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# Exploring microbial activity and metabolic requirement during the polar winter of the Arctic

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The cryosphere encompasses a wide range of perennial microbial habitats including glaciers, lakes, seas, rivers, and soils. These habitats pose intrinsic seasonally-variable challenges for microbial populations, whose activity may be temporarily constrained. Microbial dynamics in these environments during the summer and (to a lesser extent) spring have been extensively studied, however the winter season remains largely unexplored. During the winter period, microbial activity may be constrained by freezing temperatures, limited availability of liquid water, and the absence of light and thus photosynthetic carbon input. Critical aspects of microbial activity, including metabolic processes, winter-specific community profiles, and their unique functional roles in ecological processes, are still poorly understood. To address this knowledge gap, we examined microbial activity during the winter months in a range of aquatic and terrestrial Arctic habitats. Using metatranscriptomic techniques, we identified active microorganisms and uncovered their core metabolic requirements for sustaining activity. We also employed BONCAT (bioorthogonal noncanonical amino acid tagging) to assess the ratio of live to dead microbes across different habitats and utilized qPCR and RT-qPCR to quantify organism abundance. Our results revealed significant differences in community composition, abundance, and activity across environments. Notably, glacial snow and lake slush snow exhibited high RNA-to-DNA ratios, with distinct differences in microbial diversity. Lake slush snow, in particular, displayed a more uneven microbial community compared to its snow counterpart. In contrast, soil showed very low activity despite a high DNA content. Among the ice cores, glacial ice exhibited both high diversity and moderate microbial activity. Overall, our findings suggest that microbial communities in winter are active, with activity levels varying across different habitats. These variations may be driven by factors such as differences in microbial seeding sources and the availability of free water. Despite limited energy reserves, we suggest that winter microbial communities contribute to the mineralization and recycling of biomass and elements, playing a crucial role in sustaining ecological processes in the Arctic cryosphere.