Mercury and Methylmercury Processes in North San Francisco Bay Tidal Wetland Ecosystems- CalFed ERP02D-P62 Annual Project Report 2005

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B. Introduction

Efforts to restore wetland ecosystems are being proposed or underway in various areas of the San Francisco Bay estuary. Although wetland restoration provides ecological benefit, in some cases restoration of mercury-contaminated areas may negatively impact wildlife or human health. Among the concerns are impacts on vertebrates that are linked closely with tidal marsh habitats that may accumulate potentially harmful concentrations of mercury (Hg), including state-listed threatened species like the California Black Rail. The goals of this study are to improve understanding of environmental processes including:

- The spatial and temporal distribution of total mercury (Hg_T) and methylmercury (MeHg) in selected tidal wetlands
- Factors influencing the net methylation of Hg in these areas
- MeHg bioaccumulation and potential impacts in California Black Rails and other species at lower trophic levels in these environments
- Contribution of MeHg in tidal wetlands to the rest of the San Francisco estuary

Improved understanding of these ecosystem processes will allow better management of wetland restoration through informed decision-making to minimize negative impacts on wildlife and human health.

Previous studies (primarily freshwater) have found correlations between MeHg and percentage of wetland coverage in watersheds (Hurley et al. 1995; Rudd 1995; St. Louis et al. 1996), although identifying the specific causal factors (chemical, physical, hydrological) with wetland abundance has remained elusive. Hg present in soils and vegetation is released to aquatic environments after flooding and transformed into MeHg, with resulting increases in fish tissue concentrations (Bodaly et al. 1984; Hecky et al. 1987; Kelly et al. 1997). MeHg is particularly high in newly flooded wetlands, due to large quantities of organic carbon available for bacteria to generate anaerobic conditions (Kelly et al. 1997).

Newly flooded restored wetlands in the Bay-Delta could also result in a similar spike in environmental MeHg concentrations. MeHg degradation in the environment would reduce the impact of a single spike over time, but a concern for longer-term ecosystem health is cycling on annual and shorter time scales that result in repeated production and distribution of MeHg, e.g. cycling on diurnal, daily and monthly tidal cycles, and annual seasonal cycles in precipitation, riverine flows, and temperatures.

A number of environmental parameters such as total mercury (Hg_T) (Benoit et al. 1998; Watras et al. 1995a), salinity (Barkay et al. 1997; Mason et al. 1996), sulfate (Benoit et al. 1998; Chen et al. 1997; Gilmour et al. 1998; Oremland et al. 1995), sulfide (Benoit et al. 1999), temperature (Choi et al. 1994), pH (Rose et al. 1999; Westcott and Kalff 1996; Xun et al. 1987), dissolved or total organic carbon (Barkay et al. 1997; Krabbenhoft et al. 1995; Westcott and Kalff 1996), and wetting and drying cycles (Krabbenhoft et al., 2005) have been shown to influence Hg bioaccumulation and MeHg production or degradation. These factors may interact in antagonistic or synergistic manners and can vary in wetlands spatially and on annual and smaller time scales. This project aims to improve undertanding of these factors on Hg processes in local wetlands.

Current working hypotheses

Problems with Hg contamination arise when a number of factors occur:

- Hg is elevated above natural concentrations;
- Bacterial transformations convert inorganic Hg into MeHg ;
- MeHg bioaccumulates in the food web to harmful levels;
- MeHg is exported to other ecosystems and food webs where it bioaccumulates

Problems may occur in tidal wetlands due to their tendency to entrap sediments (with associated Hg) and hydro-geomorphic and soil characteristics conducive to net MeHg production in habitats supporting wildlife of concern. These conditions will occur in predictable spatial and temporal patterns due the physiographic template of mature marshes. This template serves as the sample frame for assessing patterns of MeHg production that might be translated into habitat design and management recommendations.

Three wetlands along the tidal reach of the Petaluma River are being studied: Black John Slough (BJS), nearest the mouth of the river; Mid-Petaluma Marsh (MP), a well-established ancient marsh approximately halfway between the city of Petaluma and San Pablo Bay; and Gambinini Marsh (GM), the site with most freshwater influence, adjoining a ranch just downstream of the City of Petaluma. A map of the study area is in the Appendix (Fig. A-1).

Project Approach

This study focuses on two habitat elements of the tidal marsh physiographic template: moderate sized sloughs (2^{nd}-3^{rd} order channels) and adjoining high marsh plains. We sample these elements in the habitat of the California Black Rail, a species of special concern targeted as a potential indicator of Hg problems in tidal marshes. Similarities and differences within and among these wetlands will allow us to identify factors that reduce or elevate Hg risks to these birds and other resident biota. Through spatially and temporally distributed sampling among wetlands and habitat elements, we aim to identify factors affecting Hg processes that may be used for management decisions.

Management goals and objectives addressed by the project

Timely scientific information will help natural resource managers minimize the risk of Hg problems by improving tidal wetland design and management practices. Improved information about Hg processes can assist CalFed in assessing potential risks to the ecosystem in tidal wetland restoration. Informed decisions on impacts of restoration location, timing, and design features at the scale of habitat elements can be made to minimize Hg risks. Potential Hg methylation and bioaccumulation are only two of many factors that should be considered; wetland restorations should also be guided by the life cycles and other needs of particularly desired biota (e.g. species endangered or possessing commercial and recreational value). As restorations proceed, additional studies can then be conducted to further refine our understanding of Hg transformation and bioaccumulation in an iterative and adaptive management process.

C. Project Timetable and Milestones

The target start date for the project was fall/winter of 2004/2005 for scouting of sampling locations, with the first sampling to occur in spring of 2005. The start of sampling was slightly delayed due to contracting issues, but were resolved soon enough that birds were captured and tagged by the middle of breeding season for spring 2005. Summer 2005 sampling was conducted on schedule. The need to wait for CBDA subcontract approval for an analytical laboratory subcontract delayed sending of biota samples (for MeHg analysis) but that subcontract was approved in September, so no significant issues remain with regard to schedule. Two more field sampling trips are scheduled for spring and summer of 2006. Monitoring of tide heights and salinity to help assess the tidal hydrological controls on Hg processes of the marsh plains and channels will span at least 12 months of tidal action concurrent with the other sampling efforts. Full analysis and reporting of research results will be completed in 2007.

