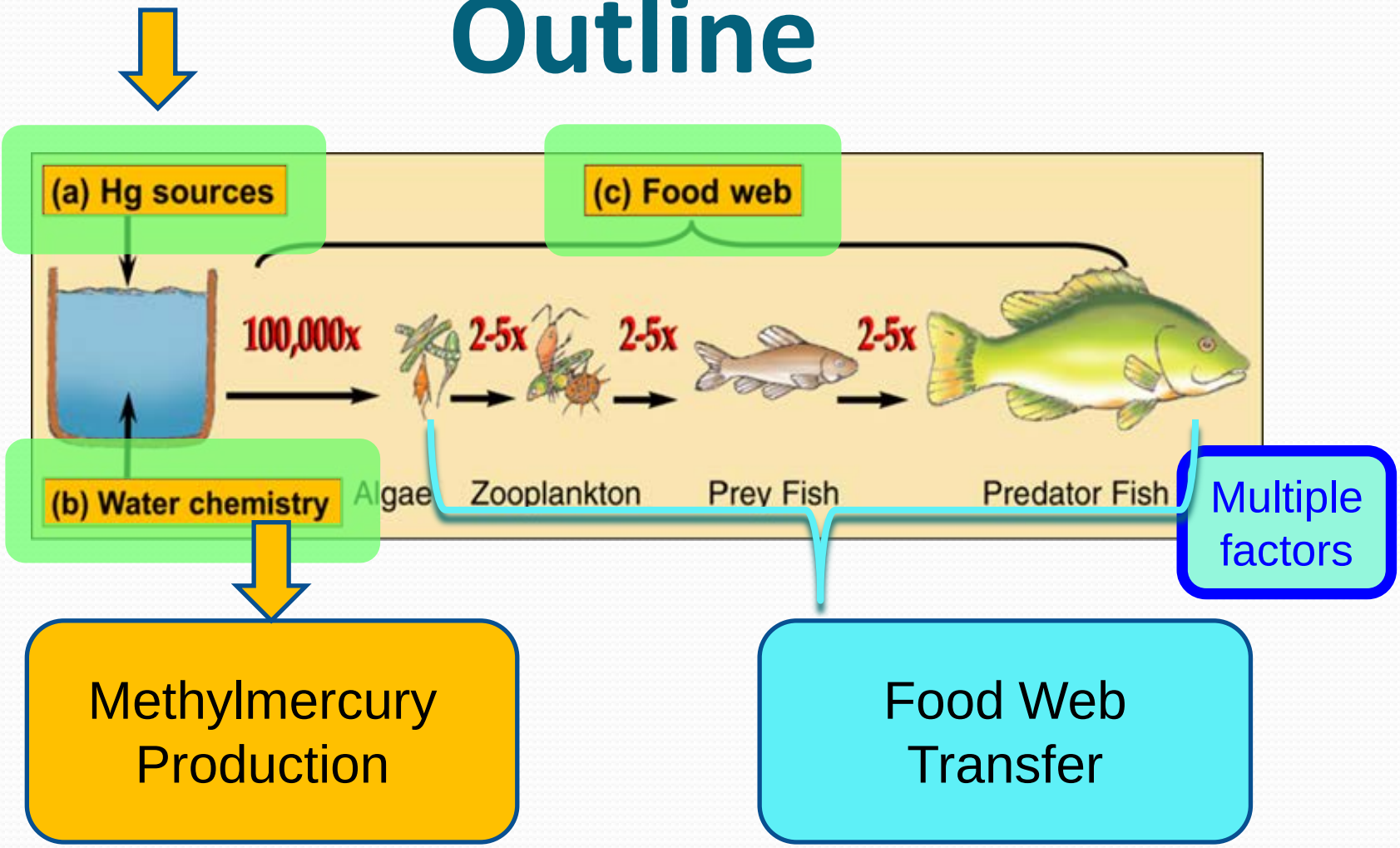
* Highlighted environmental factors indicate statistically significant correlations with fish tissue mercury concentrations for the parametric, non-parametric, or both analyses (using their respective two-sided tests of significance, P < 0.05).

