Seagrass – Shellfish Interactions: focusing on the role of positive impacts on community development, stability and restoration

Marine Community Ecology
Peterson Lab

Vol. 213: 143–155, 2001 | MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser | Published April 4

Positive interactions between suspension-feeding bivalves and seagrass — a facultative mutualism

Bradley J. Peterson[1,*], Kenneth L. Heck Jr[2]

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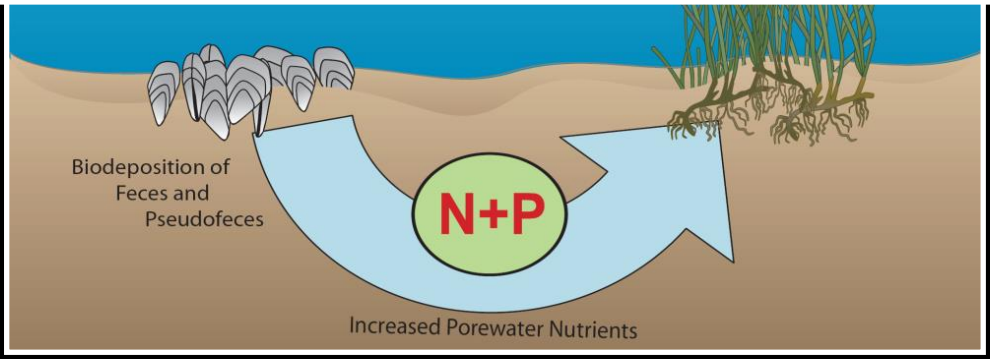
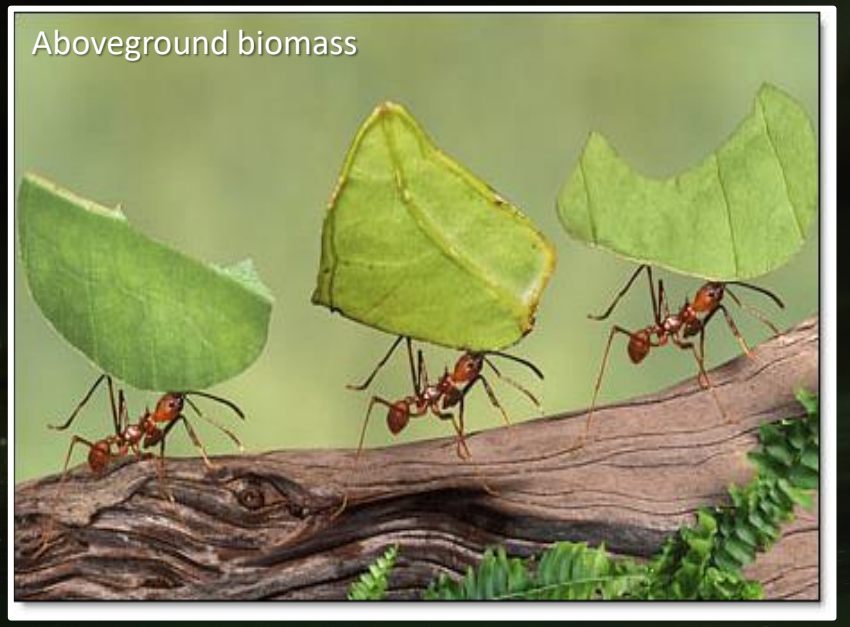
[2]Dauphin Island Sea Laboratory, PO Box 369–370, Dauphin Island, Alabama 36528, USA



Peterson and Heck 1999, 2001a, 2001b


PCSGA
DIE BAUEN
Taylor
Shellfish
Farms


Reproductive output


Aboveground biomass


Belowground biomass


Resource providers

Reproductive output

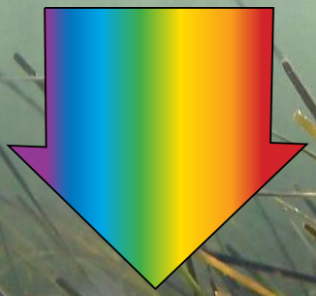
Aboveground biomass

Belowground biomass

Resource providers

Organisms as “resource providers”

Seagrasses have the highest light requirement of any plant on Earth



How do suspension feeding bivalves *facilitate* *light* to eelgrass?

Vol. 357: 165–174, 2008
doi: 10.3354/meps07289

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published April 7

Facilitation of seagrass *Zostera marina* productivity by suspension-feeding bivalves

Charles C. Wall*, Bradley J. Peterson, Christopher J. Gobler

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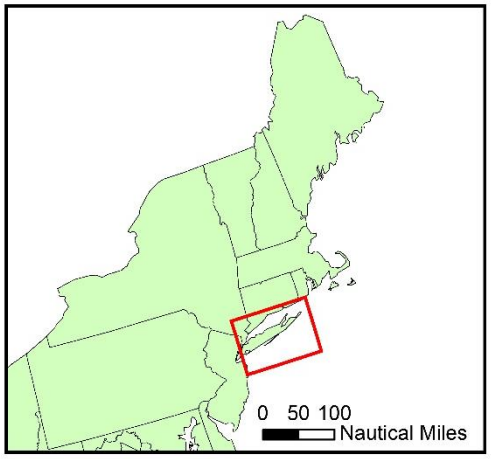
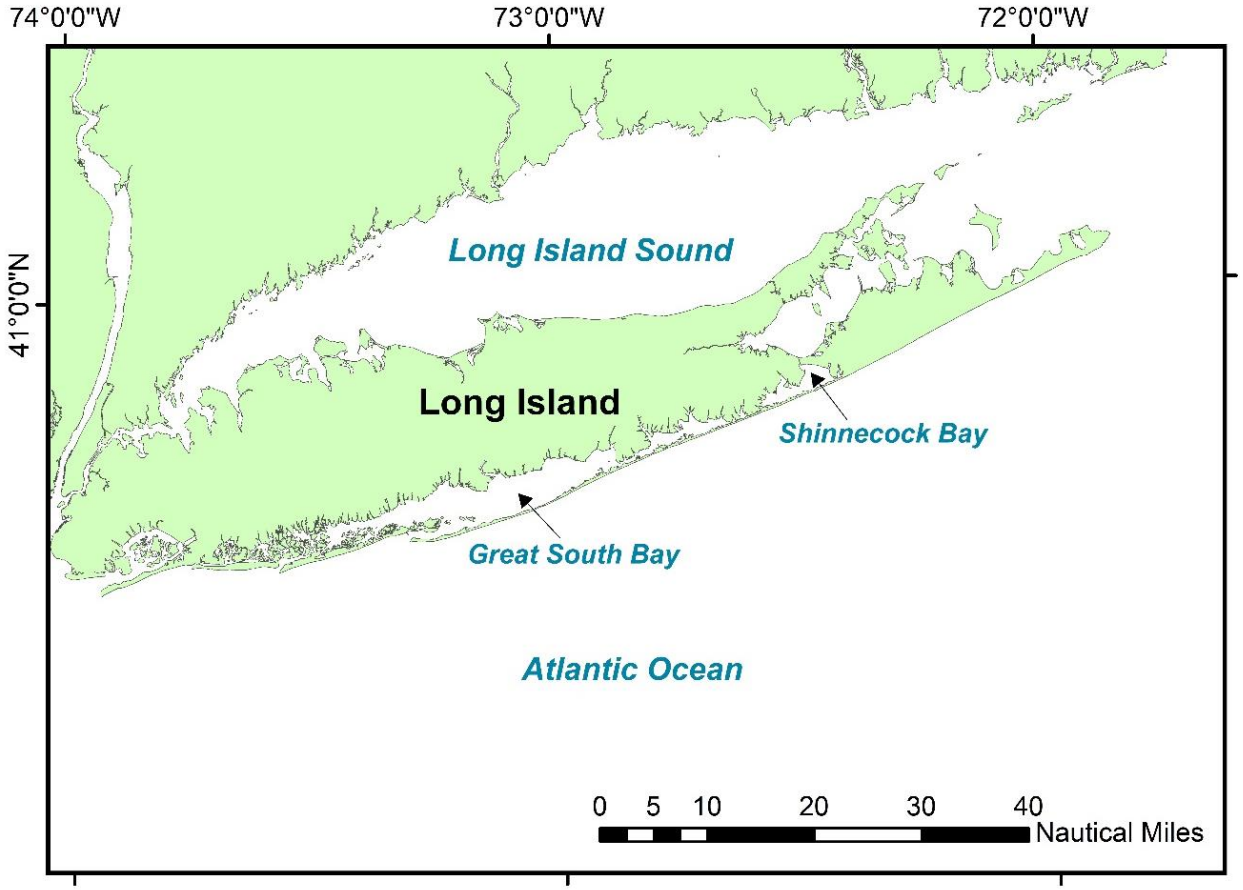
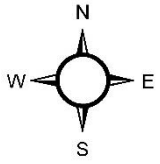
South Shore Estuaries in Long Island, NY





Stony Brook University



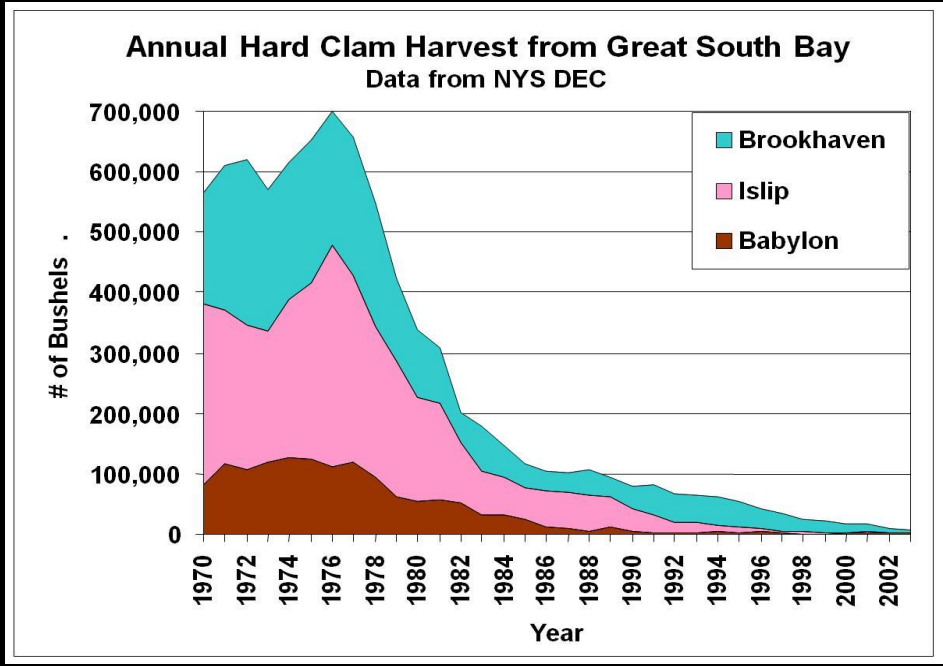
Coordinate System: NAD 1983 UTM Zone 18N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Author: Peter Larios

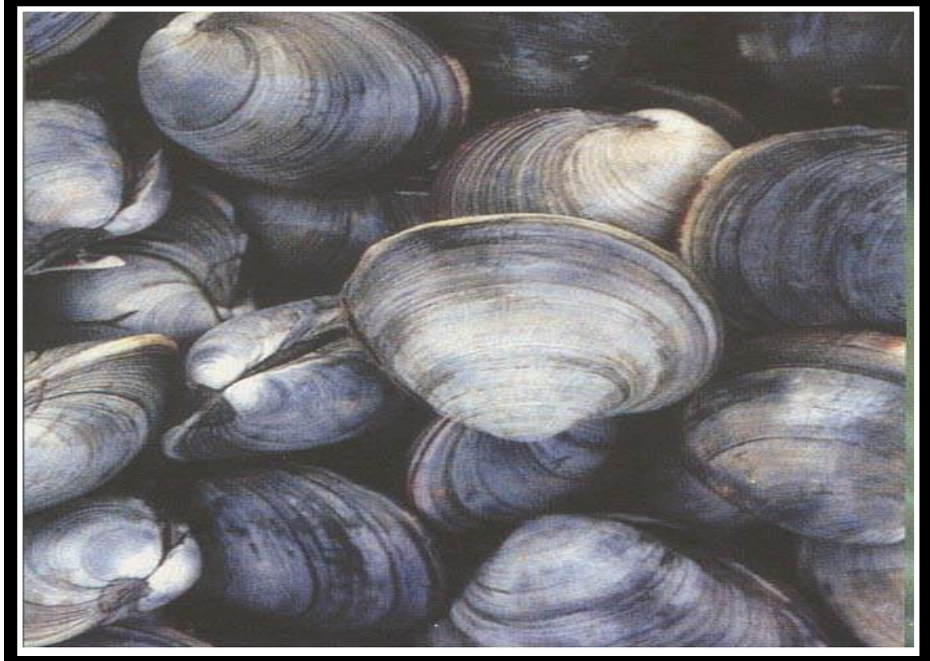
Hard clams: A lost source of natural filtration

