Mercury Open Water Final Report for Compliance with the Delta Mercury Control Program

Chapter 7. Conclusions-Management Implications

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Contents

List of Acronyms and Abbreviations

BMP	Best Management Practice
CCSB	Cache Creek Settling Basin
Delta	Sacramento-San Joaquin Delta system
D-MCM	Dynamic Mercury Cycling Model
DSM2	Delta Simulation Model 2
DWR	(California) Department of Water Resources
fMeHg	Filter-passing Methylmercury
Hg	Mercury
MeHg	Methylmercury
uHg	An unfiltered (aqueous) mercury (sample)
uMeHg	An unfiltered (aqueous) methyl mercury (sample)

Management Implications

Field and Laboratory Results

One of the most important findings associated with our research was identifying the important role decomposing vegetation may play in the production of MeHg in the Yolo Bypass. Independent MeHg load extrapolations of pastureland laboratory results compared favorably with the robust load calculations for the entire Yolo Bypass in the 2017 water year flood season. Although several assumptions went into these extrapolations, the results suggest that mesocosm and laboratory experiments captured mechanisms exhibited under extended flooding in the Yolo Bypass, when most of the MeHg is discharged to the Delta.

Managing vegetation as a key component of reducing winter internal Yolo Bypass methylation has important management considerations and provides a starting point for future open water control studies and development of Best Management Practices (BMPs). However, it is important to note that the (California) Department of Water Resources (DWR) is not a landowner in the Yolo Bypass, therefore any changes in land use practices are outside its jurisdiction and must be pursued and negotiated by the Regional Water Quality Control Board in cooperation with the individual land-owners and agencies. In addition, any changes in land use management does not address the underlying problem of mercury (Hg) delivery via the discharge of Hg laden sediment from upstream abandoned mines. As detailed by Singer and others (2013), major flood events continue to erode legacy Hg-laden sediment. They estimate this process will continue for at least another 10,000 years. Since control studies were not conducted, our research cannot answer specifics on control studies' feasibility, effectiveness, cost, and compliance.

Much attention has been placed on the Cache Creek Settling Basin (CCSB) and its contributions of inorganic Hg and MeHg to the Yolo Bypass. However, our coarse estimates of MeHg mass generated from decaying vegetation suggests that reductions in vegetation biomass could substantially help with the Yolo Bypass load allocation reduction required in the DMCP. However, these mass estimates need to be refined to accurately reflect the true MeHg mass of decaying vegetation,

Additionally, from a management standpoint, the source of the Hg resulting in this vegetative methylation in the Yolo Bypass (whether from the CCSB, over-toppings of the Fremont weir, the atmosphere, or other sources or pathways), requires further evaluation. For example, Bloom (2002) determined that mine derived solids from the Cache Creek watershed were approximately 20 times less bioavailable towards methylation than Hg (II). Focusing on discharges from the CCSB, while not understanding the Hg source behind vegetative methylation and methylation in general in the Yolo Bypass, could lead to management actions that unintentionally have less impact on in-bypass MeHg production than anticipated. It is not clear from our experimental work whether the key influence of vegetation on methylation is via effects on the activity of methylating microbes (e.g., via a supply of labile carbon) or via changes to the concentration of available Hg(II) for methylation (e.g., via increased DOC).

The sections below briefly highlight some of the management implications associated with vegetation and land use management as a possible BMP.

Disking of Pastureland

Disking vegetation into the soil appears to be a promising approach to reduce the internal production of MeHg in the Yolo Bypass. Our vegetation senescence studies clearly showed that disking pasture vegetation into the soil results in less MeHg production over a vegetated soil (see Chapter 3 and Technical Appendix E). However, like any proposed BMP, this approach also needs to be evaluated holistically within the full context of the environment that the BMP would be used. From a livestock perspective, it may be undesirable to disk pastureland. From a climate change perspective, tillage of vegetation is discouraged because of the loss of sequestered carbon in the soil during tillage and the loss of carbon sequestration from standing vegetation (Woodbury and Wightman, 2017). Whether this is an issue for the Yolo Bypass is unknown. From a regulatory perspective, it needs to be determined how a disking requirement would be implemented. Therefore, while disking appears to be a promising BMP, its implementation requires closer examination.

Reduction in Vegetation Biomass

Our vegetation senescence studies suggest that understanding the role of vegetation quantity, quality, and type in the Yolo Bypass may provide approaches to future BMPs. However, management implications of this approach are complicated due to the complex interplay between plant growth and the environment. For example, our experiments had mixed results on MeHg production when plant biomass was reduced by grazing. Complicating this picture were results suggesting that the quality of the vegetation (e.g., new versus old growth), as well as the quantity, influences MeHg production from senescing vegetation (see Chapter 3 and Technical Appendix E). Moreover, the current research focused only on rye grass. It is unknown whether other vegetation types will respond in a similar fashion. These caveats confound the simplistic explanation that less vegetation will equal less MeHg production. Therefore, while an encouraging start, the dynamics between vegetation quality, quantity, and vegetation type requires further investigation before a definitive BMP can be proposed.

