

Running Tide Iceland Research Program Progress Report

2023 overview

March 2024

This report outlines the progress and status of Running Tide's research program in Iceland, submitted to the Marine and Freshwater Research Institute and the Environment Agency of Iceland, and is part of the consultation and progress update requirements set out in the research permit issued by the government of Iceland on July 8, 2022.

This document highlights the overall progress of the program in 2023. In addition to this overview, Running Tide will be submitting specific reports as follow-on addendums, with more detail on various subjects. Details on those are below. In parallel we're finalizing an update to the Running Tide Research Roadmap previously published and shared with both EAI and MFRI.¹

This report includes the following information:

- **Overview of research deployments conducted in 2023** across the three types: Carbon Removal System Deployments, Sensor Deployments, and Macroalgae Deployments.
- **Discussion of in-progress research and reports** based on the findings and data collected as part of the research deployments.
- **Discussion of progress related to macroalgae** cultivation and growth tracking.

For any additional questions, please contact

- Kristinn Hróbjartsson, General Manager, kiddi@runningtide.com
- Íris Mýrdal Kristinsdóttir, Research Manager, iris@runningtide.com

¹ See **Running Tide: Research Roadmap (2023)** shared on May 9, 2023.

Overview of Research Deployments

Running Tide performed 23 research deployments in 2023. 15 of these deployments were conducted at a larger research scale in the Atlantic Ocean within the Iceland Exclusive Economic Zone (EEZ), moving carbon from the fast to slow cycle by sinking wood coated in alkaline material to depths greater than 1,000 m. These deployments resulted in over 25,000 net tonnes of CO₂e removed, allowing Running Tide to issue and deliver carbon credits to early catalytic supporters. In addition, 5 smaller macroalgae experimental deployments and 3 sensor-only deployments were part of 2023 deployments.

| Running Tide 2023 Research Deployments | | |
|--|--|---|
| Type | Purpose | Details |
| Carbon Deployments | Evaluate system performance (carbon removed) and environmental impacts | 15 deployments in the Atlantic Ocean within the Iceland Exclusive Economic Zone (EEZ). Involved sinking wood coated in alkaline material to depths greater than 1,000 meters, facilitating the transfer of carbon from the fast to slow cycle |
| Macroalgae Deployments | Track and measure offshore growth of <i>Ulva Lactuca</i> and <i>S. Latissima</i> | 5 open ocean macroalgae growth experiments, both in the North Atlantic and the Pacific with the goal of validating growth of macroalgae in the open ocean |
| Sensor Deployments | Assess and tune ocean transport models | 3 open ocean deployments of verification sensor suite. The purpose was to mimic workflows required for the open ocean experiments, to test the sensor systems, sea-truth models with collected data and identify and resolve bugs and errors |

Carbon Removal System Deployments overview

A series of 15 replicated pilot scale carbon removal system experimental deployments in the open ocean were executed at conservative rates of 429.52-1,676.57 tons of substrate (dry mass) per deployment. The previously planned cadence of one every 2-5 weeks had to be sped up to once per week on average due to weather conditions and vessel constraints.

In total, Running Tide deployed 19,338 tonnes of material. Given the permit allows for deployment of up to 50,000 tons during the 4 year timeframe, we've exhausted 39% of the permit, on schedule.

As part of the deployments, our team of scientists and engineers researched and developed a methodology and framework protocol for the quantification of carbon removed.²



Left: Loading of deployment vessel. Right: Deployment vessel en-route.

Below is an overview of the 15 deployments, the amount of material deployed, the tonnes of CO₂e removed from the fast cycle and stored durably (net of all embodied carbon emissions and process related emissions), and the date of deployment.

| Open Ocean Carbon Removal System Deployments | | | |
|--|-----------------------|---|--------------------|
| ID | Deployment volume (t) | Net Tonnes of CO ₂ equivalents removed | Date of deployment |
| IS-CD-1 | 429.52 | 275.86 | May 17, 2023 |
| IS-CD-2 | 842.31 | 1,015.95 | June 2, 2023 |
| IS-CD-3 | 1,004.51 | 1,132.89 | June 6, 2023 |
| IS-CD-4 | 1,013.80 | 1,250.51 | June 12, 2023 |
| IS-CD-5 | 1,160.84 | 1,411.90 | June 18, 2023. |
| IS-CD-6 | 1,313.74 | 1,709.64 | July 2, 2023 |
| IS-CD-7 | 1,408.77 | 1,852.17 | July 10, 2023 |
| IS-CD-8 | 1,432.00 | 1,848.40 | July 17, 2023 |
| IS-CD-9 | 1,470.64 | 1,661.10 | July 22, 2023 |
| IS-CD-10 | 1,347.65 | 1,851.46 | July 30, 2023 |
| IS-CD-11 | 1,520.98 | 2,180.52 | August 6, 2023 |
| IS-CD-12 | 1,606.94 | 2,257.16 | August 13, 2023 |
| IS-CD-13 | 1,471.08 | 2,087.38 | August 17, 2023 |
| IS-CD-14 | 1,676.57 | 2,292.96 | August 24, 2023 |
| IS-CD-15 | 1,639.16 | 2,438.99 | September 6, 2023 |
| Total | 19,338.51 | 25,266.89 | |