Time to filter GSB:

1976: 3 days

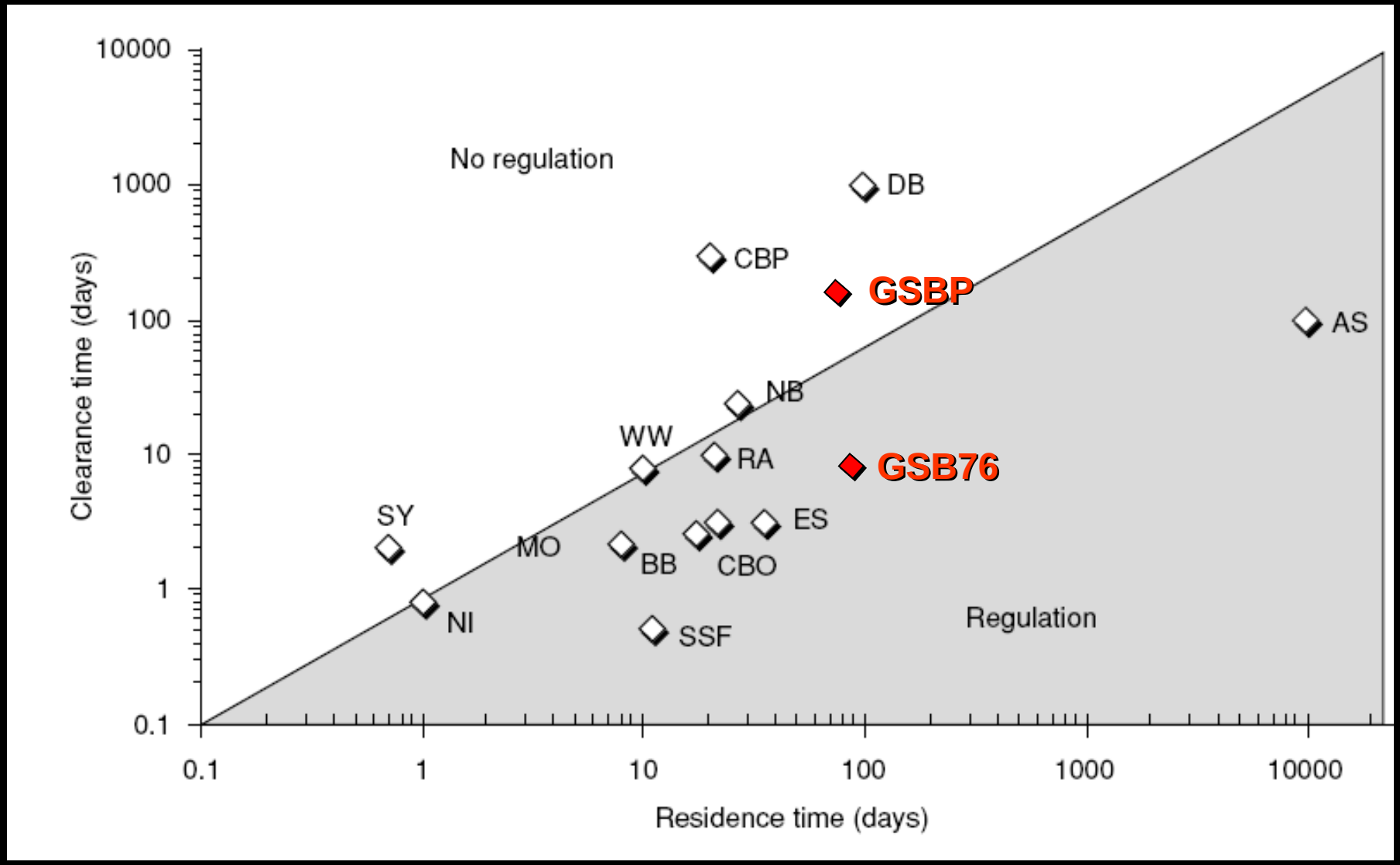
2024: > 3 months



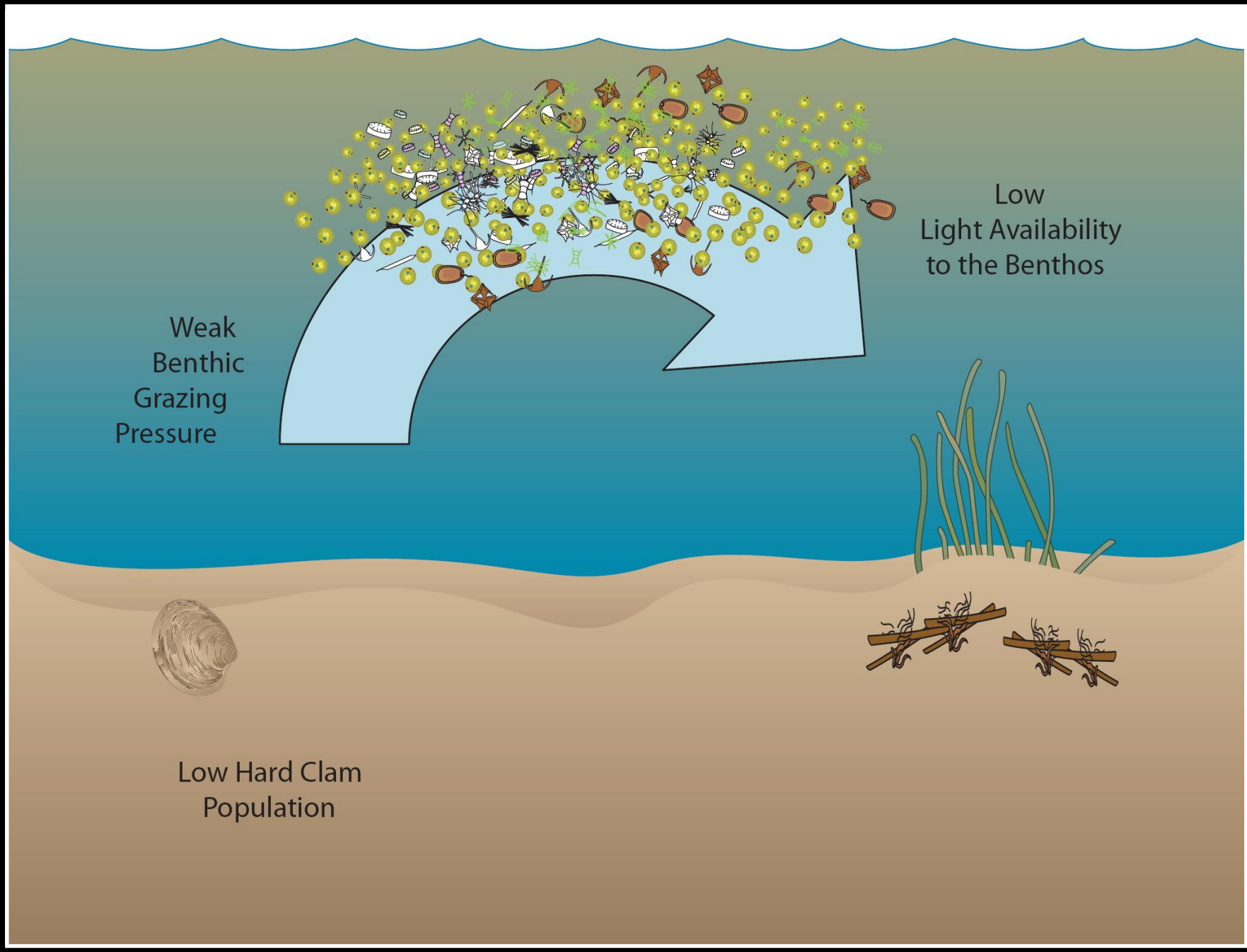


Tank without clams
Brown tide densities > 10^5

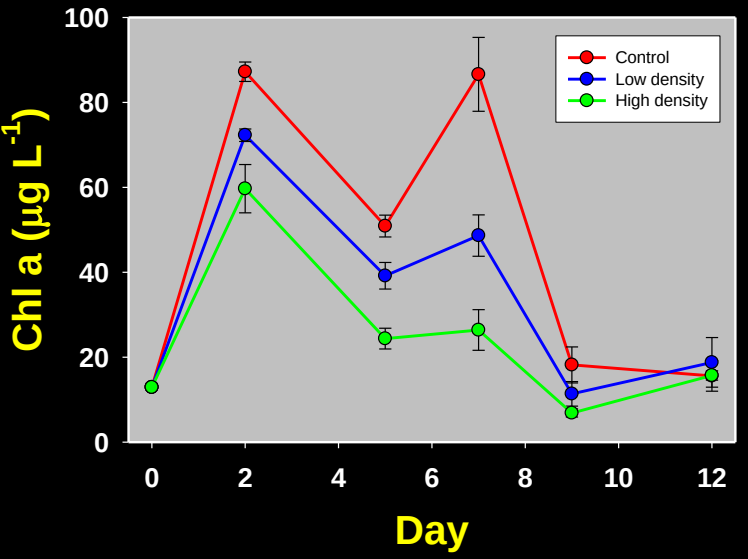
Tank with clams:
Brown tide densities < 10^4

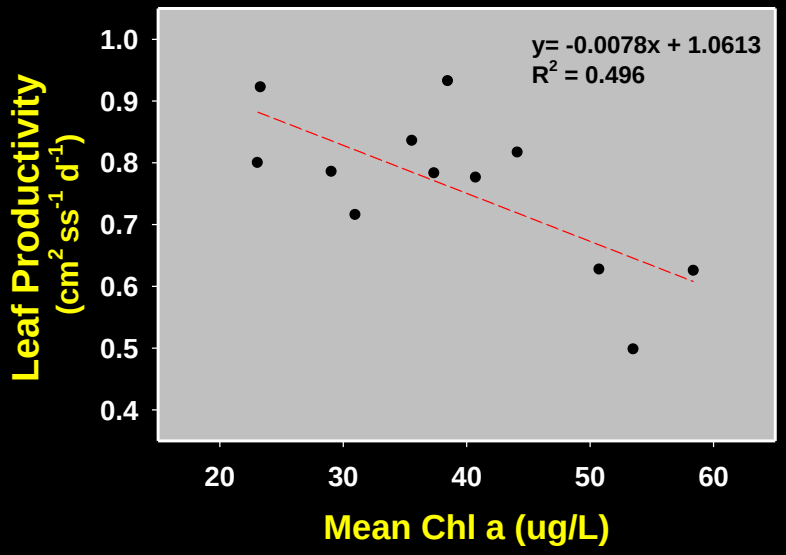


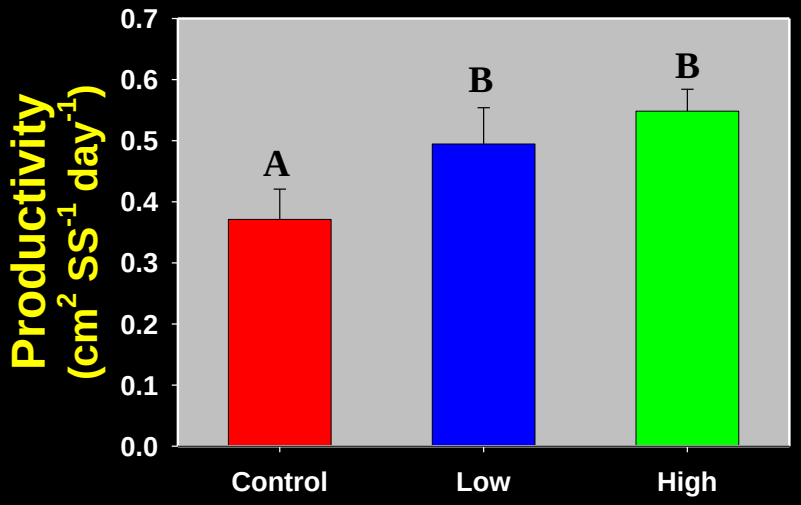
CBO: Chesapeake Bay, Past; NB: Narangasett Bay; DB: Delaware Bay; CBP: Chesapeake Bay, Present. (From Dame, 1996)


