

Carbon removal for ocean health: Integrating foundational science and applied technology to assess the environmental impact of ocean-based carbon removal pathways



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Background:

- Carbon removal projects in the open ocean are one technology being used to sequester carbon from the atmosphere on timelines from centuries to millennia (and more!)
- Ocean-based carbon removal is intended to amplify natural processes and includes pathways of carbon removal such as sinking organic carbon to the deep sea and adding alkalinity to the surface ocean
- While the net, positive impacts are expected to be well quantified as part of the marketplace, concerns have been raised regarding potential negative impacts locally and particularly as technologies increase in scale (in tonnage, space, and time)
- Here, we show how the environmental impact can be considered and integrated in an emerging carbon removal technology development plan, showing a case study from a series of carbon removal projects and experiments that were conducted in 2023

Conclusions:

- Many negative impacts can be mitigated with intentional carbon removal material testing and project design modifications
- Further understanding and re-assessment of impacts with project scale will be important as carbon removal projects continue to mature
- Governance and guidelines are needed that are applicable and relevant for carbon removal projects
- Articulation of a project design and impact framework is a critical first step, and as that is changed the system needs to be re-evaluated
- We look forward to modeling, observational, and experimental studies that look into the impact of carbon removal projects with scale across different pathways, as each comes with different considerations

Establish carbon removal project design

Pathway:

- Sinking biomass
- Limited alkalinity addition

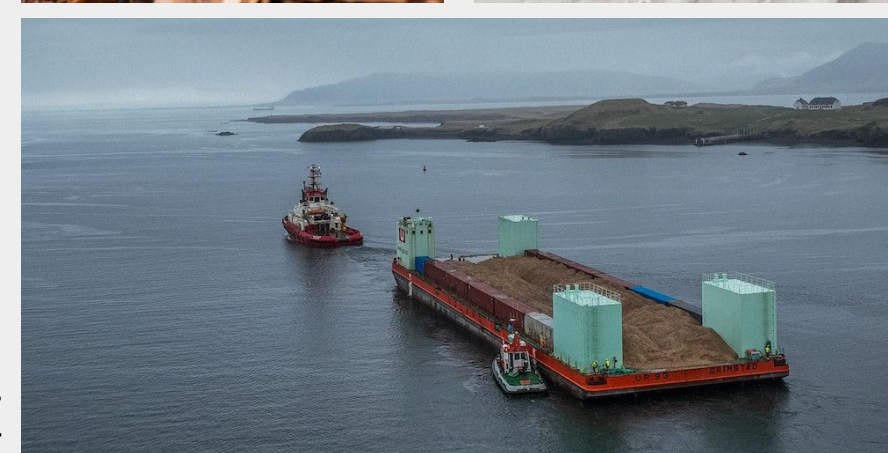


Scale:

- >25,000 tCO₂eq over 5 months

Location:

- Iceland EEZ



Determine potential environmental impact

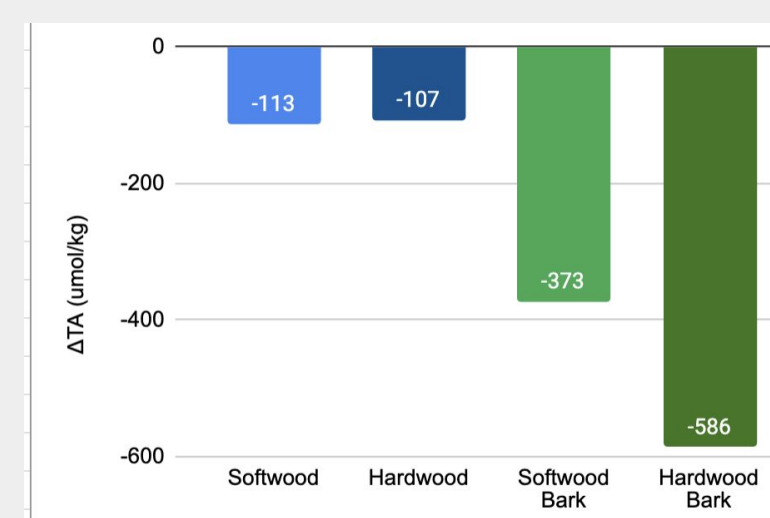
Environment	Impact
Pelagic	Shading of light
	Novel ecologic connectivities
	Exposure to foreign substances
	Harm to marine mammals
Benthic	Alkalinity perturbation
	Organic carbon perturbation
	Increased oxygen consumption
	Redox perturbation
	DIC perturbation
	Alkalinity perturbation
	Introduction of foreign substances

Identify gaps and remaining questions

- Where data and access is limited, how do we address assessing impact?
- At what scale are there measurable impacts to the environment?
- What is the most effective way to integrate models and data to inform quantification and impact?