D. Project Highlights and Results

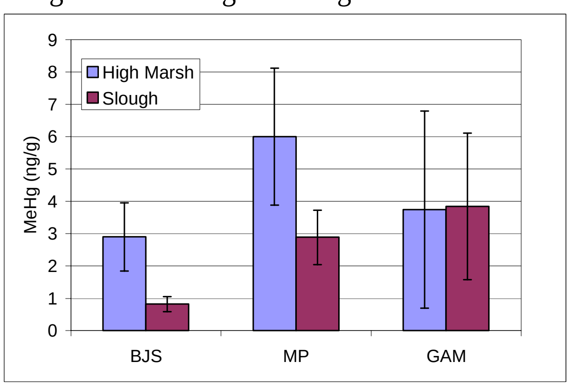
Mercury and methylmercury distribution

Our findings on Hg and MeHg distribution in tidal wetlands to date indicate:

1) Wetland sediment Hg_T concentrations are elevated above natural background, but are not elevated relative to current conditions in the San Francisco Bay-Delta. In contrast, wetland sediment MeHg concentrations are ~10x higher than in San Pablo Bay.

Sediment Hg_T in the study wetlands, range 0.18-0.34 µg/g dry weight in sediment composites from sloughs and high marsh plain, and from 0.10-0.53 µg/g for individual sections from 20 cm cores. In contrast, background concentrations average 0.08 µg/g in deep Bay muds deposited prior to mining and other anthropogenic inputs. However, wetland sediment Hg_T concentrations are similar to those of contemporary human-influenced Bay sediments, averaging ~0.3 µg/g in surface (0-5 cm) sediments collected in San Pablo Bay by the Regional Monitoring Program (RMP) and 0.28 µg/g (range 0.08-.40 µg/g) in NOAA/EMAP. Petaluma wetland sediments primarily originate from many of the same Delta and local watershed sources as those found in San Pablo Bay, as sediments are mixed into the water column and carried with tidal flows into the wetlands. Therefore we expect similar Hg_T concentrations in the Petaluma wetlands and San Pablo Bay sediments.

In contrast, MeHg in Petaluma wetland sediments are significantly elevated (range ~0.5-9 ng/g; average 3.4 ng/g) over RMP San Pablo Bay samples (range 0.2-0.3 ng/g). The highest MeHg levels in sediment are generally observed in high marsh sites, except in GM slough where slough and high marsh concentrations overlap.



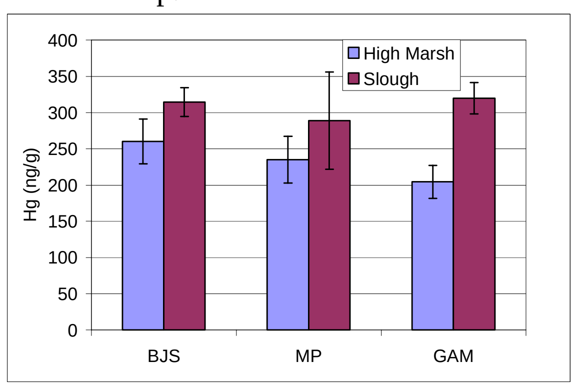


Figure 1. Sediment MeHg and Hg_T in Petaluma wetland habitat elements Differences in Hg_T are small and generally not significant, but MeHg varies among wetlands and between habitat elements.

2) Differences exist in sediment Hg_T and MeHg within and among wetlands.

Differences in sediment Hg_T concentrations are generally not significant, but MeHg concentration differences among wetlands (for a given habitat element) and between habitat elements (for a given wetland) can be significant (Figure 1). Black John Slough (BJS, nearest San Pablo Bay) had the lowest MeHg in both habitat elements, while MP had the most MeHg in high marsh, and GM had the greatest MeHg in slough sediment composites.

Between habitat elements within each wetland, average Hg_T was higher in the slough sediments than in the high marsh plain at all three wetlands, although this difference was not significant ($p > 0.05$) at MP. Sediment composite MeHg concentrations were generally lower in sloughs than in high marsh plains. Slough and marsh plain composites at GM showed similar concentrations, but GM high marsh core surface sections (Figure 2) had MeHg concentrations averaging 3.5x those in sloughs.

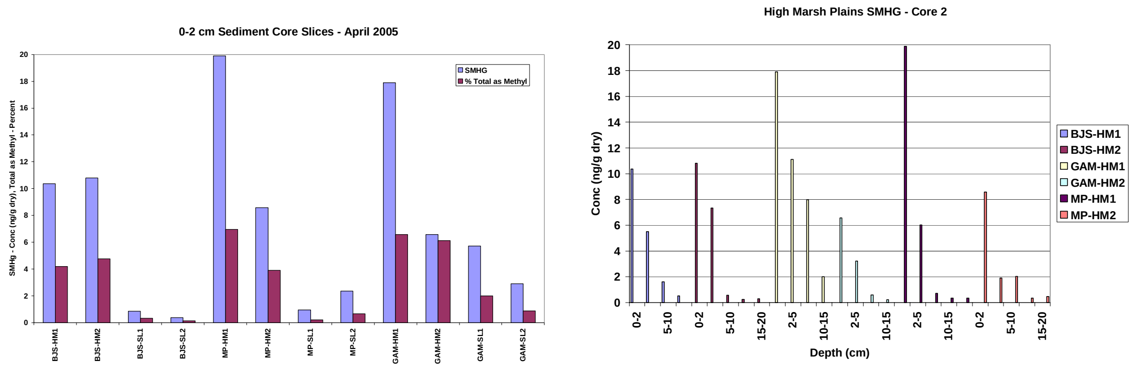


Figure 2. Sediment MeHg in surface (left) and deeper (right) core sections from high marsh plains

Sediment cores from high marsh plains (Figure 2) show declining MeHg with depth, with surface (top 2 cm) concentrations ranging 8-20 ng/g, and much lower (<1 ng/g) concentrations in the deepest (15-20 cm depth) sections. Mirroring sediment composites, individual core surface sections show higher MeHg in high marsh than in sloughs. This is important when considering MeHg exposure in Black Rails and their prey (e.g. benthic invertebrates). The strong depth profiles suggest that sediment MeHg is the result of *de novo* production, rather than transport and deposition to the site like Hg_T. More data is needed to know with confidence what controls MeHg differences, but sediment organic carbon (as loss on ignition (LOI)) correlates strongly with MeHg (Figure 3). This correlation is strongest in surface sections, which is likely due to greater microbial activity (i.e., anaerobic sulfate reducers producing MeHg, discussed later in this report) commonly observed near the sediment-water interface (Krabbenhoft et al., 1998).

