Evaluating Ocean Alkalinity Enhancement for Carbon Dioxide Removal The WHOI LOC-NESS Project

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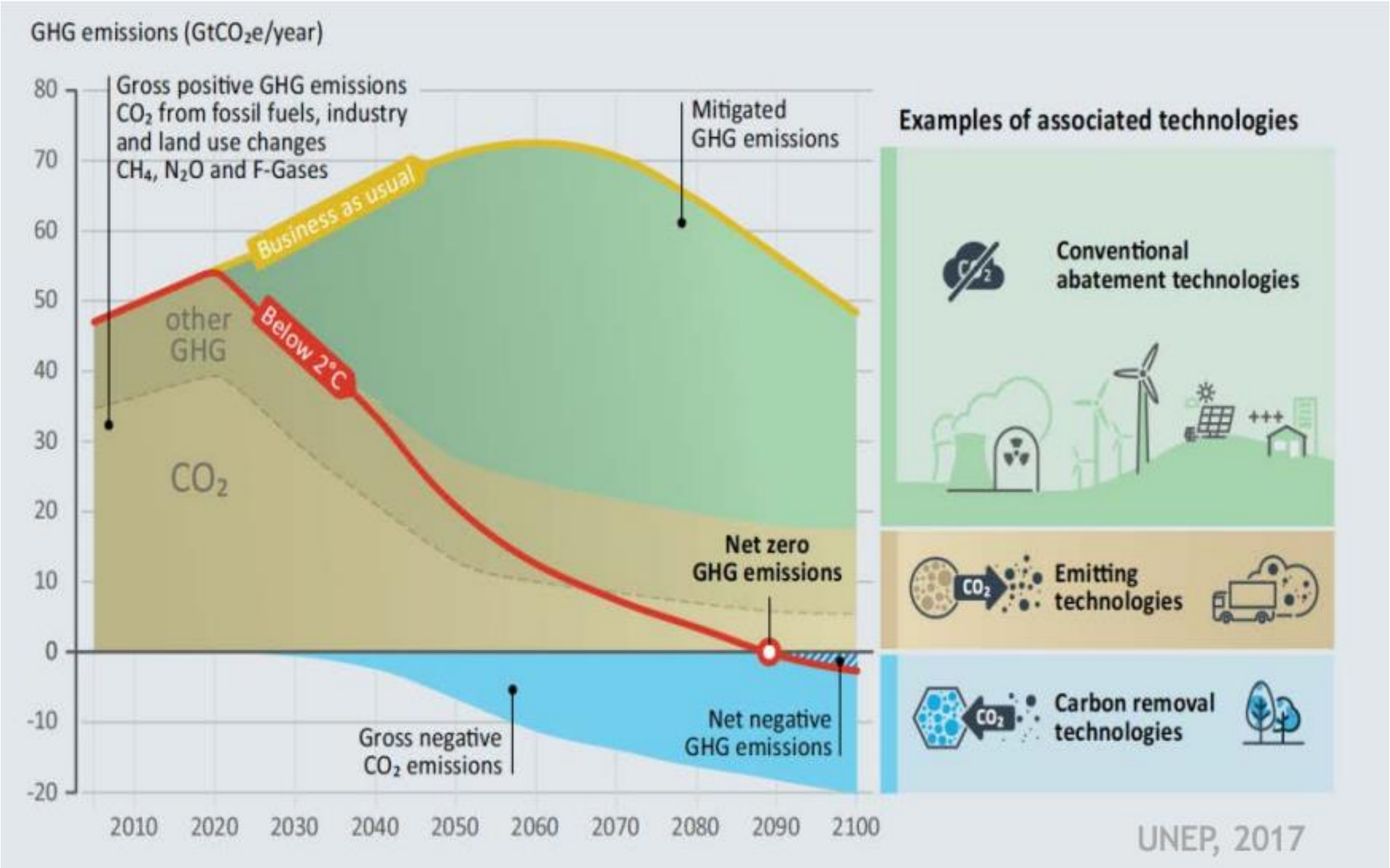
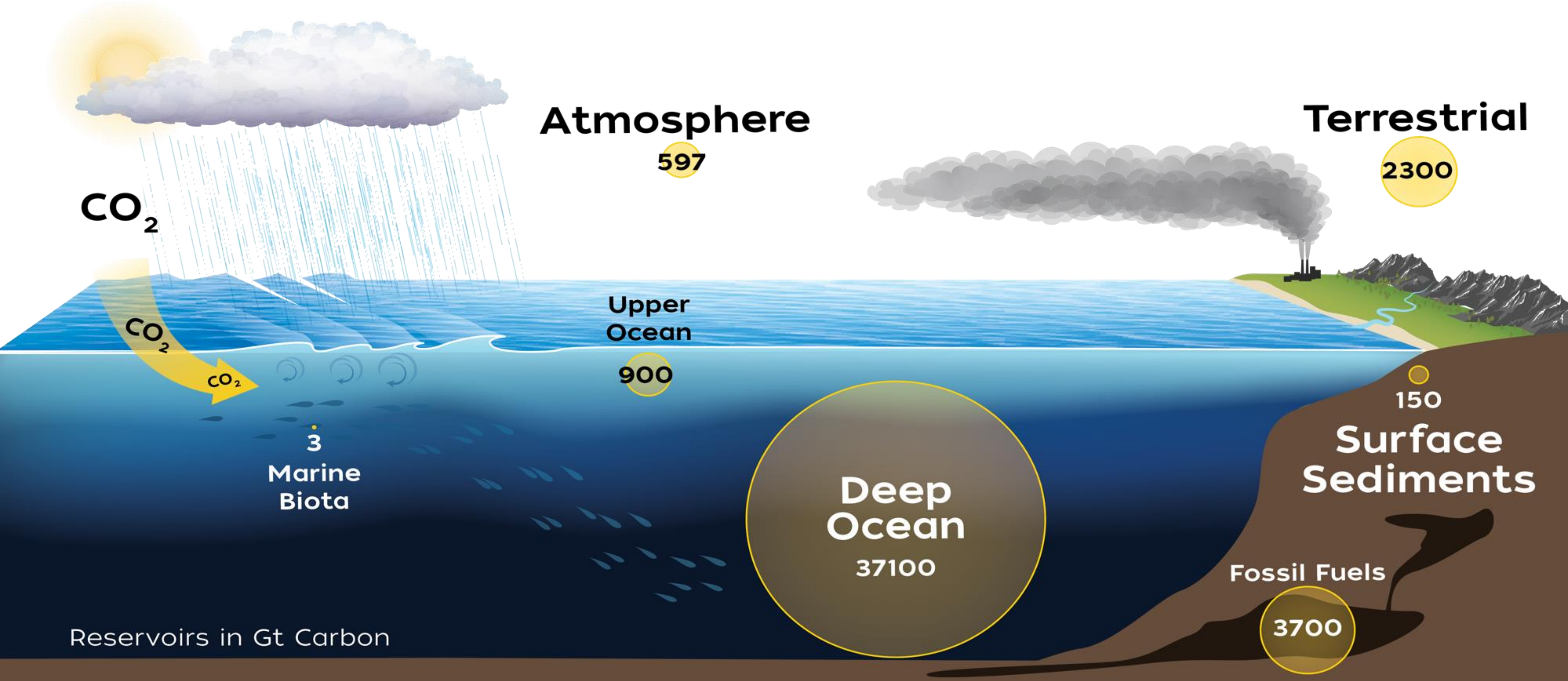
Reduce emissions and remove carbon to reach climate goals



Can the ocean help us to fight climate change?