² See **Running Tide: Quantification Methodology** shared on July 14, 2023

Macroalgae Deployments

Between June and September of last year, we executed a total of 5 open ocean macroalgae growth experiments, both in the North Atlantic and the Pacific with the goal of validating (or not) growth of macroalgae in the open ocean. Additionally, Open Ocean Growth Experimental deployments serve as a baseline assessment of the macroalgae product in a given oceanic location over time, setting an important starting point and uncovering opportunities for improvement in our system design. Key results from the open ocean growth experiments performed in Iceland, show a successfully demonstrated baseline of visual growth.³



Images from our verification hardware showing growth of U. Lactuca in open ocean

Sensor Deployments

Starting in December 2022, Running Tide executed three open ocean deployments of the company's proprietary verification sensor suite. The purpose of the experiments was to mimic workflows required for the open ocean experiments, to test the sensor systems, sea-truth models with collected data and identify and resolve bugs and errors in computational automation and infrastructure. The verification sensor suites provide critical in-situ data for analytical comparison with model output. The process of gathering data and modeling the results helps us understand and ensure the efficacy of the carbon removal using Running Tide's system.⁴

For each of the deployments, the modeling team selected a deployment location based on the prediction model, optimized for float time, distribution and terminal location. The data from the experiments was then used to improve our modeling approach and test quantification automation in preparation for our first open ocean carbon removal system deployments. Using the results of these sensor experiments, we were able to develop a methodology for parameter tuning our trajectory model. This unlocked our ability to run Monte Carlo simulations to quantify uncertainty in the terminal distribution of substrate on the seafloor.

³ See **Macroalgae Deployment Report** shared on November 10, 2023

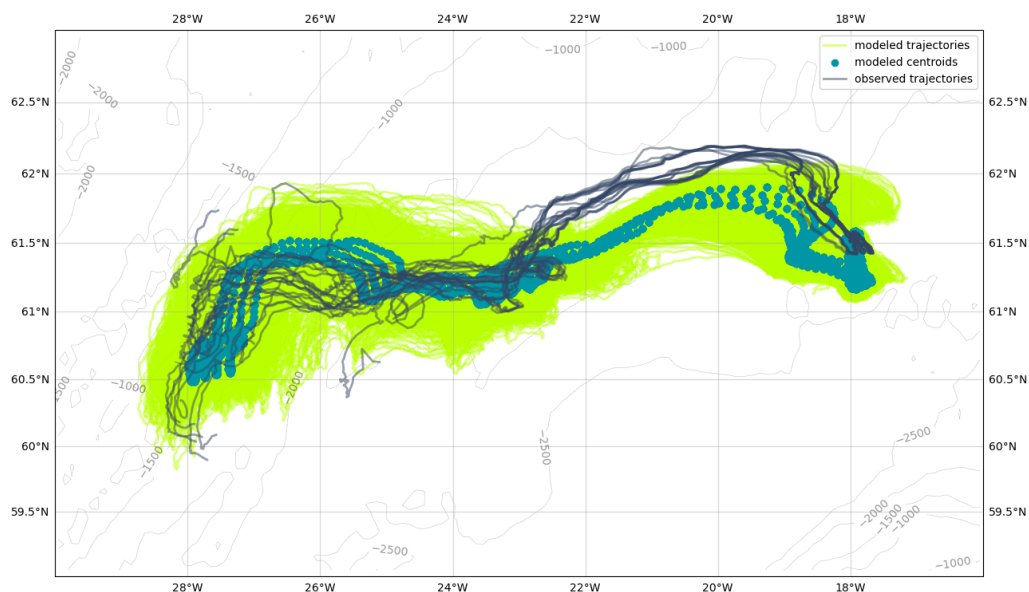
⁴ See **Open Ocean Sensor Deployments** shared on July 14, 2023

Improving predictive modeling with Alpha Tuning

Empirical data from the sensor deployments as well as the carbon removal system research deployments was used to improve and update our predictive trajectory modeling.

When we say “alpha tuning,” we are referring to tuning the superposition of velocity components which combine to describe total velocity: ocean dynamics, Stokes drift, and windage. The alpha tuning project applied a gradient descent algorithm in a novel way to improve modeled trajectories, better representing the position and spread of Running Tide’s in-situ GPS sensor buoys.⁵

Once we were able to accurately represent drift trajectories with modeled trajectories, we were able to take a statistical approach to uncertainty, use a Monte Carlo simulation to determine drift, dispersion, and ultimately terminal location on the seafloor. This is further detailed in our *Ocean Surface Transport Methodology Report*, covering the methodology used for the surface transport section of the overall quantification methodology.



Modeled and observed trajectories.

Quantifying Environmental Impact

A review of potential impacts was completed prior to the research deployments and shared with - among others - the Environmental Agency and Marine and Freshwater Research Institute,⁶ and the potential impacts that were identified as the most important to consider at that time are the focus of quantification.

