

EFFECTS OF WETLANDS RESTORATION ON THE PRODUCTION OF METHYL MERCURY IN THE SAN FRANCISCO BAY-DELTA SYSTEM: PRELIMINARY RESULTS

Thomas H. Suchanek¹, Darell G. Slotton², Brenda S. Johnson¹, Shaun Ayers², and Douglas C. Nelson³

¹Department of Wildlife, Fish & Conservation Biology, UC Davis

²Department of Environmental Science & Policy, UC Davis

³Section of Microbiology, Division of Biological Sciences, UC Davis

BACKGROUND

Mercury pollution and, particularly, the bioaccumulation of toxic methyl mercury in food webs, is a global problem impacting aquatic ecosystems and all consumers of aquatic organisms. The toxicity of mercury to higher order consumers of aquatic organisms is well documented, although its effects on reproduction, development, and juveniles of aquatic and aquatic-feeding species is only poorly understood. Mercury constitutes a significant potential human health hazard through consumption of fish caught from the San Francisco Bay-Delta (hereafter: Bay-Delta) and it has been identified by most California state agencies as an aquatic pollutant of great concern. Because of the widespread nature of mining-related bulk mercury contamination in California (see below), virtually every sub-region of the Bay-Delta and its watershed is affected. All of the named CALFED priority habitats and priority species (in addition to numerous others) are exposed to this ecosystem stressor.

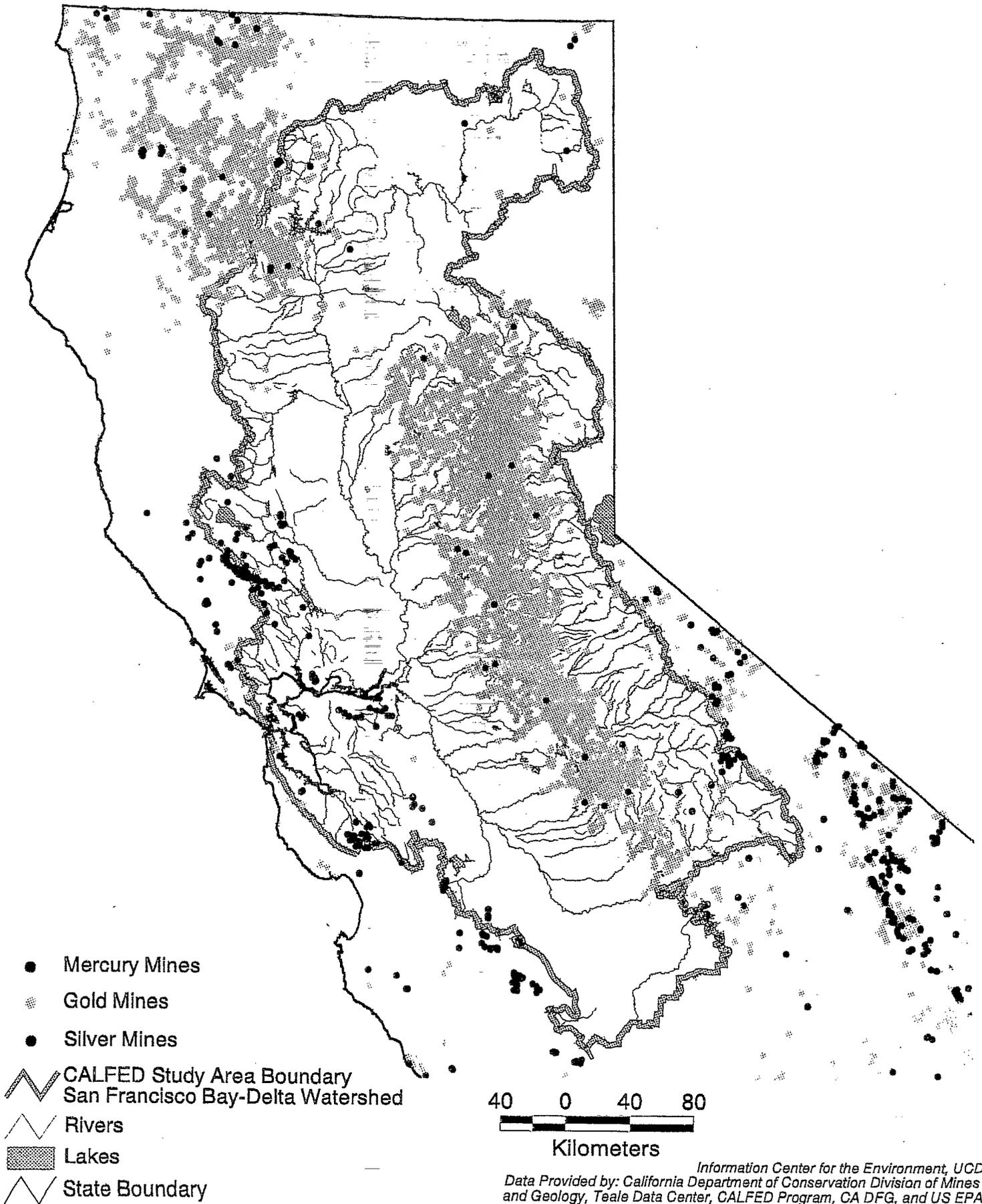
During the past 150 years, large amounts of mercury coming from mines in the California Coast Range, as well as residual mercury from gold and silver mining in the Sierra Nevada, have been, and continue to be, deposited in Bay-Delta sediments (see Figure 1 for distribution of mines). The extensive Sacramento-San Joaquin Delta levee system that originated in the 1860s effectively isolated and converted ("reclaimed") wetlands for the production of agricultural crops and other uses, and in doing so dramatically altered the natural functioning of these wetlands. Many levees were likely constructed in locations which already contained considerable mercury

