# Fish Mercury Impairment in California Reservoirs:
## Historic Mines and Other Factors

EPA Region 9 State-of-the-Science Workshop on Mercury Remediation in Aquatic Environments

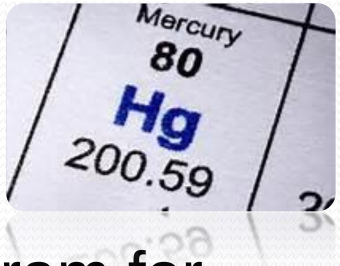
September 26, 2013


California Water Boards

Multi-Region Team

*Michelle Wood, Carrie Austin, Steve Louie & many others*

# Outline




- Introduction to Statewide Mercury Control Program for Reservoirs
- Quick overview of:
  - California reservoirs fish MeHg impairment
  - Linkage between fish MeHg bioaccumulation, sources, and other factors
  - Mercury sources and where they occur
- Where might mine remediation enable measurable **and** timely fish mercury reductions?

**WANTED: Your Feedback!**

# Outline

***total mercury (Hg)***
***inorganic mercury***


- Introduction to Statewide Mercury Control Program for Reservoirs
- Quick overview of:

  ***monomethylmercury***

  - California reservoirs fish **MeHg** impairment
  - Linkage between fish MeHg bioaccumulation, sources, and other factors
  - Mercury sources and where they occur
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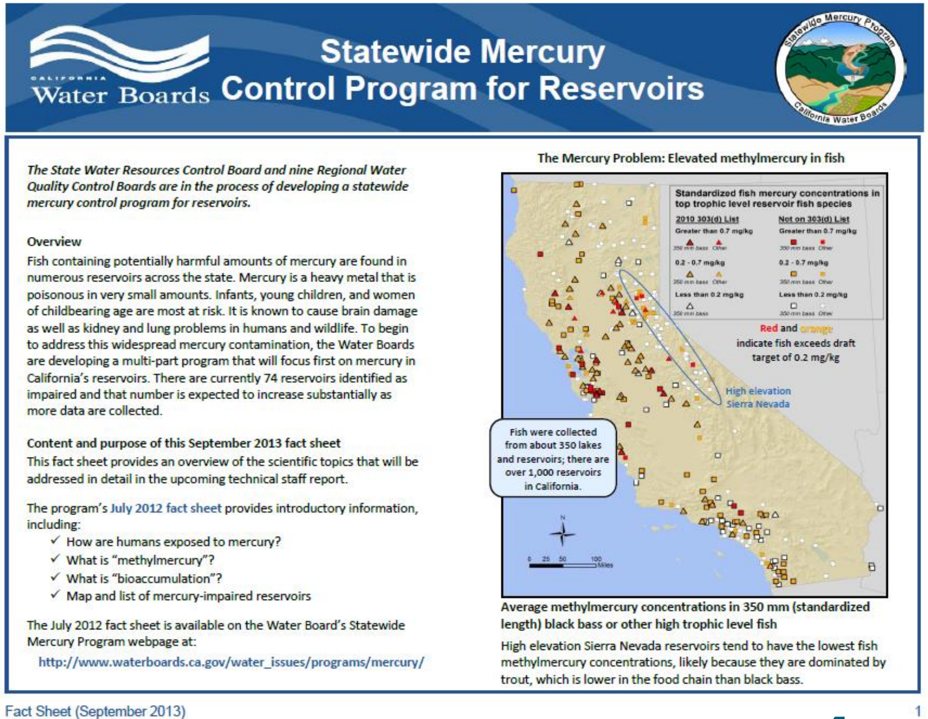
# Statewide Mercury Control Program for Reservoirs

**Goal:** Quickly, measurably reduce fish MeHg

- **Website with fact sheets & updates**
  www.waterboards.ca.gov/water_issues/programs/mercury
- **Sign up for email notices at:**
  www.waterboards.ca.gov/resources/email_subscriptions/swrcb_subscribe.shtml#quality



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## Statewide Mercury Control Program for Reservoirs

*The State Water Resources Control Board and nine Regional Water Quality Control Boards are in the process of developing a statewide mercury control program for reservoirs.*

**Overview**

Fish containing potentially harmful amounts of mercury are found in numerous reservoirs across the state. Mercury is a heavy metal that is poisonous in very small amounts. Infants, young children, and women of childbearing age are most at risk. It is known to cause brain damage as well as kidney and lung problems in humans and wildlife. To begin to address this widespread mercury contamination, the Water Boards are developing a multi-part program that will focus first on mercury in California's reservoirs. There are currently 74 reservoirs identified as impaired and that number is expected to increase substantially as more data are collected.

**Content and purpose of this September 2013 fact sheet**

This fact sheet provides an overview of the scientific topics that will be addressed in detail in the upcoming technical staff report.

The program's July 2012 fact sheet provides introductory information, including:

- ✓ How are humans exposed to mercury?
- ✓ What is "methylmercury"?
- ✓ What is "bioaccumulation"?
- ✓ Map and list of mercury-impaired reservoirs

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**The Mercury Problem: Elevated methylmercury in fish**



