



Phytoremediation potential of kelp and eelgrass

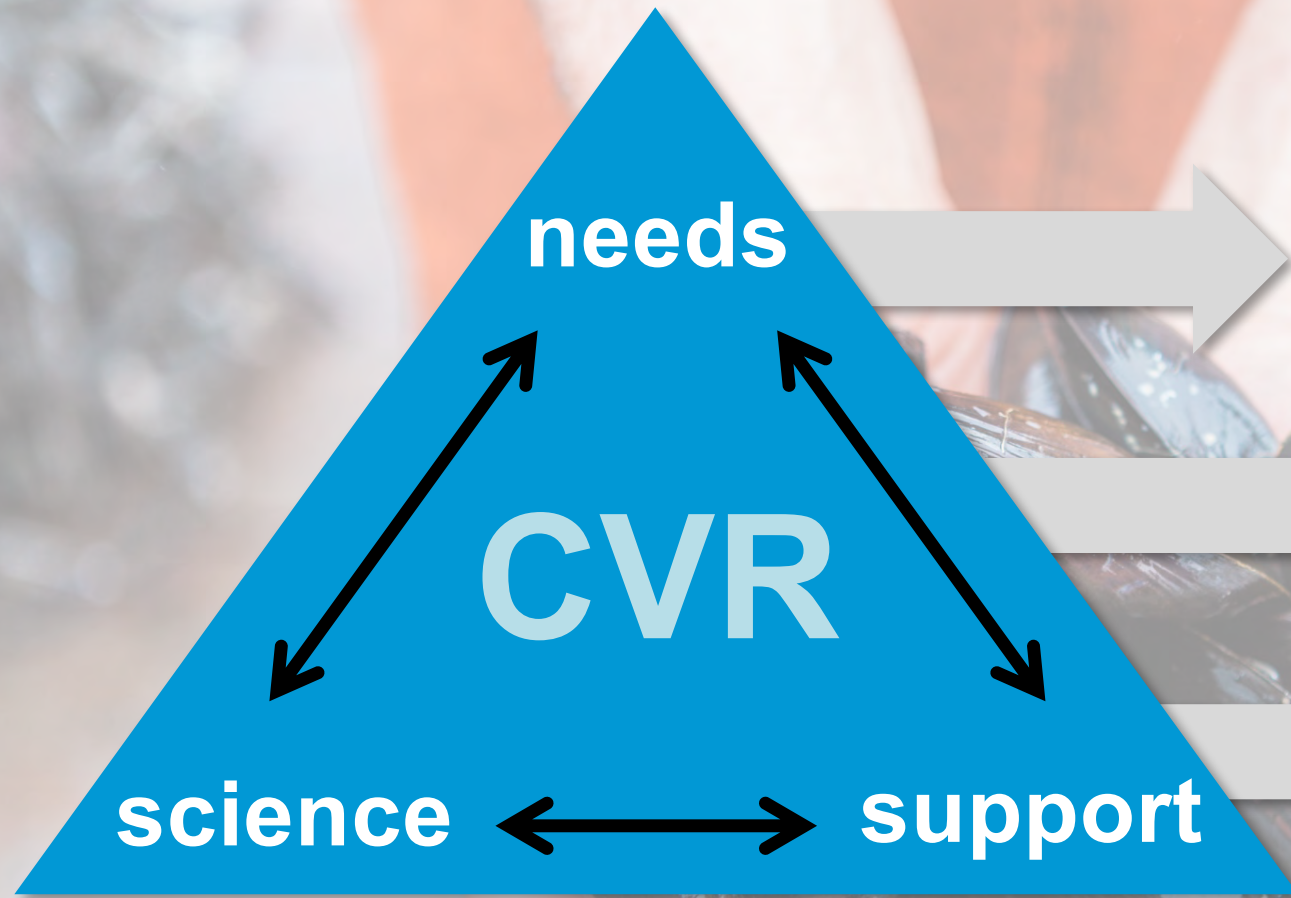
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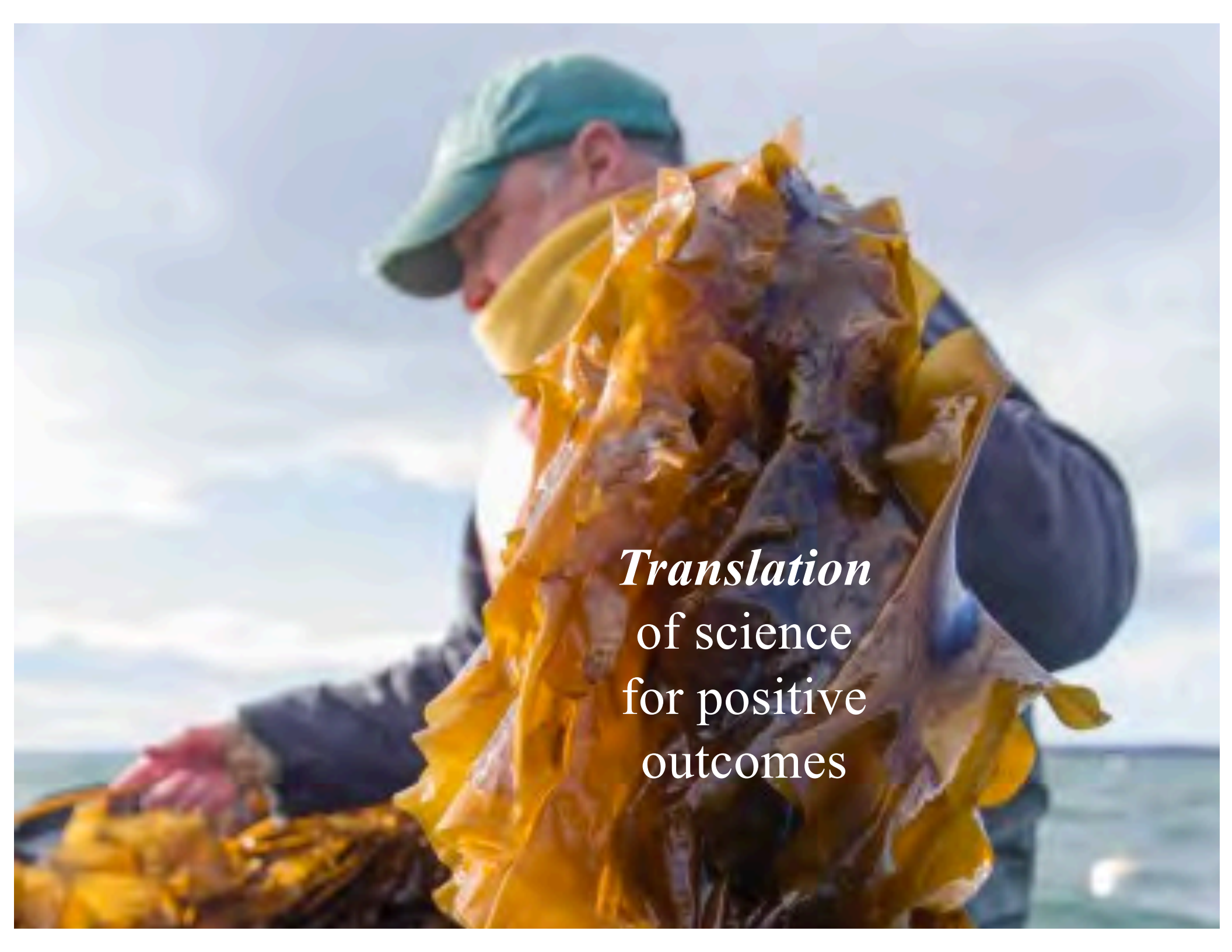
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**science-based
solutions**

