The Influence of Ice and Ocean Interactions on Microbial Communities under Ice Shelves

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Life Under Ice: The Antarctic continent is ringed by hundreds of floating ice shelves up to kilometers thick, which form as ice flows into the ocean faster than it melts or calves into icebergs. Ice shelves cover ~1.56×10^6 km^2 of the Southern Ocean, but the cold, remote, and aphotic oceans below are understudied.

Ocean Worlds. Other worlds in our solar system (e.g. Europa) are also thought to have saline oceans below thick ice shells at similar temperatures and pressures. Study of terrestrial ice shelf systems can then provide insight into processes, and possibly habitability, of other ocean worlds (Schmidt, 2020).

Ross Ice Shelf. The ~5×10^5 km^2 Ross Ice Shelf (RIS) represents a third of all floating glacial ice on Earth. The first glimpse of the ocean beneath came during the 1977-78 season at the J9 site, where fish and other macrofauna were found ~500 km south of the Ross Sea. Aphotic sub-shelf oceans are isolated from photosynthetic production, but Horrigan (1981) suggested chemoautotrophic production (then, recently discovered) by ammonia oxidizing bacteria was sufficient to support the observed community.

However, inorganic nutrients must ultimately be sourced from either the open ocean, melting ice, subglacial water input, or sediment pore waters – and the relative balance of these inputs to the J9 ecosystem remained an open question. Decades passed before the next RIS borehole, but in the past 10 years several more projects have accessed the ocean as well as upstream subglacial lakes and a subglacial channel.

Goal: We will share a multi-year 16S rRNA gene abundance survey of microbial diversity and metabolic potential in the sub-RIS water column from 47 samples across a three site transect: the northern terminus by McMurdo Ice Shelf (MIS), a mid-RIS site (HWD2), and the RIS grounding zone (GZ) or shoreline, ~700 km south of the open Ross Sea.

Preliminary results (Lawrence et al., 2019) found that microbial community composition was correlated with water masses defined by ice-ocean interactions, and that ammonia-oxidizing *Nitrosopumilus* was abundant in both MIS-adjacent and HWD2 samples. Here, we add GZ data and seek to understand how water column structure, ice composition, and ocean-driven ice melt and freeze processes combine to influence the microbial ecosystem, and to discuss the relevance of ice shelf systems as analogs for other oceans worlds in our solar system.

Sub-Shelf Ecosystems: In support of the J9 results, comprehensive multi-omics work at HWD2 during the 2017-18 season found a chemosynthetically-driven ecosystem, and that genes for ammonia and nitrite oxidation (nitrification) were the most highly transcribed (Martínez-Pérez et al., 2022). Ice melt was inferred as a primary source of ammonia, which was elevated in the upper water column at both J9 and HWD2.

Subglacial Subsidies: Upstream of the RIS GZ in Subglacial Lake Whillans (SLW), chemoautotrophic production was also measured in excess of the heterotrophic carbon demand, with additional contributions of carbon from underlying marine sediments (Christner et al., 2014) and possibly redox species from ice-driven comminution (Gill-Olivas et al., 2021). Flux of water from subglacial lakes and estuaries is now recognized as a major source of relict and microbially-processed carbon and nutrients into the sub-shelf ocean (Vick-Majors et al., 2020).

Ice and Ocean Interactions: Subglacial water can flow into the sub-shelf ocean either directly as a liquid, or as a solid – in the form of basal ice frozen onto the meteoric ice sheet upstream of the grounding zone. Basal ice is then advected across the GZ where it melts and releases nutrients into the sub-shelf water column. The spatial distribution of basal ice and rate of melting is determined by ice flow speeds along with ocean currents and heat, which we hypothesize combine to influence microbial community composition, metabolic potential, and chemosynthetic production. Ice-ocean interactions could prove similarly important in Europa's ocean, where melting of the ice shell releases oxidants and nutrients into the ocean below (e.g. Schmidt, 2020).

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