Alpers, C. N.* (1), M. P. Hunerlach (1), M. Marvin-DiPasquale (2), N. P. Snyder (3, 4), D. P. Krabbenhoft (5). (1) U.S. Geological Survey (USGS), Placer Hall, 6000 J Street, Sacramento, CA 95819. (2) USGS, MS 480, 345 Middlefield Road, Menlo Park, CA 94025. (3) Department of Geology and Geophysics, Boston College, 140 Commonwealth Ave., Chestnut Hill, MA 02467. (4) USGS, 400 Natural Bridges Drive, Santa Cruz, CA 95060. (6) USGS, 8505 Research Way, Middleton, WI 53562. cnalpers@usgs.gov

MERCURY AND METHYLMERCURY IN THE UPPER YUBA RIVER WATERSHED: FLUVIAL TRANSPORT AND RESERVOIR SEDIMENTATION

The potential introduction of anadromous fish to the upper Yuba River watershed (upstream of Englebright Dam) has raised questions concerning possible risks associated with exposure to mercury contamination from historical gold mining. These concerns were investigated by monitoring mercury (Hg) and methylmercury (MeHg) concentrations in water, suspended sediment, and reservoir-bed sediment during 2001–2003.

Concentrations of Hg and MeHg were determined in both unfiltered and 0.45-micrometer-filtered water, along with suspended-sediment concentration (SSC) at gaging stations on the South Yuba River (SY), the Middle Yuba River (MY), and the Yuba River below Englebright Dam. At SY and MY, there were positive correlations between discharge, SSC, and Hg in unfiltered water. Average Hg in suspended silt and clay at SY was about 350 nanograms per gram (ng/g) dry sediment. The highest concentrations of Hg and SSC relative to discharge at SY and MY occurred during rising limbs of early-wet-season storms. About 25% of unfiltered MeHg analyses were > 0.10 nanograms per liter, mostly during storms.

Deep sediment coring during 2002 penetrated the entire post-dam sediment pile at six locations in Englebright Lake. Sediment thickness ranged from 6 m near Englebright Dam to 33 m in the mid-reservoir area. Sediment Hg concentrations ranged from 2 to 1,150 ng/g (median 139 ng/g, n=166); MeHg concentrations ranged from 0.007 to 6.8 ng/g (median 0.36 ng/g; n=166). The persistence of moderately elevated MeHg concentrations throughout the sediment pile suggests several causative factors, including rapid burial and preservation of the deposited MeHg, moderately low rates of MeHg demethylation, and (or) persistent Hg methylation in relatively organic-rich sediments.

Exposure levels of MeHg in water and sediment in upper Yuba River watershed may represent significant ecological risk to aquatic species. Potential MeHg exposure and associated risk should be considered in the development of anadromous-fish-introduction scenarios above Englebright Dam.

Ashley*, R.P.(1), J.J. Rytuba (1). (1)U.S. Geological Survey (USGS), Menlo Park, 345 Middlefield Rd. Mail Stop 901, Menlo Park, CA 94025 ashley@usgs.gov

MERCURY ASSOCIATED WITH GOLD DREDGE TAILINGS IN THE CLEAR CREEK AND TRINITY RIVER WATERSHEDS, CALIFORNIA

From 1900 until the 1960s placer gold deposits in northern California were mined mainly by dredging. The alluvial material processed was screened and coarse clasts (usually >1 cm) were discharged using a stacker. The finer material was washed through sluice boxes charged with mercury to capture fine gold by amalgamation. Thus release of mercury and subsequent uptake by biota is of concern in restoration projects that involve moving or using mercury-contaminated dredge tailings. The purpose of this study is to determine distribution, speciation, and mobility of mercury in tailings from floating dredges operated on lower Clear Creek and the middle Trinity River, in the eastern Klamath Mountains. Stacker tailings deposited above water level have relatively low mercury concentrations, no more than about twice background values (10-60 ng/g). Stacker tailings deposited below water level contain fine interstitial material (silt-clay), which was released into the dredge pond during digging or cycled through the sluices, and dispersed into the coarser tailings by infiltration. These fines, which also settled to form lenses in the coarser tailings, have as much as 150 ng/g mercury. Pebbly sand lenses in the tailings, which represent discharge from the dredge sluices, contain as much as 4000 ng/g mercury. Thus mercury concentrations vary widely in dredge tailings, but materials that may be of concern such as sluice sands can be recognized in the field, using knowledge of tailings stratigraphy and history of dredging operations. Sequential extraction studies reveal that 40-60% of the elemental mercury introduced to the tailings has been converted to soluble and base-leachable organically bound forms; 5-20% has been converted to mercury sulfide (HgS). Although methylmercury concentrations in undisturbed dry tailings are generally very low, fines released from tailings and introduced to methylating environments result in high methylmercury levels in water, sediments, and biota.

Bodensteiner*, S.B., J.Q. Word. MEC-Weston Solutions, Inc., 98 Main Street Suite 428, Tiburon, CA 94920 bodensteiner@mecanalytical.com

