Headwater Mercury Source Reduction Strategy in the Sierra Nevada

Carrie Monohan, The Sierra Fund and California State University, Chico, carrie.monohan@sierrafund.org
Alexandria Keeble-Toll, The Sierra Fund and California State University, Chico, alex.keeble-toll@sierrafund.org

The State of California's longest neglected environmental problem is mercury contamination from the Gold Rush. The largest contributor to the Bay Delta mercury load is the tributaries in the Sierra Nevada and in the Coast range. Mercury contaminated sediment from legacy gold mines in the Sierra continues to be a source of inorganic mercury (Hg) to the environment. Watershed-wide management decisions need to be informed by an understanding of mercury fate and transport that begins with accurate data for headwater legacy mine sources. Remediation strategies for hydraulic mines often includes the retention of contaminated sediment on site, creating or enlarging a pond, and the extent to which these ponds become areas where mercury can methylate is largely unknown. Mining and mercury use was extensive in the Yuba, Bear and American River watersheds and mercury contamination in these watersheds is pervasive. Fish mercury concentrations in the reservoirs of these watersheds reflect the long-lasting effects of mercury pollution as well as the imminent threat to public health through sport fish consumption. Remediation of contaminated sediment accumulated behind reservoirs using innovative technology may reduce the fish mercury levels in sport fish. Baseline data of fish mercury concentrations in reservoirs before and after remediation of contaminated sediment is critical to measuring success. The Headwater Mercury Source Reduction Strategy is informed by data from these efforts. Future work includes the inventory of the mercury sources in the Yuba and Bear River Watersheds on the Tahoe and Plumas National Forests, the evaluation of these sources in order to prioritize them for remediation, and standardizing methods for their assessment and remediation. The Strategy will be incorporated into the updated Forest Plan, institutionalizing this project into future land management decisions that address legacy mercury contamination in the State of California.

Keywords: Mercury, Headwaters, Source, Fish, Sediment, Mines, Risk, Baseline, Strategy, Remediation

Poster Cluster: Headwater Mercury Source Reduction Strategies

Sediment and Mercury Loads to Humbug Creek:
A Sierra Nevada Tributary Impacted by the Malakoff Diggins Hydraulic Mine

Carrie Monohan, The Sierra Fund and California State University, Chico, carrie.monohan@sierrafund.org
Harihar Nepal, California State University, Chico, carrie.monohan@sierrafund.org

The largest contributor to the Bay-Delta mercury load is the tributaries in the Sierra Nevada and in the Coast range. Mercury contaminated sediment from legacy gold mines in the Sierra continues to be a source of inorganic mercury (Hg) to the environment. The discharge from Malakoff Diggins, once one of the largest hydraulic mines in California, is a source of Hg and sediment to Humbug Creek. The purpose of this study was to estimate the load of particulate bound Hg and suspended sediment in Humbug Creek for Water Years 2012 and 2013. Grab samples were taken from baseflow and multiple storm events and analyzed for nonfiltered Hg (total), filtered Hg (dissolved) and total suspended sediment (TSS). A stage discharge relationship was developed for the Humbug Creek gage station over a range of flow conditions. Samples were collected from Humbug Creek upstream of the Malakoff Diggins discharge point, from the discharge point and downstream of the discharge and Humbug Creek confluence at a stream gage. The annual load in Humbug Creek for suspended sediment and particulate bound Hg was calculated at the gage using relationships established with continuously monitored turbidity (15 min data) and grab samples of total suspended sediment (n = 25, R^2 = 0.82) and particulate bound Hg (n = 15, R^2 = 0.80). The annual load was 100-120 grams of particulate bound Hg and 475,000-575,000 kg of suspended sediment. For both water years, as much as half of the annual sediment load was from a single storm event during which 3-4g of particulate bound mercury was released per day. The contribution of mercury loads from legacy hydraulic gold mines should be quantified as it is a critical source control strategy to the Bay-Delta Mercury TMDL.

Keywords: Mercury, Headwaters, Source, Sediment, Mines, Load, Discharge, Baseline, Strategy, Particulate, Turbidity

Poster Cluster: Headwater Mercury Source Reduction Strategies

Mercury in Fish of the American and Bear Watershed Reservoirs: Baseline Conditions and Exposure Risk at Lake Clementine and Rollins Reservoir, CA

Alexandria Keeble-Toll*, The Sierra Fund and California State University, Chico, alex.keeble-toll@sierrafund.org
Carrie Monohan, The Sierra Fund and California State University, Chico, carrie.monohan@sierrafund.org

The largest contributor to the Bay-Delta mercury load is the tributaries in the Sierra Nevada and in the Coast range. The primary pathway of human exposure to mercury is the consumption of contaminated fish. Identification of patterns of fish tissue mercury levels are a key mechanism for understanding risk drivers and human exposure potential. Site-specific fish tissue data aid the Office of Environmental Health Hazard Assessment (OEHHA) in the development of consumption advisories and establish baseline conditions to evaluate headwater mercury source reduction strategies at legacy gold mines. This research consists of Year 1 of a three year project to collect fish data from six reservoirs downstream of historic hydraulic mines in the Cosumnes, American, Bear, Yuba watershed region. Angler survey data informed sampling to ensure that commonly caught and consumed species were harvested from Lake Clementine and Rollins Reservoir. A total of 72 samples from four species groups were collected in 2015. Geometric mean THg (ppm, wet weight) were highest for black bass at both Lake Clementine ($n = 8$, THg = 0.41) and Rollins Reservoir ($n = 26$, THg = 0.60), with a significant positive relationship between fish total length and THg at both water bodies (rho = 0.85, $p<0.05$; rho = 0.85, $p<0.01$). Sunfish data for both reservoirs were lower in THg than black bass ($n = 29$, THg= 0.16; $n = 24$; THg = 0.20), with a significant positive relationship between fish total length and THg at Lake Clementine (rho = 0.83, $p<0.01$). These data allow OEHHA to develop warranted site-specific fish consumption advice at both locations and can be used as a metric to determine if actions to address inorganic mercury (Hg) sources at legacy gold mines result in reduced human exposure risk at downstream waterbodies.

