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Fungi stabilize carbon across the land-sea interface in high-Arctic ecosystems

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Anthropogenic climate warming is amplified in the Arctic and has resulted in glacial melting and a shift from marine to land termination at the land-ocean interface and pioneer soil formation over glacial deposits. These pioneer soils are oligotrophic, but following initial colonization by microorganisms, accumulate organic carbon and nutrients over time. These changes are associated with altered marine ecosystems and a weakening of the Arctic carbon sink, but the microbial mechanisms driving carbon stabilization under these conditions remain unclear. Here we traced amino acid uptake by microorganisms in (a) recently deglaciated high-Arctic soils, and (b) in an Arctic inner-shelf fjord ecosystem with retreating marine-terminating glaciers. We show that fungi play a critical role in the initial stabilization of the assimilated carbon and that osmotrophic fungi play an important role in stabilization of assimilated carbon in marine sediment. Glacial fed streams were identified as an important source of the osmotrophic, amino acid assimilating fungi with to the fjord where they maintain a relatively high carbon use efficiency (CUE) after being deposited into the sediment at the seafloor. In contrast, bacterial amino acid assimilation was predominant in fjord seawater and associated with increased respiration and low CUE. In a soil chronosequence, pioneer basidiomycete yeasts were the predominant taxa responsible for carbon assimilation, which were associated with overall high amino acid use efficiency and reduced respiration. In intermediate and late-stage soils, lichenized ascomycete fungi were prevalent, but bacteria increasingly dominated amino acid assimilation, with substantially decreased fungal:bacterial amino acid assimilation ratios and increased respiration. The active fungi that assimilated amino acids in the marine sediment were conspicuously not detected in nearby tundra soils or glacial till, indicating a specialized niche for aquatic osmotrophic fungi in the marine sediments. These results demonstrate that osmotrophic marine fungi with high CUE play an important role in carbon stabilization in coastal arctic shelf sediments influenced by marine-terminating glaciers. Together, our findings demonstrate that fungi are important drivers of pedogenesis in high-Arctic ecosystems and show fungal osmotrophy and CUE are important traits stabilizing organic carbon in Arctic marine sediments, that are currently subject to deglaciation from global warming.