**Identifying Drivers of Divergent Methane Flux Patterns and Budgets from Restored Wetlands**

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Restored wetlands in the Sacramento-San Joaquin Delta region of California are created as a means to reduce land subsidence and greenhouse gas (GHG) emissions from drained peatland agriculture. While these wetlands tend to be carbon sinks on a year-to-year basis, variation in methane ($CH_4$) emissions determines whether sites are GHG sources or sinks. In the case of two recently restored wetlands, $CO_2$ budgets are similar across sites, whereas $CH_4$ budgets vary by a factor of two, making it necessary to understand drivers of divergent $CH_4$ fluxes to better predict wetland GHG balances. Using eddy covariance data collected from three restored wetlands, we use data-driven approaches to identify scale-emergent biophysical controls of $CH_4$ fluxes, and a wetland biogeochemical process model to evaluate alternative hypotheses to explain differences in $CH_4$ fluxes across sites.

We observed large differences in $CH_4$ flux controls and patterns between a 'high $CH_4$ flux' and 'low $CH_4$ flux' recently restored wetland. Methane emissions were largest one year after restoration for the high-flux site and steadily decreased each year post-restoration, while annual $CH_4$ budgets for the low-flux site steadily increased each year post-restoration but never reached flux magnitudes observed at all other wetland sites. Differences in biophysical controls of $CH_4$ fluxes between high- and low-flux wetlands were most notable one year post-restoration when differences in flux magnitudes were also greatest. Here, physical transport processes were coupled to diel and multiday $CH_4$ emission patterns from the low-flux site, while plant transport processes were coupled to emission patterns from the high-flux site; however, flux controls at both sites converged multiple years after restoration. Model-based hypothesis testing demonstrates that the diminished fluxes observed at the low-flux site are best explained by 1) long-term inhibition of methanogenesis, potentially due to the presence of alternative electron acceptors, or 2) limited soil organic carbon pools present in pre-restoration soils. Models of both scenarios capture $CH_4$ flux patterns from both recently restored sites, as well those from an old restored wetland; however, the C limitation hypothesis significantly underestimates respiration fluxes from the low-flux site. Preliminary data suggests that high concentrations of oxidized iron in the low-flux site sediments may be responsible for reduced $CH_4$ emissions, but additional soil sampling across sites is needed to confirm this hypothesis. These findings demonstrate that $CH_4$ emissions from restored wetlands can vary considerably across local scales, and a better understanding of site-level soil biogeochemistry will aid in predicting wetland GHG exchange.