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Measuring and modeling mercury transformation and flux processes downstream of the historical Black Butte Mercury Mine (Oregon, USA)

Authors: Chris Eckley[1], Todd Luxton[2], Chris Knightes[3], Geoff Millard[2], Jenny Goetz[2], Anna Wade[2], Collin Eagles-Smith[3], Steve Dent[4], Jason Silvertooth[4], Jennifer Crawford[1]

1. US EPA Region-10, Seattle, WA
2. US EPA ORD, Cincinnati, OH
3. US PE ORD, Narraganset, RI
4. USGS FRESC, Corvallis, OR
5. CDM Smith

Background: Black Butte Mine Superfund Site

Historical Hg Mine: underground mine; surface waste rock & tailings

Deposit: primarily cinnabar

Operation timeframe: 1890 to late 1960s

Ore Processing: elemental mercury was produced on the site by heating crushed ore in a furnace.

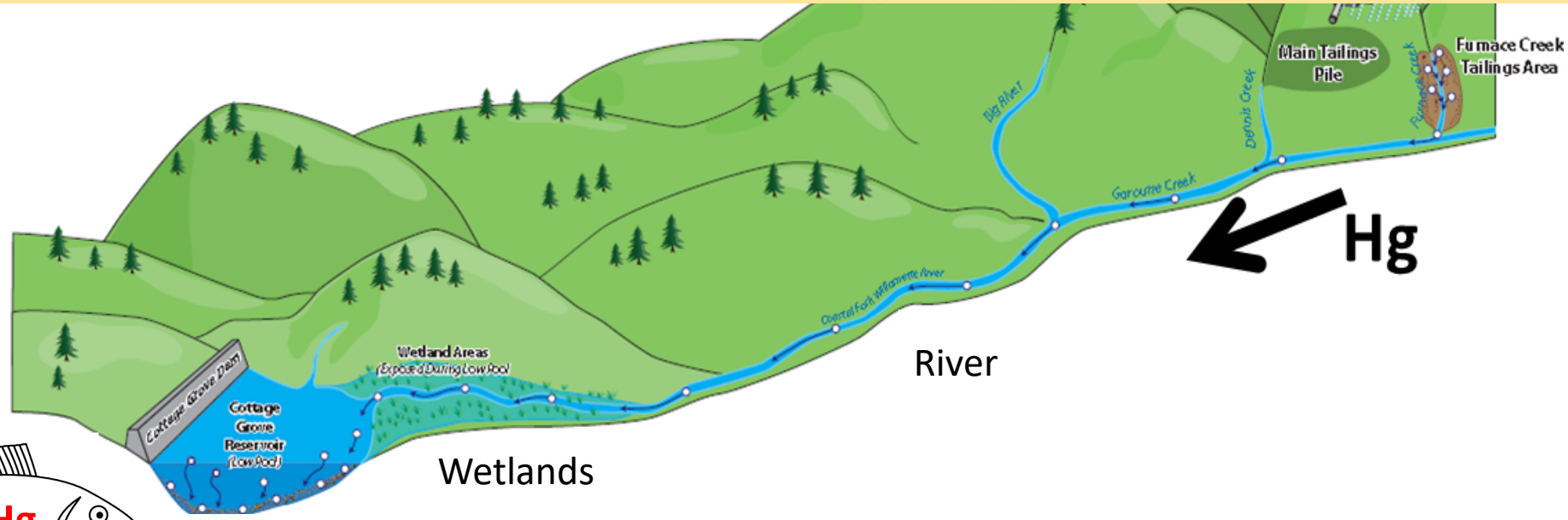
Production: ~635,000 kg of Hg


Black Butte Mine Adit

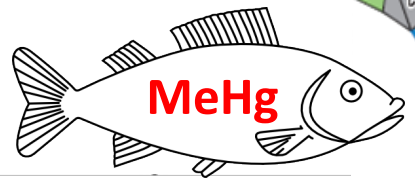

Black Butte Ore Processing Furnace


Black Butte Mine Current Conditions

***Study Objective**:* Quantify the key processes controlling MeHg production & degradation across a range of downstream landscape conditions:
river, wetlands, reservoir with water level fluctuations



Primary area of human exposure to MeHg



River

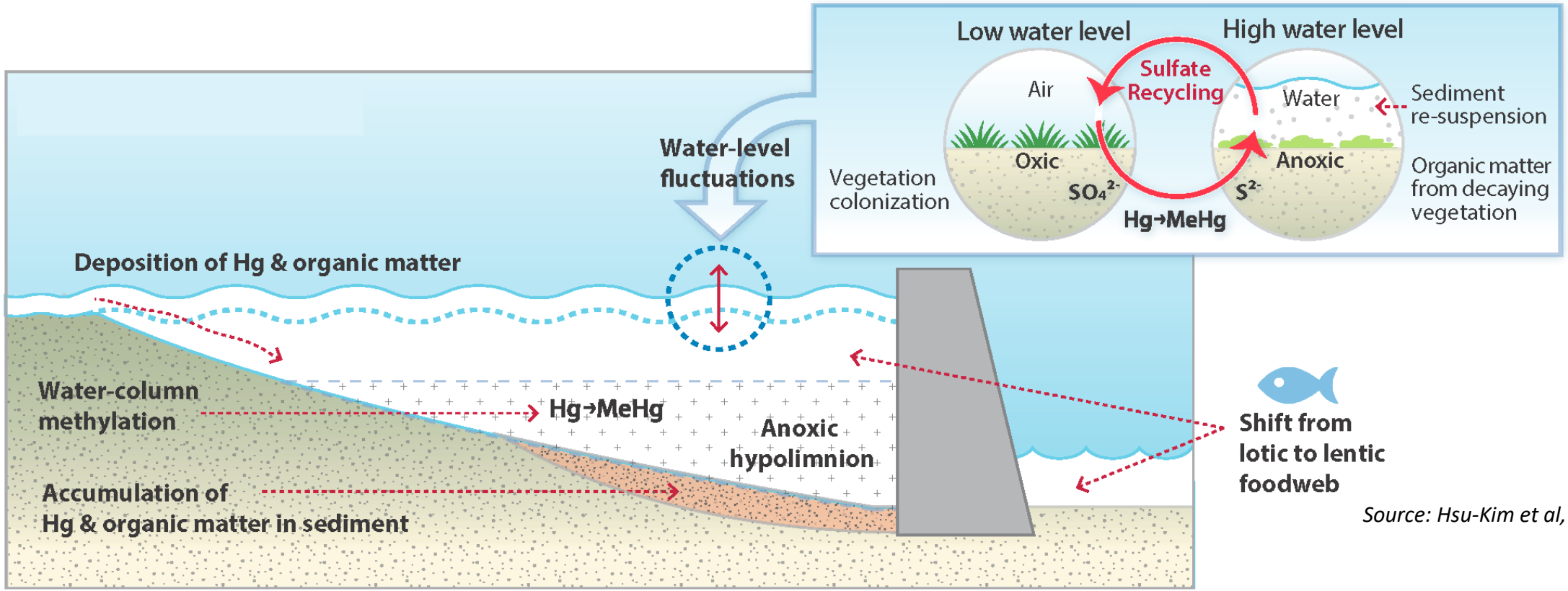
Wetlands

Reservoir

Range of landscape characteristics impacted by Hg contamination

Background: River/Reservoir Hg dynamics

- Existing literature suggests that reservoirs should have higher MeHg production than rivers & that wetlands can be important zones of MeHg production
- This study applies this knowledge to help improve the management of a contaminated site