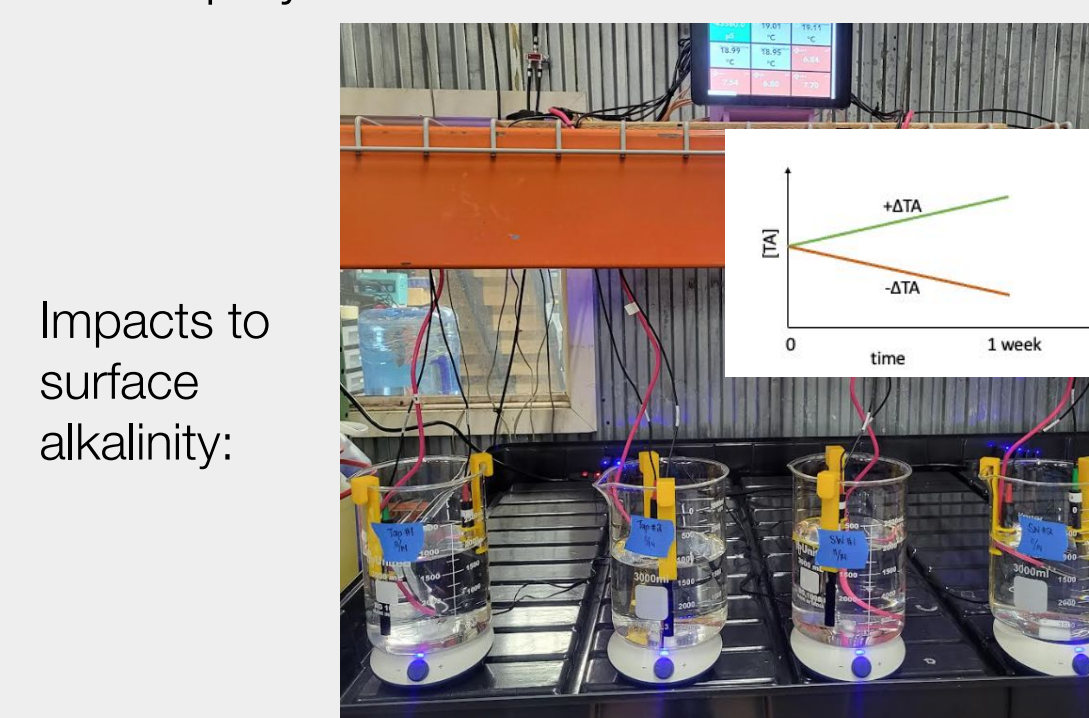
Evaluate carbon removal materials and project design through an environmental lens

- Test materials, compare to available guidance, modify carbon removal materials as needed to mitigate negative impacts



Material 1	Material 2
<ul style="list-style-type: none"> **** All guidance passed for As **** All guidance passed for Cd No results for Co **** All guidance passed for Cr **** All guidance passed for Cu **** All guidance passed for Fe No results for Hg **** All guidance passed for Ni **** All guidance passed for Pb **** All guidance passed for Se No results for V 	<ul style="list-style-type: none"> **** All guidance passed for As **** All guidance passed for Cd **** All guidance passed for Cr **** All guidance passed for Cu **** All guidance passed for Fe **** All guidance passed for Hg **** All guidance passed for Ni **** All guidance passed for Pb **** All guidance passed for Se **** All guidance passed for V

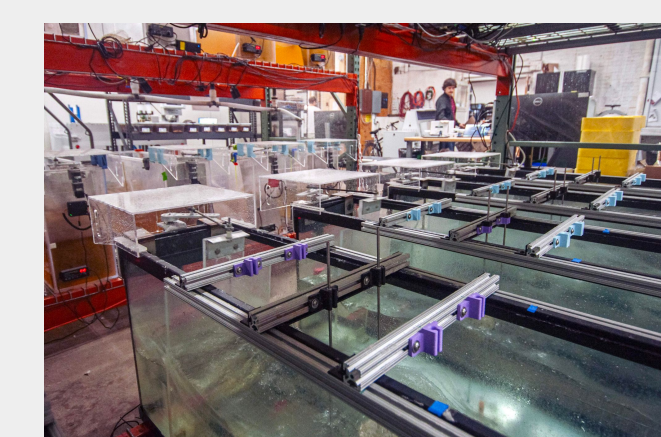
- Test whole carbon removal system and establish required design criteria for deployment



