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Sediment and organic carbon delivery control methane emissions from urban stormwater ponds

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Stormwater management ponds (SWMPs), like other small inland water bodies, emit greenhouse gases (GHGs), including methane (CH_4), carbon dioxide, and nitrous oxide, in amounts disproportionate to their size. SWMPs are rapidly increasing in number due to urbanization and are increasingly recognized as potential hotspots of GHG emissions. However, the external landscape-scale and the internal bio-geochemical controls on CH_4 production and release from SWMPs remain poorly understood. This study presents results from 11 SWMPs in the City of Kitchener, Ontario, Canada, sampled in 2026 fall, integrating measurements of ebullitive CH_4 fluxes and isotope compositions ($\delta^{13}C$-CH_4), dissolved CH_4 concentrations, water chemistry, sediment characteristics, and vegetation coverage with external information on pond management, organic carbon inputs, and catchment information. To reduce the multivariate dataset to the major dimensions explaining the observed within- and between-SWMP variability in the CH_4 fluxes, we used principal component analysis (PCA). The PCA results showed that ebullitive CH_4 fluxes, dissolved CH_4 concentrations, sediment depth and accumulation rate, and turbidity are strongly correlated along a common gradient, suggesting a strong relationship between sediment delivery and CH_4 release. CH_4 fluxes were positively correlated with catchment and vegetated zone area-based estimates of organic carbon delivery, indicating that organic matter inputs, alongside sediment accumulation, exert a strong control on CH_4 production. Ebullition $\delta^{13}C$-CH_4 further supported the important role of organic carbon inputs, with $\delta^{13}C$-CH_4 values relatively more enriched in ^{13}C when CH_4 fluxes were higher, indicating that high CH_4 production rates were driven by acetoclastic methanogenesis, which is indicative of labile organic matter supply. These results provide insight into the factors controlling CH_4 emissions from urban SWMPs and explain the heterogeneity, which can help to inform pond design and maintenance strategies as well as efforts to upscale CH_4 emission estimates to larger scales.