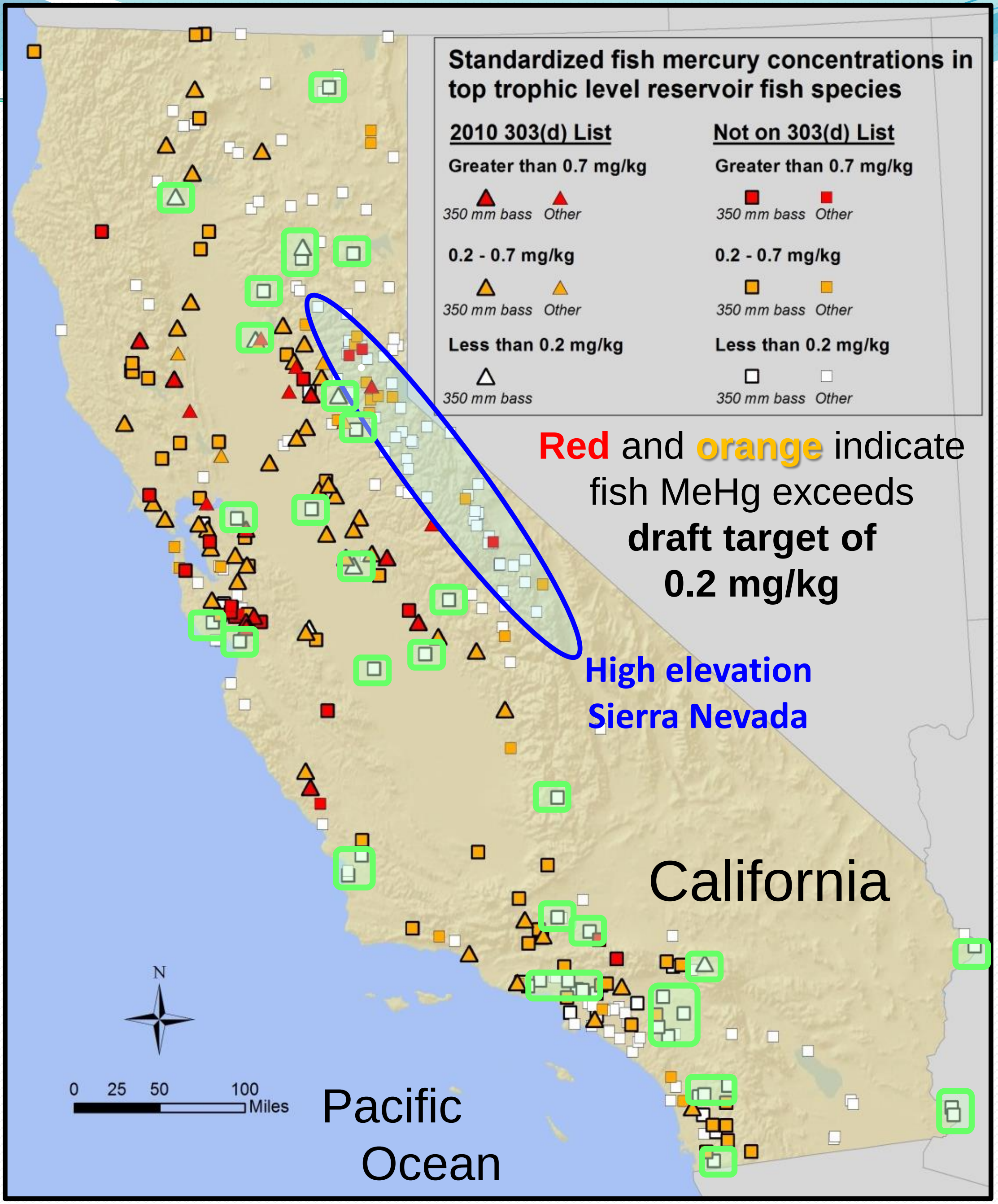
**Average methylmercury concentrations in 350 mm (standardized length) black bass or other high trophic level fish**

High elevation Sierra Nevada reservoirs tend to have the lowest fish methylmercury concentrations, likely because they are dominated by trout, which is lower in the food chain than black bass.

Fact Sheet (September 2013) 1

# Fish MeHg Levels

- 74 CWA 303(d) listed reservoirs
- another ~70+ soon to be listed
- Rainbow trout have low MeHg
- But so do black bass! [green boxes]