It is recommended that before additional studies are conducted, landowners and agencies, such as the Resource Conservation Districts, will need to be consulted to determine if the ecological and cost-benefit impacts, associated with this potential management approach, are reasonable or practical.

Selective Flooding

Selective flooding of pastures in the fall, prior to the winter flood season, may be another approach to reduce or remove the standing biomass of vegetation and reduce methylmercury production from vegetation during a flood event. Throughout the fall, prior to major flooding in the Yolo Bypass, rice fields and seasonal wetlands are intentionally flooded to break-down plant material, leach salts, and provide habitat for migrating waterfowl. Previous work (Heim and others, in prep.) has shown that when flooded in the fall, seasonal wetland MeHg concentrations in water quickly spike after fall flood-up and return to lower levels by early December. Flooding of pasture vegetation in the fall potentially has the advantage of removing vegetation biomass available for microbial respiration prior to major flooding and downstream export and potentially increasing MeHg destruction from photodegradation (Fleck and others, 2014). However, the seasonality of elevated MeHg concentrations in decaying vegetation can be highly variable and requires further study. For example, in a study by Alpers and others (2014), water was applied in mid-November 2007 to a post-harvest white rice field in the Yolo Wildlife Area, resulting in very high concentrations of uMeHg and fMeHg three months later, in February 2008, during region-wide flooding of white rice fields. Therefore, to be considered a useful tool, the timing of fall flood-ups and draw-downs and vegetation decay rates requires investigation. For this approach to work, it will be critical that most of the vegetation has decayed and been removed from the system prior to winter flooding. Additionally, depending on the timing, holding water may result in elevated mercury exposure to wildlife using the area. Therefore, whether this land management practice is achievable or practical within current pasture management practices will require further investigation and discussion with current landowners.

Liberty Island

Our studies did not evaluate the cause(s) behind the MeHg loads originating from Liberty Island in water year 2017. While not as large a source as the upper reach of the Yolo Bypass, from a management perspective, understanding the sources of MeHg contributions from Liberty Island may require management approaches specific to that area.

Modeling Results

Yolo Bypass

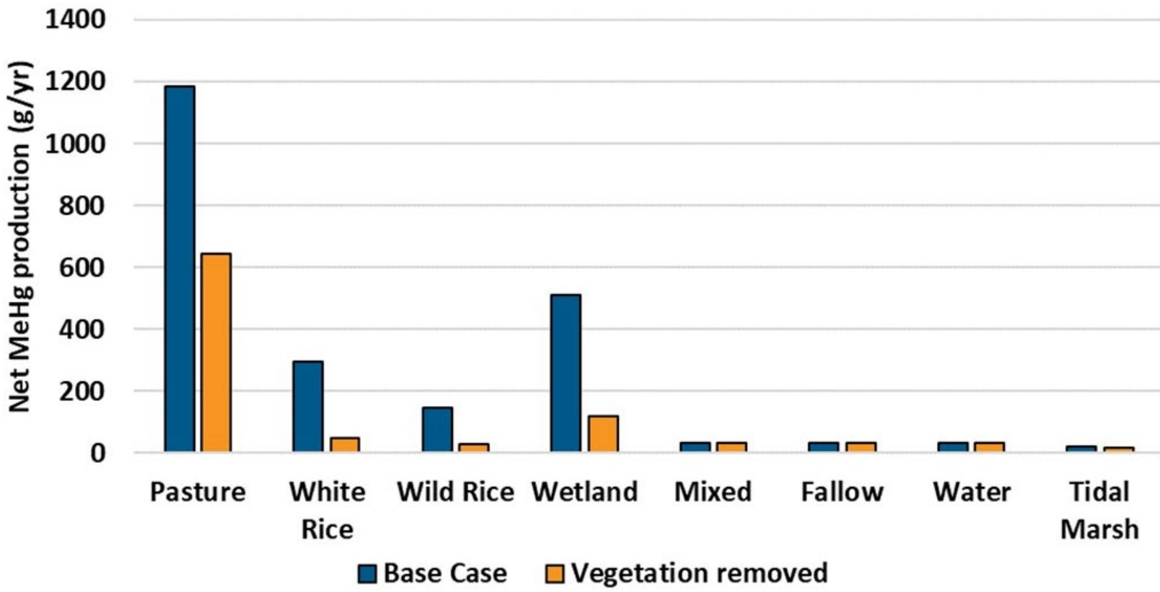
Model sensitivity runs in the Yolo Bypass examined possible management approaches to reduce MeHg supply. These simulations imposed 50% reductions on selected model inputs anticipated to affect MeHg supply, including factors affecting MeHg production in the Yolo Bypass, and tributary loading rates for solids, inorganic Hg and MeHg. The choice of 50% reductions was meant to be large enough to generate a response in the model and was not necessarily intended as a practical real-world scenario in all cases. The sections below briefly highlight some of the management implications associated with the biogeochemical Hg modeling results from the Yolo Bypass D-MCM model. The Delta DSM2-Hg model was calibrated, but due to insufficient time and resources, sensitivity runs were not conducted.

