Field experiments to evaluate the effects of amplifying natural ocean processes for carbon dioxide removal

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Background

In marine ecosystems, anthropogenic activities and perturbations of the global carbon cycle have resulted in marine habitat loss, ocean warming, shifting species ranges, loss of biodiversity, and ocean acidification, among other impacts. Carbon dioxide removal (CDR) has been identified by the IPCC as one necessary tool to counter the adverse effects of anthropogenic CO_2. To this end, Running Tide develops technology for restoring ocean health by sustainably amplifying several pathways in the natural carbon cycle, such as **(1) sinking of terrestrial biomass** in the deep (> 1 km) ocean, **(2) open ocean growth and sinking** of macroalgae, and **(3) ocean alkalinity enhancement** (OAE). As CDR via these pathways continues to develop, there is an increasing need to quantify and monitor positive and negative impacts, particularly in the context of biodiversity and ecosystem functioning. Here we present several experimental approaches to assess the efficacy and environmental effects of amplifying the natural ocean processes described above.

Figure 1. Setup of the Iceland Coastal Benthic Experiment (see below). From left to right: (A) The 5 experimental net cages next to the test site (30m depth) in Hvalfjörður, Iceland. Each cage contains 100kg of wood coated with a mixture of $CaCO_3$ (80%)and $Ca(OH)_2$ (20%). (B) RT staff placing loggers to record dO, pH, temperature, and conductivity at test and control site. (C) Sediment at both sites was very fine grained (silt/clay) with detritus feeders such as brittle stars (Ophiouroidea) in abundance.

Iceland Coastal Benthic Experiment

Aims

- To understand the biodegradation and impact of deposited terrestrial biomass and natural alkaline minerals on the benthic environment

Methodology

- Wood coated with a mixture of $CaCO_3$ (80%) and $Ca(OH)_2$ (20%) was deposited in 5x nets (100 kg wood in each) in Hvalfjörður, W-Iceland, at 30 m depth in July 2023 and will be monitored for 12 months (Fig. 1, above)
- Control site - 100 m distance from the test site
- Impacts on the environment are monitored with loggers, seawater and sediment samples, focusing on nutrients, carbon and oxygen content, as well as microbial and macrofauna community composition

Preliminary results

- Baseline information on the two sites:
  - Sediment at both test and control site was categorized as silt/clay
  - Benthic biota consisted mainly of Polychaeta, Bivalvia, Nematoda, Ostracoda and Ophiuroidea and species community composition did not differ significantly between the two sites (*Permanova*, F=2.57, p=0.1)
  - Microbial OTU community composition was also similar for the two sites (*Permanova*, F=2.49, p=0.1)
- 14 weeks after the start of the experiment, no significant effects of the deposited biomass have been observed (lm and glm, p>0.1) on the following variables:
  - Seawater (Fig. 2): pH, TA, calcium and Dissolved Organic Carbon
  - Sediment (Fig. 3): Total N and Total Organic Carbon

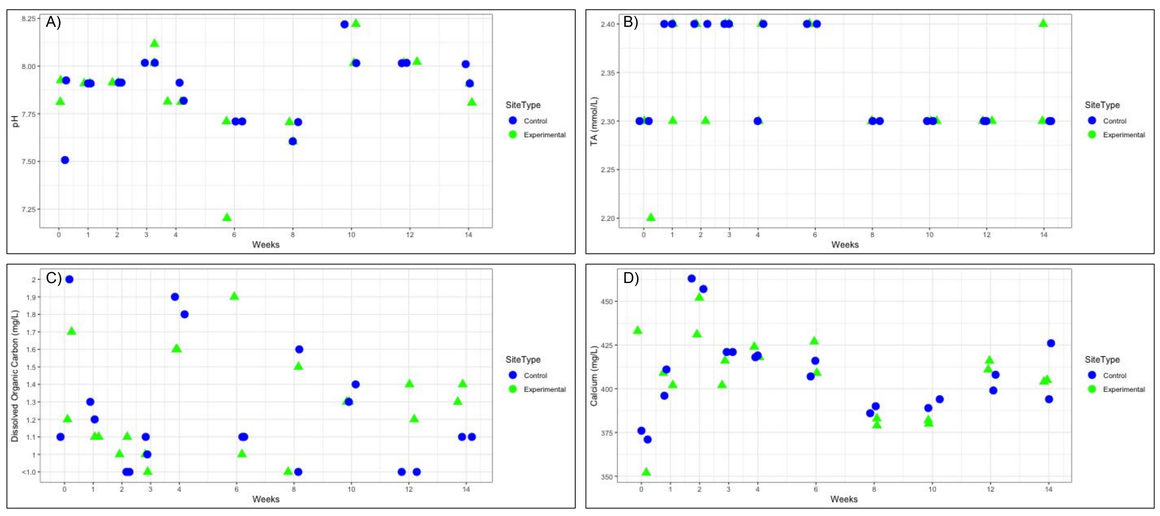

Figure 2. Preliminary results from the Iceland Coastal Benthic Experiment - analysis of seawater samples collected on a weekly basis after the baseline (0) samples were obtained and the experiment deployed: (A) pH; (B) total alkalinity; (C) dissolved organic carbon, missing samples were under the limit of DOC quantification (<1.0 mg/L); (D) Calcium. Blue circles = control site; green triangles = experimental site.