Source: Hsu-Kim et al, 2018

Methods:

Processes investigated in this study in the river, reservoir & wetlands were:

- MeHg production sediment, water, and periphyton
- MeHg degradation in sediment and water
- Fluxes of THg and MeHg between the sediment and water

Stable isotope additions of inorganic Hg and MeHg as part of short-term incubation experiments.

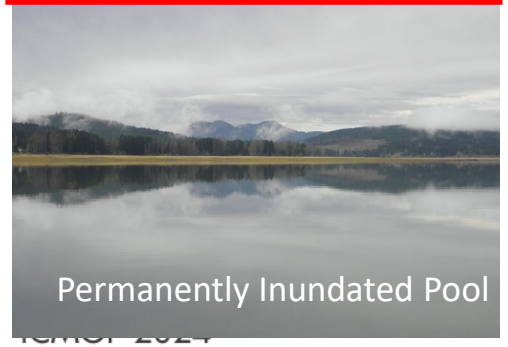
Processes contextualized using the Water Quality Analysis Simulation Program (WASP8) model

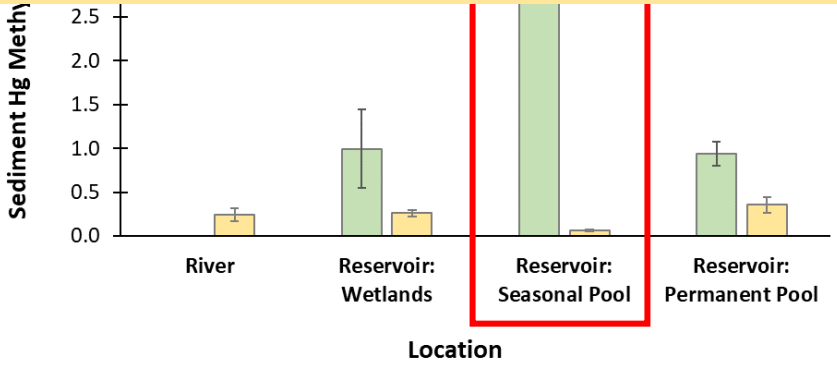
Sediment methylation

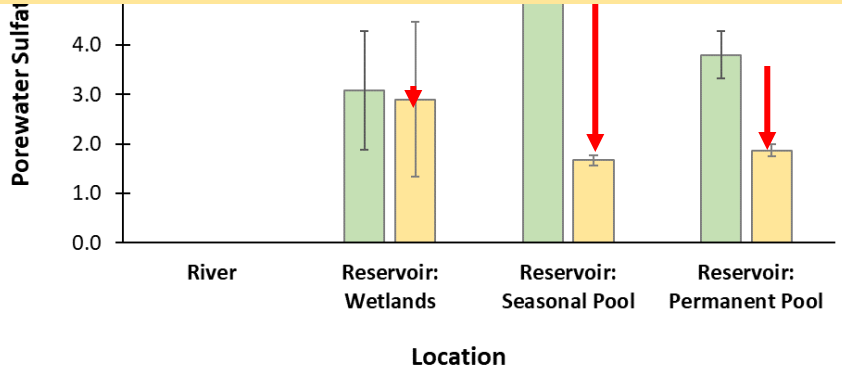
Photo-demethylation

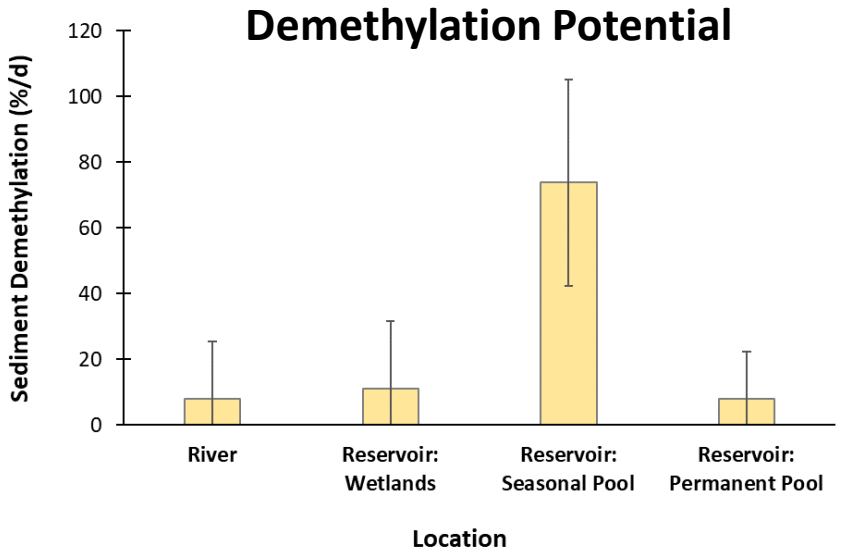
Periphyton flux

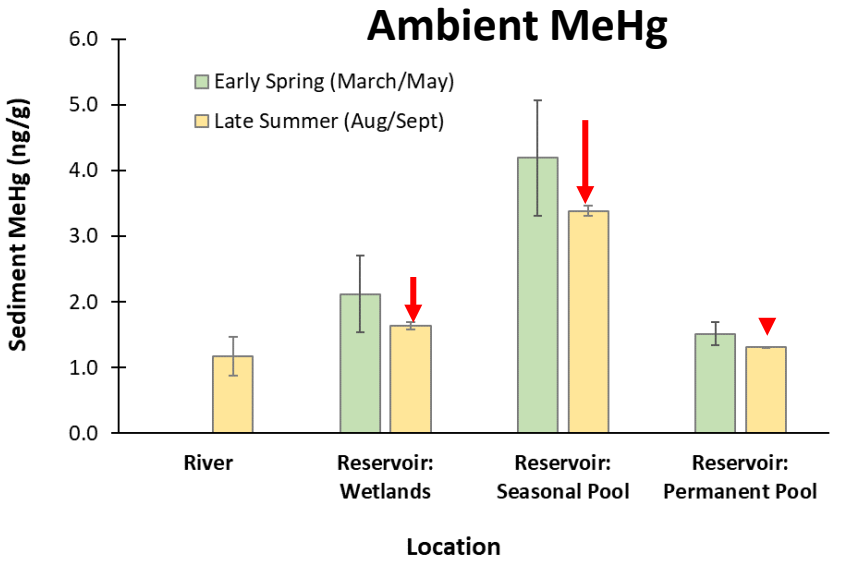
The dynamic influence of water-level fluctuations on redox cycling can have a large influence on MeHg production immediately after inundation