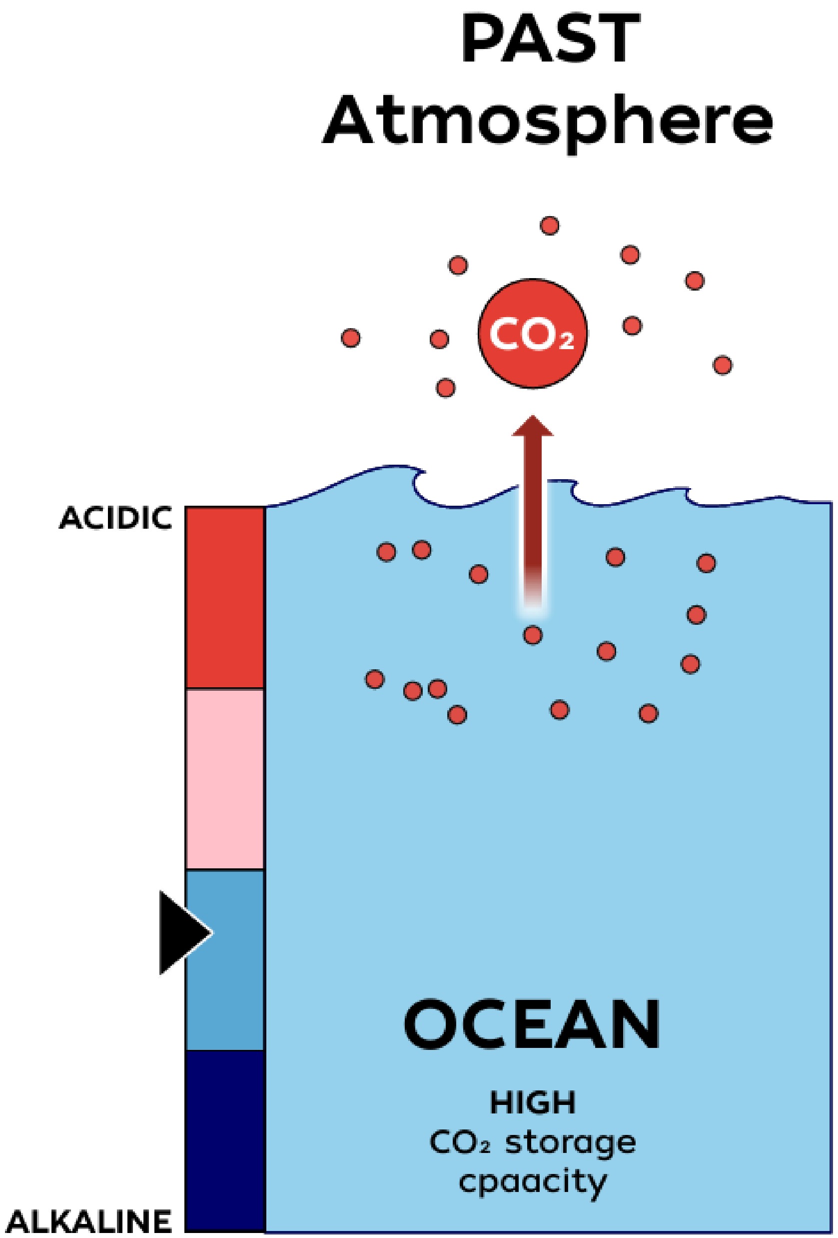


Deep ocean stores >50x more C than atmosphere

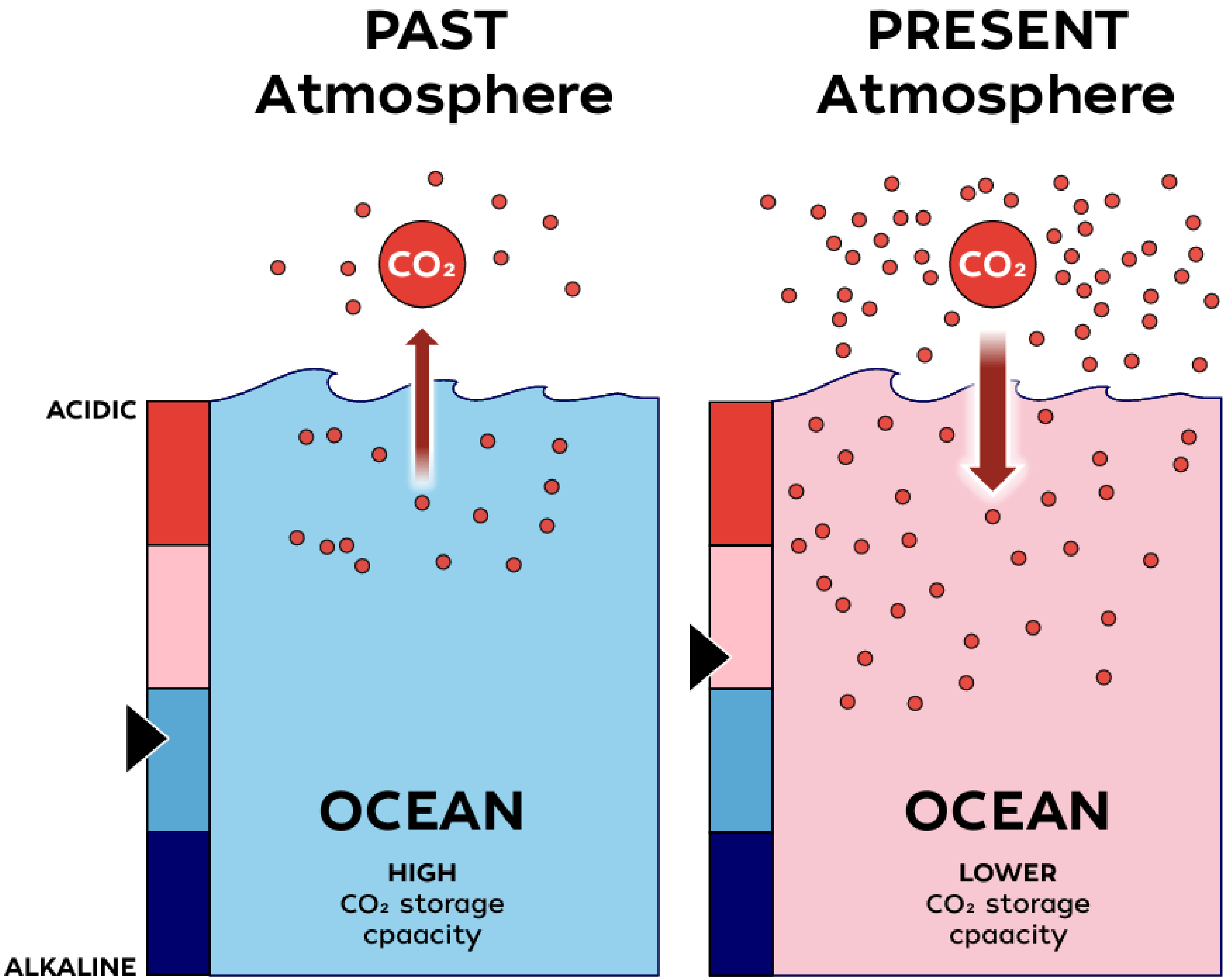
15-20x more C than land plants and soils

5000 x more C than coastal blue C

How does Ocean Alkalinity Enhancement work?



How does Ocean Alkalinity Enhancement work?



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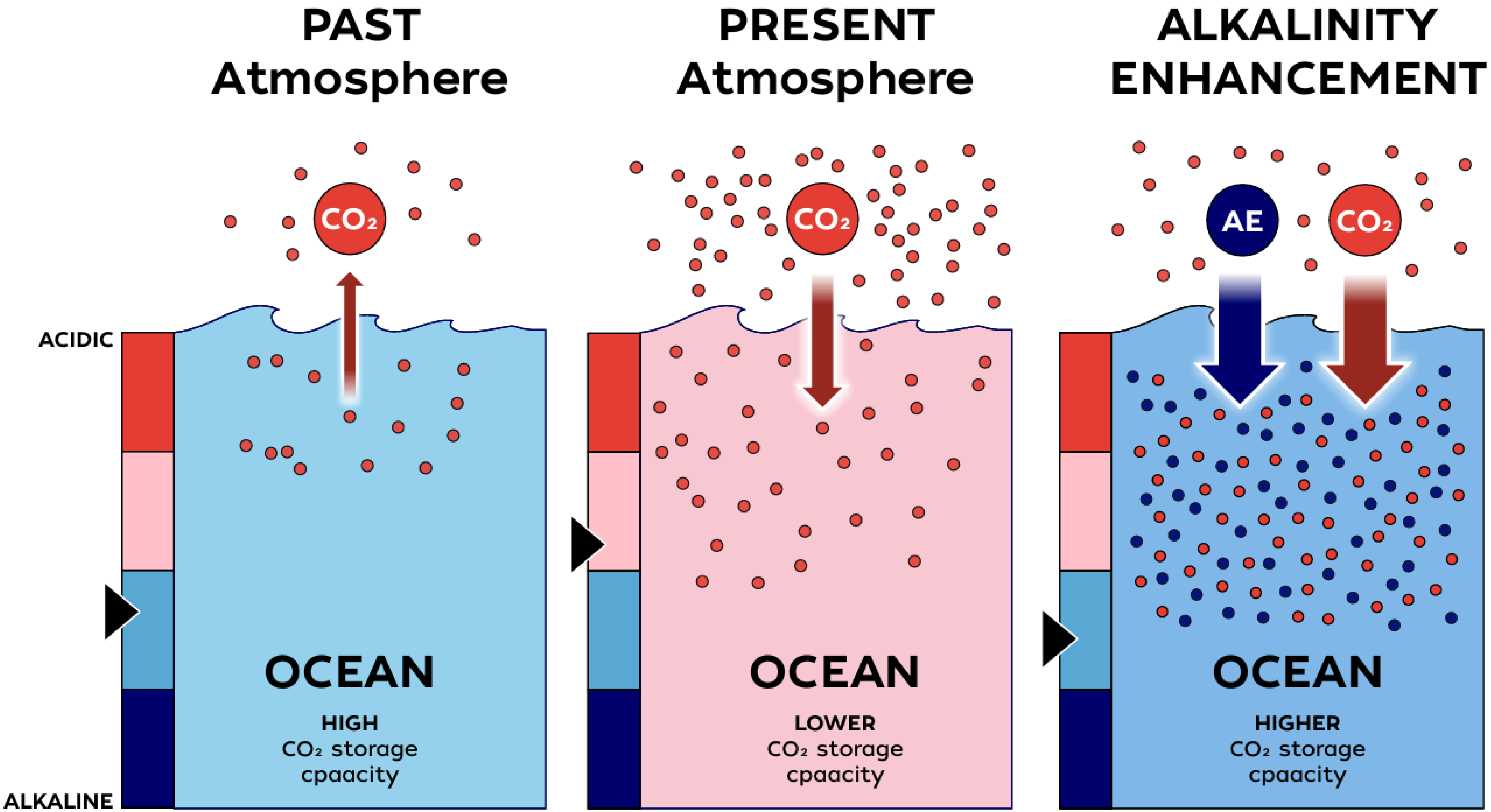


Los Angeles Times

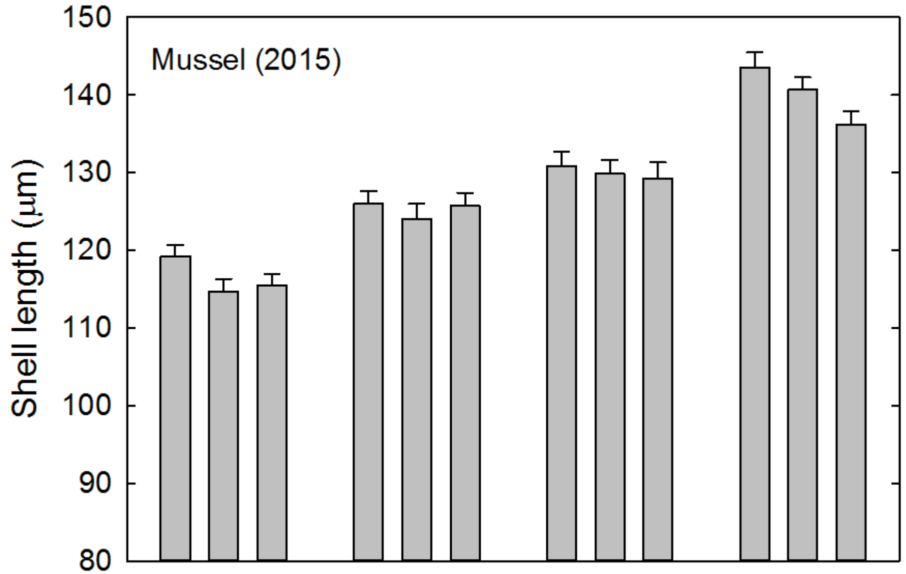
WORLD & NATION

Lime Treatment a Stunning Cure for Sweden's Atran River, Sick From Acid Rain

By HARALD MOLLERSTROM

Dec. 6, 1987 12 AM PT

Alkalinity Enhancement improves shellfish yields



Increasing Alkalinity

Bennet-Smith, Lindell, and McCorkle, unpub.

Buffering System for Shellfish Hatcheries

Delivering a buffering solution into a water storage tank using a pH controller and pump

- Buffering system using inexpensive meters and controllers to increase and maintain pH and alkalinity levels

Water storage tank used to fill larval rearing systems

pH meter/controller and pump with long cords to reach other tanks

55-gal polypropylene tank with saturated solution of soda ash (98 lbs)

- A meter measures pH of tank water, adds buffer (soda ash) to achieve optimal pH via an injection pump
- A controller calculates the required injection rate and activates the system

ebb carbon

VESTA

VYCARB

CAPTURE6

PLANETARY

Equatic

BANYU CARBON

CarbonRun

captura

SeaO2

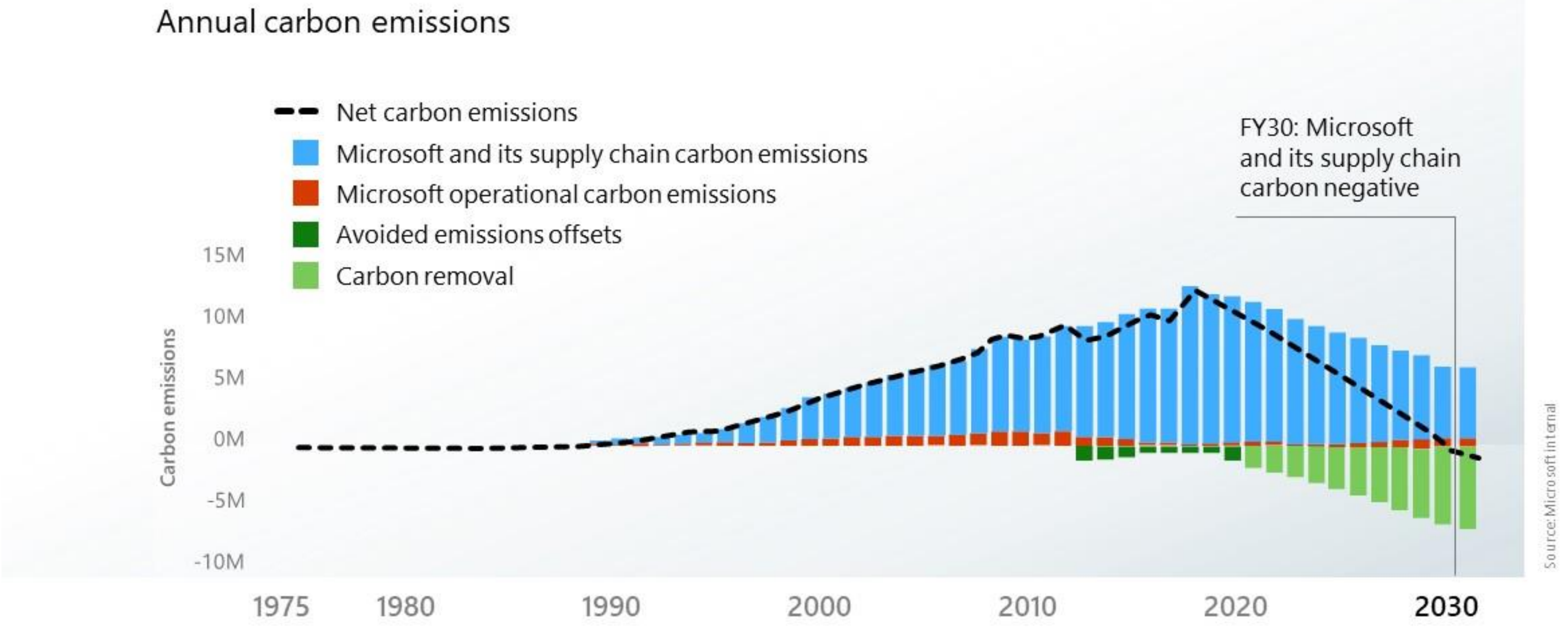
Contracted by Microsoft for **350,000 tonnes** removal via NaOH by 2035

100 tonnes per year CO_2 removal from the ocean and high-pH discharge

300+ tonnes magnesium hydroxide discharged in Halifax harbor and in the Chesapeake. **Carbon credits officially issued**

9,000 tonnes olivine sand added to N.C. sediments ~300m water depth

Microsoft's pathway to carbon negative by 2030



We are an interdisciplinary team of 20+ scientists, engineers, and communicators who are committed to a transparent, rigorous, scientific evaluation of ocean alkalinity enhancement.

We are not a company selling CO_2 credits and we are not participating in the carbon market.