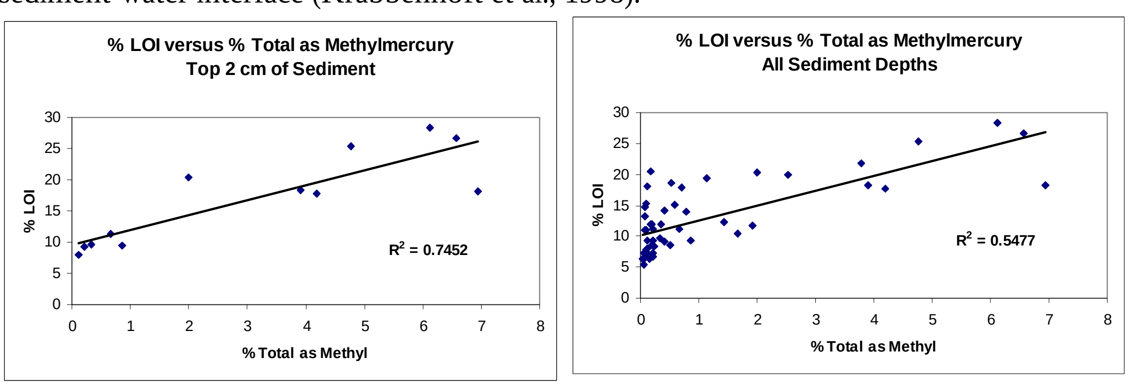


Figure 3. Sediment %MeHg vs LOI in surface (left) and deeper (right) core sections

3) Differences exist in water Hg_T and MeHg among wetlands, largely reflecting patterns seen in slough channel sediments.

Water column concentrations of Hg_T and MeHg were measured only in slough waters, as high marsh plains were only periodically wetted (i.e. dry during our spring sampling). The majority of MeHg and Hg_T in water was found in the particulate phase (68 and 87%, respectively), more than seen in most aquatic ecosystems (Krabbenhoft et al., 1999). Among the three wetlands, dissolved Hg_T (0.7 µm filtered) concentrations in slough samples were lower at BJS than at GM and MP in both spring and summer sampling, although the difference was significant only in spring (Figure 4). Dissolved Hg in slough waters was also lower in summer than in spring (significant at BJS and GM). Analyses of dissolved MeHg in slough waters have also been completed for spring samples, although most were below or near the detection limit (0.04 ng/L).

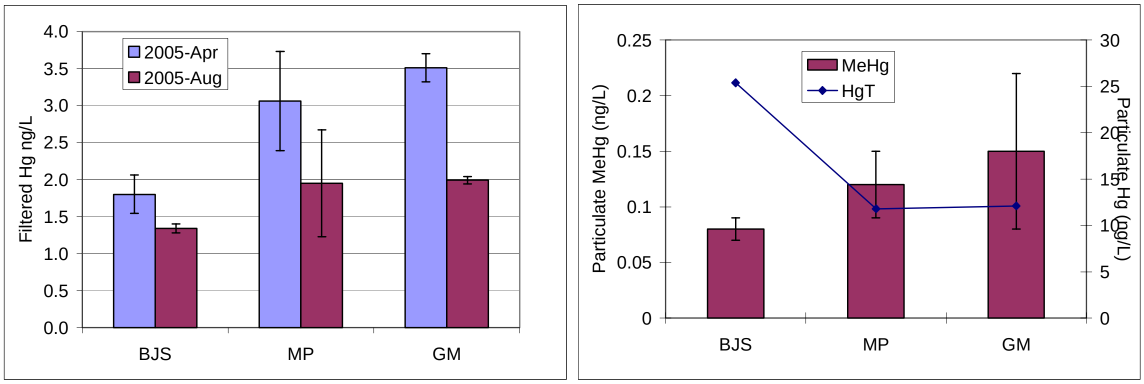


Figure 4. Filtered slough water Hg_T and particulate MeHg and Hg_T (spring sampling only) in Petaluma wetlands. BJS had the lowest MeHg and GM the highest in spring slough waters.

Currently, particulate MeHg analyses in slough water samples have been completed for spring samples, with mean BJS concentrations found to be lower (but not significantly) than those at the other sites. However, particulate Hg_T was significantly higher in BJS sloughs than at the other two stations. BJS had the lowest percentage of MeHg relative to particulate Hg_T in the water column, mirroring the results in BJS slough sediments.

Low MeHg in slough waters is somewhat surprising given the high sediment MeHg levels and generally high (average 9 mg/L) DOC in waters at all the wetlands. The lower MeHg at BJS is in part due to lower DOC in surface water there (average 6 mg/L) compared to MP and GM (both ~10 mg/L). DOC serves to stabilize and mobilize MeHg from sediment to the overlying water column and reduces MeHg photodemethylation. Figure 5 shows results of a photo incubation experiment using filtered and whole site water with added $Me^{199}Hg$ tracer to estimate loss of MeHg to photolysis. Filtered water from BJS has higher rates of photodemethylation, which likely contribute to the lower MeHg in waters seen there. These experiments provide the first known estimates of photodemethylation for SF Bay waters and suggest the importance of this process for overall MeHg mass balance in the region (~80% lost to photodemethylation and volatilization in a week).

