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Ecophysiology of Polar Sea Ice Microorganisms in a Changing World

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Abstract

Earth's oceans are predominantly cold, with nearly 90% of their volume having temperatures below 5 °C. Microorganisms commonly referred to as psychrophiles have adapted to the temperatures of these cold waters. The most extreme psychrophiles are found inside the sea ice of polar oceans, where bacterial growth can be observed down to -20 °C. Sea ice consists of a matrix of ice and high-saline water (brine) that provide a unique habitat for microbial communities. Microscopic algae and bacteria dominate these extreme environments, which are considered very stressful as they are characterised by large variations in salinity, low temperatures, and low radiation levels. However, the brine-filled channels also provide a platform from which microscopic algae remain in the euphotic zone and refugees from significant grazing, thereby enabling net autotrophic growth. As a result, sea ice hosts some of the highest chlorophyll *a* concentrations on the planet, and is one of the most important factors controlling primary production and bloom dynamics in polar areas.

In this thesis, I focus on the ecophysiology of psychrophiles adapted to the sea ice environment. Physiological acclimation to environmental change needs to be studied in order to address how different stressors may influence organisms' capacity to tolerate both naturally- and climatically-driven changes. Extremophiles growing close to their physiological limits may be especially susceptible to environmental stressors, such as rapid climate change. Therefore, a series of studies has been performed to investigate how environmental stressors, such as increased temperature and elevated CO_2, affect microbial physiology and community structure in polar areas.

The ecophysiology of sea ice microorganisms has been addressed in laboratory experiments (Papers I, II, and IV) and in field measurements (Paper III). In brief, relatively small changes in temperature had considerable effects on the physiology of sea ice diatoms, and indirectly affected the structure of sea ice bacterial communities. Increasing temperature (on both climatic and seasonal scales) positively affected the growth and primary productivity of two sea ice diatom species, and negatively affected the taxonomic richness and diversity of sea ice bacterial communities, probably by the subsequent changes in salinity.

On the other hand, sea ice diatoms seem quite tolerant to changes in pH and partial pressure of CO_2 (pCO_2) in terms of growth, probably due to the fact that they grow in an environment with large seasonal variations in the carbonate system. However, increased pCO_2 resulted in other cellular changes that may have important ecological consequences, such as cellular stoichiometry. This includes changes in fatty acid composition and dissolved organic carbon exudation, which are important components in food webs and biogeochemistry in many marine ecosystems.

Although most studies on marine organisms have focused on short-term responses to increased pCO_2, acclimation and adaptation are key components in order to identify the consequences of climate change in biological systems. In Paper IV, the physiological responses to long-term acclimation to high pCO_2 were investigated in the psychrophilic sea ice diatom *Nitzschia lecointei*. After long-term acclimation (194 days), a small reduction in growth was detected at high pCO_2. Previous short-term experiments have failed to detect altered growth in *N. lecointei* at high pCO_2, which illustrates the importance of experimental duration in ocean acidification studies.

Keywords: Climate change, ocean acidification, ocean warming, CO_2, Arctic, Antarctica, Southern Ocean, algae, bacteria, psychrophiles