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Responses of phytoplankton community to silicate-based and calcium-based ocean alkalinity enhancement

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Ocean alkalinity enhancement (OAE) has been proposed as a strategy to sequester carbon dioxide (CO_2) from the atmosphere by adding alkaline substances to seawater. In addition to alkalinity, various dissolution products could be released under OAE, depending on the choice of alkali mineral used. These products such as silicate and changes in carbonate chemistry can impact the competitive fitness of phytoplankton species, which could directly or indirectly affect the compositions of the phytoplankton community. Currently, there are knowledge gaps pertaining to the potential ecological impacts of alkalinisation on natural phytoplankton communities, which hamper a comprehensive evaluation of OAE for its large-scale implementation.

To address these gaps, we carried out an *in situ* mesocosm experiment examining the response of a natural plankton community over 53 days in the temperate mesotrophic waters of the Raunefjord south of Bergen, Norway to two alkali mineral applications. We simulated two mineral types, a calcium-based (quicklime) and silicate-based (olivine) alkalinisation in a non-equilibrated approach. NaOH was used in both mineral treatments to establish a gradient of six alkalinity levels ranging from ambient (~2400 µmol kg^{-1}) to ~3000 µmol kg^{-1} in steps of 150 µmol kg^{-1}. Silicate-based and calcium-based alkalinisation were simulated through the addition of $MgCl_2$ and $CaCl_2$, respectively. Additionally, the treatment simulating olivine-based OAE received 70 µmol L^{-1} of $Si(OH)_4$. Since phytoplankton was nutrient limited from the onset of the experiment, nutrients (nitrate, phosphate) were added halfway through the study to allow for an explicit detection of responses.

Here we report on the responses of the phytoplankton community to the simulated OAE scenarios. Our results indicate that phytoplankton abundances remained largely unaffected across the alkalinity gradient and between mineral types during the oligotrophic phase of the experiment. However, significant differences in the phytoplankton community response were observed post nutrient addition. Here, coccolithophores exhibited a negative response to increasing alkalinity in the silicate-based treatment, whereas the correlation was relatively weak in the calcium-based treatment. We attribute these responses, in part, to changes in carbonate chemistry such as low pCO_2, which may limit coccolithophore growth and the out-competition by diatoms favoured by added silicate.

Overall, our findings suggest minimal risks associated with OAE under oligotrophic conditions over a 20-day period. However, the potential for species-specific negative impacts of increasing

alkalinity should be carefully considered under high nutrient availability. These results represent a crucial first step towards understanding the ecological responses of phytoplankton communities, helping to define the safe operating space in non-equilibrated OAE implementations.