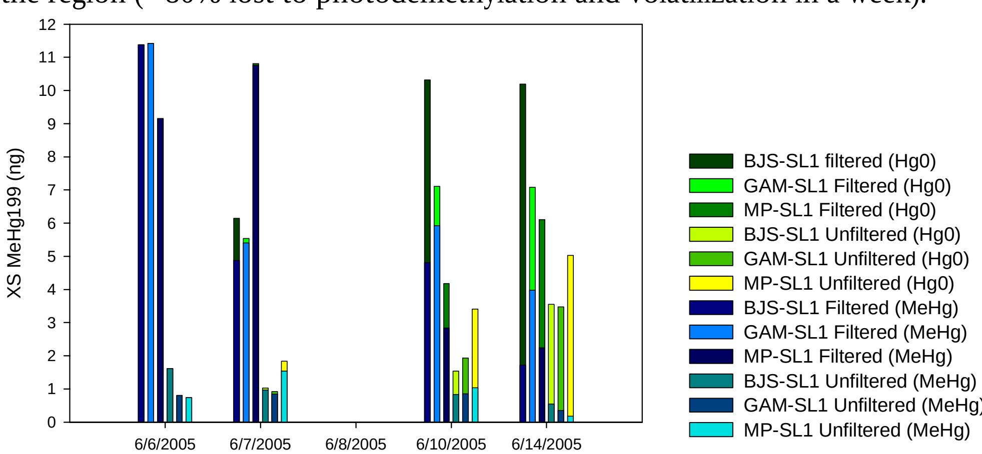


Figure 5. Labelled $Me^{199}Hg$ losses during photo incubation experiment

4) Slough channel water MeHg concentrations are similar to those previously measured in northern San Francisco Estuary.

Concentrations of total MeHg in waters of nearly 0.2 ng/L have been previously reported for northern San Francisco Bay (Choe and Gill 2003). Measurements for the San Francisco Estuary RMP similarly have found concentrations up to ~0.3 ng/L in San Pablo Bay, although the average is below 0.1 ng/L. MeHg in water ebbing from these Petaluma wetlands was approximately in the same range (between 0.11-0.24 ng/L). Given similar concentrations, more temporally and spatially intensive data would be needed to determine whether Petaluma wetland waters are net sources or sinks of MeHg to San Pablo Bay.

5) Hg_T and MeHg concentrations do not correlate spatially and temporally, but MeHg correlates to organic material.

In both high marsh and slough sediments, Hg_T and MeHg concentrations are generally not correlated. This result is not surprising, as mercury methylation is not often Hg limited except at extremely low Hg concentrations. BJS was the only wetland showing a correlation between Hg_T and MeHg in sediments. The correlation was negative, primarily due to the sloughs at BJS having both higher Hg_T and lower MeHg than the high marsh sediments. However, as illustrated previously (Figure 3), sediment MeHg content appears to be strongly correlated with organic carbon levels.

Some studies have found significant correlations between Hg_T and MeHg concentrations in sediments (Benoit et al. 1998) and water (Watras et al. 1995b), but CalFed-funded studies in the Delta have not yet indicated significant influence of Hg_T on net MeHg concentrations (Slotton et al. 2000). Interpretation may thus far be confounded by other factors at the sampled sites. Some research has suggested a threshold (ca. 5,000 ng/g dry wt.) above which additional Hg(II) does not increase MeHg production (Krabbenhoft et al. 1999; Rudd et al. 1983), but Hg_T concentrations at our wetland study sites are well below this threshhold, so the lack of correlation is likely due to other factors

Microbial mercury transformations

We hypothesize that differences in MeHg distribution among and within tidal wetlands are controlled by factors impacting microbial Hg methylation and demethylation. Our findings to date indicate:

1) Higher MeHg in high marsh plains than slough channels reflects geomorphological differences affecting wetland hydrology and multiple biogeochemical factors mediating MeHg production and degradation.

Radiolabeled mercury species (^{203}Hg(II) and Me^{203}Hg) were used in combination with measured concentrations of $Hg(II)_R$ and MeHg to calculate potential rates of MeHg production and degradation, respectively (Figure 6). Results to date suggest strong spatial differences in both mercury cycling dynamics and associated goechemistry between sediments collected in vegetated high marsh plains and those collected in unvegetated sloughs, . Many of these geochemical and microbiological differences between habitat elements may be due to dense vegetation on the high marsh plain. Difference across the plains themselves may also be due to plant ecology, soil bulk density, and tidal inundation regimes that relate to distance from channel banks, factors we have proposed to test in an upcoming project amendment proposal.

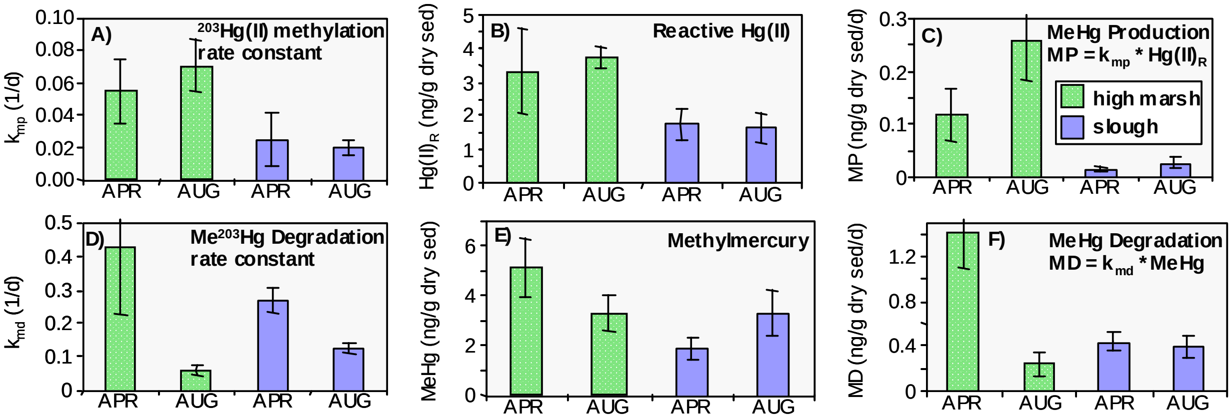


Figure 6. Average (n = 6) values for composite surface sediment (0-2 cm) samples collected from high marsh and slough sites in three Petaluma River wetland regions, during April (APR) and August (AUG) 2005. Parameters include A) ^{203}Hg(II) radiotracer derived methylmercury (MeHg) production rate constants, B) reactive inorganic mercury ($Hg(II)_R$), C) calculated rates of MeHg production, D) Me^{203}Hg radiotracer derived MeHg degradation rate constants, E) MeHg concentrations, and F) calculated potential rates of MeHg degradation.

