Forum on Science to Support Management of Methylmercury in Restored Tidal Marshes
December 17th, 2013
California Department of Public Health
Meeting Summary
Facilitator: Christine Boschen

Review of Agenda and Goals of Meeting

Naomi Feger opened the Forum by stating that from 2004 through 2010 the RMP has sponsored workshops on Mercury in San Francisco Bay. This Forum is an outgrowth of those workshops and is meant to open up the conversation, create consistency, and encourage a regional approach for Hg monitoring and process studies. The ultimate goal of the Forum is to ensure the right questions are being asked, in order to help refine the Mercury Strategy for the Bay and to help implement the Mercury TMDL.

Christine Boschen noted that participants will be able to post their comments on the Forum's webpage. Immediate decisions will not be made during the Forum; the goal is to collect information from the scientific community so management decisions can be coordinated. All of the management questions that will be discussed have associated hypotheses. The participants will be asked what degree of confidence they have in the hypotheses and if there is a lack of confidence, what further questions need to be asked.

RMP Mercury Synthesis [Jay Davis]

Jay Davis began his review of the Mercury Synthesis by stating that the RMP formed the Mercury Strategy in 2007, before the TMDL was approved, to be strategic and determine Hg information needs to support management decisions. The Mercury Strategy team came up with a list of priority questions (listed below) that the RMP then used to guide monitoring studies. The San Francisco Bay Mercury Synthesis was a compilation of the results from the monitoring studies conducted as part of the Mercury Strategy and studies done by other programs.

Hg Strategy Priority Questions:

1. Where and when is Hg entering the food web?
2. What are the high leverage processes, sources, and pathways?
3. What are the best opportunities for management intervention?
4. What are the effects of management actions?
5. Will total mercury reductions result in reduced food web accumulations?

Jay then provided some background on Hg's environmental fate. He noted that Hg is present in many forms, but methylmercury (MeHg) is the one form that causes biological harm because it is bioaccumulative and toxic. Methylmercury is a byproduct of bacterial metabolism; sulfate-reducing bacteria in low oxygen areas methylate Hg to form MeHg. Jay made clear that demethylation of MeHg can also occur; it is the net methylation (formation versus degradation) that is important.

Jay noted that Hg has a long residence time, the Hg found in the Bay has been there since the gold rush era. Simply managing total Hg would not result in short-term declines. However, there are potential intervention points including:

1. *Methylation and Demethylation*: Methylation and demethylation rates are dynamic; low oxygen levels can increase methylation rates, while sunlight can cause (photo)demethylation. Aquatic ecosystems can be designed to increase oxygen levels and enhance the amount of sunlight entering the water column.
2. *Biodilution*: If there is a high abundance of phytoplankton, each cell will accumulate a lower amount of MeHg than a system with low phytoplankton abundance. All tropic levels above phytoplankton will then accumulate a lower amount of MeHg. Similarly, fish populations where food is abundant will likely have lower MeHg concentrations because the tissue mass is greater (MeHg is diluted).

Jay then described what the RMP has learned from the three main Mercury Strategy studies (small fish survey, Hg isotope study, and sport fish survey). The small fish survey made clear that small fish are a good indicator of MeHg concentrations in the food web. Few of the samples were below the TMDL target of 0.03 ppm; however, there were no clear high leverage pathways, indicating that there is widespread background Hg impairment in the Bay. The Hg isotope study showed that the Hg isotope patterns in small fish matched those in sediment, indicating that the Hg in sediment is getting into fish. The isotope study also indicated that sediment Hg sources include historic Hg mining in South Bay and gold mining and urban/industrial sources in North Bay. The sport fish survey found that Hg concentrations in San Francisco Bay striped bass were the highest in the nation. The concentrations in striped bass sampled in the 1970s were essentially the same as the concentrations sampled in 2009, consistent with an influence of the Bay's mining legacy. The absence of a decline suggests that atmospheric deposition and other Hg inputs are not the primary source of Hg in the Bay.

The Mercury Synthesis recommended monitoring biosentinel species because they are linked to beneficial uses, integrate over space and time, and indicate Hg exposure in a particular habitat. For example, striped bass integrate over the entire estuary while cormorants and song sparrows forage in the open Bay and in marshes. The synthesis recognized that the options for managing Hg concentrations differs based on habitat (open Bay, tidal marsh, managed pond, and reservoir). Managing Hg inputs from runoff would affect all habitats, but concentration decreases would only be observable over a long period of time.

