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Quantifying methylmercury loads from California rice fields

Principal Investigators:

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Project Summary

In flooded soils, such as those found in rice fields, microbes convert inorganic mercury to its more toxic form, methylmercury (MeHg). In flooded rice fields, MeHg is accumulated in rice grain, potentially affecting human health; in addition, it can be transported exported in surface drainage water to ecosystems downstream in drainage water where it can negatively impact wildlife. In the Sacramento Valley, the combination of 200,000 ha of rice and a history of Hg contamination in the surrounding mountains makes MeHg an important concern. We conducted two studies: 1) a MeHg mass balance for a rice field in the Sacramento Valley to better understand the risks due to MeHg in this system and identify periods during which management may reduce those risks, and 2) a controlled replicated experiment testing the effectiveness of alternate wetting and drying (AWD) as a potential MeHg management practice.

We found that total Hg (THg) content in soil was low (<60 ng g^{-1}) compared to previous studies (>300 ng g^{-1}). Rice grain had MeHg concentrations well below levels of concern for human health. MeHg concentrations in irrigation and drainage water were lower than seen in studies in the Sacramento-San Joaquin Delta. Together, these results suggest that risks of MeHg in Sacramento Valley rice are lower than previously thought. However, compared to the growing season, MeHg concentrations were notably elevated in fallow season drainage water, and the fields primarily exported MeHg during this time. Thus, management practices may be desired to manage MeHg export in the fallow season. Compared to conventional continuously flooded (CF) management, AWD management resulted in significant reductions in MeHg concentrations in soil, surface water and rice grain. In addition, yields did not differ significantly between CF and AWD. This suggests that AWD could be used to manage MeHg both in California, and elsewhere.

Research Program

The bioaccumulative and toxic pollutant MeHg may be produced in flooded soils such as those in rice fields. MeHg may then be accumulated in rice grain potentially affecting the health of people who consume it. Additionally, MeHg in the surface water of rice fields may be bioaccumulated by wildlife both within the fields and in downstream areas that receive rice drainage water. This can negatively impact the fitness of wildlife, and the health of humans who consume fish from affected areas. In California, MeHg in rice fields is a concern due to a history of Hg contamination in the mountains surrounding the Sacramento Valley, where 200,000 ha of tice is grown.

Drainage water from Sacramento valley rice fields ultimately enters sensitive wildlife habitat the Sacramento-San Joaquin Delta. The overall objective of this research was to determine if MeHg in and discharged from CA rice systems pose a health risk to human and wildlife fish consumers, and how farmers could cost-effectively minimize that risk. Two studies were conducted to address these objectives.

Study 1: Dynamics of MeHg import and export from rice fields.

While MeHg may be produced in rice fields, it may also be imported in irrigation water. Furthermore, other transformations, such as degradation mediated by microbes or light,

bioaccumulation by rice plants and physical transport processes impact how much MeHg is exported in drainage water. An understanding of integrated effect of these processes is necessary to determine how rice fields impact MeHg and associated risks. The objective of this study was to determine the annual cycle of MeHg import and export from rice fields.

The annual MeHg and total Hg (THg) budget was monitored two Sacramento Valley rice fields. The fields were managed by commercial rice growers, following typical management practices for the Sacramento Valley. Monitoring involved collecting water samples from the inlet and outlet of each field during the growing and fallow seasons. The amount of water entering and leaving the field was continuously monitored to estimate loads (concentration * flow). Soil and plant samples were also collected. All samples were analyzed for MeHg and THg.

We observed low (<60 ng g^{-1}) THg concentrations in soils compared to other studies (>300 ng g^{-1}) of MeHg in rice fields. Rice grain MeHg and THg concentrations were among the lowest reported in the literature and well below levels of concern for human health. These results suggest that the fields studied here have comparatively low levels of Hg contamination over all.

MeHg and THg concentrations in drainage water were similar to irrigation water in the growing season, but fallow season drainage water had elevated MeHg and THg concentrations. Based on surface water budgets, fields were net MeHg and THg importers during the growing season and net exporters during the fallow season. During the fallow season, the two fields exhibited different temporal patterns in drainage water MeHg concentration. One spiked early and then decreased while the other increased over the flooded period. These results show that the period of concern for MeHg export from rice fields is during the fallow season.