Low
Light Availability
to the Benthos
Weak
Benthic
Grazing
Pressure
Low Hard Clam
Population

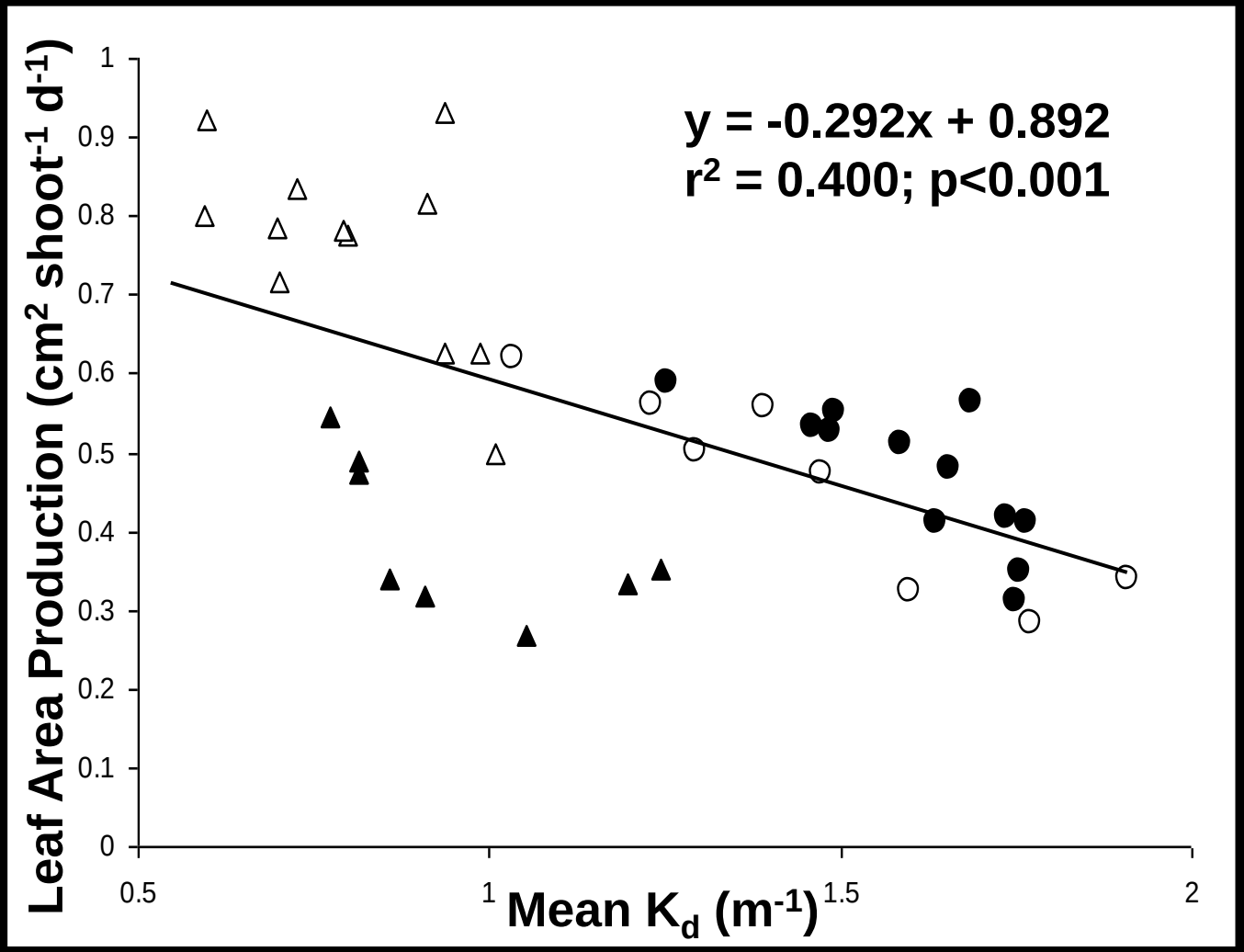
Can hard clams enhance light availability?







Eelgrass growth *vs.* Light Attenuation



Wall et al. 2008 MEPS 357:165-174

Estimated turnover times, using mean individual clearance rates, number of individuals, and tank volume.

Species	Densities Used	Turnover Times
Hard Clams (Quahogs) *Mercenaria mercenaria*	14 individ. m^{-2}	4.5 days
	29 individ. m^{-2}	2.2 days
	57 individ. m^{-2}	1.1 days
Eastern Oysters *Crassostrea virginica*	4 individ. m^{-2}	2.5 days
	7 individ. m^{-2}	1.3 days
	14 individ. m^{-2}	0.6 days
Blue Mussels *Mytilus edulis*	57 individ. m^{-2}	14.5 days
	229 individ. m^{-2}	3.6 days

- Current density of hard clams in Great South Bay: 0.5-2 individ. m^{-2} Historical density: 53-105 individ. m^{-2} (Cerrato et al., 2004)

- Current density of oysters in Chesapeake Bay: 0.43 individ. m^{-2} Historical density: 43-150 individ. m^{-2} (Newell & Koch, 2004)

How do suspension feeding bivalves *facilitate* *nutrient availability* to eelgrass?

Vol. 369: 51–62, 2008
doi: 10.3354/meps07593

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

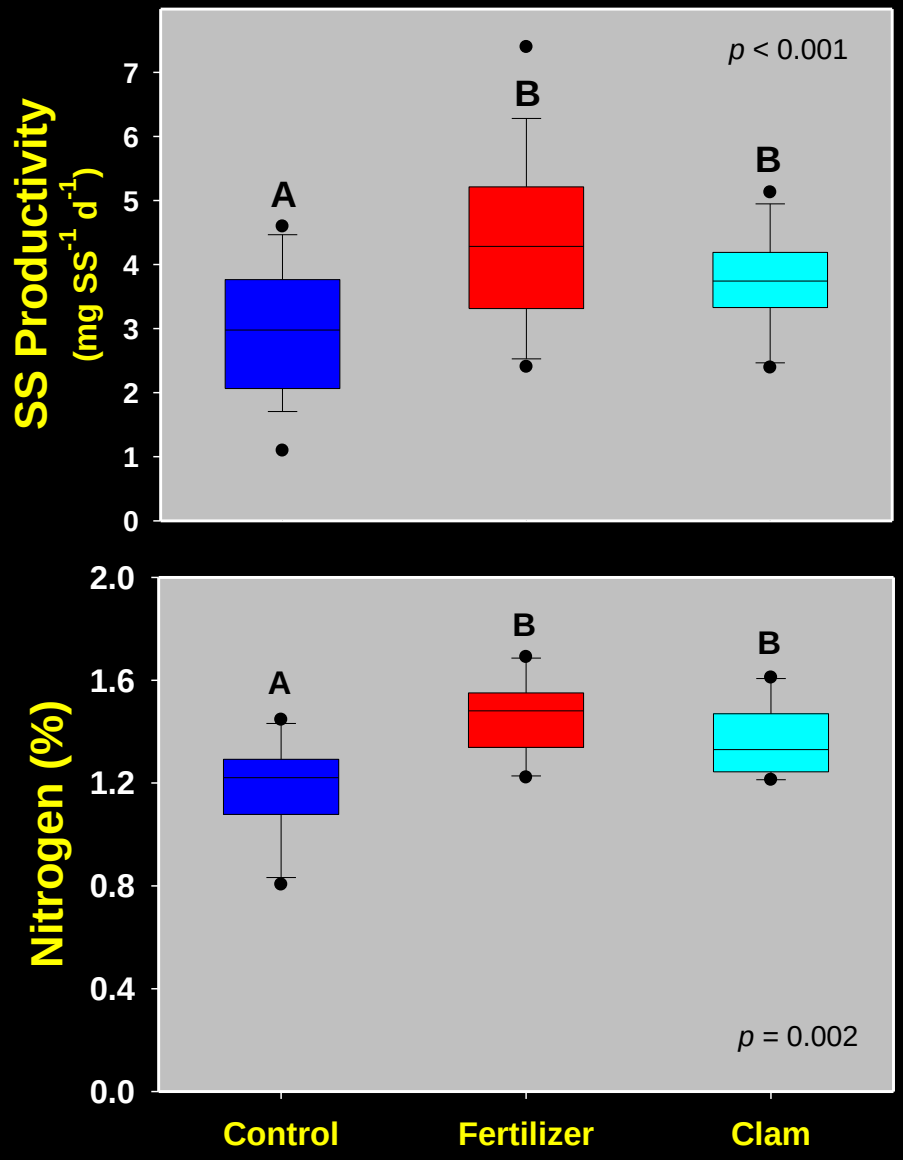
Published October 13

Resource-restricted growth of eelgrass in New York estuaries: light limitation, and alleviation of nutrient stress by hard clams

John Carroll*, Christopher J. Gobler, Bradley J. Peterson

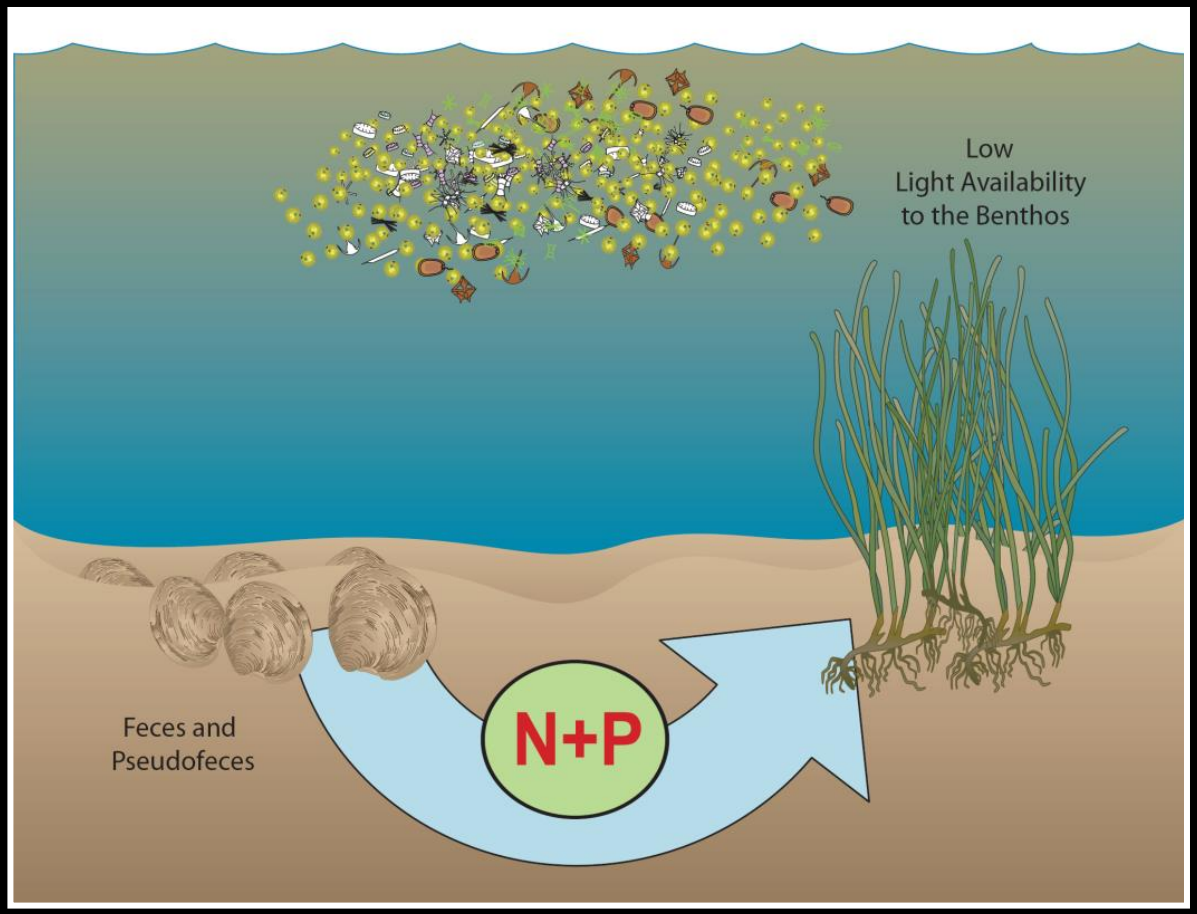
School of Marine and Atmospheric Sciences, Stony Brook University, 239 Montauk Hwy, Southampton, New York 11968, USA