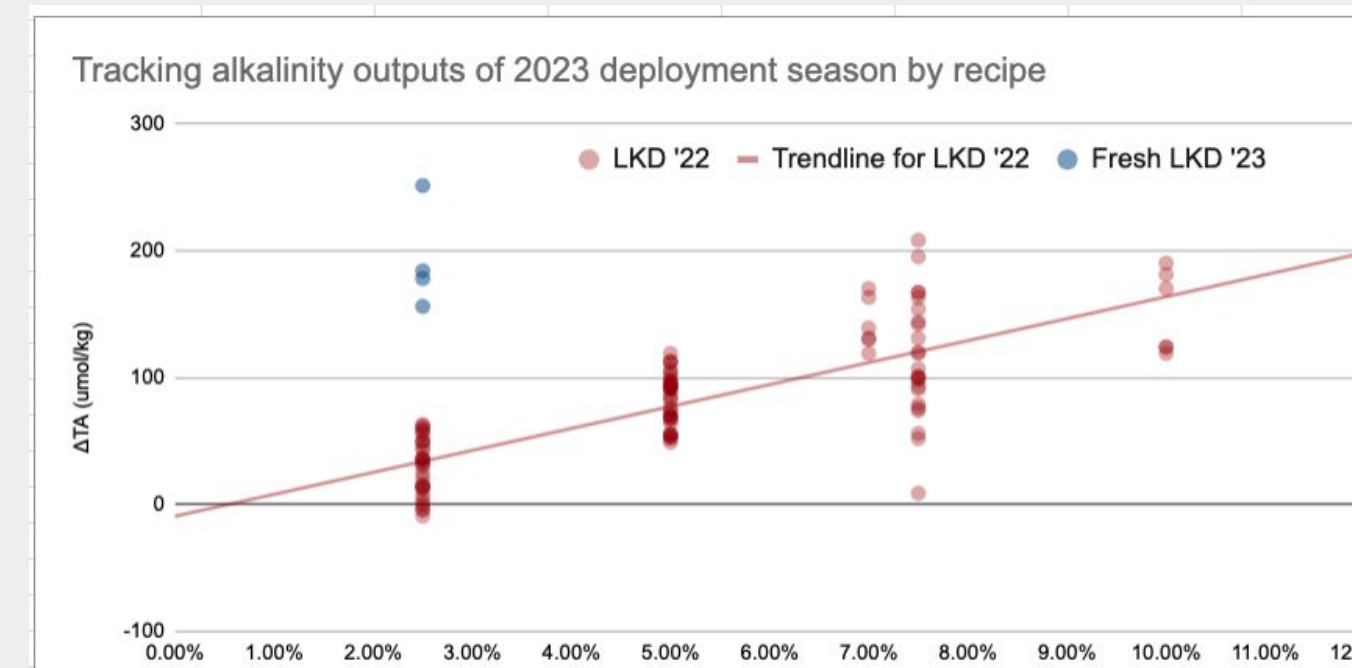
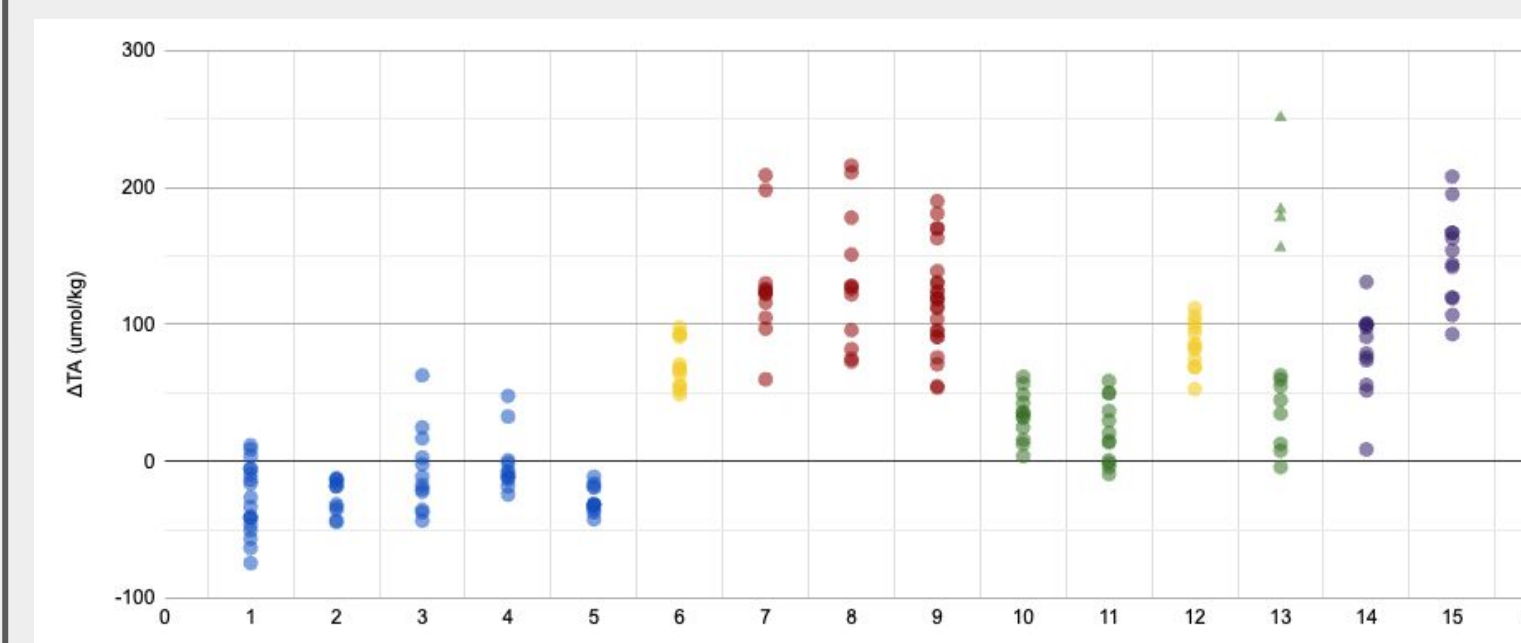
Impacts to surface alkalinity:

Impacts to benthic organic carbon:

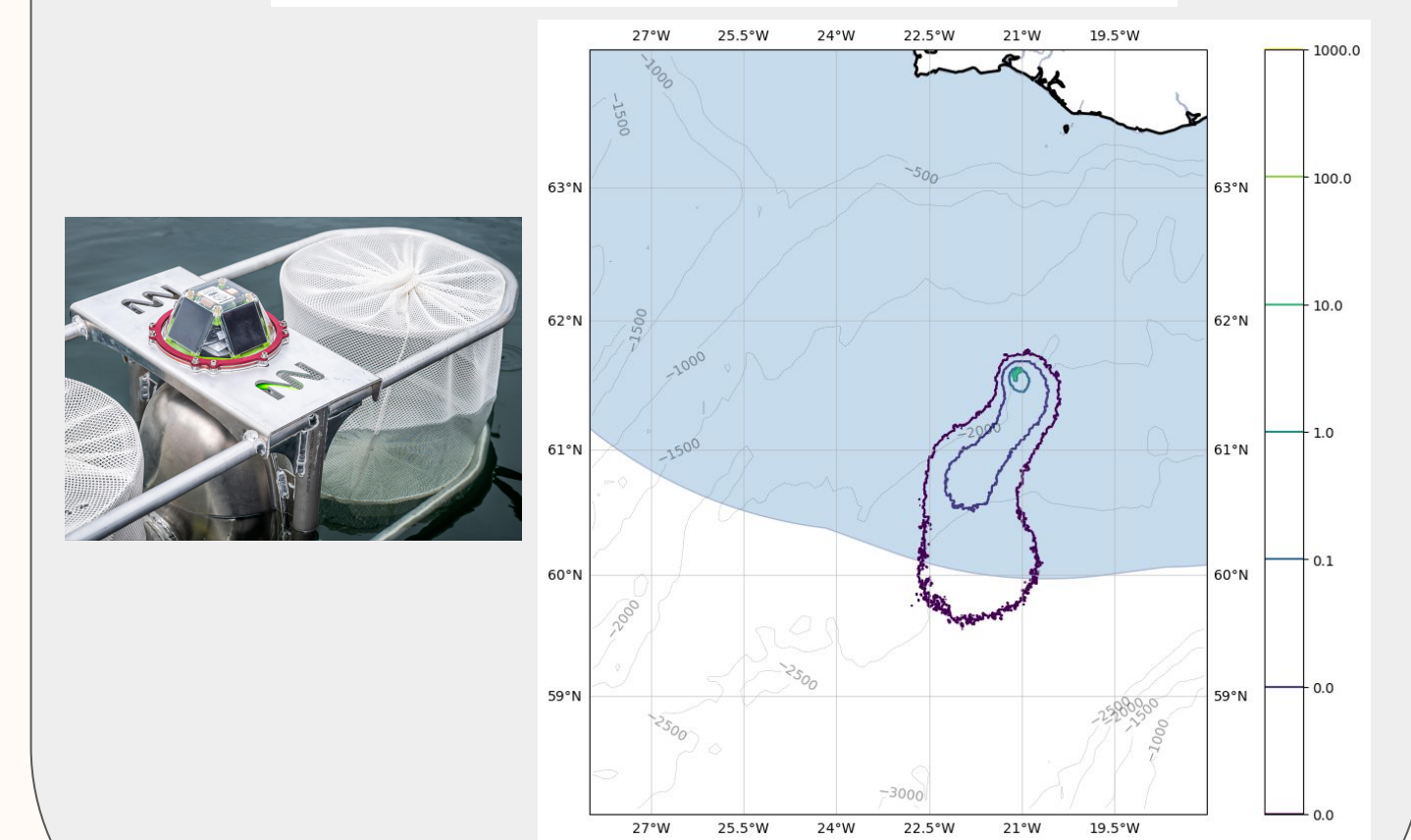
