Bridging the Divide: Communicating Science Synthesis to Meet Decision Makers' Needs

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Synthesis in an integral part of communicating science to policy makers, as this process integrates components of a complex system to provide a clear overview of the current state of knowledge. Presented in a manner that informs decision makers, synthesis can facilitate more effective policy-science interactions, forming the basis for science-based policy. Effective synthesis of scientific knowledge is especially needed in the Delta, where much of this information is in a fragmented state, housed separately in several databases, agencies, and research institutions. This talk will provide an overview of how science synthesis is used in communicating knowledge and how the outcomes from the mercury workshop series (January and June, 2016) will be integrated into future Delta plans and programs. An overview of how the Delta Science Program will use the outcomes from the mercury synthesis workshops to advance the understanding of mercury issues in the Delta will be discussed and how this communication of knowledge in turn provides decision makers with the best scientific information and tools to use when confronted with challenging decisions related to mercury in the Delta and beyond. The discussion will also provide a road map of the various collaborative efforts and agencies that will benefit from this updated knowledge on mercury sources, cycling, and biotic effects.

Keywords: Mercury, environmental management, synthesis, Delta Science Program
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Building a Scientific Foundation to Manage the Mercury Threat in the San Francisco Estuary

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Mercury contamination is a primary threat to environmental health across the San Francisco Bay-Delta Estuary. In January 2016, we assembled a diverse group of scientists, managers and policy makers to participate in a series of technical workshops designed to integrate and discuss the current understanding of mercury contamination and the processes that influence its cycling and bioaccumulation across the region. This scientific assessment was conducted within the context of informing management strategies to minimize mercury risk in the region. We found strong evidence that mercury contamination poses an ongoing threat to wildlife that forage within the Estuary and human health through fish consumption. Methyl mercury exposure was most strongly related to habitat. Wetlands, tidal wetlands, lakes, and riverine habitats all showed significant biotic exposure, but wetlands harbored biota with the greatest exposure. Differences between habitats were primarily attributed to differences in their propensity for methylmercury production, physical transport processes, and food web characteristics. Biota mercury exposure was also related to their proximity to mining-related mercury sources, but mercury source effects were localized and imposed little effect at the regional scale. Advances in our understanding of the relative availability of different mercury sources for methylation has improved vastly, but further characterization remains a focus for future research efforts. Recent efforts have focused on testing and developing strategies for managing mercury methylation and removal mechanisms to control biotic mercury exposure, mostly through the reduction of surface water loadings to open waters. Results of these efforts have yet to produce any widespread implementation of management actions but have been profoundly helpful in refining our conceptual model of mercury cycling in the estuary and have highlighted the challenges to modeling mercury exposure.

Keywords: mercury, methyl mercury, wetlands, ecosystem risk, bioaccumulation, synthesis, contaminants
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The Delta Doughnut: A Persistent Pattern for Methylmercury Metrics

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Concerns regarding human and wildlife health posed by mercury contamination in the food web has led to the development of numerous fish-consumption advisories and regulatory policies in the San Francisco Bay-Delta watershed (SFBDW). A comprehensive understanding of processes driving observed spatial patterns of fish mercury concentrations is necessary to effectively develop strategies to predict and potentially manage for lower fish mercury throughout the system. We evaluated the spatial patterns of fish, water, and sediment mercury and methylmercury in open water habitats across the SFBDW and found a persistent pattern of low methylmercury concentrations in the central delta, and higher concentrations in all matrices in the delta periphery. Four untested hypotheses suggested for this commonly observed phenomenon include: a) closer proximity to legacy mining-related Hg sources in the periphery, b) more mercury methylation in the seasonal wetlands of the periphery, c) more degradation and settling of tributary-sourced methylmercury in the open waters of the central delta, and d) more tidal dispersion and rapid flushing in the central delta. Preliminary evaluation of field data and transport of conservative tracers using D3D-FM/Delwaq modeling platform suggests that the observed spatial trends could be explained by any one of these proposed processes, but likely reflect a combination of several or all. A more complete assessment of the primary factors driving the observed spatial distribution of mercury in fish and water will necessarily include more direct measurements of methylmercury production and degradation across dominant habitat types, hydrodynamic mixing and transport models, and a more complete food web characterization. Management options to decrease mercury bioaccumulation in fish are evaluated. The information provided by this analysis will inform future efforts to control mercury exposure, such as the Delta methylmercury total maximum daily load (TMDL) implementation.