**informed
policy**

**public
awareness**

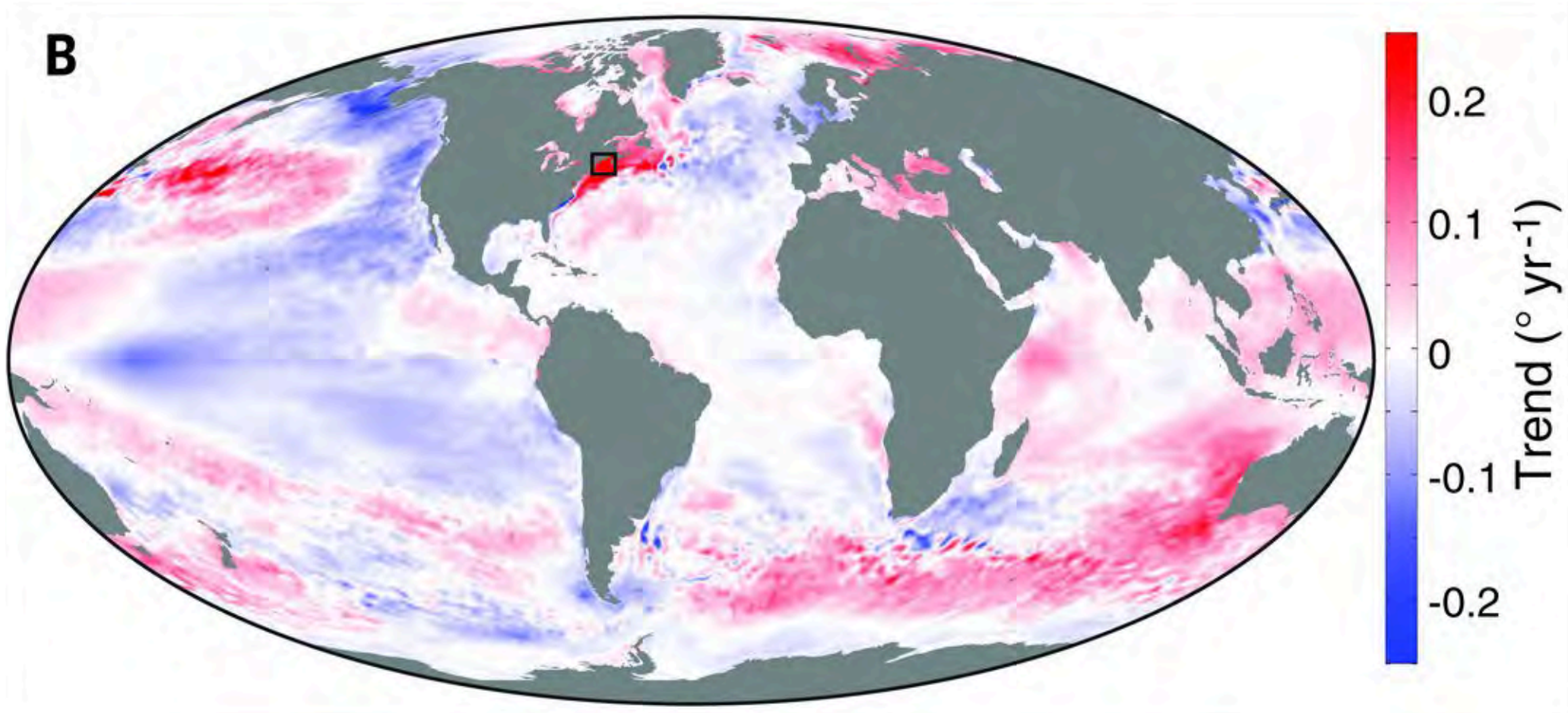


Translation
of science
for positive
outcomes

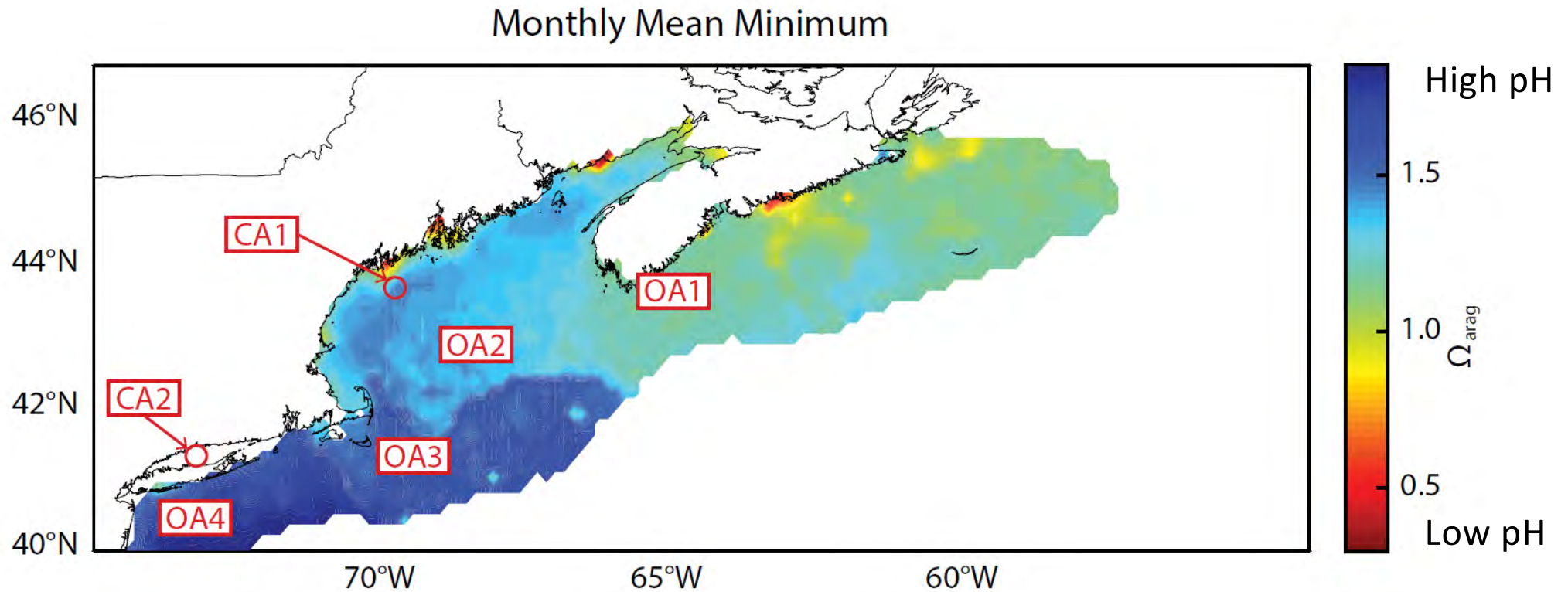


Aquaculture the future of the working waterfront in the Gulf of Maine?

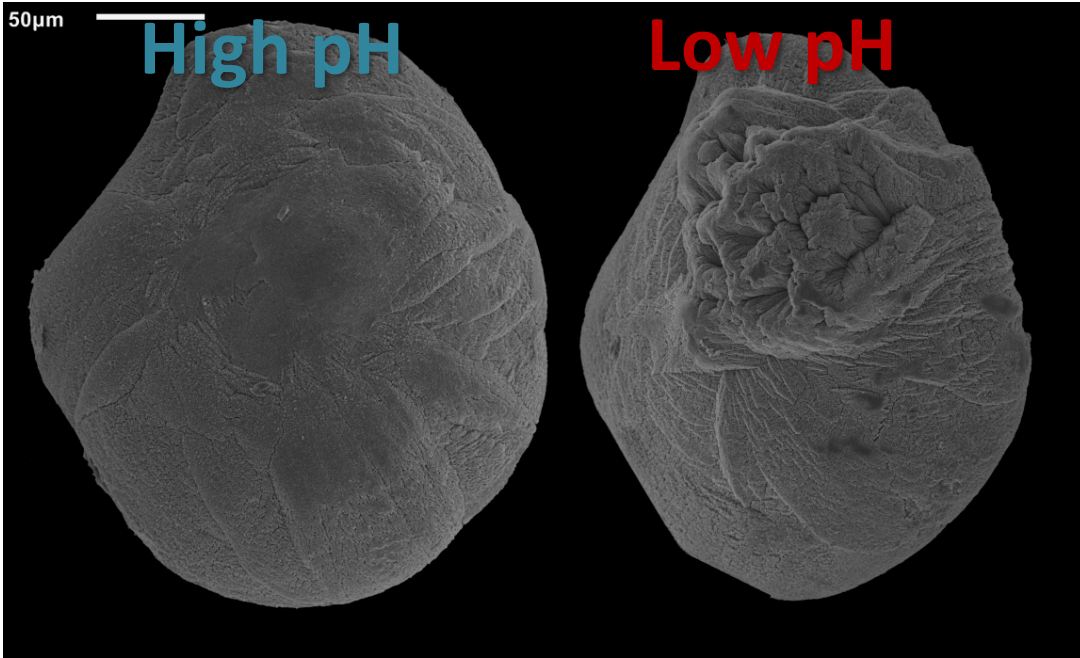
Ocean warming in the Gulf of Maine ~5 times more rapid than almost anywhere else



The Maine coastline is prone to acidification







As are mussels...



Shellfish disease virulence under OA?

The Pathogen: *Vibrio tubiashii* (Vt)



- Gram-negative, facultative anaerobe
- Causative agent of vibriosis in early stage shellfish
- Pathogenic to a variety of marine invertebrates, including Pacific oyster and blue mussel
- Higher infection rate with long-term exposure to acidity



Will mussels be able to 'hold on' in a more acidic ocean?



Where have Maine's mussels gone?

Scientists and environmentalists are working to find out why the once plentiful 'people's seafood' has practically vanished from our rocky shores.

BY MARY POLS STAFF WRITER

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Mussel harvester Phil Gray approaches a South Harpswell shoreline covered with the mollusks in 2009. Wild mussels once covered over 50 percent of Maine's intertidal zone, researchers say, but they are now much harder to find. *Staff file photo by Gordon Chibroski*



MEET

Ellen Griswold wins yearlong fellowship with Maine Farmland Trust



MEET

Alexandria Brasili is an aquaculture teacher with a goal



MAINE GARDENER

Despite drought, peppers turned very red, carrots came on strong



MAINE GARDENER

The state's school gardens survive the drought



Predators



Acid mud



Clam cancer

Charting Maine's soft-shell clam harvest

Over the past four decades, Maine's soft-shell clam harvest has dropped dramatically and lately plateaued because of predation, regulatory changes, environmental factors and other challenges to the fishery. A mild winter has raised fears that predatory green crabs will be abundant - and hungry - this summer.



SOURCE: Maine Department of Marine Resources

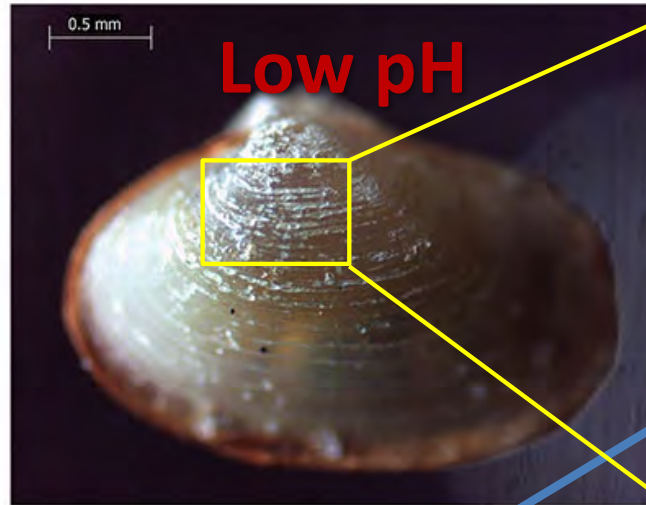
STAFF GRAPHIC | MICHAEL FISHER



...and clams



Clam A



Clam B



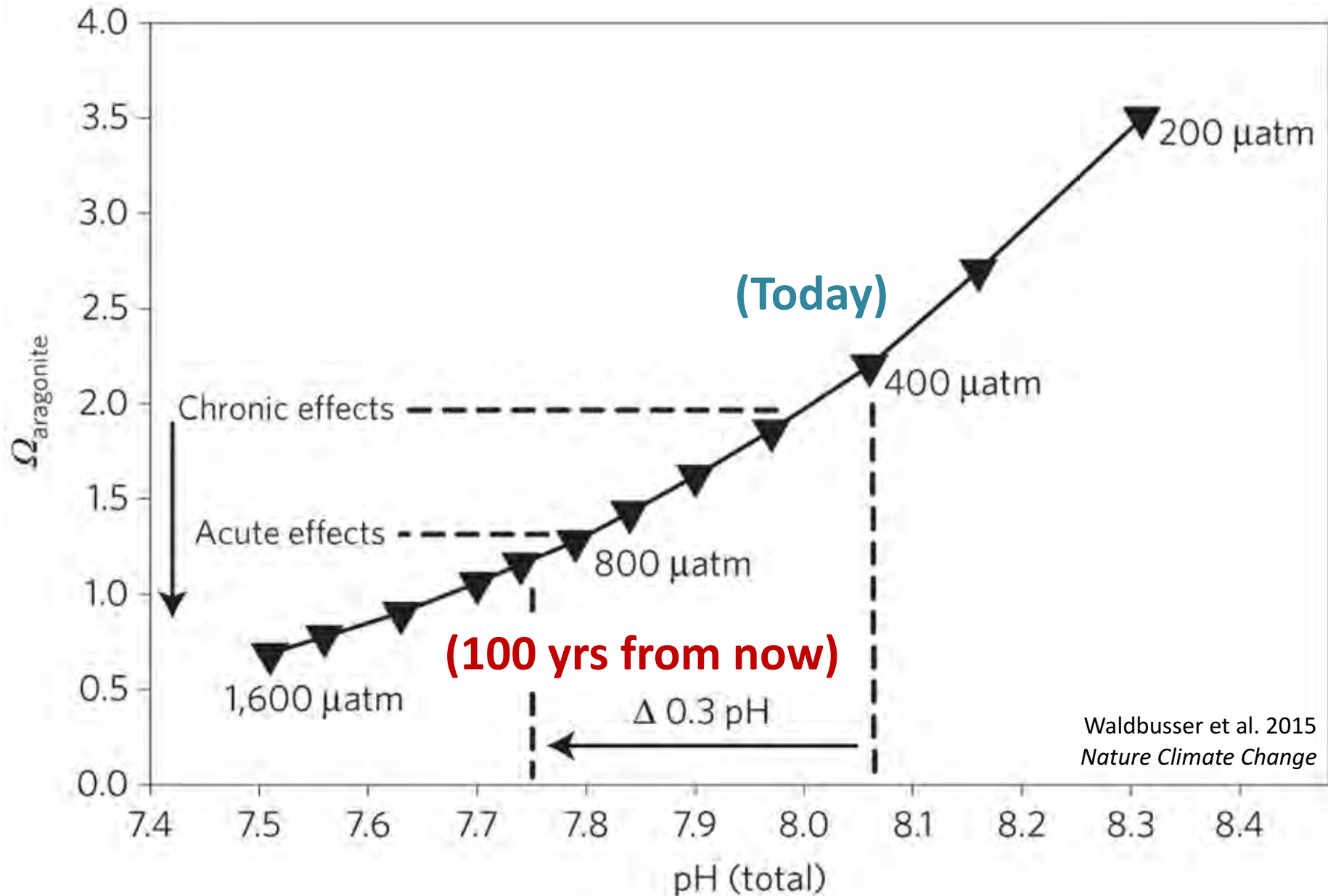
Clam C



Acidified muds are the suspected cause of 'pitting' in baby clam shells



Thresholds in acidity for shellfish





Ocean Forests

An underwater photograph of a kelp forest. The scene is filled with tall, green kelp stalks reaching towards the surface. The water is a clear, deep blue. Several fish are visible: a bright orange fish is prominent in the middle ground, and several purple fish are scattered throughout the lower part of the frame. The overall atmosphere is serene and vibrant.