deposits, and some of these historic, mercury-laden diked wetlands have long been isolated from normal tidal inundation. Upstream, mercury is still being released from contaminated watersheds and it continues to be transported to Delta environments by way of sediments, water, and organisms.

It is well known that newly flooded wetlands typically produce elevated levels of methyl mercury (Cox and others 1977; Bodaly and others 1984; Slotton 1991). This phenomenon occurs even under conditions in which *in situ* mercury concentrations are relatively low. In addition to the "new flooding" phenomenon of initially enhanced mercury methylation, wetland habitats have been found to promote mercury methylation at enhanced rates on an ongoing basis as well. Because some of the projected restoration projects for the San Francisco Bay-Delta system involve the intentional breaching of existing dikes and levees, with subsequent flooding or re-inundation of adjacent areas to create "restored" (reflooded) wetlands, there is a tangible risk that these restoration activities will increase levels of toxic methyl mercury entering the Bay-Delta ecosystem. Indeed, with natural breaching of some of the Bay-Delta levees (from storm and flooding events), there have likely been notable, but unquantified, increases in the level of methyl mercury production from these tracts. In addition, some source watersheds, depending on the distribution, nature, and magnitude of mining, likely contribute disproportionately to regional mercury loading, resulting in locally high concentrations of mercury. Environmental gradients in salinity, organic matter, and other toxic contaminants such as selenium, are known to affect mercury cycling and may also influence production of methyl mercury in the Bay-Delta.

Future restoration projects involving deliberate breaching of existing dikes and levees will likely result in a similar production of methyl mercury as a result of new flooding. Thus it is important that we quantify the potential risks of any future restoration project to the ecological health of the Bay-Delta system.

Figure 1. Mercury, Gold, and Silver Mines



OBJECTIVES

The goal of our project is to investigate Delta tracts that have been flooded inadvertently by storm events (over the past 1 to 75 years), together with additional representative sites throughout the region, to evaluate the potential impacts of projected restoration projects on biologically available mercury in different regions of the Bay-Delta system. These data will be used to make recommendations that are intended to improve water quality in this ecosystem, and hence minimize the exposure of biological resources to toxic mercury.