Fertilization Experiment

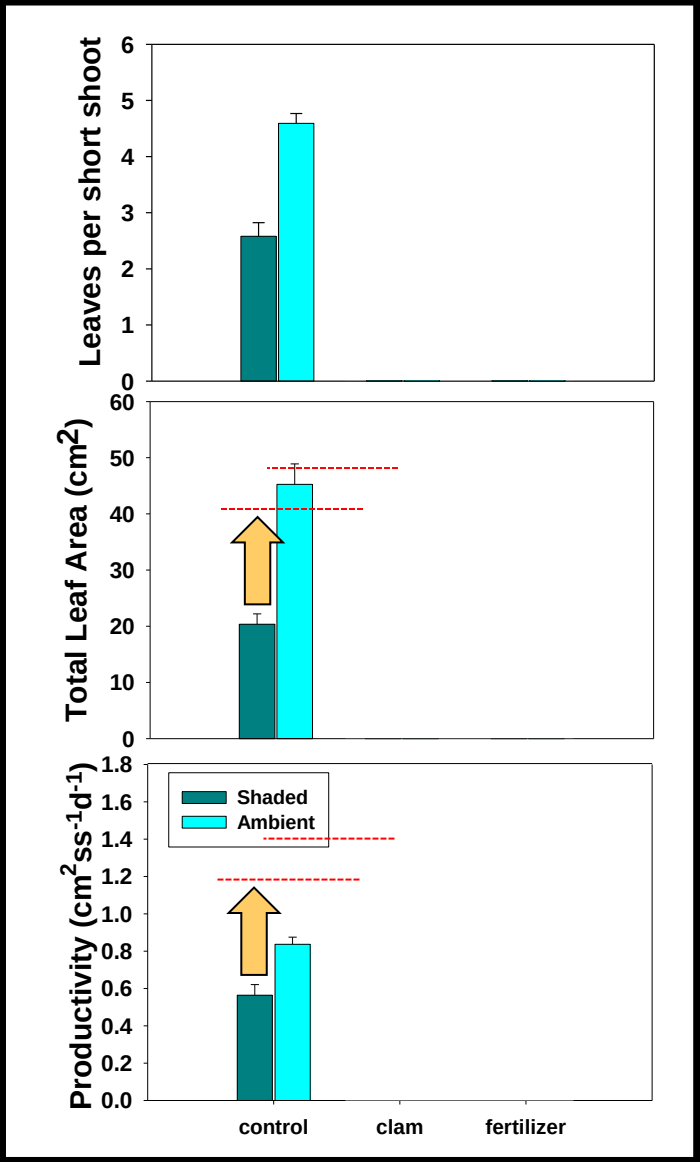


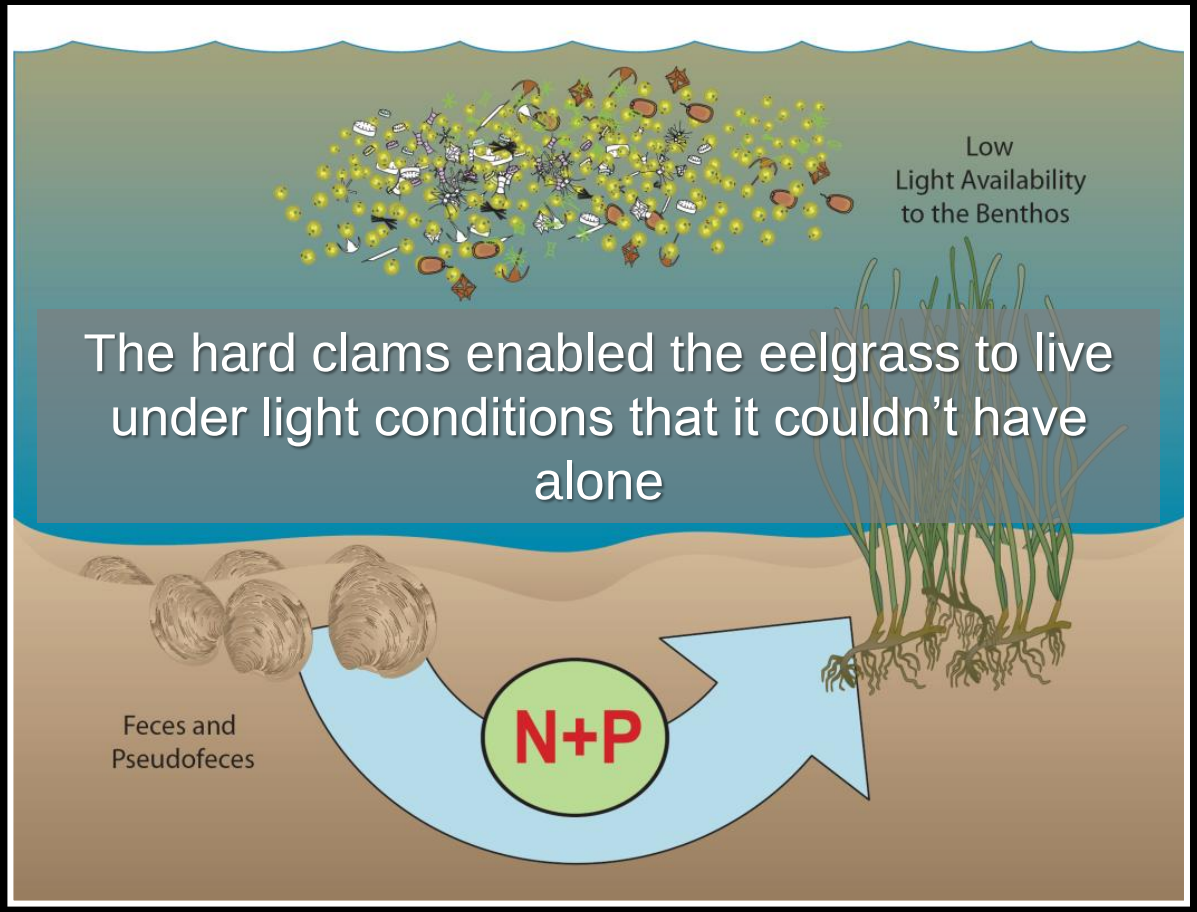
Fertilization Experiment

Can this enhancement of nutrient availability impact eelgrasses response to light limitation?

