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Transcriptomic analysis reveals distinct mechanisms of adaptation of a polar picophytoplankter under ocean acidification conditions

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ABSTRACT

Human emissions of carbon dioxide are causing irreversible changes in our oceans and impacting marine phytoplankton, including a group of small green algae known as picochlorophytes. Picochlorophytes grown in natural phytoplankton communities under future predicted levels of carbon dioxide have been demonstrated to thrive, along with redistribution of the cellular metabolome that enhances growth rate and photosynthesis. Here, using next-generation sequencing technology, we measured levels of transcripts in a picochlorophyte *Chlorella,* isolated from the sub-Antarctic and acclimated under high and current ambient CO_2 levels, to better understand the molecular mechanisms involved with its ability to acclimate to elevated CO_2. Compared to other phytoplankton taxa that induce broad transcriptomic responses involving multiple parts of their cellular metabolism, the changes observed in *Chlorella* focused on activating gene regulation involved in different sets of pathways such as light harvesting complex binding proteins, amino acid synthesis and RNA modification, while carbon metabolism was largely unaffected. Triggering a specific set of genes could be a unique strategy of small green phytoplankton under high CO_2 in polar oceans.

1. Introduction

Driven by rapid industrialization and deforestation, atmospheric carbon dioxide is currently experiencing a rate of increase in concentration unprecedented over Earth's geological timescale (Zeebe et al., 2016). Atmospheric CO_2 is predicted to rise, in the absence of any mitigation strategies, to 1000 ppm from the current levels of 419 ppm (parts-per-million) by year 2100 (IPCC, 2021). More CO_2 is dissolving into the ocean, changing the carbonate chemistry and leading to acidification of the ocean, from ~pH 8.1 to ~pH 7.8 within the next century (Dickson, 2010; IPCC, 2021).

Rapid changes of oceanic chemistry will affect marine phytoplankton, the major primary producers forming the basis of most oceanic food webs (Pomeroy, 1974). Fixing carbon via photosynthesis, marine phytoplankton contribute half of global primary production (Field et al., 1998). Marine phytoplankton drive the biological pump of the ocean (Millero, 2007) by fixing dissolved inorganic carbon (DIC) for conversion into intracellular organic carbon (Sui et al., 2020). Some marine phytoplankton contain silicon frustules and calcium carbonate coccoliths that enhance ballasting of their organic carbon and facilitating transport of carbon down to the deep ocean (Richardson, 2019). Compared to terrestrial carbon turnover, which occurs over scales of 9–20 years (Carvalhais et al., 2014), marine carbon turnover is fast with turnover times between 7 and 21 days (Falkowski, 1998), making it more susceptible to climactic shifts. As the Southern Ocean takes up 40% of total anthropogenic CO_2 absorbed by the ocean (Takahashi et al., 2009), and its colder waters have higher dissolved CO_2, it is important to examine the molecular responses of phytoplankton from this oceanic region.

Given the low affinity of ribulose bisphosphate carboxylase

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