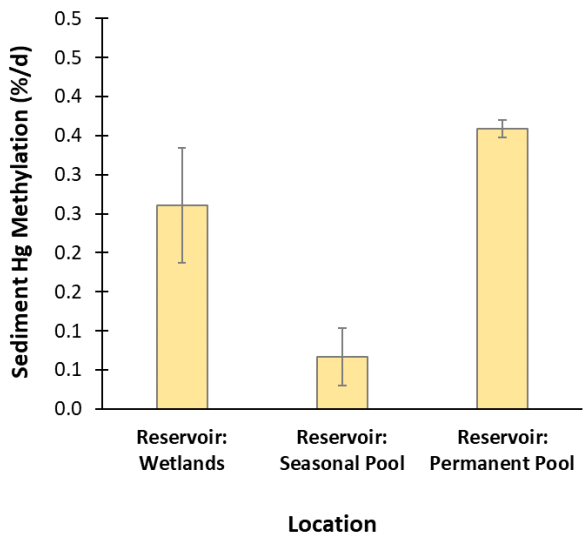


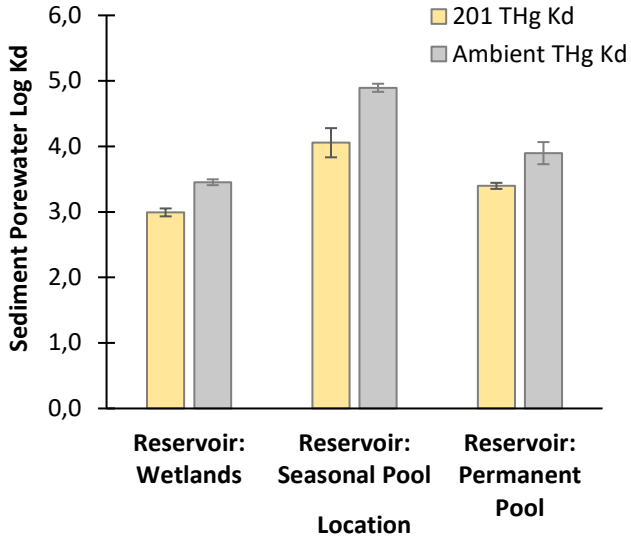


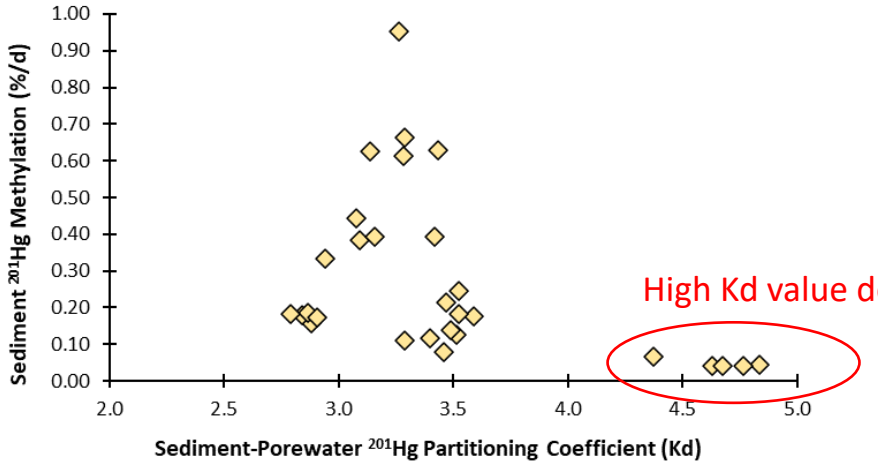




Sediment-porewater Kd values may be an important variable impacting methylation rates & may influence sediment amendment effectiveness