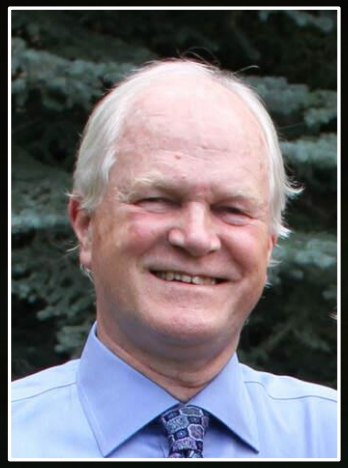


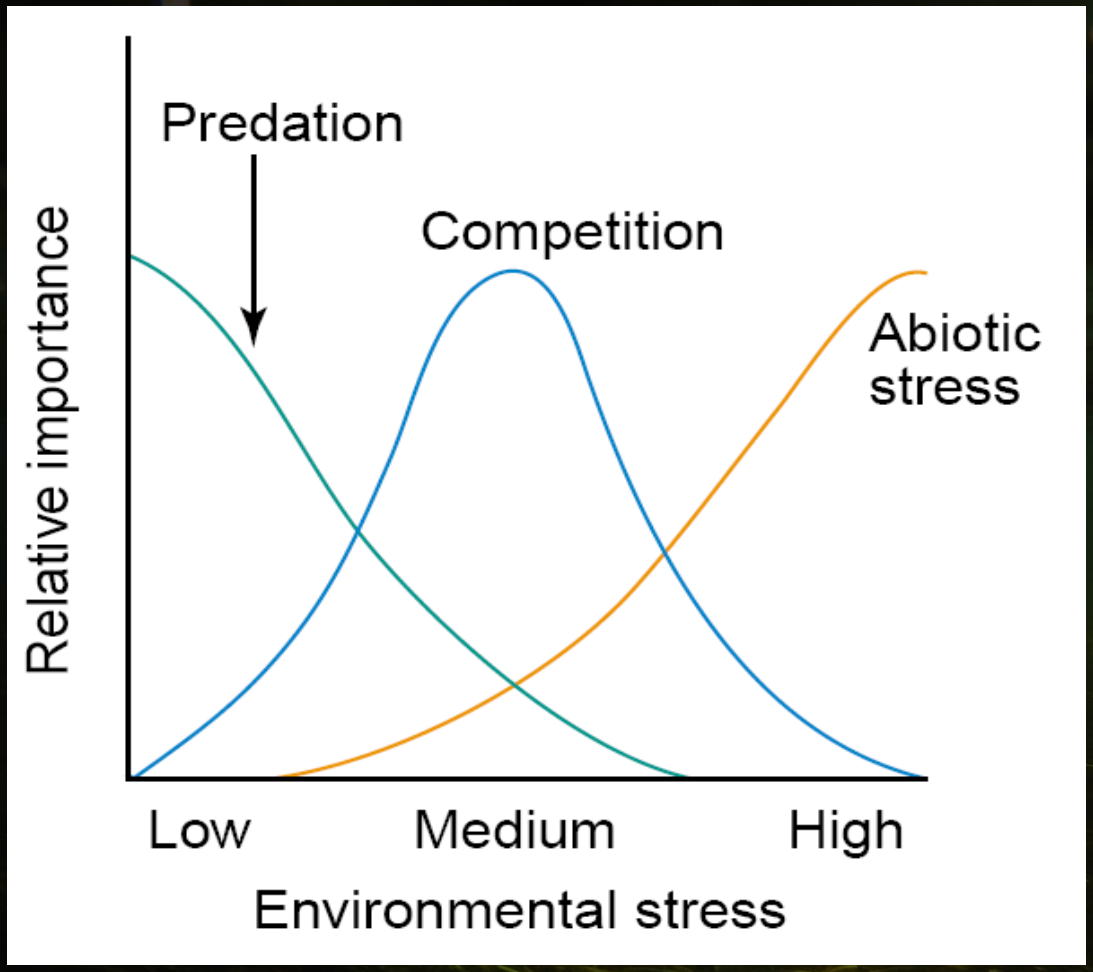
Carroll et al. 2008 MEPS 369:51-63



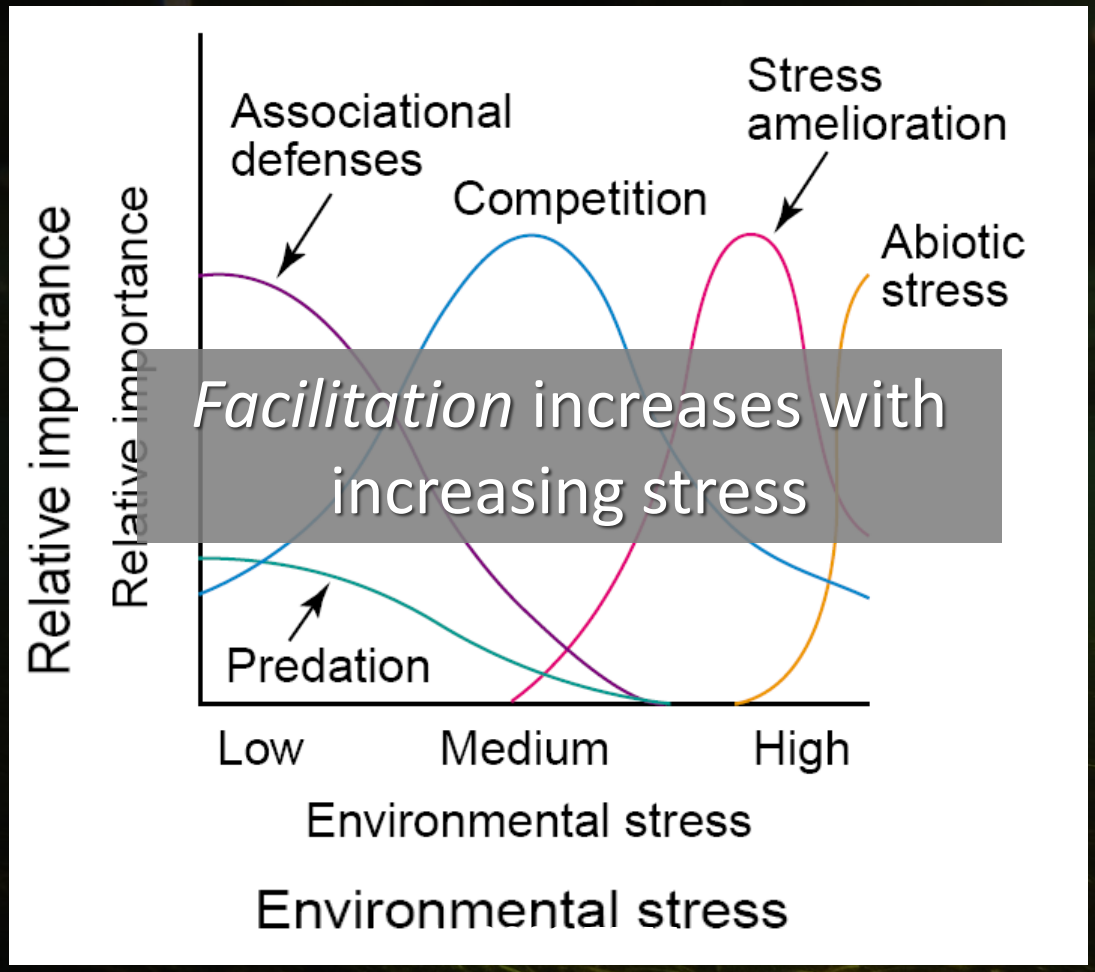


Carroll et al. 2008 MEPS 369:51-63





Menge and Sutherland. 1976 Am. Nat. 110:351-369



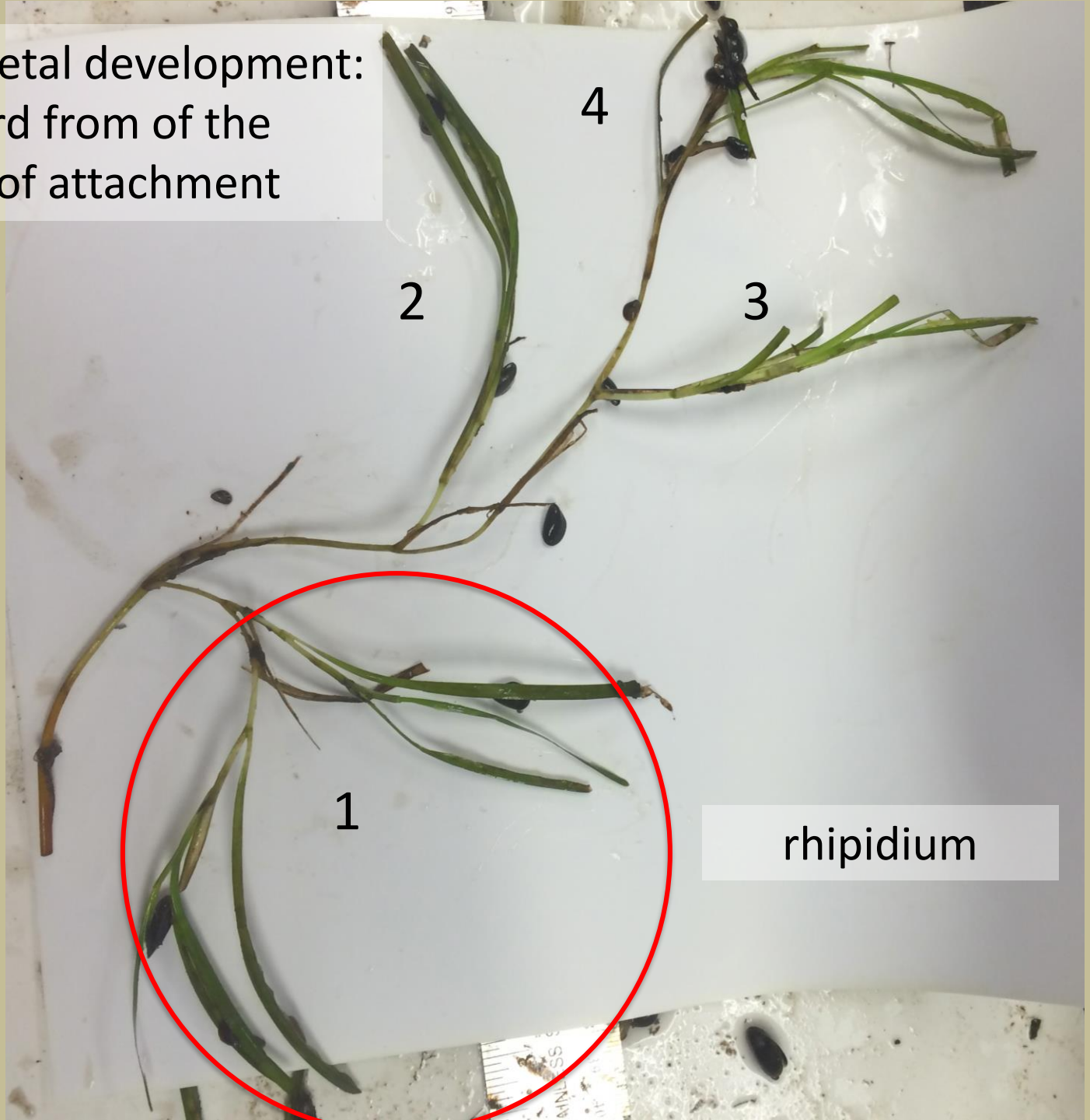
Facilitation increases with increasing stress

