Ocean Visions Expert Advising and Evaluation Team for Running Tide Technologies, Inc.

Progress Report 1

Introduction

Ocean Visions works to catalyze science and engineering to support scalable, equitable, and sustainable ocean solutions. In furtherance of this mission, Ocean Visions has partnered with the Grantham Environment Trust to evaluate and advance ocean-based. Ocean Visions and the Grantham Environmental Trust work together to evaluate the science and engineering of proposed ocean-climate innovations, and Ocean Visions provides third-party advice and assistance on research, development, field testing, impact analysis, and optimization to Grantham Environmental Trust grantees.

Under this initiative, Ocean Visions ("OV") has assembled a team of experts ("The Expert Team") to advise and independently evaluate a research project being conducted by Running Tide Technologies, Inc. ("Running Tide"), a company that specializes in scalable aquaculture solutions. Running Tide is working on development of a proprietary system of open ocean kelp farming for carbon sequestration. They intend to conduct field trials to determine the efficacy and impacts.

Ocean Visions' Expert Team will provide external, third-party review of Running Tide's research plans and all findings that come from the field trial. Specifically, the OV Expert Team will:

1. Review Running Tide's research plan and provide feedback on ways to optimize the design and implementation to maximize performance, efficacy, and data integrity.
2. Review potential environmental risks and upstream and downstream impacts of the field trial and advise on how to minimize any potential negative impacts.
3. Provide review and advice on design of monitoring systems and protocols to measure overall performance, and in particular, carbon sequestration and environmental impacts of the field trial.
4. Review results of the field trial as they become available.
5. Provide an independent final report to Running Tide, the Grantham Environmental Trust, and the interested public on the overall effort, the validity of the findings, any areas of disagreement and suggested next steps with respect to the field trial.

Background

OV Expert Team members include Jim Barry, Ph.D., Tom Bell, Ph.D., Annalisa Branco, Ph.D., Wil Burns, Ph.D., and Alex Rogers, Ph.D., as well as David Koweek, Ph.D., Ocean Visions Science Director and Brad Ack, Ocean Visions Executive Director.

The Expert Team and Running Tide have convened for virtual meetings on a biweekly-to-monthly basis since the formation of the Expert Team in January 2021. There have also been a series of ad-hoc meetings between representatives of Running Tide and members of The Expert Team. This document describes progress on the areas of engagement laid out in the joint research plan between Running Tide and The Expert Team. Briefly, the joint research plan summarizes collaboration around four key areas:

1. Coastal and pilot offshore kelp growth experiments
2. Environmental impacts assessments
3. Ocean modeling to simulate trajectories of free-floating kelp growth lines
4. Legal and governance considerations for operating in international waters

Interested individuals can read the full joint research plan.

This progress report is produced by The Expert Team and Ocean Visions staff independent of Running Tide.

Assessing the Potential Environmental Impacts

Running Tide approached The Expert Team having done some initial discovery on potential environmental impacts. The Expert Team provided additional considerations and guidance about strategies to assess, contextualize, and quantify impacts.

The initial phase of the discussion attempted to enumerate potential ecological impacts at a hypothetical full scale, assuming one or more gigatons of carbon dioxide sequestration per year. Through these discussions, it became apparent to Running Tide and to The Expert Team that there was a more urgent need to characterize environmental impacts of Running Tide's activities at the research scale (~100 microfarms; Running Tide's name for its free-floating buoy growth system) and medium scale (~12,500 microfarms) before considering hypothetical activities at larger scales.

Broken down by scale, potential impacts in need of research identified by Running Tide and The Expert Team include:

Research-scale (~100 microfarms)

- Entanglement of marine mammals, turtles, or other megafauna in microfarms
- Potential navigation (collision with ships) and debris generation issues (washing up on shores)
- Provision of temporary hard substrata for attachment of organisms.

Medium-scale (~12,500 microfarms)

- Transport of invasive species and/or influence of genetic connectivity of fouling communities.
- Influence on the distribution of fish and other pelagic organisms as well as seabirds through aggregation effects of floating structures.
- Aggregation of mobile scavenging communities around microfarm drop locations as well as successional communities as the seaweed and associated rope and flotation devices degrade.
- Localized impacts on benthic infaunal, epifaunal, and near-bottom organisms in the vicinity of seaweed falls including through food enrichment and possibly localized oxygen decreases in the sediment and possibly the benthic boundary layer

Megaton-scale and Beyond

- Effects on nutrient availability in surface waters and nutrient competition with phytoplankton communities.
- Effects on light penetration into surface waters.
- Other effects on biogeochemistry (e.g., production of DMS).

- Changes in the abundance and species composition of benthic fauna related to the increase in organic carbon flux to the deep seabed.
- Possible regional changes in community composition as operations scale up to the gigaton scale
- Effects on near-bottom hydrochemical conditions, particularly dissolved oxygen and pH changes associated with remineralization of sunken organic carbon.