Environmental variables can affect distribution and activity of bacteria involved in MeHg production and degradation or impact the availability of $Hg(II)_R$ and MeHg to microbes. In this study, controls affecting both were evident. MeHg concentrations (Fig. 6E) and percentages (relative to Hg_T) were higher in high marsh sites due to factors including:

a) higher reactive inorganic Hg (Fig. 6B), the Hg fraction readily available to bacteria
b) lower pH and higher chloride, favoring ionic Hg species and enhancing microbial uptake
c) higher microbial MeHg production and sulfate reduction rates (SRR) rates (Fig. 6A & 6C), indicating the role of sulfate reducing bacteria (SRB) in net MeHg production
d) higher organic content and pore water sulfate, substrates for SRB anaerobic activity
e) lower solid-phase total reduced sulfur (TRS) and moderately anoxic sediments, with decreased sulfide binding of reactive Hg

There was a significant positive relationship between microbial SRR and sediment MeHg (Fig. 7). This correlation is not uncommon, as SRB are key microbes in Hg(II)-methylation. In addition, a negative exponential relationship between solid phase TRS and the percentage of $Hg(II)_R$ available for methylation (Fig. 8) reflected the strong binding of Hg to S. As sediment TRS increases, more of the inorganic Hg(II) binds particle-associated S and becomes less available for methylation.

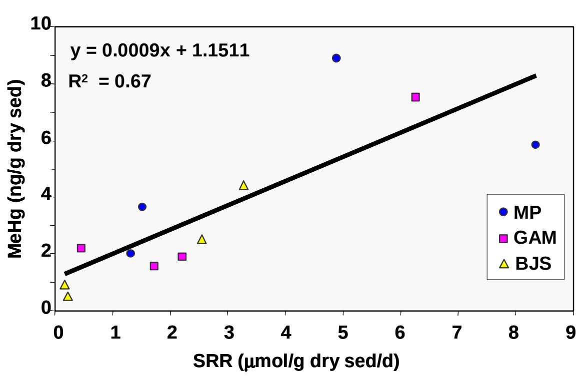


Figure 7. Microbial sulfate reduction rate (SRR) and methylmercury (MeHg) concentration are positively correlated for April 2005 in the three wetlands. SRR data from August 2005 is pending. The best fit linear regression and associated r2 value is given.

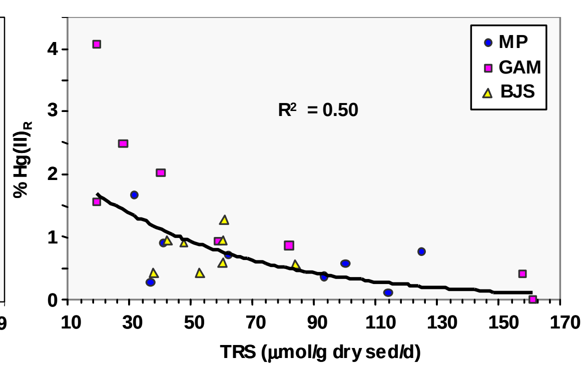


Figure 8. The negative exponential relationship between sediment concentrations of total reduced sulfur (TRS) and the percent of inorganic reactive mercury (% Hg(II)R) during both April and August 2005 for the three wetland regions studied.

Reduced-S content of sediment is typically positively correlated to the activity of sulfate reducing bacteria, so the positive relationship between SRR and MeHg concentration, concurrent with the negative relationship between % Hg(II) and TRS, suggest a balance between microbial activity and Hg(II) availability more optimal in the vegetated high marsh environment than in sloughs. Saltmarsh plants may mitigate reduced-S by transferring oxygen into sediment, which both protects the plant from toxic levels of reduced-S and stimulates microbial activity in the root zone. Since few direct measurements of Hg-dynamics have been made in densely vegetated high marsh wetland environments, enhanced Hg-cycling observed in high marsh compared to adjacent sloughs suggests the importance of plant-mercury interactions, currently very poorly understood.

2) MeHg production and degradation vary seasonally, with higher net production in summer.

There was a general increase in MeHg production (Fig. 6C) and a decrease in MeHg degradation (Fig. 6F) potential rates in high marsh sediments between April and August. One area of uncertainty is the effect of periodic tidal wetting of the high marsh to variability in MeHg concentrations and production/degradation rates. In April (a neap tide series), the high marsh surface was only moist (no standing water), but in August (a spring tide), many areas of high marsh had standing water and higher soil moisture. A field meter to measure oxidation/reduction potential is currently being deployed to determine if noticeable variation in redox conditions occur in high marsh sites on spri ng/neap tidal cycles.

Mercury bioaccumulation

The wetland food web is being studied to determine whether patterns seen in net MeHg production in sediment or water translate into patterns in food web contamination, in particular to resident California Black Rails. Findings to date are described below:

1) California Black Rails were found in all the study wetlands

We captured 64 Black Rails in 2005. Birds were banded, age and sex were determined, and feathers were pulled for Hg and stable isotope analyses. Blood and gut content samples were collected when possible. Blood samples from rails with unknown sex have been sent to Zoogen, Inc. for sex determination.

2) Resident California Black Rails occupy limited ranges, but the wetlands they are found in and their locations within these wetlands differ between spring and summer.

