Running Tide Technologies, Inc.

January 28th, 2021

Offshore Microfarms Project

Kelp Pilot Discussion for Ocean Visions

Overview

1. Introduction to Running Tide
2. Kelp Project: history & updates
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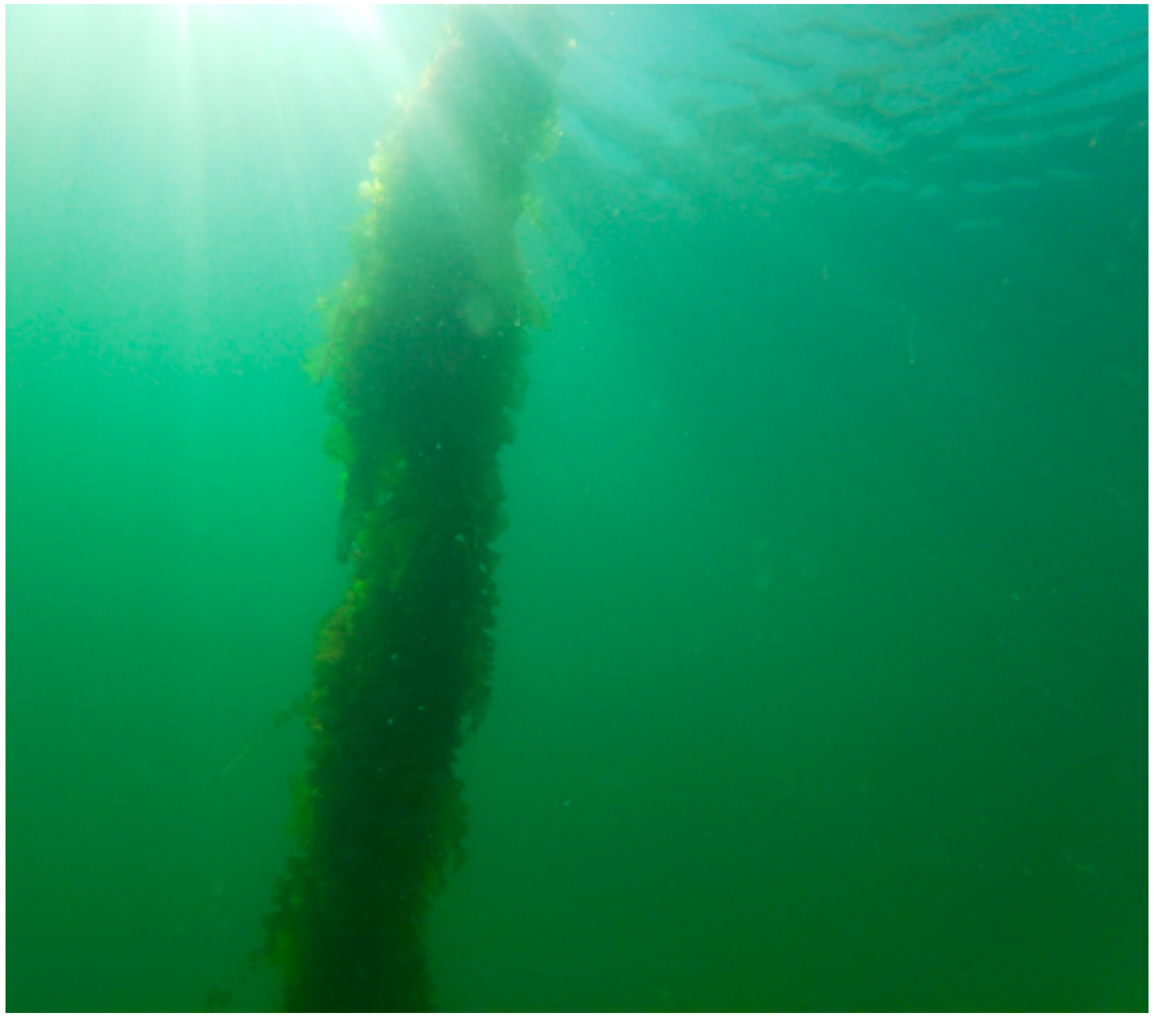
4. Research goals & approach
   - Nursery development
   - Microfarm development
   - Kelp varietal investigation
   - Sequestration validation
5. Schedule
6. Advisory Committee
   - Proposed meeting cadence and communication
   - Discussion of reporting structure



Introduction to Running Tide, the Kelp Project & the Team

Running Tide Technologies, Inc.

- Running Tide is a vertically integrated ocean farming company that uses advanced automation, robotics and machine learning to produce low-cost shellfish at high volumes.
- Oysters are a low-carbon, low-input source of proteins.
- Automated growing and harvesting system developed to lower costs of growing oysters by an order of magnitude
- Founded in 2017 and Based in Casco Bay, Maine with offices in Portland.

Running Tide Technologies, Inc.

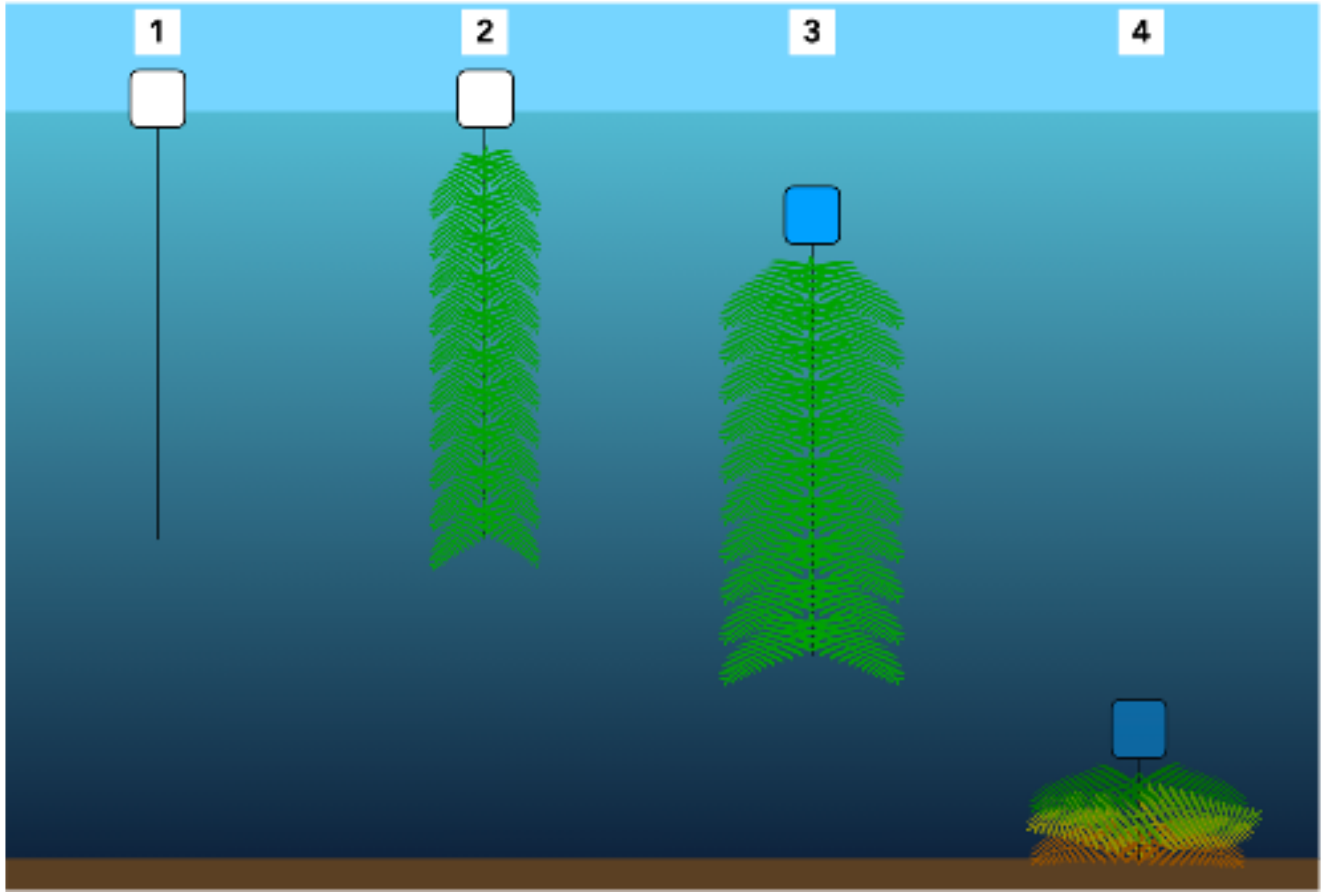
- Vertical integration of oyster hatchery, nursery and grow-out systems.
- In-house manufacturing of ocean vessels and robotic systems for oyster harvesting and sorting at our 7,000 sqft manufacturing facility.
- Automation and Big Data / ML analytics used to scale shellfish aquaculture.
- Experience with algae culture for oyster production used to feed juvenile oysters.
- The learnings from hatchery-related algae for early oyster growth applied to kelp allowed us to quickly scale kelp hatchery.

Kelp Project: Overview

- Purpose: develop a macroalgae-based technology capable of sequestering carbon dioxide with a sequestration permanence >1,000 years, as well as scaling the production to the gigaton scale.

- Each individual microfarm consists of a vertical, kelp-seeded line [1] tethered to a biodegradable buoy that will drift in the open ocean [2] and let the kelp sink after a predetermined duration [3].

- Once it sinks to the deep-sea floor [4], the macroalgal carbon will either:
  - become sediments —> sequestered for geological scales
  - remineralize into the bottom seawaters —> will not resurface back to the atmosphere for ~1,000 years.



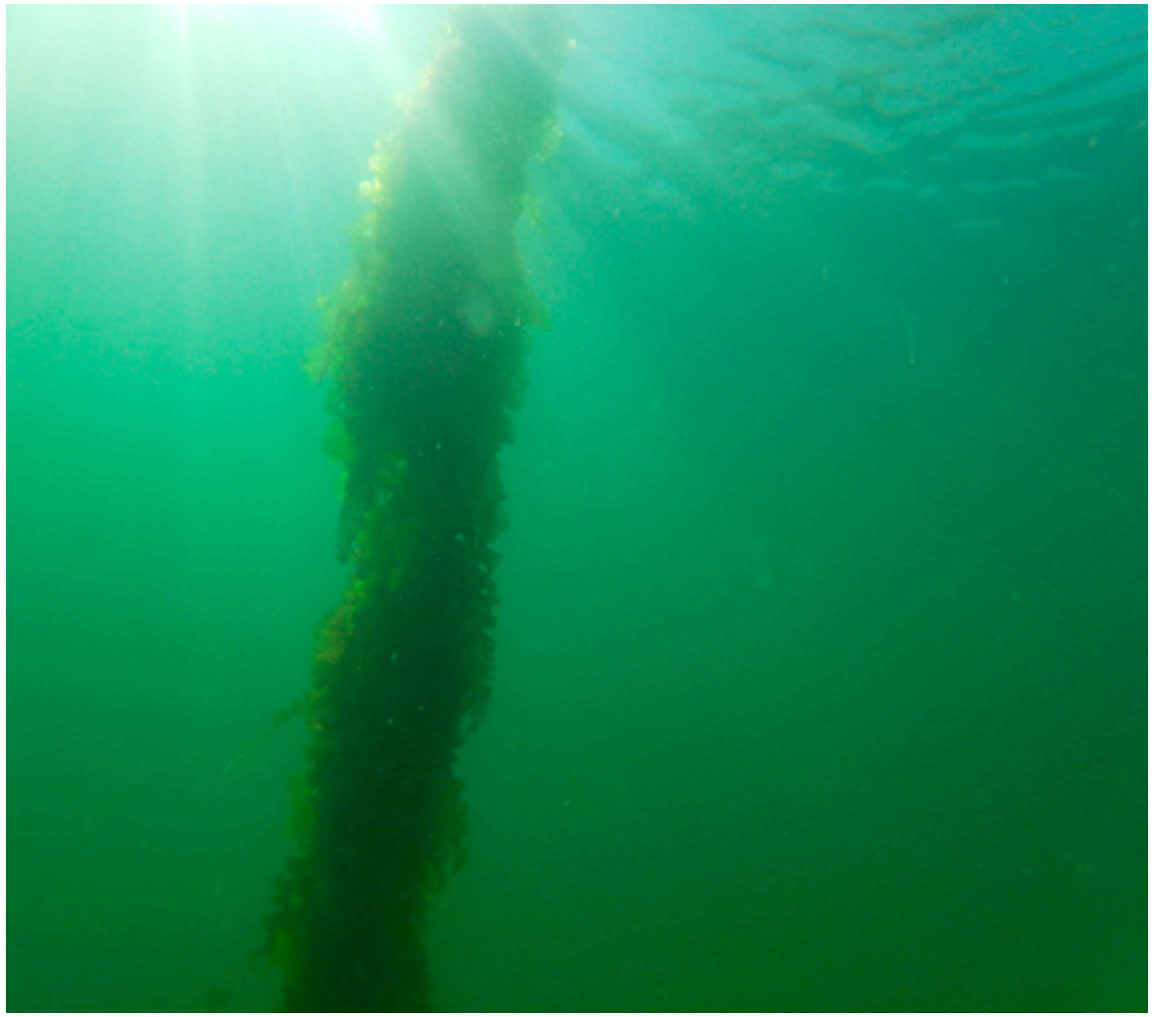
Kelp Project: History

- 2017-2020: development of a moored prototype to confirm that kelp can grow on vertical lines attached to flotation devices.

- Engaged with Palo Alto-based consulting company Function Engineering to study feasibility of microfarm:
  - sensitivity model, cost-driving factors, material selection, onboard stocking density to allow for scalability.

- November 2020: Running Tide modified oyster hatchery during the off season to hatch seed for kelp deployment.

- January 2021: entered into a development contract with Grantham's Neglected Climate Opportunities to study the feasibility of using kelp to sequester CO_2.