Sensitivity Analyses

Of the sensitivity runs investigated for the Yolo Bypass, those primarily affecting MeHg production in surface sediments had the largest benefit (up to a 20% reduction in the export of MeHg from the Bypass). This suggests potential benefits for management options that reduce MeHg production in the Yolo Bypass sediment bed. Methylation rates in sediments are influenced by a range of factors that can broadly be grouped into two categories: those affecting the activity of microbes that produce MeHg and those affecting the concentration of Hg(II) available for the production of MeHg. Related site conditions potentially include changes in the supply of organic matter (e.g. via vegetation), temperature, water chemistry (DOC or pH) and the rate of supply of Hg(II) to sites of methylation. In terms of practical management options, the supply of organic matter (e.g., from vegetation) and reduced inputs of inorganic Hg(II) to the Yolo Bypass emerge as initial candidates. In the case of vegetation, Figure 7-1, shows the reduction in MeHg production in different land use areas in the Yolo Bypass for a simulation identical to the base case calibration, except with the removal of all vegetation.

Other sensitivity simulations had less effect than initially expected. For example, reducing the load of suspended sediments from the CCSB (and associated Hg(II) and MeHg) had a small effect on MeHg concentrations and export in the Yolo Bypass, despite CCSB being an important source of Hg(II) in the Yolo Bypass budget. Upon closer examination, the 16-year simulation may not have allowed sufficient time for the effects of this simulation to be fully realized. This points out the need to consider the time for management actions to take effect and the need to understand (via field work and modeling) what controls the rate of response following management actions.

Figure 7-1 Modeled Effect of Net MeHg Production (g/year) due to Removal of all Vegetation by Land Use Type in the Yolo Bypass



Delta

Based on resource and time constraints, exploration of management implications was limited. However, the Delta mercury model was used to simulate conditions from October 1999 to July 2006. Relative contributions of mercury sources and how those sources vary during wet and dry years can be explored. Given the rapid water throughput in the Delta, tributary loads were important sources of solids, inorganic Hg, and MeHg in simulations. The Sacramento River was the largest tributary source of MeHg to the Delta (roughly half of the total), followed by Yolo Bypass (one third of the total for the full simulation period, up to half in a wet year). The relative importance of different tributary sources varied among years in simulations. For example, the Yolo Bypass was more important as a source of MeHg during wet years. In the future, the model could be used to simulate relative changes in MeHg loads and concentrations in the Delta for various management or source reduction alternatives. Modeling management alternatives would require additional resources and may require running other models (e.g., such as reservoir operations models).

The model analysis also pointed out that seemingly straightforward management options may have multiple effects on hydrology, sediment transport, Hg cycling, and MeHg supply, sometimes in competing directions. For example, tributary loads are the product of concentrations and flows. Some loads could be high as a result of high flows, with relatively low concentrations. A reduction in the supply of water from such a source would indeed reduce the load of a constituent but might not have a corresponding effect on reducing concentrations in receiving waters. Essentially, a tributary with these characteristics could help dilute concentrations that would occur otherwise. The distinction between lowering loads and lowering concentration could also emerge when recognizing that the food web in the Delta does not bioaccumulate based directly on MeHg loads. Exposure is based on MeHg concentrations. The duration of exposure for fish is the same in wet or dry years, and their uptake is based on concentrations during those periods. Given that the relative importance of MeHg sources to the Delta varied among years in simulations, consideration should also be given to exposure in dry years and sources of MeHg during those periods. This issue was not fully explored during the model analysis but warrants further consideration.

Overall, model results for the Delta and Yolo Bypass illustrated high variability in loads of suspended sediments, inorganic Hg, and MeHg, strongly influenced by the dynamic hydrology of the system. This variability occurred under short and longer time scales (e.g. events to years). This has important implications when estimating present-day baseline loads, assigning load allocations, and monitoring for compliance with regulations in the future. A multi-year perspective is needed, designed to capture year to year variability, but with sufficient resolution to also capture short term variability (or not be biased by it), and show longer term systematic trends that might occur (e.g., via climate change).

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