This research project is carefully designed to answer key questions about the effectiveness and environmental impacts of OAE.

This research project is not a pathway to, or an endorsement of, deploying alkalinity enhancement, or for the use of sodium hydroxide as an alkalinity source for other OAE projects.

What are the goals of mCDR field research?

- Evaluating real-world efficacy and durability of carbon removal
  - Develop Monitoring, Reporting, and Verification (MRV) protocols using data and models
- Assessing safety and environmental impacts
  - Develop Environmental MRV (eMRV) protocols
  - Help guide regulations
- Testing CDR technologies
  - Identify “showstoppers”
  - Continue to test promising approaches
- Educating and gathering public opinion
  - Build literacy and confidence
  - How do communities view and interact with mCDR research?

The importance of OAE research is internationally recognized

NATIONAL MARINE CARBON DIOXIDE REMOVAL RESEARCH STRATEGY

A Report by the
FAST TRACK ACTION COMMITTEE on
MARINE CARBON DIOXIDE REMOVAL

of the
SUBCOMMITTEE ON OCEAN SCIENCE AND TECHNOLOGY
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

Goals for engagement:

- Public education about mCDR
- Dispel mis- and disinformation about LOC-NESS
- Seek feedback from communities concerned about the project
- Incorporate that feedback where possible

Who have we received feedback from?

- EPA public comment period
  - 40 days, 115 comments
- Official consultation and consistency review
  - USFWS ESA, NOAA ESA, NOAA EFH, MA CZM
- 33 engagement events since May 2024, reach of >1200
  - Policymakers (5), State/Federal Regulators (5), Tribal (3), Commercial Fisheries (10), Recreational Fisheries (3), Public (3), NGO/other (5)
- Local and National Media interviews
  - WSJ, NYT, National Fisherman, Provincetown Independent, MV Times, etc.
- Survey targeting feedback from fishermen on species of concern and location of field trial
  - 26 respondents (fishermen, state/federal, tribal)

What are communities worried about?

- Commercialization and scaling
- Ecosystem impacts, in particular plankton and commercial fish larvae
- Impacts on higher trophic levels
- Overlap with fishing activity

How have we responded?

- Expanded engagement and outreach activities
- Begun higher trophic level experiments (copepods first, next will be larvae)
- Deeper analyses of biological and fishing activity in the region
- Consideration of alternate dispersal locations

What are we doing?

- Studying regional datasets, running a regional ocean model (Baseline data is critical)

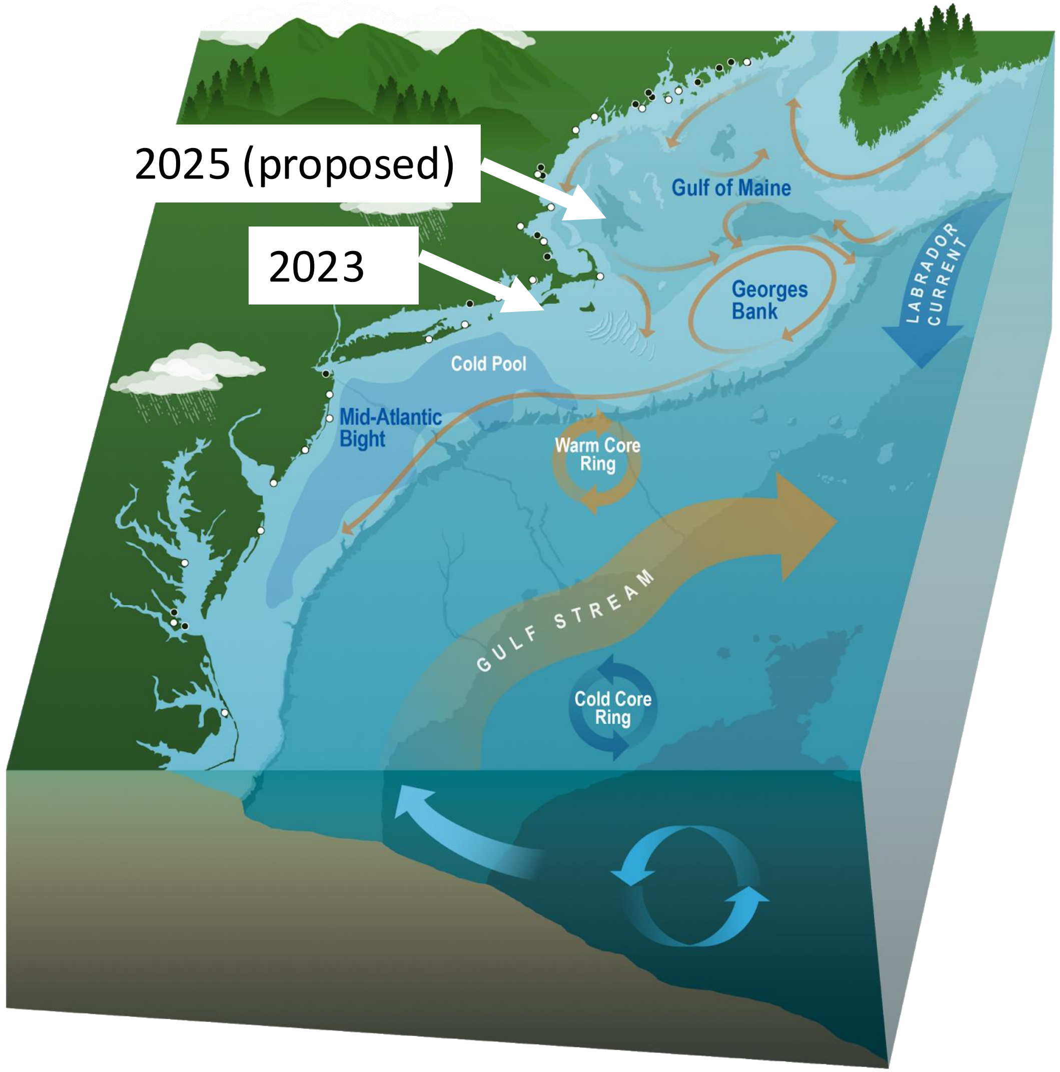
- Conducting biological impact studies in the lab and in shipboard experiments.

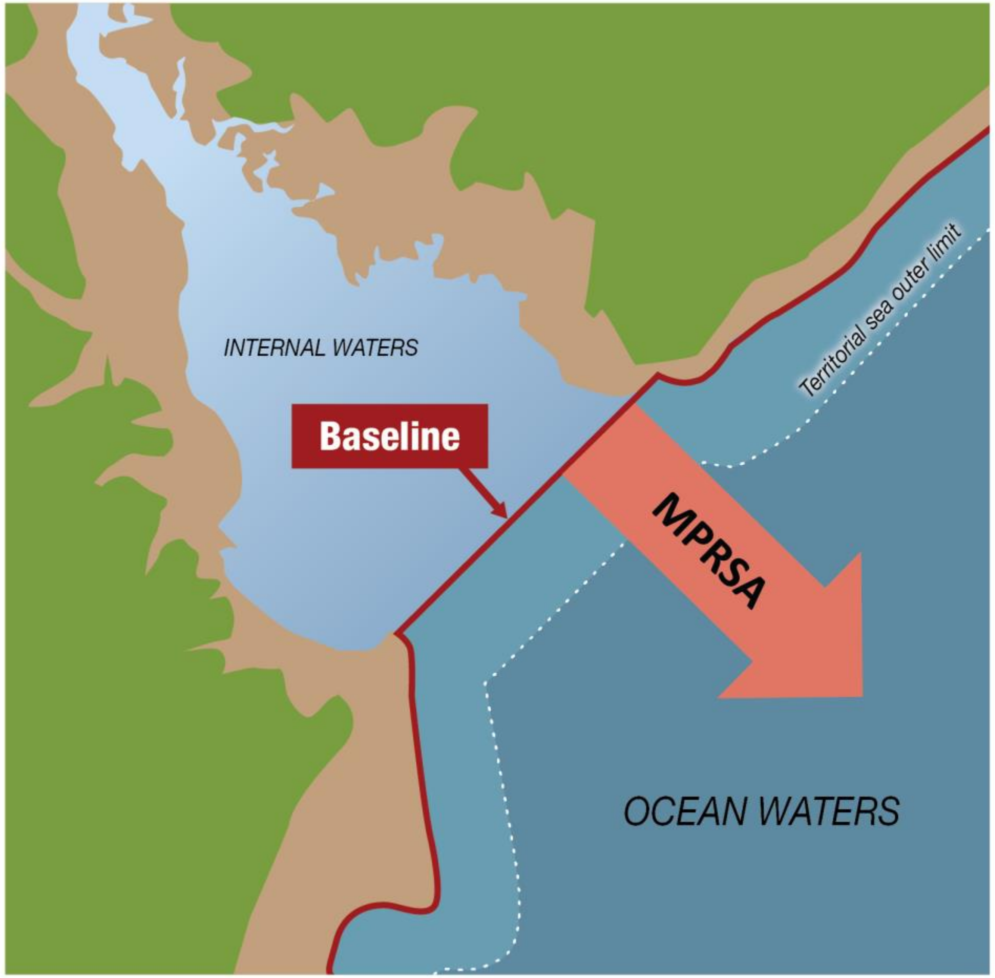
- Dispersal and geochemical tests, ship-wake modeling

- Hosting workshops, listening sessions, seminars, and presentations

- Alkalinity dispersal using 50% NaOH plus water tracer dye with continuous shipboard and remote sensing monitoring.

