MEMO

To:	Yolo WRA, Mercury Subcommittee	
Date:	April 11, 2014	
Subject:	Summary of Yolo rice studies and relationship to the Delta MeHg TMDL and upstream rice cultivation	

Stephen McCord, Ph.D., P.E.

759 Bianco Court
Davis, CA 95616

(530) 220-3165

sam@mccenv.com

Overview

The US Geological Survey (USGS) has conducted several studies since 2003 related to mercury cycling in agricultural and managed wetlands in the Yolo Bypass[1]. Most recently, researchers from USGS and elsewhere measured concentrations of methylmercury (MeHg) and much more in sediment, water, and biota (plants, invertebrates, and fish) from May 2007 to July 2008 in three types of shallowly-flooded agricultural wetlands (white rice, wild rice, and fallow) and two types of managed wetlands (permanently and seasonally flooded). Replicates varied primarily in their water source. The study sites were all in the Yolo Bypass Wildlife Area, which comprises about one-quarter of the entire Yolo Bypass. About one-third of the Wildlife Area is managed for rice production.

The research team compiled eight papers (including one synthesis) about the study in the journal *Science of the Total Environment*. Lead researchers for this study were:

- USGS: Lisamarie Windham-Myers, Jacob Fleck, Josh Ackerman, Mark Marvin-DiPasquale, Craig Stricker, Collin Eagles-Smith, Charlie Alpers
- Tetra Tech: Phil Bachand
- Moss Landing Marine Labs: Wes Heim, Mark Stephenson
- Pacific Northwest National Lab: Gary Gill

For interests locally and regionally (especially other rice-growing areas), this memo summarizes the study findings, explains their significance and implications, and suggests next steps.

Key Findings and Their Significance

Critical to understanding these findings is the point that while similar processes of MeHg production, degradation, transport, and biotic uptake occurred in all wetlands studied, their relative importance to the MeHg budget varied profoundly. The following key findings are

[1] See http://ca.water.usgs.gov/mercury/yoloBypass.html.

summarized by processes that seemed to drive MeHg levels in the various types of wetlands and compartments (water, sediment, biota).

- Hydrology – the depth, duration, frequency, and timing of flooding – appeared to be the primary drivers of geochemical and biological differences among the wetlands studied.
- The Yolo Bypass does not drain in summer—all available water in the Toe Drain is recirculated.
- Over the full annual cycle, the availability of labile organic matter (from decomposing plant material) was the primary factor varying MeHg production among sites. Sulfate additions did not appear to influence methylation rates.
- Tracking the movements and transformations of MeHg was complicated, but largely achieved. The most interesting findings were in summer: rice stalk cover significantly reduced potential photodegradation rates, and transpiration drawing water down from the water into sediments negated diffusion of MeHg from those sediments into the water.
- Drainage during initial floodup and while harvesting wild rice "wet" produced the largest daily export loads of MeHg.
- Birds on the wetlands consuming rice grain or invertebrates are exposed either way to potentially harmful levels of MeHg.
- Major flooding events (the primary purpose for the Bypass) export the largest load of MeHg, and complicate the assignment of responsibility for such loadings between land managers and flood managers.

Some results can be compared to the Delta MeHg TMDL's requirements:

- *Every* water sample collected for this study exceeded the TMDL's MeHg concentration goal of 0.06 ng/L. Maximum MeHg values were among the highest ever recorded in wetlands. But interestingly, where the source water was greater than about 1 ng/L, the wetland was a MeHg sink; if less, the wetland was a MeHg source.
- Reducing MeHg exports (to address the TMDL) can exacerbate bioaccumulation on site.
- The TMDL allocates 78% reductions in MeHg loads from wetlands and irrigated agriculture in the Yolo Bypass. Exports from rice fields in summer and winter were within the range reported for other shallow aquatic systems. The study sites appeared to *reduce* MeHg loads during the irrigation season by 21% on average (although 3 of 6 fields increased loads); however, the net ecosystem production was always positive (some of the produced MeHg was temporarily retained in sediments).
- MeHg concentrations in caged fish varied greatly, but generally followed trends in concentrations of unfiltered MeHg in their water.
- The TMDL's two equations produce unrealistic results when combined (an exponential function within an exponential function). In other words, the assumed relationship between MeHg in smaller fish and in water is not valid at higher MeHg_aq concentrations.

Potential Management Practices

The purpose for the study was to provide guidance on the development of management practices that minimize MeHg production in managed wetlands and export to the Delta. Fields were managed by farmers to optimize rice production. Such actions included the timing of field flooding, draining, harvesting, seeding, fertilization, and other amendment practices, as well as the control of surface water flow rates and residence time.

Potential management practices for control of MeHg production, export, and bioaccumulation in agricultural and/or seasonally flooded wetlands are listed and evaluated in **Table 1** by type of management practice, in order of most likely effective first: (1) hydrology, (2) biogeochemistry, and (3) soil/vegetation. All except two of the practices listed were noted in the synthesis. The evaluation criteria are consistent with those used by the NPS Workgroup for evaluating MPs for all wetlands and irrigated agricultural lands in the Delta. These practices and their “Interest” determinations were largely—although not exclusively—suggested in the synthesis. Scoring is by me, but is largely consistent with input from the NPS Workgroup.