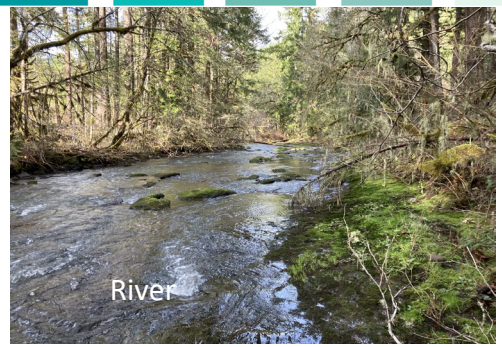




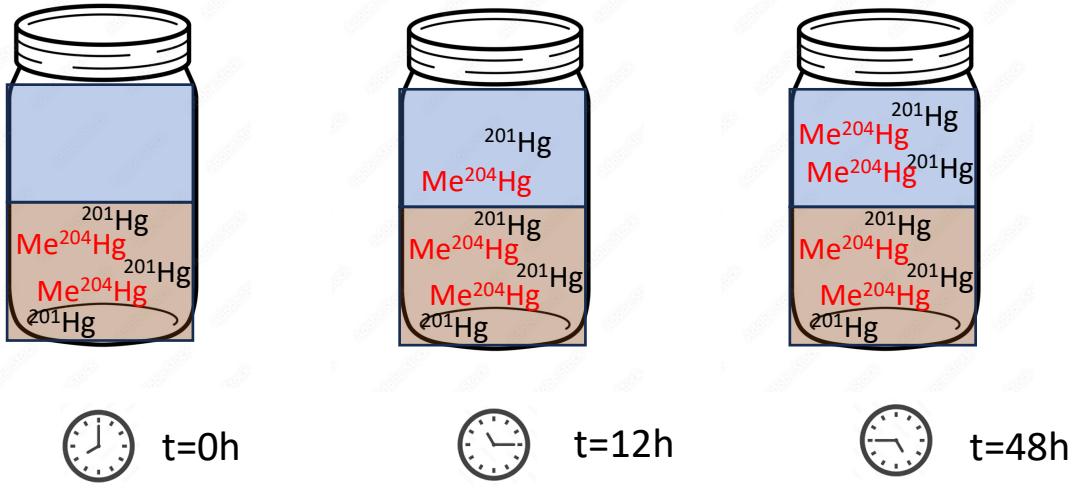


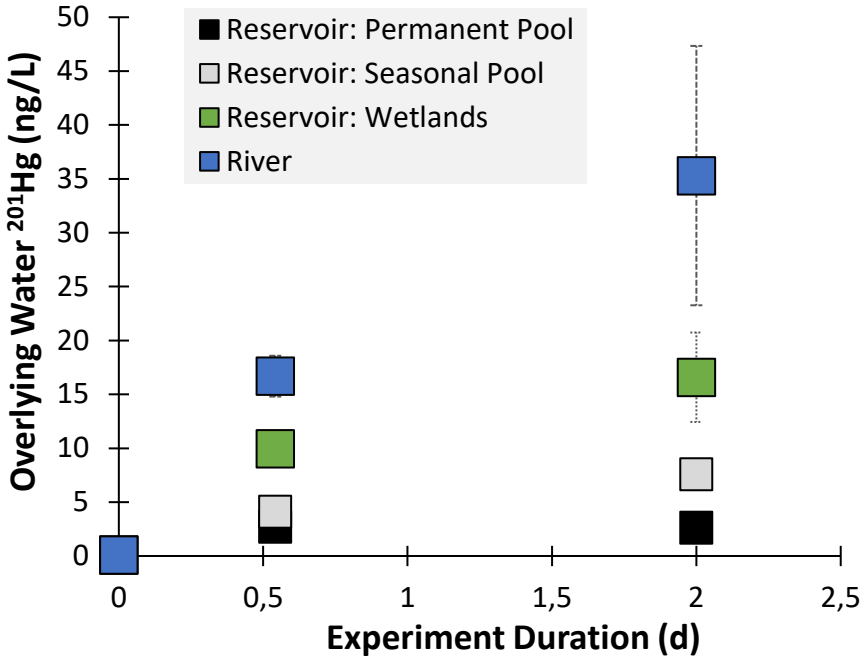
High Kd value decreases MeHg production

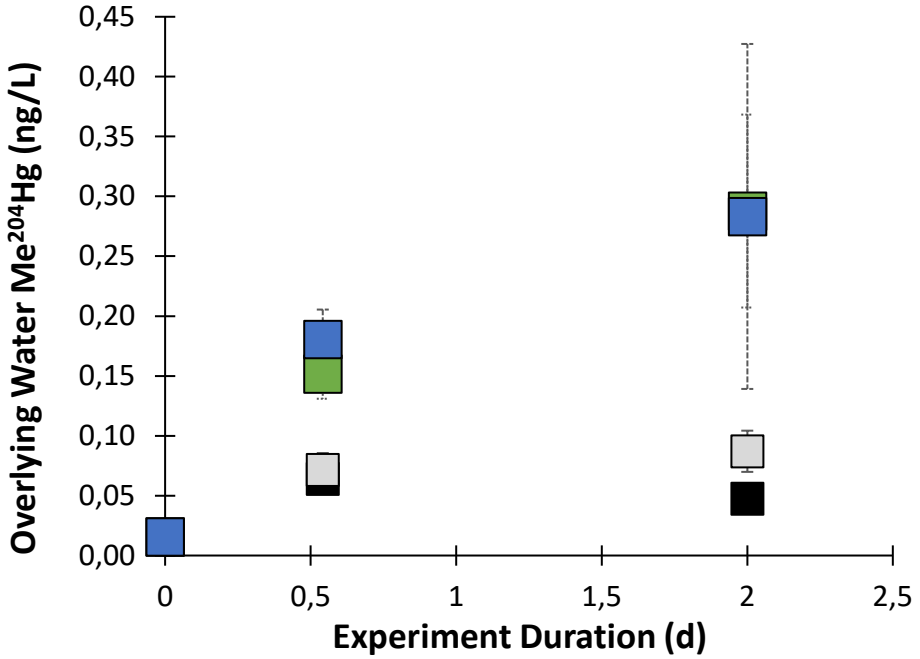
Results: Flux of THg & MeHg from sediment to water



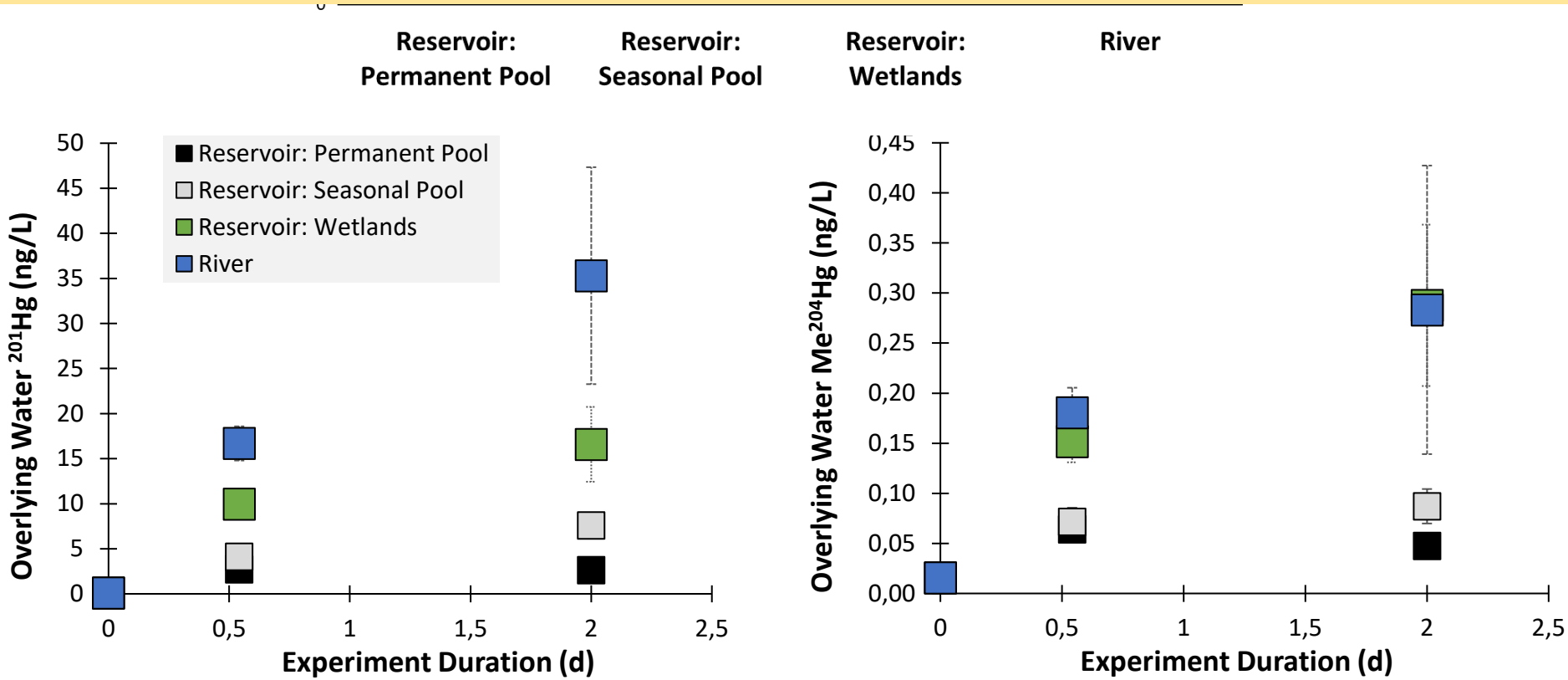
4 landscape types
5 replicates
3 time points