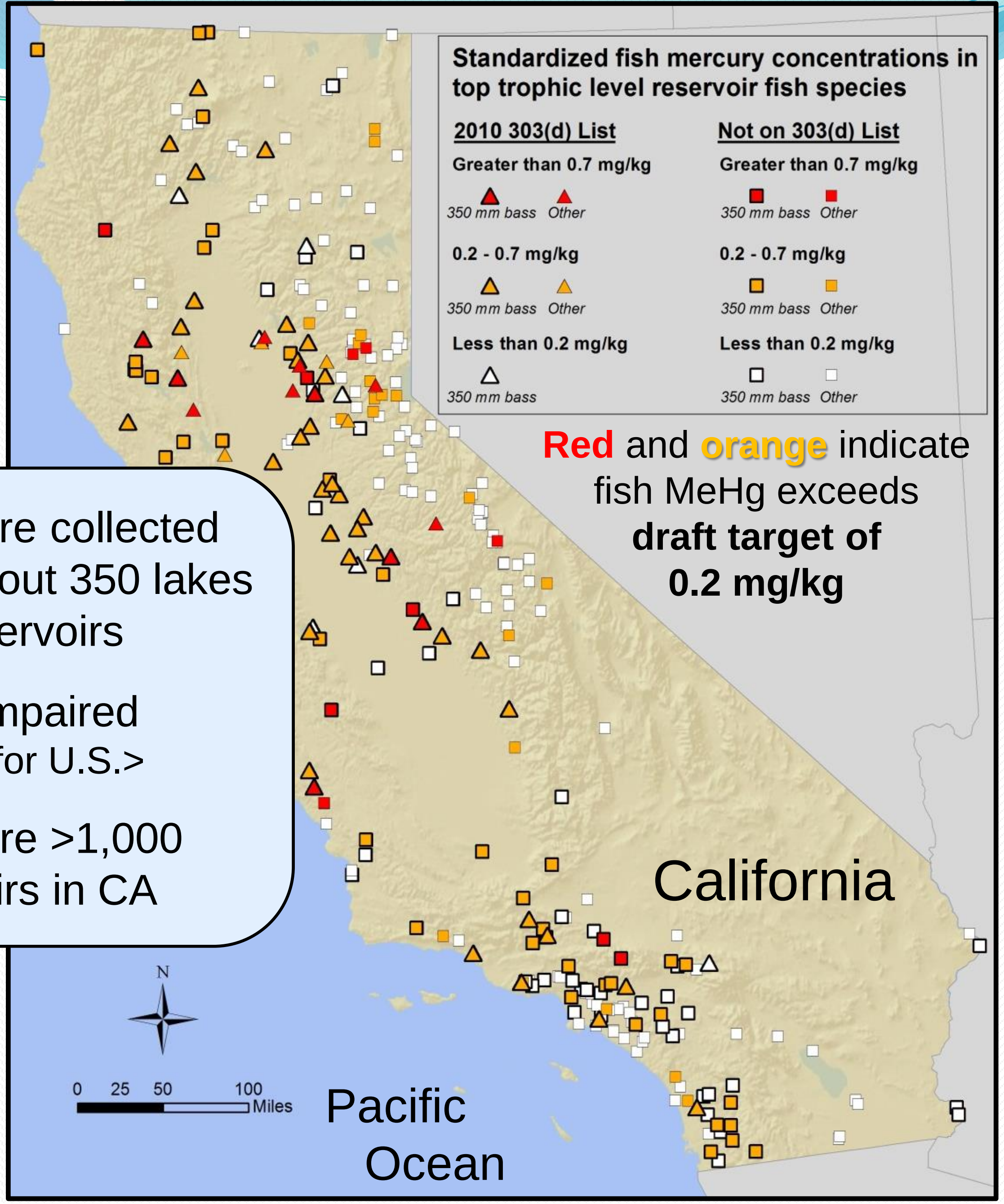


# Fish MeHg Levels

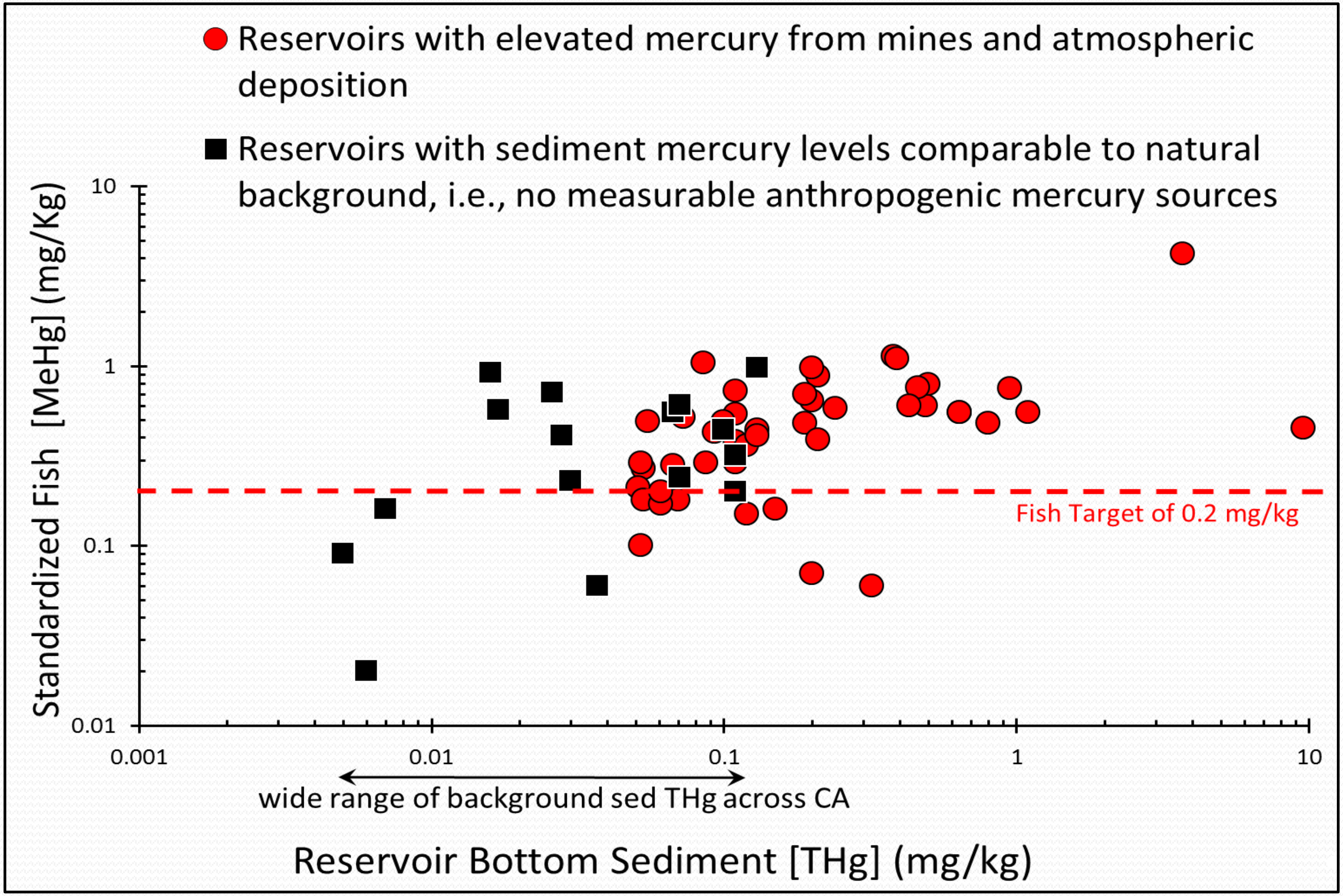
- 74 CWA 303(d) listed reservoirs
- another ~70+ soon to be listed

- Fish were collected from about 350 lakes and reservoirs
- ~50% impaired <typical for U.S.>
- There are >1,000 reservoirs in CA