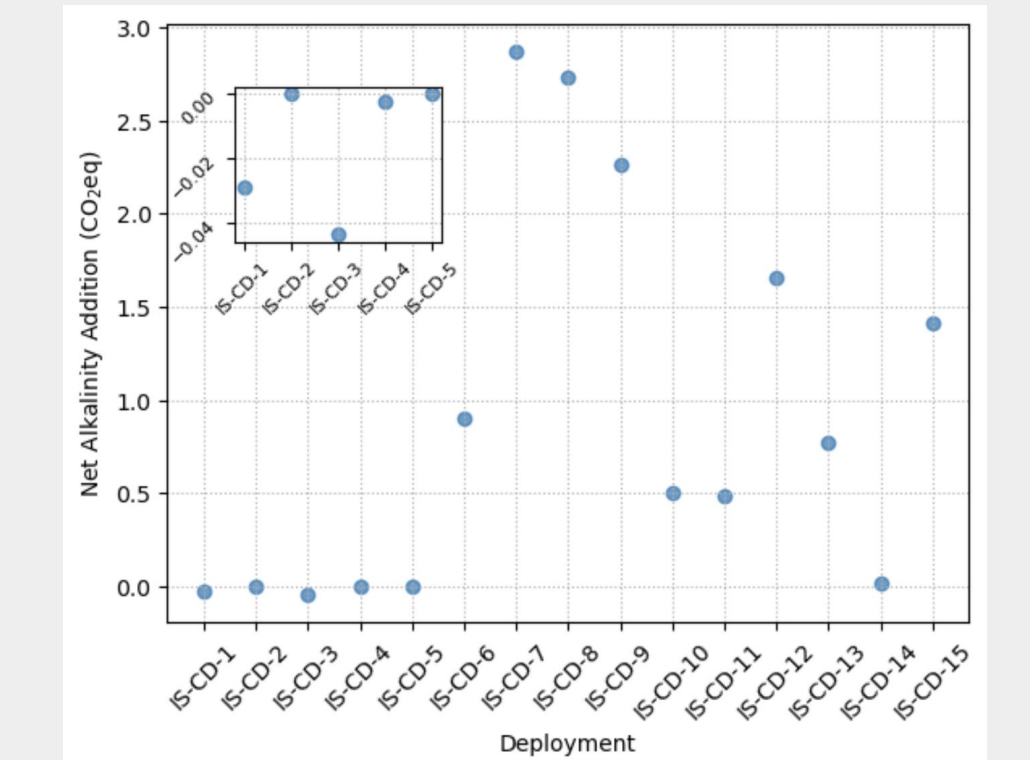
Seafloor density = $f(\text{float time, ship speed, ocean transport})$