Keywords: Mercury, Headwaters, Source, Fish, Exposure, Mines, Risk, Health, Baseline, Strategy

Poster Cluster: Headwater Mercury Source Reduction Strategies

Metal-Based Coagulant Effect on Dredged Sediment Slurry for Lake Combie Reservoir Sediment and Mercury Removal Project, Grass Valley CA

Nicholas Graham*, California State University, Chico, ngraham7@mail.csuchico.edu
Sandrine Matiasek, California State University, Chico, smatiasek@csuchico.edu
Carrie Monohan, The Sierra Fund and California State University, Chico, carrie.monohan@sierrafund.org

The largest contributor to the Bay-Delta mercury load is the tributaries in the Sierra Nevada and in the Coast range. Removal and treatment of mercury contaminated sediment from behind reservoirs may be an effective control strategy to limit the downstream transport of mercury. This study was conducted to assist the Nevada Irrigation District (NID) with the analysis of the sediment and mercury removal and treatment process at Lake Combie Reservoir. Sediment removal from the reservoir creates a turbid slurry that was tested and treated before water was returned to the reservoir. Bench scale jar tests were conducted using varying concentrations of coagulants to determine an effective dose for field scale tests. Field scale tests were conducted using batch material from the reservoir and monitored at multiple treatment steps until the treated water was adequate for release. Treated slurry water was tested for turbidity and metals concentrations, including Mercury (Hg), Chromium (Cr), Iron (Fe), Molybdenum (Mo), Nickel (Ni), and Zinc (Zn). This study presents a method for continuous in-situ prediction of total mercury (THg) and dissolved mercury (DHg) concentrations using in-situ measureable parameters as proxies for mercury in the treatment process. These parameters (TSS, TDS, and UV_{254}) were selected using a step wise multivariate regression model with p-values <0.0001 and R^2 values equal to 0.85 and 0.97 for the prediction of DHg and THg, respectively. Removal and treatment of sediment from contaminated reservoirs will remove an environmental toxin, mercury, from the aquatic environment and improve reservoir trapping efficiency and water storage space, creating a multiple benefits solution to a legacy contamination problem that has both local and regional effects.

Keywords: Mercury, Source, Headwaters, Reservoirs, Mines, Coagulant, Treatment, Storage, Removal, Transport

Poster Cluster: Headwater Mercury Source Reduction Strategies

Shallow Subsurface Groundwater Quality and Flow Paths in the Malakoff Diggins Hydraulic Pit

Travis Moore*, California State University, Chico, mooretravis098@gmail.com
Sandrine Matiasek, California State University, Chico, smatiasek@csuchico.edu
Steffen Mehl, California State University, Chico, smehl@csuchico.edu
Carrie Monohan, The Sierra Fund and California State University, Chico, carrie.monohan@sierrafund.org

Remediation of hydraulic mines with contaminated discharge often involves creating or enlarging a pit pond. Characterization of the shallow groundwater environment is critical baseline data prior to remediation because methylation of mercury is more efficient in environments with low dissolved oxygen, high organic matter and sulfate and iron reducing bacteria. This study aims to characterize the shallow groundwater environment in the Pit at Malakoff Diggins, once the State's largest hydraulic mine site, and to determine its contribution to Hiller Tunnel, a point source of contaminated surface water discharge. Constituents including dissolved oxygen (DO), pH, temperature, electrical conductivity (EC), and oxidation reduction potential (ORP) were measured in eight piezometers bi-weekly starting in November 2015. Water quality in Hiller Tunnel was measured bi-weekly starting in April 2016. Preliminary data indicates that DO varied spatially and temporally while EC varied spatially. Groundwater in piezometers at the edge of the pit near where surface water enters the Pit had higher concentrations of DO (1.82 – 3.81 mg/L) and EC (0.893 – 1.667 mS/cm) compared to groundwater distal to the surface water sources. pH was neutral to slightly acidic on average at all locations (6.18 – 7.15). High DO may be attributed to freshly mixed runoff percolating into the subsurface. ORP may be related to the proximity to surface water inflow. Piezometers further from the surface water inflow had reducing conditions (0 – -141.5 ORP), which is consistent with lower DO (0.13 – 1.43 mg/L) at these locations. Future work will include determination of dissolved organic carbon and metals concentrations (mercury, methylmercury, copper, lead, nickel, and zinc) in the shallow groundwater of the Pit. This information is pertinent to Bay- Delta management because Malakoff Diggins is a known source of sediment and mercury contamination to the South Yuba River, a tributary to the Bay-Delta system.

Keywords: Mercury, Headwaters, Source, Sediment, Mines, Methylation, Groundwater, Remediation, Water Quality

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