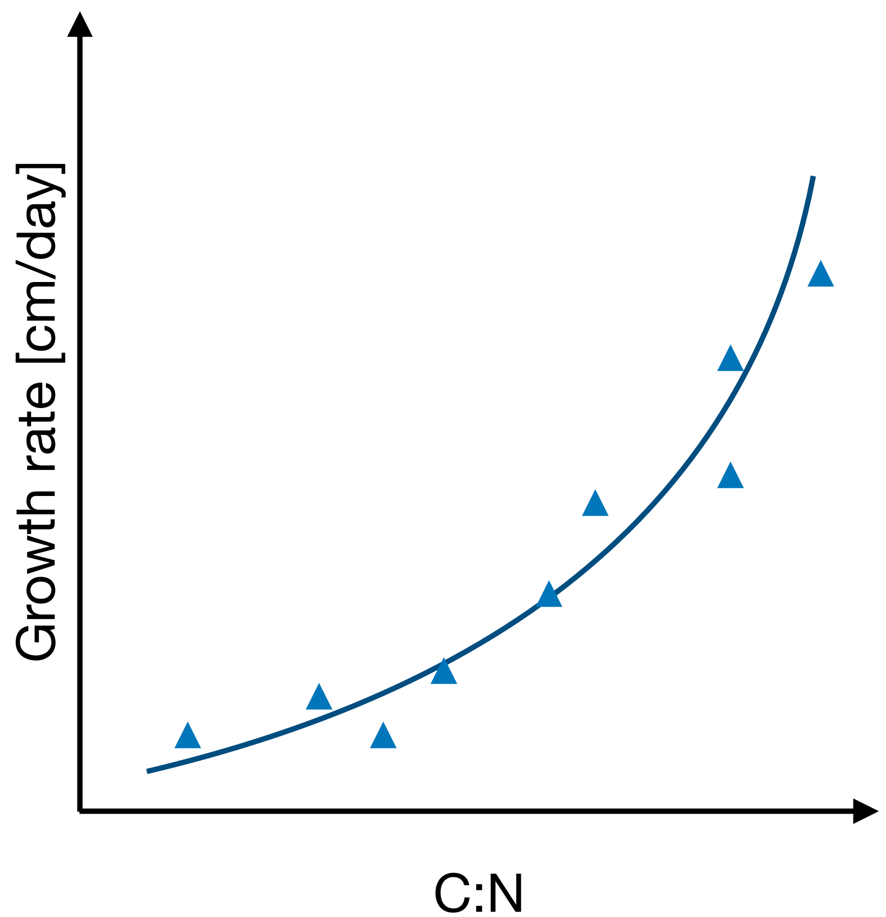


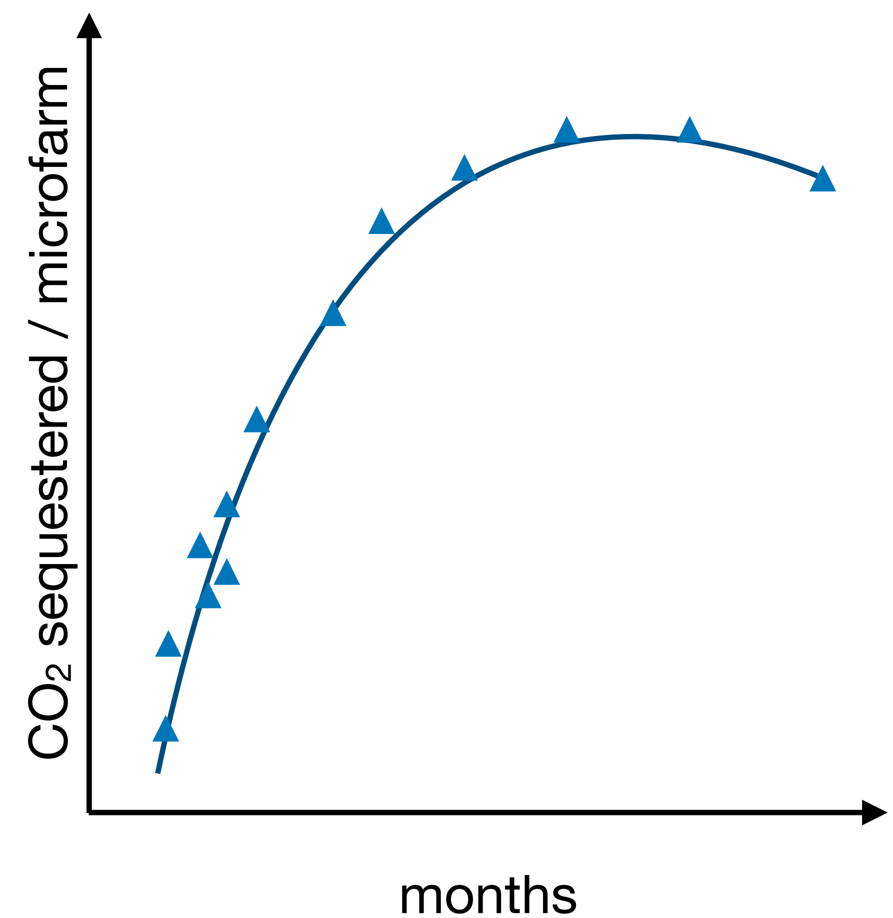
Running Tide Team

- Matthew Odlin - Principal Investigator; Founder & CEO
- Adam Baske - Head Of Business Development
- Max Chalfin - Director of Research
- Dr. Margaux Filippi - Director of Ocean Science
- Justine Simon - Project Administrator
- Steve Zadesky - Engineering Advisor

Key Questions and Research Plan

Key Questions for Running Tide





Can kelp grow offshore?

- Is the nutrient availability enough for our growth targets?

How much CO_2 is sequestered per microfarm?

- What is the variance of carbon content?
- How does it differ for different species?
- How does it evolve over the life cycle of the kelp (i.e. how long do we deploy for)?

Key Research Questions

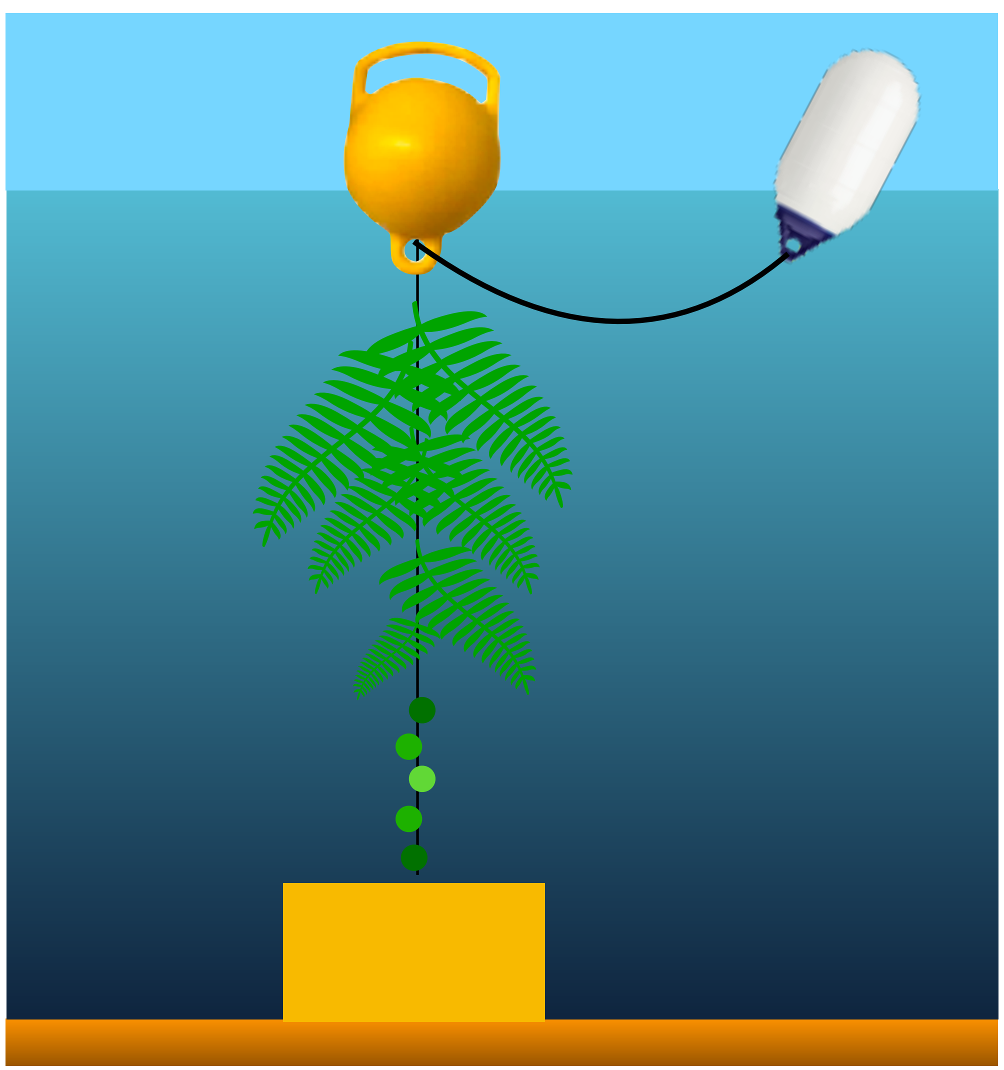
- How long until ocean-based CDR translates into atmospheric CDR?
  - Timescales of air-sea fluxes? Microfarms are point-sinks.
  - If M tCO_2 is sequestered from macroalgal C, how long until M tCO_2 is removed from the atmosphere?
- How to quantify the effects of the drifting microfarms on the pelagic ecosystems?
  - Externalities, nutrient competition but also buffer against ocean acidification
- Effects of sinking Gton of macroalgal C through dispersed, scattered microfarms:
  - Given it's a naturally-occurring phenomenon, how does it affect the deep-sea benthos?
  - Will the rapid accumulation of macroalgal C perturb the deep-sea carbon cycle? How?
  - How can we ensure high burial efficiency? (i.e. high % of sedimentation vs remineralization)
- What are the effects of the non-kelp materials on the deep-sea?
- Determination of low cost, durable and degradable buoy material options.

Kelp Pilot

- Series of experiments for 2021:

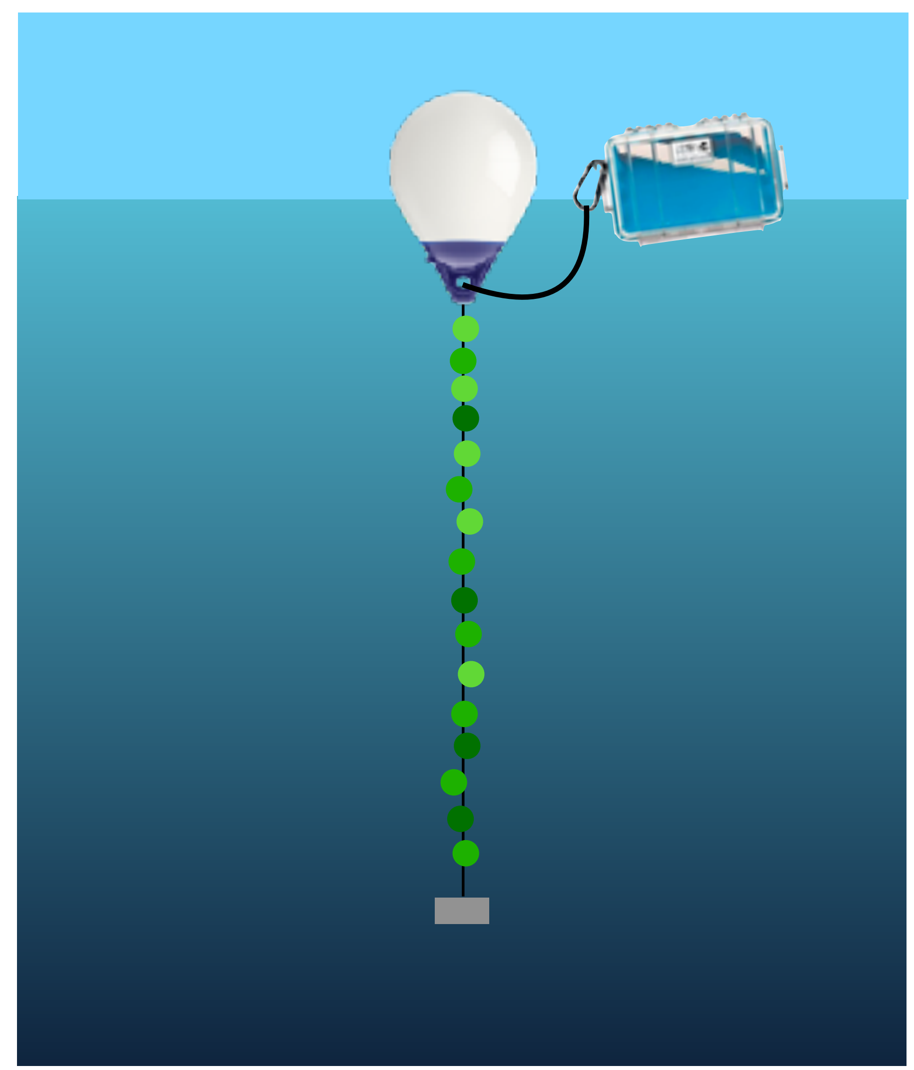
1. Large-scale coastal experiment with constant monitoring of moored microfarms