Jay summarized the various "fast knobs" for managing Hg concentrations in different habitats.

1. Open Bay Knobs: possibly controlling nutrients to alter methylation rates.
2. Tidal Marsh Knobs: managing the design and placement of restored marshes.
3. Managed Pond Knobs: managing the design, placement, and water dynamics in the pond.
4. Reservoir Knobs: water, water chemistry, and fisheries management (most possibilities for Hg management).

<u>Participant Questions:</u>
Brian Bergamaschi asked Jay to explain how controlling nutrients would affect Hg concentrations. Jay responded that if phytoplankton concentrations continue to increase, then there will be biodilution of Hg. However, increasing biomass can also create anoxic conditions, which promotes the sulfate-reducing bacteria that methylate Hg. Therefore, managing nutrient loads could either increase or decrease MeHg concentrations. Jim Wiener noted that one form of intervention that Jay did not mention is public awareness, informing people of the pathways of

Hg exposure. Robert Mason then asked if it was important to separate legacy Hg and Hg from outside sources. Jay replied that it would be useful to separate the two sources because there is more leverage in controlling outside inputs, but the prevailing hypothesis is that both are important.

Manager Information Needs [Richard Looker]

Richard Looker then presented the San Francisco Bay Hg information needs from a regulatory perspective. Mercury contamination in the Bay is a scientifically complex issue, making it challenging for regulators to formulate well-supported management decisions. Richard stated that the reason for the Forum was to learn from the participants the state of the knowledge on the set of management questions the organizers have put forward.

Richard then provided background on water quality regulations. The first is the Basin Plan, which is the master planning document for Bay water quality. The regulatory portion of the Basin Plan includes a list of beneficial uses; numerical and narrative water quality objectives; and information on the implementation program, which ensures the water quality objectives are met. Richard also mentioned the Coastal Zone Management Plan, which is the Bay Conservation and Development Commission's policy guidance document for protecting Bay habitats, wildlife, and water quality.

A Hg TMDL for San Francisco Bay was created because Hg impairs three beneficial uses: 1) sport fishing, 2) wildlife habitat, and 3) preservation of rare and endangered species. Mercury enters the Bay from a variety of sources (e.g., stormwater runoff, WWTPs, and atmospheric deposition). The SFB Water Board considers every molecule of Hg equally likely to be methylated and incorporated into the food web. Based on that assumption, the SFB Water Board determined that if the loading of Hg was reduced from 1,200 to 700 kg/year then the Hg would be reduced, over many decades, to a level that is safe for fish consumption and wildlife.

As part of the TMDL, new Hg water quality objectives were adopted:

1) 0.2 ppm of Hg in large predator fish consumed by human
2) 0.03 ppm in small prey fish to protect wildlife

Wetlands were not included in the TMDL load allocations, despite their role in methylation, because they are not a source of total Hg. The TMDL recognizes that restored wetlands are beneficial, but that they may contribute to MeHg production. Therefore, the TMDL requires permit provisions that state restored wetlands will be designed to minimize MeHg production, result in no net increase in Hg loads to the Bay, and that all projects include pre- and post-restoration monitoring. Richard stated that the SFB Water Board understands that more wetlands habitat may increase the Hg risk, but believes that there is a net benefit in increased wetland habitat. Richard would like the participants to help inform whether the Water Board's positions are correct.

Richard explained how monitoring information can help decision making. Pre-breach monitoring studies can help inform whether it is save to breach, restoration design changes, and new management measures or monitoring requirements. Post-breach studies can be used to

implement adaptive management, inform design and management at other projects, and determine if enhanced monitoring requirements should be required.

Richard then listed the management questions and associated hypotheses that would be discussed during the Forum.

1) *Short-term v long-term impacts*: What is the effect of increased tidal action and impact on methylmercury bioaccumulation in wildlife, within the project and downstream, over timescales of about one year and longer than one year?

   It is possible that a short-term spike in Hg concentrations will be observed, followed by a rapid decline back to steady state. Or, the steady state may be higher than it was before the wetland's restoration.

2) *Local v regional impacts*: What are the local (within the project or immediately downstream) versus regional environmental impacts due to restoration projects?

   The spatial extent of the impacts are unknown, but the hypothesis is that MeHg loading from restored wetlands is minor relative to Bay-wide Hg impairment.

3) *Study Design*: What types of studies do we need to design and conduct (process and biosentinel monitoring) and at what scale?