SIMULATION OF DEWATERING TECHNIQUES TO IDENTIFY METHODS TO LIMIT MERCURY METHYLATION IN UPLAND PLACED SEDIMENTS

The Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region (LTMS) has established a goal of significantly reducing the volume of in-Bay disposed dredged material. To achieve this goal, the LTMS promotes maximizing the use of upland reuse sites. An evolving concern related to upland sediment placement is the potential for enhancing transmission of mercury into Bay Area food webs. The primary reasons this concern are 1) mercury is ubiquitously present in Bay Area sediments at concentrations significantly higher than historical background, and 2) wetlands and bermed uplands may provide conditions that transform elemental mercury into its bioavailable form at a substantially greater rate than an aquatic environment. This study involved simulating three separate dewatering methods using sediment laden with mercury concentrations consistent with Bay ambient levels. The objective was to determine whether varying the dewatering method would significantly effect the production of methylated mercury. Sediment samples and an equal proportion of seawater were placed in three sets of triplicate glass containers. Each was dewatered using three different methods: stagnant evaporation, aerated evaporation, and continuous flow evaporation. Once dewatering was completed, the top two centimeters were removed from each container and submitted for analysis. Results show that the stagnant and flow-through arrangements produced methylated mercury at a significantly greater rate relative to the aerated arrangement. Although adherence to the goals of the LTMS will result in a net loss of mercury from San Francisco Bay, conventional upland dewatering methods will likely lead to an elevation in the bioavailable form of mercury at the Bay fringe. This data suggests that upland dewatering may be managed such that production of methylated mercury may be reduced and potentially eliminated in newly exposed sediments, thus minimizing the biomagnification of mercury while achieving the goals of the LTMS.

Brodberg*, R.K., Ph.D. Office of Environmental Health Hazard Assessment, P.O. Box 4010, Sacramento, CA 95812-4010 rbrodber@oehha.ca.gov

ENVIRONMENTAL JUSTICE AND DEVELOPING CALIFORNIA FISH CONSUMPTION ADVISORIES

Potentially unsafe levels of chemical contaminants (e.g., mercury) have been found in fish that people catch and eat from the Bay-Delta. The Office of Environmental Health Hazard Assessment (OEHHA) issues fish consumption advisories to protect consumers from contaminants in fish. Developing a protocol for fish consumption advisories that is applicable for different water bodies and chemicals and that incorporates principles of Environmental Justice is challenging. Resources to assess available data for fish advisories are limited, and since data are dispersed and must be compiled and scrutinized before they can be used, many areas have not been assessed. From an Environmental Justice perspective, incomplete data for fishing sites, fish species, and chemicals (e.g., pesticides and PCBs) means that fish advisories may not be completely protective.

OEHHA has developed an advisory protocol for fish consumption that yields consistent advice for water bodies statewide and provides a standard against which all consumers can measure their exposure to contaminants in fish. This protocol applies science-based risk assessment methods to data that meet quality control/quality assurance criteria for human health assessments to establish “safe” consumption levels for fish species caught in the Bay-Delta. This protocol has enabled OEHHA to more rapidly develop and issue advisories based on mercury levels in fish for sixteen water bodies in the Bay-Delta area. OEHHA’s protocol also incorporates advice that promotes safer eating habits as health protective measures for consumers.

It is critical that OEHHA continue to develop and revise advisories in the Bay-Delta area to give consumers sound health protective advice on safe fish consumption. OEHHA’s advisories are needed to protect all consumers during long-term efforts to reduce chemical contaminants in the Bay-Delta. Following consumption recommendations will keep consumers at an exposure level that is expected to be without risk of harmful effects.

Collins*, J.N. (1), C. Wilcox (2). (1) San Francisco Estuary Institute (SFEI), 7770 Pardee Lane, Oakland, CA 94621. (2) California Department of Fish and Game (CDFG), Region 3 Headquarters, P.O. Box 47, Yountville, CA 94599 josh@sfei.org

THE MEANING OF METHYLMERCURY TO WETLAND MANAGERS: HELPING MAKE SCIENCE RELEVANT TO MANAGEMENT.

Mercury bioaccumulation is broadly recognized as a health risk in the waters of San Francisco Bay. There has been a health advisory for human consumption of Bay fish since 1994. The Bay has been on California State's 303d list for mercury since 1998. The Bay Area Water Quality Control Board is developing a Total Maximum Daily Load (TMDL) to identify mercury control strategies. During this same time period, wetland restoration in the region has gained more public support and funding than ever before. Now scientists have raised concerns that wetland restoration might substantially increase the load of methymercury into the greater Bay ecosystem. Wetland managers must face the mercury issue with a clear understanding of its effect on the overall environmental costs and benefits of wetland restoration. This understanding depends on technical answers to the managers' basic questions: how is the mercury problem defined, and what can be done through project location or design to reduce the problem in measurable terms? If the answers aren't available now, then how can projects be used to learn the answers? This presentation will summarize the response of wetland scientists and engineers to the management questions.

Davis*, J.A. (1), B.K. Greenfield (1) jay@sfei.org

SPORT FISH CONTAMINATION IN THE BAY-DELTA WATERSHED

Sport fish contamination is a widespread and persistent problem in the Bay-Delta watershed. Mercury is the most pervasive problem, with a large proportion of the watershed impacted by the legacy of mercury and gold mining in the Coast Range and the Sierra Nevada. One region with low mercury concentrations has been identified, suggesting that not all areas downstream of historic mining activity are problematic. Other areas upstream of mining may also have low mercury concentrations. Some species have also been found to have consistently low mercury concentrations, even in areas where species at the top of the food web have high concentrations. Mercury concentrations in general do not appear to be declining over the long term. PCB contamination is patchy, associated with hotspots of contamination. Legacy pesticides such as DDT are more of a regional problem, particularly in the lower San Joaquin Valley and other areas of historical use in agriculture. Concentrations of PCBs and legacy pesticides appear to be declining slowly over the long term. One emerging contaminant, PBDEs, appears to be increasing in Bay-Delta food webs, raising concern for possible effects on human and wildlife health. Fish species with high fat content in their muscle tissue accumulate higher concentrations of PCBs and legacy pesticides. Minimizing human exposure to contaminants from fish consumption in the watershed will depend on a sound understanding of spatial patterns in contamination and variation among fish species, management actions to clean up sources of contamination, and effective communication of health risks while we wait for concentrations to fall below thresholds for concern.