Underway with +1,500 moored microfarms as of 1/28/21



2. Offshore experiment with drifting microfarms

Scheduled February 2021



Kelp Pilot: Coastal Experiment

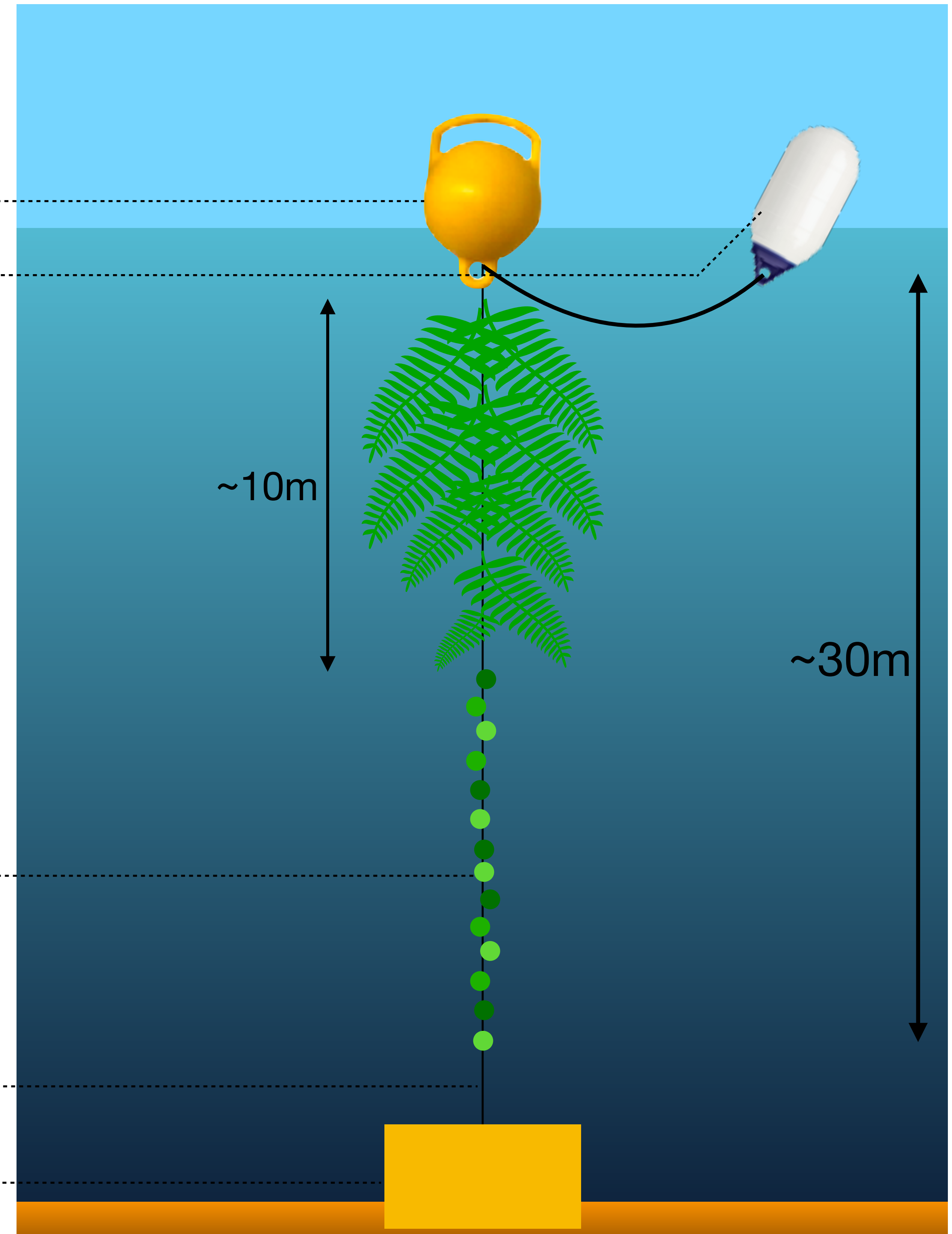
Flotation buoy with DMR license number

Lobster buoy as marker

Twine with spores

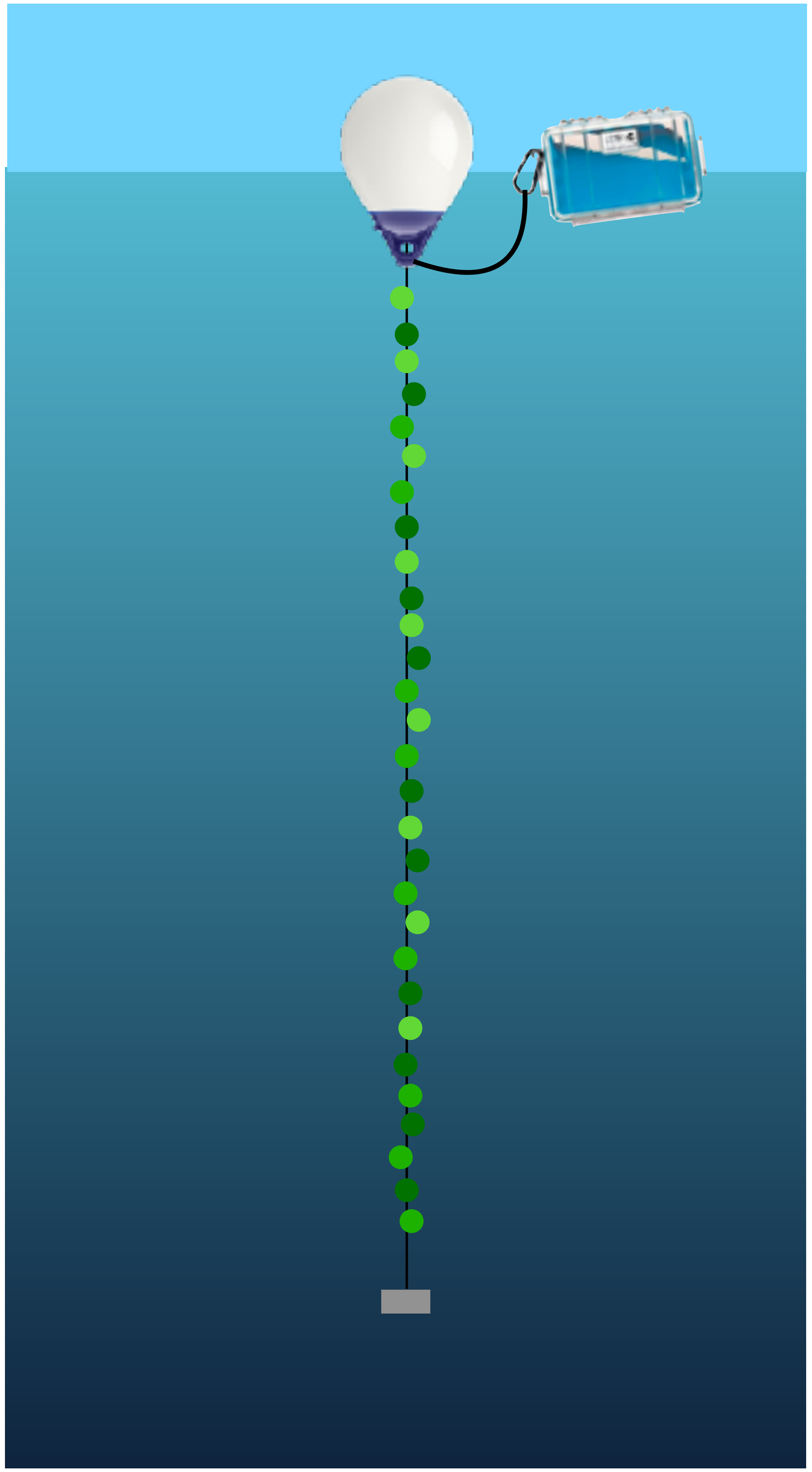
Sisal or cotton line

Anchoring block



Kelp Pilot: Offshore Experiment

- 100 microfarms to be deployed in the North Atlantic.
- Outfitted with GPS trackers
- Primary goals:
  - Verify that kelp can grow free-floating in the open-ocean environment.
  - Test our prototypes offshore, for several months.



Research Goals & Approach

4 main areas:

- Nursery development
- Microfarm development
- Kelp varietal investigation
- Sequestration validation

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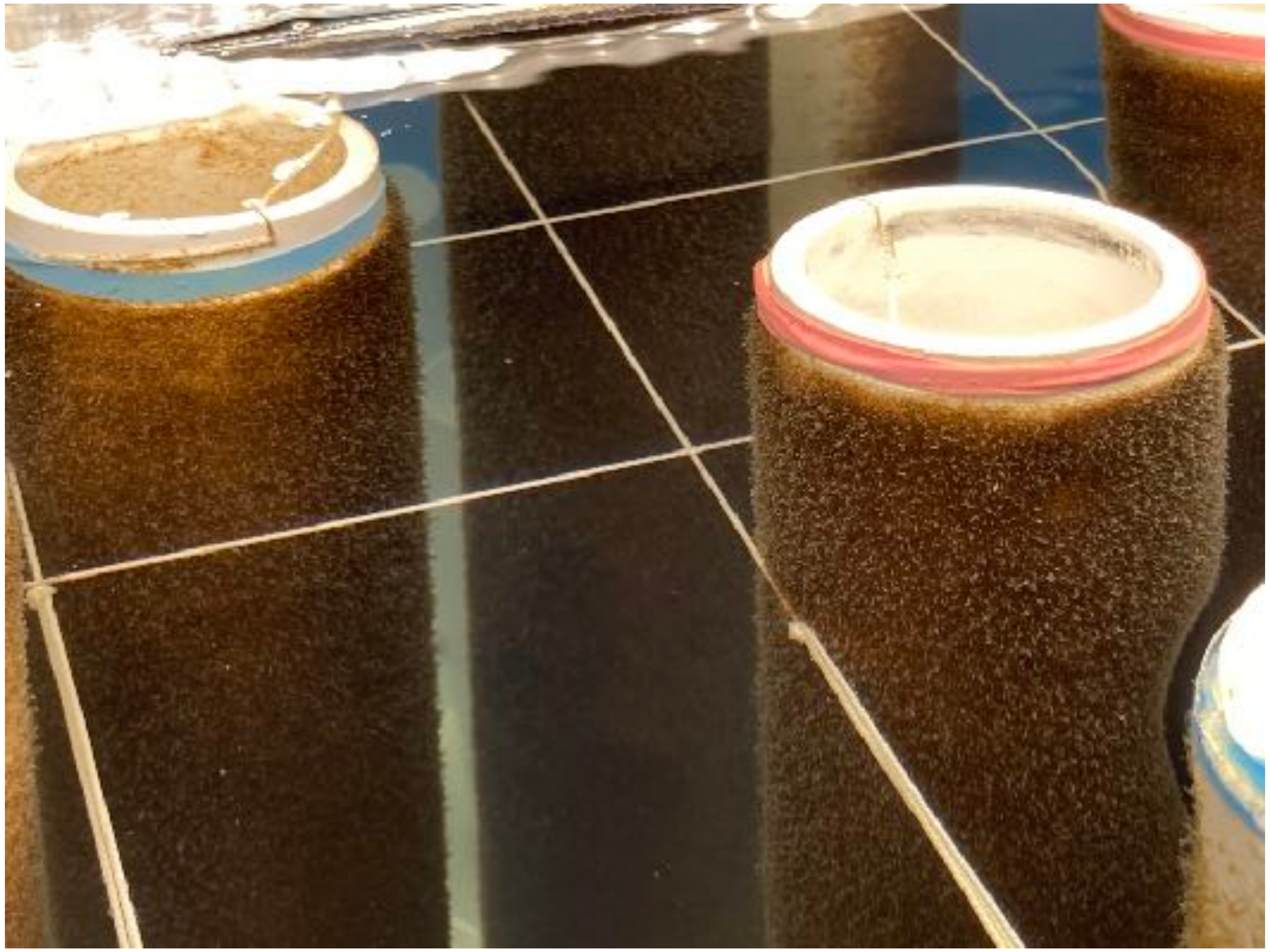
Research Goals: Nursery development

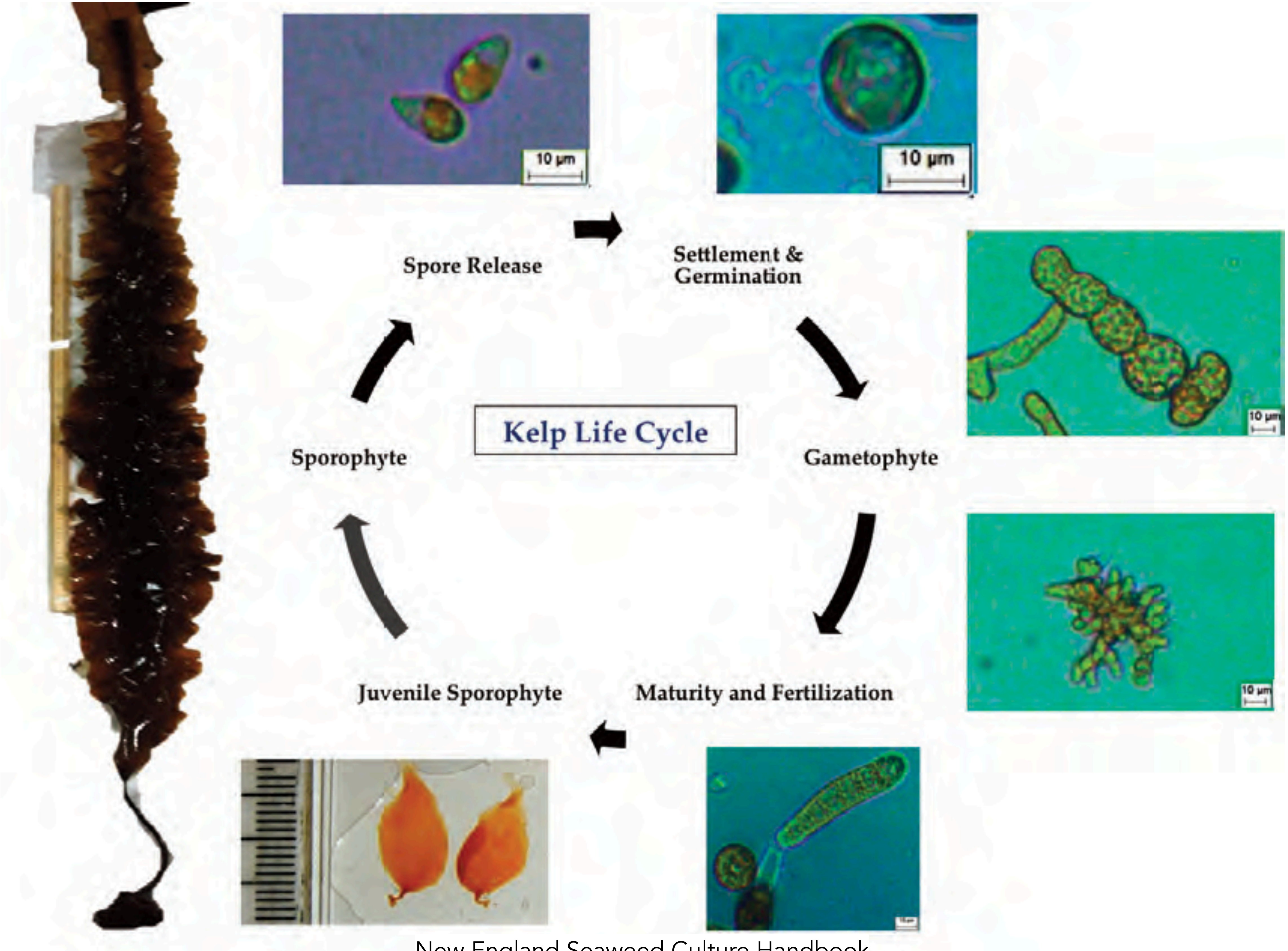
Goals (short-term):

A. Development of a kelp nursery to spawn and seed microfarms

B. Development of processes for seeding long lines



Kelp farming steps



New England Seaweed Culture Handbook

Kelp farming steps

1. Acquiring spores to grow kelp

- Manual collection by cutting sorus tissue: Tissue at center of kelp blade containing the cells that generate and contain the spores.

2. Nursery: settling of the spores onto twine

- Sorus tissue releases microspores
- Seed spools are inoculated
- Microspores settle and develop into male and female gametophytes.
- Gametophytes reproduce and are maintained under controlled conditions until they form juvenile sporophytes.

Scraping surface of sorus tissue

Spore solution

New England Seaweed Culture Handbook

A. Development of a kelp nursery to spawn and seed microfarms

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B. Development of processes for seeding long lines

B. Development of processes for seeding long lines

Research Goals: Nursery development

Approach: iterations of production rounds

- Processes for acquiring spores from donor sorus tissue, for fixing the spores and developing the gametophyte stages are repeated at regular increments to evaluate the effects of the early life stages on kelp growth and the variability of outcomes.

- Development of the spooling equipment: testing of different twine materials and different line materials (cotton, sisal) for deployment.

- To gauge the viability of our homegrown kelp, we also deployed microfarms with spores from an established kelp farm, Springtide Seaweed, as a control.

Research Goals & Approach

4 main areas:

- Nursery development
- Microfarm development
- Kelp varietal investigation
- Sequestration validation

Research Goals: Microfarm Development

- Goals:

  A. Material investigation for different microfarm components

  B. Deployment of >1,500 kelp microfarms

  C. Development of a monitoring system that quantifies growth rates, carbon content according to different environmental variables

  D. Development of a monitoring system to track the trajectories and collect growth data and drift data, to improve our model for the advection of the non-Lagrangian microfarms and understand the reliability of global ocean circulation forecasts for our purposes.

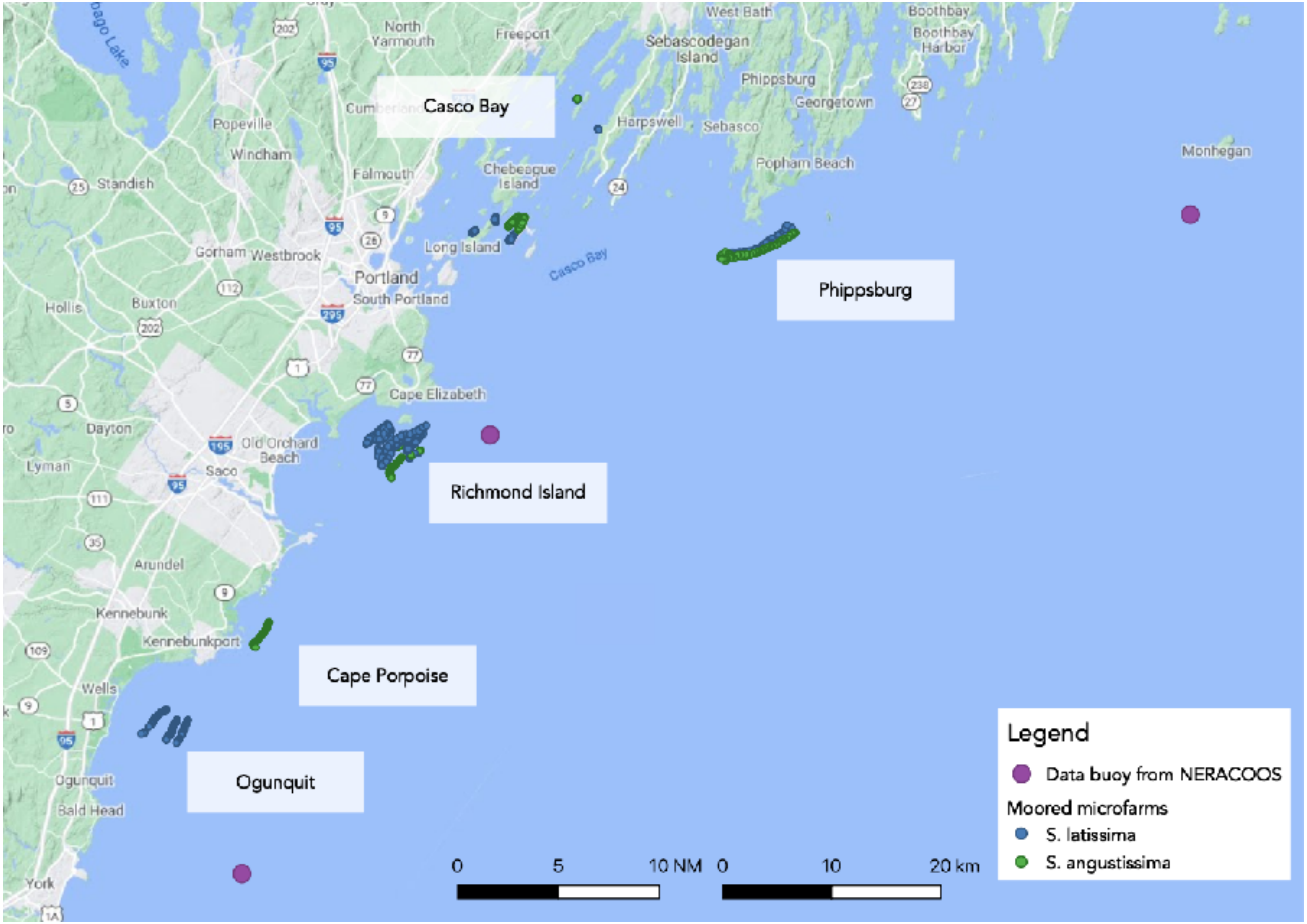
A. Material Investigation for Different Microfarm Components

- Short-term: material investigation for lines, binding agents and weights, down to selecting <3 materials for ocean deployments.
  - Strength test: the growth-free segments of the lines of the harvested microfarms will be tested for durability, both for cotton and sisal lines.