September 2013 4

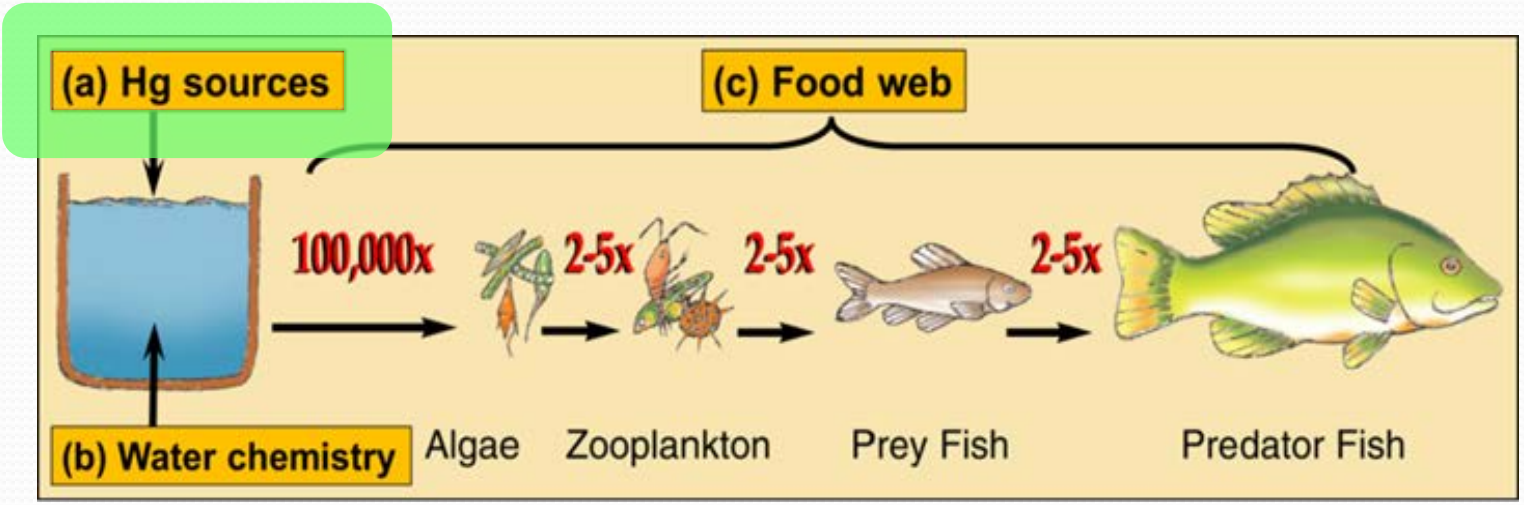
Website with fact sheets & updates

www.waterboards.ca.gov/water_issues/programs/mercury

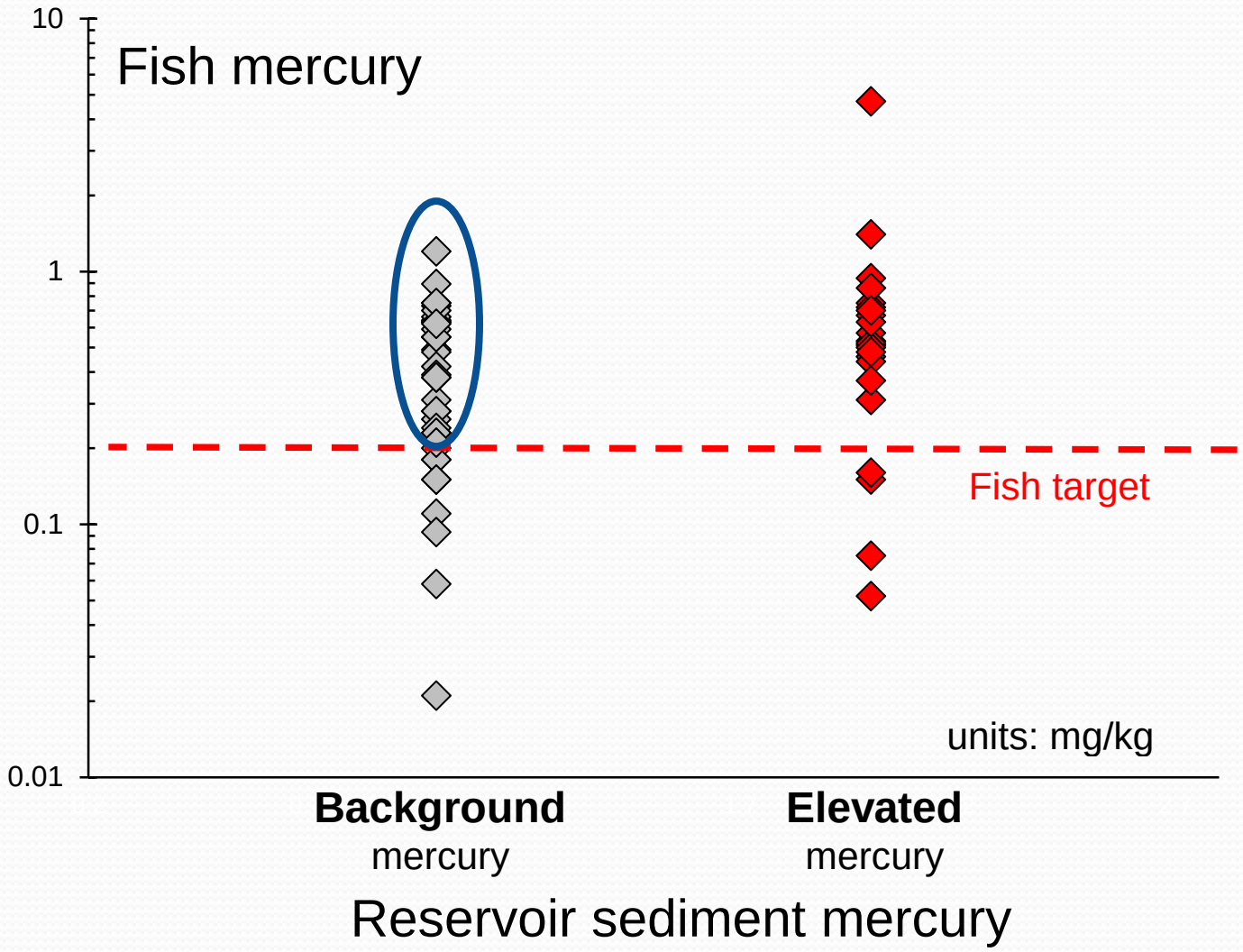
Outline


(a) Hg sources
(c) Food web
100,000x
2-5x
2-5x
2-5x
(b) Water chemistry
Algae
Zooplankton
Prey Fish
Predator Fish
Multiple factors
Methylmercury Production
Food Web Transfer

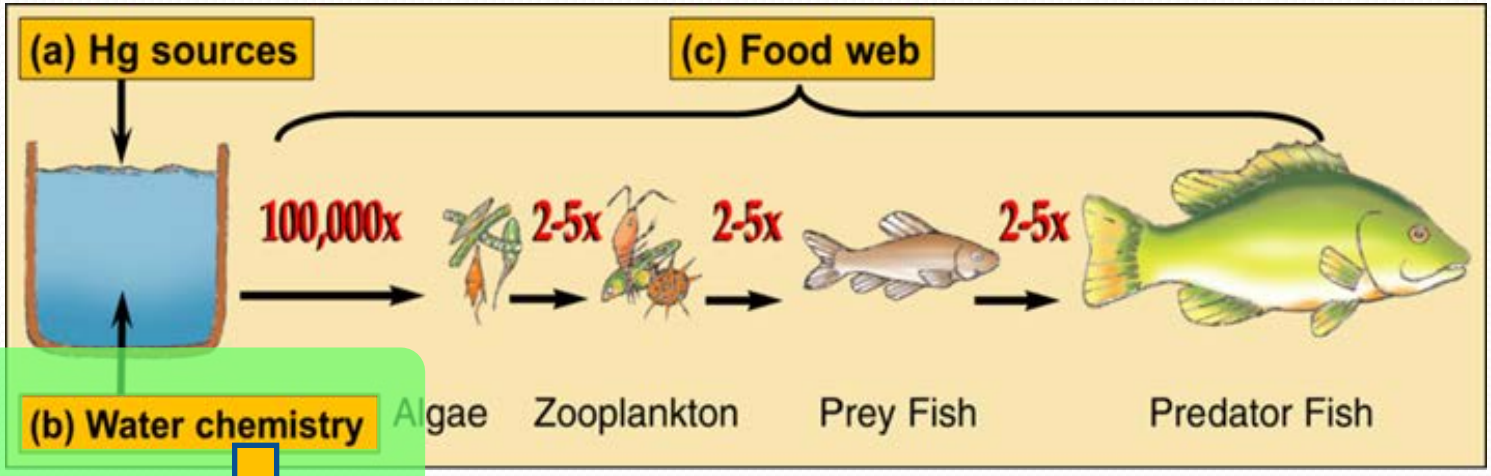
Limited benefits from source control



Limited Benefits from Source Control



Manage redox conditions



Methylmercury Production

Redox sequence:

- O_2 aerobic heterotrophs
- NO_3^- denitrifiers
- $MnO_2(s)$ fermenters
- $Fe(OH_3)(s)$ fermenters
- SO_4^{2-} sulfate reducers
- H^+ methane producers