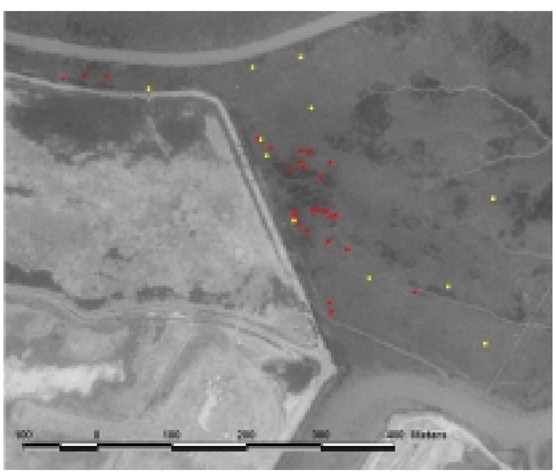


Figure 9. Black Rail locations in spring (red) and summer (yellow) at BJS

Black Rails were found in different areas between spring and summer capture periods. In the spring, rails were detected almost exclusively within 100m of the levee at BJS (red points, Fig. 9) in an area of dense vegetation with mixed *Salicornia virginica* and *Scirpus maritimus*. Rails were more often detected farther into the marsh in the summer (yellow points) in areas with very low *S. virginica*, even during high tide events. At GM, only three birds were detected during spring capture attempts (one successful), all in tall vegetation areas surrounding sloughs. During summer, 12 rails were captured at this site, often in areas of very low *S. virginica*. This seasonal difference may be due to birds dispersing from preferred breeding sites within and among wetlands when they no longer need to maintain nests. At MP, there were no apparent differences in capture locations between seasons.

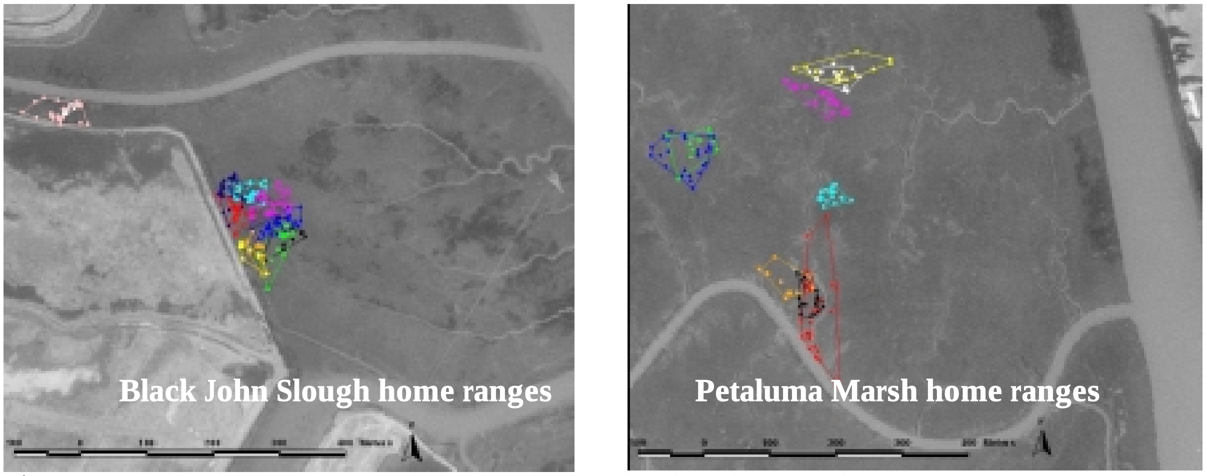


Figure 10. Black Rail home ranges at Black John Slough and Mid-Petaluma Marsh

We tracked 21 radio-marked Black Rails during the breeding period from March-May 2005 (mean 24 locations, 15 days). Home ranges averaged 0.24 ha across all sites. MP home ranges averaged larger (0.34 ha, n=9) than at BJS (0.17 ha, n=11) or GM (0.12 ha, n=1). Rail home ranges at BJS were closely packed with a high degree of overlap. At MP, home ranges were more evenly distributed, with overlap occurring only for paired males and females. Across all sites, home ranges of male Black Rails averaged larger than females (0.29 and 0.18 ha, respectively). This is consistent with studies of other rails; while both sexes share incubation duties, males tend to range farther than females (Legare and Eddelman 2001).

One uncertainty is whether home ranges differ in size between spring and summer. The distribution of capture locations within wetlands (at BJS) and among wetlands (more at GM) expanded in the summer compared to spring, but it is unknown whether the birds occupy a larger home range, as the radio tags did not remain attached through the summer.

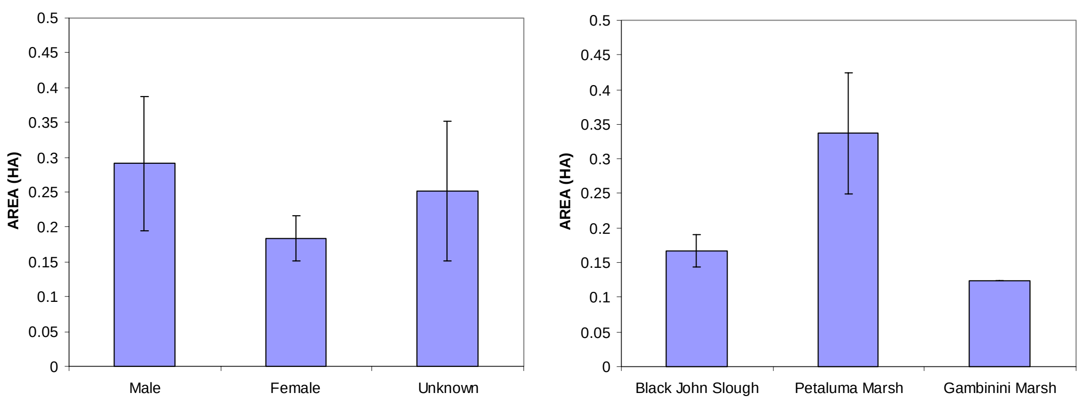


Figure 11. Spring home range size by gender (left) and wetland (right). Home ranges in BJS were significantly smaller than at MP.

3) California Black Rails primarily utilize pickleweed high marsh habitat

For each radio-telemetry location, we recorded water depth and vegetation percent cover, average height, and maximum height (Fig. 12). Rails used areas dominated by *S. virginica*, with 6-8% bare ground at all sites. Average height of dominant vegetation (*S. virginica*) ranged 25.8-35.0 cm. Mean water depth was significantly greater at Black John Slough (0.67 cm), than at by Petaluma Marsh (0.11 cm) and Gambinini Marsh (0.08 cm). Females were located in areas with deeper water than males (0.51 vs 0.23 cm, respectively).

