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Algae as Allies: Model-based assessment of Ocean Carbon Sequestration with Macroalgae Mariculture

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The urgent need to mitigate anthropogenic CO2 emissions is underscored by the slow progress in emission reductions and the ambitious climate targets set by international agreements such as the Paris Agreement. This context establishes the importance of exploring effective carbon dioxide removal (CDR) strategies to complement traditional mitigation efforts.

Our initial studies focused on the potential of macroalgae, specifically through a process called Macroalgae Open-Ocean Mariculture and Sinking (MOS), for ocean-based CDR. This involved embedding a macroalgae model into an Earth system model (University of Victoria Earth system climate model, UVic ESCM) to simulate open-ocean macroalgae cultivation followed by the sinking of carbon-rich biomass to deep seafloor areas. Key findings include the significant carbon capture potential of MOS, with and without artificial upwelling, but also notable disruptions to marine ecosystems, such as reduced phytoplankton productivity and changes to oxygen-minimum zones. In subsequent research by Wu et al. (2024), we introduced Nearshore Macroalgae Aquaculture for Carbon Sequestration (N-MACS) as another ocean-based CDR approach, utilizing nearshore macroalgae cultivation. This study assessed its impact on the global carbon cycle and marine ecosystems, revealing that while N-MACS could sequester substantial amounts of CO2, it also significantly impacted marine phytoplankton productivity and nutrient dynamics in coastal waters.

Our future research will focus on the floating brown macroalgae, Sargassum natans and S. fluitans, which form extensive blooms across the Atlantic Ocean. We plan to use the ICOsahedral Non-hydrostatic (ICON) model and the UVic ESCM to analyze Sargassum's ecological and climatic impacts comprehensively. This dual-model approach will allow us to explore both detailed regional interactions and broader, long-term climatic effects. We aim to assess the feasibility of utilizing Sargassum for CDR, given its rapid growth and high carbon to nitrogen ratio, making it an ideal candidate for nature-based climate solutions.

The studies highlight the complex balance between the potential benefits of macroalgae-based CDR techniques and their ecological impacts, underscoring the need for careful evaluation and optimization of such strategies to support global climate goals.