NONPOINT SOURCES MANAGEMENT PRACTICES TO COMPLY WITH DELTA METHYLMERCURY TMDL

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Introduction

- Delta impaired by MeHg
- MeHg is a neurotoxin
- Bioaccumulates and Biomagnifies in foodwebs
- Delta MeHg TMDL (reduce aqueous concentrations)
- Lower fish mercury levels
- Develop management practices

Definitions

- Management practice – Methods or techniques found to be effective and practical means in achieving an objective (reduce aqueous MeHg loads) while making the optimum use of resources.
- Management practice memo –Applies existing knowledge of MeHg cycling and wetland management to develop potential MPs that may reduce MeHg loads. MPs are specific to certain wetland habitats based on management regime.

Method for developing MP Memo

- NPS habitats from Synthesis Document (Windham-Myers and Ackerman, 2012)
  - Managed Wetlands
    - Permanently flooded
    - Seasonally flooded
  - Agricultural Lands
    - Flooded
    - Irrigated
  - Natural Hydrology Systems
    - Floodplains
    - Brackish-Fresh tidal marsh

Method for developing MP Memo

- Categories of MPs
  - Biogeochemistry
  - Hydrology
  - Vegetation and Soils
- Describe MPs for each category and NPS habitats
- Summarize and rank MPs in the context of land use and land management

Overview of Biogeochemistry MPs

- Coagulation
  - Add a metal based coagulant (Ferric Chloride, Ferric Sulfate, Polyaluminum Chloride) to remove dissolved Hg and MeHg by flocculation
  - Studies in progress at Twitchell Island (Henneberry et al., 2011)
  - Questions regarding this MP
    - Can the floc be safely retained on-site?
    - Does the floc bind the fraction of Hg most susceptible to methylation?
    - What are the biogeochemical effect resulting from coagulation?
    - What are the ecotoxicity effects from the presence of the metal hydroxide-Hg complex itself?

Overview of Biogeochemistry MPs

- Aeration
  - Aerate wetlands to alter redox conditions and decrease MeHg production
  - Studies have shown oxygenation didn't stop methylation (Dent et al., 2011)

Overview of Biogeochemistry MPs

- Nitrate addition
  - Add nitrate to wetlands during suboxic conditions reduces flux of MeHg from sediments by providing additional electron acceptors to non methylating bacteria allowing them to outcompete methylators (Auer et al., 2008)
  - May increase primary production which should lead to decreases in MeHg in water column
  - Negative impacts
    - Addition of nitrate would change water chemistry with unknown results

Overview of Biogeochemistry MPs

- Fish population control
  - Use small fish to sequester Hg and then harvest the fish.
  - May affect primary productivity which could alter MeHg in water column
  - Questions regarding this MP
    - Will biomagnification of MeHg remove a large fraction of MeHg from the water column?
    - Will local piscivores be adversely impacted?
    - How and where will the harvested fish be disposed?

Overview of Biogeochemistry MPs

- Iron soil amendment
  - Add ferrous iron to soil prior to flooding
  - Decreases MeHg production by decreasing formation of Hg-sulfide complexes thought to be the form of Hg methylated (Mehrotra and Sedlak, 2005)
  - Not been proven effective at landscape scale
  - Several questions regarding this MP
    - How much iron to add to a wetland?
    - Would the amount of iron added need to be determined for each location this practice is used?
    - How often do applications need to be done?
    - What does the addition of iron do to soil quality?
    - What are the unintended consequences of soil amendments?

Overview of Biogeochemistry MPs

- Sulfate soil amendment
  - Add sulfate to wetland prior to flooding
  - Makes inorganic Hg unavailable for methylation by formation of insoluble HgS
  - Test have shown adding sulfate actually increases the methylation of remaining Hg (King et al., 2002)
  - This MP would not be effective at reducing MeHg loads

Overview of Hydrology MPs

- Recirculate drainage water
  - Eliminate MeHg discharge by holding water on site and applying new water as needed
  - Potential negative impacts
    - Poor water quality
    - Increased salinity
    - Added expense of running pumps for recirculation
    - Increased bioaccumulation
    - Reduced wetland area for drainage recovery
  - Might be best suited for times when [MeHg] is high

Overview of Hydrology MPs

- Increase water residence time
  - Decrease MeHg loads by allowing natural processes to decrease MeHg concentrations
    - Photodegradation
    - Particle settling
  - Questions regarding this MP
    - Will MeHg production at a site offset the MeHg destruction processes?
    - How will increased water residence time affect water quality?
    - What residence time is most beneficial to MeHg removal?