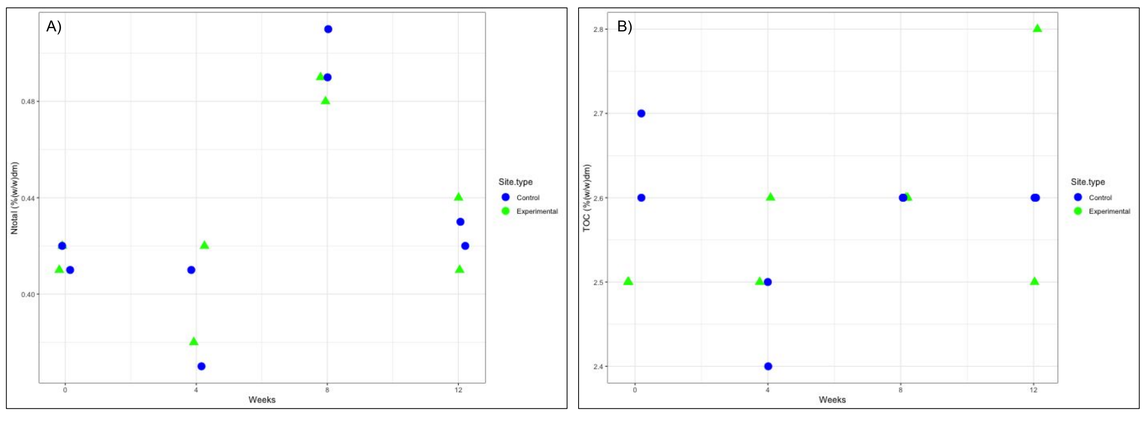

Figure 3. Preliminary results from the Iceland Coastal Benthic Experiment - analysis of sediment samples collected on a monthly basis after the baseline (0) samples were obtained and the experiment deployed: (A) Total nitrogen concentration; B) Total Organic Carbon concentration. Blue circles = control site; green triangles = experimental site.

Deep Sea Benthic Experiments

Aims

- To test the degradation rate of terrestrial biomass, macroalgae, and the 80% $CaCO_3$ and 20% $Ca(OH)_2$ coating mixture on the deep seafloor and monitor the ecological and environmental impact on the deep sea benthic ecosystem (Fig. 3, below).

Methodology

- ***Fram Strait - 4000 m depth***
  - Wood coated with a mixture of $CaCO_3$ (80%) and $Ca(OH)_2$ (20%), *Ulva lactuca,* and *Saccharina latissma* were sunk to the seafloor in 5 kg bundles in May 2023
  - Will be retrieved in a year, degradation estimated and meiofauna classified from sediments samples beneath the bundles
- ***Clayoquot Slope - 1300 m depth***
  - Wood rounds, mycelium rounds and a native kelp species were sunk in a benthic lander[1] in September 2023, off the coast of Vancouver Island, Canada
  - Sediment samples collected before and after the experiment (in a year) will be analysed with regards to macrofauna, microbial community composition and diversity as well as carbon and nutrient content of the sediment
  - Live camera feed and data stream from the lander will give an important insight into the effects of increased nutritional sources on the bathypelagic benthos