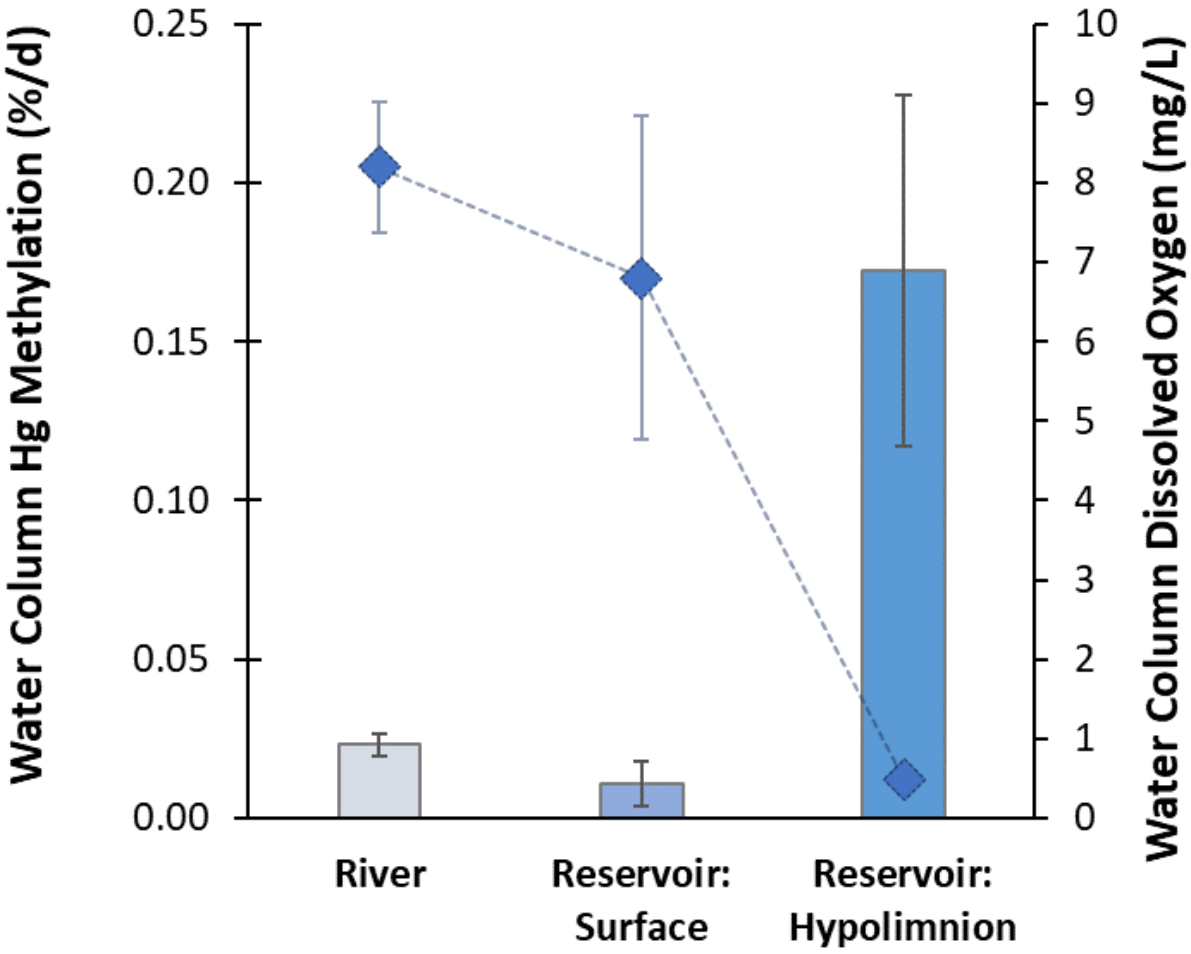




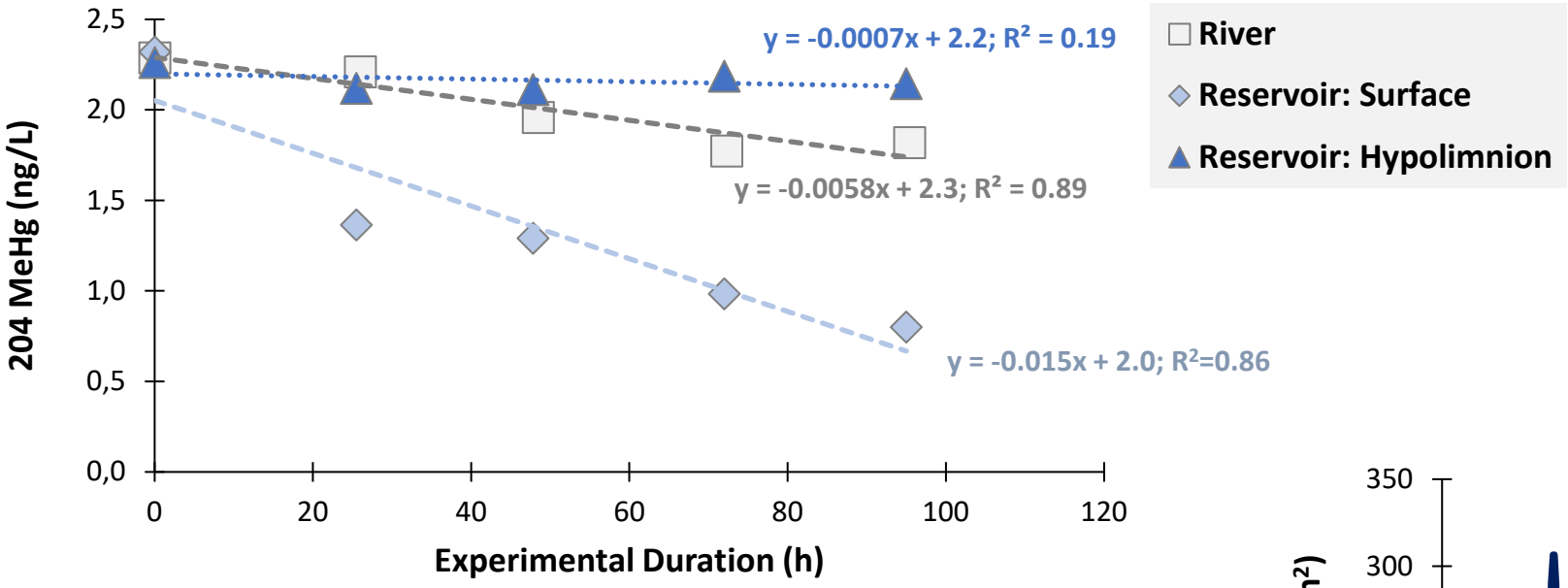
- Methylation rates & fluxes to the water may vary due to sediment characteristics
- River sediment had the lowest MeHg production; but highest flux to overlying water