Conversations between Running Tide and The Expert Team have focused on the fate of the macroalgal carbon and the impacts of its deposition on the seafloor, as well as the impacts of the sinking process on pelagic and midwater ecosystems. The Expert Team provided feedback to an internal Running Tide environmental impact assessment focused on the small scale (~100 microfarms) and medium-scale (~12,500 microfarms) environmental impacts (both positive and negative). There is agreement on the need to use field studies, laboratory studies, and computer modeling studies to evaluate the range of potential environmental impacts.

The environmental impacts of the planned field trials remain an active area of discussion between The Expert Team and Running Tide. Should operations expand beyond this initial phase of research and development and into megaton-scale or gigaton-scale, further consideration of environmental impacts will be needed.

Kelp Growth Modeling and Monitoring

The Expert Team, led by Dr. Tom Bell, has advised Running Tide on considerations for monitoring and modeling kelp growth in both the open ocean and coastal growth experiments. For the open ocean pilot experiment, The Expert Team advised Running Tide on a camera system that would monitor kelp growth on the microfarms (the proper camera to use, camera positioning, and classification models). For the coastal experiment, The Expert Team advised Running Tide on the frequency of water sampling and positioning multiple temperature loggers on or near the growth lines. These data could be used to investigate if physical variables could be used to infer seawater nutrient concentration dynamics and provide more continuous nutrient estimates.

Dr. Bell also discussed the findings of an ARPA-E MARINER kelp monitoring project and how these results could be applied to Running Tide's work. Dr. Bell directed Running Tide to several satellite products to assess the coastal and open ocean environment during their experiments and to quantify the spatial patterns of temperature, available photosynthetically active radiation (PAR), and phytoplankton production in their study domain. Additionally, Dr. Bell sent the team several relevant scientific publications and helped make connections to scientists developing methods for kelp tumble culture and the production of sterile kelp strains.

Dr. Bell did express some concerns about the open ocean experiment and long-term patterns of open ocean kelp growth. The open ocean nutrient conditions will change seasonally and likely between years. Dr. Bell thinks that it is important to quantify this variability using historical data rather than rely only on historical means and cautions Running Tide not to expect maximum growth and biomass production year after year.

Permanence of Carbon Sequestration

From prior expert consultation, Running Tide anticipated that sunk carbon could be buried or remineralized, and was focused on North Atlantic operations because of the longer sequestration times of remineralized carbon in that site arising from patterns of thermohaline

circulation. Running Tide sought guidance from the Expert Panel on characterizing the ratio of carbon remineralized versus permanently buried in sea sediments.

The Expert Team's feedback was that most of the kelp carbon is likely to be remineralized into the bottom waters through microbial degradation and macrofaunal consumption with sequestration time scales on the order of 100's to 1000's of years. These time scales would be highly dependent on depth and the ocean basin where kelp carbon is delivered. Dr. Bell connected Running Tide with researchers who had done work on global-scale ocean circulation models to make quantitative estimates of timescales until bottom water reaches the surface again, providing bounds on sequestration permanence estimates.

Modeling the Microfarm Trajectories

The Expert Team, led by Dr. Annalisa Bracco, provided recommendations on analysis tools to quantify and visualize the potential spreading of the microfarm trajectories from modeling outputs, and specifically the use of Kernel Density Estimations based on particle trajectories. The Expert Team also provided insight on potential problems/benefits of the mean ocean circulation, both at the surface and at depth, at proposed sampling locations as function of season. Finally, they recommended exploring at least one case considering how sub-mesoscale turbulence and specifically physical convergence at a scale of about 1 km could affect the microfarm spreading. Vertical mixing and deep current conditions should also be considered, to estimate where the sequestered carbon may be buried and/or transported. Regions of high vertical mixing should be carefully evaluated through modeling simulations.

Considering Governance and Legal Questions

Early conversations with The Expert Team, led by Dr. Wil Burns, articulated the evolving and incomplete coverage of domestic and international maritime law to the in-water testing and development of ocean-based CDR.

Dr. Burns provided a comprehensive review of both the letter and spirit of existing international treaties, as well as his own forecasts of how those may be projected to change especially in the presence of industrial-scale CDR such as Running Tide proposes.

In accordance with this guidance, and to better assess the impact of these overlapping international arrangements into domestic law, Running Tide retained two law firms which specialize in international maritime practice. As a result, Running Tide believes its current research operations not to be in contravention of any existing statute.

At the same time, Running Tide has discovered an acute absence of purpose-made domestic regulation for ocean-based CDR, and aided by Dr. Burns' advice, has begun the process of engagement with domestic agencies and lawmakers.

Specifically, The Expert Team, led by Dr. Burns, has provided the following advice regarding legal and governance questions faced by Running Tide:

1) Reviewed the legal analysis of the outside counsel hired by Running Tide to provide advice on legal requirements for its initial coastal experiments
2) Provided advice on pertinent international treaty regimes, including the London Convention/Protocol, Convention on Biological Diversity, United Nations Convention on the Law of the Sea
3) Gave input into scientific discussion on implications of experimental design on potential contours of environmental impact assessments

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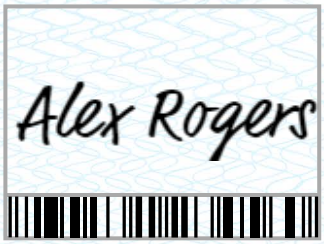

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