Desirable

Avoid

Oxygenation Pilot Tests

San Francisco Bay

Santa Clara Valley Water District

- Solar-powered circulators
- HOS line diffuser

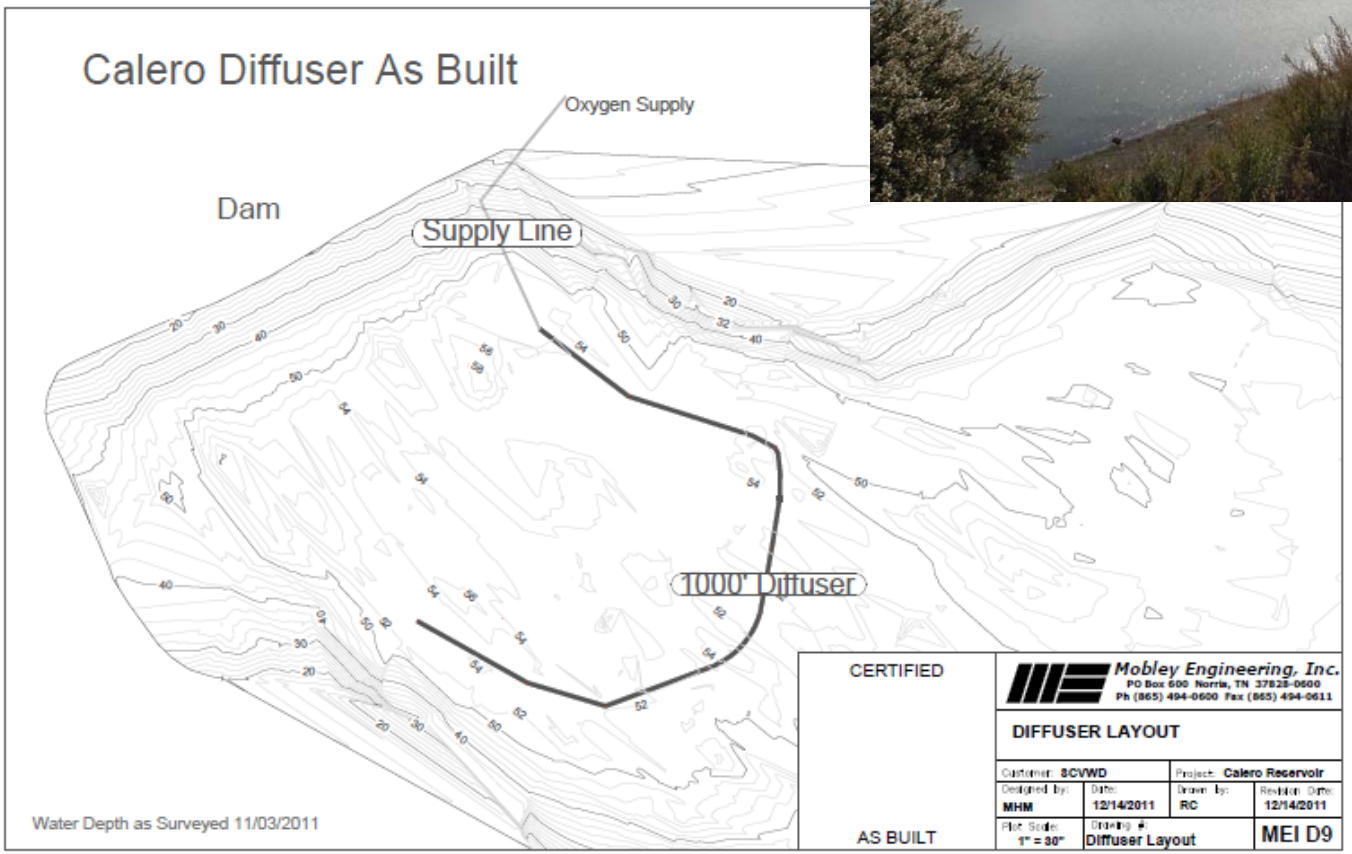
San Jose

New Almaden Mining District

N
W
E
S

0 5 10 15 20 Km

Santa Clara Valley Water District



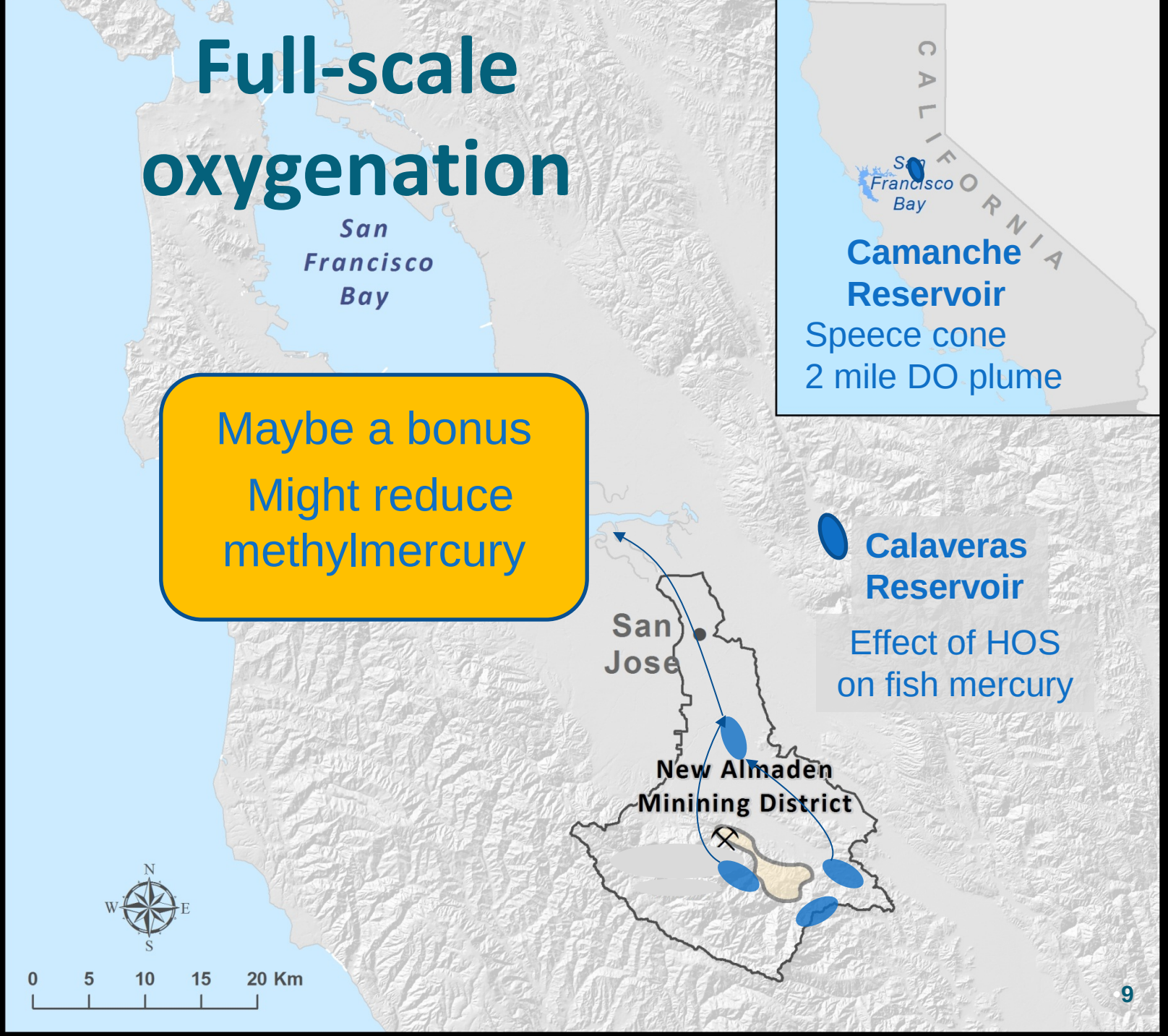
HOS:

Hypolimnetic Oxygenation System

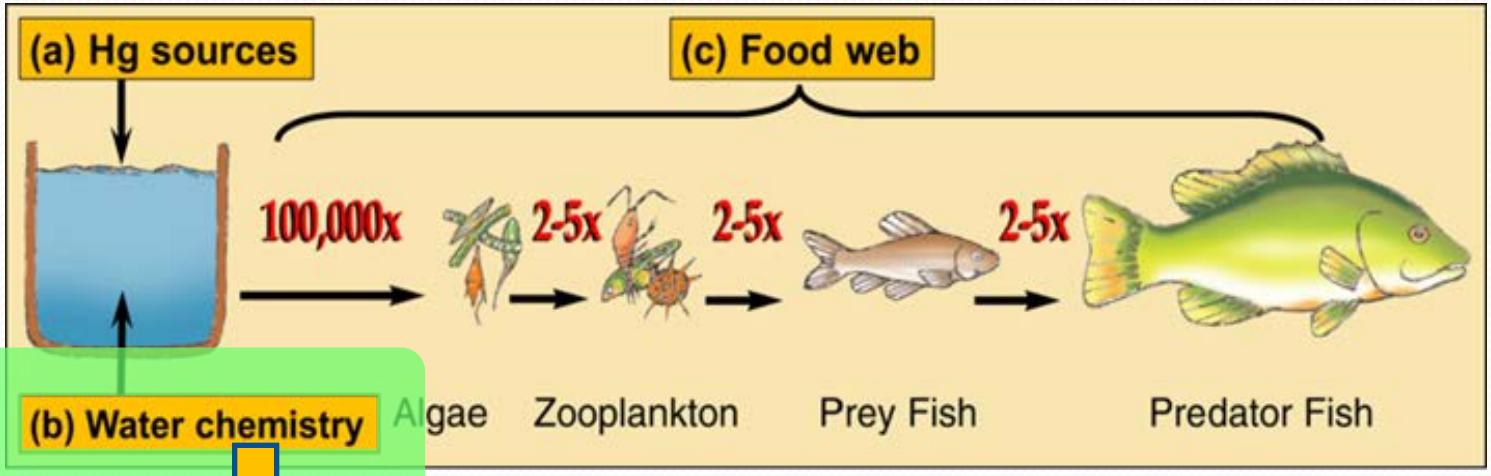
Citation:

Dave Drury
SCVWD

Full-scale oxygenation



Manage redox conditions



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Desirable

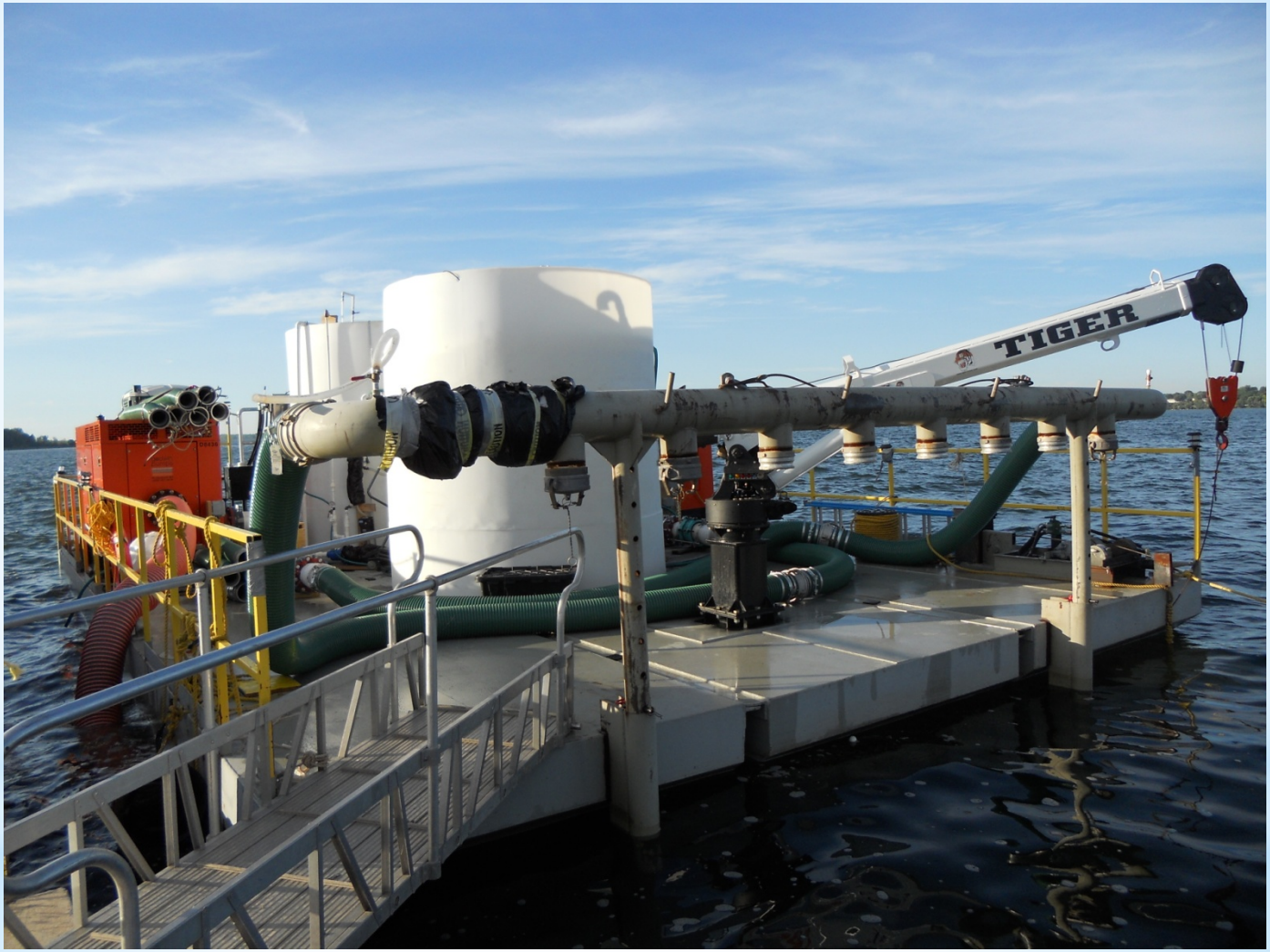
Avoid

Source Removal and Nitrate Addition Onondaga Lake, New York

Citation:

Charles T. Driscoll
Syracuse University

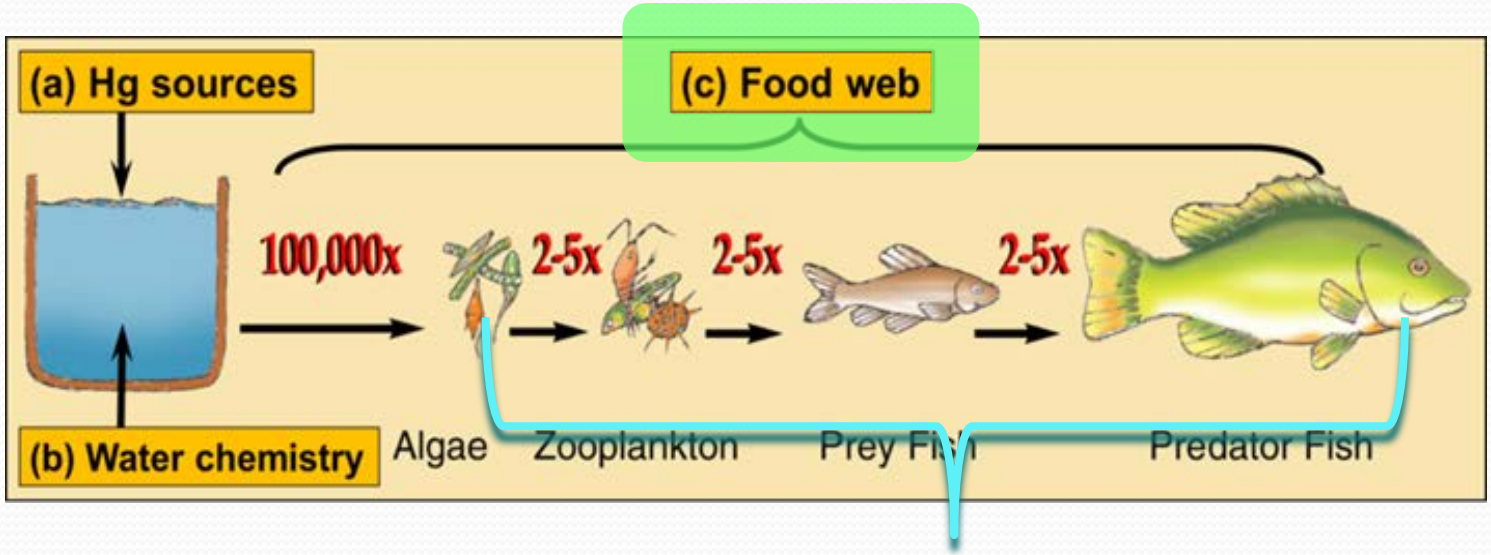
Manage redox with NO_3^-



Citation:

Charles T. Driscoll
Syracuse University

Manage fishery



Food lower in MeHg

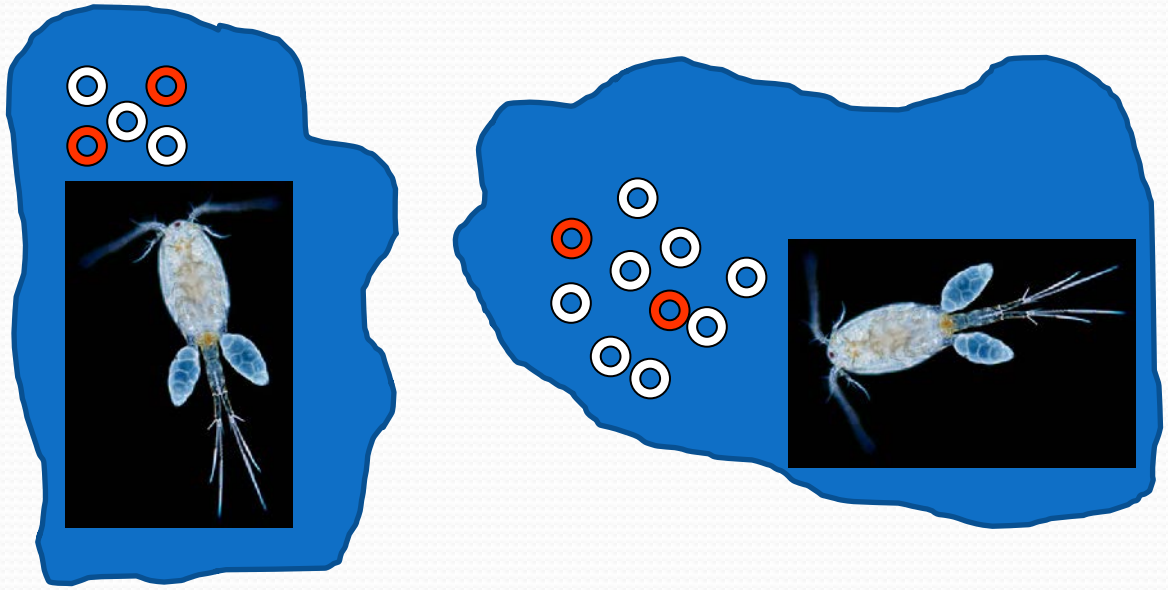
Cull fish

Select species

Food Web Transfer

Food lower in MeHg:

Algal Bloom Dilution



Fertilize

increase algae

same MeHg

Carefully

no more than 2x Chl-*a*

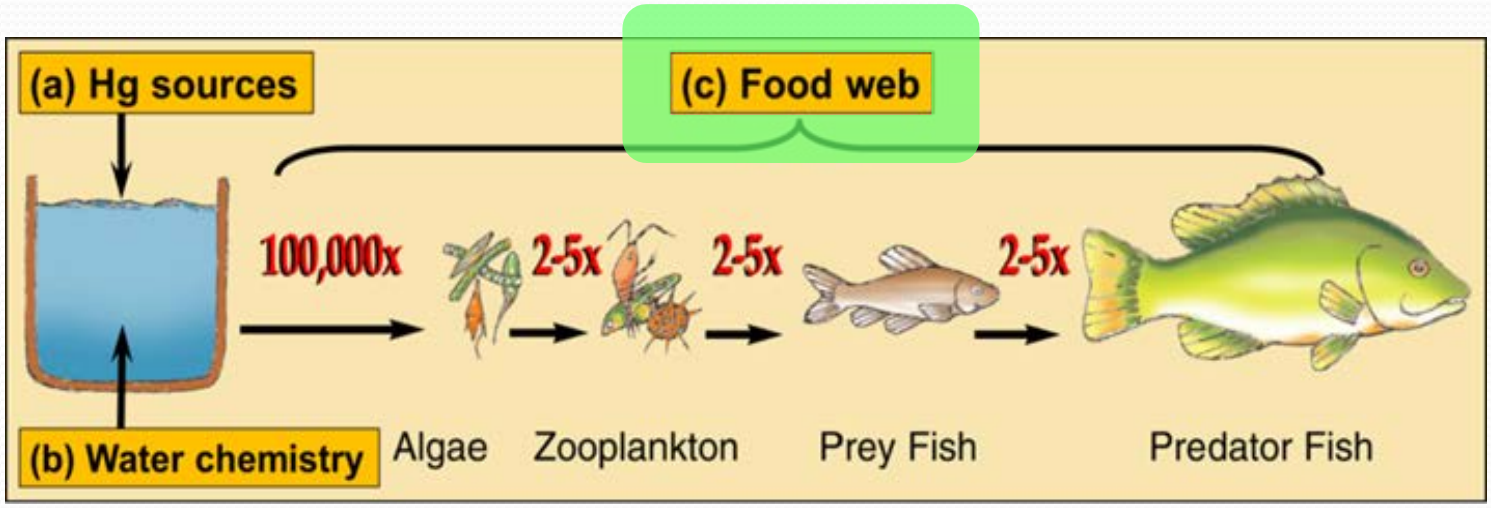
and Chl-*a* ≤5 ug/L

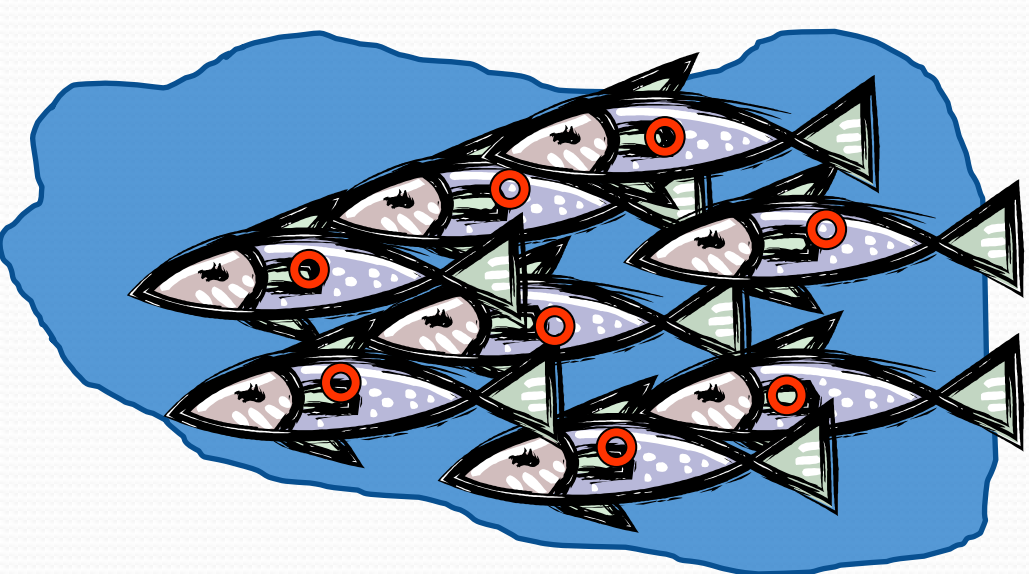
Food lower in MeHg

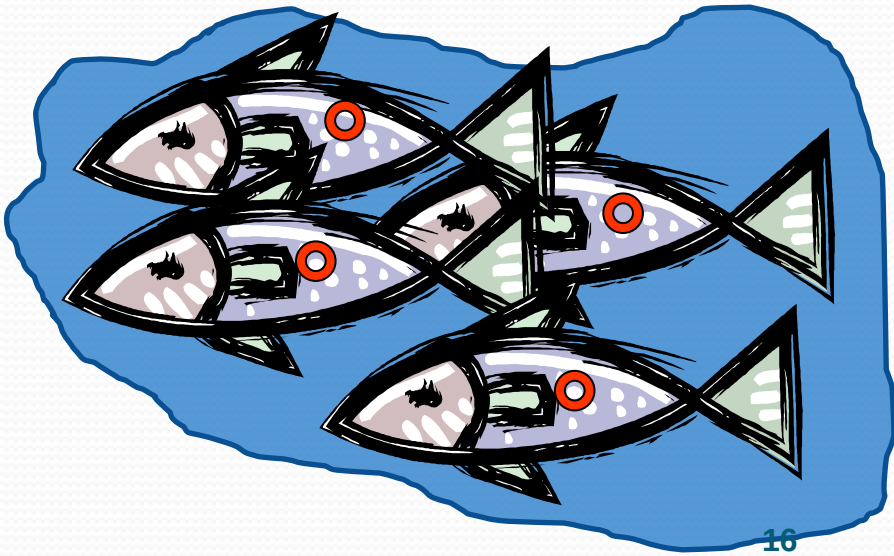
Stock prey with low MeHg e.g., Rainbow trout

Citation:
Jesse Lepak

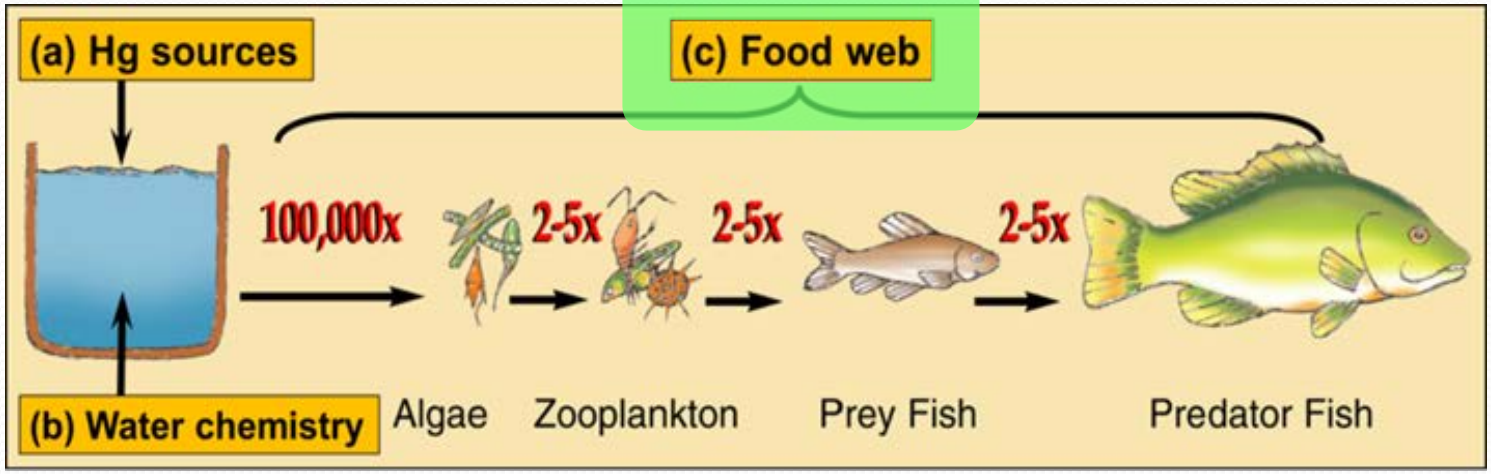
Cull or “intensive fishing”