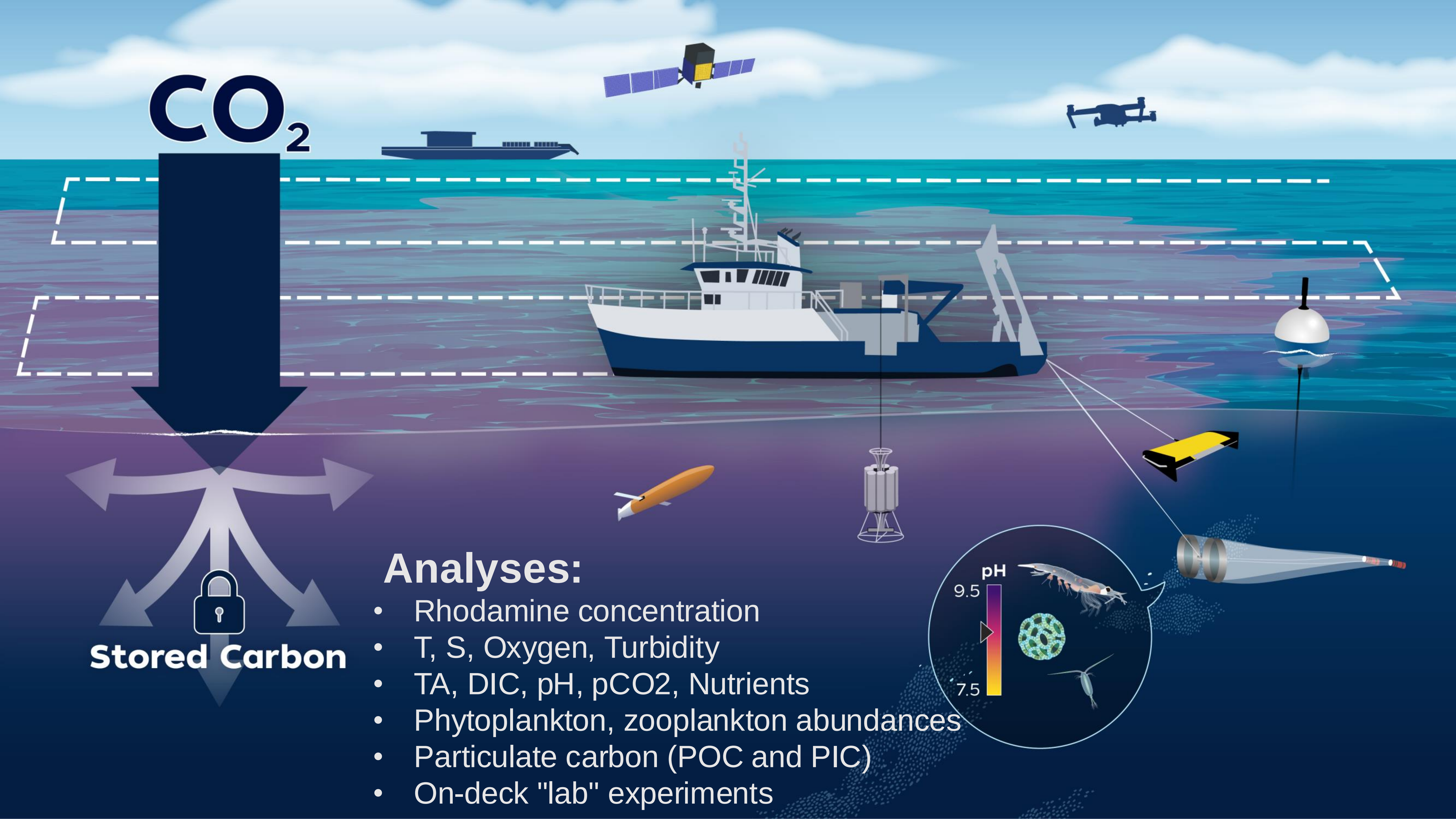
EPA Permitting through MPRSA



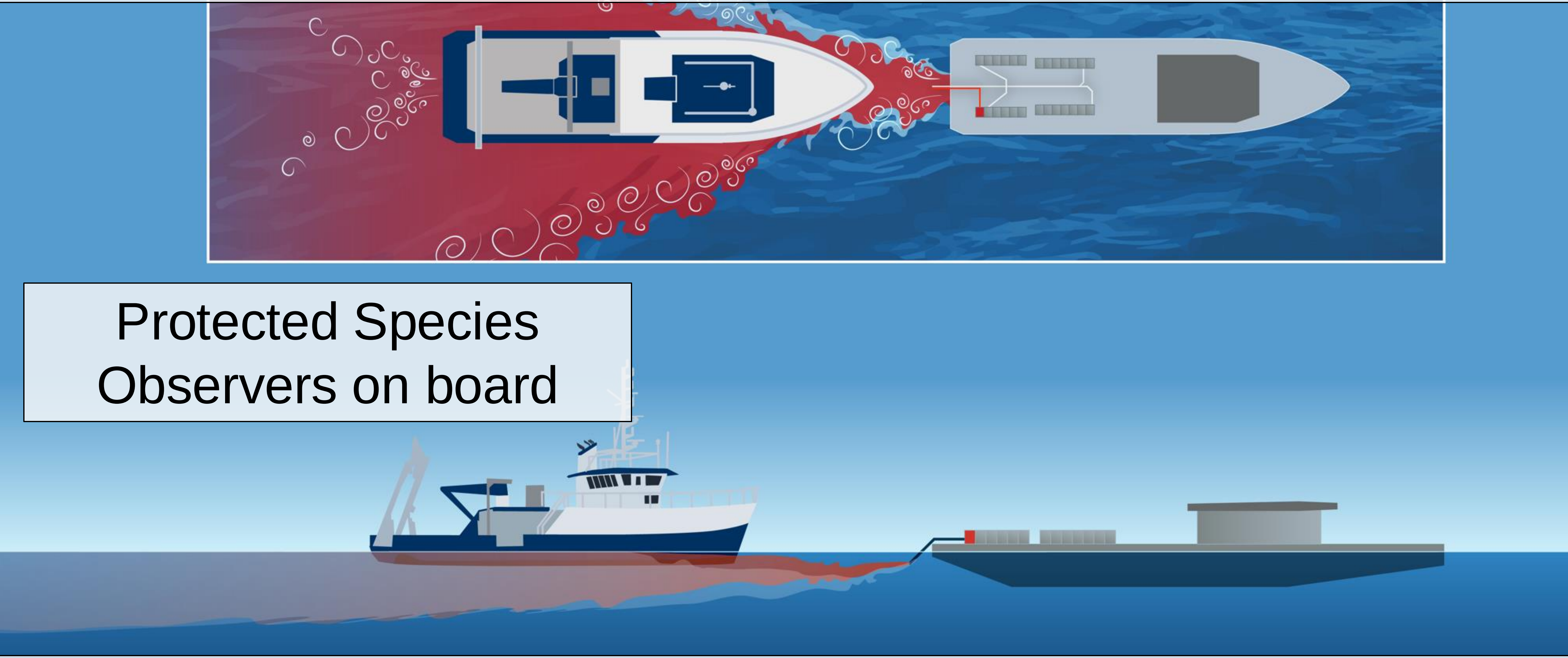


The geographic jurisdiction of the Marine Protection, Research, and Sanctuaries Act (MPRSA) begins at the U.S. baseline from which the territorial sea is measured and extends seaward. The baseline consists of the closing lines across bays, harbors, and river mouths and the mean lower low water line (MLLW) along the coast.

https://www.epa.gov/ocean-dumping/loc-ness-phase-1-and-phase-2-overview-and-project-status


CO_2
Stored Carbon
Analyses:
• Rhodamine concentration
• T, S, Oxygen, Turbidity
• TA, DIC, pH, pCO2, Nutrients
• Phytoplankton, zooplankton abundances
• Particulate carbon (POC and PIC)
• On-deck "lab" experiments
pH
9.5
7.5

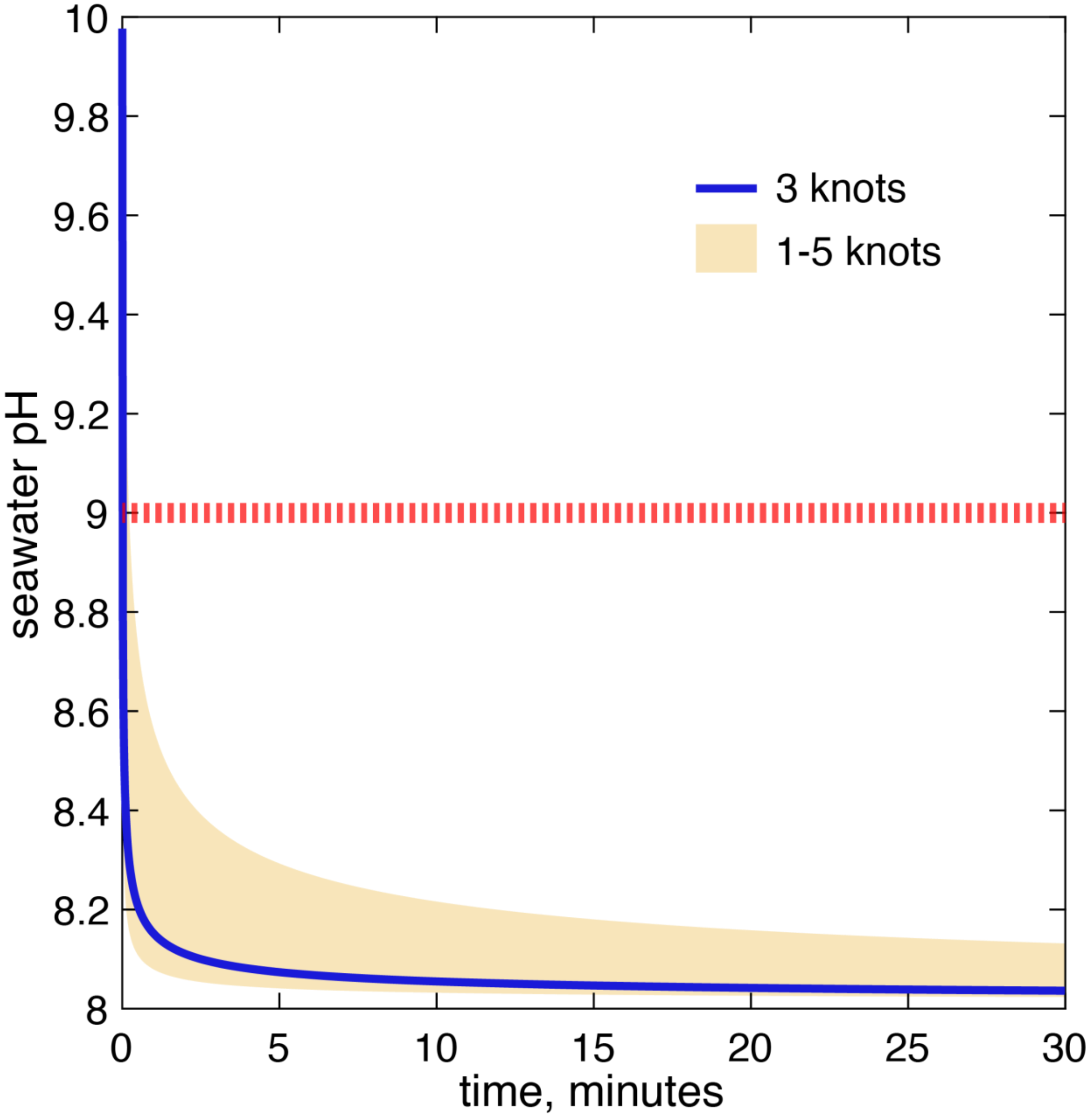
Engineered rapid, intense mixing in wake of discharge vessel



Protected Species Observers on board

Real-time data readouts for rapid decision making

At the end of the dispersal, patch pH is about 8.35



What are our criteria for an experimental site?

1. Stratified waters to hold alkalinity at surface for maximal observation and CO_2 uptake

2. Slow or constrained currents to minimize travel time and loss of signal

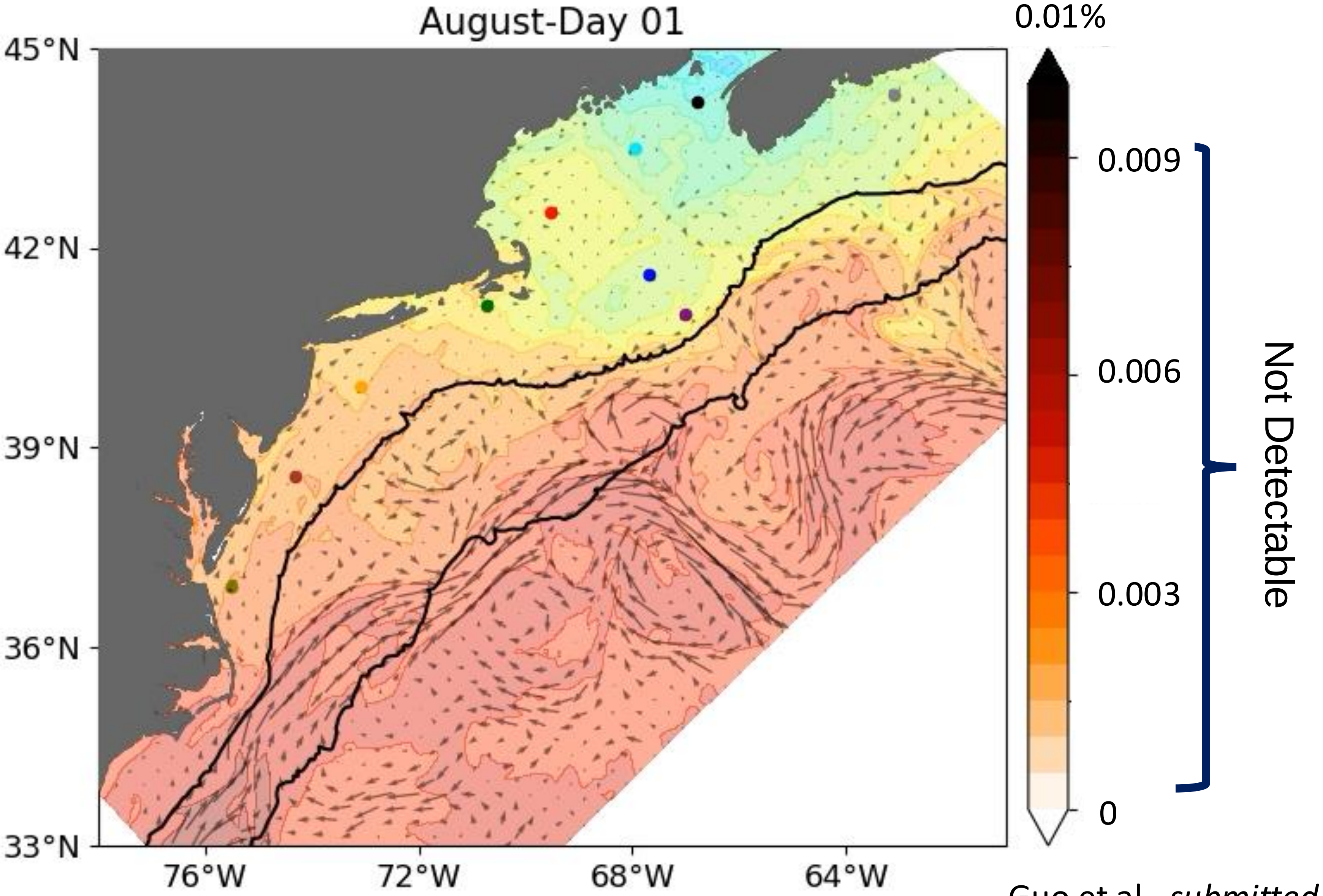
3. Ideal carbonate chemistry for minimizing CO_2 uptake timescale