To accomplish this goal, our project focuses on two primary objectives:

1. Determine if methyl mercury distribution, production, and bioaccumulation vary along physical, chemical, and biological gradients that exist in the Delta (for example, watershed source, mercury source, time since reflooding, salinity gradient, selenium concentration, and vegetation type).
2. Determine if the restoration and rehabilitation (reflooding) of diked tidal wetlands further

exacerbates the production and bioaccumulation of methyl mercury in the Delta.

APPROACH

We have chosen representative sites throughout the Delta at which we are evaluating historical mercury deposition (in cores) and the relative localized concentrations of biologically available mercury through the collection of key biological samples. At a subset of these sites, the potential for methyl mercury production is being further evaluated with a variety of sediment core experiments conducted in the laboratory.

Field collections for this project were initiated in fall 1998, with extensive sampling throughout October and November. Biological sampling across trophic levels was conducted at 29 sites throughout the Delta (Figure 2) and across gradients of several key parameters, which may be important in methyl mercury production. At each site we attempted to seine small fishes, trap crayfish and collect bivalves and amphipods. Biota were analyzed for total mercury using standard cold vapor atomic absorption spectrometry at our UC Davis Environmental Mercury Laboratory.

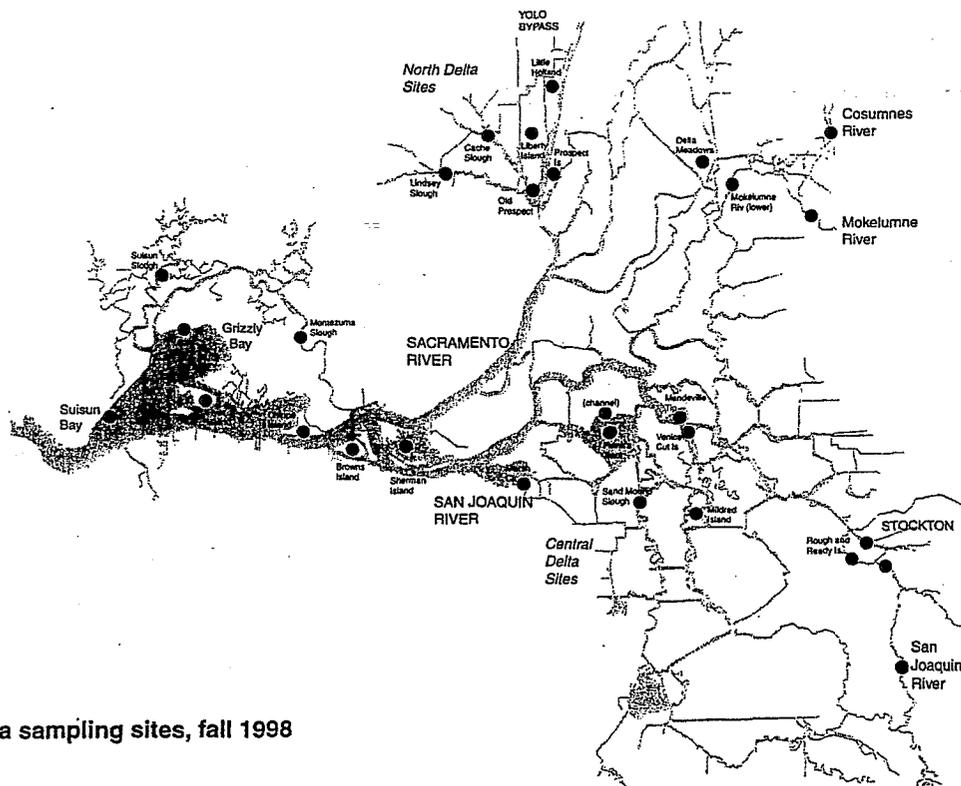


Figure 2 Delta sampling sites, fall 1998

PRELIMINARY RESULTS

Distribution of Biota

Our focus is on organisms most likely to have accumulated their mercury burdens at or very near the site captured. As opposed to wide ranging adult fish, these include smaller, more sedentary taxa such as sculpins, gobies, logperch, crayfish, clams, and small invertebrates. Not all biota of interest were obtainable at all sites studied, so comparisons among sites is somewhat restricted for many species. Two taxa that were moderately abundant across most sites were crayfish (benthic omnivores) and silversides (planktivores).