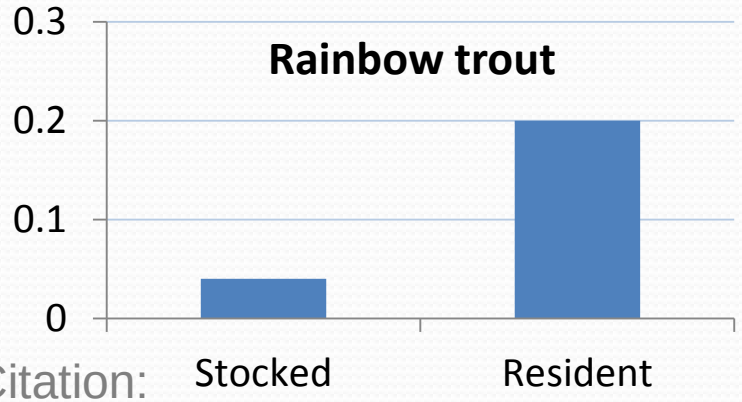




Select species

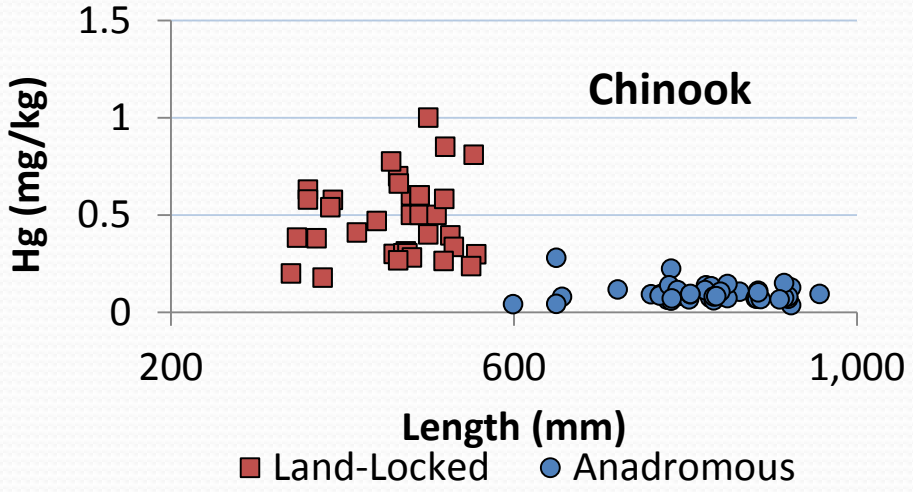


Stock – hatchery diets low MeHg



Citation:
Mike Horvath, SFPUC

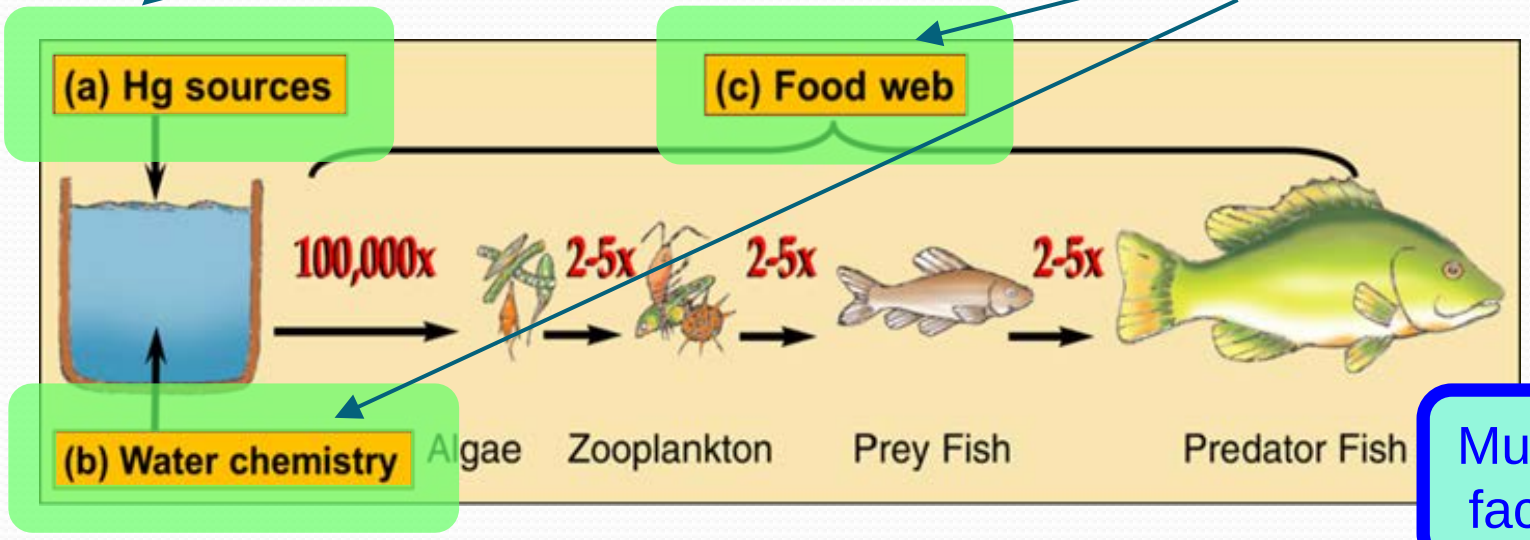
Restore native anadromous fish



California Statewide Mercury Control Program for Reservoirs

Source control
manage expectations

Pilot tests



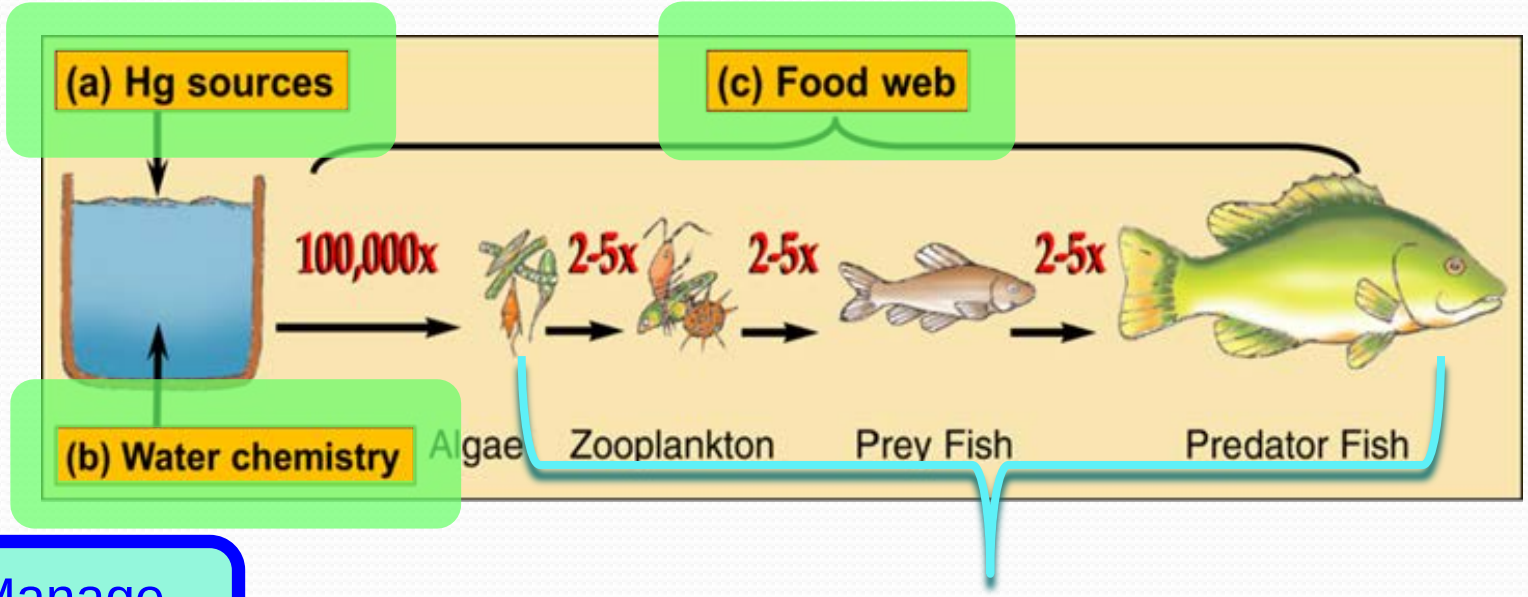
Multiple factors

Website with fact sheets & updates

www.waterboards.ca.gov/water_issues/programs/mercury

Reduce Sediment Hg

Next: 4 stations

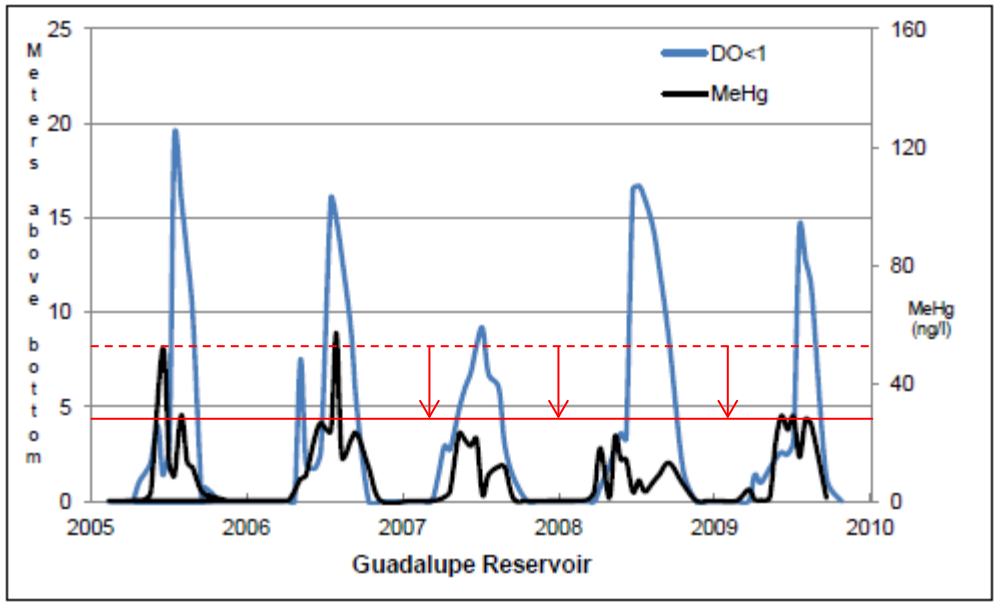