4. Low biological activity to minimize environmental impact

5. Low overlap with other ongoing ocean uses (fishing, offshore wind, etc.)

Currents and mixing determine our detection limit

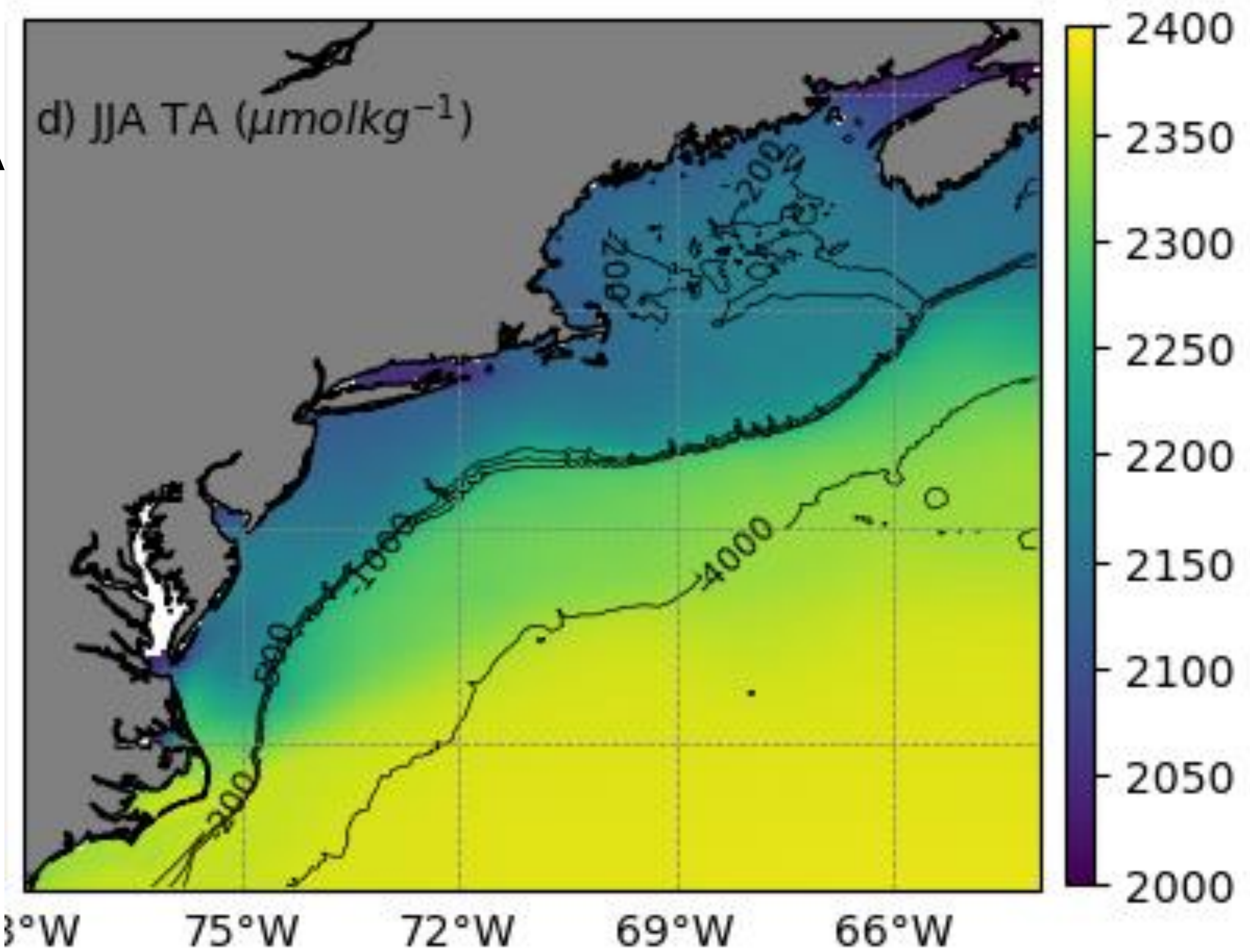
- 10 release locations (colored dots), SST and currents shown in background
- Scale expanded for visibility, only detectable at 0.1%
- Surface expression and spreading is necessary for monitoring effects and CO_2 uptake



Guo et al., *submitted*

Shelf waters are weakly buffered compared to the open ocean

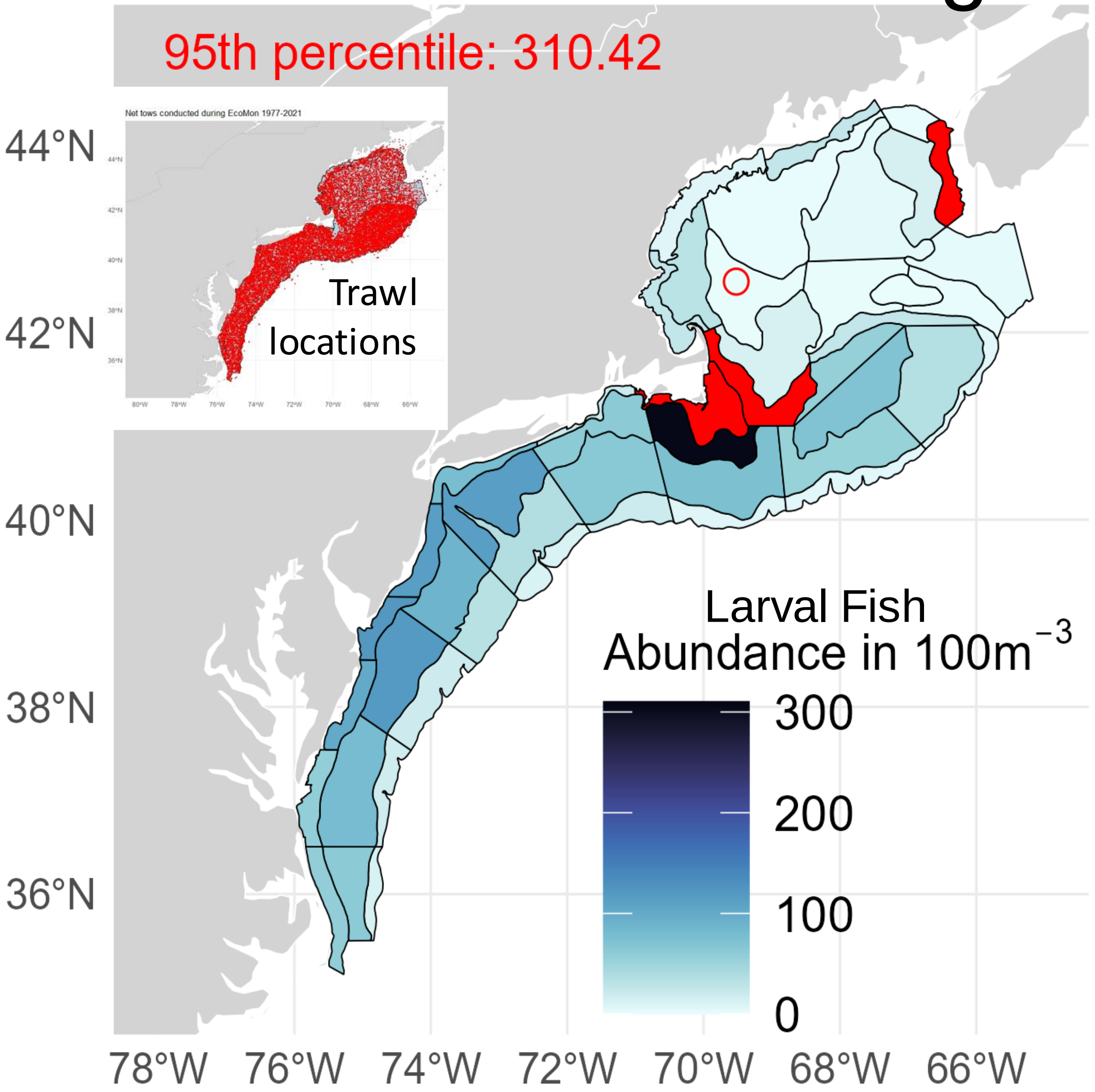
- More sensitive to OA
- Alkalinity enhancement is more effective
- Carbon dioxide uptake is faster



Rheuban et al., *in prep.*

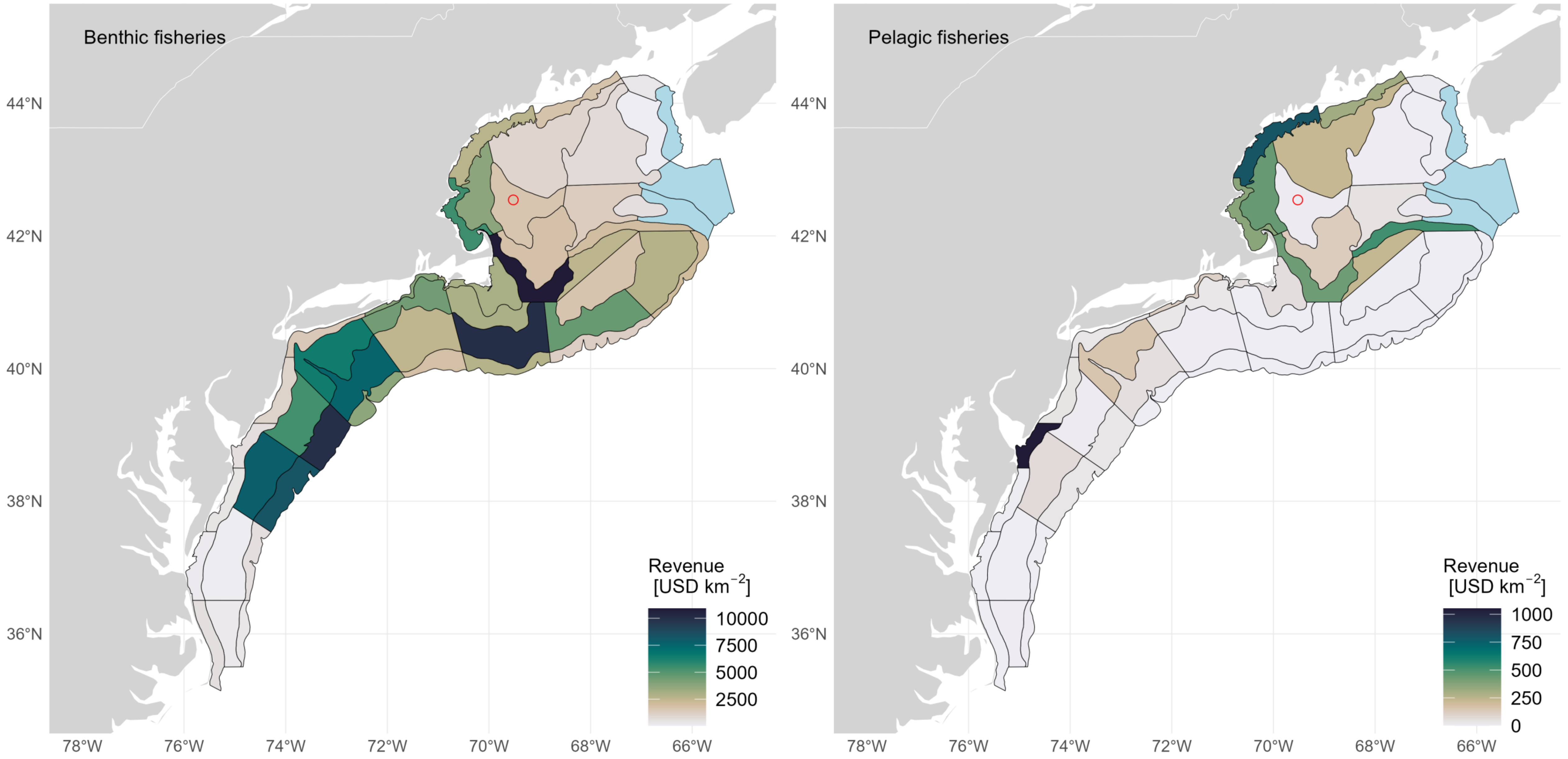
Biological activity in the Wilkinson Basin in August

- Low larval fish abundance (ECOMON)
- Low zooplankton abundance (ECOMON)
- Low Chla (NASA MODIS)
- Low ESA abundance (turtles, whales, birds, MDAT)



Marx et al., *in prep.*

Fishing activity is occurring on the seafloor (depth = ~600ft)