Edible Sea Vegetables

Seaweed harvest a long-time tradition in the Gulf of Maine

Farmer Loading his Cart with Kelp, Maine, 1882. Emma L. Coleman



“Phytoremediation” as an adaptation strategy

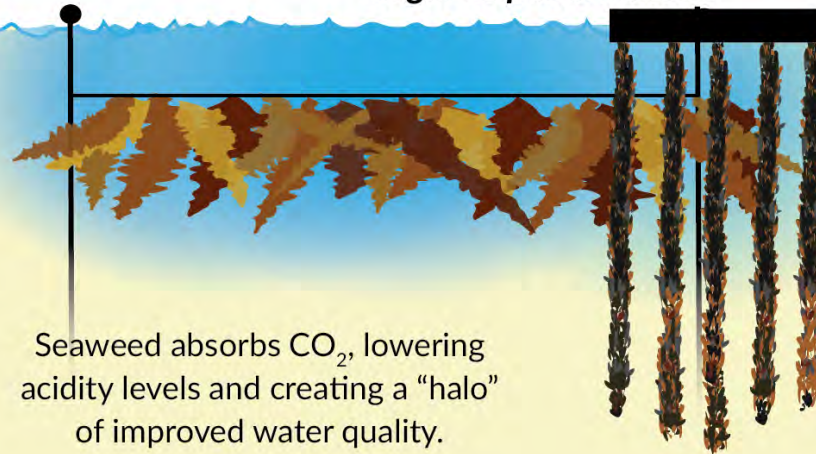
Atmospheric CO₂, nutrient runoff, and more acidic fresh water raise acidity levels in the ocean.



More acidic ocean water is damaging to shell-forming organisms, threatening shellfisheries.



Sugar kelp and mussels



Seaweed absorbs CO₂, lowering acidity levels and creating a “halo” of improved water quality.



Sell seaweed and shellfish for a win-win.

Improved water quality may mean increased shellfish production and higher profits.

IN ADDITION to sugar kelp and mussels (above), two other natural pairings will be studied for potential benefits (at right).

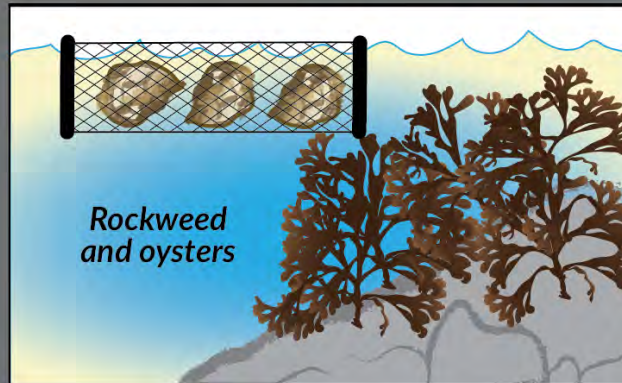
Scale: $\mu\text{atm CO}_2$ in seawater

280

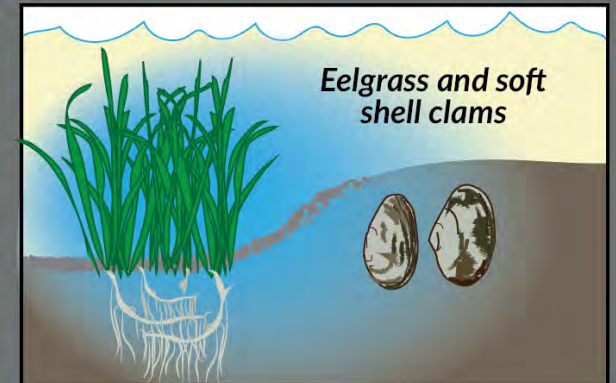
1,100

pre-industrial

year 2100 (est.)



Rockweed and oysters



Eelgrass and soft shell clams

Lab Experiment

(Today)

280 μatm

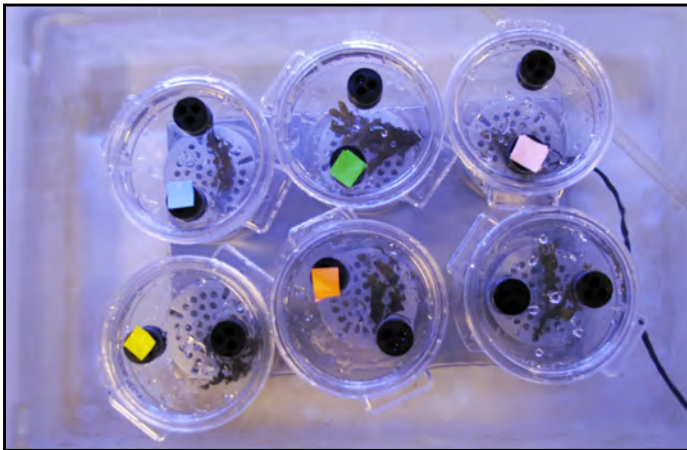
400

520

640

880

(100 yrs from now) 1120



Fucus vesiculosus

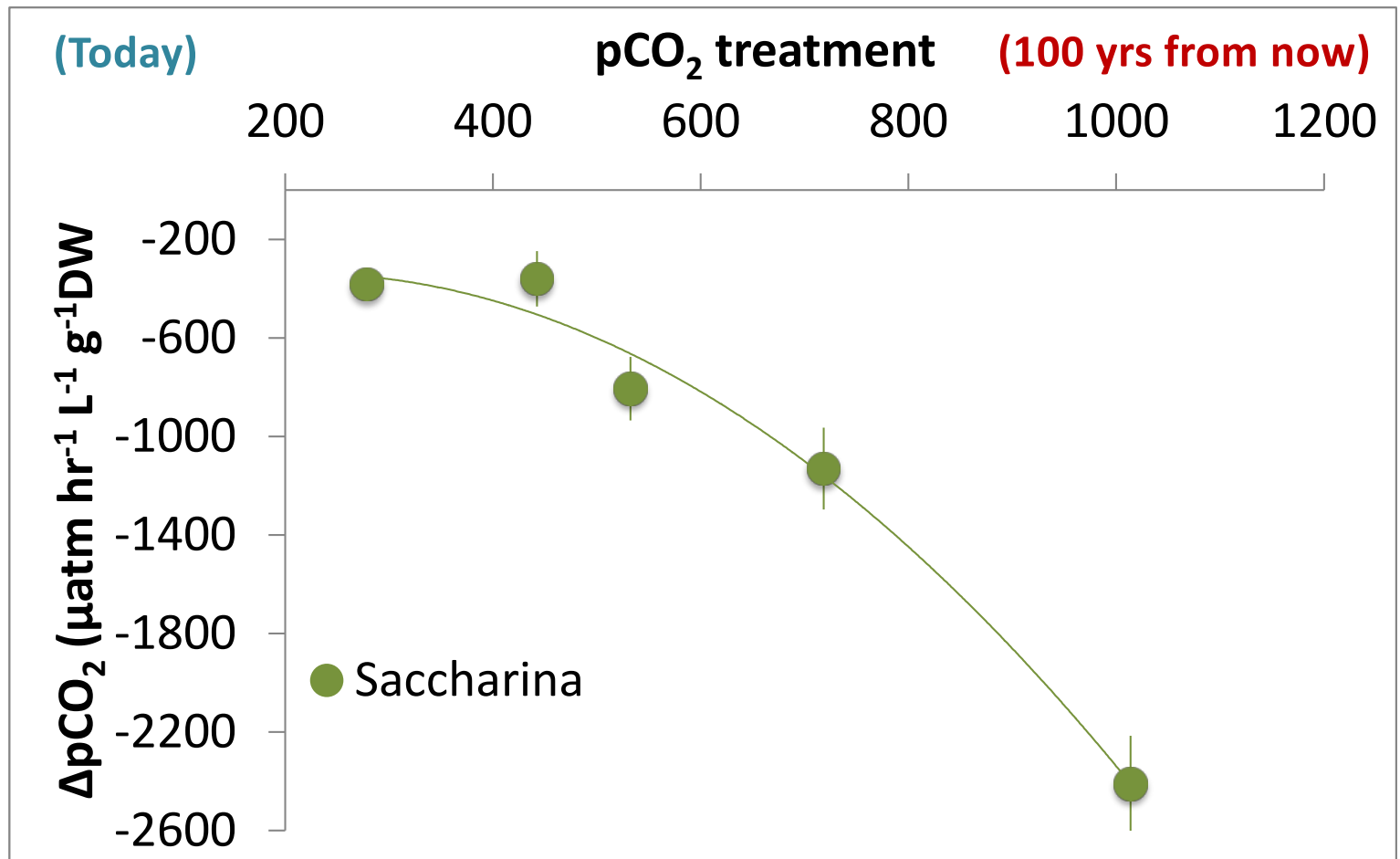
Ulva lactuca

Saccharina latissima

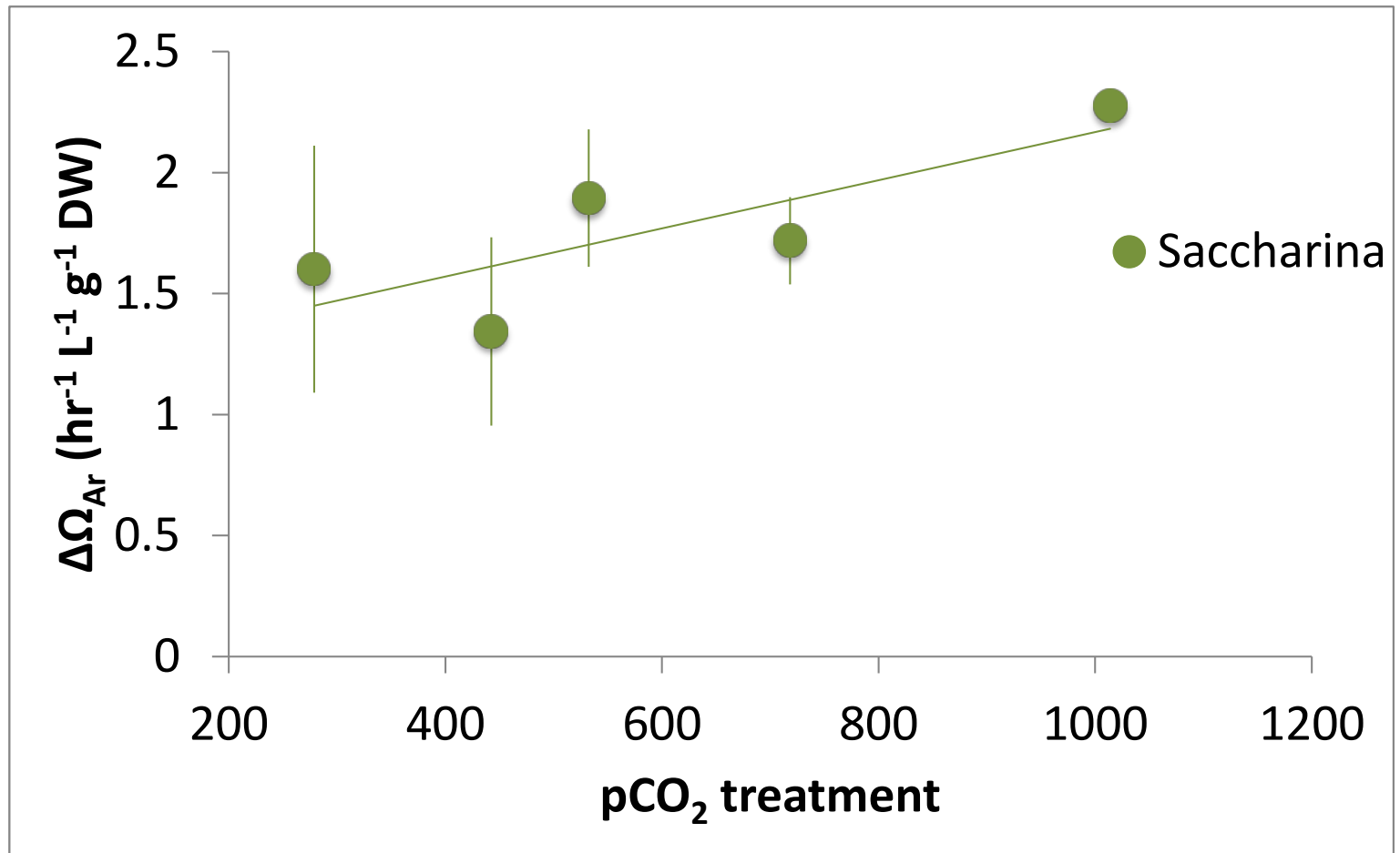
Zostera marina

How much CO_2 does each seaweed species absorb today and in a future, more acidic ocean?