Davis*, J.A. (1), B.K. Greenfield (1), M. Stephenson (2), G. Ichikawa (2). (1) San Francisco Estuary Institute, 7770 Pardee Lane, Oakland, CA 94621. (2) Moss Landing Marine Laboratories, 8272 Moss Landing Road, Moss Landing, CA 95039 jay@sfei.org

FISH MERCURY IN THE BAY-DELTA WATERSHED: A DARK CLOUD WITH A SILVER LINING.

Sport fish are a key indicator of mercury contamination in aquatic food webs because of their direct connection with human health risks. Sport fish have also proven to be useful in delineating spatial patterns in mercury contamination. Extensive sampling of mercury in sport fish has been conducted in the Bay-Delta watershed over the past few years. The largest study was funded by CALFED, with sampling conducted in 1999 and 2000. Other major studies have been conducted by USGS and UC Davis. Several general findings are supported by these recent studies. 1) We have a significant mercury problem in the watershed. Several species (including largemouth bass, striped bass, Sacramento pikeminnow, channel catfish, and white catfish) have mercury concentrations that commonly exceed a threshold for human health concern, and frequently exceed the threshold by 3-fold or more. 2) Significant spatial variation exists in the watershed, including some locations with unexpectedly low mercury. Mercury concentrations in largemouth bass from the Feather River, northern Delta, lower Cosumnes River, San Joaquin River, and Sierra foothill reservoirs were significantly elevated and in the 1 ppm range. The good news was that concentrations in the central Delta were significantly lower than other locations, and usually below the human health threshold, in spite of abundant wetlands and apparently high rates of methylmercury production in sediment in this same area. 3) Mercury in the food web appears to have changed little over the long term. Mercury concentrations in striped bass, which are integrative indicators of mercury in the watershed, have not changed perceptibly in the past 30 years.

Fleming-Singer*, M.S. (1), N. P. Hume (1), D. Slotton (2), N. Bloom (3). (1) Stillwater Sciences 2855 Telegraph Avenue, Suite 400, Berkeley, CA 94705 (2) Dept. of Environmental Science and Policy, University of California, One Shields Avenue, Davis, CA 95616 (3) Frontier Geosciences Inc. 414 Pontius Ave. North Seattle, WA 98109 maia@stillwatersci.com

MERCURY OCCURRENCE IN DREDGER TAILINGS, SEDIMENT AND BIOTA ON THE LOWER MERCED RIVER

This study assessed the occurrence and distribution of mercury in dredger tailings at the Merced River Ranch, located on the lower Merced River, California. To provide information in support of floodplain restoration and gravel augmentation projects for resident salmonids, we sampled sediment, water and bioindicator organisms along the Merced River at locations above, within, and below the dredger tailings. MeHg in Hydropsychid caddisfly (8 to 25ƒnng/g wet wt) and prickly sculpin (13 to 195ƒnng/g wet wt) were low compared with regional reference values. Raw water THg at the sampling sites was 0.5 to 170 ng/l (n=8), while MeHg ranged <0.03 to 3 ng/l (n=8). To reduce the risk of mercury mobilization and uptake into the aquatic food web, the feasibility of processing the dredger tailings was assessed by selectively removing mercury-laden size fractions through dry sorting and washing. Overall results indicated low total mercury (THg) in dredger fines (22„b16 ng/g dry wt, n=31), while fine sediments collected at in-channel and backwater sites (n=5) ranged from 48 to 138 ng/g dry wt THg and 0.1 to 3.5 ng/g dry wt methyl mercury (MeHg). Although the low mercury levels found in the dredger tailings may allow direct re-use in floodplain reconstruction projects away from the channel, removal of the mercury associated fines from the dredger tailings by sorting will further reduce the risk of mercury mobilization. Calculations based on the experimental data suggest that dry sorting of dredger tailings would result in a 50% reduction of the potential near-term mercury release and a 72% reduction of long-term maximum theoretical release. Ecosystem restoration and water quality improvement goals of the Bay-Delta Program are supported through science-based management recommendations for in-basin use of the Merced River Ranch dredger tailings, and a further understanding of current and potential mercury impacts to the Bay-Delta ecosystem.

Foe*,C.(1). (1)Central Valley Regional Board, 11020 Sun Center Drive, Rancho Cordova, 95670-6114 FoeC@rb5s.swrcb.ca.gov

METHYLMERCURY MASS BALANCE FOR THE FRESHWATER SACRAMENTO-SAN JOAQUIN BAY-DELTA ESTUARY.

A human health advisory has been posted for the Delta because of elevated methylmercury concentrations in game fish. A positive correlation has been found between annual median unfiltered methylmercury concentrations in water and trophic level 3 and 4 fish composites from different regions of the Delta. The correlation suggests that reducing fish tissue levels will require decreases in water concentrations and this will necessitate a good understanding of the major sources and sinks of methylmercury. An 18-month methylmercury mass balance was constructed for the Delta. Major incoming loads were from Central Valley Rivers, from in situ Delta sediment production, and from point sources. Major exports were to San Francisco Bay and to southern California. The estuary was found to be a net methylmercury sink. The Sacramento River was the major source of methylmercury and accounted for 60-85 percent of the river load. The combined input from all rivers was about 10-gms per day. Average sediment flux was about 6-gms per day. The input from all 13 sewage treatment plants discharging directly to the Delta was about 0.7-gms per day while urban runoff contributed about 0.1-gms per day. Exports from the Delta were about 6-gms per day with most of the methylmercury going to San Francisco Bay. The difference between the sum of all inputs (16-gm per day) and exports (6-gm per day) was 10-gms per day. This is our best estimate of the present methylmercury loss rate in the Delta.