- Long-term: develop and select materials for degradable buoys and timed sinking mechanism.

- Constraints:
  - Buoyancy: negatively buoyant kelp; can be tested in a laboratory or coastal setting
  - Durability: must resist wave forces, temperature and other factors
  - Rates of biodegradation: must be predictable for advection/dispersion
  - Environmental footprint throughout life-cycle, including embedded carbon emissions
  - Feasible to source and manufacture buoys at scale
  - Must be compact for on vessel storage and deployment

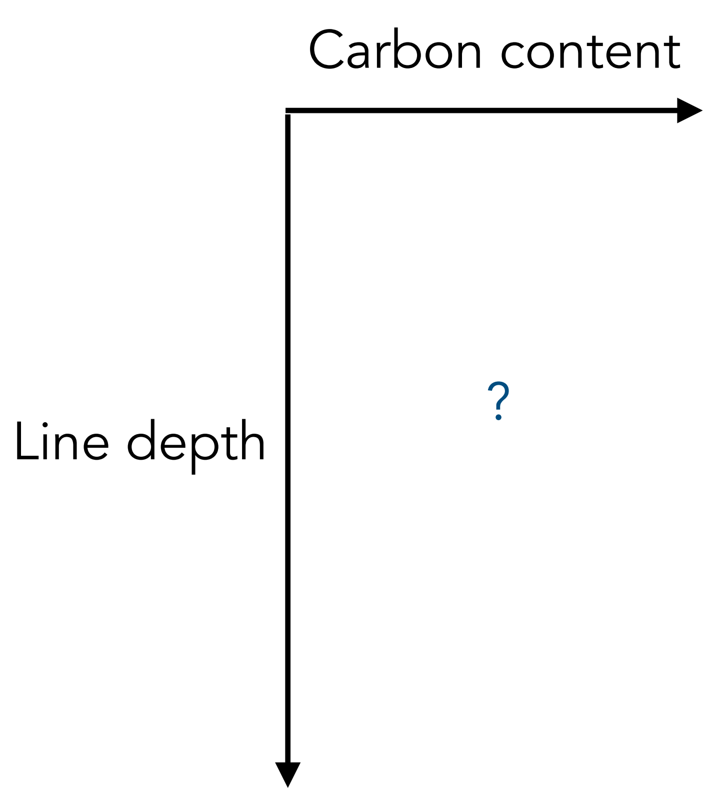
Coastal experiment updates

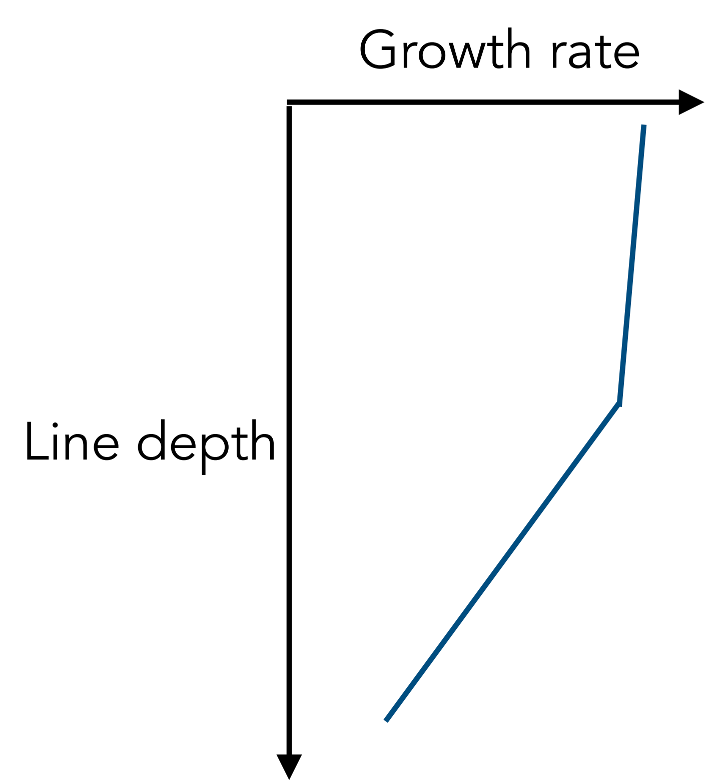


Monitoring System for the Coastal Experiment: Environmental Data

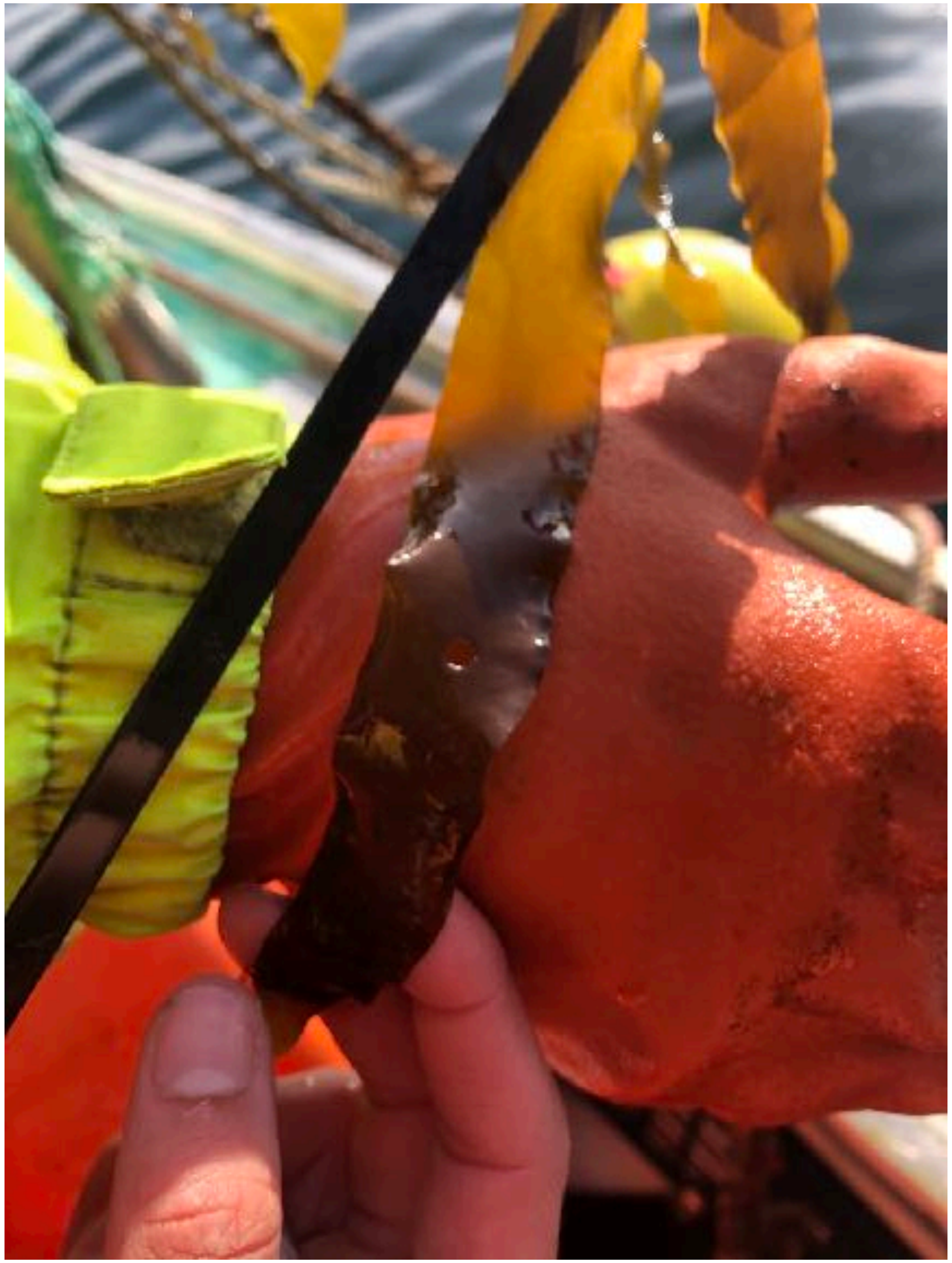
- At each station, an instrumented buoy is deployed with a suite of sensors to quantify growth rates and carbon content in correlation with different environmental variables:
  - Temperature, light sensors at 0m, 10m deep, 20m deep
  - Salinity sensors at 5m
  - pH sensors at 5m
  - Continuous data logging (15-minute intervals)
- NERACOOS/NOAA hourly buoy data also monitored and collected
- Nutrients availability: water samples regularly collected to be sent for analysis
  - Nitrate NO_3^-, Nitrite NO_2^-, Phosphate PO_4^{2-}, Silicate SiO_4, Ammonium NH_4^+

- Growth rates: periodically survey a subset of microfarms and measure through hole punching.
- One *S. latissima* and one *S. angustissima* microfarms are periodically harvested and brought back to shore for analyses of biomass growth with depth, variability in density throughout the length of the line and variability of carbon content throughout the length of the line.
- Small samples of biomass to be sent for carbon and nitrogen content analyses.





Monitoring System for the Coastal Experiment: Biological Data



Monitoring System for the Coastal Experiment: Biological Data

Monitoring System for the Coastal Experiment

Monitoring System for the Offshore Pilot Experiment

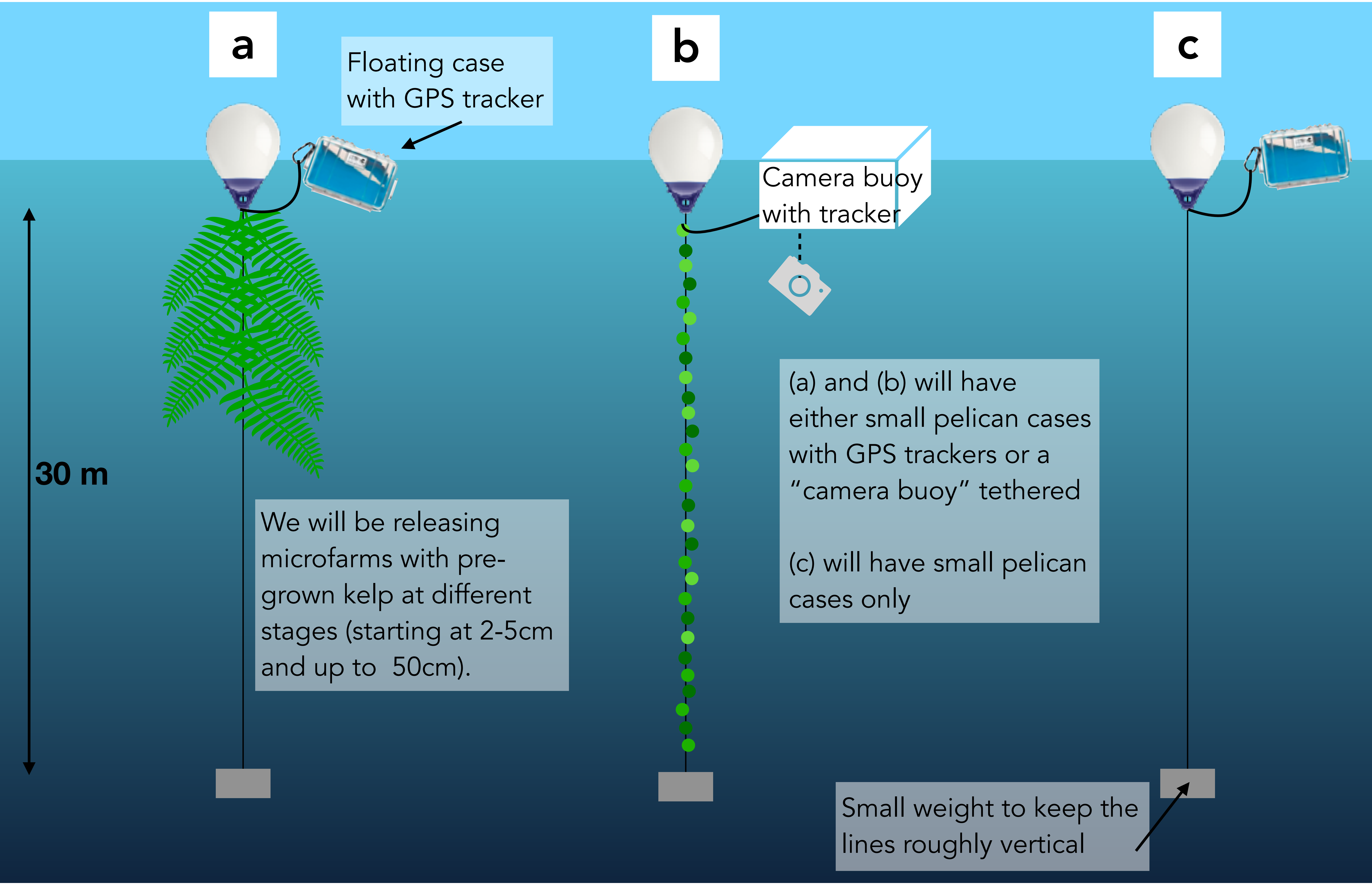
- Development of a monitoring system to track the trajectories, collect drift data, to improve our model for the advection of non-Lagrangian microfarms and understand the reliability of global ocean circulation forecasts for our purpose.
- Deployed microfarms will be equipped with satellite trackers.
- Goal is to better predict the velocity and dispersion of the microfarms.

SmartOne Solar
Globalstar

Edge Solar
Iridium

MakerBuoy

Monitoring System for the Offshore Pilot Experiment



Monitoring System for the Offshore Pilot Experiment

- Sampling the trajectories at high enough frequency (5-15 minutes) may enable us to decouple the impact of windage vs subsurface drag on grown biomass.

