Incorporating Wildlife Mercury Exposure and Risk Estimates using Biomagnification Factors into BOG California Lake Monitoring

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Introduction

The beneficial uses of numerous water bodies in California are listed under the Clean Water Act as impaired by mercury contamination. As a result of those listings, the Regional Water Quality Control Boards have been developing total maximum daily load limits (TMDLs) for affected water bodies and have included fish tissue methyl mercury objectives designed to protect humans and wildlife. Thus far, only a handful of impaired water bodies have mercury TMDLs. To meet the requirements of the Clean Water Act and to facilitate the development of TMDLs, the State Water Resources Control Board is now developing statewide methyl mercury fish tissue objectives.

The Surface Water Ambient Monitoring Program (SWAMP) via the Bioaccumulation Oversight Group (BOG) has recently completed state-wide surveys of contaminants in sport fish tissue from over 250 lakes in California and throughout coastal waters. However, this impressive effort only focused on human health issues. Because many fish-eating wildlife such as grebes, terns, cormorants, and mergansers eat fish smaller than those that were sampled by BOG, and since fish mercury concentrations are not always indicative of wildlife exposure to mercury, the current BOG surveys do not address whether wildlife beneficial uses may be impaired by mercury in these water bodies.

We are proposing the first step in developing a useful tool for methyl mercury TMDL implementation and wildlife risk determination, specifically calculating biomagnification factors for determining mercury concentrations in wildlife from fish. When properly derived, biomagnification factors are valuable because they provide managers and regulators with a quantitative tool to estimate mercury concentrations across environmental matrices, thus enabling them to adequately estimate wildlife exposure without the need for comprehensive sampling at all sites of interest. Biomagnification factors (BMF) are derived for biota from the organism's diet, and are calculated by dividing the chemical concentration in the predator by the chemical concentration in the predator's diet.

Herein, we propose to develop a biomagnification factor for mercury exposure in wildlife estimated from mercury concentrations in a lower trophic level prey animal. Specifically, we will develop a biomagnification factor by dividing the total mercury concentration in bird blood

(or eggs) by the total mercury concentration in small prey fish. This biomagnification factor can then be used for translating small fish mercury concentrations to bird mercury concentrations. We will evaluate whether this biomagnification factor is representative across California lakes, or differs by lake type or geographic region. Additionally, we will evaluate the risk of mercury exposure to wildlife by comparing measured mercury concentrations in key tissues with effects-thresholds that have been previously developed. Thus, by combining the biomagnification factor we develop among lakes, with known impairment thresholds, we will evaluate and develop a tool that will allow managers to determine the risk of mercury to wildlife by simply monitoring fish mercury concentrations.

Table 1 illustrates the potential outcome of this proposed research and the usefulness of this BMF tool (for this exercise we assumed a biomagnification factor of 11). Once the real biomagnification factor which best predicts mercury concentrations in birds from concentrations in fish has been determined using data from the proposed study, regulators and managers will be able to plug in either lake-specific prey fish or sport fish mercury concentrations (on either a wet weight or dry weight basis [with moisture content]) and any associated environmental variables that we identify in our study as being important (examples in **Table 1**). The model will then estimate the mercury concentrations in bird blood, and also translate this estimated mercury concentration into the potential risk to wildlife based on published toxicity levels.

	Model Input		**Model Output**	
	Prey Fish	Sport Fish	Grebe Blood (estimated)	Risk to Wildlife
[THg] µg/g ww	0.30		**3.30**	**High Risk**
or				
[THg] µg/g dw	1.20			
% moisture	75%			
Environmental Factors (examples)				
Lake Elevation				
Lake Size				

We present two proposal options. The first option is a 1-year study which samples only 12 lakes. The second option is for a 2-year study which doubles the number of lakes sampled (24 lakes) and increases the coverage into Southern California. We present separate budgets, timelines, and maps for each proposal, however for simplicity we detail the 2-year proposal in

the *Objectives* and *Methods* section and put in parenthesis the sample sizes under the 1-year study option.