M. P. Hunerlach* (1), Alpers, C. N. (1), M. Marvin-DiPasquale (2). (1) U.S. Geological Survey (USGS), Placer Hall, 6000 J Street, Sacramento, CA 95819. (2) USGS, MS 480, 345 Middlefield Road, Menlo Park, CA 94025. hunerlac@usgs.gov

PARTICLE-SIZE DISTRIBUTION AND MERCURY GEOCHEMISTRY OF SEDIMENTS AFFECTED BY LARGE-SCALE GOLD DREDGING, YUBA RIVER, CALIFORNIA

Several hundred thousand cubic meters of hydraulic mining debris and dredge tailings, potentially contaminated with mercury and other trace metals, are trapped behind Daguerre Point Dam in the lower Yuba River. Management alternatives ranging from dam modification to removal are being considered to improve conditions for the passage of anadromous fish. Potential impacts from disturbance of contaminated sediments are of concern.

This USGS study evaluated sediments from drilling at six locations upstream of Daguerre Point Dam. Samples were divided into size fractions that were analyzed for total mercury (Hg), methylmercury (MeHg), other trace metals, and particle-size distribution. Potential rates of Hg methylation and demethylation were evaluated using radiotracer methods on the < 2-millimeter size fraction. Scanning electron microscopy was used to determine the distribution of elemental Hg and gold-mercury amalgam.

Concentrations of Hg ranged from 6.8 to 1,100 ng/g (nanograms per gram). Mercury and amalgam were observed on gold grain surfaces. Spherules of liquid Hg up to 6 micrometers in diameter were associated with fine-grained aluminosilicate and iron-oxide minerals. Concentrations of MeHg ranged from < 0.001 ng/g to 0.611 ng/g in samples of the clay-silt size fraction. Laboratory rates of mercury-methylation potential were generally low, ranging from < 0.15 to 1.57 ng/g/d (nanogram per gram of dry sediment per day). Mercury-demethylation potential rates were moderately high, ranging from 1.0 to 2.2 ng/g/d. Concentrations of arsenic, chromium, copper, lead, mercury, nickel, and zinc are of potential concern with regard to ecological toxicity.

Mercury concentrations were higher in the finer size fractions. Although MeHg concentrations were low, Hg released from fine-grained sediments behind Daguerre Point Dam could methylate in downstream environments. Results of this study will be used by local, state, and federal agencies responsible for assessing the potential risks associated with mobilizing sediments in conjunction with fish passage improvement projects.

Marvin-DiPasquale*, M. (1). (1) U.S. Geological Survey (USGS), 345 Middlefield Rd., Mail Stop 480. Menlo Park, CA 94025. mmarvin@usgs.gov

MERCURY CYCLING CONCEPTS IMPORTANT IN THE ADAPTIVE MANAGEMENT OF WETLAND RESTORATION PROJECTS

Wetlands are known to be active zones of toxic methylmercury (MeHg) production, although the specific processes that drive this are poorly understood. Consequently, there has been much recent discussion and concern that the extensive amount of ongoing or planned wetland restoration activities in the San Francisco Bay watershed may lead to a significant increase in MeHg production. While this possibility cannot be ruled out, the extent to which enhanced MeHg production will result, and over what temporal and spatial scales, is currently unknown. Multiple investigations are currently underway to help us better understand the physical, geochemical, and microbial processes that control MeHg production in the SFB ecosystem. These investigations are being conducted at multiple scales (e.g., regional, sub-habitat, microhabitat) as appropriate to address specific ecological questions. This presentation summarizes a number of these projects, as a way of illustrating the key environmental factors known to impact net MeHg production and its bioaccumulation into the food chain. These studies emphasize a holistic understanding of the processes underlying mercury cycling in the various sub-habitat components that make up wetland environments (i.e., sloughs, mudflats, low / high marsh vegetated zones, floodplains, etc…) along the salinity gradient of the watershed. While simple solutions to the wetland MeHg production dilemma appear elusive, the management implication of this research is that it may be possible to pursue wetland restoration design strategies that minimize net MeHg production and bioaccumulation.

McFarland*, V. A. (1), C. H. Lutz (1), J. U. Clarke (1), D. K. MacMillan (2). U.S. Army Engineer Research and Development Center (ERDC), (1) 3909 Halls Ferry Road, Vicksburg, MS 39180, (2) 420 South 18th St,Omaha, NE 68102. mcfarlv@wes.army.mil

RELATIVE MERCURY/METHYLMERCURY CONCENTRATIONS AT WET AND DRY SEASONS PRIOR TO WETLANDS RECONSTRUCTION AT HAAF

Dredging ship channels is essential to the economy, but in-Bay disposal of dredged material has historically been damaging to the San Francisco Bay ecology. Using clean dredged material to reconstruct lost wetlands is a solution that addresses both economic and ecological purposes. Dredged material can form the basic shape and substrate of the wetland, and natural processes of sediment deposition and plant and animal colonization will follow. However, the devil in the details is mercury, with which the surface of the entire Bay system is contaminated. Unfortunately, wetlands tend to generate methylmercury (MeHg) when other forms of mercury are present. Management of mercury methylation in wetlands reconstruction is essential, and that requires knowledge of the amounts, rates, and processes of methylation specific to a reconstruction site. At the Hamilton (HAAF) Wetlands Restoration Site sixty stations were selected representing gradients from intertidal to upper marsh. Five surficial soil or sediment samples were taken at each station at peak wet season and were re-sampled at peak dry season. The samples were analyzed for total mercury (THg) and MeHg. Sample stations represented gradients from intertidal to upper marsh. THg was similar in soils and sediments at both seasons (~0.3 mg/g). MHg increased an average of three-fold during the wet season. Highest THg was consistently found in samples at the intertidal zone but MeHg was increased less than two-fold in the same samples during the wet season. Highest methylation occurred in samples taken closer to the levee and less influenced by tidal fluctuation. In the mid-marsh and upper marsh samples, MeHg averaged up to 9% of THg, and MeHg concentrations were as high as 23.5 ng/g dw in soil, suggesting that meteorological or surface water plays a role in mercury methylation of the higher marsh areas.