Next Steps

The CA Department of Fish and Wildlife and its Moss Landing Marine Lab are conducting a four-year project in the Wildlife Area to develop management practices to reduce MeHg exports from seasonal wetlands in the Yolo Wildlife Area. Study sites include a seasonal wetland, a series of constructed permanent ponds, and on-site mesocosms[2]. This project should be followed and reviewed at key check points for applicability elsewhere.

The suite of recent and current studies of rice fields in the Bypass, Cosumnes River Preserve, and Twitchell Island represent all important variability in the Delta region in terms of management practices, soil conditions, hydrology, etc. No additional studies of mercury in rice fields are warranted to address the Delta MeHg TMDL. However, the management practices in Table 1 should be re-evaluated for areas upstream of the Bypass based on the current understanding of their differences and similarities in conditions.

Many of the methylmercury processes have significant seasonal characteristics and potentially applicable management practices have significant seasonal applicability. These factors should be compared on an annual timeline to appreciate such overlaps and incongruities. Likewise, substantial knowledge gaps remain for quantifying costs (crop production, O&M) and benefits (MeHg concentrations and export load reductions, habitat improvement) for various practices. The NPS Workgroup’s 319(h) grant proposal under review includes task for post-processing recent studies, improving/adding to planned studies, and designing new studies.

[2] A mesocosm is a small-scale, controlled space in the natural environment wherein conditions can be managed and monitored more carefully for scientific understanding. Mesocosms provide a link between more controlled laboratory experiments and less controlled field experiments.

Table 1. Potential rice field management practices to reduce methylmercury production, bioaccumulation, and/or export.

Potential Management Practices		Costs and Benefits				Practical Challenges			Interest		General Messages
Man. Type	Management Practice	Science	Costs	MeHg Red.	Spatial Applic.	Tech. Cap.	BU Impact	Other Req.	Apply	Test*	
Hydrology	Optimize water residence time	4	4	3	3	5	3	3	Y	Y	Increased time could increase salinity, which may cause toxicity in rice; could improve by deepending pond; MLML testing in 2014
Hydrology	Incremental flooding	4	2	4	4	4	4	3	M	Y	Facilitate initial pulse and subsequent photodemethylation (or other treatment)
Hydrology	Reduce flooding period	3	3	3	4	4	1	3	M	N	Hard to reduce significantly the length of flood when producing rice; may be limited by requirements for weed/pest control, waterfowl and mosquitofish
Hydrology	Recirculate drainage water	3	2	4	3	3	3	3	Y	Y	Only applicable to some summer rice; increased salinity; already standard practice in Bypass
Hydrology	Stagger flood/drain events	3	2	3	4	5	3	3	M	N	Short time frame for flooding rice fields could limit applicability
Hydrology	Cold-water checks	3	1	3	1	4	3	4	Y	N	A technique used to pre-warm cold irrigation water; should serve same purpose as permanent ponds
Hydrology	Use permanent ponds as treatment	4	1	4	2	3	2	3	Y	Y	Drain water may be needed by d/s fields; invertebrates tend to bioaccumulate; less land for production; incr management time; MLML testing in 2014
Hydrology	Irrigate fields in series versus parallel	3	3	4	3	3	2	2	M	N	Salinity increases; challenging to redo drainage systems
Biogeo-chemistry	Apply coagulant	4	1	4	4	3	3	3	M	Y	Need space, could use at I/O; optimize per multiple WQ factors; USGS testing in Twitchell Island
Biogeo-chemistry	Add nitrate	1	3	3	2	4	1	1	N	N	Could incr. MeHg; increase eutrophication; target pollutant in CV
Biogeo-chemistry	Add activated carbon	4	2	4	4	4	2	3	N	N	Promising method for contaminated wetlands (Gilmour)
Biogeo-chemistry	Amend soil with iron	1	1	2	3	3	2	3	N	N	Maybe toxicity in rice - unclear production / inhibition could be balanced
Biogeo-chemistry	Amend soil with sulfate	1	1	2	3	3	2	2	N	N	Depends on location, water source, hydrology, soils; may *incr.* MeHg production where S-limited; could lower soil pH harming crops
Soil/ Vegetation	Burn vegetation and soil	3	4	4	2	3	2	1	N	N	Rice straw burning limited to 25% of acreage; not an option for Delta peat soils; permit cost (even if allowed); done for desease control
Soil/ Vegetation	Till (disk) vegetation below soil surface	4	3	4	3	4	2	2	M	Y	Uncertain long-term effects (may till up old organic material, eventually having no response); additional cost; contrary to recom. erosion and soil health practices; lose waste grain food source for migratory birds (unless practice AFTER rainy season bird usage); MLML testing in 2014
Soil/ Vegetation	Bale and remove vegetation	4	2	4	3	4	2	2	M	Y	Extracts some nutrients; straw value is less than expense; reduce usefulness of fields for wildlife (birds); need to replace K lost with fertilizer; reduced GHG emissions is creditable; MLML testing in 2014

* Yes if recommended in synthesis paper for further study.

Criteria values:

1 ===> **3** ===> **5**

Negative ===> Neutral ===> Positive