   Richard noted that the Hg concentrations are generally high throughout the Bay, therefore Bay-wide monitoring would be useful for detecting potential regional impacts.

4) *Restoration Design and Management Actions*: What do we know about designing and managing restoration projects to reduce the risk of mercury impairment (e.g., incorporation of meHg into the foodweb)?

   The current hypothesis is that there is currently not enough information to design tidal marshes to reduce MeHg exposure, but once the information is obtained it will be possible to do so.

Richard ended his presentation by stating that there are many more questions that need to be addressed including the best indicator species and the thresholds of concern for these species; the effect of restoring other types of system other than marshes (e.g. managed ponds); the impacts of climate change; and how the net benefits of wetland restoration can be measured and compared to the overall risk of Hg.

Topic 1: Short-term vs Long Term Effects

Hypothesis 1: The effect of tidal action on restored sites may result in a local short-term transitory spike or increase in net methylmercury production and biotic exposure, within the project and downstream, but we are unlikely to see levels of concern in biota that warrant management action.

Brief Summary of Local Data

Darell Slotton (UC Davis) presented findings from his small fish monitoring in the Estuary to provide information on the timescale and spatial extent of MeHg's effect on prey fish. Darell noted that small fish have been used as indicators of MeHg exposure since a UC Davis study measured concentrations in Delta prey fish in 1998. Since then, a number of larger projects have been completed that use small fish as MeHg biosentinels.

A study funded by CalFed from 2005-2008 found that MeHg concentrations were higher on the Delta's periphery and lower in the central Delta. The results also indicated that restored tidal marsh and salt pond areas did not possess elevated MeHg concentrations. However, there were spikes in MeHg concentrations when there was occasional flooding of organic rich soils that were allowed to go dry. For example, in Fall 2006 a newly breached pond in North Bay actually possessed significantly lower Hg concentrations than the surrounding area, but the Upper Petaluma Marsh had elevated Hg concentrations because of occasional flooding at the site. Occasional flooding occurs with high rain-runoff during winter storms, spring snow-melt, managed flooding, or episodic tidal flooding.

Darell provided another example of a pond in Alviso Slough (Pond A8) where there was concern that MeHg concentrations would spike when the pond was breached. The pond was sampled a year before the breach and during the restoration (within the same months). There was an increase in threespine stickleback Hg concentrations two months after the breach, but after four months the concentrations were within the baseline range. The same trend was seen in silversides; the concentrations spiked, but were back to the baseline range within two months. The spike in the Hg concentration in Alviso Slough after the pond breach could be because of the scour of Alviso sediment as flows increased; the transfer of the pond's high Hg water or sediment to Alviso Slough; or the movement of fish with high Hg loads from the pond into the Slough. Josh Ackerman (USGS) also monitored small fish in Pond A8 and saw an overall decline in Hg concentrations with the breach.

Darell ended the presentation by stating that the hypothesis (that there would be a short-term, transitory spike in net MeHg production, but that concentrations would not reach levels of concern in biota that warrant management action) is supported by the data, as long as the restoration sites remain wet and are not subject to occasional flooding.

Discussion

Rob Mason commented that the spike in the small fish MeHg concentrations was so large that the only thing that could account for the considerable change was the migration of the Pond A8 fish into Alviso Slough. Darell responded that fish movement out of the pond was likely, but in previous studies similar concentration changes have been observed within a month and a half. Jim McGrath wondered if it is the accumulation of sediment with elevated Hg or the landscape itself that determines the extent of MeHg bioaccumulation. Rob responded that on the East Coast of the United States there is no relation between Hg concentrations in small fish and in sediment, the correlation only exists between Hg concentrations in small fish and water.

Darell noted that the wetting and drying of the sediment makes the Hg more bioavailable. He stated that one possible management action would be to leave water on the landscape longer to let photodemethylation take place. Laura Valoppi and Letitia Grenier agreed that Darell's finding that there is a spike in MeHg with occasional flooding creates an important landscape distinction for management and monitoring efforts. Letitia added that the heterogeneity of wetlands should be acknowledged; for example, there should also be a distinction between ancient and managed marshes. A participant asked whether Darell had determined if MeHg concentrations were also influenced by the degree of tidal exchange. Darell responded that the systems where there was no tidal exchange had elevated MeHg concentrations, while the fully tidal areas were unremarkable.