McKee*, L. (1), Leatherbarrow, J. (1). (1) San Francisco Estuary Institute (SFEI), 7770 Pardee Lane, 2nd floor, Oakland, CA 94621 lester@sfei.org

SUSPENDED SEDIMENT AND MERCURY LOADS ENTERING SAN FRANCISCO BAY FROM THE CENTRAL VALLEY VIA THE DELTA

The Bay-Delta and San Francisco Bay are listed by the State of California for mercury impairment. Mercury in the Bay-Delta system is mainly derived from contaminated sedimentary deposits associated with historic Central Valley mercury and gold mining. Because mercury is transported into San Francisco Bay attached to suspended sediment, an understanding of sediment transport helps to enable the estimation of mercury loads. In 2001, San Francisco Estuary Institute began working with USGS to estimate daily and annual sediment loads and with UCSC to collect new total Hg concentration data for mercury load estimation.

CALFED has funded USGS to measure 15-minute suspended sediment concentration (SSC) at Mallard Island since water year (WY) 1995 (9 years). Delta outflow (DWR) was combined with daily average SSC data to estimate daily suspended sediment advective load. A model was developed to estimate the landward dispersive load using velocity and SSC data collected during WYs 1994 and 1996. The advective and dispersive loads were summed to estimate the total daily load. The derived 9-year average load was 1.2 Mt, a factor of 3 less than previously postulated. Total mercury concentrations were measured in 30 water samples during WY 2002 and 2003. Least squares regression was used to derive 15-minute mercury concentrations from SSC. These were averaged and combined with Delta outflow. The advective loads were adjusted using a modification of the SSC model. During WY 2002 and 2003 mercury loads were 58 and 97 kg respectfully and long-term average annual loads are 201 kg.

This study has important implications for management of the Bay-Delta system. Decreasing suspended sediment loads may help to increase erosion in the Bay-Delta system, cause remobilization of buried mercury, and reduce sediment supply to wetland restoration. New estimates of mercury loads aid the prioritization of management actions aimed at reducing impairment.

Mumley*, T.E., Johnson, B.J., Looker, R.E., San Francisco Bay Regional Water Quality Control Board, 1515 Clay Street, Suite 1400, Oakland, Ca 94612 tem@rb2.swrcb.ca.gov

SAN FRANCISCO BAY MERCURY TMDL - A SCIENCE-BASED ADAPTIVE-IMPLEMENTATION STRATEGY

The San Francisco Bay Regional Water Quality Control Board has developed a TMDL to resolve impairment San Francisco Bay by mercury. The success of this endeavor is due to a science-based collaborative approach. Through a series of reports starting in 1998, the Water Board iteratively documented the state of knowledge regarding mercury impairment and promoted an evolving strategy to fill key data gaps and establish a plan of action.

Key components of the TMDL include:

· Numeric targets for mercury in suspended sediment, fish tissue, and bird eggs to protect sport and subsistence fishing, wildlife and rare and endangered species:

· Total maximum yearly mercury load to San Francisco Bay of 702 kg on average (roughly 60% of the existing load);

· Allocation of load among mercury sources;

· Plan to implement the TMDL via actions to reduce mercury loads and actions to reduce methylmercury production;

· Monitoring program to evaluate progress towards meeting targets and allocations, and studies to improve technical understanding relevant to the mercury TMDL; and

· Plan and schedule to review progress and evaluate and revise actions.

The first three bullets reflect the technical basis of the TMDL, and the last three collectively reflect an adaptive approach to implementing the TMDL and attaining mercury water quality standards. Adaptive implementation involves taking early action commensurate with available data and information while we continuously improve our understanding of the problem and its solutions. Inherent to this approach is commitment to review and revise the TMDL and implementation plan as we gain knowledge, particularly if we discover unanticipated consequences. Studies called for in the adaptive implementation plan to improve technical understanding relevant to the mercury TMDL are consistent with the Calfed Mercury Science Strategy.

Nelson*, D.C., E.J. Fleming and N. Sunseri. Section of Microbiology, Division of Biological Sciences, Briggs Hall, University of California, Davis, CA 95616. dcnelson@ucdavis.edu

MERCURY ACCUMULATION IN CRABS AS AN INDICATOR OF INTEGRATED HG-BIOAVAILABILITY IN NORTHERN CALIFORNIA ESTUARIES.