Objectives

Over two consecutive field seasons in 2012 and 2013, we will sample birds and small fish simultaneously at 24 lakes (*12 lakes for 1-year option*) throughout California during the breeding season when birds are particularly vulnerable to potential mercury-induced reproductive impairment. Using these data, we will estimate a biomagnification factor for wildlife. In developing this biomagnification factor, we will address whether the biomagnification factor is an appropriate indicator of wildlife exposure to mercury, and, if so, whether a state-wide biomagnification factor is appropriate or if a more refined biomagnification factor is needed that incorporates the type of water body or geographic region. Specifically, we have three main objectives:

1) Sample grebes at 24 California lakes (*12 lakes for 1-year option*) to determine mercury levels in a species at the top of the food chain, and compare these data to known effects-thresholds for birds.
2) Simultaneously with grebe sampling, collect small fish (<100 mm) at these same 24 lakes (*12 lakes for 1-year option*) to determine if mercury concentrations are above current wildlife diet objectives.
3) Use these data in Objectives 1 and 2 to calculate a wildlife biomagnification factor, evaluate the biomagnification factor's usefulness for estimating wildlife exposure, and assess whether the biomagnification factor differs by lake type or geographic region.

Methods

We will use western and Clark's grebes (*Aechmophorus spp.*) as our index of mercury exposure to wildlife in California lakes. As piscivorous waterbirds, grebes are among the animals at the top of the food chains in lakes, and are widely distributed in lakes throughout California. Additionally, grebes become flightless after they arrive at their summer breeding locations. Thus, grebes are ideal representatives for wildlife risk to local, lake-specific contaminant exposure. Grebes also breed at many lakes throughout California (**Figures 2 & 3**), making them susceptible to potential impaired reproduction due to local contamination.

We will sample grebe blood (and eggs where possible) from 24 California lakes (*12 lakes for 1-year option*) during May-October of 2012 and 2013. **Figure 3** (and **Figure 2** for the 1-year option) shows the proposed primary and alternate lake sites which will be investigated further and the final 24 lakes (*12 lakes for 1-year option; **Figure 2***) will be chosen after scouting lakes in the field. We selected lakes based on (1) prior BOG sampling, (2) whether or not the lake was a potential long-term BOG sampling site, (3) whether grebes breed on the lake, and (4) the relative mercury concentrations in sport fish sampled by BOG in 2007-2011. We will sample up to 12 lakes each year and conduct the field research over a 2-year period so that we can travel to all 24 lakes and sample grebes and fish during a narrow time window in late summer. Grebes will be captured using a combination of dip nets, net guns, gill nets, and shotguns if necessary. Grebe eggs also will be sampled when possible, and we will collect 1 egg randomly from each nest (up to 15 nests per lake).

Simultaneously, small fish (25-100 mm) will be sampled using traps, seines, and dip nets from areas near grebe collections. We will sample 10 individuals each from two different prey fish species from each lake. Efforts will be made to sample the same species across all lakes, and when not possible we will sample fish that overlap in trophic guild. Fish will be sampled within two weeks of grebe sampling.

We will determine mercury concentrations in avian tissues at the USGS Davis and Corvallis Environmental Mercury Labs, and in fish at the Moss Land Marine Lab following EPA method 7473. Specifically, using an integrated sequence of sample drying and combustion, coupled with amalgamation and atomic absorption spectroscopy, we will evaluate mercury concentrations in avian and fish tissues in relation to established reference standards.

Biomagnification factors (BMF) will be calculated for each lake using the following formula:

$$BMF = \frac{mean\ [THg]\ grebe\ blood\ \frac{\mu g}{g} ww}{mean\ [THg]\ whole\ prey\ fish\ \frac{\mu g}{g} ww}$$

We will test whether BMF differs among lakes using Analysis of Covariance, with environmental lake attributes (such as lake size and elevation) as covariates and individual lake as a random effect. We also will use regression models to assess the functional form of the relationship between THg concentrations in grebe blood and THg concentrations in prey fish.

Timeline

Proposal Option 1: 12 lakes during 1 field season in 2012.

Field work for this project will be conducted in the summer (May-October) of 2012. Laboratory sample processing and mercury analysis will be conducted in winter and spring of 2012/2013. Data analysis and report writing will occur in spring and summer 2013. A final report will be delivered in October 2013.

Proposal Option 2: 24 lakes during 2 field seasons in 2012 and 2013.

Field work for this project will be conducted in the summers (May-October) of 2012 and 2013. Laboratory sample processing and mercury analysis will be conducted in winter and spring of 2012/2013 and 2013/2014. Data analysis and report writing will occur in spring and summer 2014. An update report after the first field season will be delivered in April 2013. A final report will be delivered in October 2014.

Coordination

This project will be led by four Principal Investigators. Josh Ackerman (USGS-WERC) and Collin Eagles-Smith (USGS-FRESC) will lead the bird sampling field work, bird mercury determination, and wildlife reporting. Mark Stephenson (Moss Landing) and Tom Maurer (USFWS) will lead the fish sampling field work, fish mercury determination, and fish reporting. Bird sampling will

be conducted immediately before fish sampling, and then bird collection sampling locations will be communicated to fish sampling personnel for subsequent sampling by the fish team within two weeks of bird sampling.