Keywords: mercury, methylmercury, biogeochemistry, hydrodynamics, water quality, tidal dispersion, wetland, tributary
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Using Recent Science to Advise the Delta Methylmercury TMDL

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The Central Valley Regional Water Quality Control Board is looking toward review and possible revisions of the Delta Mercury Control Program or Total Maximum Daily Load (TMDL) after 2018. The TMDL, approved in 2011, relied significantly on source and process information collected prior to 2008. This information included mass balances for mercury and methylmercury entering and leaving the Delta and measurements of mercury in ambient water, fish, and sediment within the Delta.

Mercury studies and syntheses completed after the TMDL was approved can form the basis of changes to the implementation approaches and, in a few years, the TMDL itself. To fully benefit the Delta methylmercury TMDL, however, new data and scientific understanding need to be focused to answer particular management questions. Management questions relevant for advising the Delta methylmercury TMDL will be introduced. Topics include the following:

- Criteria leading to prioritization of locations and seasons in which exposure of wildlife to mercury is of greatest concern;
- Certainty in our understanding of relative reactivities of mercury from atmospheric and legacy sources; and
- Degree of understanding of factors affecting methylmercury cycling and transport that can be further utilized in management.

Keywords: methylmercury, mercury, TMDL
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Mercury Studies in the Cache Creek Settling Basin, Yolo County: Preliminary Results from 2010–2014

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The 3600-acre Cache Creek Settling Basin partially traps sediment to minimize the volume reaching the Yolo Bypass floodway. The Cache Creek watershed is contaminated with mercury (Hg) from several sources including historical Hg mines; historical gold mines where Hg was used for amalgamation; rocks and soils with high-Hg natural background from hydrothermal activity; and active hot and cold springs. Water-quality and discharge of Basin inflows and outflows have been monitored starting in Water Year (WY) 2010 by the U.S. Geological Survey to assess suspended sediment and Hg loads, and to determine trap efficiency (TE). The spatial variability of total mercury (THg) and methylmercury (MeHg) in sediment, biota, and surface water within the Basin are being assessed across dominant habitat types to improve understanding of Hg methylation and MeHg bioaccumulation.

During WYs 2010–2014, the Basin's TE was 70% for suspended sediment, 59% for whole-water (ww) THg, and 55% for ww MeHg. Loads of filter-passing MeHg increased from inflow to outflow by 20% to 34%. Concentrations of MeHg were higher in bed sediment from organic-carbon-rich floodplain and riparian habitats compared with organic-carbon-poor agricultural and open-water habitats. Bed sediment MeHg increased in the direction of flow within the Basin (west to east) and decreased with time during dry periods. Concentrations of THg in house-wren and tree-swallow eggs were higher during 2012 (relatively wet) than 2013 (relatively dry). House-wren egg THg increased with distance downstream along the Cache Creek channel within the Basin during 2012, but not in 2013. In both caged and wild mosquitofish collected in March-April 2013, THg concentrations increased with distance downstream within the Basin. THg and MeHg concentrations in surface water collected at fish-cage sites also increased with distance downstream.

Ongoing analysis of data collected during 2010–16 will further assist the California Department of Water Resources with Basin management.

Keywords: mercury, methylmercury, Cache Creek, trap efficiency, bioaccumulation, bed sediment, loads
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In Situ Control of Methylmercury Production in Sediments Using Redox-Buffering Mineral Amendments

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Environmental risk from mercury contaminated sediments derives mainly from methylmercury production, exposure and bioaccumulation. Methylmercury is produced predominantly by heterotrophic sulfate-reducing bacteria. Our research is evaluating the ability of redox-buffering mineral-based amendments to suppress mercury methylation by inhibiting microbial sulfate reduction near the sediment surface, with the objective of reducing methylmercury exposure and food web bioaccumulation. Laboratory sediment-water "aquarium" microcosms, in which manganese(IV) oxide minerals (pyrolusite or birnessite) were either directly mixed into the upper 5 cm of sediment or applied in a thin-layer cap, have documented a substantial reduction in methylmercury production and efflux from sediment to overlying water. CO2 respirometry experiments show that the amendments stimulate microbial activity and microbial community census by PCR and DNA sequencing indicates that the addition of the manganese oxides did not significantly alter the indigenous sediment microbial community structure, although a small increase in abundance of iron and manganese reducers was observed after a 2 week incubation period. The mechanism of methylmercury suppression therefore most likely involves a shift from sulfate reduction to manganese reduction as the energetically favorable redox process, which was also confirmed by microelectrode voltammetry profiling of the sediment microcosms. Manganese X-ray Absorption Near Edge Structure (XANES) spectra of amended sediment document the gradual conversion of Mn(IV) oxide amendments to Mn(III) oxides (bixbyite), mixed-valence Mn(II/III) oxides (hausmannite) and rhodochrosite over time. This solid phase assemblage is expected to continue to buffer redox to inhibit sulfate reduction and suppress mercury methylation in the surficial sediment. The retention of the added manganese in sediment solid phases also has interesting implications for in situ self-regeneration of Mn(IV) oxides in dynamic settings where soils and sediments experience periodic water level and redox fluctuations (e.g. in intertidal zones, tidal marshes, seasonal wetlands, reservoirs), as this would prolong the effective lifetime of the amendments.