Species-specific phytoremediation potential ($\Delta p\text{CO}_2$)

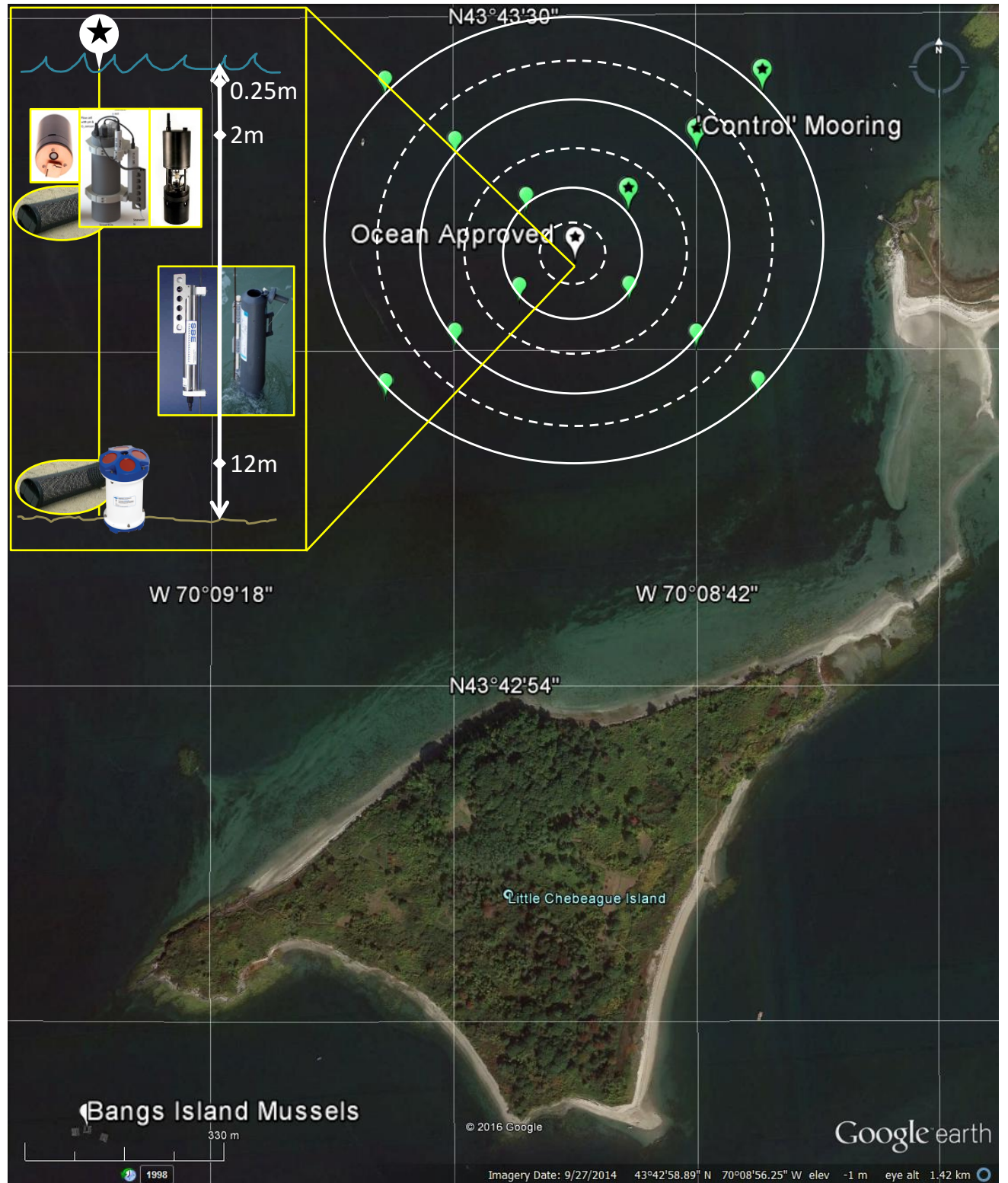


Species-specific phytoremediation potential ($\Delta\Omega_{Ar}$)



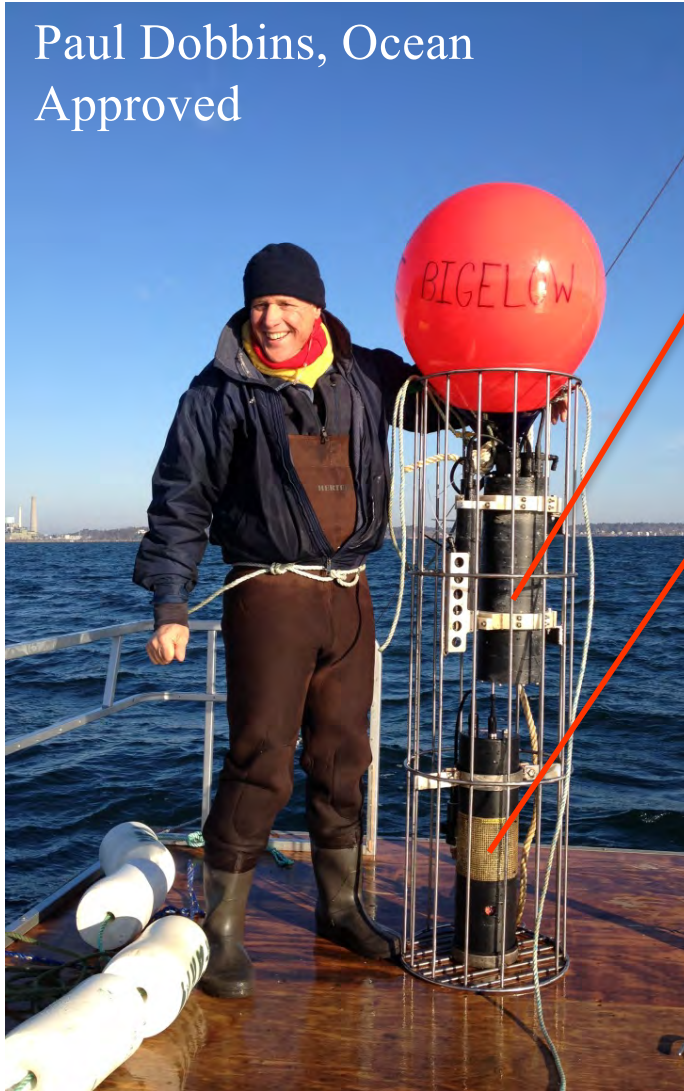
Ocean Approved Farm





Is phytoremediation possible outside of a jar?

Paul Dobbins, Ocean
Approved



Field Observations: Casco Bay

- SeapHOx
 - pH, O₂, Salinity, Temp., Depth every 30 min.
- SAMI pCO₂
 - pCO₂, Temp. every 30 min
- Discrete H₂O samples
 - Total alkalinity, total dissolved inorganic carbon every 2 weeks
- Site Selection
 - Similar bathymetry, hydrography, and residence time – ‘upstream’