- Deploying three types of microfarms:

  a. 40 microfarms with pre-grown kelp

  - *10 with 6-week-old S. Latissima (blades >50cm at upper 5m)*
  - *10 with 6-week-old S. Angustissima (blades >50cm at upper 5m)*
  - *10 with ~3-week-old S. Latissima (growing horizontally)*
  - *10 with ~3-week-old S. Angustissima (growing horizontally)*
  - *7 Globalstar trackers, 3 MakerBuoys with cameras each category*

  b. 30 microfarms with freshly-seeded *S. latissima*

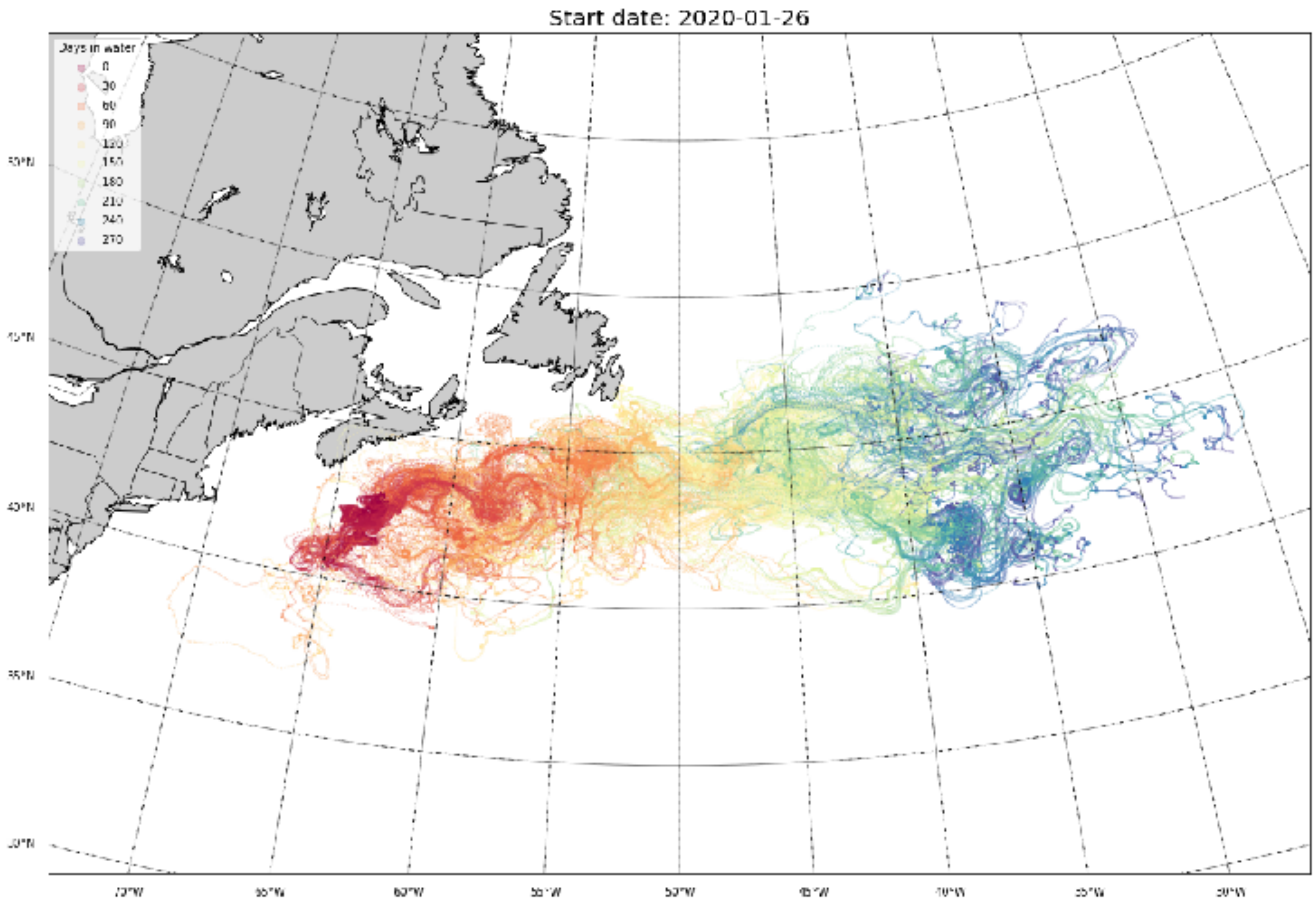
  - *17 Globalstar trackers, 8 MakerBuoys with cameras, 5 Iridium trackers*

  c. 30 "control" microfarms without growth on the lines to look at the trajectory patterns resulting from windage on the buoys and subsurface drag on the line only.

  - *25 Globalstar trackers, 5 Iridium trackers*

Monitoring System for the Offshore Pilot Experiment

- Example 9-month-long trajectories spanning the North Atlantic for non-passive objects
- Considerations: temperature ranges, salinity ranges, logistics (within 300nm), dispersion



Monitoring System for the Offshore Pilot Experiment

- GLBy0.08: HYCOM + NCODA GOFS 1/12° Analysis
  - Grid is 0.08° longitude x 0.04° latitude
  - Hindcasts for 2018, 2019, 2020 and comparing forecasts/hindcasts for 2021
  - Ocean prediction system run daily at the Navy DoD Supercomputing Resource Center

- Trajectories simulated through OceanParcels package in Python
  - Initially compared with OpenDrift package and RK45 advection for passive tracers
    [Lange & van Sebille (2017), Dagestad *et al* (2018), Delandmeter & van Sebille (2019)]

- Non-Lagrangian advection of the microfarms incorporated in these frameworks.
  - Beron-Vera *et al* (2015, 2016, 2019), Beron-Vera & Miron (2020), Miron *et al* (2020): reduced Maxey-Riley framework to simulate the influence of ocean currents and windage on the drift of blunt objects.
  - Zhang *et al* (2017); van Sebille *et al* (2020): relative windage/subsurface drag.
  - Assumptions: surface Ekman layer; biomass centered at 10m; surface currents is 3.25% of wind at 10 meters.
    - Where to find *good* predictions for atmospheric forcing?

Research Goals & Approach

4 main areas:

- Nursery development
- Microfarm development
- Kelp varietal investigation
- Sequestration validation

Research Goals: Kelp Varietal Investigation

- Goals:

  A. Laboratory experiment: growth of +2 North Atlantic kelp varietals to quantify effects of temperature, salinity, pH, light and nutrients on growth and survival under controlled environment (short-term)

  B. Sustainable supply of future North Atlantic kelp brood stock, especially for *S. Angustissima* (long-term)

  C. Investigate North Atlantic kelp varietals for growth, carbon sequestration, durability and scalability (long-term)

- Approach: determine thresholds for growth, C content through laboratory experiments.
  - *S. Latissima* and *S. Angustissima*: at least two species of North Atlantic kelp will be grown in flow tanks with controlled environments
  - Stressors such as high temperatures or low nitrate levels
  - Growth rates and tissue health will be periodically measured

Research Goals & Approach

4 main areas:

- Nursery development
- Microfarm development
- Kelp varietal investigation
- Sequestration validation

Research Goals: Sequestration Validation

- Goals (long-term):

  A. Development of microfarm tracking system to predict sinking locations

  B. Apply for approval from carbon removal marketplaces

  C. In-situ investigations to measure kelp degradation rates and quantify sequestration permanence for different seafloor conditions and depths

  D. Laboratory investigations of degradation and sedimentation rates of kelp biomass

A. Development of Tracking System to Predict Sinking Locations

- Must choose flotation device first to measure inertia, form drag and predict the importance of windage.
  - Drag can be measured in tow tanks.
- Obtain high-accuracy forecast models spanning large length- and time-scales.
  - Length scale: North-Atlantic basin
  - Time scale: 6-9 months
  - Surface and sub-surface currents
  - Forecasts for atmospheric forcing

B. Apply for Approval From Carbon Removal Marketplaces

- In the short-term:
  - Running Tide is pursuing sales of carbon contracts directly through bilaterally negotiated arrangements with corporations, foundations and NGO.
  - Running Tide is also pursuing partnerships with startup sequestration platforms.
  - The verification methodologies will be created directly with counterparties.
- In the medium term: Running Tide will pursue methodology approval with at least one major standard, likely one that supports access to international markets:
  - Gold Standard and Verra (VCS)
  - American Carbon Registry (ACR/Winrock)
  - Climate Action Reserve (CAR)

C. In-situ Investigations of Degradation and Sedimentation Rates

- Purpose: verify the sequestration process of the macroalgal carbon.
- Running Tide intends to deploy instruments to monitor the evolution of the sunk kelp in the deep-sea environment.
- Consulting with biogeochemistry experts specializing in marine sediments to guide the design and execution of these experiments
  - Target sites with high burial efficiency (high % of sedimentation vs remineralization)
- Consulting with benthic ecologists experts to understand and quantify the impacts on the deep-sea life.
- Great opportunities for collaborations!

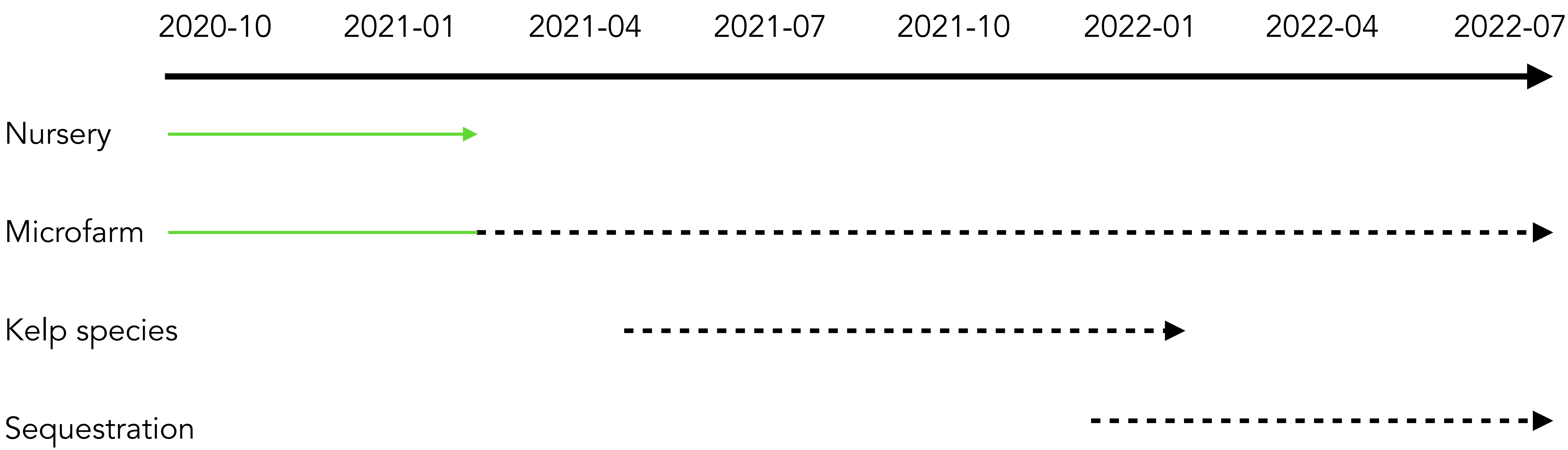
This cute Monkey Brittle Star (*Amphiophiura bullata*) eats *Sargassum*, but does it like *Saccharina*? P.C.: Rob Zugaro/Museums Victoria/CSIRO.

D. Lab Investigations of Degradation and Sedimentation Rates

- Running Tide is investigating the feasibility of laboratory experiments to measure the degradation rates and sedimentation rates of the kelp biomass.
- Purpose: recreate temperature and pressure conditions in high-pressure flow tanks, with continuous monitoring to observe the evolution of the “sunk” macroalgae over time.
- Are these good proxies for *in-situ*? What can we learn?

Schedule

- Some of these experiments are already ongoing.
- Short-term priorities:
  - Enhance our sampling/surveying protocol for grown biomass
  - Enhance our monitoring of environmental data
  - Get feedback for the offshore experiment
- Following this proof of concept, Running Tide intends to conduct sinking and sequestration experiments.



Thank you!

- Advisory Committee and Running Tide team:
  - What is the proposed meeting cadence and communication?
  - What is the reporting structure?

Appendix

- Memorandum of Understanding
- Key figures
- Example of a station layout
- North Atlantic conditions
- Coastal experiments conditions

References

- Deep-sea macroalgal carbon
- Evidence of macroalgae in benthic fauna
- Advecting non-passive floaters

Memorandum of Understanding
Between Ocean Visions and Running Tide

- RT is conducting a field trial of a macroalgae-based technology capable of sequestering CO_2 at the multi-gigaton scale with a sequestration permanence of >1,000 years. The Kelp Pilot is designed to test, measure and determine the efficacy and impacts of a proprietary system of open ocean kelp farming for CCS.

- OV's assembled Expert Panel will act in an advisory capacity to:

1. Review the Kelp Pilot plan and provide feedback to optimize its design and implementation, and to maximize overall performance, efficacy and data integrity.
2. Review potential environmental risks 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, carbon sequestration and environmental impacts.
4. Provide advice on governance-related aspects of the plan and on strategies to build social and political license for the effort.
5. Review results of the Kelp Pilot as they become available.
6. Provide an independent final report on the overall effort, the validity of the findings, any areas of disagreement and suggested next steps.
7. Work in a collaborative manner with RT, while maintaining complete scientific independence.

Memorandum of Understanding
Between Ocean Visions and Running Tide

- Key Milestones:
  1. Convene a workshop in January 2021 between RT and the Expert Team to review the overall RT research plan and calendar of activities.
  2. By mid-Feb 2021, OV and RT will develop a plan of work that identifies the key activities, objectives and milestones.
  3. Convene planning and review meetings every other week to assess progress and identify the priorities. These may eventually occur on a monthly basis.
  4. Convene a wrap-up workshop at the appropriate time to do a final review of all of data and discuss findings and next steps.
  5. Agree on regular periodic public communications about the effort and its progress.

- Confidential Information:
  - All intellectual property rights of any Party shall remain the sole property of such Party, and do not transfer to any other Party.
  - All Intellectual Property Rights that are prepared by or on behalf of OV shall be owned by OV.

Key Figures

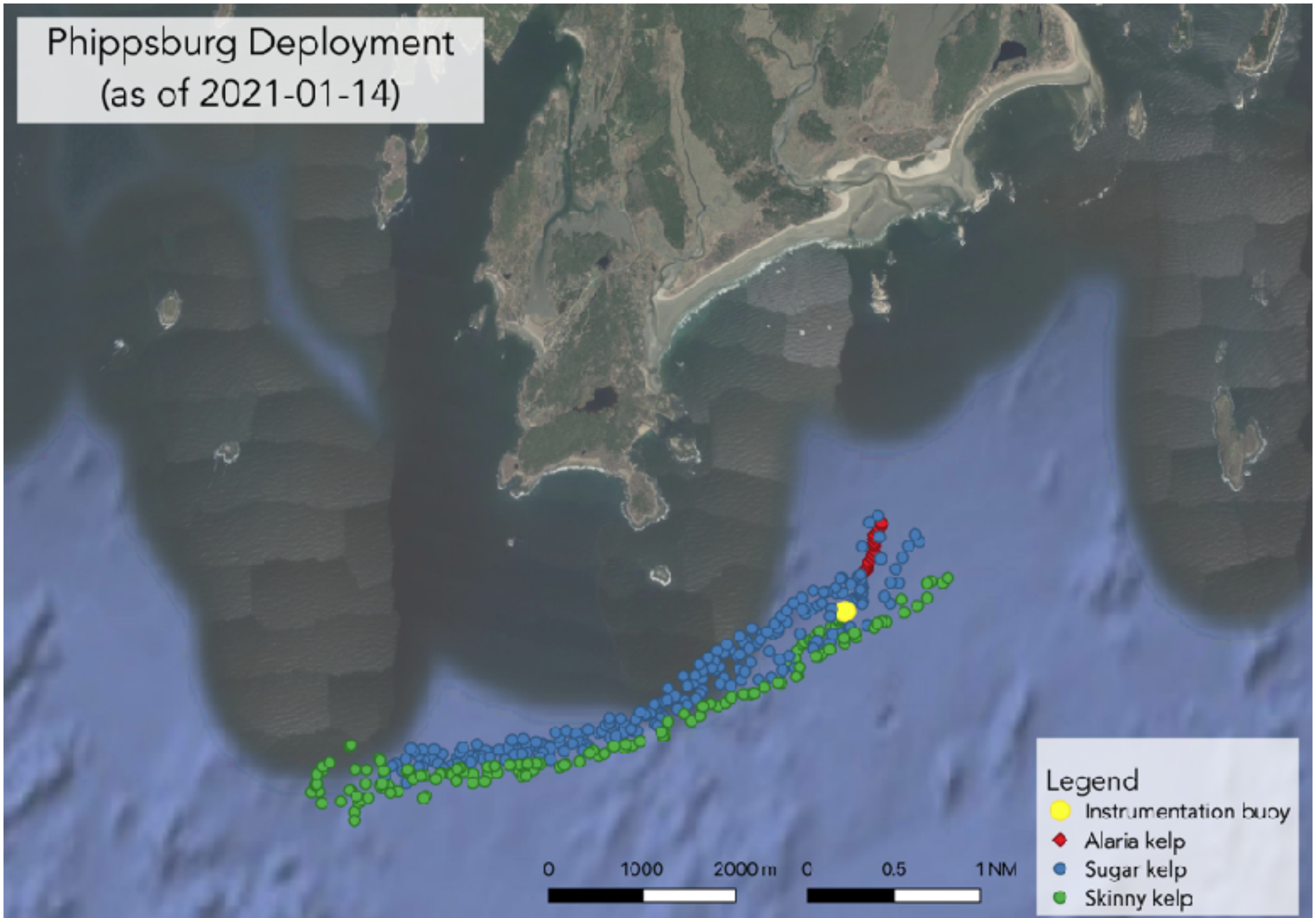
- Length of seeded line: 30 m.
  - In open-ocean conditions, we expect growth throughout.