**Control program might need to address ~500 reservoirs**



# It’s a complicated story…



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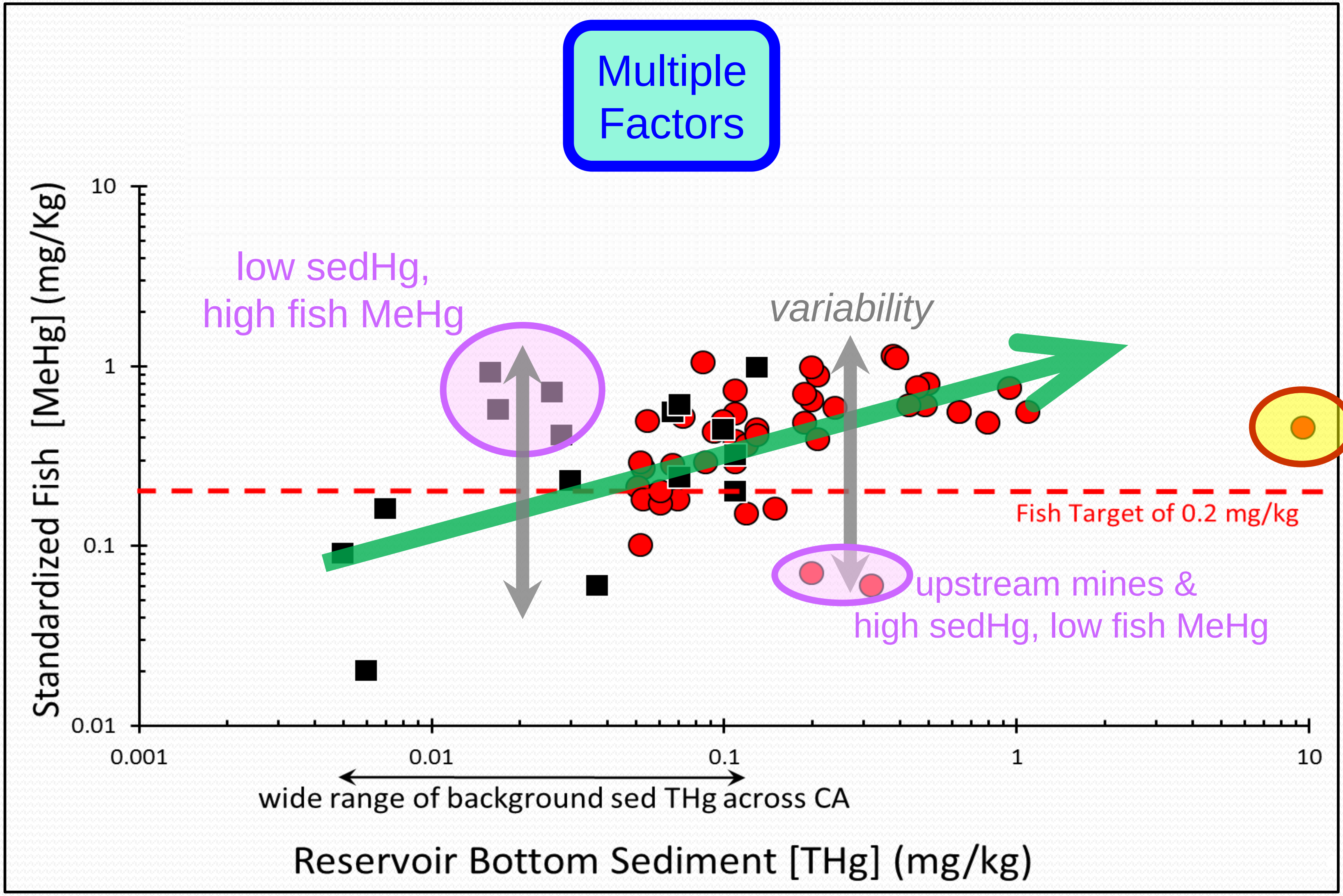


# Model Equation


LN [Fish methylmercury] =

0.563 * [aqueous total Hg]

+ 0.338 * [aqueous MeHg] / [chlorophyll-*a*]