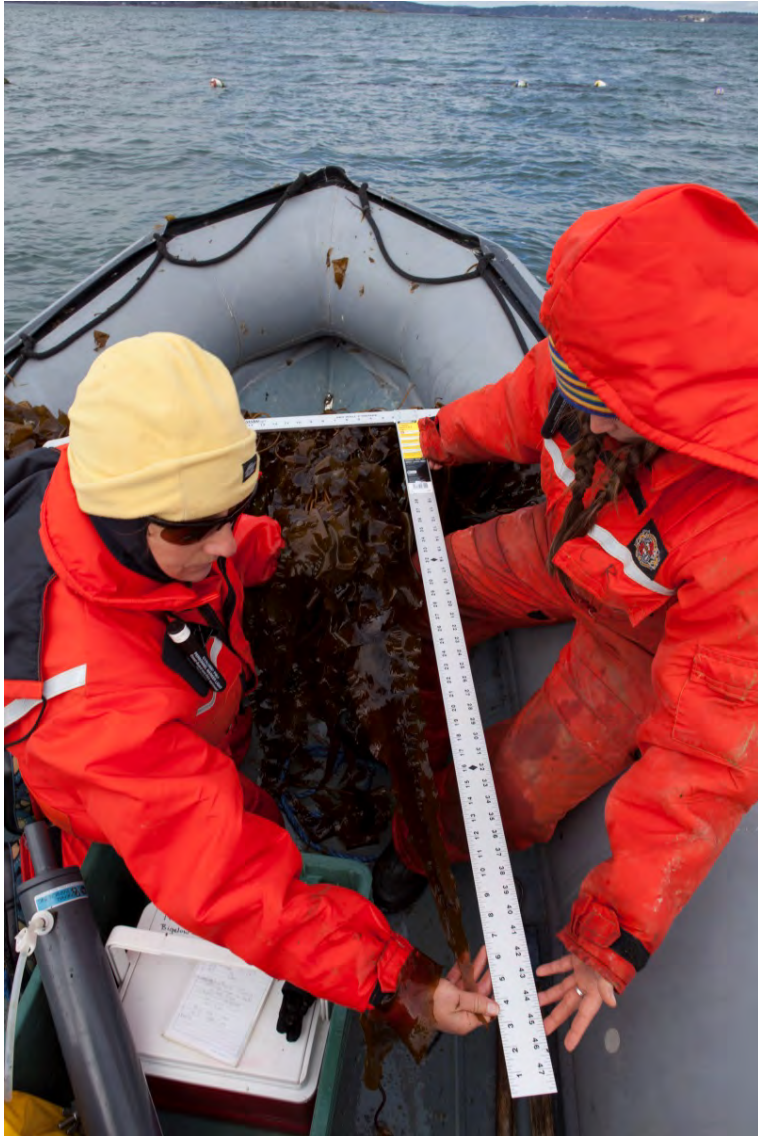
Water sampling - calibration



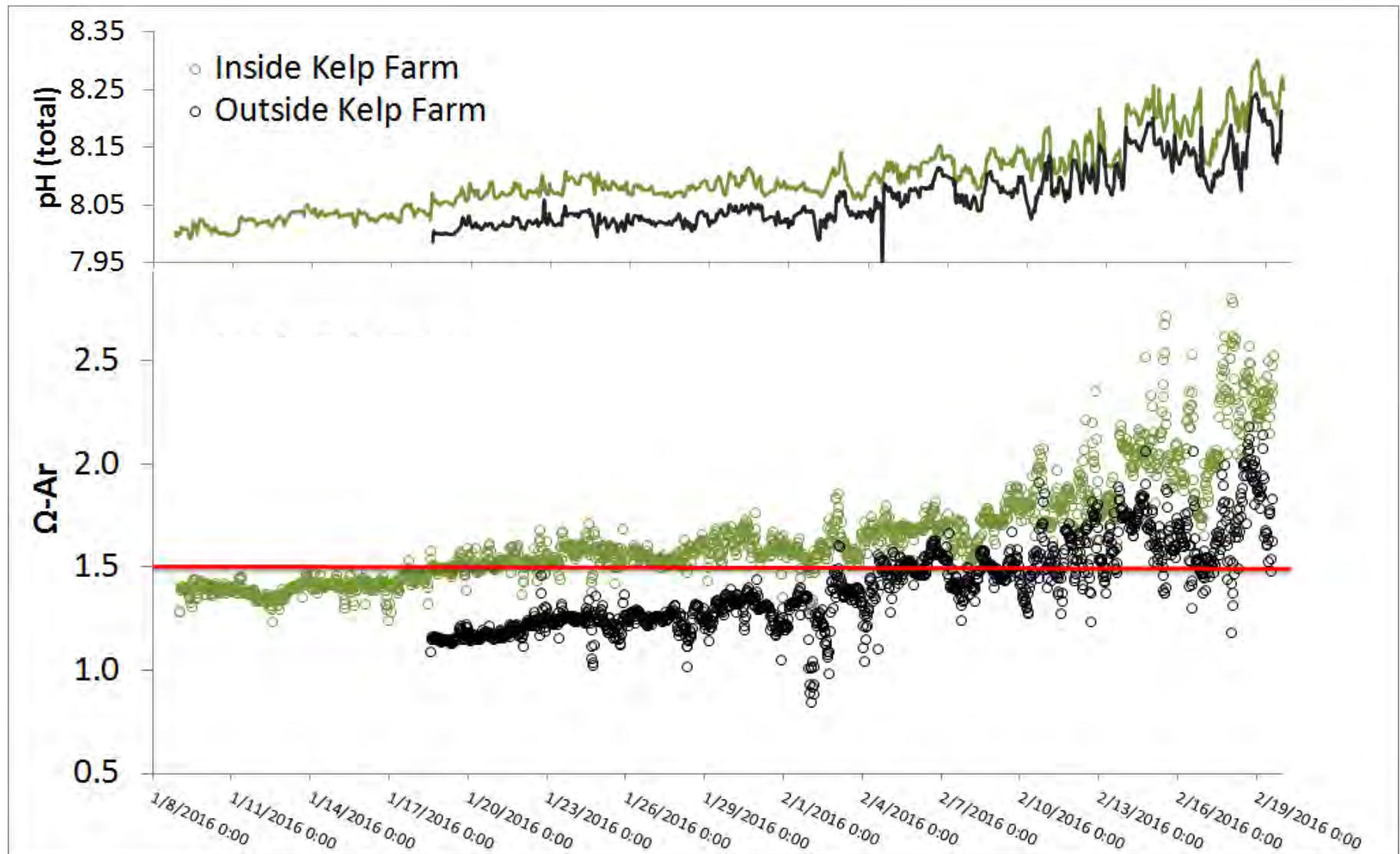
Instruments



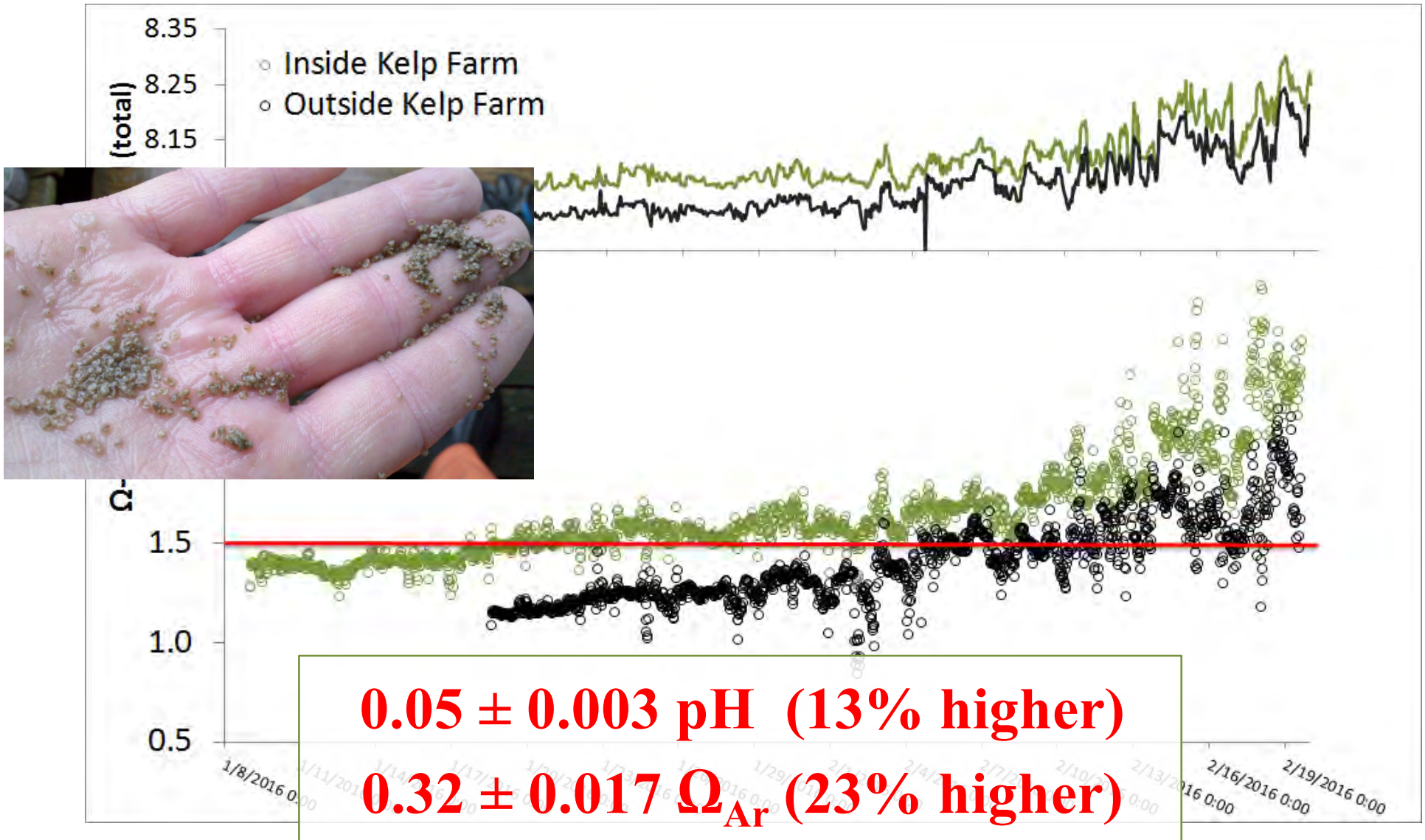
Measuring kelp growth



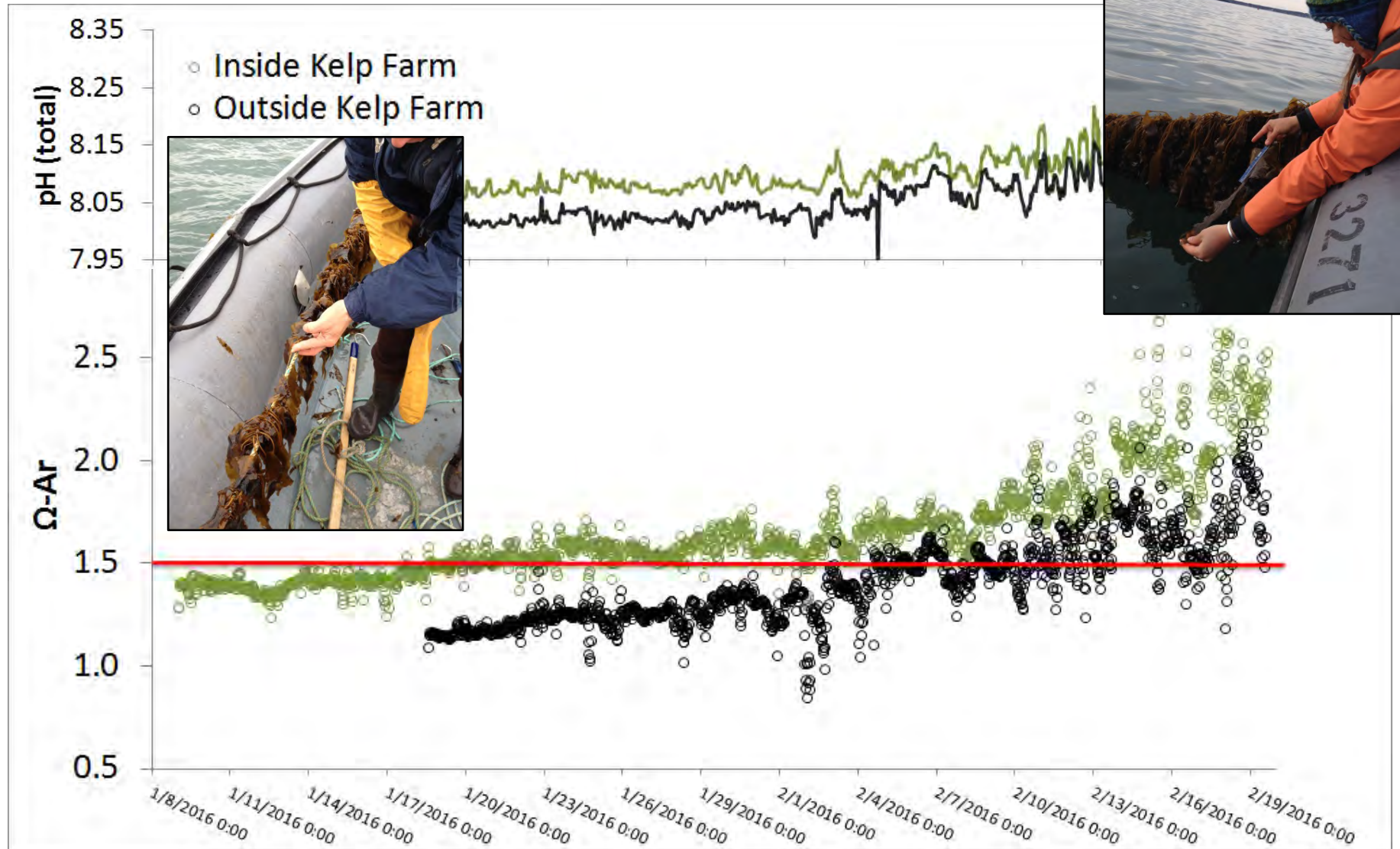
Farmed sugar kelp raise seawater pH and Ω