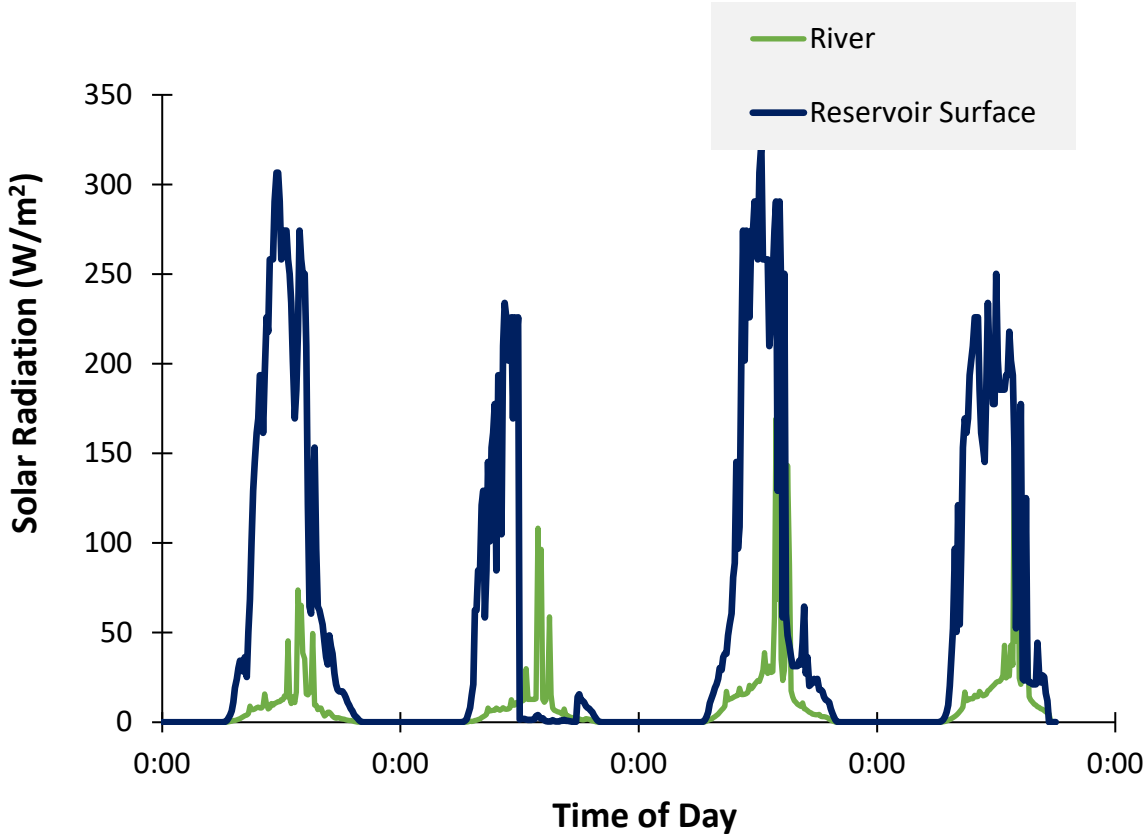


Results: MeHg production in the water column



Results: MeHg degradation in the water column

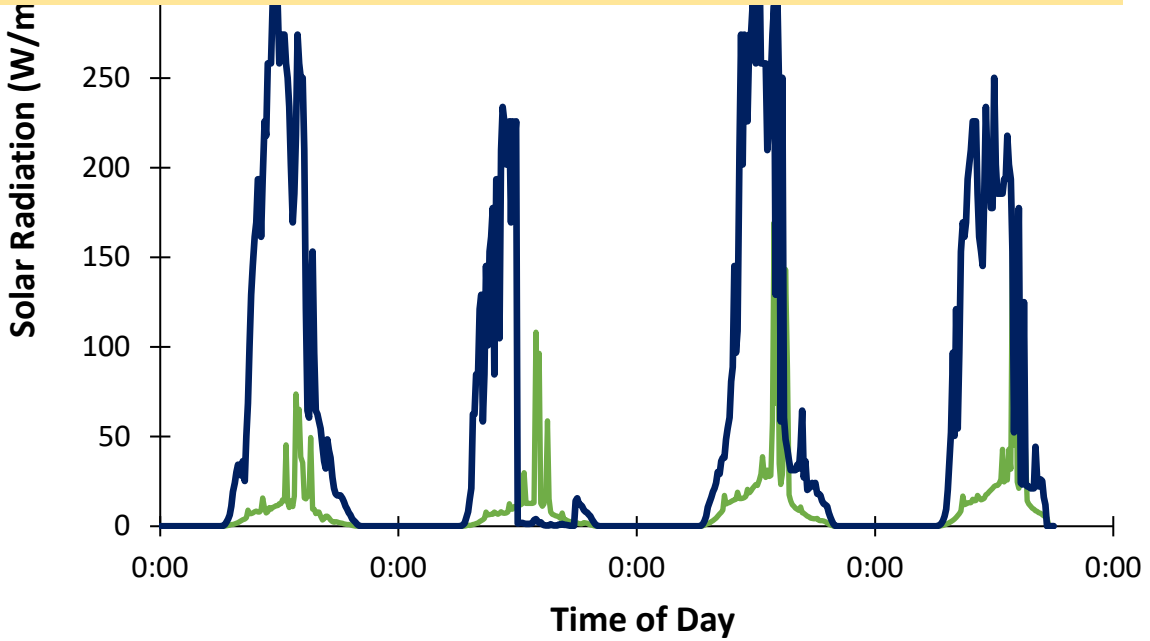




- MeHg production in the river is low; but due to shading so are photo-demethylation rates