Estuarine production of methyl mercury from inorganic mercury occurs mainly in anoxic sediments via the action of anaerobic bacteria. Methyl mercury may be "biomagnified" at higher trophic levels in food chains and can reach levels that trigger health warnings. The original goal of this study was to determine whether there existed differences in bioavailability of inorganic mercury or in Hg-methylation rates for diverse estuarine sites, which included: Walker Creek, with known Hg-contamination from mining; Tom's Point, a putatively non-impacted control site; and Stege Marsh, impacted by the typical Hg-load from San Francisco Bay. An initial survey of sediment [Hg] at Walker Creek showed high variability within and between stations. Therefore, a decision was made to refocus the study on concentrations of Hg in the lined shore crab, Pachygrapsus crassipes. Between sites this indicator showed more than a 50-fold difference, but there were very different tendencies for trophic magnification in larger crabs depending on the site. Stege crabs showed moderate Hg levels (200 ppb) and no tendency toward biomagnification in larger individuals. Similar concentrations occurred in small crabs from Walker Creek and Tom's Point, but larger individuals from these sites contained up to 1100 ppb and showed equivalently strong tendencies toward trophic magnification. These very different patterns of biomagnification may highlight food-chain differences that contribute to the relative impairment or health of a specific estuary. Nitrogen stable isotope studies in progress in the laboratory of a colleague are addressing this hypothesis. Alternatively, the presence of a suite of heavy metals and xenobiotic compounds at Stege may play some counterintuitive role in retarding biomagnification. Additional Pachygrapsus surveys are being used to assess the impact of Walker Creek sediments on various estuarine food chains throughout Tomales Bay.

Rytuba*, J. J. (1), R. L. Hothem (2), J. T. May (3), R. P. Ashley (1). (1) U.S. Geological Survey (USGS), Menlo Park, 345 Middlefield Road Mail Stop 901. Menlo Park, CA 94025. (2) U.S. Geological Survey (USGS), Dixon, 6924 Tremont Road, Dixon, CA 95620. (3) U.S. Geological Survey (USGS), Sacramento, 6000 J Street, Placer HallSacramento, CA 95819-6129 jrytuba@usgs.gov

MINIMIZING MERCURY MOBILITY AND METHYLATION IN THE CLEAR CREEK AND TRINITY RIVER RESTORATION PROJECTS, CALIFORNIA

River restoration projects such as those in the lower watersheds of Clear Creek (CC) and Trinity River (TR), California, have the potential to release mercury from tailings and mercury-enriched sediments derived from historic placer gold mining. Restoration projects such as flood plain and channel modification, sediment augmentation, and wetland formation that redistribute and utilize mercury-enriched tailings and sediment may enhance mercury methylation and bioaccumulation. Minimizing the release and methylation of mercury resulting from river restoration projects, as well as evaluating watershed response to restoration efforts, requires incorporating an understanding of mercury biogeochemistry into planning and implementation of restoration projects.

Distribution of mercury (Hg) and methylmercury (MeHg) in water, sediments, tailings, and biota (fish, amphibians, aquatic insects) have been studied in TR and CC in various riverine environments and restoration areas. Physiochemical parameters that control methylation such as Hg speciation, sulfate, and dissolved organic carbon (DOC) also were measured during repeated seasonal sampling.

Within various riverine and restoration environments, Hg and MeHg are concentrated in the fine-grain size fraction of tailings and sediments though concentrations vary considerably. Highest Hg concentrations are present in dredge sluice sands which may be exposed during restoration activities and provide a source of bioavailable Hg that can be released into surface waters. Hg methylation is enhanced in wetland and pond environments where sulfate and DOC concentrations are elevated by effluent from connate springs, mine drainage, or tributaries draining mineralized areas. Fish and aquatic insects generally have low levels of Hg in riverine environments. In natural and reconstructed wetlands and ponds where additional components such as sulfate and DOC enhance methylation, biota have moderate to high mercury concentrations.

Management of mercury in river restoration projects needs to address not only mercury sources and mobility but other variables and geomorphological processes that may enhance mercury methylation and bioaccumulation.

Shilling*, F.M. University of California, One Shields Ave., Davis, CA, 95616. fmshilling@ucdavis.edu

GEOGRAPHIC AND DEMOGRAPHIC DISTRIBUTION OF ANGLERS AND MERCURY IN BAY-DELTA FISH

Mercury contamination in fish poses a health risk to women and children who often consume the fish. Communities in the Bay-Delta watershed include subsistence fishers and others who consume fish at higher rates than is considered safe for the mercury concentrations present. Besides reducing mercury contamination, an important state responsibility when contaminated fish are consumed is to protect public health while also maintaining cultural and dietary well-being from eating fish. The distribution of angling pressure and demography of anglers was described in order to inform state agencies who are charged with mitigating the health impacts of mercury in fish. Areas were identified where fishing intensity was high and mercury concentrations in consumable fish was also high. The communities of origin of these anglers were identified and the demographics characterized of anglers fishing in areas with contaminated fish. This information is important for communicating health messages directly with potentially impacted communities. Until state and federal programs, such as the Bay-Delta Program, lead to improvements in fish contamination, well-informed health-messaging to subsistence fishing communities will be an important mitigation activity for mercury contamination in fish.

Slotton*, D.G., S.M. Ayers, R.D. Weyand. University of California at Davis (UC Davis), Dept. of Environmental Science and Policy, 1 Shields Ave, Davis, CA 95616. dgslotton@ucdavis.edu

THE ROLE OF BIOSENTINEL ORGANISMS IN THE MERCURY STRATEGY: PERFORMANCE MEASURES OF RESTORATION AND REMEDIATION

In the Bay-Delta watershed of California, mercury exposure is largely a function of historic mining influences and depositional habitat, often resulting in highly variable patterns of exposure, both spatially and temporally. Those trends and the biogeochemical dynamics underlying them need to be better understood, particularly in relation to planned habitat manipulation projects. As a part of that effort, biological measures of relative exposure are needed. Large fish data are critical for human consumption concerns. However, lower trophic level organisms provide a more sensitive measure of temporal and spatial variability. Mercury "biosentinels" are being refined as monitoring tools in several CBDA and related projects.

Small fish and invertebrate biosentinels were sampled seasonally for total and methyl mercury over a two year period from numerous Cache watershed sites spanning a wide range of exposures. Biosentinel mercury was compared to mercury in water and large fish. In other projects, biosentinels were used to assess spatial and seasonal mercury trends in relation to historic gold and mercury mining, dredging, and restoration. Various organisms were tested; statistical sampling techniques were refined.