Budget

Proposal Option 1: 12 lakes during 1 field season in 2012.

The total cost to complete the 1-year project is $299k, which includes added reporting costs in year-1 to that of the 2-year proposal option below. Funds will be spread over 2 calendar years in 2012 and 2013. Additionally, a match of approximately $95k is provided by USGS, USFWS, and MLML to support project development, implementation, and interpretation. Salary rates include benefits.

1-YEAR PROJECT BUDGET

	Year-1	Year-2	Total	*In-Kind Total*
Salary and Benefits				
Wildlife exposure determination	$ 70,381	$ -	$ 70,381	*$ 38,374*
Fish sampling	$ 43,252	$ -	$ 43,252	*$ 5,000*
Sample Processing and Mercury Determination				
Grebes ($100 per sample [12 lakes/yr * 10 grebes/lake * 2 tissues])	$ 24,000	$ -	$ 24,000	*$* -
Fish ($100 per sample [12 lakes * 10 fish/lake * 2 species])	$ 24,000	$ -	$ 24,000	*$* -
Supplies				
Field supplies, boat gas, equipment and maintenance	$ 13,500	$ -	$ 13,500	*$ 17,250*
Lab supplies & equipment	$ 2,000	$ -	$ 2,000	*$ 2,000*
Travel				
Per diem	$ 14,220	$ -	$ 14,220	*$* -
Lodging	$ 10,890	$ -	$ 10,890	*$* -
Vehicles	$ 9,000	$ -	$ 9,000	*$ 1,000*
Total Direct Costs	$ 211,243	$ -	$ 211,243	*$ 63,624*
Indirect Costs	$ 88,319	$ -	$ 88,319	*$ 31,468*
Total Costs	$ 299,563	$ -	$ 299,563	*$ 95,092*

Proposal Option 2: 24 lakes during 2 field seasons in 2012 and 2013.

The total cost to complete the 2-year project is $596k, and funds will be spread over 3 calendar years from 2012 to 2014. Additionally, a significant match of approximately $160k is provided by USGS, USFWS, and MLML in kind. Salary rates include benefits.

2-YEAR PROJECT BUDGET

	Year-1	Year-2	Total	*In-Kind Total*
Salary and Benefits				
Wildlife exposure determination	$ 64,424	$ 76,679	$ 141,103	*$ 76,748*
Fish sampling	$ 41,252	$ 42,902	$ 84,154	*$ 10,000*
Sample Processing and Mercury Determination				
Grebes ($100 per sample [12 lakes/yr * 10 grebes/lake * 2 tissues])	$ 24,000	$ 24,000	$ 48,000	*$ -*
Fish ($100 per sample [12 lakes * 10 fish/lake * 2 species])	$ 24,000	$ 24,000	$ 48,000	*$ -*
Supplies				
Field supplies, boat gas, equipment and maintenance	$ 13,500	$ 13,500	$ 27,000	*$ 17,250*
Lab supplies & equipment	$ 2,000	$ 2,000	$ 4,000	*$ 2,000*
Travel				
Per diem	$ 14,220	$ 14,220	$ 28,440	*$ -*
Lodging	$ 10,890	$ 10,890	$ 21,780	*$ -*
Vehicles	$ 9,000	$ 9,000	$ 18,000	*$ 1,000*
Total Direct Costs	$ 203,286	$ 217,191	$ 420,477	*$ 106,998*
Indirect Costs	$ 84,750	$ 91,349	$ 176,099	*$ 53,056*
Total Costs	$ 288,037	$ 308,540	$ 596,576	*$ 160,054*

Figure 2. ***Proposal Option 1: 12 lakes during 1 field season in 2012.***
Proposed lakes for sampling mercury concentrations in western grebes and fish for calculating a biomagnification factor. Red-scale color palette sites are those lakes where grebes are known to have recently bred. Blue-scale color palette sites are those lakes where grebes are known to have bred historically. Green-scale color palette sites are those lakes where grebes occur in the summer but it is not known whether or not they breed. Darker colored sites indicate a long-term BOG site for sport fish trend monitoring. Stars indicate sites that have been previously sampled by BOG for sport fish. Circles indicate the 12 primary lakes selected, whereas squares indicate alternate lakes that will be used if grebes cannot be sampled at a primary lake. The relative size of the symbol indicates mercury concentrations in sport fish from BOG sampling during 2007-2011.