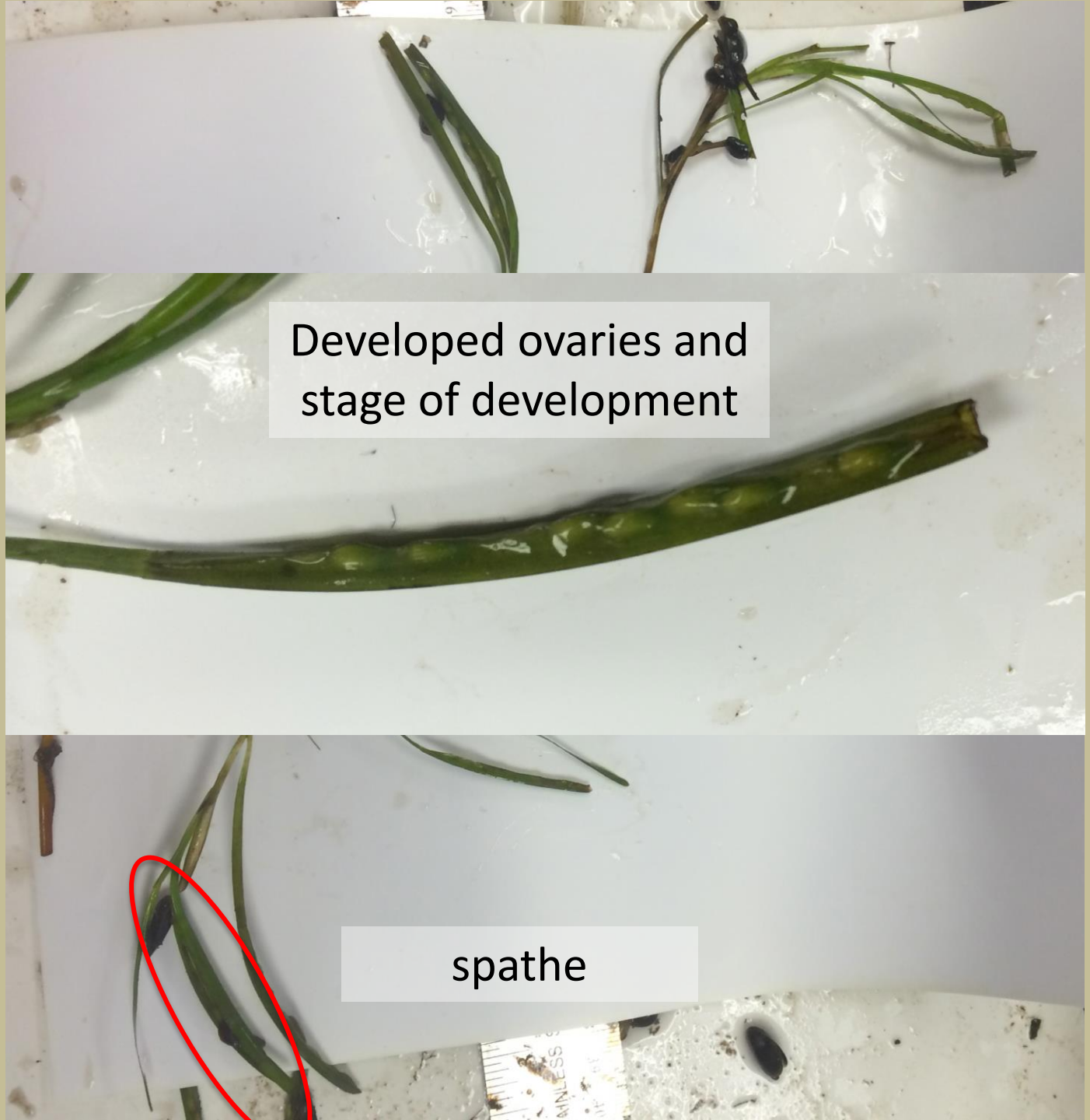
Bruno et. al. 2003 TREE 18:119-125

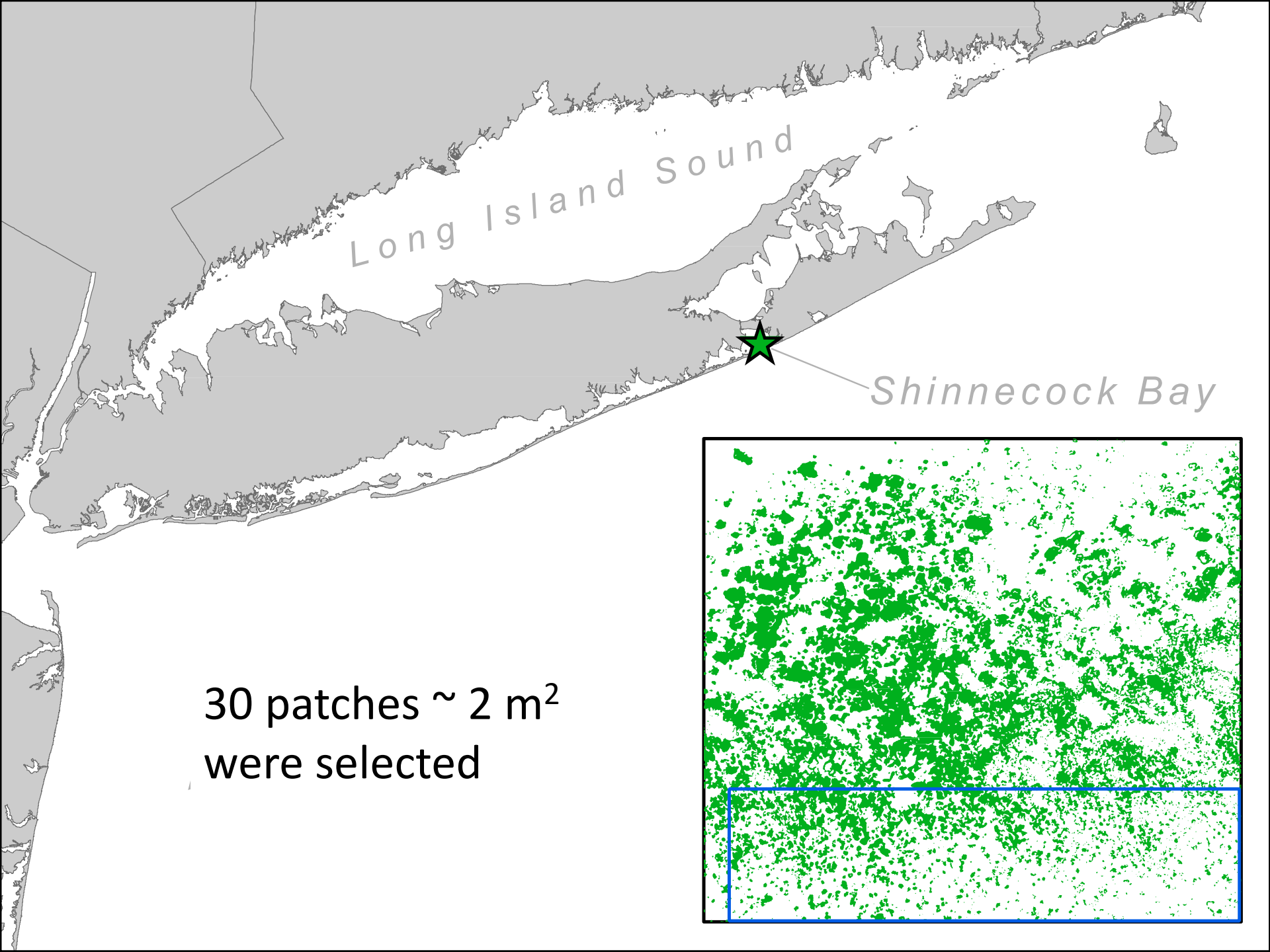
What effect does nutrient enrichment have on reproductive shoots?

Jackson et al. 2017 JEMBE 489:1-6

Acropetal development: upward from of the point of attachment




Developed ovaries and stage of development
spathe



30 patches ~ 2 m^2 were selected

- 36% increase in reproductive shoot height
- 40% increase in seeds per spathe
- 99% increase in seeds per shoot
- 23% increase in developed spathes