+ 0.394 * (annual water level fluctuation) – 0.912

**3 factors are equally important!**

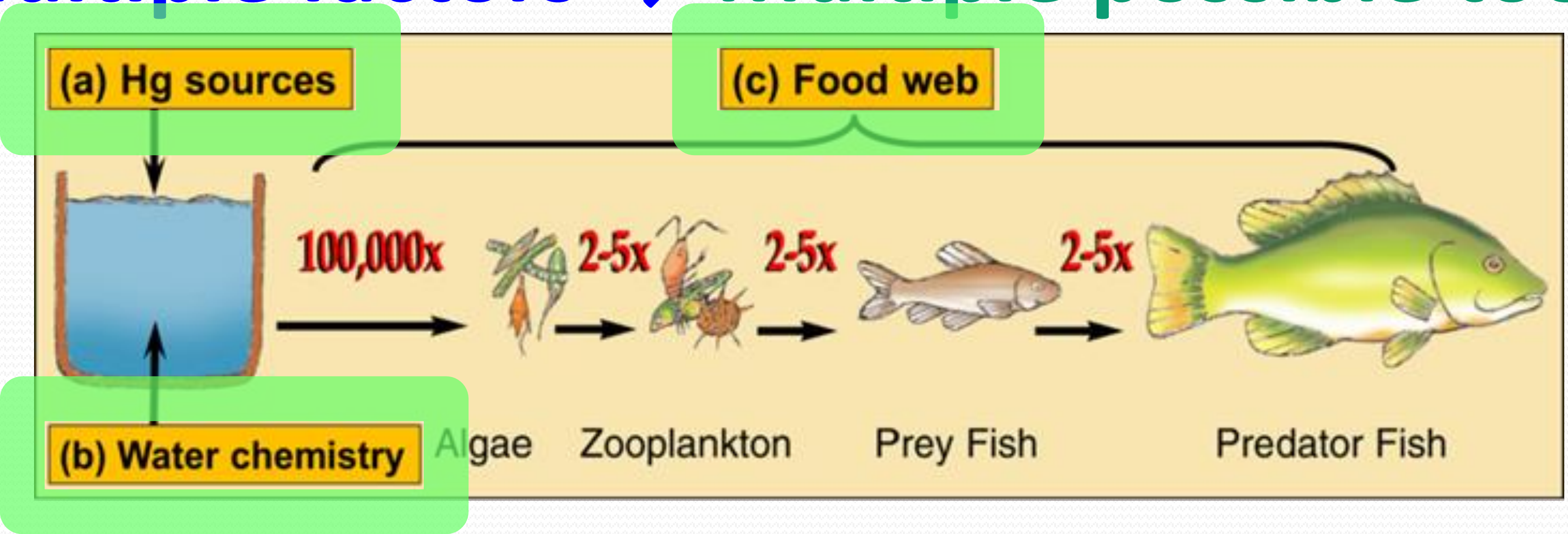
$R^2 = 0.83$

Adjusted $R^2 = 0.81$

Predicted $R^2 = 0.72$

n = 26 reservoirs, $P < 0.001$

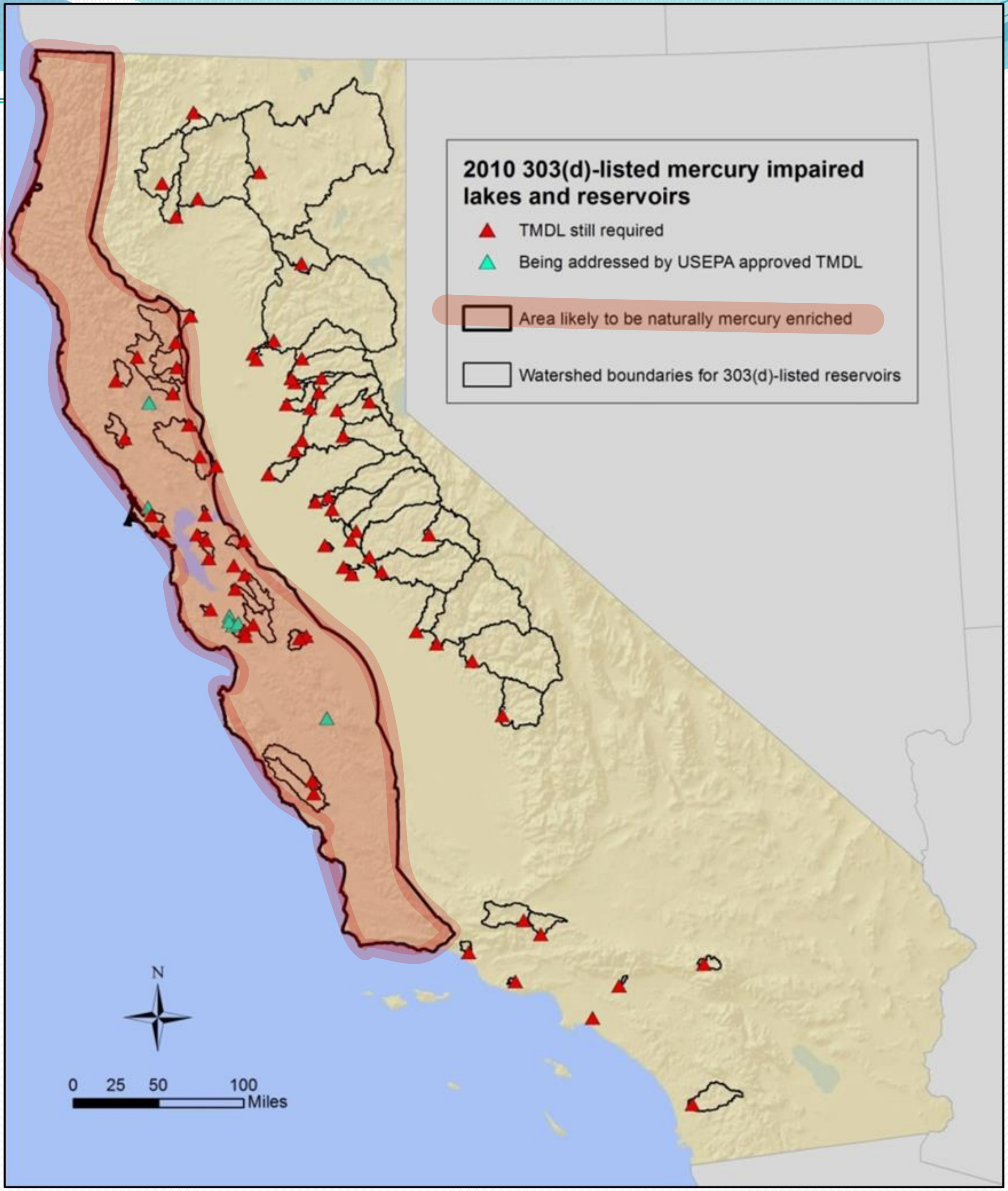
# Multiple factors → Multiple possible tools




**(a) Source control:**
Reduce Hg sources to reduce MeHg production in reservoirs

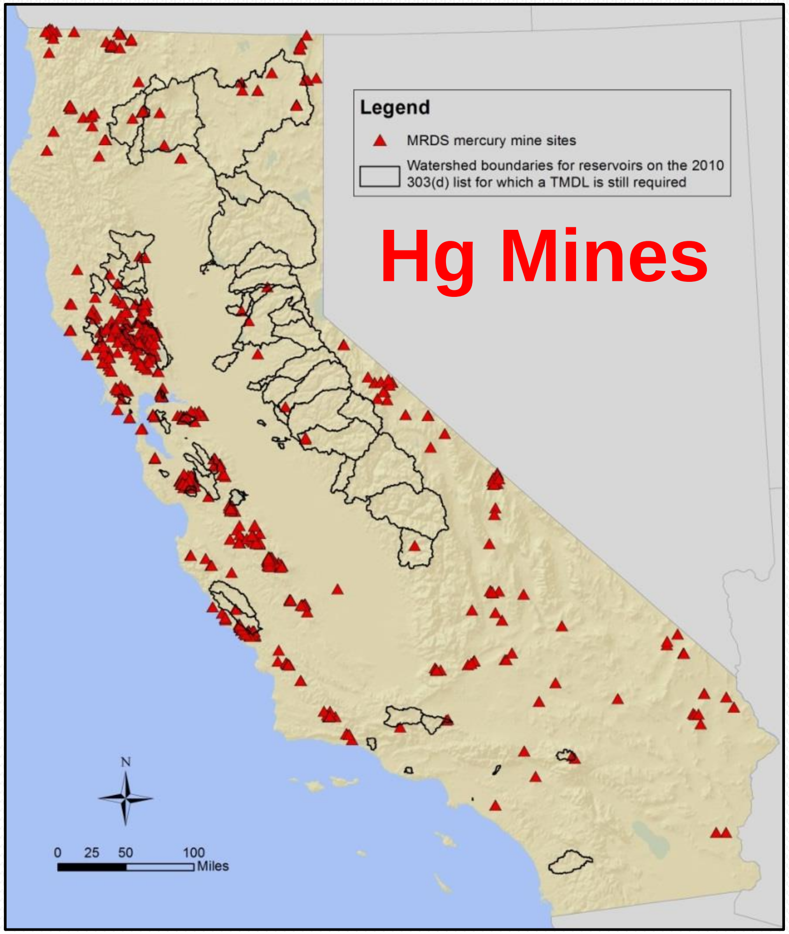
***Today's focus: mine waste remediation***