Marx et al., *in prep.*

The Wilkinson Basin satisfies these criteria

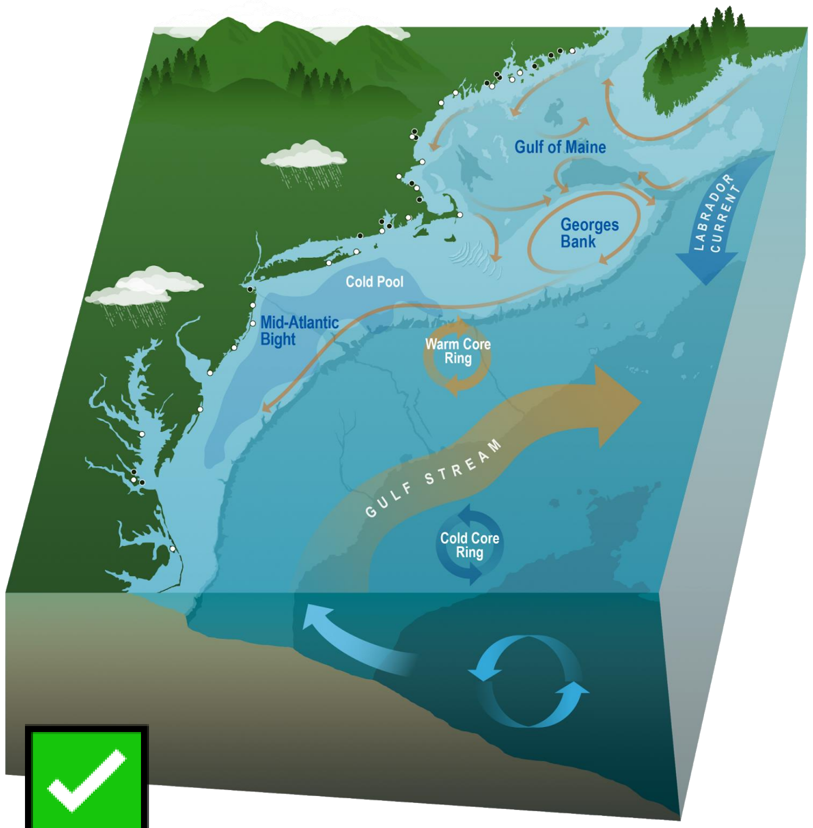
1. Stratified waters to hold alkalinity at surface for maximal observation and CO_2 uptake ✓

2. Slow or constrained currents to minimize travel time and loss of signal ✓

3. Ideal carbonate chemistry for minimizing CO_2 uptake timescale ✓

4. Low biological activity to minimize environmental impact ✓

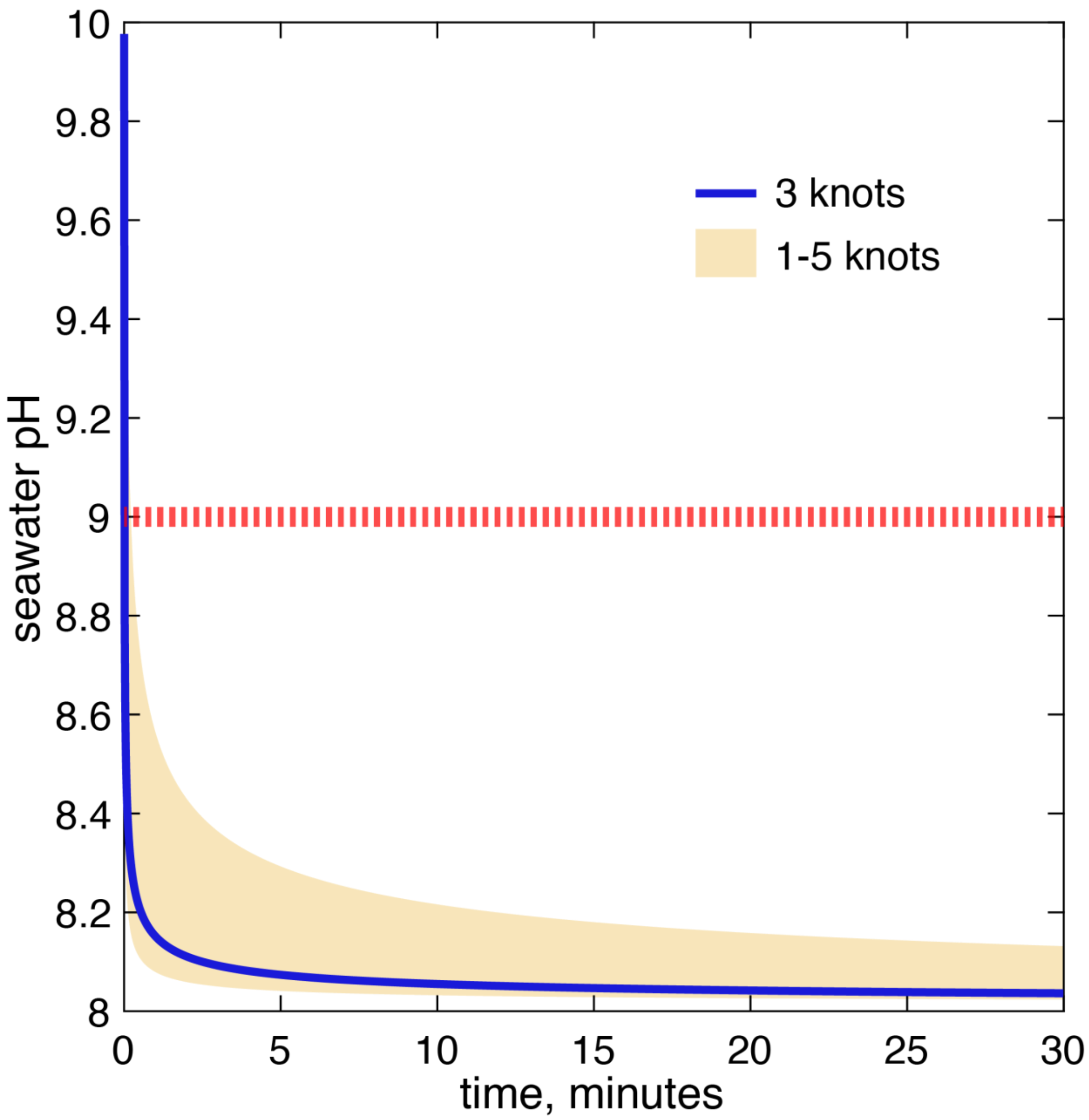
5. Low overlap with other ongoing ocean uses (fishing, offshore wind, etc.) ✓



What about the effects of pH on marine life?

Species studied	pH below which no observed effect at 24h
Diatom growth *Phaeodactylum tricornutum*	8.78
Copepod mortality *Acartia tonsa*	9.06
Oyster embryotoxicity *Crassostrea gigas*	8.88
Fish cell viability *Sparius aurata*	10.01
OAE Dispersal Patch	**8.34**