Jackson et al. 2017 JEMBE 489:1-6

Ambient Controls

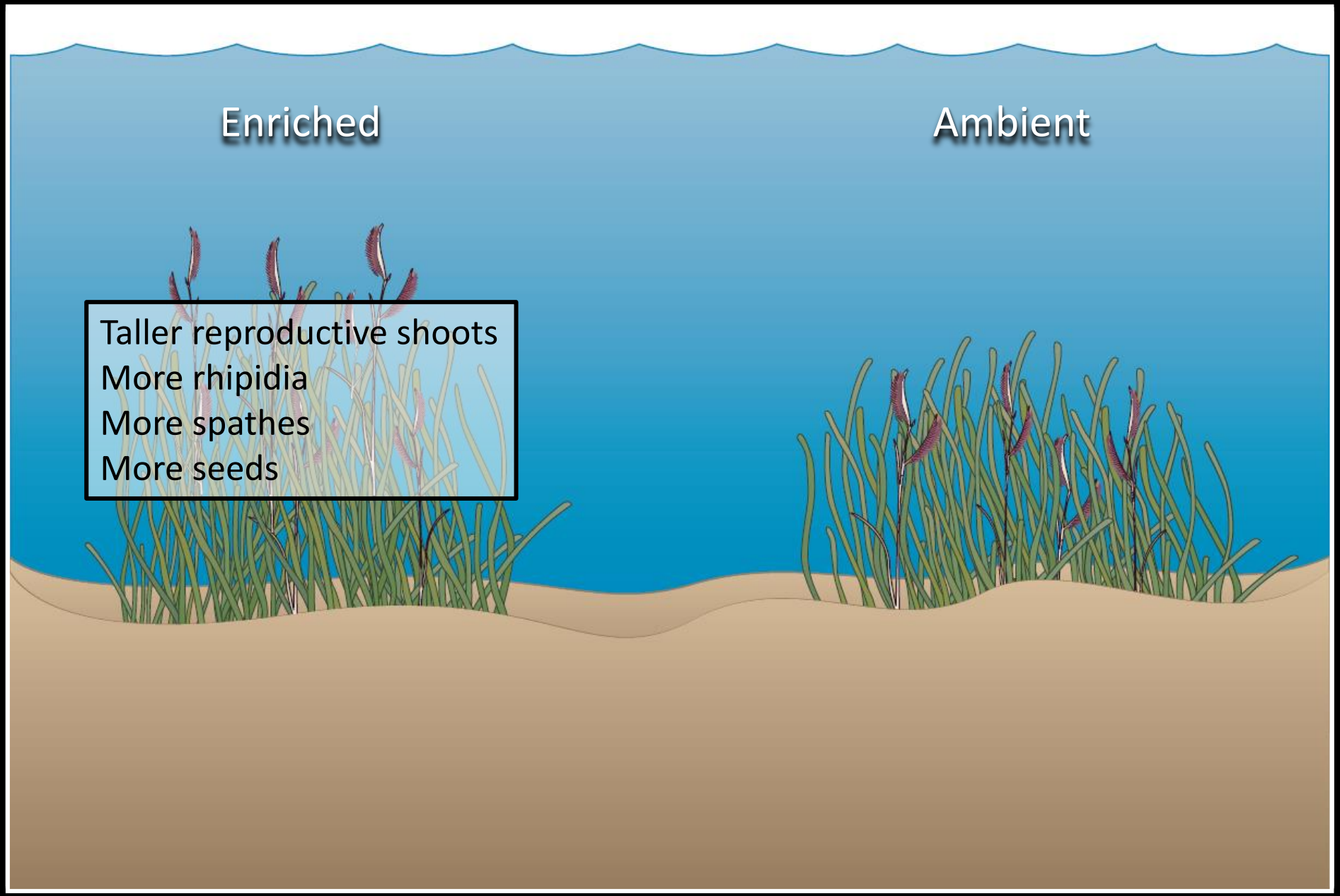
N:P:K 15:3:3

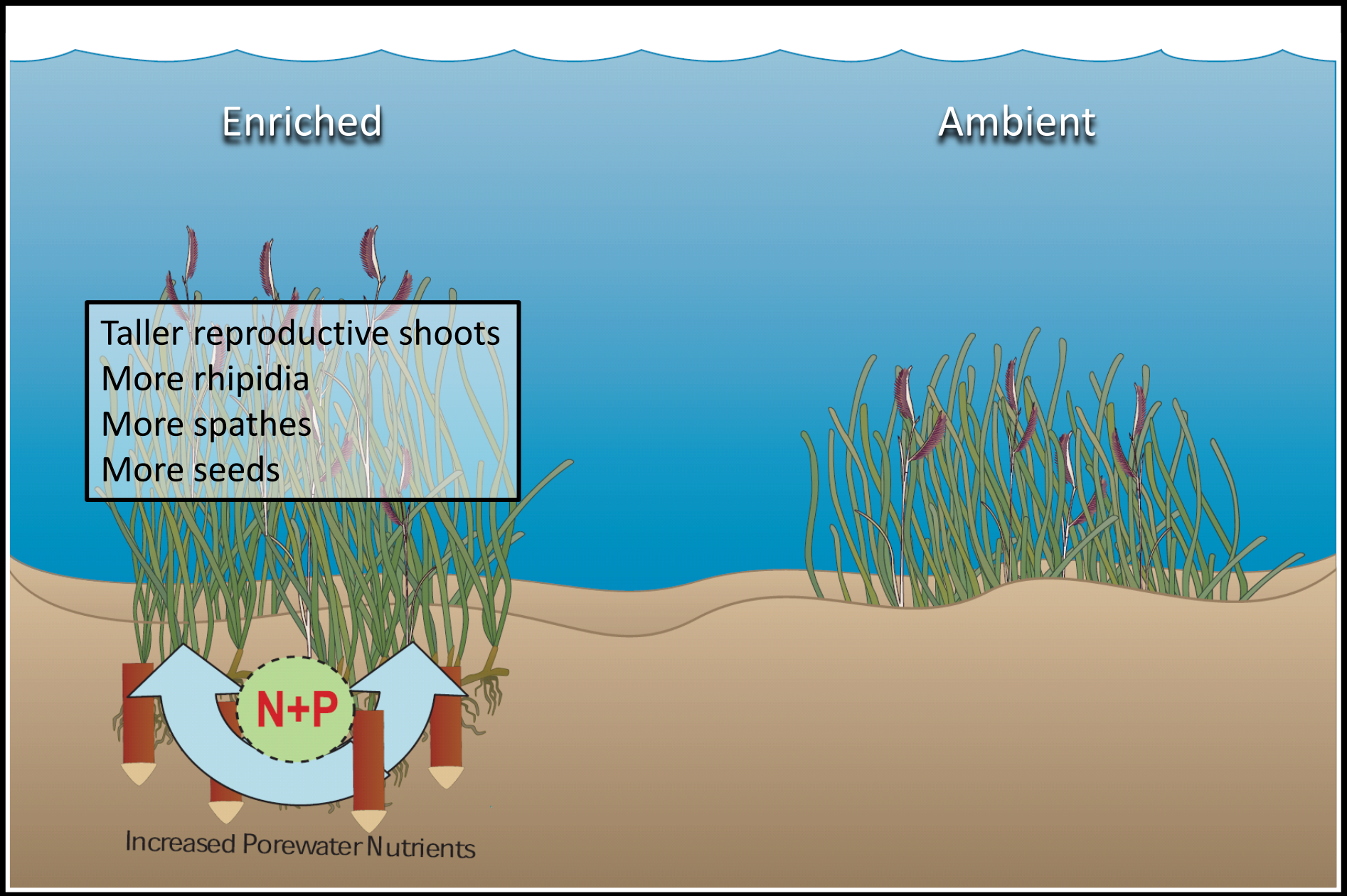
Live clams

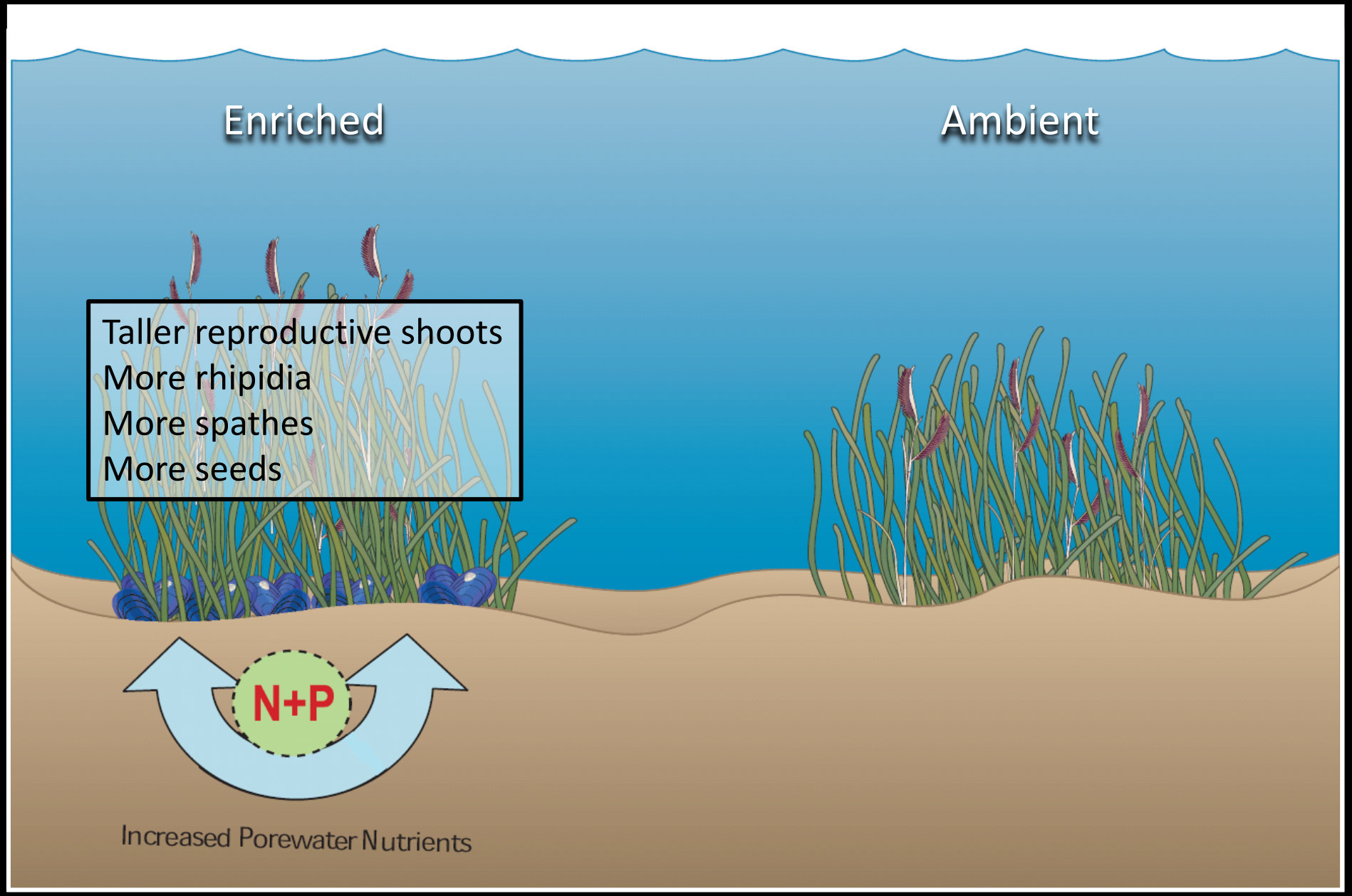
Dead clams + N:P:K

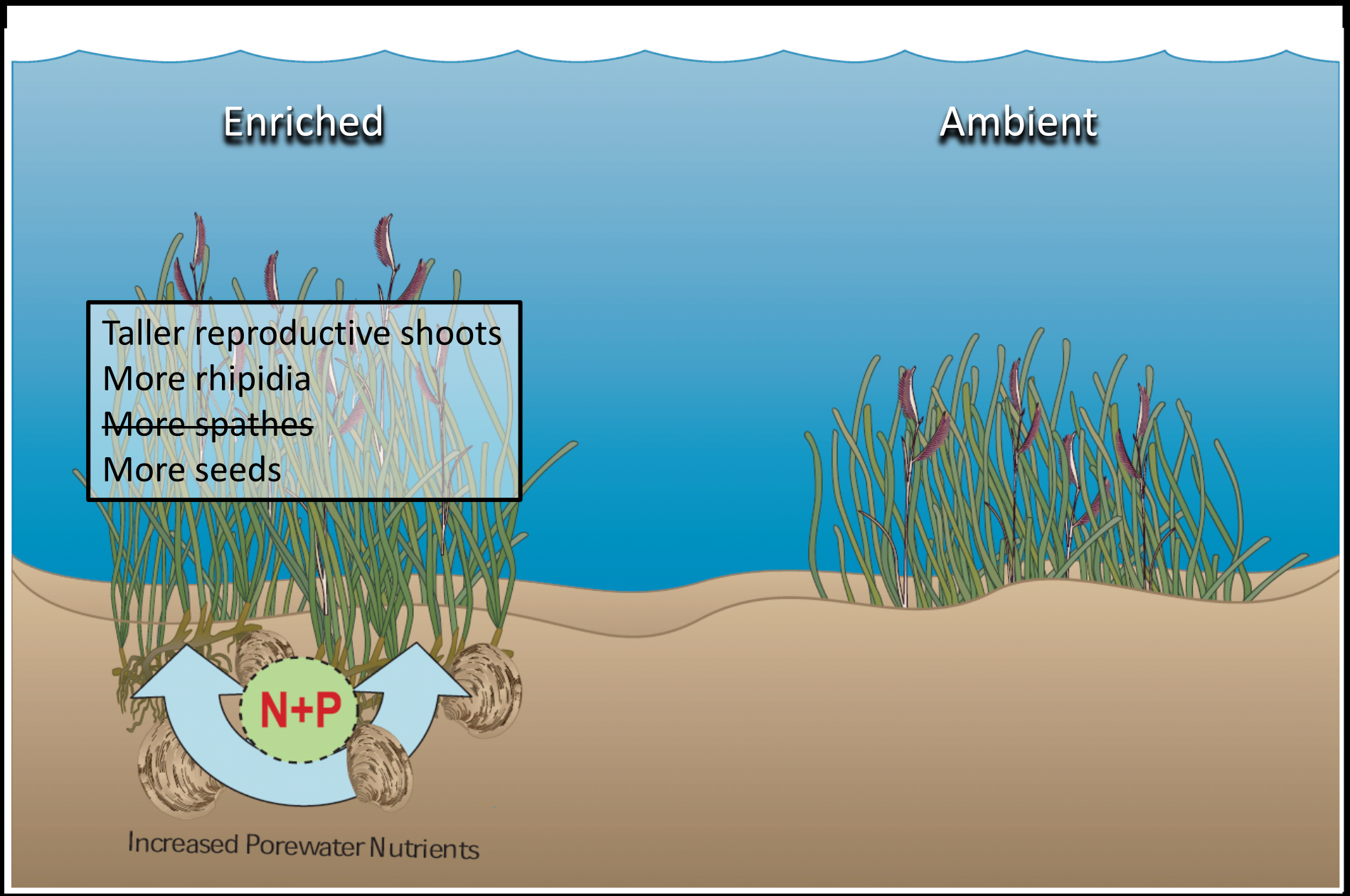
Dead clams

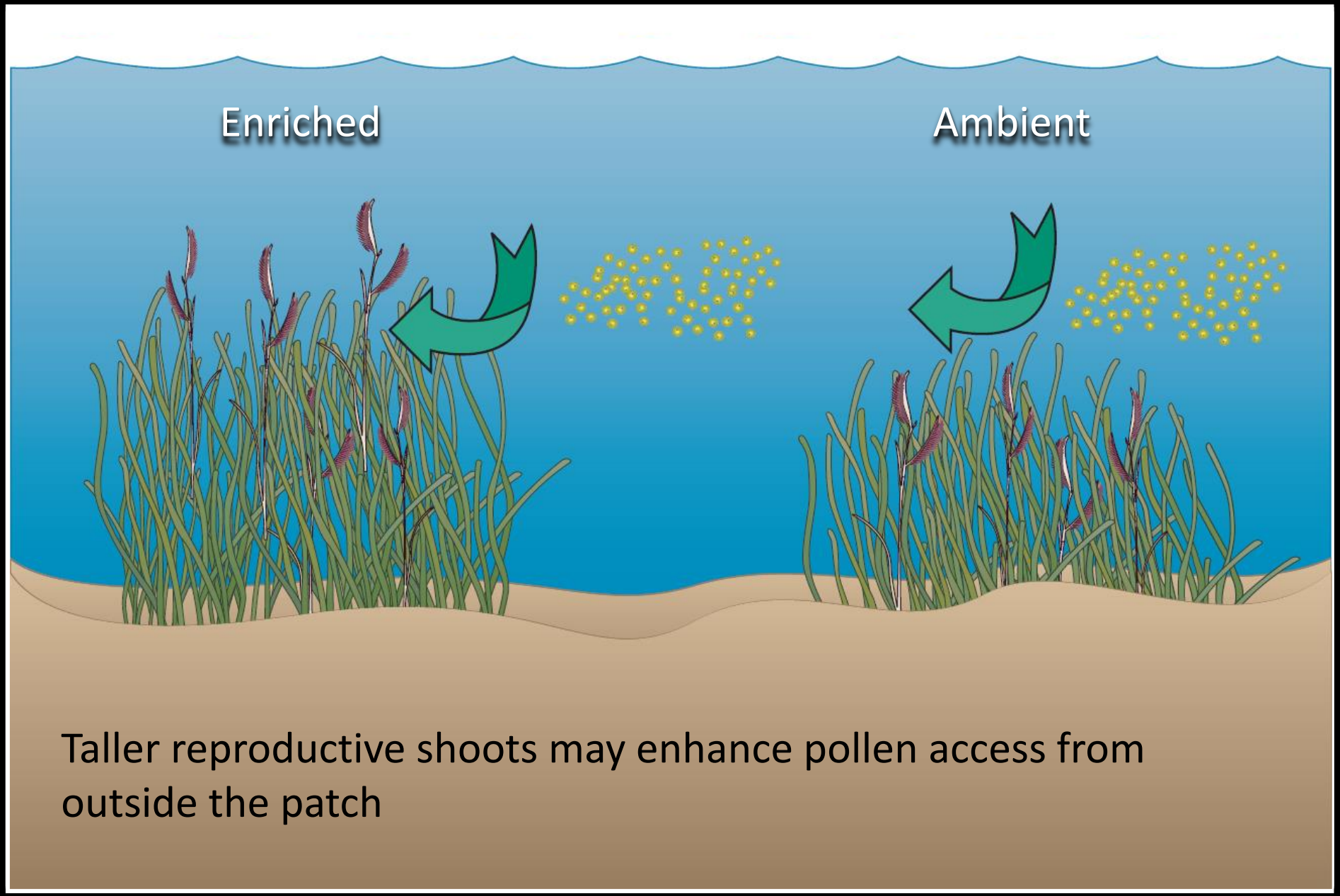
Natural recruitment


Enriched
Ambient
Taller reproductive shoots
More rhipidia
More spathes
More seeds

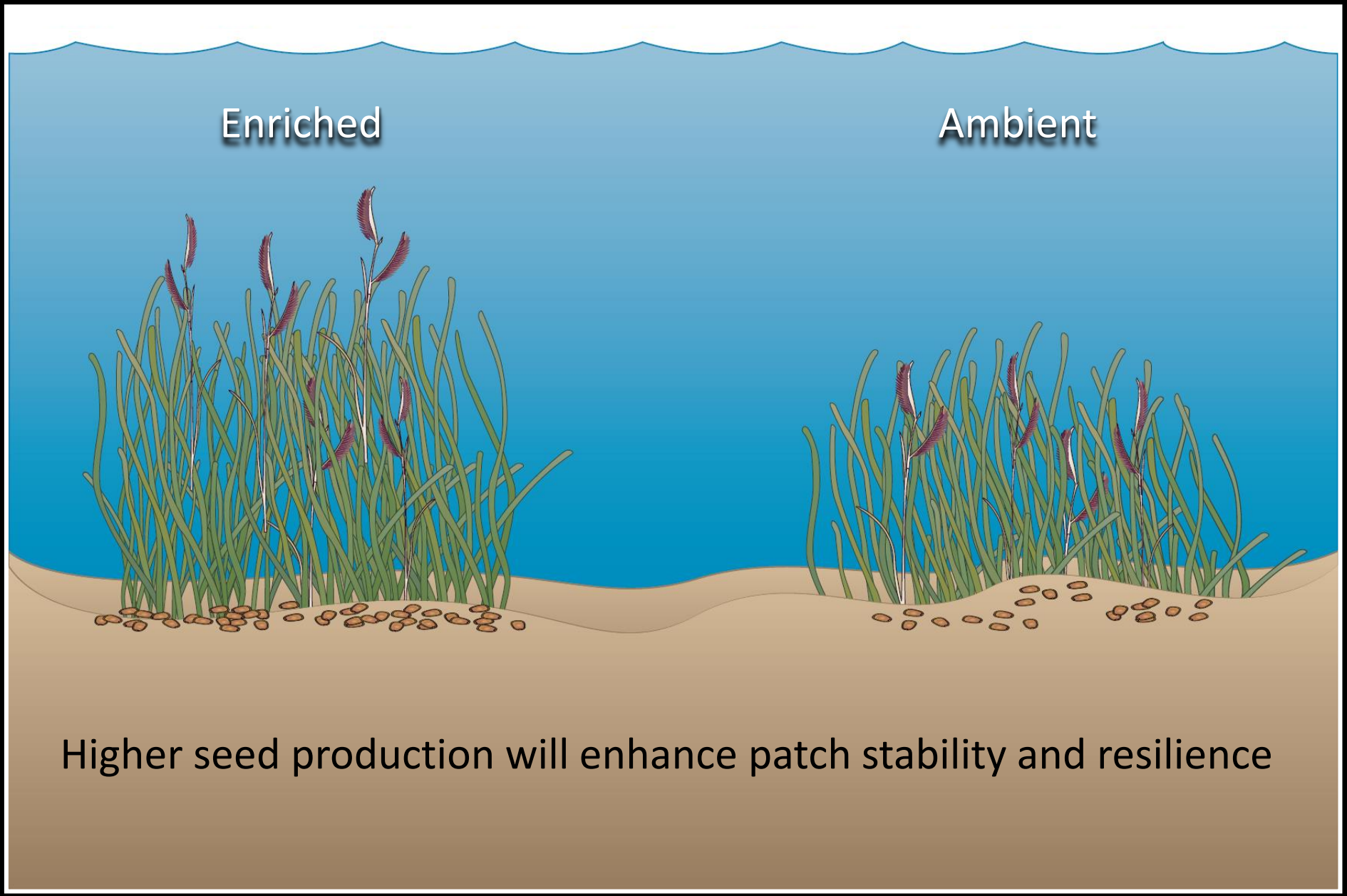

Enriched
Ambient
Taller reproductive shoots
More rhipidia
More spathes
More seeds
N+P
Increased Porewater Nutrients