Crayfish

We collected two species of crayfish: (1) *Procambarus clarkii* (the introduced Louisiana swamp crayfish which typically constructs burrows in muddy substrata), and (2) *Pacifasticus leniusculus* (the introduced signal crayfish which is usually found in rocky habitats and faster moving water). At most sites we captured only one species, but we are hopeful that future sampling will generate more sites with both species to facilitate interspecific comparisons.

- Concentrations of mercury in crayfish were not uniform throughout the Delta. Some sites exhibited relatively low mercury concentrations, whereas mercury in crayfish at other sites was notably elevated. We observed a nearly five-fold range in mercury concentrations for *Pacifasticus* and about a 16-fold range in *Procambarus*, with the highest concentrations over 2.0 ppm dry weight (wt) (Figure 3).
- Elevated mercury concentrations in crayfish occurred at locations in and downstream of the Cosumnes River and at many North Delta sites exposed to Yolo Bypass and Sacramento River flows (in other words, Little Holland Tract, Liberty Island, Cache Slough, Lindsey Slough and Old Prospect tracts). Elevated mercury levels in *Pacifasticus* were also observed in channels near Frank's Tract and Mandeville Island.

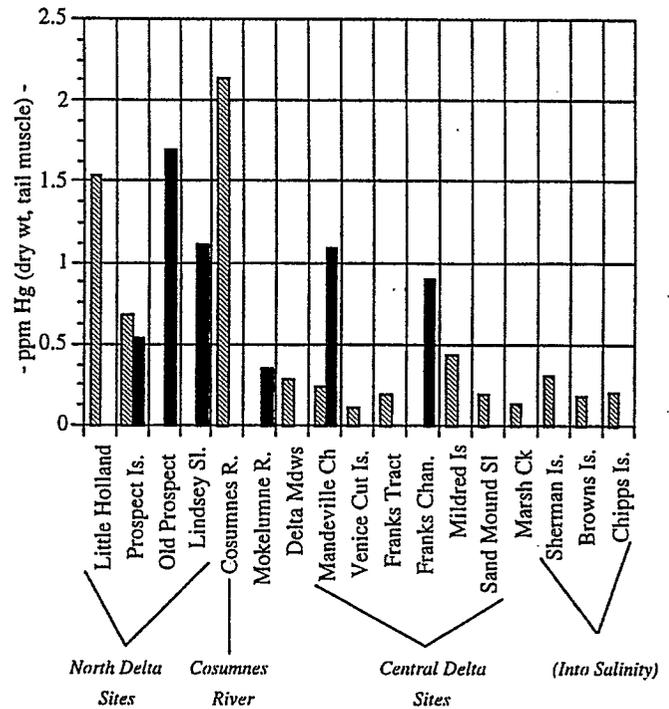


Figure 3 Mean mercury in two species of crayfish (*Procambarus* = striped bars and *Pacifasticus* = solid bars) at 17 Delta sites

- There is no clear relationship between the concentration of mercury in crayfish and time since flooding of a particular tract. Some of the preliminary data (Figure 4) may suggest a possible peak within the Old Prospect tract, which has an age since flooding of 36 years. However, peaks seen in the preliminary data are also confounded by the fact that Little Holland Tract and Old Prospect are both in the path of water flowing through the Yolo Bypass in winter, some of which originates in the mercury-rich coast range. More intensive sampling, with more replicates and from other variously aged tracts will be needed to elucidate this pattern further.