Manage Redox

Increase Productivity

Manage Fisheries

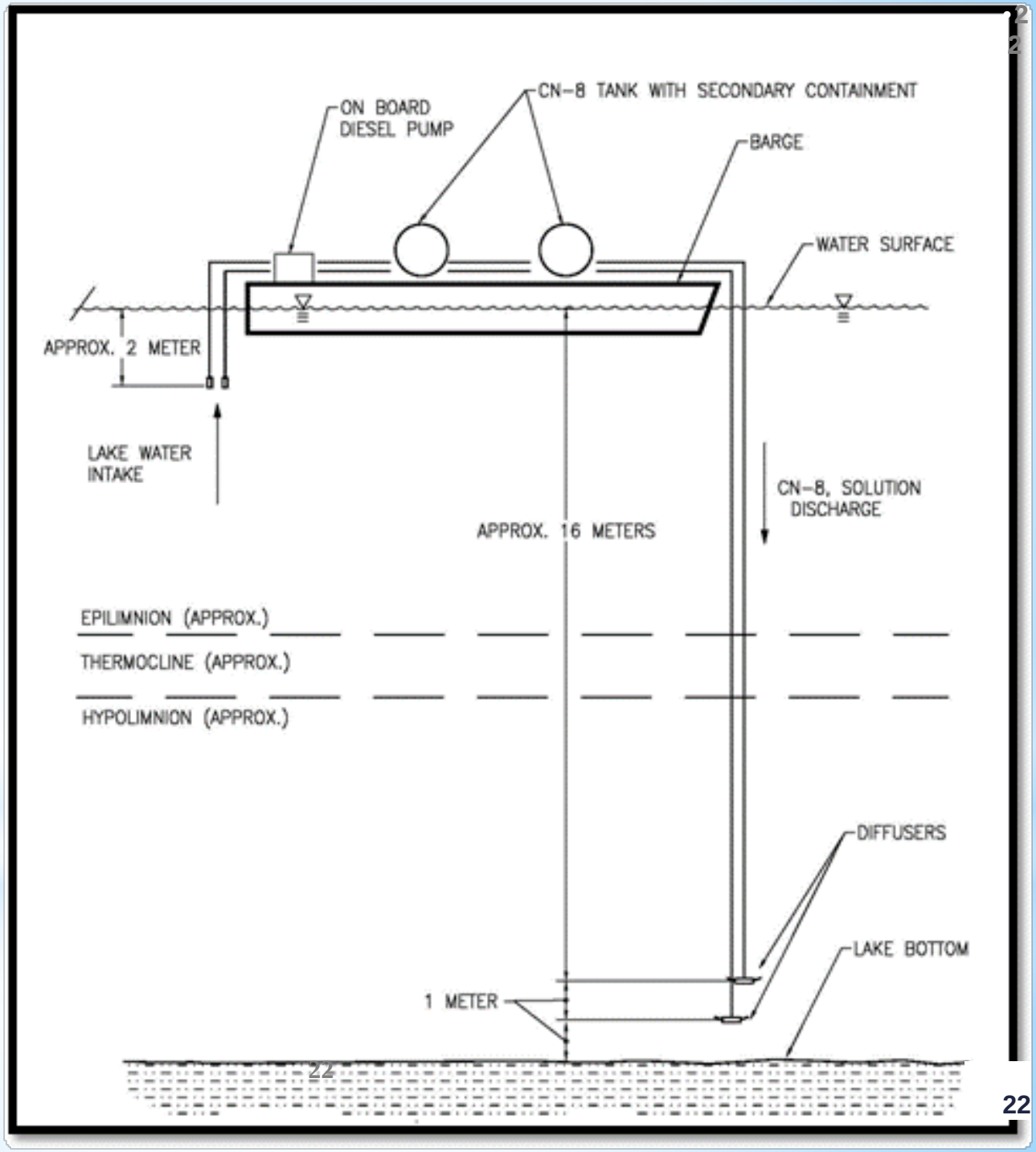
Solar-powered circulator↓MeHg



Annual coincidence: MeHg & seasonal anoxia

Citation: Santa Clara Valley Water District

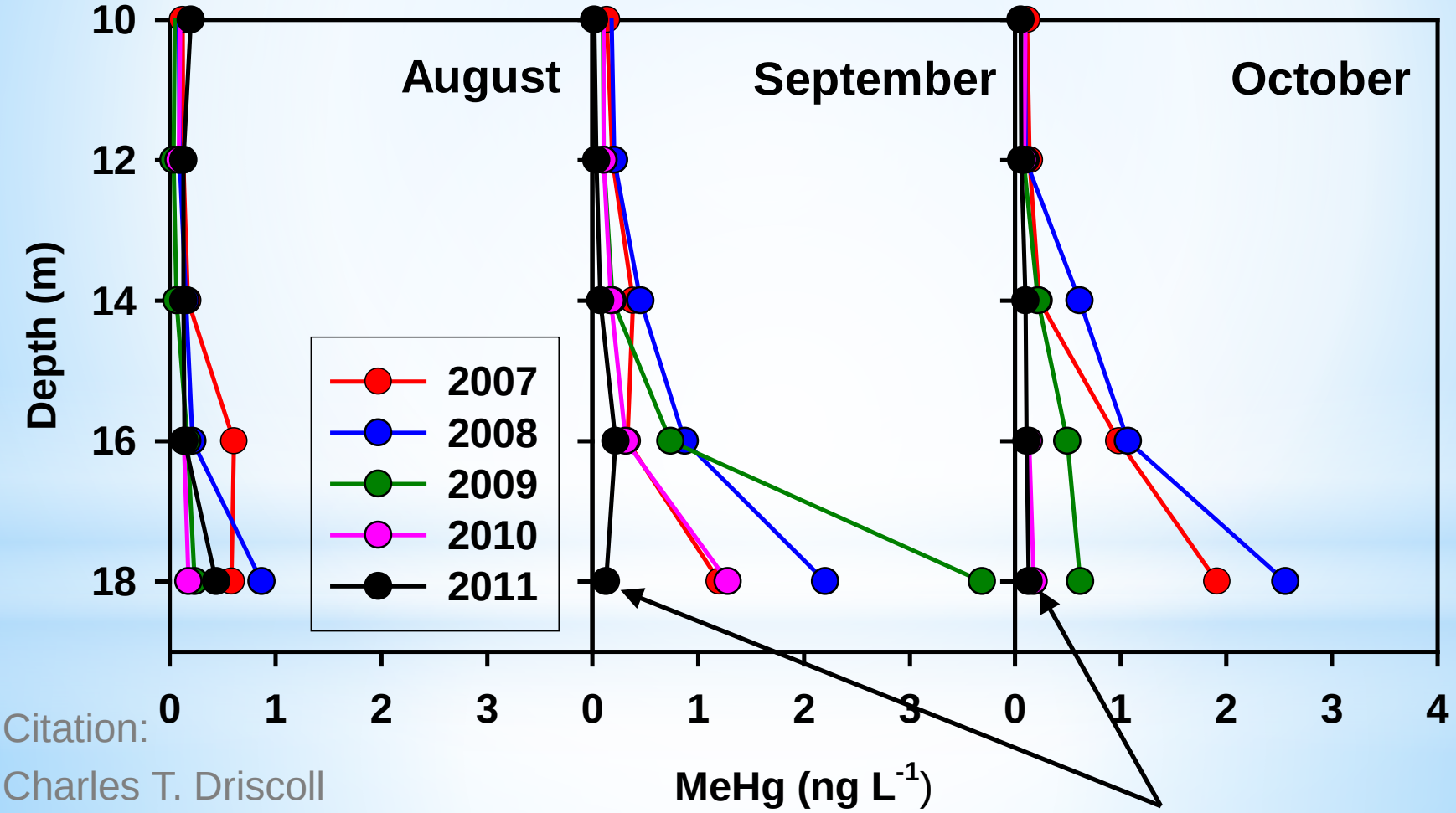
Manage redox with NO_3^-



Citation:

Charles T. Driscoll
Syracuse University

Vertical Profiles of MeHg: 2007-2011



Citation:

Charles T. Driscoll
Syracuse University

Upland and in-lake remediation areas

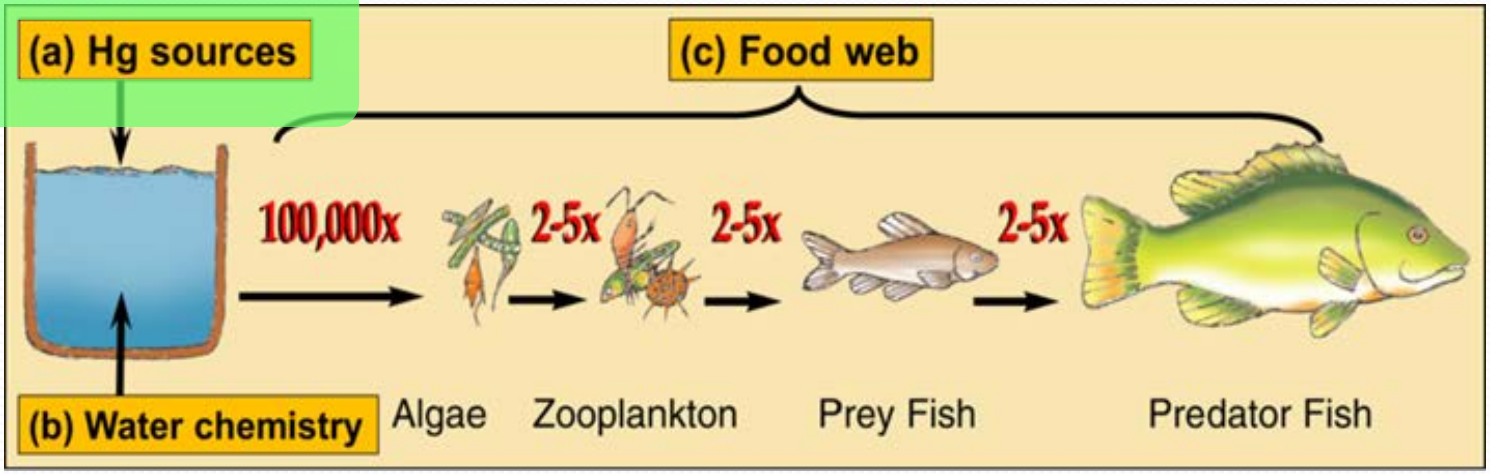
Isolation cap 172 ha

Thin layer cap 11ha

Citation:

Charles T. Driscoll
Syracuse University

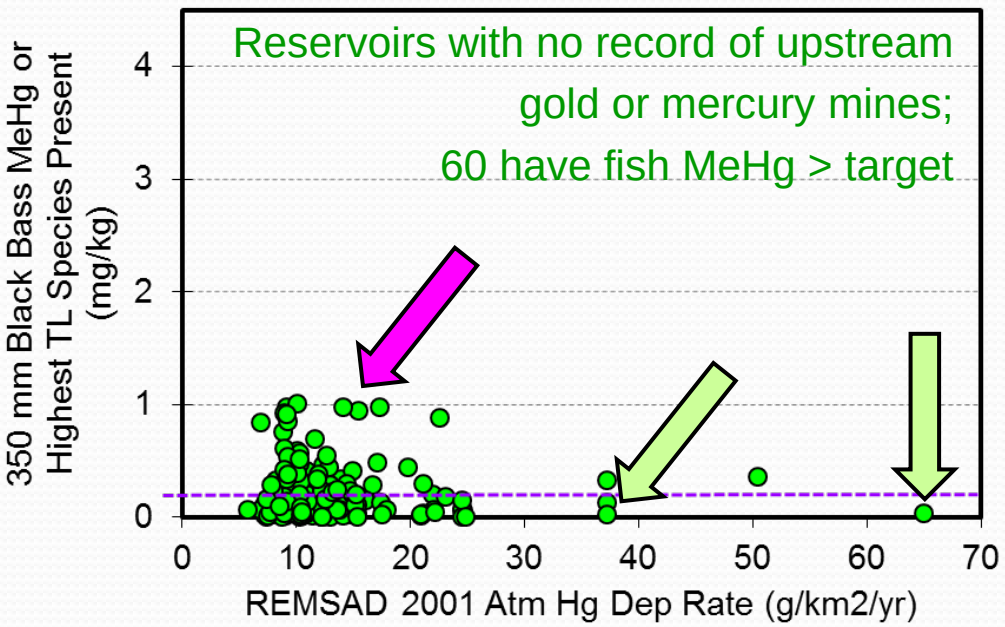
↓ Hg → reservoir (source control)

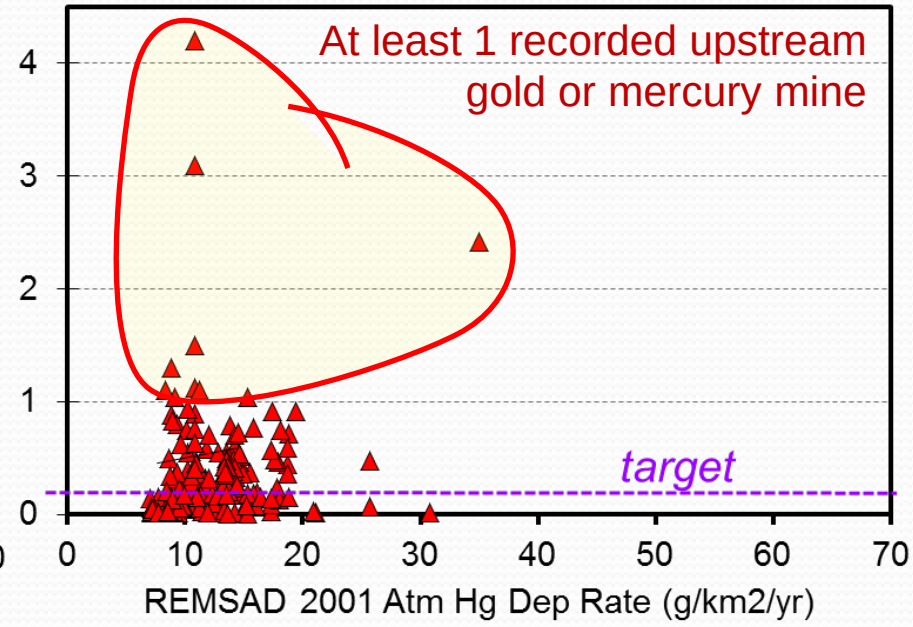


Mines
mercury and gold

Atmospheric Deposition

Mercury from atmospheric deposition and mines

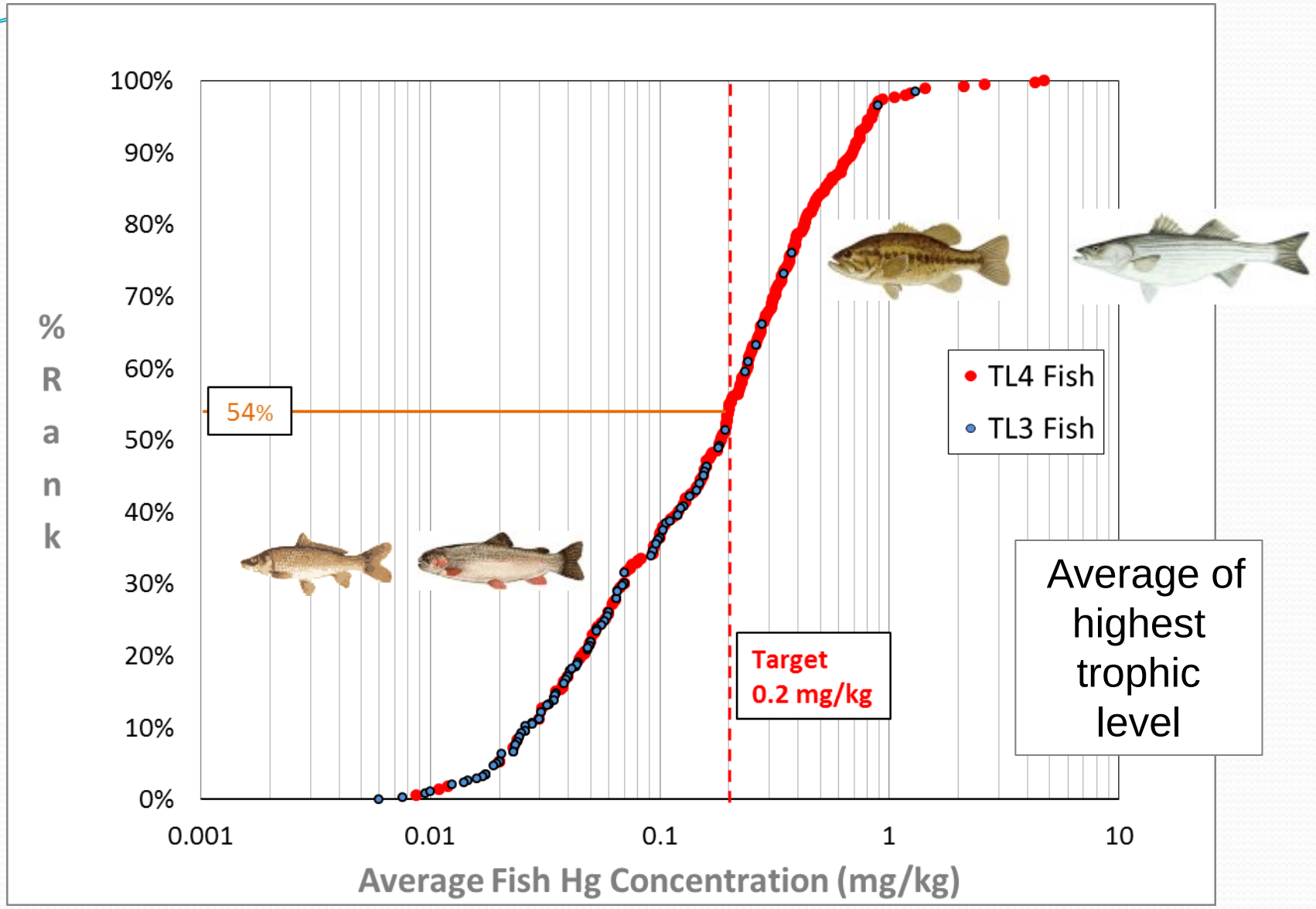




Multiple Factors

- Can have high fish MeHg but low atm dep and no mines
- Can have low fish MeHg but very high atm Hg dep
- Very highest fish MeHg associated with extensive Hg mining

Multiple factors: fish species



California: 350 reservoirs and lakes

SF Bay Region: hotspot for high fish mercury levels