Overview of Hydrology MPs

- Water depth
  - Decrease MeHg by discouraging the growth of emergent vegetation
    - Decrease available carbon and habitat shown to promote methylation
  - Questions regarding this MP
    - Will ecosystem productivity by decreased?
    - Will habitat value be decreased?
  - Only applicable to permanent wetlands were water levels could be maintained year round

Overview of Hydrology MPs

- Increase water velocity
  - Decrease exposure of water to MeHg hotspots within shallow wetlands
    - Decrease exposure of water to areas of emergent vegetation
    - Move water through high velocity channels
  - Questions regarding this MP
    - Can wetlands be effectively short circuited without diminishing other water quality parameters?
    - Will bioaccumulation in the wetland be increased?
    - What will be the effect on habitat value?
  - Best suited for locations that have low [MeHg] source water

Overview of Hydrology MPs

- Pre-flood wetland
  - Flood-up cycle of flooding, draining, and immediately re-flooding
    - Initiates vegetation decomposition
    - Saturates the soils
    - Establish flow paths within wetland
  - This MP was monitored at Suisun Marsh duck clubs (Siegel et al., 2011)
  - Resulted in large spikes of MeHg discharged during first flush

Overview of Hydrology MPs

- Flood and hold
  - Eliminate discharge of wetland water into adjacent water
    - Allows for photodemethylation
    - Allows for microbial degradation of DOC to take place in wetland rather than deteriorating water quality by discharging
  - This MP was monitored at Suisun Marsh duck clubs (Siegel et al., 2011)
  - Different from recirculating in that no new water is applied
  - This MP could potentially be used if wetland management issues can be resolved.
    - Deteriorated water quality
    - Impairment to water fowl habitat
    - Increased salinity

Overview of Hydrology MPs

- Limit water discharge
  - Decrease exchange of wetland water with adjacent water during times of poor water quality
    - Eliminating discrete drain events and decreasing exchange reduces MeHg load (Windham-Meyers et al., 2010)
    - Similar to "flood and hold" but does allow for limited amount of discharge
    - Potential for deteriorated water quality
    - Potential for increased bioaccumulation within the wetland

Overview of Hydrology MPs

- Delay fall flood up
  - Flood wetlands as late as possible in advance of fall waterfowl management and hunting season
    - Flood-up occurs when water temperatures are lower
    - Limits temperature-dependent microbial activity
  - Siegel et al. (2011) reported this temperature effect was relatively small during the fall period
  - Major disadvantages
    - Compress time period over which a suite of wetlands diverts water
    - Hinder normal wetland management operations
    - Decrease habitat available for early migrating waterfowl

Overview of Hydrology MPs

- Stagger flood/drain events
  - Flooding and draining of multiple wetlands connected to one waterway are staggered
    - Decrease magnitude of net-upstream flow
    - Decrease magnitude of MeHg load to receiving water
  - This MP is a temporal dilution (Siegel et al., 2011)
  - Questions remain on water quality within wetland while waiting to discharge
  - Implementation would require close coordination between wetland managers

Overview of Hydrology MPs

- Permanent wetlands as treatment ponds
  - Route high MeHg concentration tailwater from seasonal wetlands into permanent wetlands
    - Yolo Bypass Seasonal wetlands have relatively higher [MeHg] compared to permanent wetlands (Heim et al., In review)
    - Allows removal processes to work on MeHg in permanent wetland
    - Bioaccumulation in permanent wetlands is not increased (Ackerman and Eagles-Smith, 2010)
    - Most effective in locations where [MeHg] concentration of permanent wetland receiving water is relatively high

Overview of Hydrology MPs

- Short flooding period
  - Control the time a field is flooded
    - Shortened inundation will limit summer vegetation growth
    - Less organic matter on field when flooded
    - Less MeHg production due to carbon limitation (Windham-Meyers et al., 2010)
    - Study in progress at Cosumnes (Eagles-Smith and Ackerman)
    - Questions remain regarding effect of this MP on habitat value and vegetation selection

Overview of Soils and Vegetation MPs

- Burn vegetation and soils
  - Burn soil and vegetation prior to flooding
    - Removes inorganic Hg
    - Removes organic material
    - Results in decreased MeHg production
  - Decreases air quality
  - Local restrictions limit or prohibit this MP
- Till Vegetation below soil surface
  - Move vegetation below the layer of soil where methylation occurs
    - Decreased MeHg production as organic matter moved below horizon where methylation occurs
  - May remove desired food sources of water fowl
  - Study in progress at Cosumnes (Eagles-Smith and Ackerman)