Farmed sugar kelp raise seawater pH and Ω



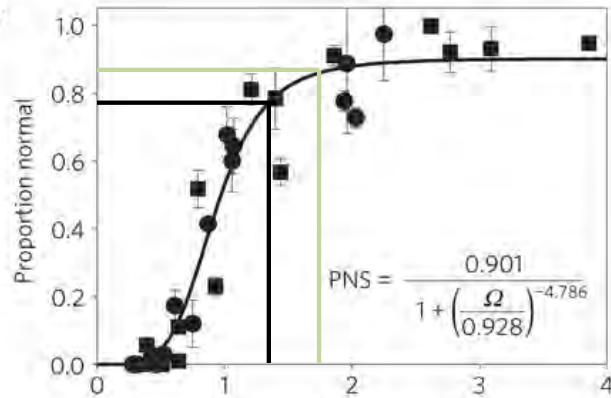
Farmed sugar kelp raise seawater pH and Ω



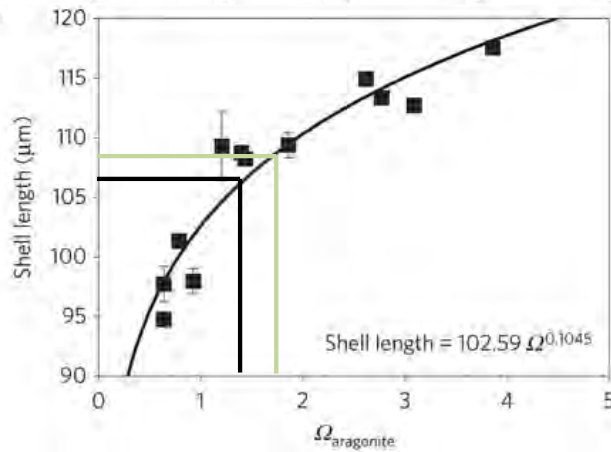
A close-up photograph of a large pile of mussels. The shells are dark, almost black, with a glossy, ribbed texture. Many of the mussels have their siphons extended, and some have their byssus threads (the fibrous threads used for attachment) visible, extending downwards. The mussels are piled together, and the background is a light-colored, possibly wooden, surface.

What does this mean for mussels?

Phytoremediation Today

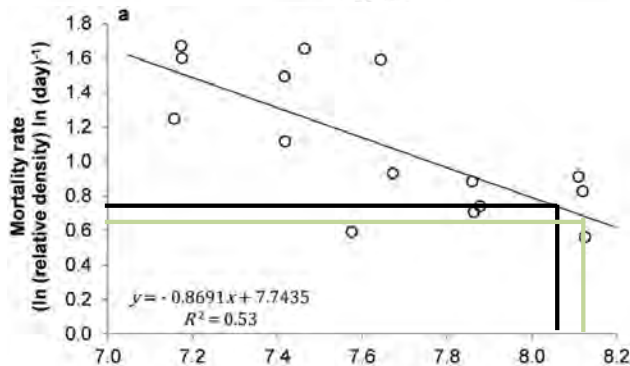


**7% more
develop
normally**



13% larger

Waldbusser et al. 2015
Nature Climate Change



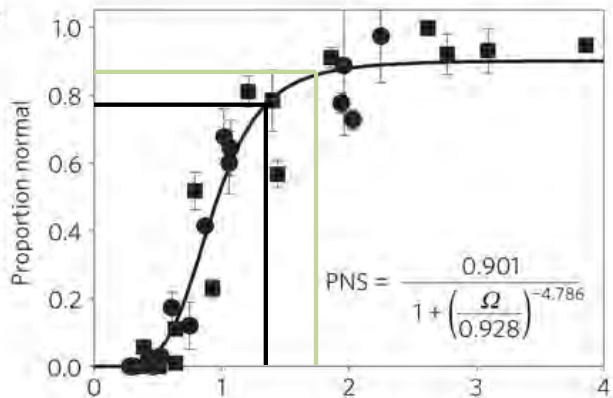
**4% more
survive**

Ventura, Schulz, and
Dupont 2016
Scientific Reports

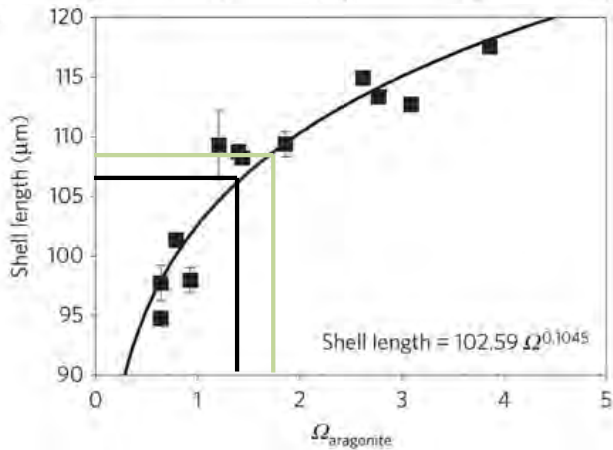
Phytoremediation Today



Phytoremediation Future

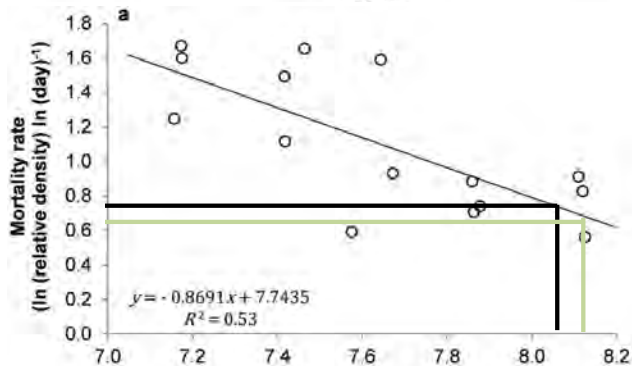


7% more develop normally



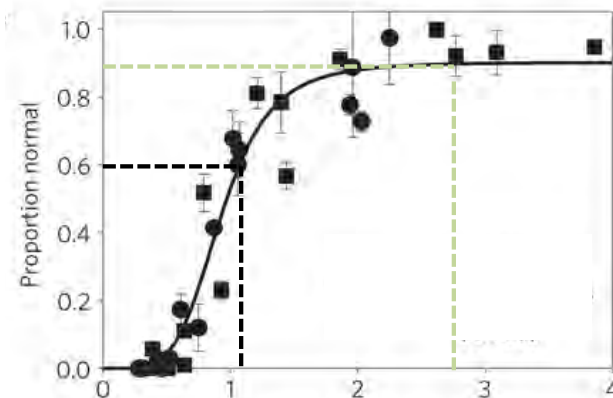
13% larger

Waldbusser et al. 2015
Nature Climate Change

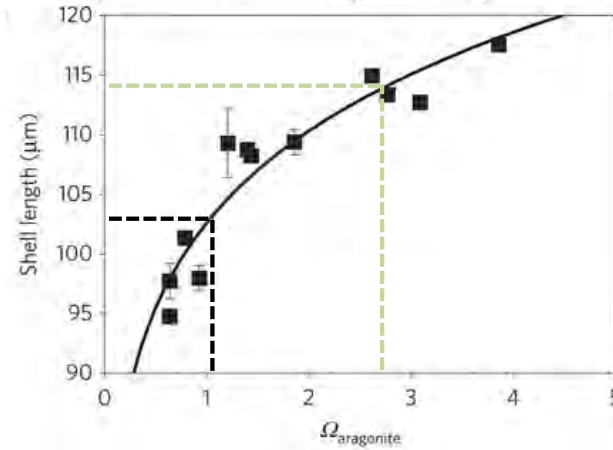


4% more survive

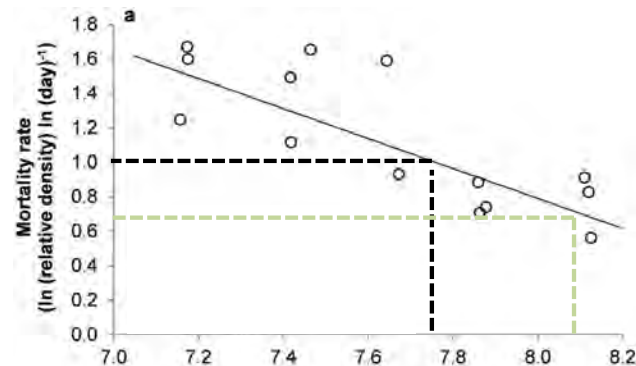
Ventura, Schulz, and Dupont 2016
Scientific Reports



37% more develop normally

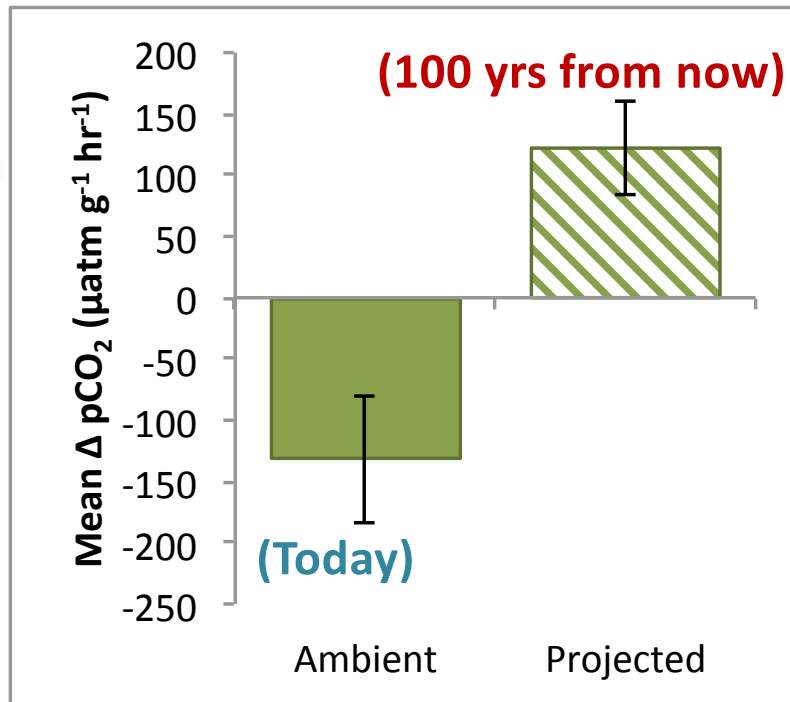


48% larger



30% more survive

How much CO₂ does sugar kelp absorb today and in a future (more acidic & warmer) ocean?