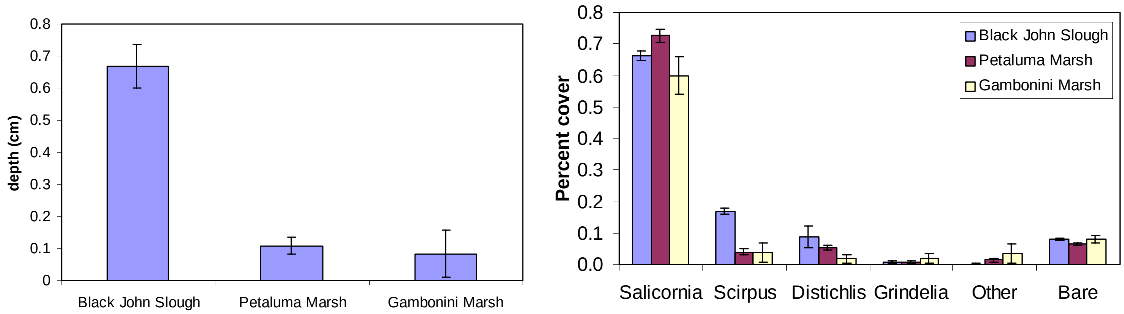


Figure 12. Water depth (left) and vegetation cover (right) at Petaluma wetland Black Rail telemetry locations. Habitat used by Black Rails was predominantly pickleweed in high marsh.

4) California Black Rails are opportunistic, feeding primarily on high marsh plain invertebrates, but specific prey species and relative quantities of each are not resolved.

We collected 21 gut content samples from Black Rails using tartar emetic to induce emesis. Diet samples have been sorted and some items identified. Partially digested parts of beetles, flies, and seeds have been identified. The remaining samples will be identified with asssistance from invertebrate experts at the UC Davis Bohart Museum of Entomology during Fall/Winter 2005-2006.

5) Invertebrates suitable as Black Rail prey items and other resident biota (fish and invertebrates in slough channels) are present, but MeHg analyses are not yet done.

We hypothesize that MeHg concentrations in lower trophic level resident biota will reflect distributions of MeHg in the wetland waters and/or sediments, but results are not yet known. We collected high marsh invertebrates in spring and summer 2005 for mercury and stable isotope analyses. Fish and invertebrates were also collected from the sloughs where sediment sampling occurred in Spring 2005. The number and type of samples collected are summarized in Appendix Table 1. Samples were sent to Battelle for MeHg analysis. Analytical results are expected in late 2005.

6) Mercury in Black Rail feathers mirrors differences in high marsh MeHg among wetlands.

We collected 64 feather and 28 blood samples from birds for Hg and stable isotope analyses. Thirty feather samples were analyzed for total Hg at the USGS Davis Field Station. Black Rails molt feathers only after breeding (July-August), so Hg in feathers collected represent exposure in the previous summer (Figure 13). Rails at MP had the highest mean Hg in feathers (10.33 mg/kg, n=11), followed by BJS (5.89 mg/kg, n=18) and GM (4.61 mg/kg, n=1). Males had slightly higher total Hg than females (8.26 mg/kg, n=13 and 6.78 mg/kg, n=12, respectively). This difference may occur because females can dump Hg into eggs in the spring. Blood samples were sent to Battelle for MeHg analysis and to the USGS Davis Field Station for total mercury analysis. Stable isotope analyses from feather and blood samples will be conducted in fall and winter 2005-2006.

Although differences among wetlands found in feather Hg concentrations are significant, it is unknown whether these differences would affect Black Rail survival and reproductive success rates. A review of Hg effects in wildlife (Wolfe et al. 1998) suggests reproductive impairment can be seen in some bird species with Hg feather concentrations as low as 5 ppm, although toxic risk threshholds as high as 40 ppm in feathers are suggested for some bird species. Assuming that effects in Black Rails are seen at the lower threshhold, Hg concentrations at MP may be of concern.

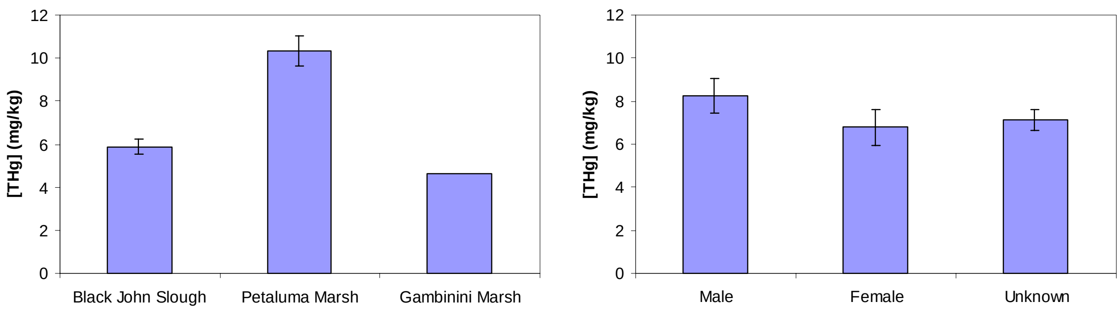


Figure 13. Total Hg in feathers, by wetland (left graph) and by gender (right, for all sites combined)

E. Potential Management Implications of Findings to Date

Information from this study improves our understanding of Hg and MeHg distribution in tidal wetlands for the SF Estuary. Total Hg is fairly evenly distributed among wetlands, so there does not appear to be any elevated Hg source within the main reach of the Petaluma, and Hg_T from atmospheric deposition, watershed urban and non-urban runoff, and sediments from the Bay are sufficiently uniform or well-mixed within the Petaluma system that no gradient is seen in wetlands along the river.

Wetland slough channel sediments (particularly at GM, the lowest salinity site) show higher MeHg concentrations than typically seen in Bay sediments, but slough channel waters show similar concentrations to those already measured in San Pablo Bay. Although much more spatially and temporally intensive sampling would be required to resolve the direction and magnitude of MeHg transport between the wetlands and Bay, the similarity in concentrations does not suggest large export flux from these wetlands.

Concentrations of MeHg in high marsh sediments are greater than those typically found in Bay habitats. High marsh plain MeHg concentrations at the mid-Petaluma wetland were greater than those in high marsh upstream and downstream. Work by other researchers have suggested optimal Hg uptake and methylation at intermediate salinities, but differences found were not likely due to such differences; the greater MeHg at MP relative to other sites occurred in both seasons despite increased average and decreased range in water salinities in summer (3-10ppt from GM to BJS, respectively, for April, to 19-21ppt for August). We will continue to examine the data more closely to identify possible causes for these differences.