Overview of Soils and Vegetation MPs

- Bale and remove vegetation
  - Vegetation is hauled off-site for disposal
    - Removes a major source of labile carbon
    - Decreased MeHg production after flood-up
  - Laboratory tests verified role of vegetation residue as source of enhanced MeHg production (Heim et al., In review)
  - Issues with implementation if soils too soft for heavy bailing equipment
  - Decreased food value of habitat
  - Study in progress at Cosumnes (Eagles-Smith and Ackerman)

Overview of Soils and Vegetation MPs

- Graze fields with livestock
  - Plant consumption by grazing will remove a major source of labile carbon and reduce MeHg production (Heim et al., In review)
  - Main concern with grazing is consumption of plant seeds
  - Questions regarding this MP
    - Does grazing reduce seed production or disbursement of preferred vegetation?
    - What type of livestock is best suited for grazing?
    - For which livestock is predation an issue?
    - Will certain livestock such as cattle have footing issues or damage the habitat through trampling?
    - What is the contribution of cattle waste (i.e., manure) to DOC and other water quality constituents of concern?

Priorities in Permanent Managed Wetlands

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Coagulation	√
Biogeochemistry	Fish population control	≡
Biogeochemistry	Aeration	X
Biogeochemistry	Nitrate addition	X
Hydrology	Recirculate drainage water	√
Hydrology	Increase water residence time	√
Hydrology	Limit water discharge	√
Hydrology	Water depth	≡
Hydrology	Increase water velocity	≡
Hydrology	Stagger flood/drain events	≡

Priorities in Seasonal Managed Wetlands

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Coagulation	X
Biogeochemistry	Aeration	X
Biogeochemistry	Nitrate addition	X
Biogeochemistry	Iron soil amendment	X
Biogeochemistry	Sulfate soil amendment	X
Hydrology	Recirculate drainage water	√
Hydrology	Increase water velocity	√
Hydrology	Permanent wetlands as treatment ponds	√
Hydrology	Pre-flood wetland	X
Hydrology	Flood and hold	≡
Hydrology	Delay fall flood up	≡
Hydrology	Stagger flood/drain events	≡
Hydrology	Short flooding period	≡
Hydrology	Increase water residence time	X
Vegetation and Soils	Bale and remove vegetation	√
Vegetation and Soils	Till vegetation below soil surface	≡
Vegetation and Soils	Graze fields with livestock	≡
Vegetation and Soils	Burn vegetation and soil	X

Priorities in Flooded Agricultural Lands

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Nitrate addition	X
Biogeochemistry	Iron soil amendment	X
Biogeochemistry	Sulfate soil amendment	X
Hydrology	Recirculate drainage water	√
Hydrology	Stagger flood/drain events	√
Hydrology	Permanent wetlands as treatment ponds	√
Hydrology	Short flooding period	≡
Hydrology	Increase water residence time	X
Vegetation and Soils	Bale and remove vegetation	√
Vegetation and Soils	Till vegetation below soil surface	≡
Vegetation and Soils	Burn vegetation and soil	X

Priorities in Irrigated Crop Lands

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Iron soil amendment	X
Biogeochemistry	Sulfate soil amendment	X
Hydrology	Recirculate drainage water	√
Hydrology	Stagger flood/drain events	√
Vegetation and Soils	Bale and remove vegetation	√
Vegetation and Soils	Till vegetation below soil surface	≡
Vegetation and Soils	Burn vegetation and soil	X

Priorities in Natural Hydrology Systems (Floodplains)

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Iron soil amendment	X
Biogeochemistry	Sulfate soil amendment	X
Vegetation and Soils	Graze fields with livestock	≡
Vegetation and Soils	Burn vegetation and soil	X
Vegetation and Soils	Till vegetation below soil surface	X
Vegetation and Soils	Bale and remove vegetation	X

Priorities in Natural Hydrology Systems (Brackish-Fresh Tidal Marsh)

Management Type/Focus	Management Practice	Rank
Biogeochemistry	Nitrate addition	X
Biogeochemistry	Coagulation	X
Biogeochemistry	Fish population control	X
Hydrology	Stagger flood/drain events	≡
Hydrology	Increase water residence time	≡

Conclusion

- MPs are categorized by Habitat
- MPs are categorized by Type
- MP ranks are specific to management setting
- Many MPs have first scientific tests completed
- Many MPs untested at scale
- Tested MPs with poor results are included
- Focused on practical MPs
- What are managers able to do?
  - Optimal use of resources
  - Control MeHg loads

Discussion/Questions

Photo Credit: http://www.dfg.ca.gov/lands/wa/region3/yolo/photos.html