Tim Stevens asked which agency will be responsible for determining if the benefit of restoring a marshland or pond outweighs the risk of increased Hg methylation. He asked if either the National Marine Fisheries Service or the California Department of Fish and Wildlife would be the most appropriate agencies to determine if the burden of MeHg on wildlife was acceptable. Bruce Wolfe responded that under the Water Quality Control Act and the Clean Water Act the Water Boards have the ability to issue permits to protect water quality. Bruce stated that input is needed from all agencies and interested parties to optimize the restoration effort. Joe Dillon asked if the concentrations in small fish can be correlated to effects in wildlife, such as terns. Darell responded that Josh Ackerman has monitored MeHg concentrations in wildlife for multiple years. In fact, Josh observed a decrease in tern MeHg concentrations during the North Bay restoration project. In the South Bay, tern MeHg concentrations did spike during Pond A8's restoration, but similar to the small fish, concentrations returned to baseline

Panel Comments

Jim Wiener noted that Darell Slotton and others have collected a robust set of data that can be used to examine the potential effects of flooding. Jim Wiener added that other studies have similarly associated a spike in microbial MeHg production with flooding. Jim described the results of an article published by R.A. Bodaly and J.P. Fudge in 1999, in which a two to three fold increase in Hg concentrations was observed in fish up to two months after a reservoir was flooded. Jim also mentioned a group in Canada who found that before a reservoir was flooded 5-10% of the total Hg (THg) was MeHg, while after flooding 60-80% of the THg was MeHg. Unlike Darell's findings, the concentrations remained elevated over a long period of time. Jim ended by stating that reservoirs are the worst case scenarios; reservoir creation generates rapid bioaccumulation of MeHg in fish that can last 25 to 30 years.

Rob Mason agreed with Jim that reservoirs show elevated concentrations that last for long periods of time. Rob suggested returning to Pond A8 to determine if there any observed effects over the long-term. He also recommended looking at Hg data from ponds in the Everglades and in Georgia that occasionally flood to determine if concentrations may spike in similar Bay Area landscapes. He questioned whether MeHg spikes during occasional flooding because MeHg is already in the sediment and the flux is increasing or if there is new MeHg production occurring. Rob ended by stating that scientists and managers need to understand what the concentrations in the biosentinels are actually reflecting. The assumption is that forage fish are reflecting sediment

concentrations, while the fish concentrations may be a better indicator of MeHg in the water column.

Jeremy Lowe noted that if occasional flooding of organic rich soils causes MeHg spikes, then climate change will have a direct impact on MeHg concentrations in marshes. With sea level rise, natural marshes may become subject to more frequent flooding. He stated that as we think about restoring tidal marshes, the group also needs to consider about how the whole system will be changing.

Jim thought that the hypothesis the forum organizers put forward should be split into two hypotheses: 1) There will be a short-term spike in net MeHg production and biotic exposure and 2) We are unlikely to see levels of concern in biota that warrant management action. Jim agreed with the first hypothesis and stated that monitoring studies can be designed at a local and regional scale to test the hypothesis. Rob noted that the various types of wetlands need to be examined and defined in greater detail before the monitoring studies begin. Jeremy added that restored marshes are dynamic and continue to evolve 10 years or more after their creation. Both Jeremy and Rob agreed that long-term monitoring is needed to evaluate change. The panelists did not make any definitive statements about the second part of the hypothesis.

Group Comments

Brenda Goeden stated that the Bay Area restoration community is adjusting their practices to account for sea level rise by creating higher tidal marsh transition zones. She was concerned that those areas would be inundated on a rare basis, creating a spike in MeHg. Jeremy responded that there would be a concern if the area was a large marsh plain, but Brenda was referring to marsh on an upland slope; therefore, the area of concern is very narrow. Also, the source of the sediment that you are placing in the restored marsh is important. Brian Bergamaschi stated that climate change is not the only large change in the Bay system, nutrient and sediment supply in the Bay is also shifting. Letitia Grenier added that the water may not make it all the way from the transition zone Brenda mentioned into the Bay.

Letitia noted that the Forum is not addressing how much MeHg that is produced in the marsh remains in the marsh. The MeHg concentrations in existing tidal marshes are already considered elevated and restored marshes are likely to behave similarly, although there are no data on MeHg in restored marshes. Darell noted that the largest restoration projects are in salt ponds, which are not subject to occasional flooding.