⁵ See **Ocean Surface Transport Methodology Report**

⁶ See **Running Tide: Catalog of Environmental Exposures** shared on May 22, 2023.

A report based on this data is underway where we investigate and quantify, to the best of data availability, the environmental impacts of these carbon removal research deployments. This report is intended to be a component of Running Tide’s commitment to transparency and development of carbon removal technology that has a net positive impact to the ocean ecosystems and the earth system at large.

The report will touch on both our internal research projects and projects conducted with partners globally and is expected to be shared with our consultation partners mid to late Q2-2024.

Researching impact on the benthic environment

In addition to quantifying the impact of the research deployments, we started several research projects both internally and with partners on the fate and impact of depositing biomass (terrestrial and marine) on diverse benthic environments.

- **Benthic study in Hvalfjörður Iceland** to expand the knowledge and understanding of carbon additionality in the benthic layer of coastal sites across Running Tide’s operating locations. The study will provide data on the ecological impact of sinking organic terrestrial carbon substrates and eventually macroalgae biomass.⁷
- **Benthic study with Ocean Networks Canada** to continually observe the impact of organic terrestrial substrate and marine biomass introduction and degradation in a deep sea (~1300m) benthic environment.
- **Benthic study in collaboration with Seafields and Alfred Wegener Institute for Polar and Marine Research** to understand the fate of different seaweed species and coated biomass in the deep sea (~4000 m).



Left: From ONC deep-sea experiment. Right: Start of Hvalfjörður benthic experiment

⁷ See upcoming **Iceland Benthic Study Final Report**

Macroalgae

Our R&D efforts related to Macroalgae in 2023 focused broadly on three topics:

- 1) Upscaling of macroalgae production in Iceland
- 2) Understanding attachment and growth on various substrates
- 3) Understanding offshore growth of macroalgae species

In the year 2023 Running Tide built up a macroalgae research and production facility named Alda, at Breið in Akranes. The facility is fully equipped with all laboratory equipment needed for high through-put production at pilot-scale. The cultivation of two macroalgae species *Ulva lactuca* and *Saccharina latissima*, both native to Iceland, takes place in specially outfitted cooling rooms where photobioreactors are used to grow the macroalgae. Running Tide scientists apply specially developed methods to attach macroalgae spores to substrate of choice.

Our system aims to apply macroalgae seed in some form to a substrate, transport that substrate offshore, deploy, and quantify the growth of the macroalgae on the substrate. Our work last year has been focused on understanding the attachment and growth of macroalgae seed to various types of substrates under various circumstances, and replicating that in the open ocean.



Left: *U. lactuca* cultivation system, Right: *S. latissima* gametophyte banking

The primary goal of 2023 for the Macroalgae facility was to research and develop the methods for cultivating the two species in a scalable way, for future replication, and to scale up seedstock production to the levels needed to seed substrate at scale for research deployments in 2024 and beyond.

Between June and September of last year, we executed a total of 5 open ocean macroalgae growth experiments, both in the North Atlantic and the Pacific with the goal of validating (or not) growth of macroalgae in the open ocean. Additionally, Open Ocean Growth Experimental deployments serve as a baseline assessment of the macroalgae product in a

given oceanic location over time, setting an important starting point and uncovering opportunities for improvement in our system design. Key results from the open ocean growth experiments performed in Iceland, show a successfully demonstrated baseline of visual growth.

| Documents referenced in this report | |
|--|---|
| Running Tide: Research Roadmap 2023 | See Running Tide: Research Roadmap (2023) shared May 9, 2023. |
| Running Tide: Catalog of Environmental Exposures 2023 | See Running Tide: Catalog of Environmental Exposures shared May 22, 2023. |
| Sensor Deployments 2023 | See Open Ocean Sensor Deployments shared July 14, 2023 |
| Quantification Methodology 2023 | See Running Tide: Quantification Methodology shared July 14, 2023 |
| Macroalgae Deployments 2023 | See Macroalgae Deployment Report shared November 10, 2023 |
| Research Roadmap (2024) - Upcoming | This is an updated version of our 2023 Research Roadmap |
| Environmental Impact Report 2024 - Upcoming | This report investigates and quantifies, to the best of data availability, the environmental impacts that are the result of these carbon removal research deployments. |
| Macroalgae at Alda - 2023 Annual Report - Upcoming | This report will cover the cultivation progress of two macroalgae species <i>Ulva lactuca</i> and <i>Saccharina latissima</i> in Running Tide's facilities in Akranes |
| Ocean Surface Transport Methodology Report - Upcoming | This report details the methodology used for the surface transport section of the overall quantification methodology |
| Iceland Benthic Study Final Report - Upcoming | This report covers a year-long experiment in Hvalfjörður Iceland, intended to expand the knowledge and understanding of carbon additionality in the benthic layer of coastal sites across Running Tide's operating locations. |

A note on sharing of research efforts and results

As part of our ongoing research and development efforts we regularly share our findings and progress. Our key documentation, whitepapers and other updates are shared through our [document repository](#). We attend various scientific events and share our findings and progress there. Posters and presentations are shared in the document repository as well.