Bigelow Services: Kelp 'Seed' on demand

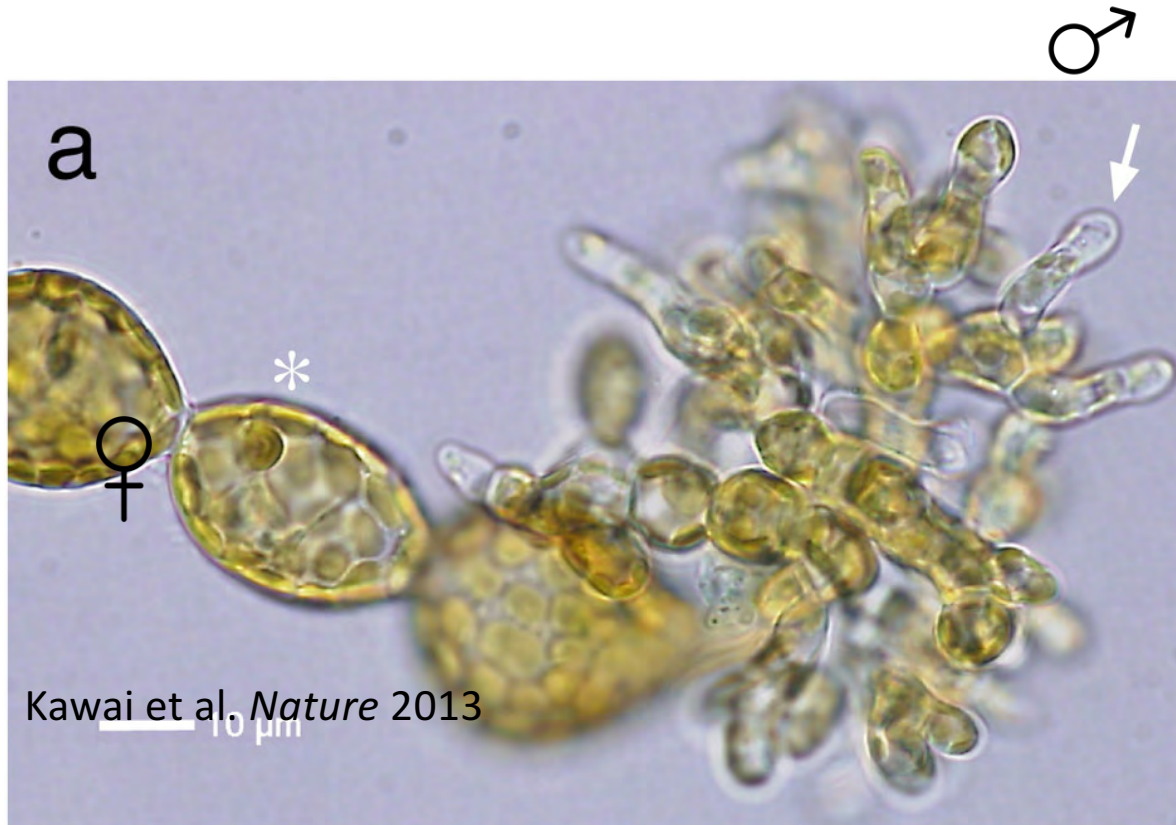


Figure 2.13 Sample twine viewed under the microscope used to monitor growth of sporophytes



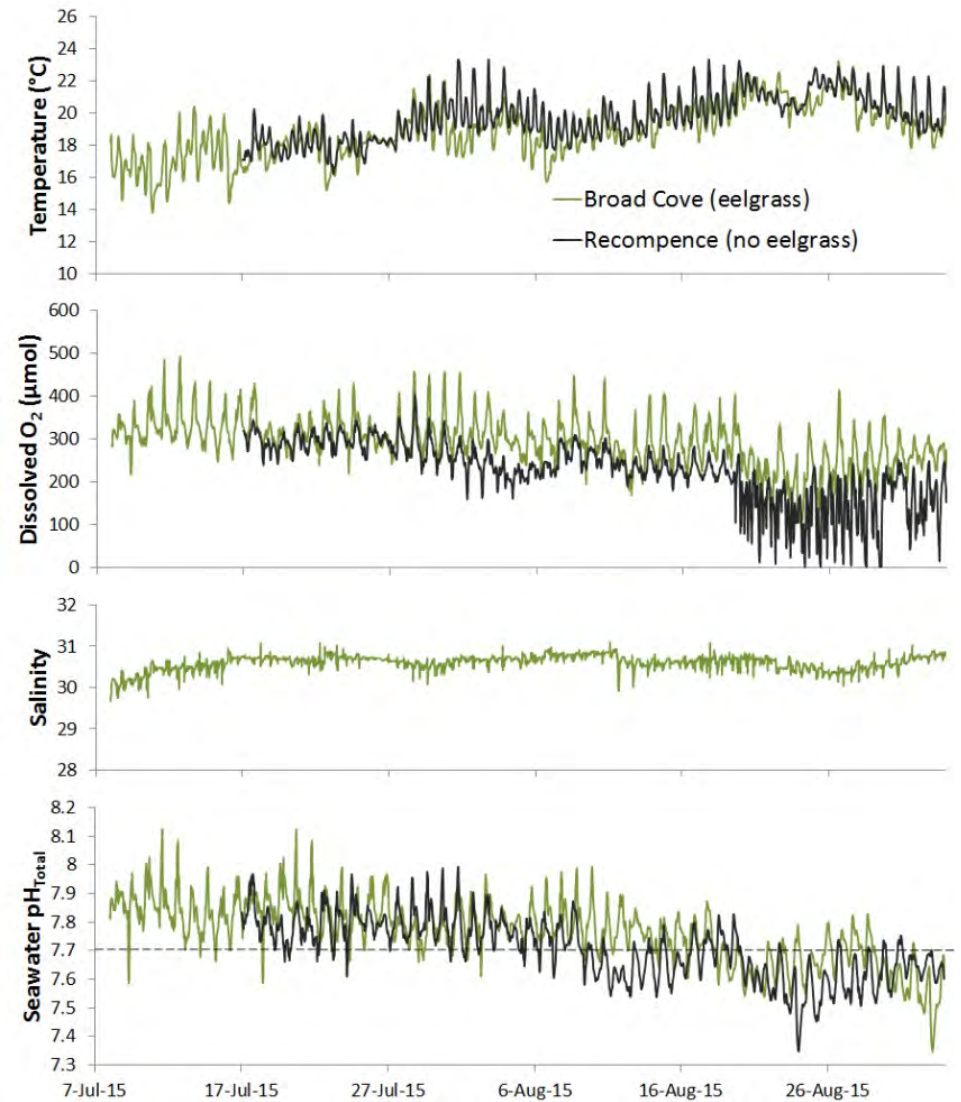
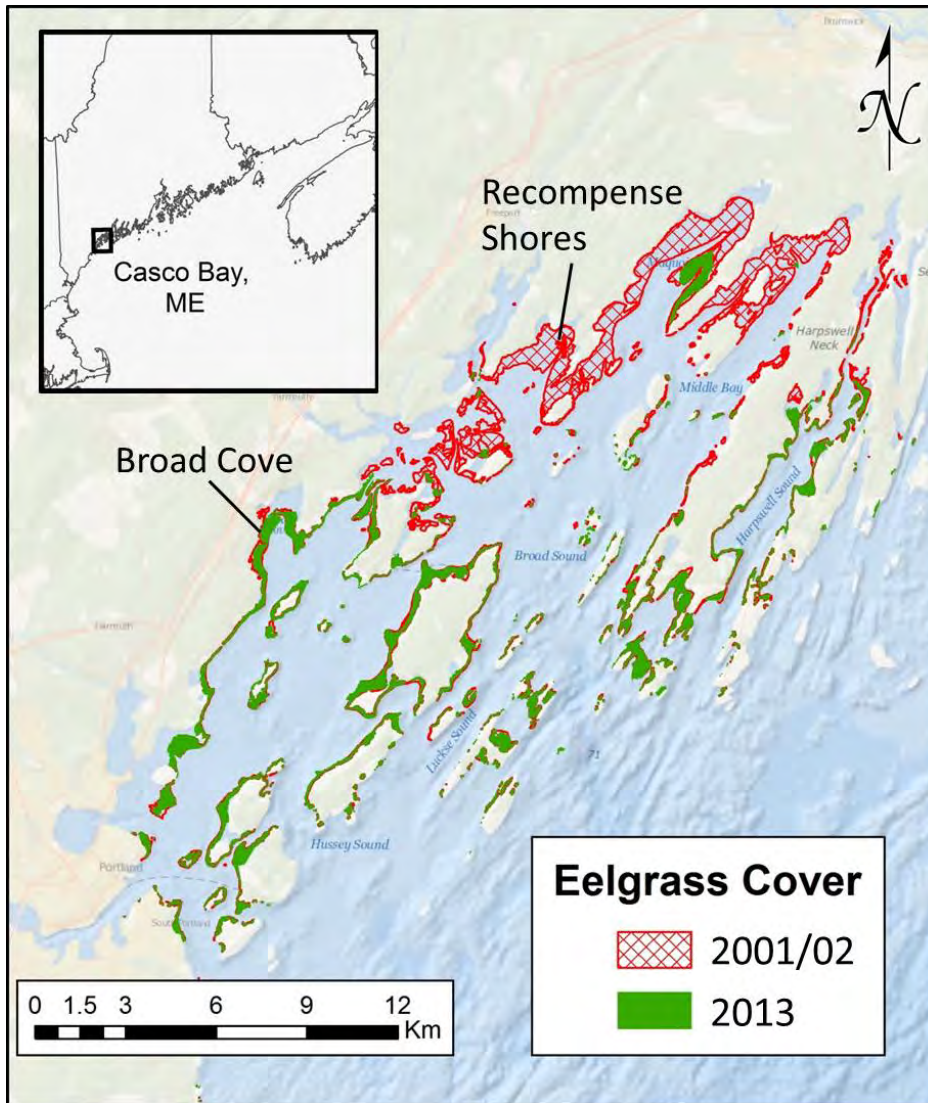
Ocean Approved Kelp Manual

- Spore sorting and gametophyte cloning
- Cryopreservation of favored strains
- Seeding lines for aquaculture
- Sporophyte grow-out in optimal conditions