- Near-shore yield:
  - 18.1 kg of wet weight / meter of line for *S. angustissima* [Augyte, 2017]
  - Mean dry:wet weight ratio ~15.38%

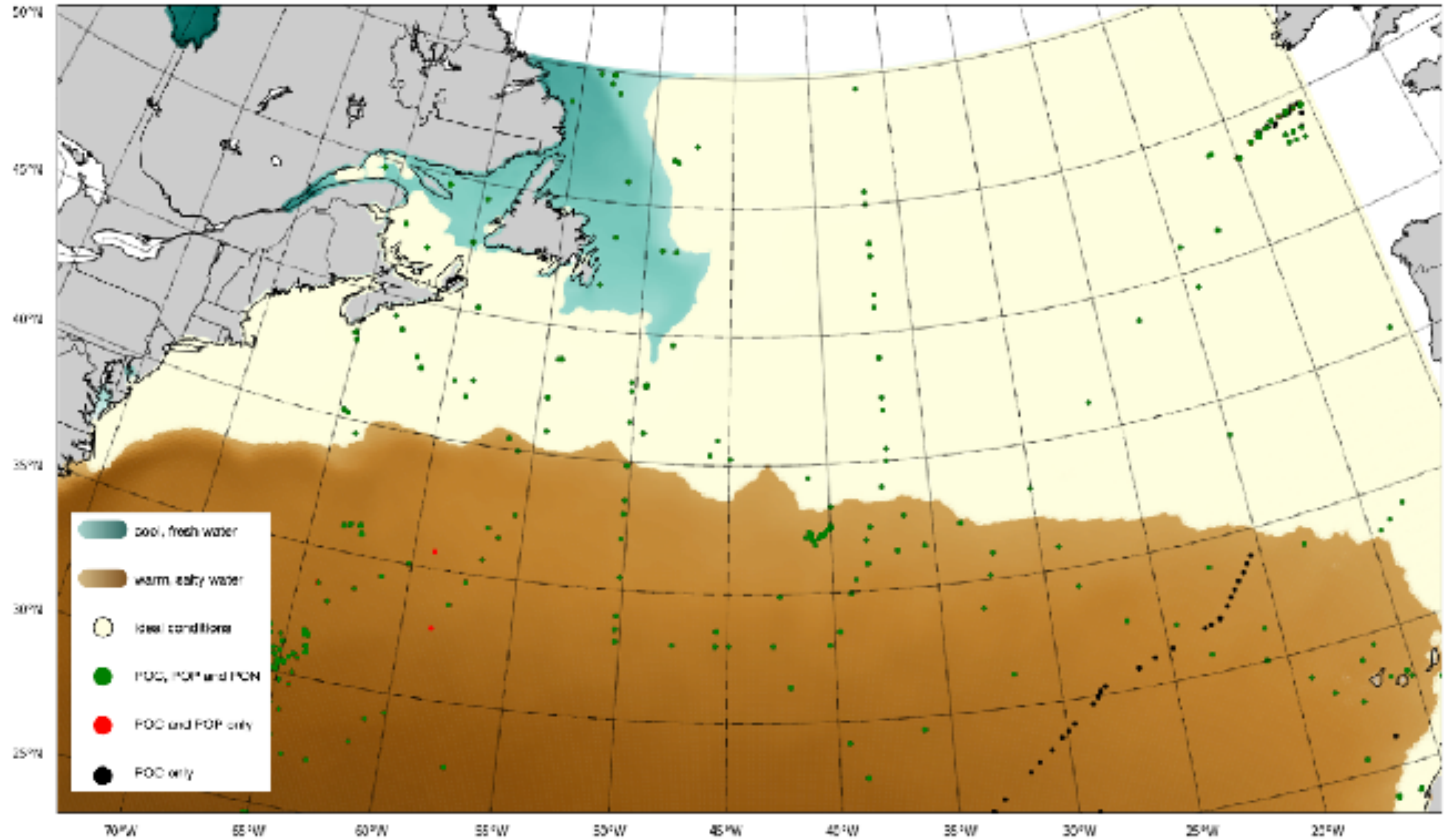
- We estimate 0.0019 tCO_2 / meter of longline as a safety factor

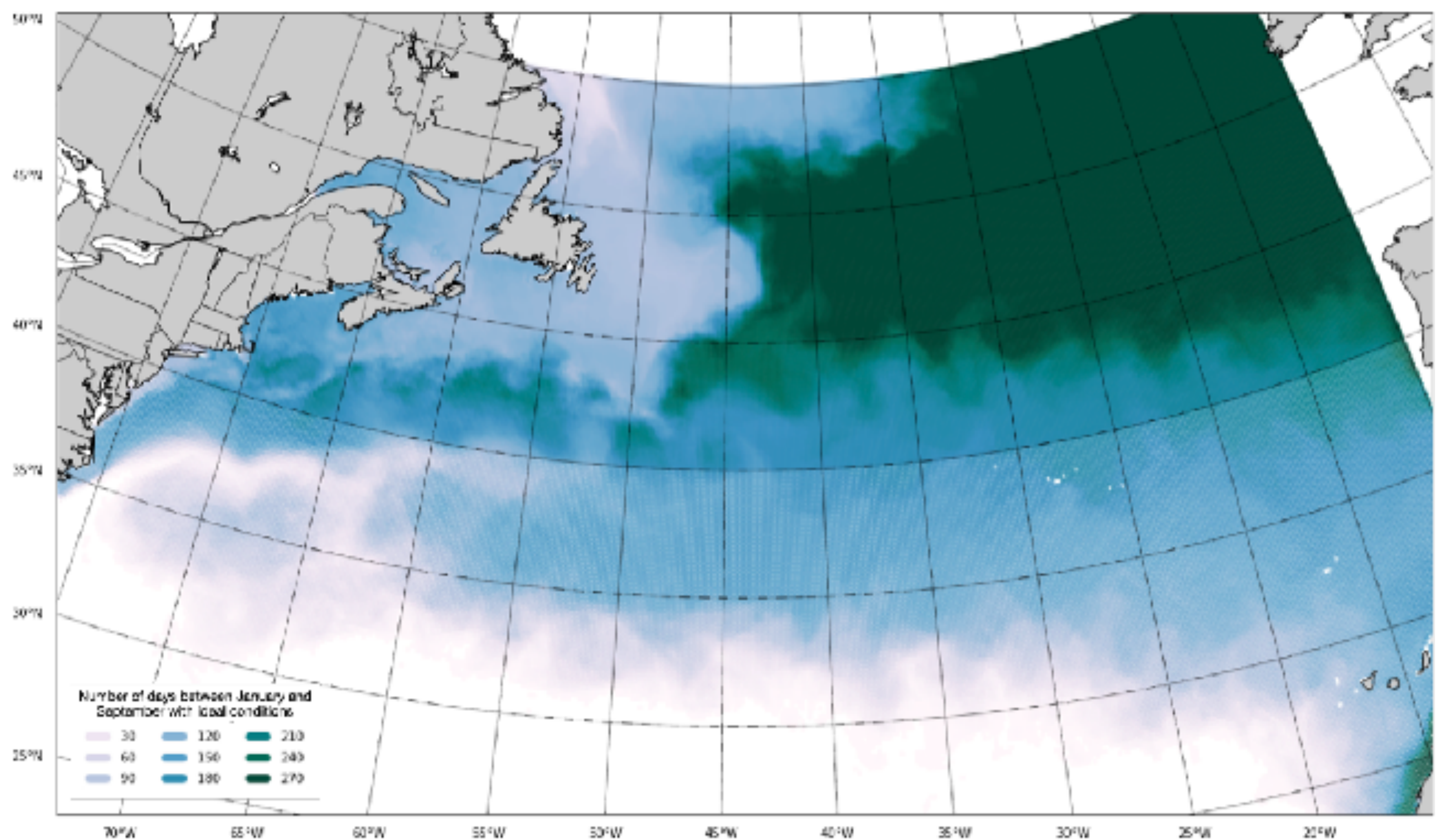
	S. latissima	*S. angustissima*
Carbon content	37.4%	34.9%
Mass CO_2 sequestered / kg wet kelp	0.211 kg	0.196 kg
tCO_2 / meter of longline	0.0038 tCO_2	0.0036 tCO_2

Appendix: example layout of a station for the coastal experiment



Appendix:
North Atlantic





Appendix: Coastal experiment conditions

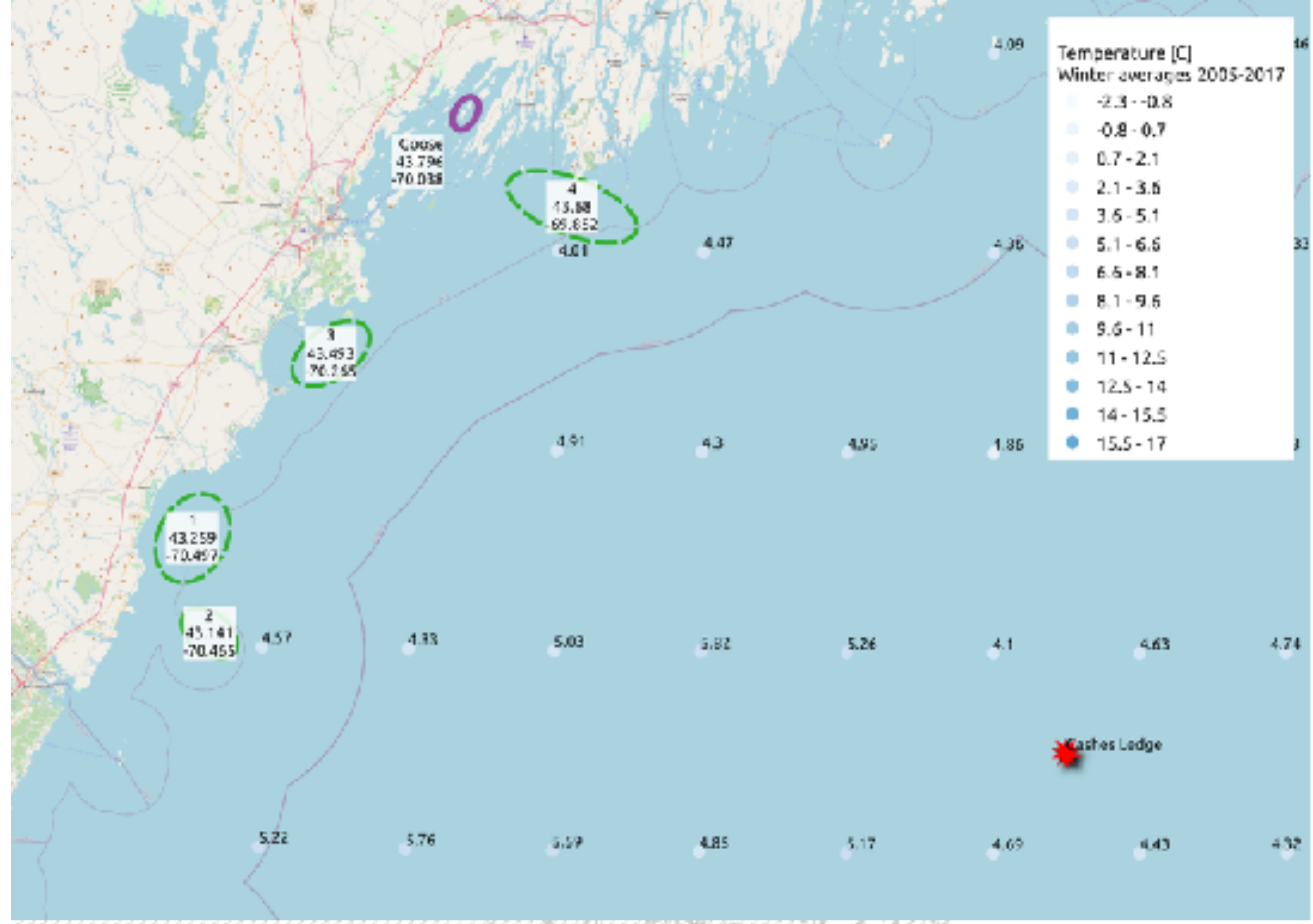
- Temperature
- Salinity
- Nitrate (also looked at phosphorus
- Comparison with northwest North Atlantic

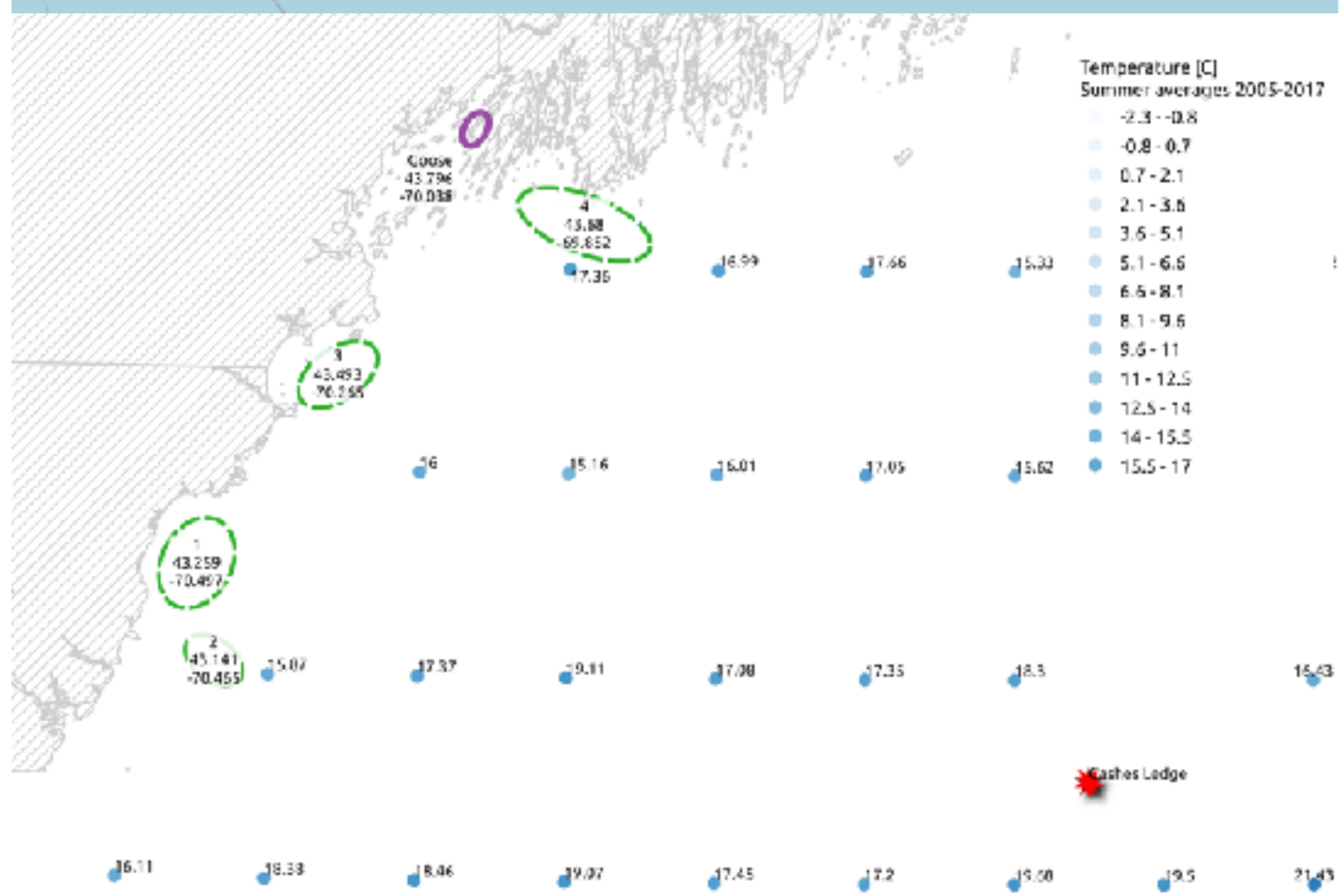
Temperature variations

Average temperature for 2005-2017 on a 0.25° grid. Data from NOAA.