Feather Hg concentrations in resident Black Rails closely mirror high marsh plain concentrations of MeHg in surface sediments. It therefore appears likely that management actions that reduce MeHg in sediments could reduce the Hg risk to high marsh biota. Published effects levels for Hg in Black Rails are lacking, but at two of three sites feather Hg concentrations are at the low end of the published effects range for other bird species. Maximum concentrations found thus far exceed this threshhold by a factor of two, but effects could be more severe if Black Rails have relatively high sensitivity to Hg.

Benefits of this information can extend beyond this particular species; by measuring Hg in organisms from lower trophic levels and Hg transformation processes in wetlands, we aim to better understand general mechanisms of MeHg production and bioaccumulation. This information can be used in design of monitoring strategies (e.g. temporal and spatial stratification) and to identify potential factors for controlling Hg risks from wetlands. Identifying factors indicating a high risk for Hg contamination and bioaccumulation in wetlands would also allow managers to make appropriate decisions on how to manage or avoid such risks in choosing and designing restoration projects.

F. (Appendix) Products to date (list reports, publications, and presentations)

Mark Marvin-DiPasquale, Public Presentation: "*Toxic Mercury in Aquatic Ecosystems: Why Quality Trumps Quantity*" , September 29th, 2005, U.S. Geological Survey, Menlo Park, CA. Video-archived on-line at: http://online.wr.usgs.gov/calendar/2005.html

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H. Acknowledgements

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APPENDIX.

		Sample type	ALL SITES			BLACK JOHN SLOUGH			PETALUMA MARSH			GAMBONINI MARSH		
			MeHg	THg	Isotope	MeHg	THg	Isotope	MeHg	THg	Isotope	MeHg	THg	Isotope
High Marsh	Spring05	Pardosa	9	4	9	3	3	3	3	0	3	3	1	3
		Snail	21	12	34	11	5	16	3	2	8	7	5	10
		Beach Hopper	27	14	27	11	4	14	7	5	7	9	5	6
		Mussel	7	4	7	2	1	2	2	1	2	3	2	3
High Marsh	Summer05	Pardosa	9	9	9	3	3	3	3	3	3	3	3	3
		Snail	9	9	9	3	3	3	3	3	3	3	3	3
		Beach Hopper	18	18	18	6	6	6	6	6	6	6	6	6
		Mussel	2	2	2	0	0	0	2	2	2	0	0	0
Channel	Spring05	Mussel	22	22	29	14	14	14	3	3	10	5	5	5
		Macoma	16	13	35	6	2	14	6	10	17	4	1	4
		Amphipod	7	2	12	4	1	4	0	0	4	3	1	4
		Isopod	0	0	6	0	0	2	0	0	1	0	0	3
		Shore Crab	14	14	14	2	2	2	6	6	6	6	6	6
Fish	Spring05	Mosquito fish (adult)	5	1	7	3	1	4	1	0	1	1	0	2
		Mosquito fish (juv)	0	0	5	0	0	1	0	0	1	0	0	3
		Mudsucker (adult)	4	4	4	0	0	0	0	0	0	4	4	4
		Mudsucker (lg juv)	2	2	4	0	0	0	0	0	0	2	2	4
		Mudsucker (sm juv)	0	0	6	0	0	2	0	0	1	0	0	3
		Stickleback	14	14	14	2	2	2	6	6	6	6	6	6
		TOTAL MARSH	102	72	115	39	25	47	29	22	34	34	25	34
		TOTAL CHANNEL	59	51	96	26	19	36	15	19	38	18	13	22
		TOTAL FISH	25	21	40	5	3	9	7	6	9	13	12	22
		GRAND TOTAL	186	144	251	70	47	92	51	47	81	65	50	78

Table A- 1. Benthic and fish samples collected from study wetlands

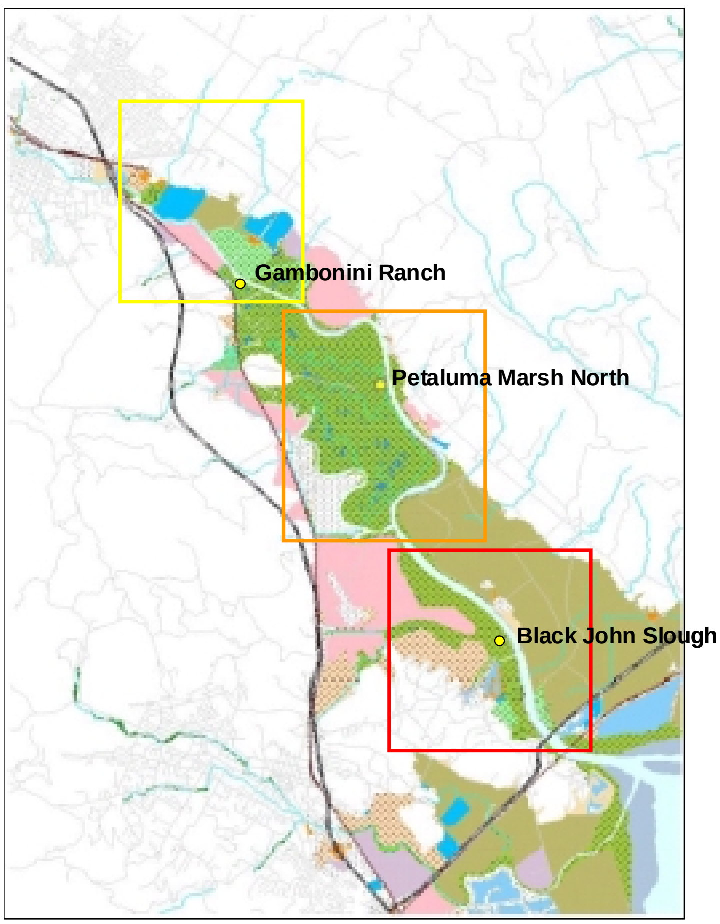

Figure A-1. Map of studied wetlands along the Petaluma River