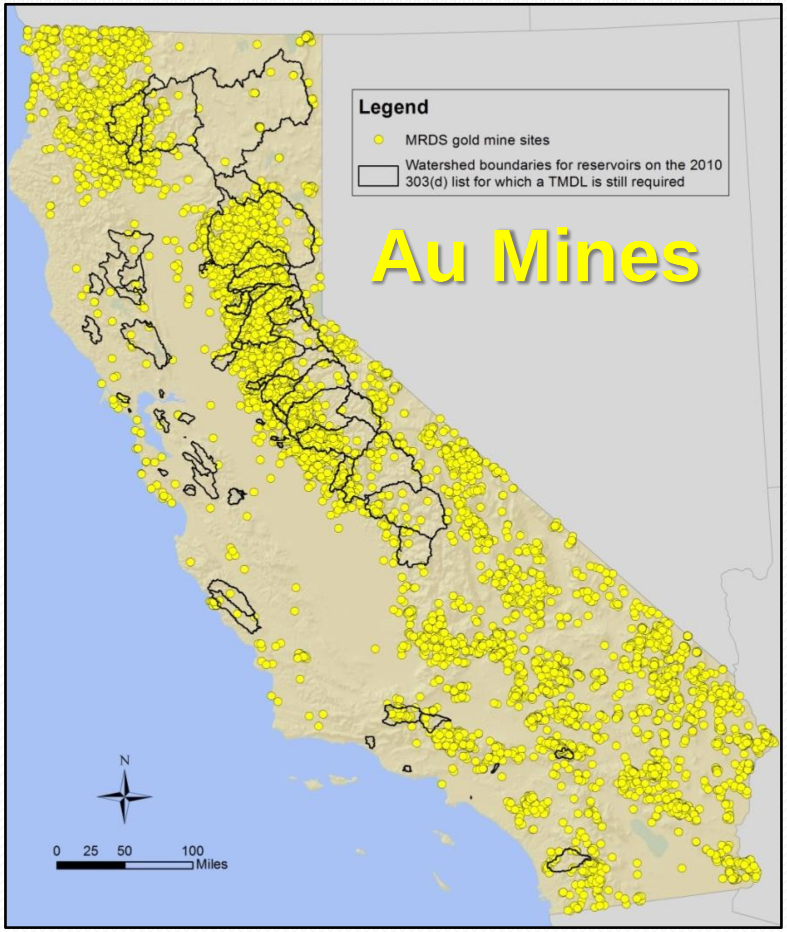
# Some reservoirs are in naturally Hg-enriched areas



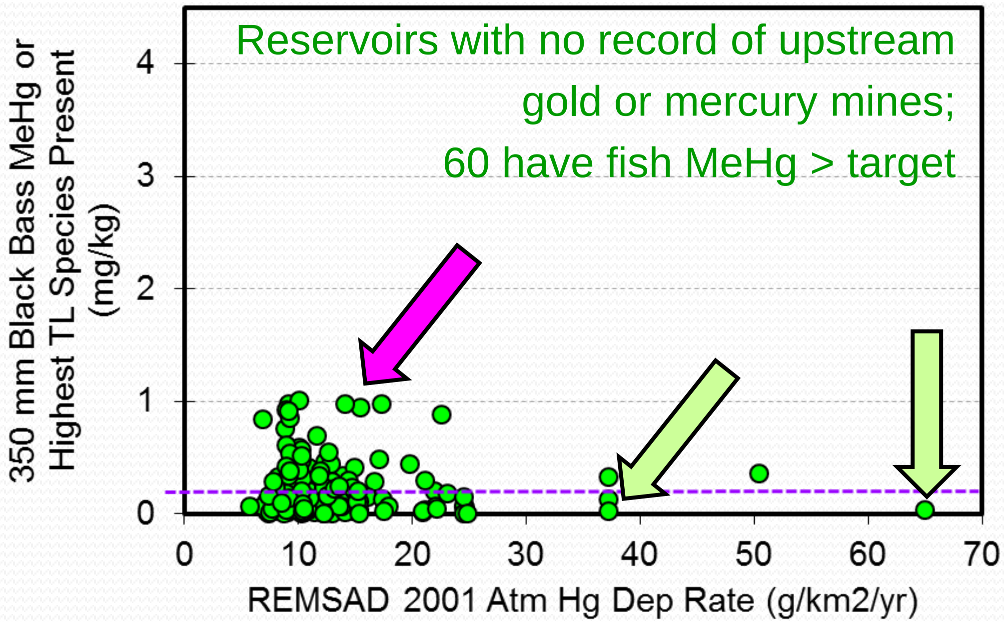
# Mercury & Gold Mines

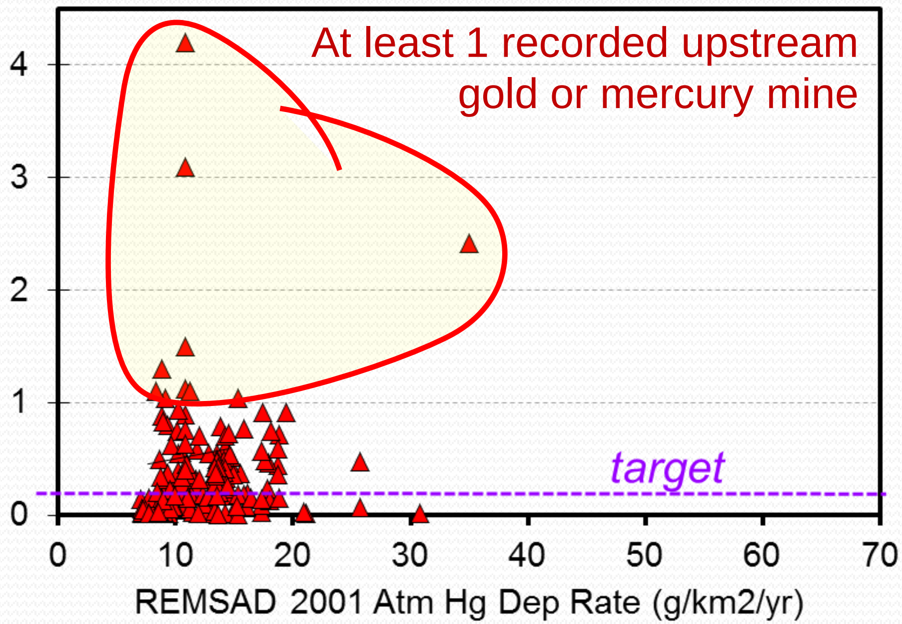
74 303(d)-Listed reservoir watershed boundaries indicated by black outline