Temperature difference between zones 2 and 4:

- Winter: 0.56°C (top)
- Spring: 0.84°C
- Summer: 1.49°C (bottom)
- Fall: 1.12°C





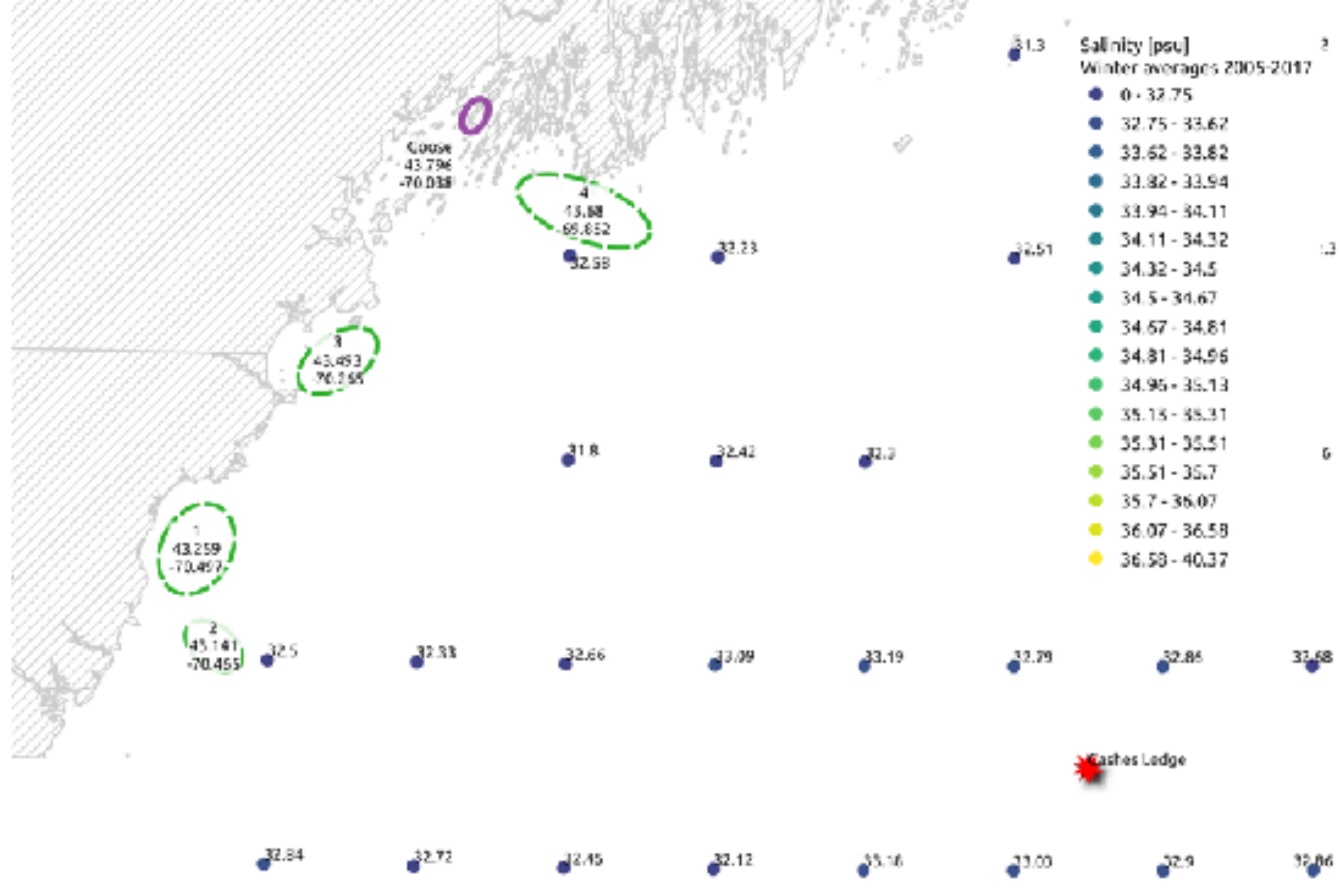
Salinity variations

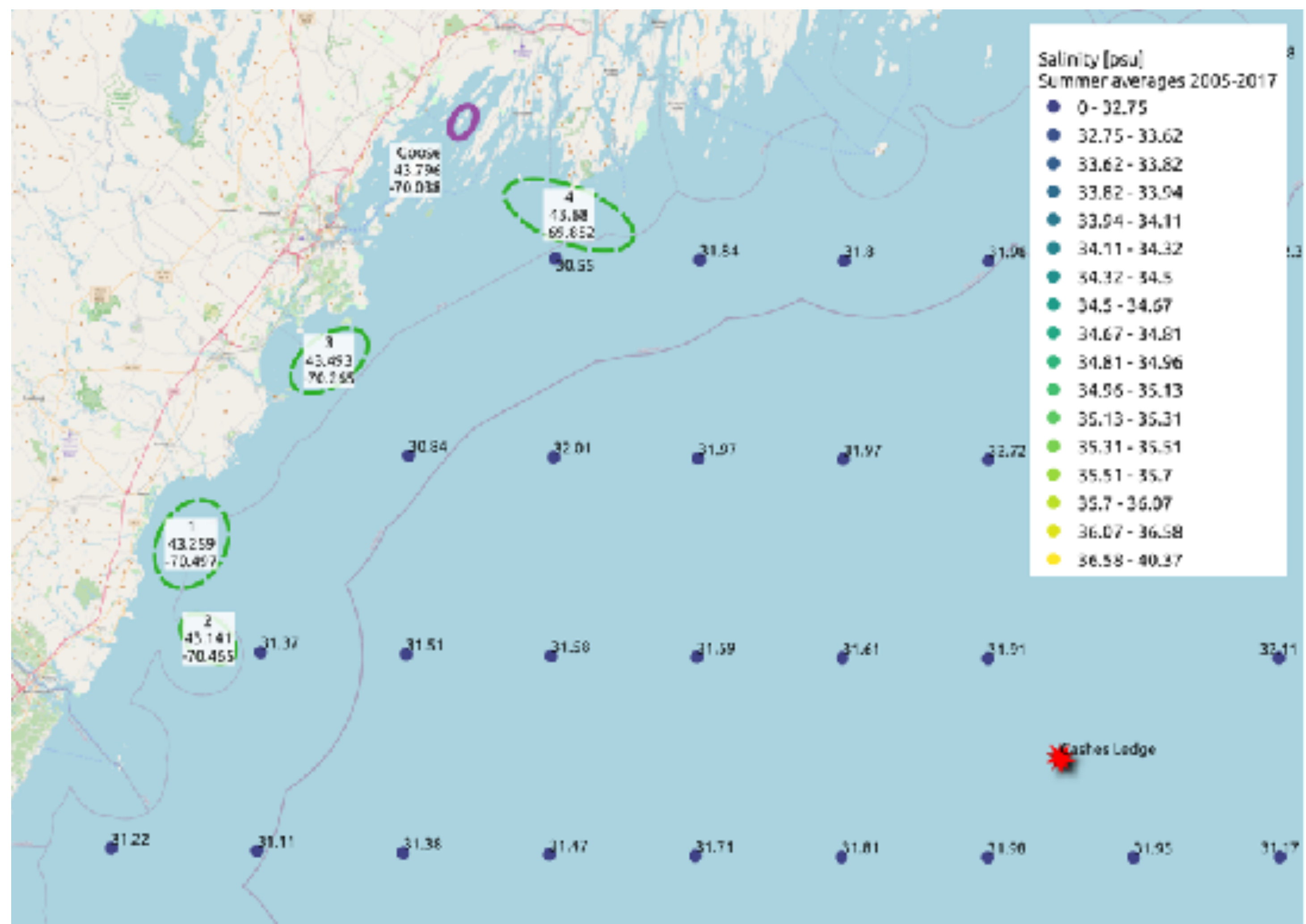
Average salinity for 2005-2017 on a 0.25° grid. Data from NOAA.

Salinity difference between zones 2 and 4:

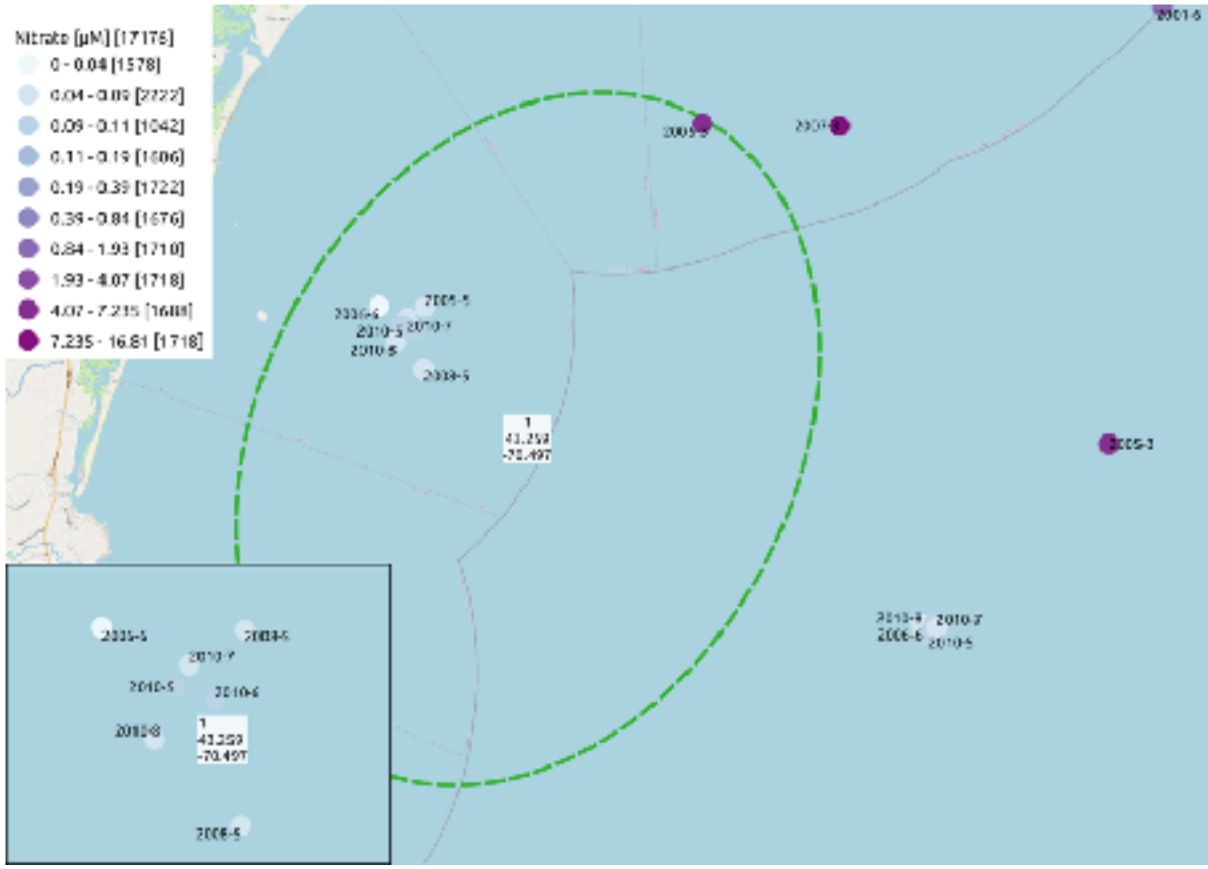
- Winter: 0.08 psu* (top)
- Spring: 0.44 psu
- Summer: 0.82 psu (bottom)
- Fall: 0.27 psu

*practical salinity unit, i.e. parts per thousand





Nutrients data by zone

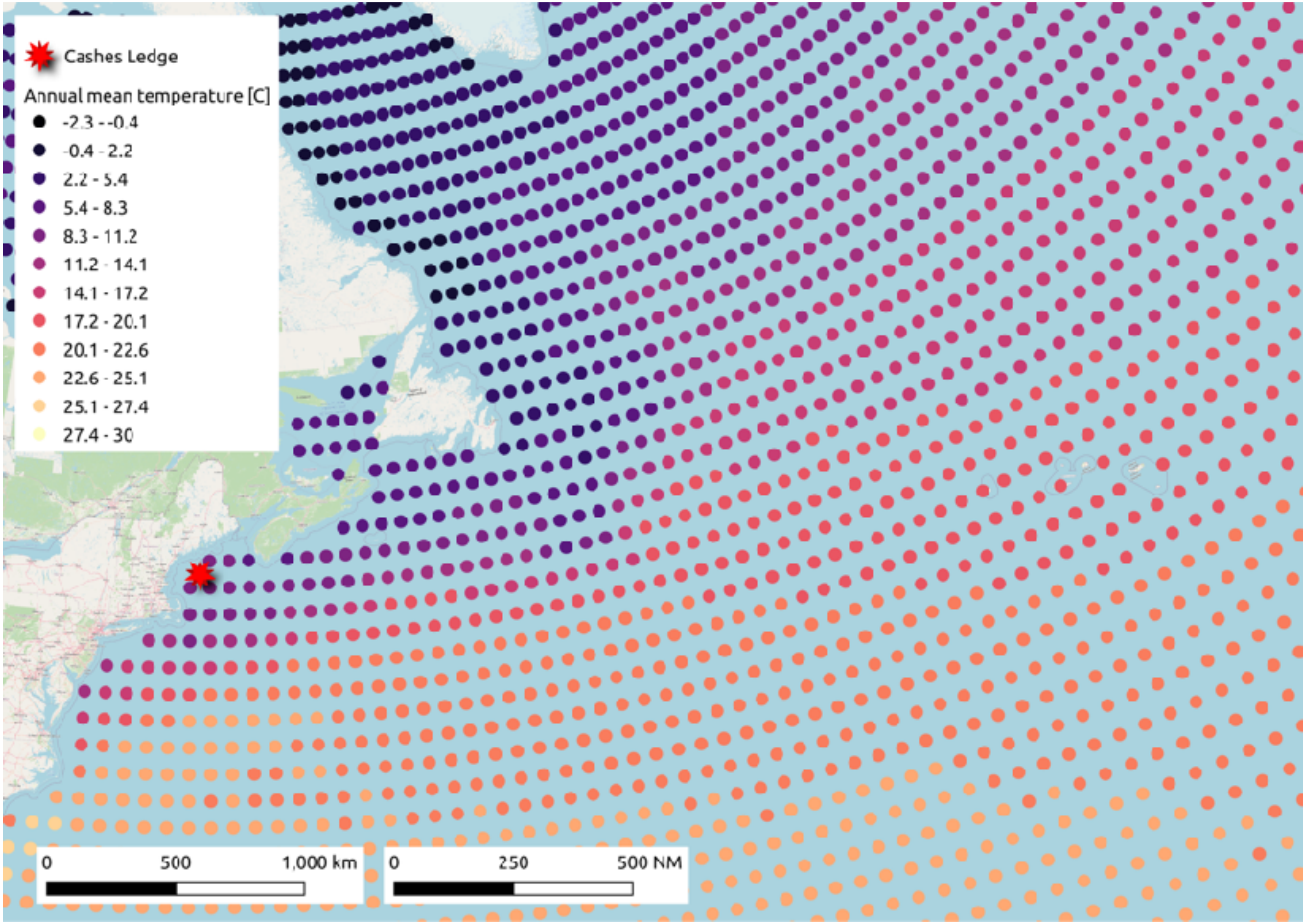


- Data was compiled by N. Rebuck, D. Townsend and M. Thomas, School of Marine Sciences, University of Maine:

  The majority of data come from two public sources: the World Ocean Database maintained at the National Oceanographic Data Center ([WOD](), Boyer et al. 2006) […] Much of the new and unreleased data come from samples collected and processed by the DW Townsend Lab at the University of Maine ([DWT]()). In addition, observations were provided by the Atlantic Zone Monitoring Program ([AZMP]()), the University of New Hampshire Coastal Ocean Observing Center ([UNHCOOA]()), data collected on Alexandrium and other survey cruises by D. McGillicuddy at the Woods Hole Oceanographic Institute ([WHOI]()), the Massachusetts Water Resource Authority ([MWRA]()), and the Marine Monitoring and Assessment Program at the Northeast Fisheries Science Center of NOAA ([MARMAP]()).