Study 2: Alternate wetting and drying as a MeHg management practice

Alternate wetting and drying (AWD) is a rice water management practice that has been shown to provide multiple benefits including reduced water use, methane emissions and arsenic accumulation in rice grain. However, previous studies of MeHg production suggested AWD might increase MeHg, while other studies suggested the opposite. We conducted a controlled, replicated experiment to determine how alternate wetting and drying water management (AWD) affects MeHg in rice systems.

Two treatments, AWD and continuously flooded control (CF), were compared in a randomized complete block design field experiment. Each treatment was replicated 3 times in plots 0.2 ha in size. Beginning after canopy closure (~50 days after planting), irrigation of AWD plots was stopped. After soil in AWD plots dried to 35% volumetric water content, plots were re-flooded. This procedure was repeated once for a total of two drying cycles in AWD plots. Continuously flooded control plots (CF) were flooded throughout the growing season. Water, soil and plant samples were collected throughout the growing season and fallow and analyzed for MeHg and THg.

Compared to CF, AWD resulted in significant reductions in MeHg concentrations in soil, surface water and rice grain. Rice yields in AWD plots were not different from yields in plots under

conventional continuous flooded management. These results suggest AWD may be an effective way to decrease problems associated with MeHg production in rice fields. Since AWD also reduces water use, greenhouse gas emissions and rice grain arsenic, while maintaining yields, it has potential for adoption by growers.

Information Transfer/Outreach Program

The results of this project were made available to a wide variety of stakeholders. Outreach efforts included poster presentations at the annual Rice Field Day at the Rice Experiment Station in Biggs, CA, and at the workshop *Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem.* Presentations were given to the Delta Tributaries Mercury Council, a local stakeholder group that includes regulators, environmental groups and industry leaders. These results were also presented to a scientific audience at the annual meeting of the Agronomy, Crops and Soils societies.

Notable Achievements

There is a total maximum daily load (TMDL) in place for MeHg in the Sacramento River Watershed. Data from this study provides valuable information to regulators about how much MeHg is in rice field drainage water and will likely influence regulatory decisions related to meeting the TMDL requirements. Importantly we found that MeHg concentrations and loads in the Sacramento Valley were significantly lower than those found in the Delta (where previous studies had been conducted).

AWD may be utilized to reduce MeHg concentrations not only in the Sacramento Valley, but also in rice growing areas where Hg is a concern worldwide. MeHg in rice grain is an important human health concern in areas with a legacy of Hg pollution, and AWD may prove to be a valuable tool for producing healthier rice in those areas.

Student Support table

	Students Funded Through This Project		Supplemental Awards	**Total**
	Federal Funding	State Funding		
Professional Researchers	0	0	0	**0**
Masters Students	0	0	0	**0**
PhD. Students	0	0	1	**0**
Acad. Coordinator	0	0	0	**0**
Other Acad./Researchers	0	0	0	**0**
Professor/summer	0	0	0	**0**
Total	0	0	1	**0**

Publications from prior projects

Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, Kenneth Tate, Stephen A. McCord and Bruce A. Linquist, A. 2017. The contribution of rice agriculture to methylmercury in surface waters: a review of data from the Sacramento River watershed. Journal of Environmental Quality, 46:133-142, http://dx.doi.org/10.2134/jeq2016.07.0262.

Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, 2017, Rice fields with low soil mercury export little methylmercury in drainage water and produce low methylmercury rice, (submitted).

Tanner, K. Christy, 2017, Methylmercury in California Rice Ecosystems, Ph.D Dissertation, Horticulture and Agronomy, College of Agriculture and Natural Resources, University of California Davis, Davis, California, 118 p.

Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, November 9th, 2016, Alternate wetting and drying decreases methylmercury in rice ecosystems. Meeting of the American Society of Agronomy, Crops Science Society of America and Soil Science Society of America. Phoenix, AZ.

Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, Kenneth Tate, Stephen A. McCord and Bruce A. Linquist, January 26-28th, 2016, The Contribution of Sacramento Valley Rice Systems to Methylmercury in the Sacramento River. Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem, Sources Workshop.

Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, January 26-28th, 2016, Methylmercury Export from Rice: Field Scale Methylmercry Budgets for the Sacramento Valley. Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem, Biogeochemistry Workshop.

Tanner, K. Christy, June 15th, 2015, Sacramento Valley Rice Field Mercury Studies, Delta Tributaries Mercury Council.

Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, October 29th, 2014, The Contribution of Sacramento Valley Rice Systems to Methylmercury in the Sacramento River. Eighth Biennial Bay Delta Science Conference.

Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, and Bruce A. Linquist, Alternate wetting and drying decreases methylmercury in rice ecosystems. Rice Field Day.