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Salinization as a catalyst for methane production in a freshwater peatland

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Rising sea level increases salinization of freshwater ecosystems, affecting coastal peatlands and below-sea-level freshwater wetlands. Over 30% of the world's soil organic carbon is stored in peatlands, and this carbon is vulnerable to decomposition, emitting greenhouse gases like carbon dioxide (CO_2) and methane (CH_4). The formation of new peat as quaking fen is key to carbon sequestration. However, a knowledge gap remains on how salinization affects microbial activity, biogeochemical processes, and carbon cycling in these freshly formed peat layers. Generally, salinization is known to decrease CH_4 release. Recent evidence, however, suggests that CH_4 can accumulate in quaking fens under saline conditions, although the mechanism remains unknown. In this long-term field and laboratory-based study, we aimed to identify key drivers of microbial CH_4 cycling in quaking fens vs. older peat layers under freshwater and brackish conditions. Geochemical analysis of the sediment and porewater suggests that high abundance and bioavailability of carbon and organic matter in the quaking fen increased microbial activity and carbon turnover compared to deeper layers. Additionally, incubations with methanogenic substrates revealed a dominance of methylotrophic methanogens in the quaking fens, with 10 times more CH_4 produced under brackish conditions in 10 days. Furthermore, untargeted metabolomics shows increased abundance of trimethylamine N-oxide in brackish quaking fens. This osmolyte is common in aquatic ecosystems and one of the main substrates for methylotrophic methanogenesis, likely contributing to increased CH_4 production under saline conditions. Our results shows that neither aerobic nor anaerobic methanotrophy was influenced by salinization. 16S rRNA gene amplicon sequencing and qPCR analysis of the bacterial 16S rRNA gene, pmoA (aerobic methanotrophy), mcrA (methanogenesis), and dsrA (sulfate reduction) revealed a similar community composition with higher absolute abundance of methanogens in the brackish system. Together, this suggests that the higher CH_4 release originates from increased substrate availability and subsequent stimulation of methylotrophic methanogenesis rather than decreased methanotrophy in quaking fens influenced by salinization. Although most studies show that salinization reduces CH_4 emissions, our results indicate that seawater intrusion into freshwater systems may increase CH_4 production and potentially amplify the global-warming feedback loop.