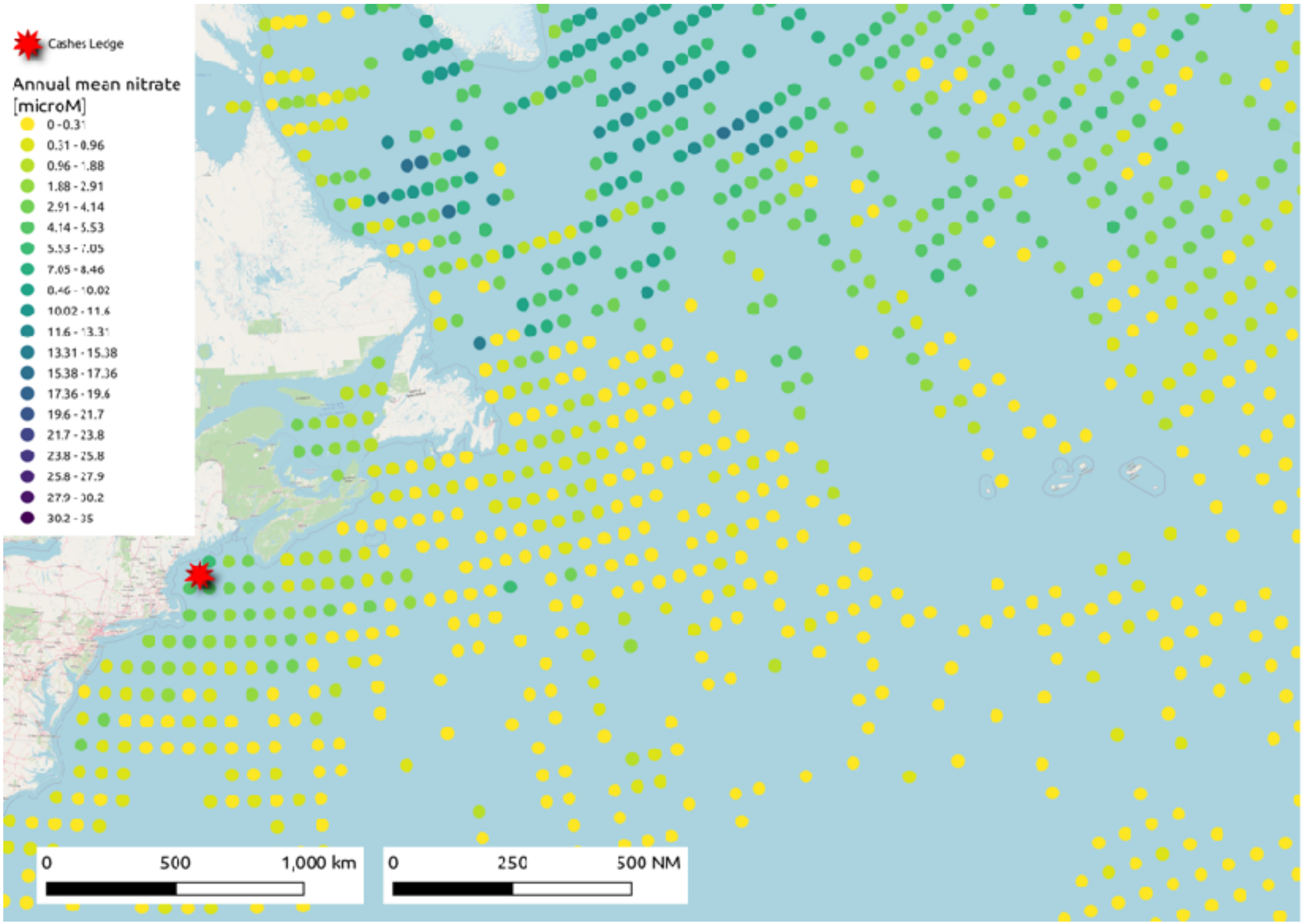
  Link here, cropped to data collected between 2000 and 2010.

Coastal vs. North Atlantic: Temperature



- Gulf of Maine, including Cashes Ledge, is much cooler than offshore North Atlantic

Coastal vs. North Atlantic: nitrate



- Higher nutrients (nitrate) in coastal zones

Appendix: Deep-sea Macroalgal Carbon

- Macroalgal carbon export to the deep-sea as a naturally-occurring phenomenon
  - Ortega, A., Geraldi, N.R., Alam, I., Kamau, A.A., Acinas, S.G., Logares, R., Gasol, J.M., Massana, R., Krause-Jensen, D. & Duarte, C.M. Important contribution of macroalgae to oceanic carbon sequestration. *Nature Geoscience* **12**, (9):748-754 (2019). doi.org/10.1038/s41561-019-0421-8
    "findings indicate that macroalgae are exported across the open and the deep ocean"
  - Krause-Jensen, D. & Duarte, C.M. Substantial role of macroalgae in marine carbon sequestration. *Nature Geoscience* **9**, (10):737-742 (2016). dx.doi.org/10.1038/ngeo2790
    First-order global estimate of 173 Tg C / yr of macroalgal C potentially sequestered in sediments and deep-sea waters, about 11% of macroalgal net C production
  - Krause-Jensen, D., Lavery, P., Serrano, O., Marbà, N., Masque, P. & Duarte, C.M. Sequestration of macroalgal. carbon: the elephant in the Blue Carbon room. *Biology Letters* **14**, 20180236 (2018). dx.doi.org/10.1098/rsbl.2018.0236
  - Dierssen, H.M., Zimmerman, R.C., Drake, L.A. & Burdige, D.J. (2009) Potential export of unattached benthic macroalgae to the deep sea through wind-driven Langmuir circulation. *Geophysical Research Letters* **36**, (4):L04602.

Appendix: Evidence of Macroalgae in Benthic Fauna

- Macroalgal fragments in guts of bathyal (1,000 - 3,000m) and abyssal (3,000-6,000m) crustaceans: see compilation of reports in Table S1, Krause-Jensen & Duarte [2016].

- Northern Atlantic: turbidity currents transport "large quantities" of materials of shallow-water origin to the deep-sea floor, with fragments of green macroalgae *Halimeda* having been observed in sediment cores sampled down to 7,955 m in the Puerto Rico Trough.
  - Ericson, D.B., Ewing, M. & Heezen, B.C. Turbidity currents and sediments in the North Atlantic. *AAPG Bulletin* **3,** (3):489-511 (1952).

- Off the coast of New England specifically, the brown macroalgae *Sargassum* is a source of food for the Monkey Brittle Star (*Amphiophiura bullata*) at depths between 3000-5000 m.
  - Wolff, T. Macrofaunal utilization of plant remains in the deep sea. *Sarsia* **64**, (1-2):117-143 (1979).

- In the Pacific Ocean, the deepest observation was *Sargassum* found in the guts of benthic animals that had been sampled by trawlers at 6,475 m deep in the Japan Trench.

Appendix: Advecting non-passive floaters

- Beron-Vera, F.J., Olascoaga, M.J., Haller, G.,Farazmand, M., Triñanes, J. & Wang, Y. (2015) Dissipative inertial transport patterns near coherent Lagrangian eddies in the ocean. *Chaos* **25**, 087412.

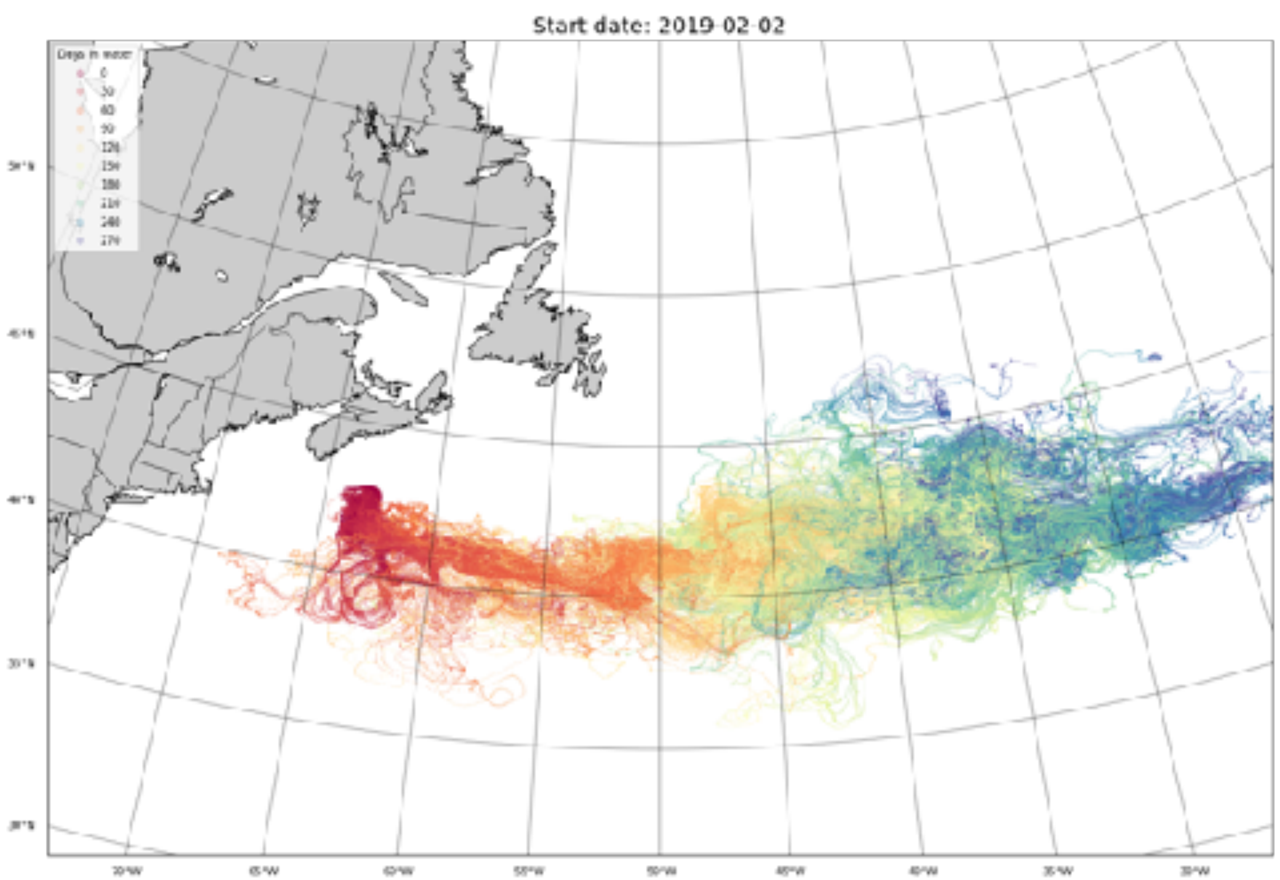
- Beron-Vera, F.J., Olascoaga, M.J. & Lumpkin, R. (2016) Inertia-induced accumulation of flotsam in the subtropical gyres. *Geophysical Research Letters* **43**, 12228–12233.

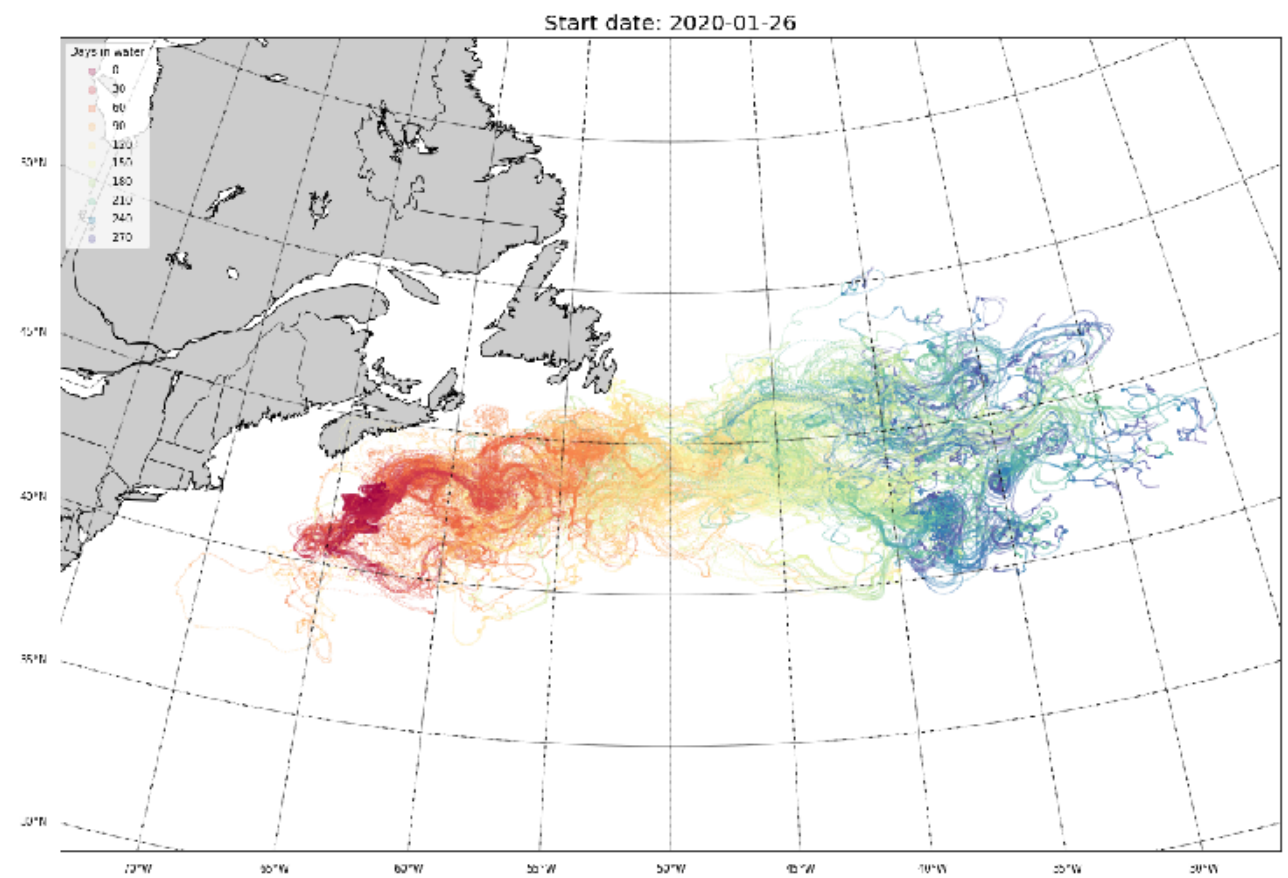
- Beron-Vera, F.J., Olascoaga, M.J. & Miron, P. (2019) Building a Maxey–Riley framework for surface ocean inertial particle dynamics. *Physics of Fluids* **31**, 096602.

- Beron-Vera, F.J. & Miron, P. (2020). A minimal Maxey–Riley model for the drift of Sargassum rafts. *Journal of Fluid Mechanics*, submitted (e-print arXiv:2003.03339).

- Zhang, J., Teixeira, Â.P., Soares, C. G. & Yan, X. (2017). Probabilistic modelling of the drifting trajectory of an object under the effect of wind and current for maritime search and rescue. *Ocean Engineering* **129**, 253-264.

Appendix: 2019, 2020 trajectories seeded at our target location





Appendix: January 2021 trajectories: comparing forecasts and handcarts