Keywords: methylmercury, mercury, sediment, water quality, remediation, in situ, reactive amendments
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An Experiment to Decrease Methylmercury Export from Managed Wetlands

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Wetlands are critical for wildlife and healthy ecosystem function, and yet are also important areas for methylmercury (MeHg) production and export to adjacent water bodies. Therefore, preserving or restoring wetland habitat, while limiting MeHg export, provides a unique challenge to wetland managers. This two-year study examined how wetland design could influence MeHg export. The study area consisted of eight ~10 hectare managed wetlands, annually flooded (4-20 cm) during mid-September thru late April to provide habitat for winter migratory waterfowl. The four 'treatment' wetlands were constructed with two distinct cells separated with a narrow berm. Eighty percent of the wetland was maintained shallow for waterbird habitat, where 20% of the area (~2 hectare) at the outflow end was excavated to a depth of ~1 m. The four 'control' wetlands were shallow and uniform in depth. Treatment wetlands were operated in a semi-continuous flow-through mode, while control wetlands were operated in a 'fill-and-hold' mode, where water was only released at the end of the managed flood period. We quantified three MeHg removal mechanisms (particulate settling, benthic demethylation, and photo-demethylation) in the deep-water treatment cells. During Year-1, mean whole-water MeHg load (by mass) decreased 41% from the in-flow to the outflow in the deep cells. Photodegradation accounted for 19% of the mass removed, while particle flux to the benthos accounted for the remainder. Benthic MeHg degradation was exceeded by MeHg production, and was thus not a major loss term. While deep-cells within the treatment wetlands served as net sinks for MeHg, overall the net MeHg export from the flow-through treatment wetlands (20±12 mg) exceeded export from the fill-and-hold control wetlands (2±4 mg). The use of deep cells in wetland design was effective in lowering MeHg exports under flow-through conditions, but further optimization of flow rates is needed prior to widespread implementation.

Keywords: mercury, methylmercury, methylation, demethylation, wetlands
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Methylmercury and Total Mercury Imports and Exports of Two Tidal Wetlands in the Yolo Bypass and Suisun Marsh

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Mercury (Hg) has been a contaminant of concern in the Bay-Delta Region, based on elevated concentrations of methylmercury (MeHg) in fish and wildlife, particularly in areas of frequent wetting and drying, such as wetlands. Because future tidal wetland restorations are planned, determining loads from tidal wetlands is imperative.

Because of the potential of tidal wetlands to be methylmercury sources, the Department of Water Resources (DWR), under a regulatory obligation by the Central Valley Regional Water Quality Control Board, is characterizing and quantifying imports and exports of total mercury (THg) and MeHg of 3-4 tidal wetlands, and has already completed one-year studies of two of those wetlands, one in the Yolo Bypass (YB) and one in Suisun Marsh (SM).

DWR began the YB study in May 2014, and the SM study in June 2015, and completed one-year load studies at both sites. Staff collected samples for flood and ebb tides of 10 tidal cycles at both sites over the course of the year, generally more frequently in the warm months, and less frequently in the cold months.

The preliminary data at the tidal wetland in the Yolo Bypass indicate that the tidal wetland was always a sink for water, and generally a sink for THg and MeHg. The Suisun Marsh tidal wetland was more variable in whether it was a source or sink of water, as well as being a source or sink of THg and MeHg. Data from two more freshwater wetlands will be collected, and compared to the existing data to determine if any trends exist and whether it may be possible to manage methylmercury imports and exports from tidal wetlands.

Keywords: Methylmercury, Mercury, Tidal Wetlands, Blacklock, Yolo Bypass, Suisun Marsh
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