Don Yee asked how the panel would suggest designing a monitoring program based on the knowledge that restored marshes are evolving continuously. Jim recommended monitoring at a higher frequency in the short-term and using the data to modify the design over time. Darell responded that there is 10 years' worth of monitoring data for the North Bay salt ponds restoration projects and no substantial changes in MeHg concentrations have been observed. Laura Valoppi added that Pond A8 was monitored in 2010, 2011, and 2013. Additionally, funding was secured to monitor in 2014 to determine if increasing the number of notches in Pond A8's gates would change the rate of methylation/demethylation. Jim stated that process studies should also be completed to strengthen the inferences gained from biosentinel monitoring; he

referred to biosentinel monitoring as hypothesis generating and process studies as hypothesis testing.

Jacob Fleck stated that he was concerned with a "silver bullet" approach to managing restored landscapes. He believed the hypothesis gave the perception that not much is known about MeHg in restored areas, but a lot of data are available. The difficulty is that various restored sites may respond differently from one another and process studies are needed to understand how to manage each type effectively.

Local vs Regional Impacts

Hypothesis 2: Methylmercury loading from tidal wetland restoration projects is a minor contribution to the total pool of methylmercury available for uptake into the Bay's food web and therefore is a minor factor relative to Bay-wide mercury impairment (e.g., bird and fish tissue levels).

Brief Summary of Local Data

Don Yee addressed hypothesis two by summarizing his findings from a MeHg mass budget. The main difference from a THg model is the methylation and demethylation component, which can occur rapidly. A MeHg budget can synthesize all of the Bay data (e.g., loading, production, degradation, and sediment-water exchange), identify which factors influence MeHg fate, and determine whether a more refined model is needed. A MeHg mass budget cannot identify local "hot" spots or predict the long term fate of MeHg.

Don then quantified the external loads of MeHg into the Bay including wet atmospheric deposition (0.1 g/d), Delta discharge (9.8 g/d), local watersheds (4.9 g/d), wetlands (2.0 g/d), and POTWs (0.8 g/d). Based on the estimates, about 10% of the external MeHg loads to the Bay are from wetlands. The 2.0 g/d estimate was generated by determining the total area of wetlands in the Bay and extrapolating based on data in the literature. The model assumed that MeHg was being exported and imported on Bay tides. The model incorporated other processes including internal MeHg production, biouptake, volatilization, outflow through the Golden Gate, burial, degradation, and the sediment-water exchange.

Don created a base case run based on the current status of the Bay. In the sediment the biggest source is methylation and the biggest loss term is demethylation. After the base case, the parameter sensitivity was tested varying the parameters by a factor of three. When the load in the water column is increased, there is almost no change in sediment and only a small change in the water MeHg concentration. The model indicated the system is more sensitive to methylation and demethylation rates. The water loads, including those from wetlands, will have a small effect on MeHg loads to Bay water. The wetland area would have to increase by a factor of 20 for the Bay water MeHg load to increase by 50%. Letitia Grenier noted that even if the Baylands Ecosystem Habitat Goals were achieved, the amount of wetland area would only double. Based on the model results, Don stated that restoration may be better than the status quo. Unless there is an

area where MeHg concentrations are very high; in that the case, the pros and cons of restoration may need to be weighed.

Hypothesis 3:We do not expect to be able to measure the regional impacts to the Bay's food web from tidal wetland restoration projects.

April Robinson then addressed hypothesis three by reviewing the biosentinel monitoring from probabilistic surveys conducted in 2008. April noted that even in ambient conditions, some species already possess MeHg concentrations above levels of concern. Interestingly, the data show that there is no statistical difference between small fish (Long-Jawed mudsuckers and Threespine stickleback) MeHg concentrations from salt ponds and marshes. However, there were differences in MeHg trends based on the type of biosentinel that was monitored because they represent different habitats.

April then reviewed the potential regional effects of restoration projects. April noted that MeHg could enter the Bay from the marsh through abiotic factors, including re-suspended sediment or moving through the water column. MeHg could also be transferred to the Bay through biota. For example, fish can move from the Bay into the marsh to feed. However, to date, Bay-wide increases in MeHg, in both sport and small fish, have not been detected, even in areas where sampling took place near restoration projects. April ended her presentation by stating that the influence of marsh restoration on Bay-wide trends will be difficult to detect because of the small expected change in MeHg input; the mobility of indicator species; and the variability in the factors influencing MeHg in Bay wildlife.