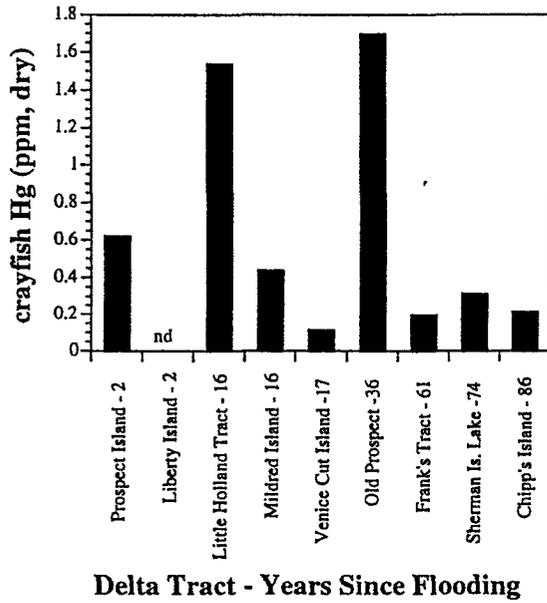


Figure 4 Mercury in crayfish as a function of "years since flooding" in Delta tracts. The letters "nd" indicate no data available.

Fishes

We collected 15 species of small fishes by seining, but in these preliminary results we report only on the introduced inland silverside, *Menidia beryllina*, which was the most ubiquitous species collected (Figure 5). Other species collected include threadfin shad (*Dorosoma petenense*, introduced), bigscale logperch (*Percina macrolepida*, introduced), prickly sculpin (*Cottus asper*, native), red shiner (*Notropis lutrensis*, introduced), shi-mofuri gobi (*Tridentiger bifasciatus*, introduced), yellow-fin goby (*Acanthogobius flavimanus*, introduced), tule perch (*Hysterochampus traski*, native), mosquitofish (*Gambusia affinis*, introduced), and juveniles of the following species: bluegill sunfish (*Lepomis macrochirus*, introduced), redear sunfish (*Lepomis microlophus*, introduced), white crappie (*Pomoxis annularis*, introduced), largemouth bass (*Micropterus salmoides*, introduced), striped bass (*Morone saxatilis*, introduced), and splittail (*Pogonichthys macrolepidotus*, native).

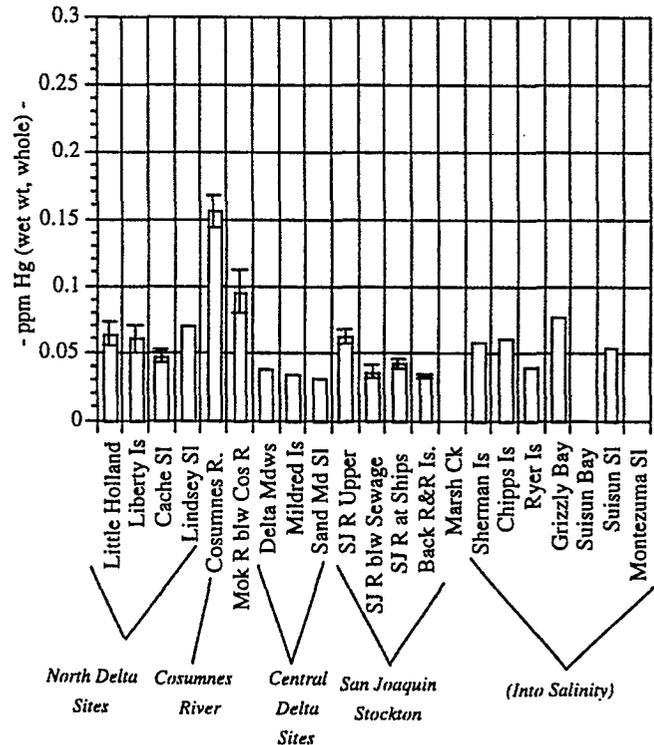


Figure 5 Mean mercury in multi-individual, whole body composites of silversides for size class 2 (45 to 60 mm length) at 18 Delta sites ± standard deviation for sites with three replicates

- As with crayfish, silversides exhibited elevated mercury levels in the Cosumnes River. Concentrations remained notably elevated well downstream of the Cosumnes River confluence, in the lower Mokelumne River. Somewhat surprisingly, silversides also exhibited higher mercury concentrations in the San Joaquin River above Stockton than at or below that urban site. Slightly elevated concentrations from the Suisun and Grizzly Bay area may be indicative of a salinity-enhancement effect or localized mercury deposits.
- The preliminary data do not suggest any strong trends in the concentration of mercury in silversides as a function of time since the flooding of a particular tract (Figure 6). The variability in mercury concentrations in silversides is considerably less than that for crayfish. And, we were unable to collect silversides for some of the intermediate aged tracts such as Old Prospect Island, where cray-

fish exhibited the highest mercury concentrations. Additional sampling during 1999 will provide further evidence to evaluate the influence of this parameter on mercury uptake.