Small fish and invertebrate methylmercury was found to correspond closely with large fish mercury over wide regions, providing a dynamic measure of biotic exposure. A strong, site-specific correlation was found with time-integrated aqueous methylmercury. Bioaccumulation was confirmed to be highly variable both spatially and seasonally. Compositing and replication strategies were refined to demonstrate statistically significant fine scale spatial and seasonal methylmercury exposure trends in regions including: the Cache Creek watershed (remediation and regulatory target), the Yuba River (dam removal feasibility), the Merced River (salmon habitat restoration), and a demonstration wetlands restoration.

A suite of small fishes and invertebrates have been shown to be ideal sentinels of relative methylmercury exposure in the Bay-Delta watershed, providing a biologically relevant performance measure for restoration and remediation projects.

Walker*, I.D. Lee A. Ujihara S. Jones S. Lee E. Weiss iwalker@dhs.ca.gov

ENVIRONMENTAL JUSTICE FROM DESIGN TO MESSAGE

Elevated levels of mercury and PCBs in the San Francisco Bay and Delta region have necessitated the development of advisories limiting the consumption of fish in these areas. The Bay-Delta watershed area is also home to diverse ethnic populations making fish consumption an Environmental Justice (EJ) issue. The multi-ethnic composition of the fishing community raises unique obstacles for both researchers working to characterize human health risks and educators providing outreach to EJ populations.

This session will discuss the challenges presented in identifying and addressing EJ issues in the Environmental Health Investigations Branch's (EHIB) San Francisco Bay Fish Project, and will include a discussion of techniques for working with both disproportionally affected populations, and conducting outreach to hard-to-reach populations with limited access to information.

In an effort to identify EJ populations consuming bay fish, EHIB conducted the San Francisco Bay Seafood Consumption Study in 2000. Target populations were identified early in the planning process, and multi-lingual interviewers hired to reach non English-speaking anglers. EJ issues were brought to the forefront of the data analysis, which resulted in specific recommendations for EJ populations. The study found that EJ populations, specifically Southeast Asian, African-American, women and children were disproportionally affected by fish contamination in the San Francisco Bay and Delta region. To conduct effective outreach to these groups, EHIB engaged in a spectrum of activities, including providing small grants to local community based organizations (CBOs) already engaged in health promotion activities. As a part of the grant, CBOs were given extensive training, and assisted with the development of educational materials for their populations. EHIB also developed and field tested advisory signs and educational materials to reach a broad range of ethnicities and education levels. EHIB's activities can be used as a model for future research and outreach for the bay and delta.

Wiener*, J. G. (1), C. C. Gilmour (2), D. P. Krabbenhoft (3), C. N. Alpers (4), M. Stephenson (5). (1) University of Wisconsin-La Crosse, River Studies Center, 1725 State St., La Crosse, WI 54601. (2) The Academy of Natural Sciences, Estuarine Research Center, 10545 Mackall Rd., St. Leonard, MD 20685. (3) U.S. Geological Survey (USGS), 8505 Research Way, Middleton, WI 53562. (4)USGS, Placer Hall, 6000 J St., Sacramento, CA 95819-6129. (5) California Department of Fish and Game, Moss Landing Marine Laboratories, 7544 Sandholt Rd., Moss Landing, CA 95039. wiener.jame@uwlax.edu

A UNIFYING FRAMEWORK FOR SCIENCE, MANAGEMENT, AND ECOLOGICAL RESTORATION IN A MERCURY-CONTAMINATED ECOSYSTEM

Restoration of the San Francisco Bay-Delta and tributaries is complicated by widespread mercury contamination. Ecological restoration of wetlands and rivers could affect the transport and microbial methylation of mercury, potentially increasing biotic exposure to methylmercury, a toxic compound that re adily bioaccumulates in exposed organisms and biomagnifies in food webs. Methylmercury can adversely affect native wildlife, diminish benefits derived from fisheries, degrade water and sediment quality, and pose health risks to humans. Success in achieving strategic restoration goals for this ecosystem will, therefore, depend partly on an ability to mitigate the production, transport, and bioaccumulation of methylmercury. We describe a unifying framework, or strategy, for integrated mercury investigations to build a scientific foundation for restoration, environmental management, assessment, and eventual reduction of mercury-related risks in the Bay-Delta ecosystem. The strategy contains seven interconnected components, each addressing a management goal and including supporting research, monitoring, and management activities (source remediation, risk communication, ecosystem restoration, and landscape management). Components address assessment and remediation of mercury sources; effects of restoration on methylmercury exposure; monitoring of mercury in sport fish and bioindicator organ ASSESSMENT OF DELTA RECREATION IMPACTS ONisms, health-risk assessment, and risk communication; ecological risk; and identification of potential management approaches for reducing methylmercury contamination. The overall goal – to avoid increasing, and to eventually decrease, biotic exposure to methylmercury – should provide a unifying sense of purpose to guide scientific investigations and adaptive management. This framework incorporates three approaches for reducing methylmercury exposure: (1) reduction of mercury releases, (2) provision of fish-consumption advice, and (3) management of contaminated landscapes to decrease production of methylmercury.