Discussion

Jim Wiener asked if there was any evidence of increased photodemethylation with increasing water clarity in the Bay. Don responded that process studies haven't been completed to answer that question. But, increasing water clarity may support productivity, which would increase anoxia in the Bay. Rob Mason noted that the model Don presented may be underestimating the role of external sources to the Bay's MeHg load. He suggested improving the understanding of the relative contributions of 1) flux out of the sediment and 2) external sources to the total MeHg load. Don replied that changing the relative contribution would not significantly affect the overall load, but he recognizes that the model is oversimplified. Brian Bergamaschi said that he modeled the flux of MeHg, expressed in yield per unit area, and arrived at a similar estimate as Don. Brian asked whether Don had divided the MeHg budget spatially (North versus South Bay) or temporally. Don responded that dividing the budget seasonally or spatially has not been attempted, but it is possible to do so.

One participant asked what Don thought about the assumption that "all Hg is created equal" and whether Hg from different sources was more prone to methylation. Don replied that Hg from atmospheric deposition may be more available, but in the context of multi-decadal planning, all Hg begins to look the same. Stuart Siegel asked whether the model results may change depending on whether the water is brackish or freshwater. Don responded that his model is on a Bay-wide scale, but a similar one-box model could be applied, with different parameterization, to a specific region (e.g., Suisun Bay).

Tim Stevens asked if other states are experiencing the same conflict between increasing the risk of MeHg exposure and the restoration of wildlife habitat. Jim Wiener responded that he is not aware of an analogous situation. He noted that in order to protect wildlife, there must be successful reproduction and reproduction is affected by MeHg exposure.

Panel Comments

Jim Wiener agreed with hypothesis two, stating that the hypothesis could be tested with a regional biosentinel monitoring program. Jim recommended rephrasing hypothesis three to something similar to - *the regional impacts to the Bay's food web from tidal wetland restoration projects will not be statistically significant.* Rob Mason noted that studies conducted on the east coast found a correlation between MeHg in fish and particulate MeHg, indicating that "not all MeHg is created equal." Therefore, Rob recommended conducting a more in-depth mass balance of MeHg in the Bay. MeHg sources could be differentiated based on the likelihood of food web uptake. Jeremy maintained that hypotheses two and three do not reflect the diversity of habitats in the Bay. Rob suggested moving from one box to a multi-box model; Don replied that the mission is to create as many boxes as needed, but fewer data are available for smaller boxes.

Group Comments

Mike Connor noted that the salinity can affect whether sulfate reduction occurs, which affects methylation rates. He added that methylation rates may vary based on the light attenuation coefficient. Tim asked whether the hypotheses would change if the group had differentiated between freshwater tidal wetlands and wetlands in San Francisco Bay. Jim stated that freshwater systems are more sensitive to factors that change the methylation rate and he would be more concerned about the risk of MeHg. Rob mentioned that wetland areas are a small source of MeHg.

Tamara Kraus noted that the regional impact of restoration projects will be different depending on the region. In the Delta there is a MeHg TMDL and the Delta is an area with a lot of Hg in the system. Therefore, in the Delta, containing elevated MeHg water rather than completing restoration projects may be a regional goal. Stuart Siegel agreed that the Delta is a different environment because there are no natural wetlands; to begin a monitoring program the restorable land needs to be classified.

Topic 3: Study Design

Principle 1: Measuring mercury in one or more biosentinel species is an appropriate approach to provide information on management questions 1, 2, 3 and 7, and to identify circumstances where more detailed studies should be performed to understand methylation and bioaccumulation processes.

Principle 2: Process studies should be done at only a subset of sites, which biosentinel monitoring can help identify. Process studies can help to answer management question 5.

Principle 3: The monitoring program should have a regional scope to ensure that data are relatively consistent across projects so that site-specific variability may be distinguished from regional trends and phenomena.

Discussion

Tom Gandesbery was concerned about the ability to modify the design of the restoration projects after they were completed to reduce MeHg exposure. He said that manipulating the water and hydrology of a completed project may create another water quality problem. Letitia Grenier agreed with Tom and stated that a monitoring program could scientifically prove if restoration projects increased MeHg exposure, but could not determine an appropriate control effort.