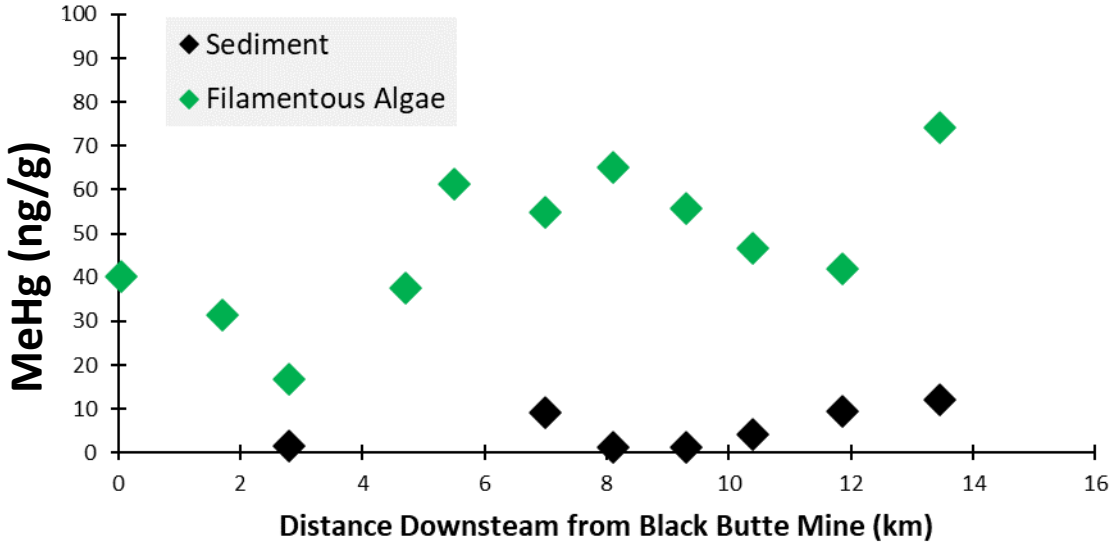
- The reservoir results in 6-fold higher sunlight in surface waters, which enhance MeHg degradation

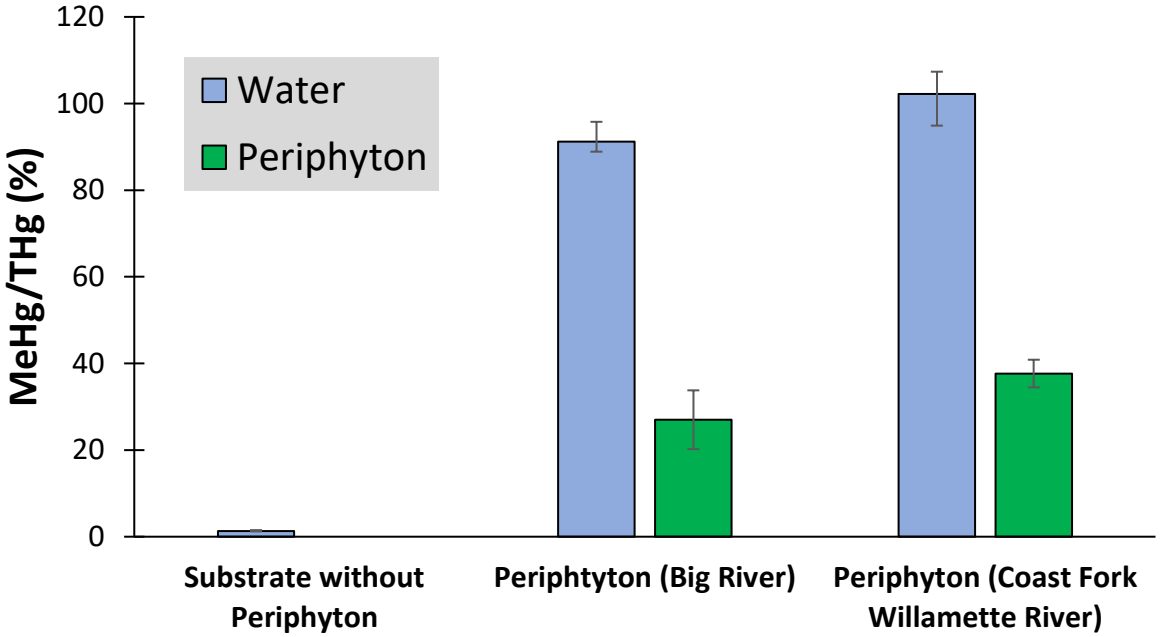
- MeHg production in the anoxic hypolimnion is not degraded via photo-processes.

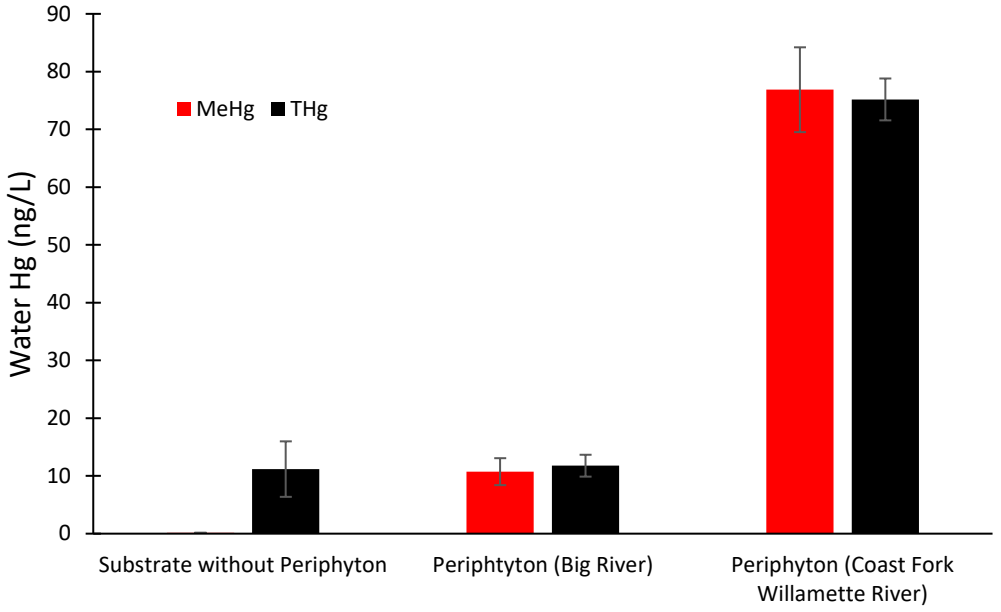


Results: Periphyton MeHg concentrations & fluxes

Periphyton retain inorganic Hg, but produce & release MeHg to the surrounding water