- Monitor carbon removal system and ensure negative impacts are addressed



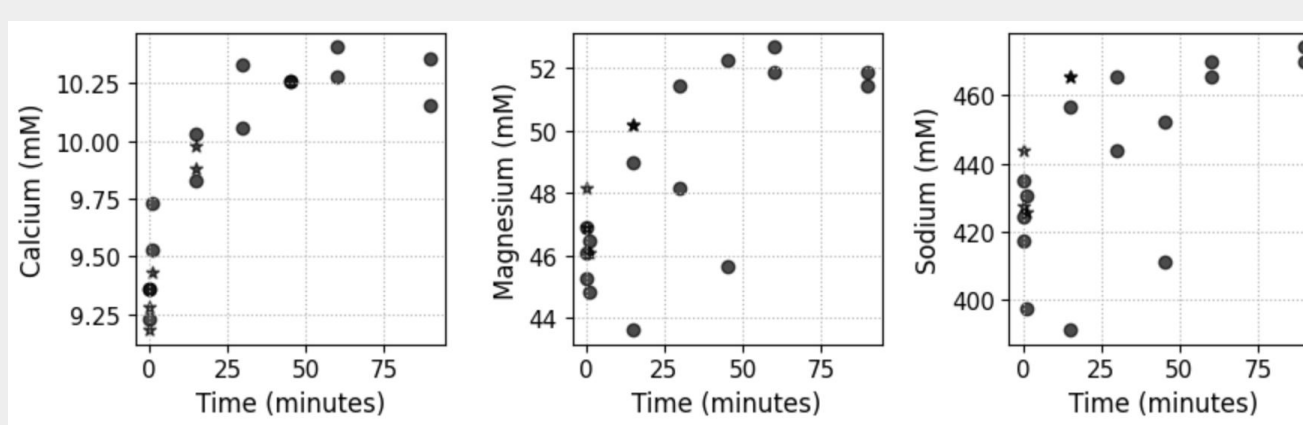
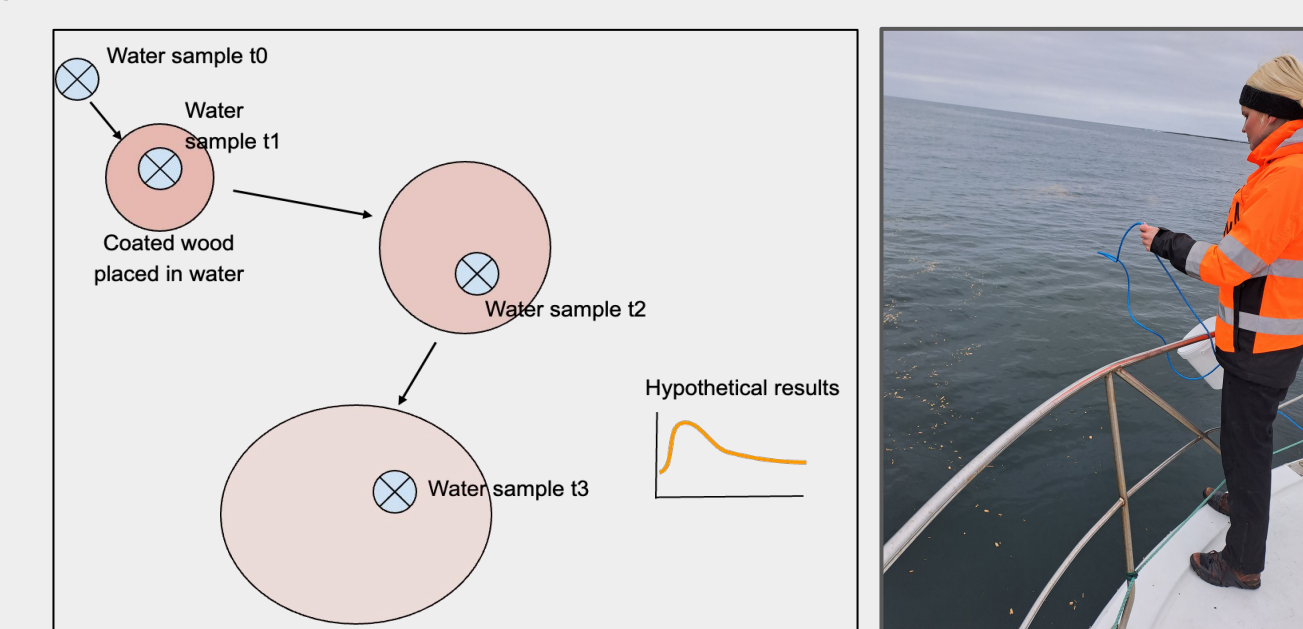
Quantify and monitor impact