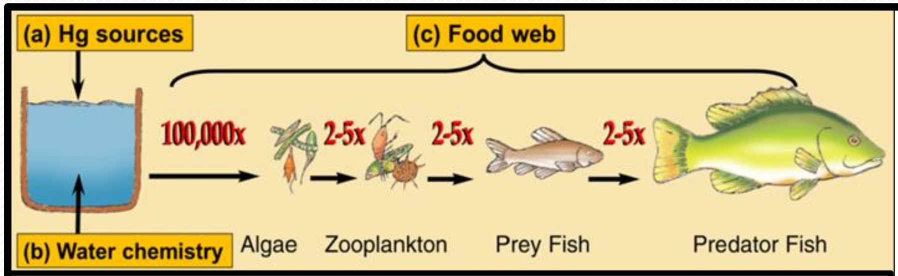
# Reservoir fish MeHg compared to modeled 2001 atmospheric Hg deposition rate




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




**(a) Source control:** Reduce Hg sources to reduce MeHg production in reservoirs

**Program Goal:** Quickly & measurably reduce fish MeHg

# Key Question:

## Where can mine waste remediation make quick reductions in reservoir fish MeHg?

# Desk-top [GIS-based] analysis: Mine factors considered

- High reservoir sediment Hg compared to background
  - indicates substantial mine contribution
- Mine sites localized to a relatively small watershed area
  - indicates highly contaminated soils likely not dispersed throughout watershed
- Mines near reservoirs (e.g., within 10 to 20 km)
  - likely do not have many miles of creek channels filled with waste that can be difficult to remediate

# Initial desk-top analysis results:

- 53 of the 74 Hg-impaired reservoirs have at least one recorded upstream mine or prospect

- Of these 53:

  **only 3 “probably” and 2 “maybe”**

  reservoirs where mine waste remediation expected to make timely and measurable improvements

# A comparison of two neighbors… *Part 1*

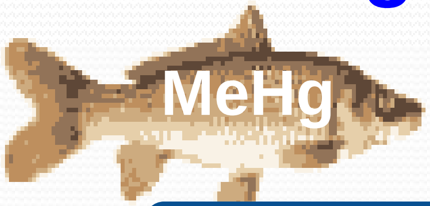
| | 350 mm Bass MeHg (mg/kg) | Reservoir sediment Hg (mg/kg) | Localized mines? | Mine proximity (km) | REMSAD atm dep rate (g/km2/yr) |
|---|---|---|---|---|---|
| San Antonio | 0.24 | 0.07 | 1 prospect | na | 8.0 (low) |
| Nacimiento | 1.1 | 0.39 | Yes | <10-20 | 8.2 (low) |

# A comparison of two neighbors… Part 2

| | Likely fish MeHg reduction from source control |
|---|---|
| San Antonio | *minimal* |
| Nacimiento | **~40%** |

**↑ Halfway to target**

## Linkage Model




**= TotHg sources**

**+ aqMeHg / Chlor-*a***

**+ water level fluctuation**

# A comparison of two neighbors… Part 2

*Not controllable* (→ Watershed soil Hg)

| | Likely fish MeHg reduction from source control | Watershed soil Hg (mg/kg) | Reservoir sediment Hg (mg/kg) |
|---|---|---|---|
| San Antonio | *minimal* | 0.04 | 0.07 |
| Nacimiento | **~40%** | 0.08 | 0.39 |

**Halfway to target** (↑ ~40%)

# A comparison of two neighbors… Part 2

*Not controllable*

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Halfway
to target

## Linkage Model


**= TotHg sources**

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**+ water level fluctuation**

# A comparison of two neighbors… Part 2

***Nacimiento ≈ MeHg machine!***

*Likely not controllable* — *Not controllable* — *Likely controllable*

| | Likely fish MeHg reduction from source control | Watershed soil Hg (mg/kg) | Annual reservoir water level fluctuation (feet) | Aqueous MeHg Geomean [peak] (ng/L) | Chlor-*a* (µg/L) |
|---|---|---|---|---|---|
| San Antonio | *minimal* | 0.04 | 25 | 0.04 [0.9] | 6.2 |
| Nacimiento | **~40%** | 0.08 | **48** | **0.08 [3.7]** | **2.2** |

Halfway to target

aqMeHg/Chlor-*a* ratio **>5x higher** in Nacimiento

**Key Question:** Where can mine waste remediation make timely reductions in reservoir fish MeHg?

We evaluated:

- High reservoir sediment Hg compared to background
- Localized mine sites
- Mines near reservoirs

What other factors can we consider?

- mine processes
- mine productivity
- others???