Wiener*, J. G., University of Wisconsin-La Crosse, River Studies Center, 1725 State Street, La Crosse, WI 54601 wiener.jame@uwlax.edu

DEGRADATION OF FISHERY RESOURCES BY BIOACCUMULATIVE CONTAMINANTS: PROSPECTS FOR REDUCING CONTAMINATION AND HUMAN EXPOSURE

Bioaccumulative contaminants, such as methylmercury, have degraded fishery resources in many North American waters. Consequences of mercury contamination of fish include direct adverse effects on human health; diminished nutritional, cultural, socioeconomic, and recreational benefits of fishery resources; and adverse socio-cultural effects in some communities that had fished for subsistence. Inorganic mercury from historic mining activities and other sources contaminates much of the aquatic habitat in the San Francisco Bay-Delta ecosystem. There is concern that some ecological restoration activities could increase the microbial production of methylmercury and its bioaccumulation in fish in this ecosystem. Methylmercury readily bioaccumulates and can biomagnify to high concentrations in organisms atop aquatic food webs. Moreover, consumption of fish is the primary pathway for human exposure to methylmercury, the dominant form of the metal in fish. The development of a program for monitoring mercury in fish, coupled with risk communication, was given high priority in the Mercury Strategy developed for the California Bay-Delta Authority. Monitoring can provide a scientific foundation for developing fish-consumption advice for decreasing methylmercury exposure in humans who eat fish. Monitoring should be designed to identify species and size ranges of fish with low, as well as high, concentrations of mercury, to identify alternatives for reducing dietary exposure. Information from monitoring should be communicated to increase public awareness of (1) mercury in fish, (2) the health risks of methylmercury exposure, and (3) steps that can be taken to reduce exposure. The health benefits of eating clean fish should also be emphasized. Remedial approaches for reducing mercury contamination of this ecosystem should also be identified and critically evaluated. Within a timeframe of a few years, however, risk communication linked to a well designed monitoring program is the most realistic approach for reducing human exposure to methylmercury in this contaminated ecosystem.

Wood*, A.W.(1), R.Bernknopf(1), J.Rytuba(1), D.Singer(1), R.Champion(1), W.Labiosa(2). (1) U.S Geological Survey (USGS) 345 Middlefield Road, Menlo Park, CA 94025. (2)Stanford University, Stanford, CA 94305 awood@usgs.gov

USGS ADAPTIVE MANAGEMENT APPROACH FOR MITIGATING MERCURY SOURCES UNDER TMDL GUIDELINES

Problem statement: Mercury (Hg) contamination is widespread in the Sacramento-San Joaquin Watershed, with Cache Creek Watershed contributing a large portion. Physical, chemical, and biological processes for Hg in aquatic environments are complex and contain significant uncertainties for identifying the ecosystem dynamics. The uncertainty of these underlying scientific processes may produce similarly large uncertainties in the decision-making process.

Approach: The U.S. Geological Survey (USGS) is developing an adaptive management framework on a regional watershed scale (Cache Creek Watershed) to help meet discharge permit requirements for Hg under Total Maximum Daily Loads (TMDL). USGS research has focused on using alternative econometric and statistical methods to explicitly state and reduce these uncertainties so that they are better incorporated in policy decision-making. Specifically, the approach taken consists of applying probabilities using a Bayesian Probability Network (BPN) which integrates information of varying rigor and detail into a model of a complex system allowing easy updating of prediction and inference when observations of model variables are made. The relationships are identified and quantified using historical data, physical process-based models, conceptual models, and expert judgment.

Results: The adaptive management approach allows TMDL stakeholders to analyze various decision-making scenarios based on different mitigation choices to see whether discharge permit requirements can be achieved at least cost. Subsequently, decisions can be made using this information through decision utility analyses based on their preferences and risk aversions.

Relevance: This research project seeks to critically analyze society's use of science and statistics to produce an optimal methodology for water quality analysis. In addition, this research provides alternative statistical methods for TMDL and water quality analyses explicitly stating the uncertainty of economic and scientific results. This science-based management strategy will help achieve Bay-Delta program goals in meeting water quality objectives and potentially in ecosystem restoration.

Aiken*, G.
U.S. Geological Survey, Boulder, CO
Graiken@usgs.gov

CARBON, SULFUR AND MERCURY - A BIOGEOCHEMICAL AXIS OF EVIL

The ecological fate of Hg in aquatic systems is dependent, in large part on dissolved organic matter (DOM) concentration, the concentrations of inorganic ligands, especially sulfide (S^{-2}), and the presence of sulfate-reducing bacteria that convert Hg^{+2} into MeHg, a highly toxic form of Hg that is readily bioaccumulated . Our research has shown that DOM can influence the transport, reactivity and bioavailability of Hg in aquatic systems by strong Hg-DOM binding and through interactions with mercuric sulfide (HgS). The binding of Hg to DOM under conditions present in many aquatic systems, including the Sacramento-San Joaquin Delta and San Francisco Estuary, (very low Hg/DOM ratios) is controlled by a small fraction of DOM molecules containing strong-binding thiol functional groups($K_{DOM}' = 10^{23.2\pm0.5}$ L kg^{-1}). In oxygenated waters (sulfide-free), DOM-Hg complexes are favored over Hg complexes formed with inorganic ligands. Where measurable sulfide concentrations are present in surface water and pore water, Hg-sulfide complexes predominate. In these cases, common in sulfate reducing environments, DOM interacts strongly with HgS (log K_{sp} = -52.4) to inhibit aggregation and precipitation of HgS by colloidal stabilization. Finally, in a process relevant for mercury cycling in the Sacramento-San Joaquin Delta, significant amounts of Hg can be solubilized by DOM in the Delta from solid HgS (cinnabar) transported from upstream sources. Interactions with of DOM with HgS, therefore, can influence the geochemistry and bioavailability of Hg in aquatic environments by maintaining higher dissolved total Hg concentrations than predicted by speciation models. This information is directly applicable to the effective management of the Sacramento-San Joaquin Delta, and has important implications for planners of the Bay-Delta restoration program.