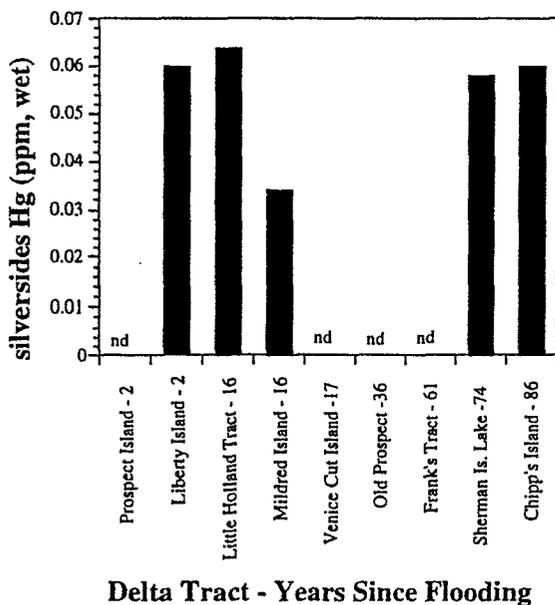


Figure 6 Mercury in silversides as a function of "time since flooding" in Delta tracts. The letters "nd" indicate no data available.

CONCLUSIONS

Contrary to some previous assumptions, preliminary data from a single field season with limited replication suggest that mercury concentrations in biota are not uniform throughout the Delta. In fact they may vary widely, by as much as 10- to 20-fold within taxa and among sites. There are numerous gradients that could contribute to the variability in mercury concentrations in biota among various Delta sites. These potential gradients include source regions of riverine inputs (Sierra compared to Coast Range), chemical composition of mercury sources (originating from different mine sites or different regions within individual mines), time since flooding, salinity, extent of vegetation coverage, plant community or stage of succession, sediment resuspension, speed and direction of current flow and presence of other contaminants, among others. The preliminary results indicate that proximity to key watershed mercury source regions may be an important factor influencing relative mercury bioavailability.

Further sampling is necessary to test the significance of these various gradients on the production and bioaccumulation of mercury within various Delta habitats. The next phase in our analysis will also include establishment and sampling from *ex situ* microcosm experiments to determine potential local rates of mercury methylation.

RELEVANCE TO BAY-DELTA MANAGEMENT-LEVEL DECISIONS

Regions demonstrating enhanced mercury bioavailability may not be the most desirable locations for large-scale wetland restoration efforts, particularly if similar habitat options are available at alternate sites. Regions exhibiting relatively low mercury bioaccumulation may suggest sites for alternative restoration and rehabilitation plans. At sites where there is already a commitment for restoration, it may be possible to modify engineering plans to minimize the mercury-related consequences of the projects. For example, alternate levee breaching schemes may be possible at several of these sites, with dramatically lower mercury source water and suspended sediment present on one side as compared to the other. The McCormick-Williamson Tract and Prospect Island appear to offer exactly this type of alternative. These kinds of specific alternatives will be investigated in greater detail in ongoing work. We may also be able to develop additional management options aimed at the minimization of mercury bioaccumulation, both at individual restoration sites and regionally. The initial findings of this project confirm that mercury considerations should be addressed in wetlands restoration plans for the Bay-Delta system.

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- Slotton DG. 1991. Mercury bioaccumulation in a newly impounded northern California reservoir [dissertation]. Davis (CA): University of California, Davis. 363 p. Available from: Division of Environmental Studies, University of California, Davis.