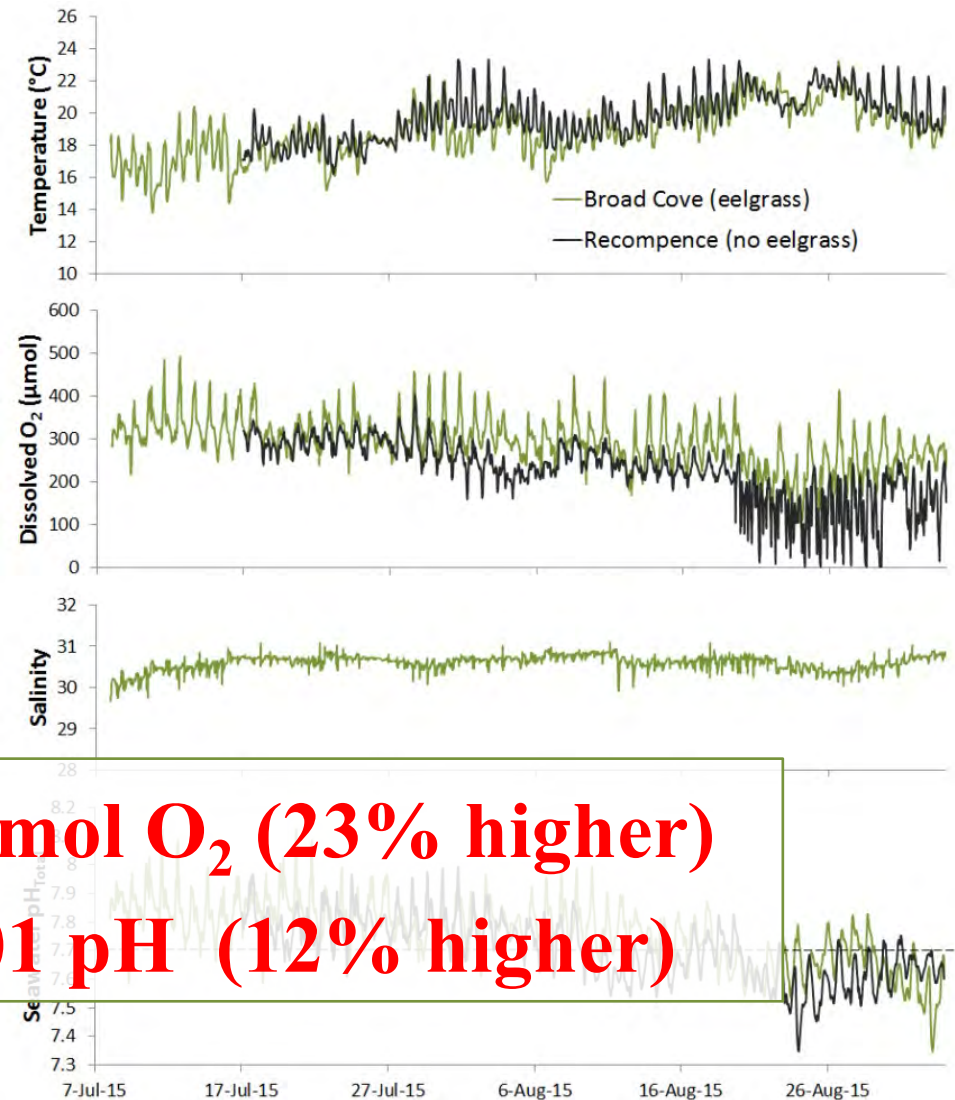
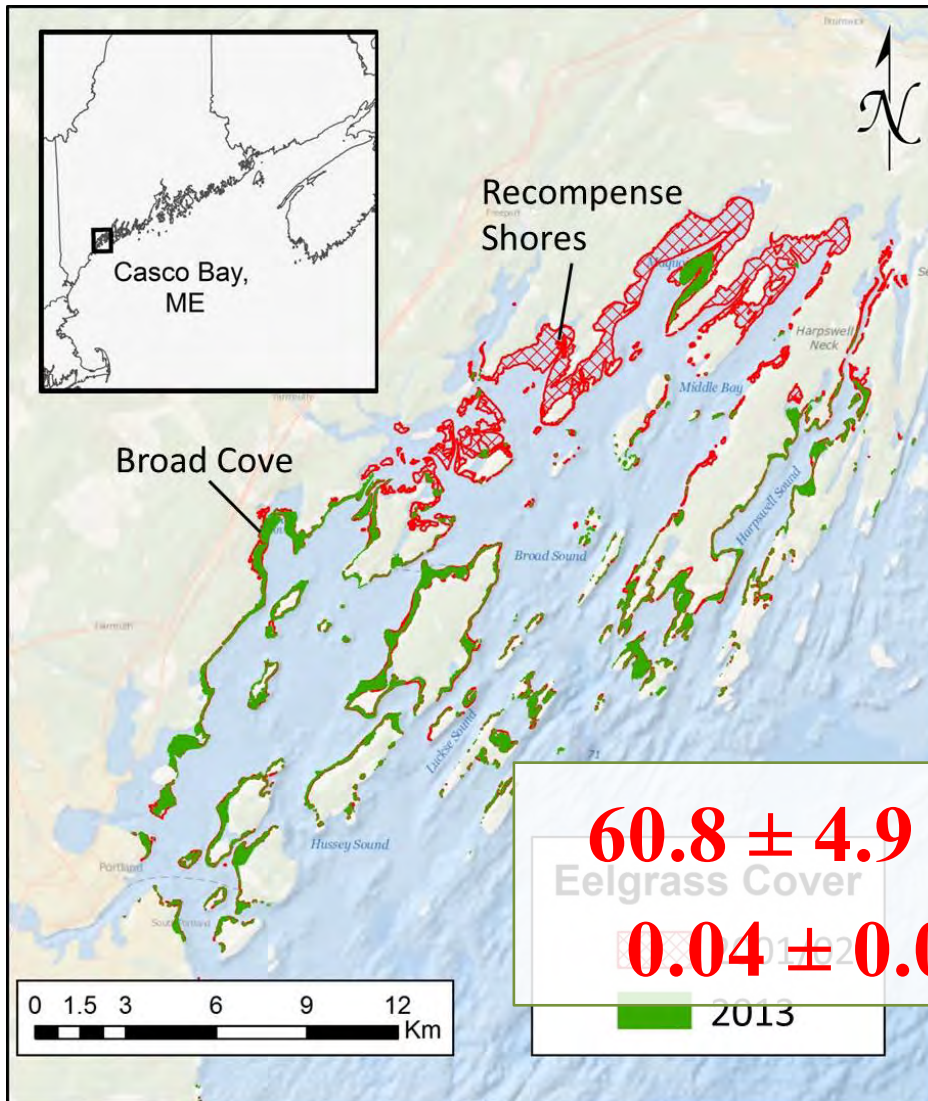


Eelgrass carbon sequestration

Eelgrass raises seawater pH



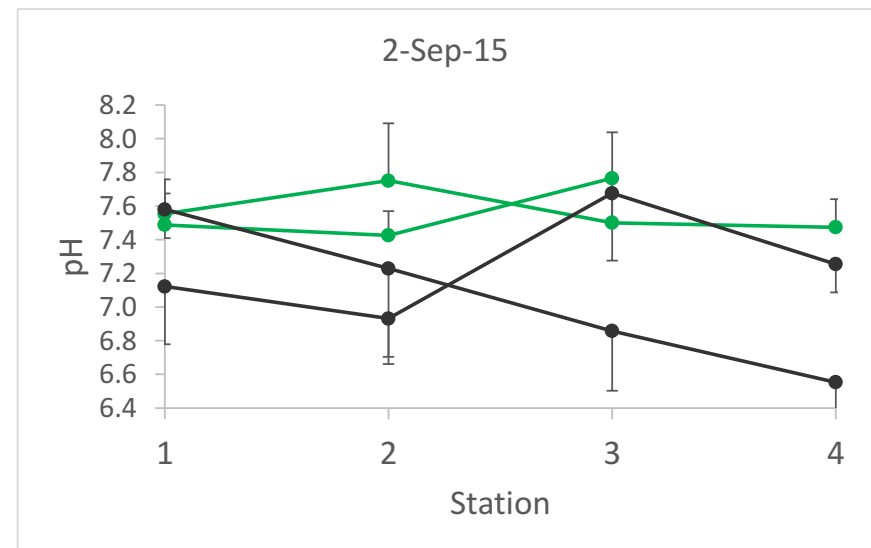
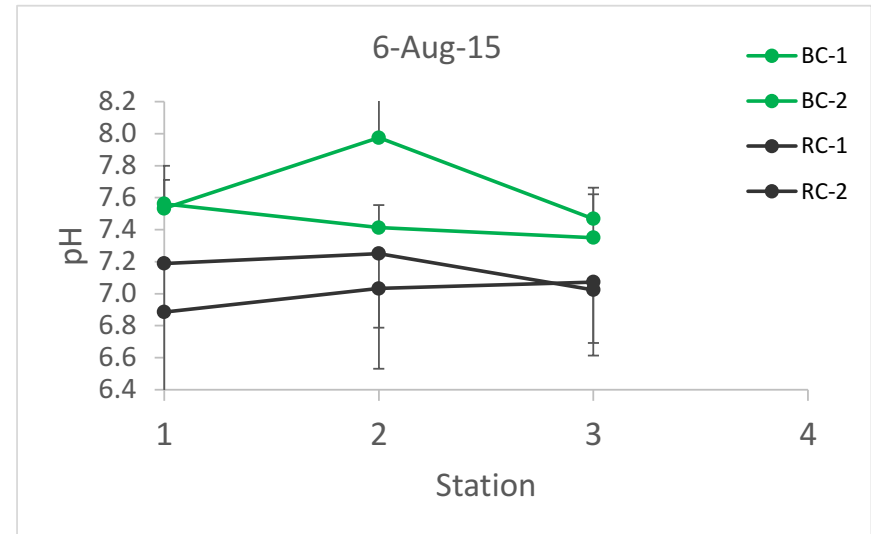
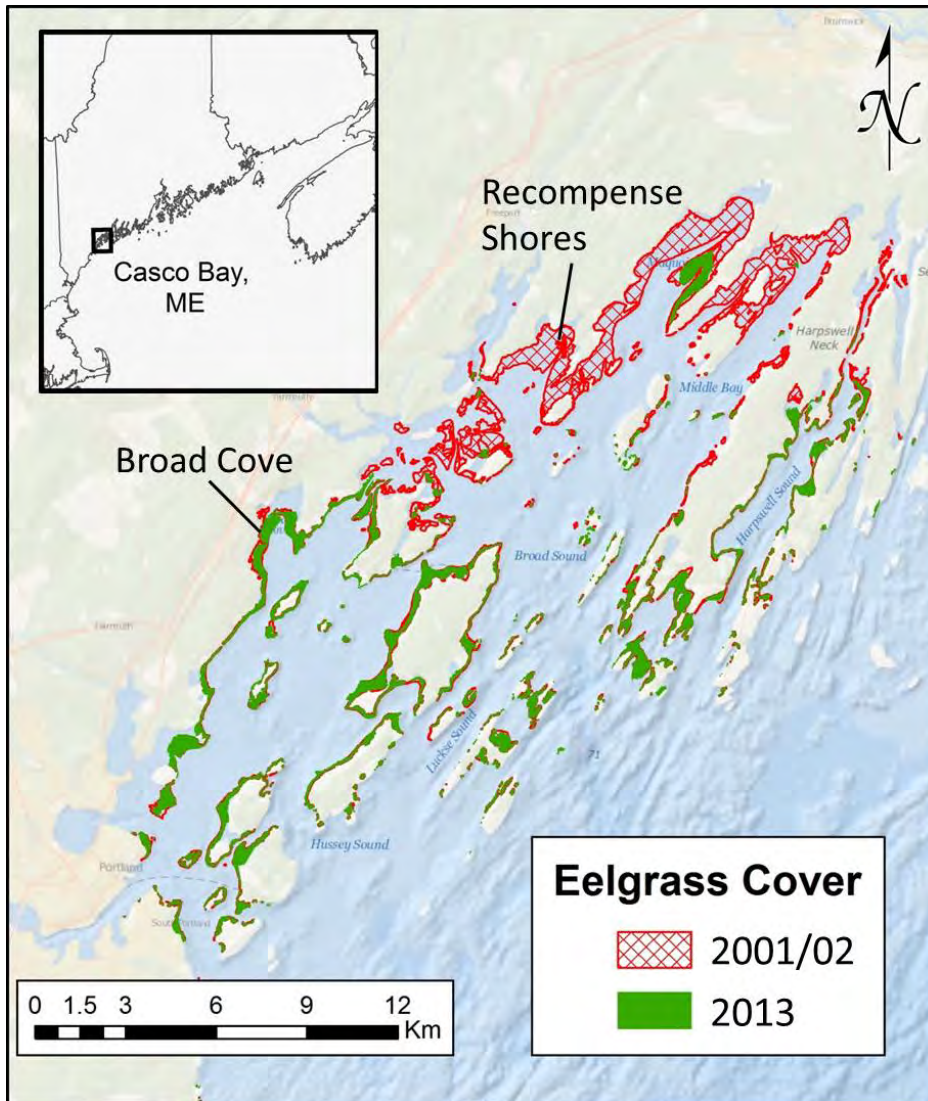
Eelgrass raises seawater pH



$60.8 \pm 4.9 \mu\text{mol O}_2$ (23% higher)

$0.04 \pm 0.001 \text{pH}$ (12% higher)


Sediment pH next to eelgrass bed is higher during peak productivity



“Phytoremediation” as an adaptation strategy

- Implications:
 - Seaweed photosynthesis sufficient to ‘buffer’ acidification
 - Integrated multitrophic aquaculture could increase shellfish growth rate **today**
 - Mitigate eutrophication, hypoxia, and acidification simultaneously
- Future directions:
 - Further quantification of size and magnitude of ‘halo’
 - Relate to directly to biomass in situ (how much kelp?)
 - Understand important of timing of harvest
 - Wild-harvested species and carbon removal?





**Rockweed harvest =
stimulation of CO₂
absorption?**



Put science to work!

Acknowledgements

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