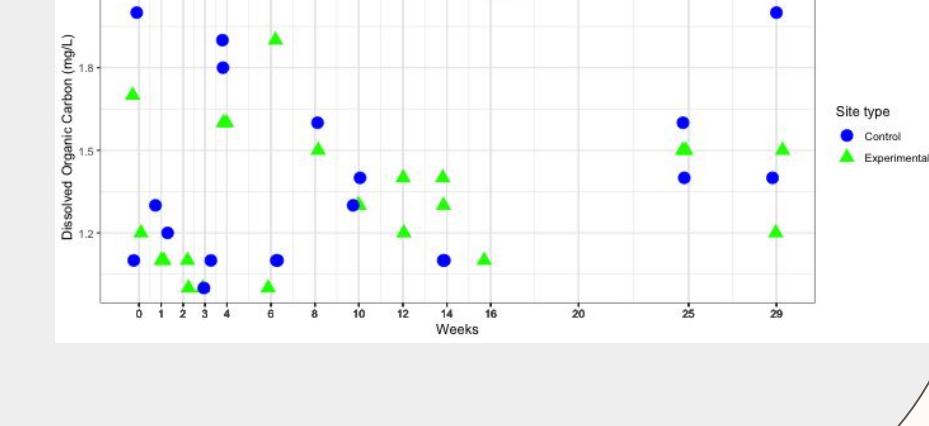
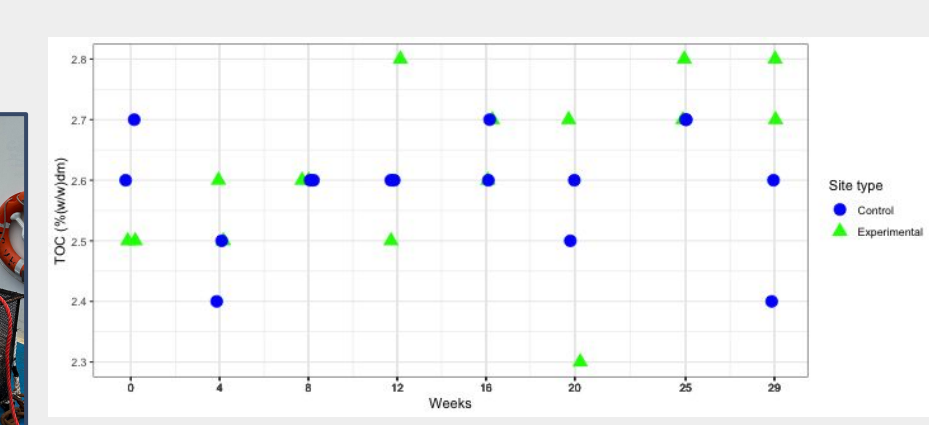
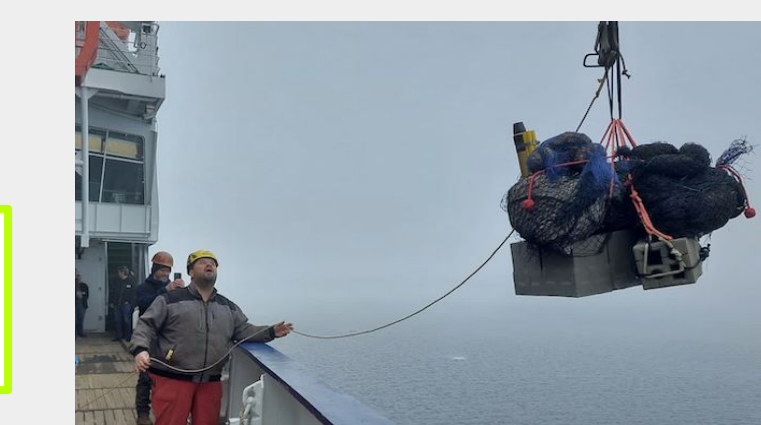
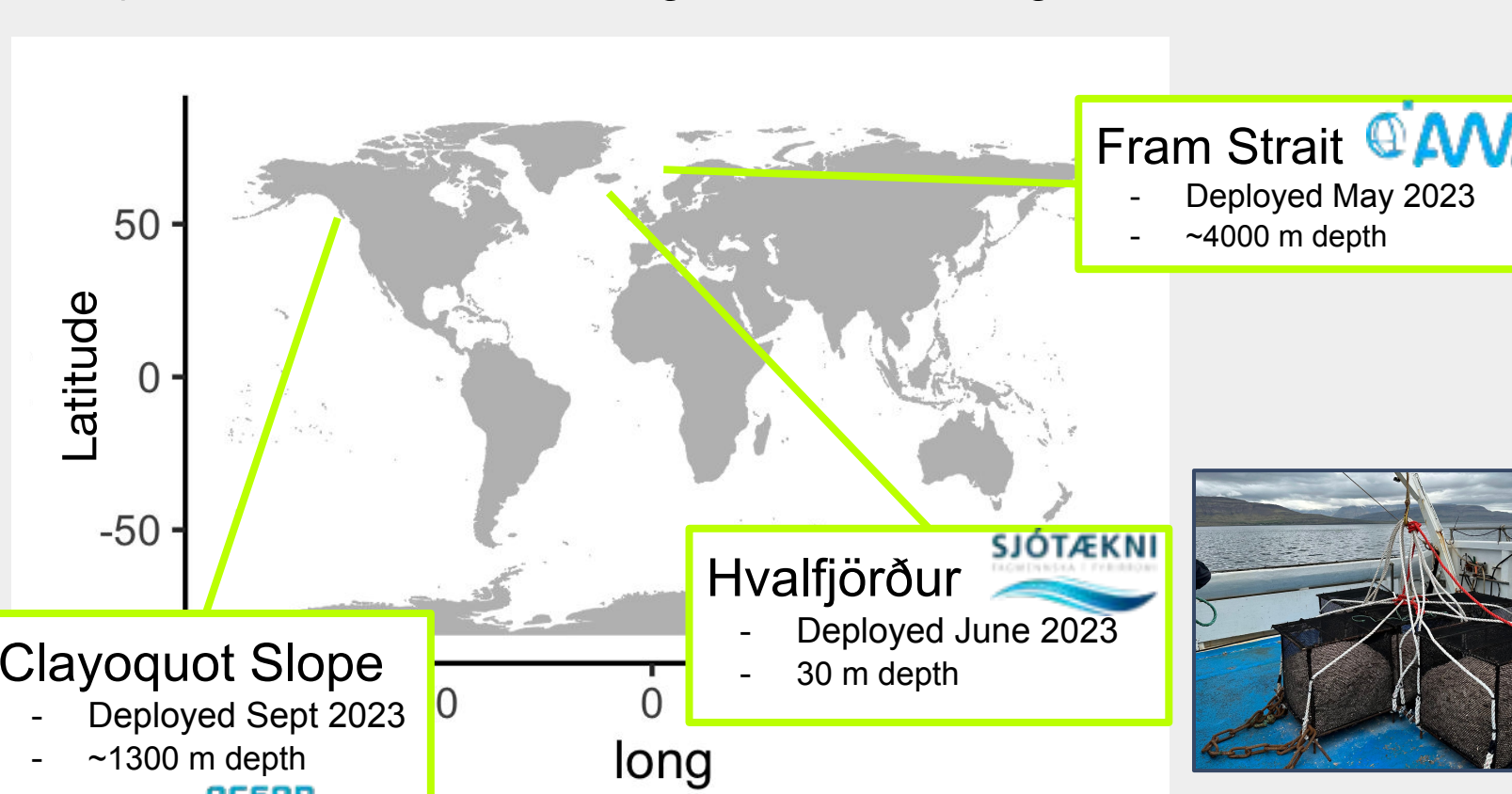
See Anna Savage at CM24A-1134 for more info

Develop and support research projects and programs to address gaps in understanding

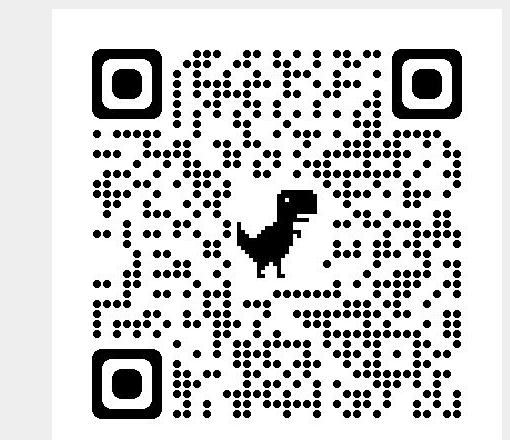
Impact to the surface ocean - mineral dissolution and trace metals



Impact to the benthos - organic carbon degradation



Transparent reporting



<https://docs.runningtide.com/library/>

Acknowledgements:

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Additional Notes:

^AAt RT from 2/2023 to 1/2024 ^BAt RT from 8/2022 to 2/2024 ^CAt RT from 10/2021 to 1/2024