Laura Valoppi then relayed Josh Ackerman and Mark Marvin Di-Pasquale's eight recommendations for designing a monitoring plan:

1. Have a clear understanding of the management questions
2. Complete process studies alongside biosentinel monitoring
3. Have a robust statistical approach with a large sample size
4. Control for the time period when completing biosentinel monitoring (sampling during the breeding season would be useful)
5. Include control sites in the sampling design
6. Monitor more than one species at different trophic levels
7. Complete a study in which Hg concentrations are measured at a site over a 24 hour period during different seasons to understand short-term changes in a tidal system.

Mike Connor stated that the group was ready to create a robust monitoring strategy that includes whether process studies are needed and what additive management strategies are available. Tim suggested distinguishing between compliance monitoring for a permittee and a full monitoring program that includes multiple contributors.

Brian Bergamaschi asked why the forum organizers are focused on biosentinel species as an endpoint as opposed to other possible endpoints. Jay Davis replied that biosentinel species are good indicators of impairment over space and time. Additionally, with limited funds they are an appropriate first-level screening effort. Richard Looker and Stuart Siegel stated that the information obtained from biosentinel monitoring can be used to inform more expensive process studies at certain sites. Stuart noted that with limited funding the process studies need to be very focused.

Panel Comments

Jim Wiener stated that Principle one should change from "in one or more biosentinel species" to "in more than one biosentinel species." Jim agrees that process studies are critical and that the monitoring program should have a regional scope. Rob Mason recommended including "super sites" in the monitoring design: sites where monitoring occurs at a more intensive level and where process studies are completed. Jeremy Lowe noted that the principles should mention the

need to communicate the information gained from monitoring to help design future restoration projects.

Group Comments

Laura Valoppi stated that the Pond A8 restoration project is an example of why process studies are important. Process studies can answer the "why" questions, such as why the fish concentrations rose and then fell after Pond A8's breach. Richard Looker stated that there is no conflict between biosentinel monitoring and process studies, both need to be completed together. He added that a process study should be completed for each wetland type; therefore, the group should agree on how to categorize the various wetlands. Caitlin Roddy disagreed that the group could find a representative site for each wetland type.

Brian asked why energy was not being invested into studying MeHg production. Naomi Feger responded that the production of MeHg has been examined previously, but methylation/demethylation occurs quickly and biosentinels are a better integrator over time. Darell added that the wildlife concentrations may not be correlated to MeHg production levels. Brian also asked whether biosentinel monitoring would be site specific or if there would be a regional approach. Naomi replied that the group is still deliberating on what biosentinel monitoring to consider on a regional versus local scale.

Rob Mason stated that if biosentinel monitoring is completed before a process study takes place, the same biosentinel sampling effort should be repeated after the process study is complete to measure the variability in the system. Rob added that the process study has to be strongly driven by the management question. Jim ended the discussion by stating that Darell's data could be used to start thinking about where process studies would be valuable to answering management questions.

Topic 4: Restoration Design and Management Actions – Restored Marshes

Hypothesis 4: We do not yet have sufficient information to design tidal marsh restoration projects to reduce methylmercury exposure.

Hypothesis 5: It is possible to design or manage restored marshes to reduce methylmercury exposure.

Brief Summary of Local Data

Letitia Grenier stated that, as of now, no studies have attempted to answer whether it is possible to design tidal marsh restoration projects to reduce MeHg exposure. Testing and monitoring is needed before recommendations are made for designing restored tidal marshes. She recommended that for a biosentinel monitoring program, each habitat should be matched to a specific species.

Letitia then reviewed biosentinel monitoring data from a GRTS survey of South Bay to elucidate any landscape scale patterns. There was no relation to distance from Alviso Slough and MeHg concentrations in brine flies or in small fish. However, in song sparrows, MeHg concentrations decreased as distance to the Bay increased. A conceptual model was created that evaluated factors that may affect Hg risk, including salinity, THg legacy, the frequency of wetting and drying, and topography. The data indicated that there was no relationship between topography, THg legacy, or frequency of wetting/drying and MeHg exposure. However, salinity may be affecting MeHg exposure. Therefore, Letitia stated that managers could restore the fresh to saline marsh gradient in the Bay. There are many benefits to restoring the gradient (e.g., protection against sea level rise), but also potential problems including managing nutrient and contaminant levels. There was also a relationship between song sparrow Hg and the percent of Hg in sediment that was MeHg.

Letitia noted that when considering management options is important to consider the marsh or pond area compared to the surrounding environment. Generally there is an elevated ambient condition in the marshes, rather than localized hotspots (in which case, tidal influence should not be restored). Additionally, marshes are often thought of as a Hg problem, but they are important for sediment sequestration. With sea level rise, there will be a considerable loss of marsh and the remobilized sediment may create a MeHg problem for the Bay. A possible high leverage water quality action is preventing erosion of extant marshes.