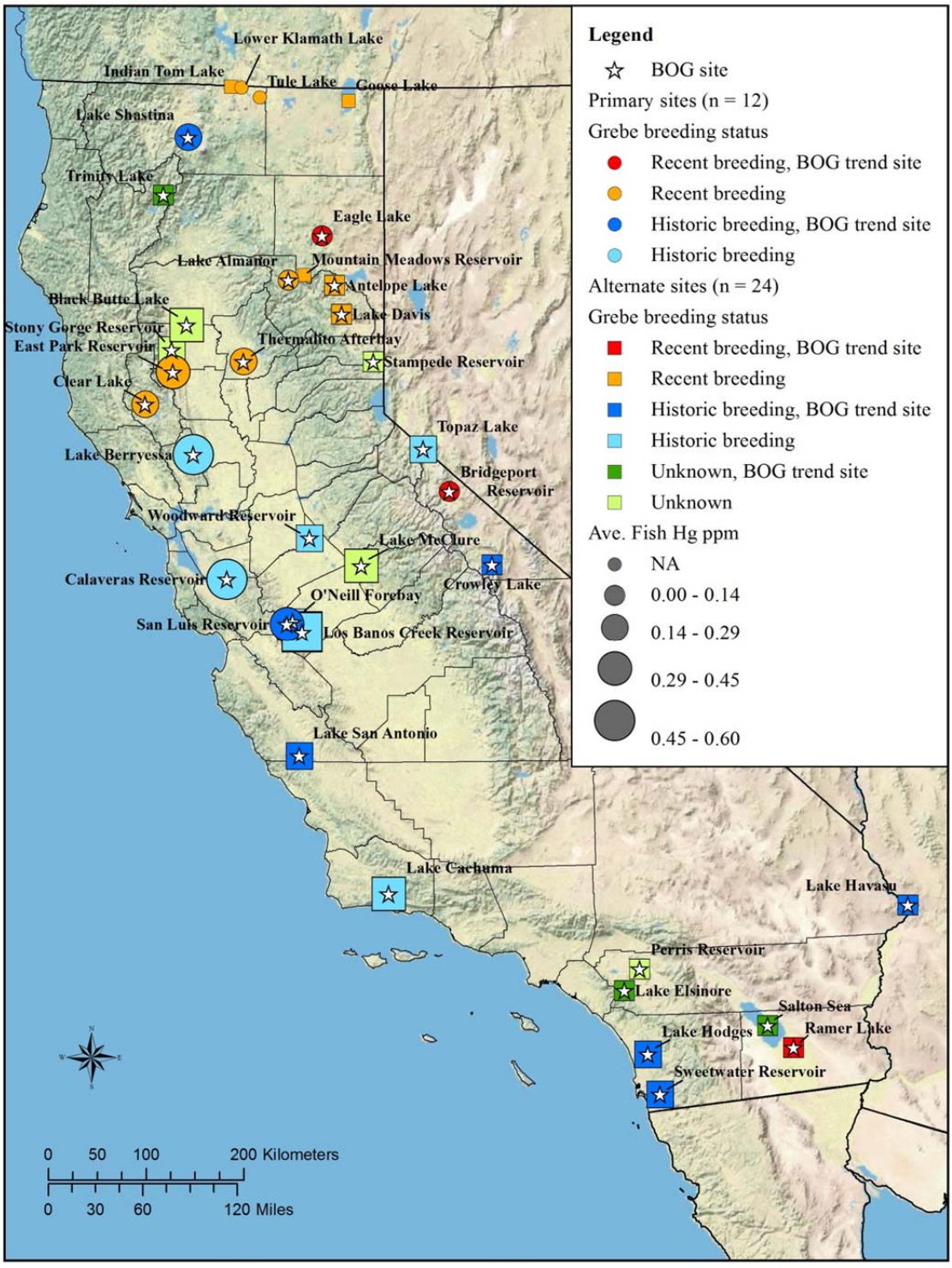

Figure 3. ***Proposal Option 2: 24 lakes during 2 field seasons in 2012 and 2013.***
Proposed lakes for sampling mercury concentrations in western grebes and fish for calculating a biomagnification factor. Red-scale color palette sites are those lakes where grebes are known to have recently bred. Blue-scale color palette sites are those lakes where grebes are known to have bred historically. Green-scale color palette sites are those lakes where grebes occur in the summer but it is not known whether or not they breed. Darker colored sites indicate a long-term BOG site for sport fish trend monitoring. Stars indicate sites that have been previously sampled by BOG for sport fish. Circles indicate the 24 primary lakes selected, whereas squares indicate alternate lakes that will be used if grebes cannot be sampled at a primary lake. The relative size of the symbol indicates mercury concentrations in sport fish from BOG sampling during 2007-2011.