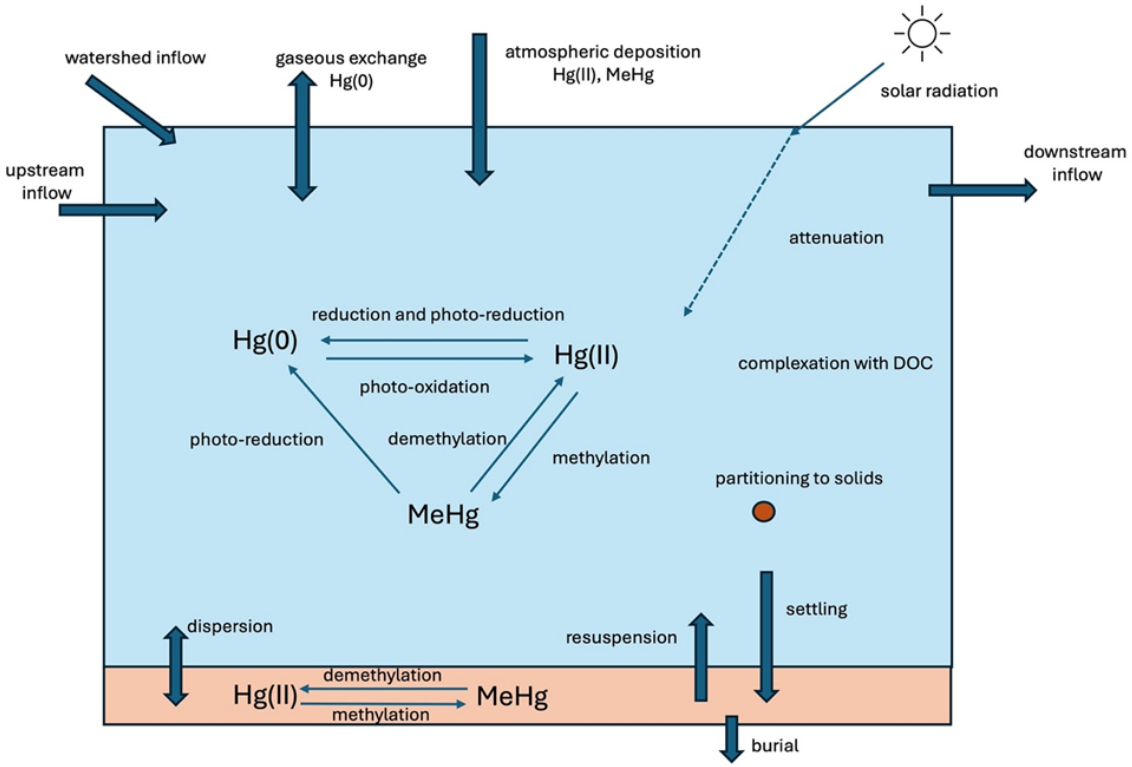


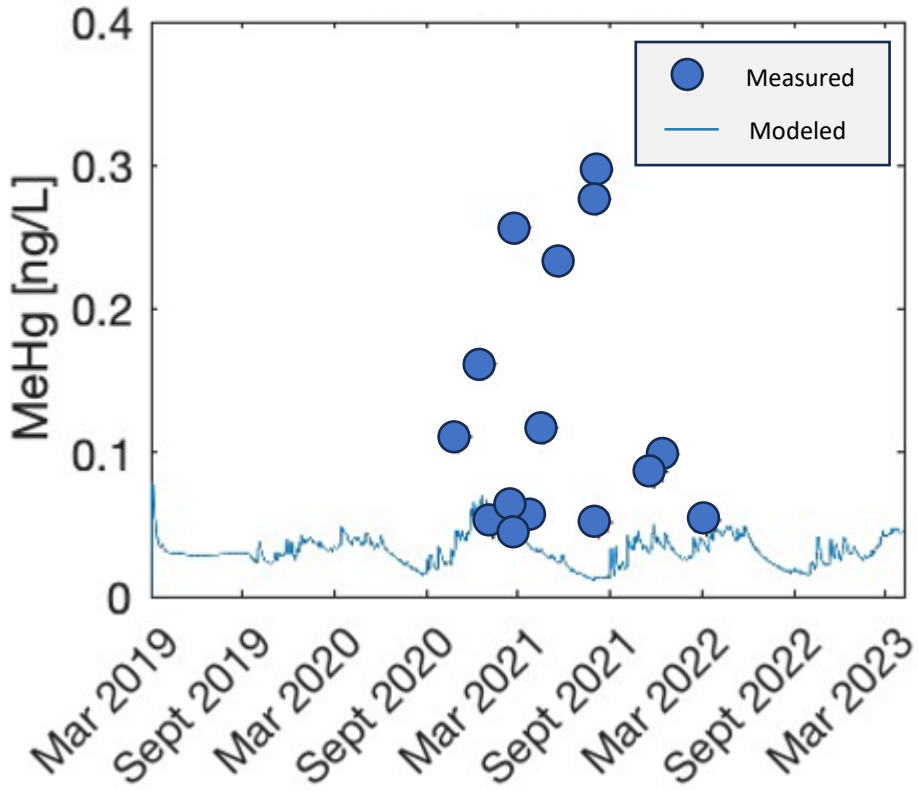




The WASP Model run without including MeHg production in periphyton greatly underpredicts measured MeHg concentrations in the river—suggesting that the flux of MeHg from periphyton into the river is significant on the watershed scale

Water Quality Analysis Simulation Program (WASP) Model Processes





Conclusions:

Differences in landscape variable have important implications for Hg mobility and methylation downstream of an abandoned mine site

Specifically:

- Sediments subject to water-level fluctuations have higher MeHg production (and degradation).
- Sediment MeHg production related to partitioning into the porewater (Kd values)
- Release of THg & MeHg from sediment to overlying water varies between lotic/lentic/wetlands and may not be correlated with zones of highest MeHg production
- Reservoir surface waters have higher photo-demethylation rates compared to river waters
- Periphyton have higher MeHg concentrations than sediments and release MeHg into the surrounding water at levels that can influence water column concentrations.

Questions