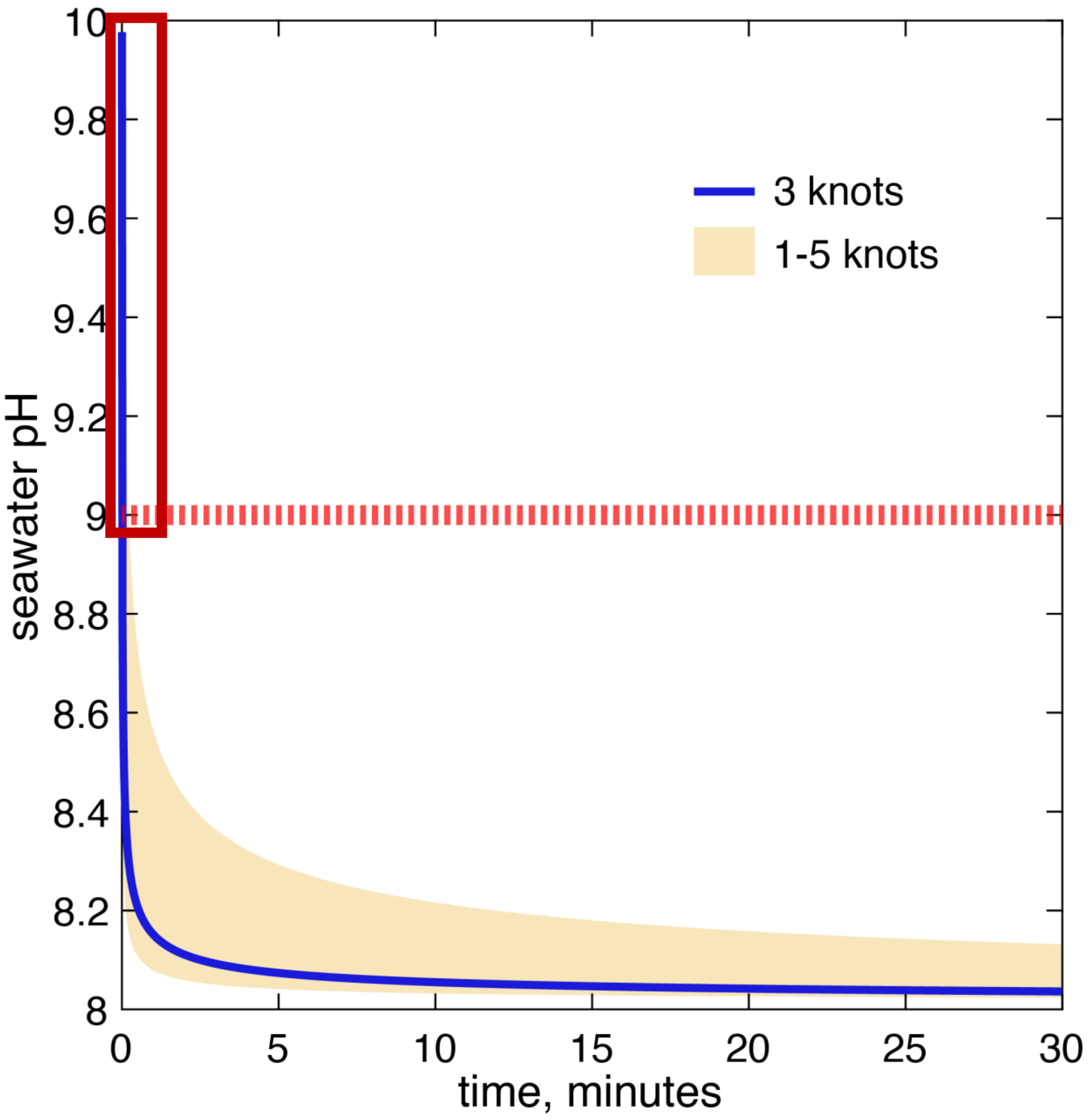
Faucher et al., *in prep*



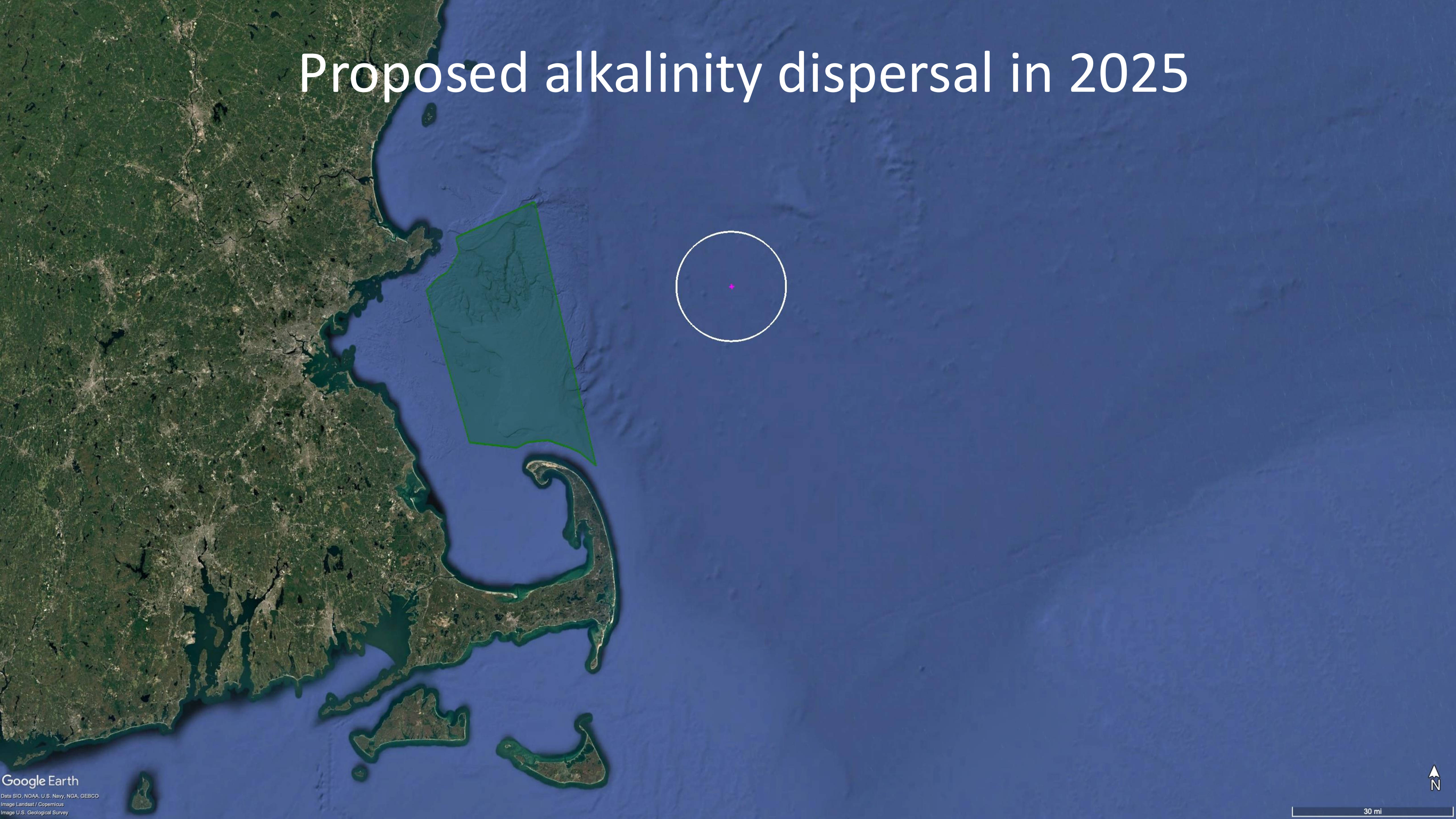
We are testing short duration, high exposure impacts

Proposed experimental design for OAE experiments on the copepod *Calanus finmarchicus*. Four pH/alkalinity treatments will be tested at four exposure durations (D1, D2, D3, D4) to reflect the possible range of exposure times specific to each treatment level during OAE deployments under natural conditions. A 1-minute exposure will be included for each treatment to enable comparisons across treatments. A control test will be conducted in parallel with each treatment exposure to account for any physiological effects arising from the experimental setup.

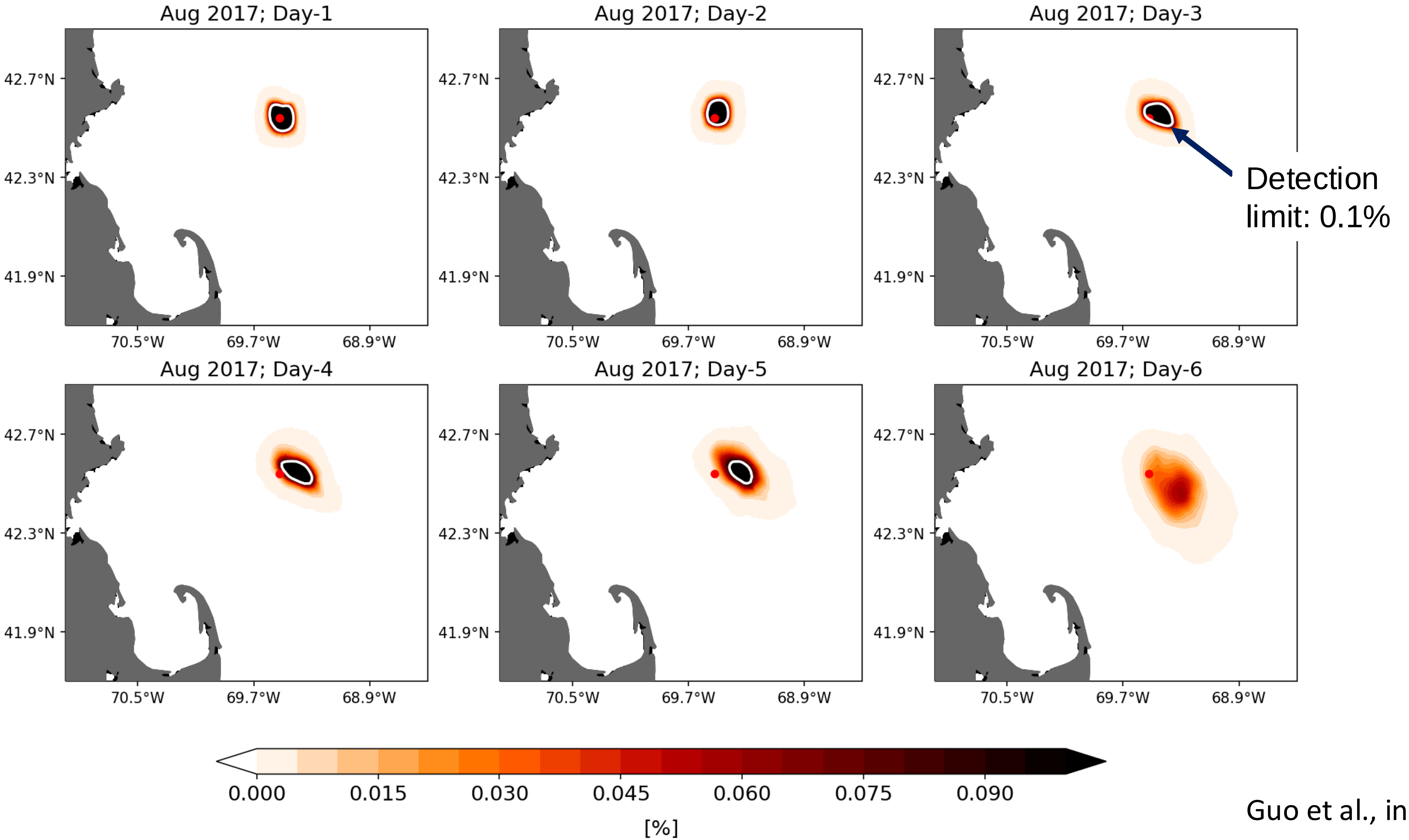
pH	D1 (min)	D2 (min)	D3 (min)	D4 (min)
12	0.02	0.25	0.5	1.0
10	0.5	1.0	2.0	4.0
9	1.0	2.0	4.0	8.0
8.4	1.0	15.0	30.0	60.0
Control (7.95)	---	---	---	---



Proposed alkalinity dispersal in 2025

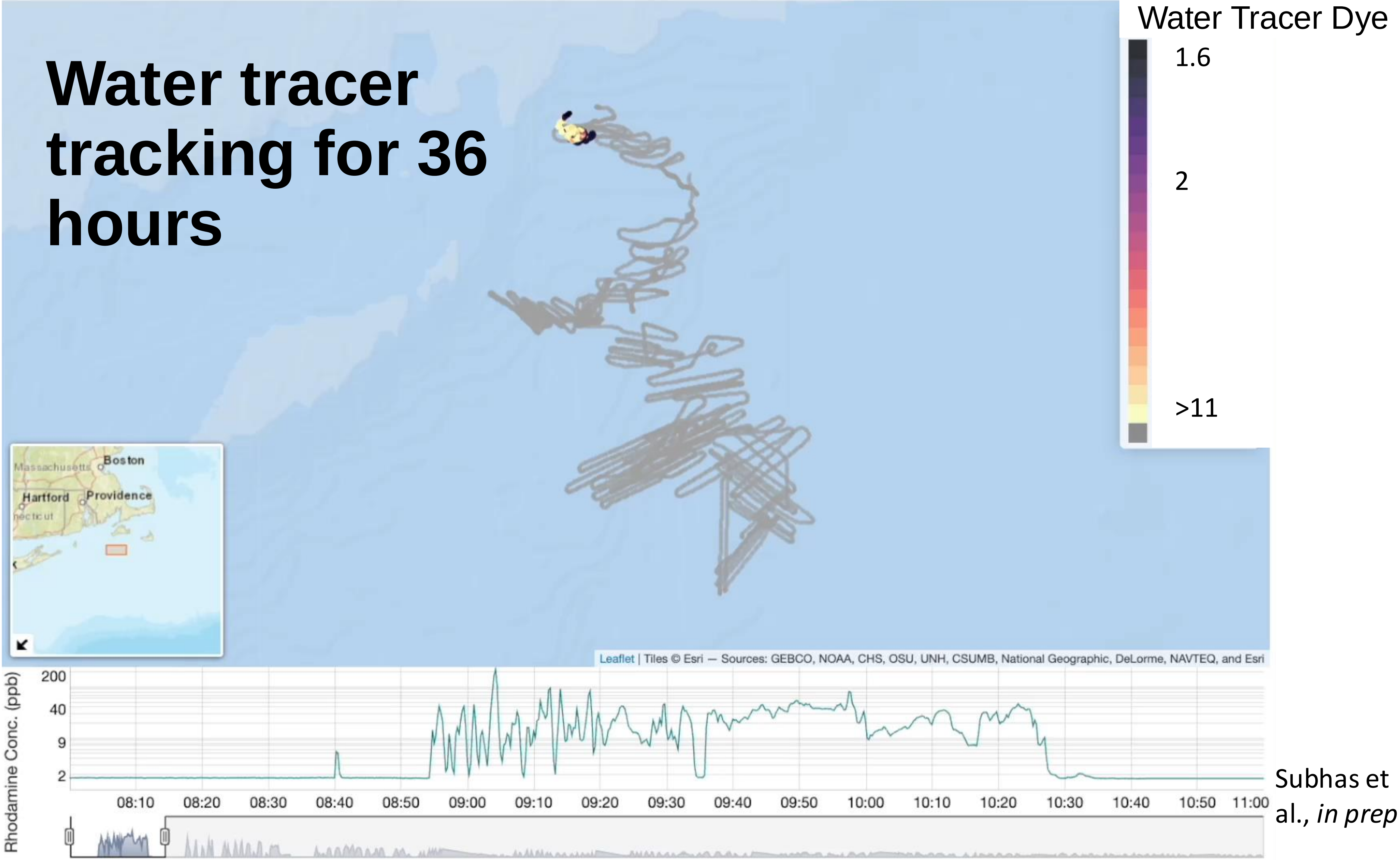


Where will the patch go in the Wilkinson Basin?



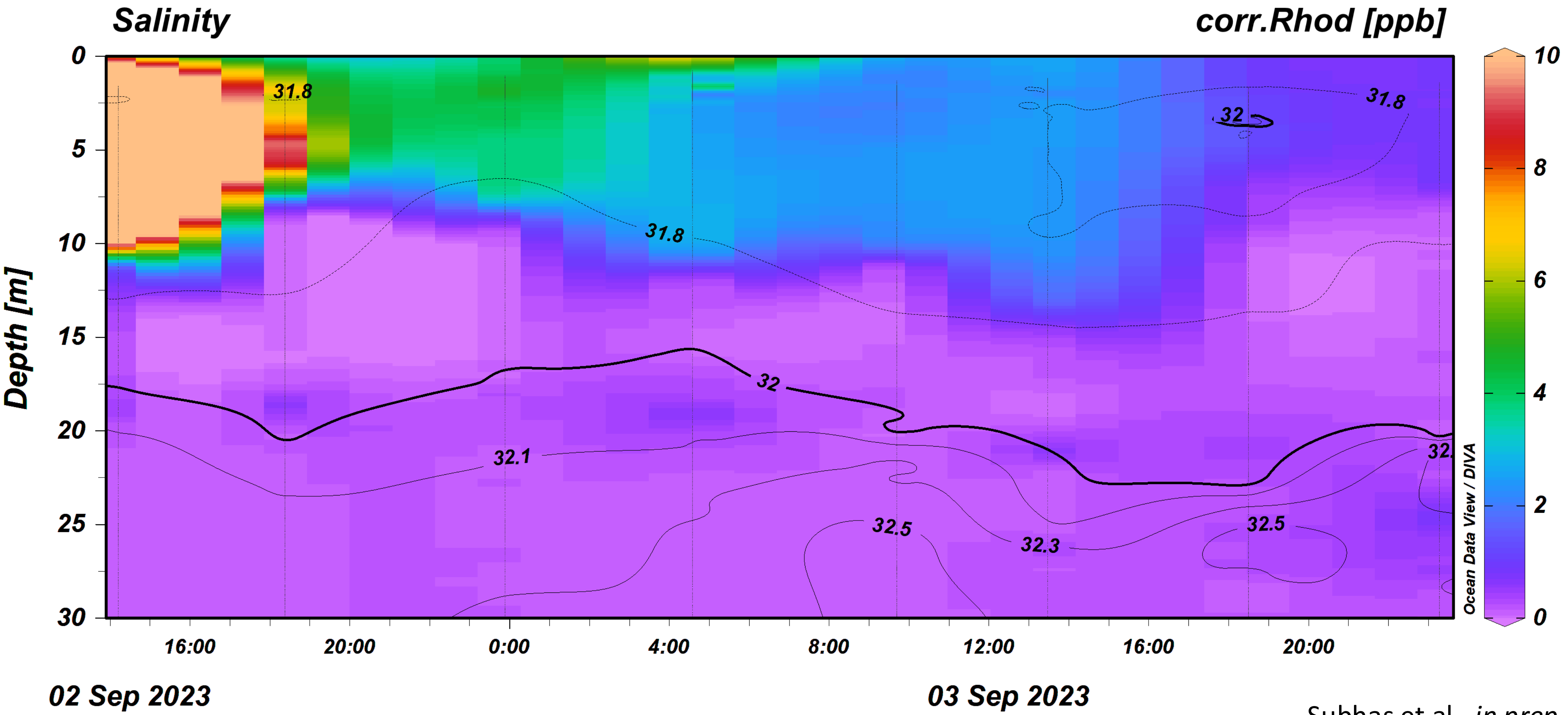
Guo et al., in prep

Water tracer tracking for 36 hours



Subhas et al., *in prep*

Water tracer stays at the surface



Subhas et al., *in prep*

Key Takeaways

Companies are already selling CO_2 credits in the ocean, and research is urgently needed