Letitia finally reviewed the tidal marsh species that live in San Francisco Bay and are at risk for reproductive impacts due to MeHg exposure. To help protect the rare and endangered species we can protect the extant marshes, restore the marshes to fully tidal, reestablish the fresh to saline gradient, work to understand variation among marsh plains, and ensure that restoration occurs in the correct places.

Initial Thoughts

Don Yee asked about the spatial separation between the song sparrow samples in the South Bay GRTS survey. Letitia responded that there was not a clear reason why there was high bioaccumulation in some areas and low bioaccumulation in others. However, if we knew where each sparrow eats, a pattern may emerge. Josh Collins noted that wetlands with elevated MeHg concentrations can also be a feeding ground for terrestrial wildlife, some of which may be endangered.

Laura Valoppi noted that Bay sediment with elevated Hg concentrations is being deposited on marshes, which may be improving the sediment quality in the Bay by accumulating the sediment. Richard responded that the difference between Hg in the open Bay and marshes is that methylation is more likely to take place in marshes. Laura replied that the sediment from the Bay is being deposited and then buried in the South Bay Salt Ponds. Don stated that sediment accumulation in marshes may reduce the Hg concentration in South Bay, but the deposition will most likely not affect the overall Bay balance. Jim Wiener agreed and said that the burial of contaminated sediment may occur in South Bay, but the North Bay and South Bay act very differently in terms of erosion. He added that the energy in Bay winds and the tides make

complete burial of the contaminated sediment unlikely. Brian Bergamaschi noted that Hg that enters the marsh with sediment deposition can also leak off in the dissolved phase.

Jay Davis asked Letitia's level of confidence with hypotheses four and five. Letitia responded that there are lines of evidence that could be followed-up on (e.g. importance of salinity gradient). However, until studies are completed, it is not possible to manage restored marshes to reduce MeHg exposure. Mike Connor stated that he did not find Letitia's data compelling and argued that there is no evidence to support or reject the hypotheses.

Panel Comments

Jim Wiener stated that the hypotheses didn't read like an hypothesis, but rather an announcement of the state of the science. He wasn't convinced that the two hypotheses were important for moving forward. He suggested changing hypothesis five to a question: *Is it possible to design or manage restored marshes to reduce methylmercury exposure?* The question is whether there is anything scientists and managers can do to reduce MeHg production.

Rob Mason was interested in the role of salinity and also wondered if the elevation of the marsh could influence MeHg risk. He wanted to hear the options for designing marshes that may reduce the MeHg risk.

Jeremy Lowe noted that the objectives need to be clear before examining the various design options and the goals for Bay restoration efforts remain unclear. He listed some possible design options including importing sediment, capping areas, improving drainage by increasing the number of channels, and reducing shoreline erosion. Jeremy noted that the Bay is not static and there are number of issues that need to be dealt with (e.g., sea level rise). Therefore, experimental/pilot projects are needed to begin exploring design options.

Group Comments

Don noted that some restoration projects in the Bay have already been designed to reduce contamination. The Montezuma Wetland Restoration Project buried and capped contaminated sediment. But, the majority of the group's questions are related to the design of less engineered solutions to MeHg risk. Brian stated that we already have knowledge on designs that to reduce the MeHg risk, such as promoting biological and photochemical demethylation. Jeremy said that the design should provide a landscape that will evolve in a manner that scientists and managers can predict. Letitia noted that there are not enough data to indicate there is a significant MeHg problem; therefore, there is limited funding for designing the sites.

One participant did not agree with the wording of the hypotheses, instead of designing "to reduce methylmercury exposure," the design should not <u>increase</u> exposure. Restored marsh habitat is important for wildlife and the design should focus on creating the least amount of damage. Andria Ventura stated that there are Hg TMDLs that require managers to reduce exposure rather than continuing with the status quo.

Letitia noted that the forum participants appear to agree that MeHg export from wetlands to the Bay is not a large problem. But, within the marsh there may be a risk of MeHg exposure in wildlife. Janis Cooke responded that the Central Valley is struggling with the same issue of how to manage the MeHg risk within the wetland itself. Tim ended the discussion by arguing that the overall advantage of restored estuarine and tidal marsh will greatly surpass any potential environmental impairment from MeHg.