***We need realistic expectations***

*of where quick improvements are possible from mine waste remediation*

*Let there be no doubt…*

# We are still advocating mine waste remediation as a tool to reduce fish MeHg…

And we are looking forward to coordinating with stakeholders to explore ways to prioritize specific sites within a watershed, e.g.…

- Proximity and erosion of waste to surface water:
  - High threat - visual evidence or high potential of wastes eroding into surface waters
  - Medium threat - wastes near waters but no visual evidence of erosion
  - Low threat - wastes located far from waters and no visible evidence of erosion
- Level of Hg contamination:
  - Historical mine processes and productivity
  - Waste pile and portal discharges: Hg concentrations and volumes
  - Hg concentrations in downstream water and sediment
- Site accessibility

# Find Out More, Stay in Touch

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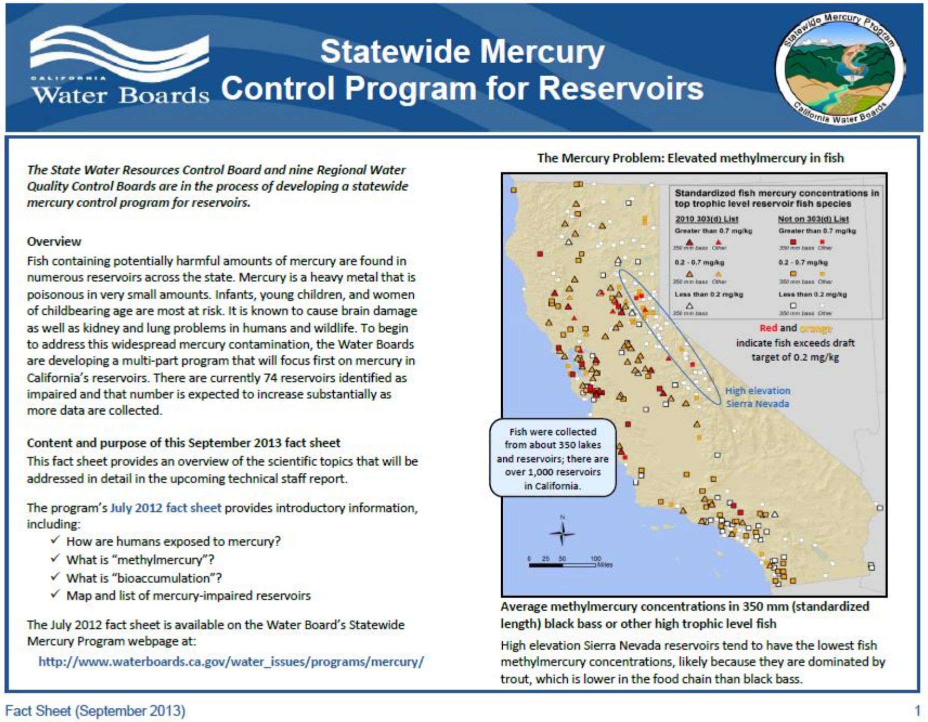
- **Hand out**
  - Project goals & contact info
  - Discussion questions from this presentation



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Statewide Mercury Program · California Water Boards

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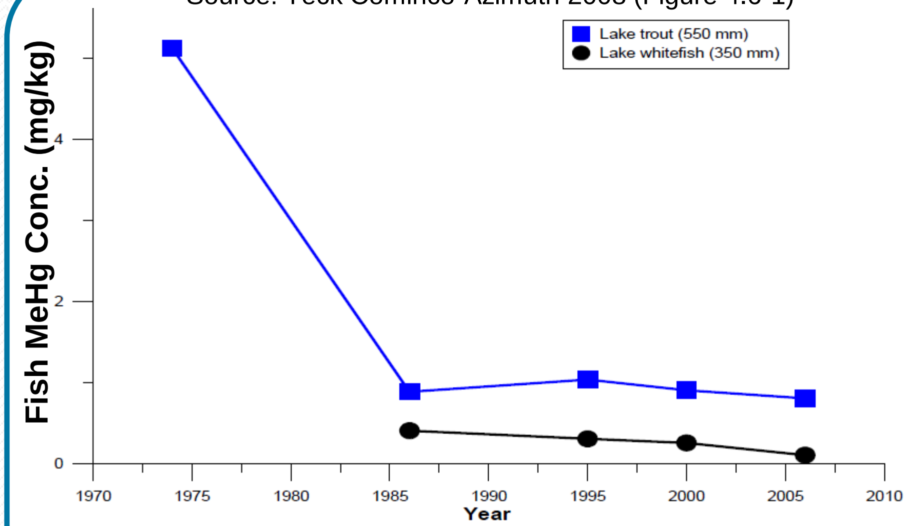
***<u>We need realistic expectations</u>***
*of where quick improvements are possible from mine waste remediation*

# We have reasons to be hopeful…

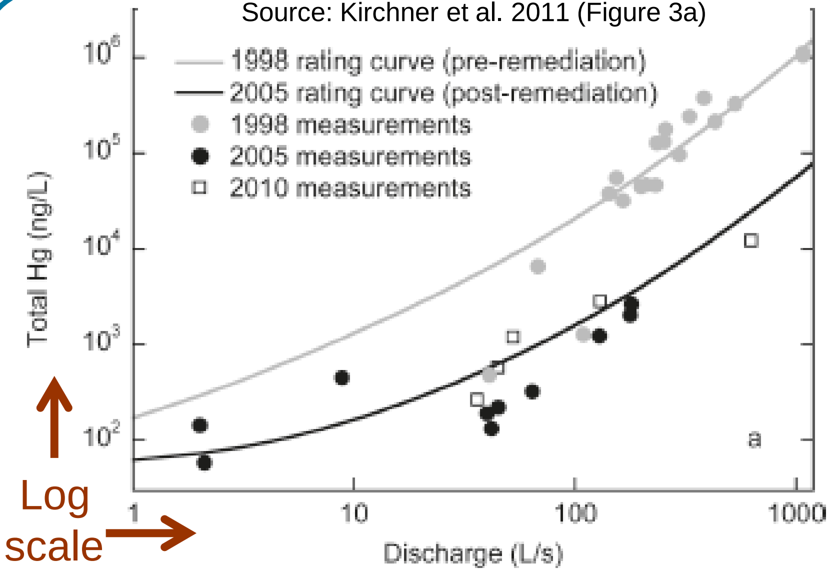
Source: Teck Cominco-Azimuth 2008 (Figure 4.6-1)




## Lake Pinchi Mercury Mine, BC

- Some waste capping & erosion control since 1975 mine closure; additional remediation planned
- Initial dramatic fish MeHg reduction, then modest reductions
- Coring indicate slow burial process – no large tributaries to provide significantly cleaner sediment

Source: Kirchner et al. 2011 (Figure 3a)




## Gambonini Mercury Mine

- Largest Hg pollution source to Walker Creek & Tomales Bay
- Erosion control alone – *no capping!* **>90%** Hg load reductions & **>50%** sediment load reductions
- But we don't yet have fish MeHg data