Pairing in-water experiments with models and data analysis is critical to answering unknown questions

Through careful site selection, in-water MRV of mCDR does appear to be possible

More study of biological/environmental impacts is needed

Communities deserve to know and be informed about mCDR

theloc-nessproject

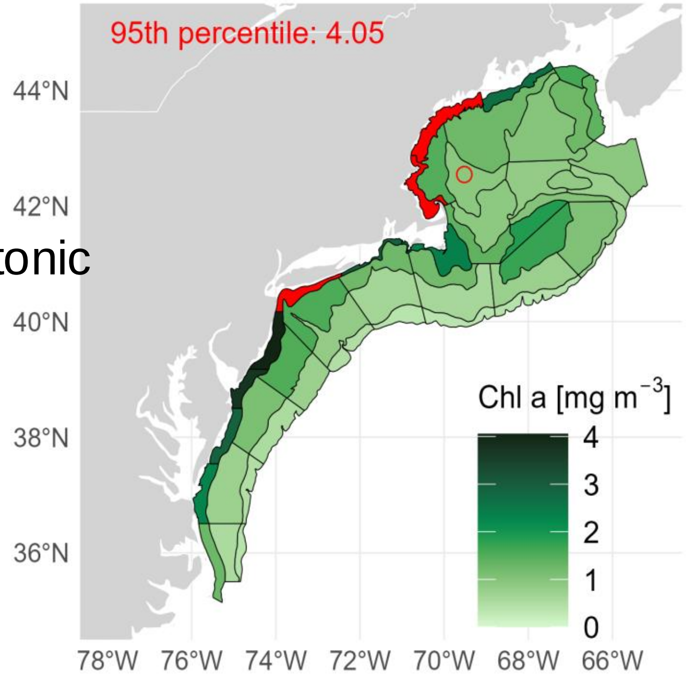
- 12/16: 3-6pm Workshop at Gloucester City Hall
- 1/9: NROC Tribal Webinar, time and link TBD, email us if interested.
- 1/29: Tabling at Portsmouth, NH NEFC Meeting
- 1/31: Presentation and tabling at Massachusetts Lobstermen's Association Meeting

Link to workshop sign up sheet!

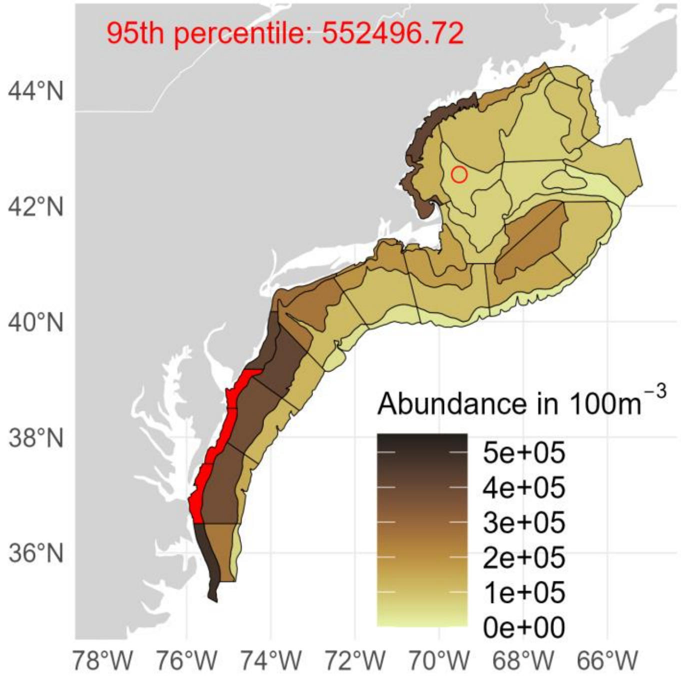
NOAA · Carbon to Sea Initiative · climateworks FOUNDATION · ICONIQ · WOODS HOLE OCEANOGRAPHIC INSTITUTION

Extra Slides Below

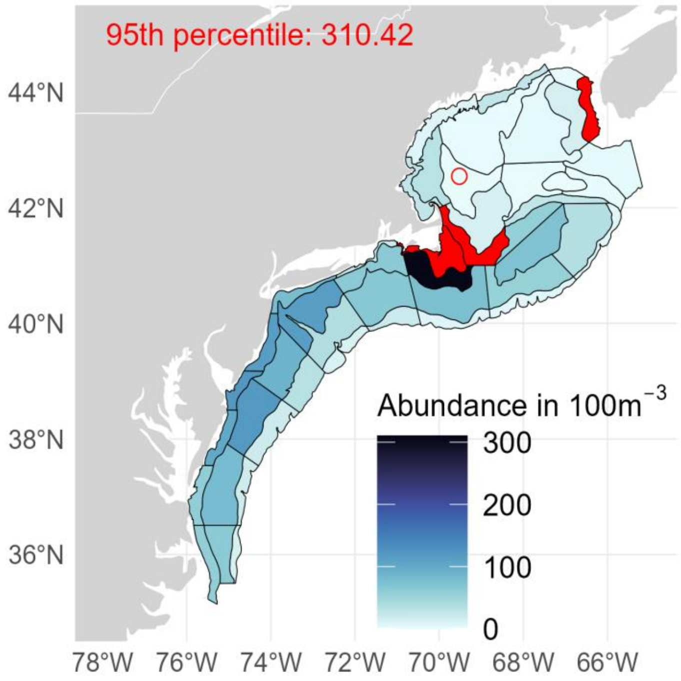
Chl *a* – Phytoplanktonic biomass



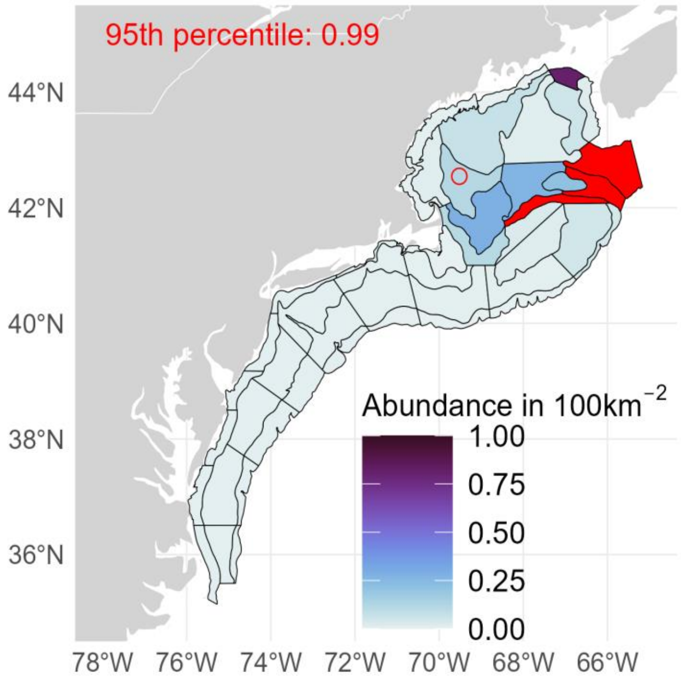
Zooplankton abundance



Fish larvae abundance

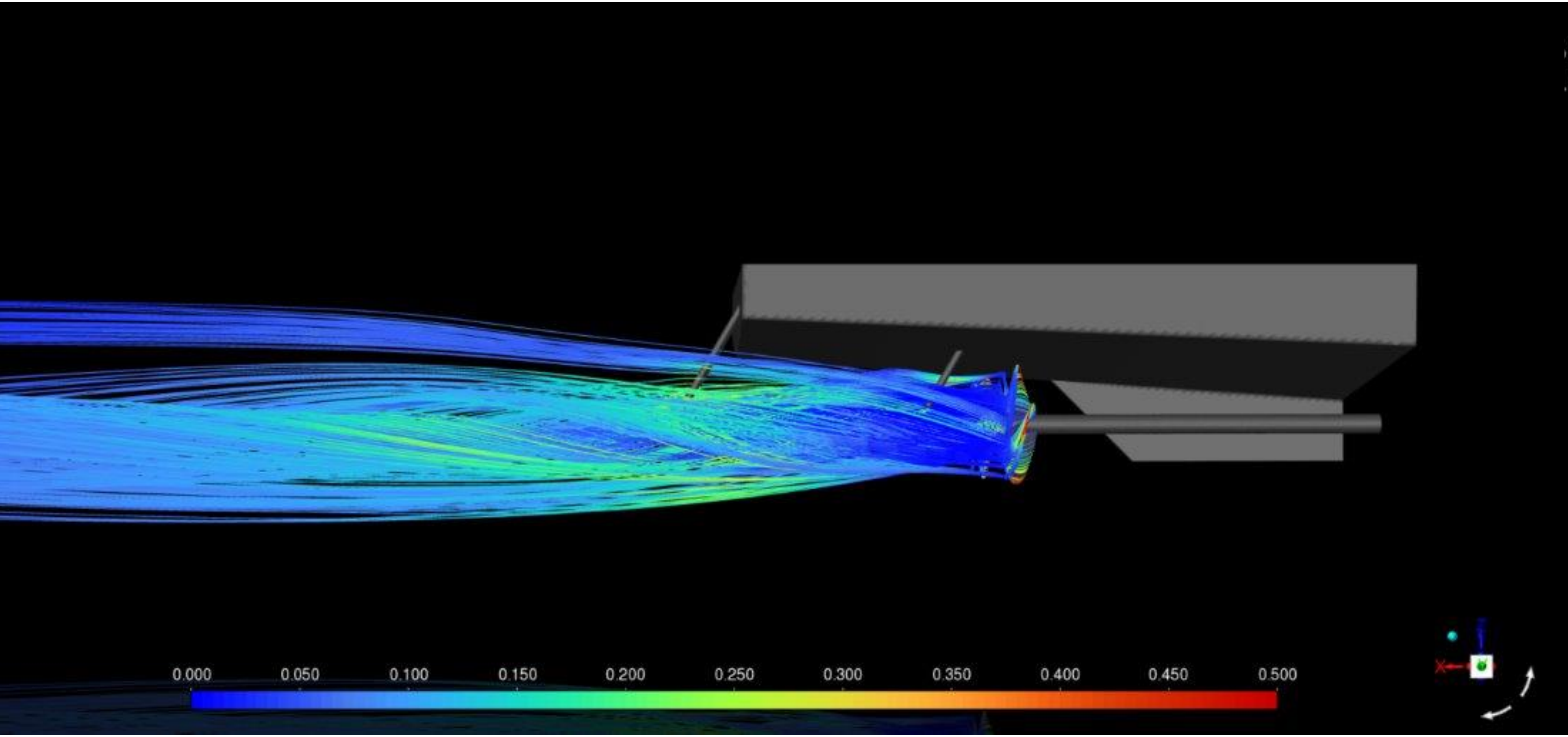


North Atlantic Right Whale abundance



Marx et al., *in prep.*

Dispersal validation: Prop wash modeling and lab tests



Patch extent is limited in size and in time

Model result at the 0.1% detection limit for 6 days after release (pink circles)

Overlain on VMS Multispecies vessel data, 2014-2019