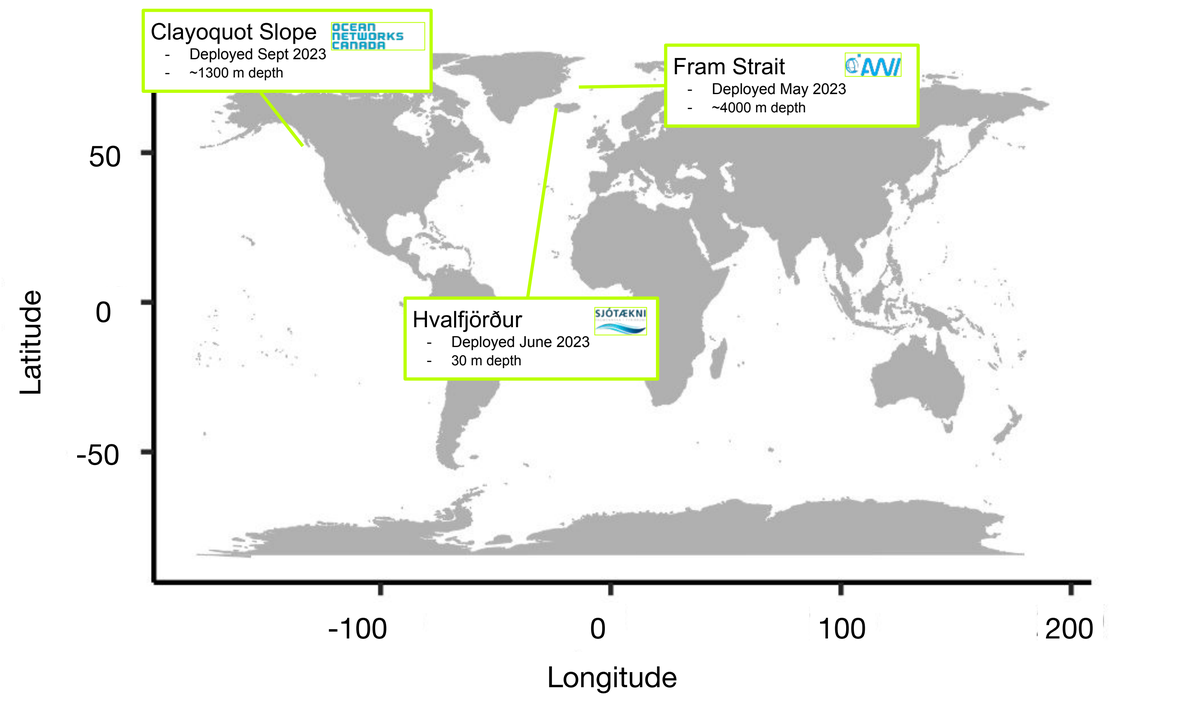

Figure 3. Overview of the location of the benthic experiments Running Tide has collaborated on and organised in the last year to test the degradation rate of terrestrial biomass, macroalgae and 0% CaCO3 and 20% Ca(OH)2 coating mixture and impact on the benthic environment.

Open Ocean Carbon Removal Study

Aims

- To understand the efficacy and environmental impacts of deploying Running Tide's carbon removal system (i.e., sinking of terrestrial biomass and ocean alkalinity enhancement) on the surface layer of the ocean.

Methodology

- 1500-4000 metric tonnes of wood coated with a mixture of $CaCO_3$ (80%) and $Ca(OH)_2$ (20%) were deployed off the south coast of Iceland (~190 Nm) in 15 iterations over the summer of 2023 (Fig. 3C, left)
- Deployment sites were selected based on weather and current forecast using Running Tide's prediction models - taking float time and dispersion of the biomass into account
- Seawater samples obtained before, during and after deployment were analysed for pH, TA, conductivity, and trace, minor, and major elemental concentrations.
- Results are pending

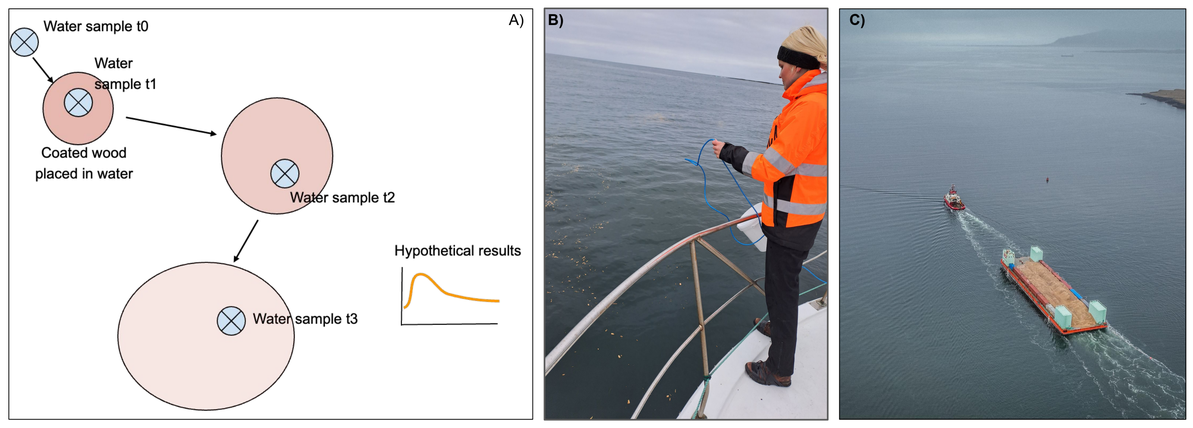

Figure 4. Research of effects and impacts of Running Tide's CDR methods in the surface layer of the ocean. From left to right: (A) General setup of ocean surface experiments. (B) RT staff collecting water samples from the plume; (C) A barge full of wood coated with a mixture of $CaCO_3$ (80%) and $Ca(OH)_2$ (20%) on its way to the deployment site off the Icelandic south coast.

Iceland Coastal Surface Experiment

Aims

- To understand the effects of deposited terrestrial biomass and natural alkaline minerals on the surface ocean environment

Methodology

- 20 kg of wood coated with a mixture of $CaCO_3$ (80%) and $Ca(OH)_2$ (20%) deployed in Faxaflói, W-Iceland in May 2023
  - Two iterations were implemented
- Seawater samples were collected from the wood plume just after deployment and then at 15 minute intervals until the plume thinned out (Fig. 4, above)

Preliminary results

- At this scale, no significant differences in elemental concentrations between the control and test sites were detectable

Next steps

- Scale up to 50 kg and then incrementally larger volumes, where carbonate chemistry will be taken into consideration as well

References

[1]Harbour et al. 2021. *Trophic ecology surrounding kelp and wood falls in deep Norwegian fjords.*