Enriched
Ambient
Taller reproductive shoots
More rhipidia
More spathes
More seeds
N+P
Increased Porewater Nutrients

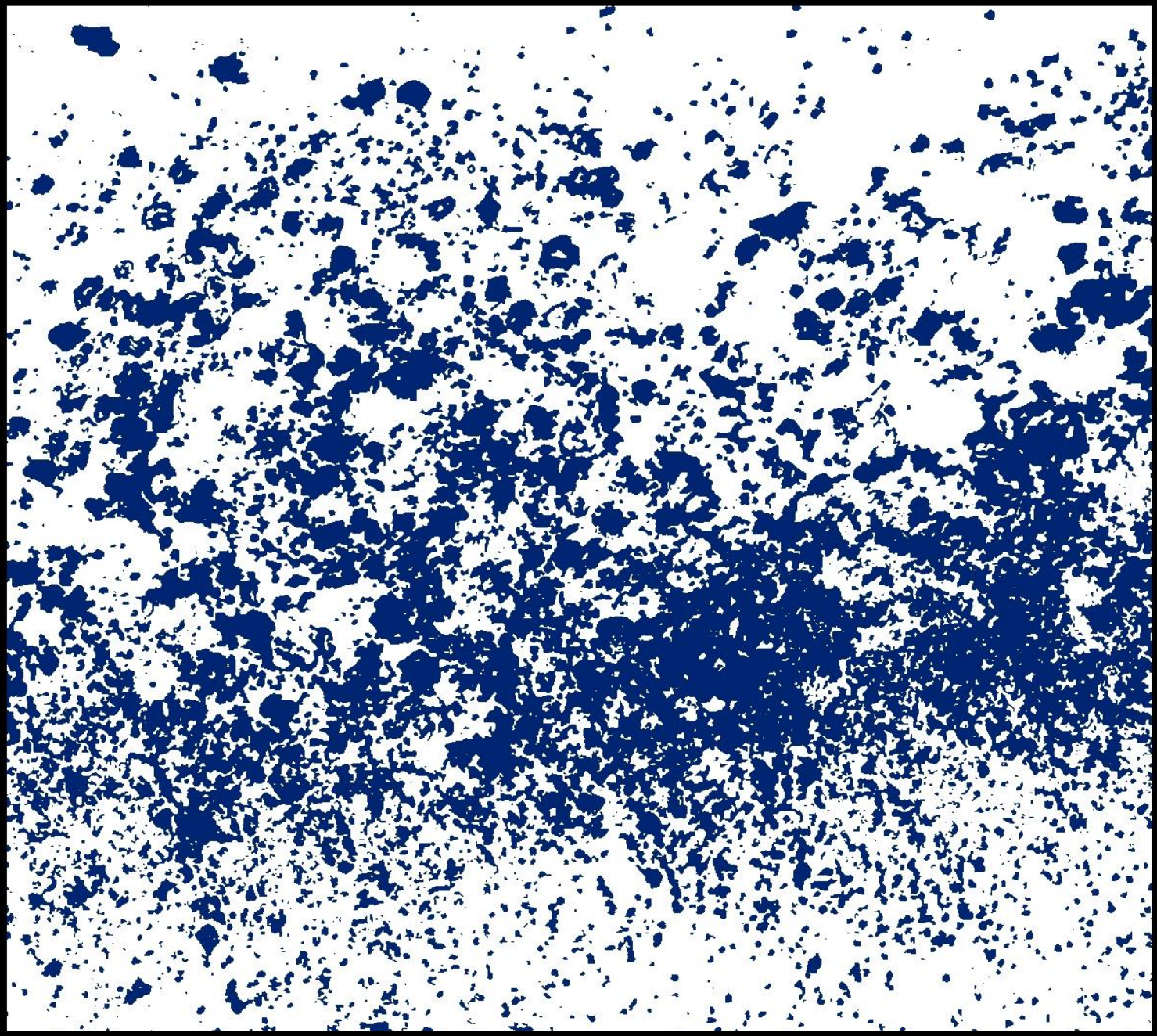

Enriched
Ambient
Taller reproductive shoots
More rhipidia
~~More spathes~~
More seeds
N+P
Increased Porewater Nutrients

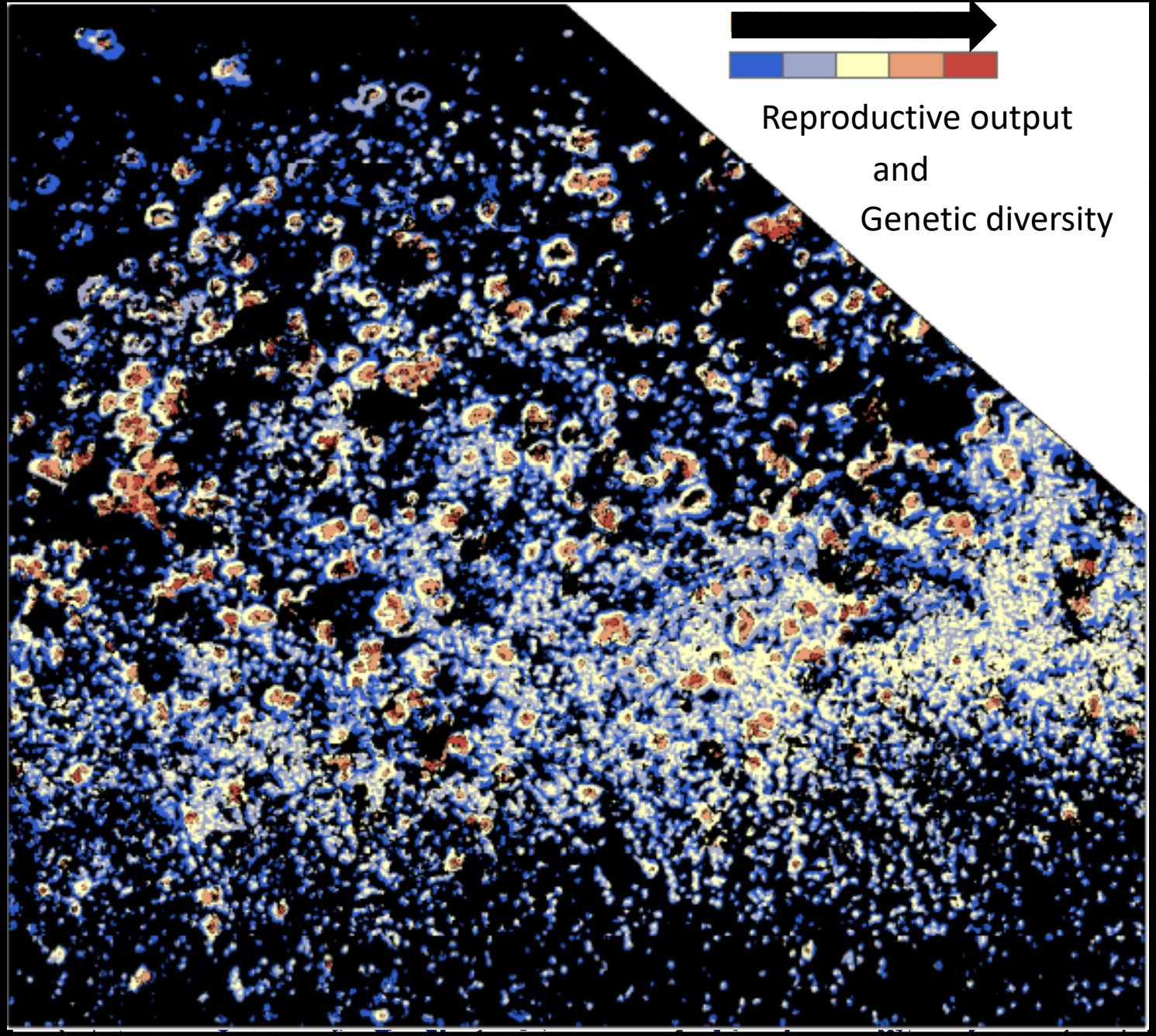


Taller reproductive shoots may enhance pollen access from outside the patch



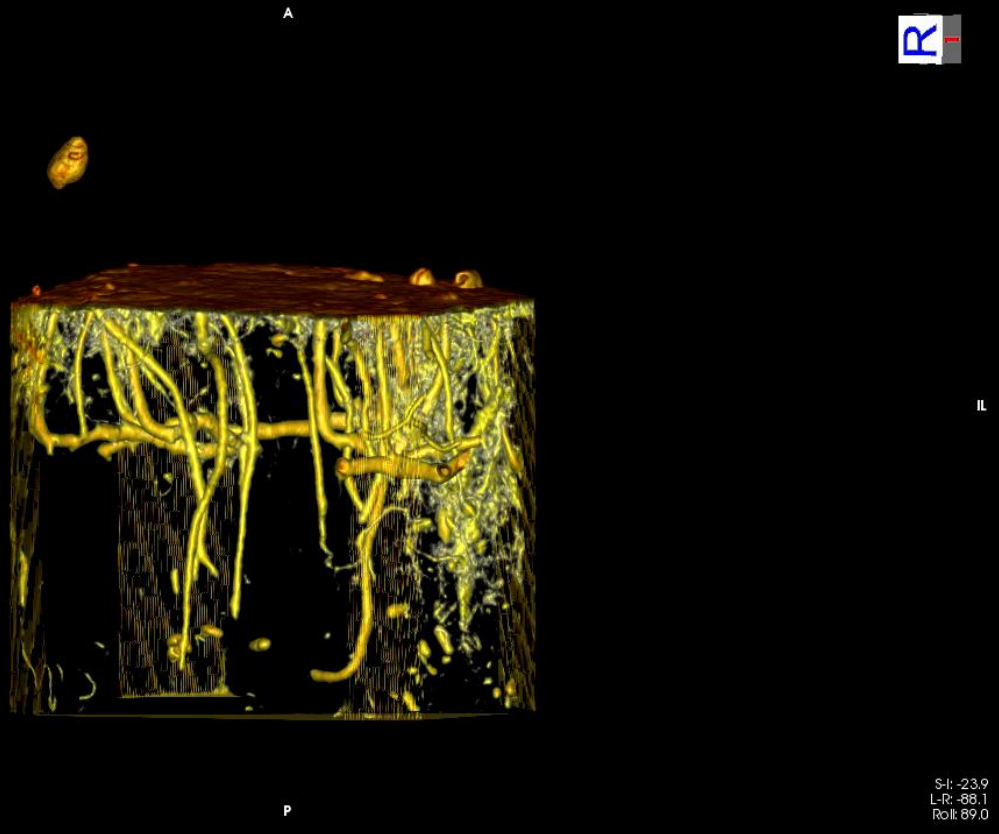
Higher seed production will enhance patch stability and resilience




Reproductive output
and
Genetic diversity

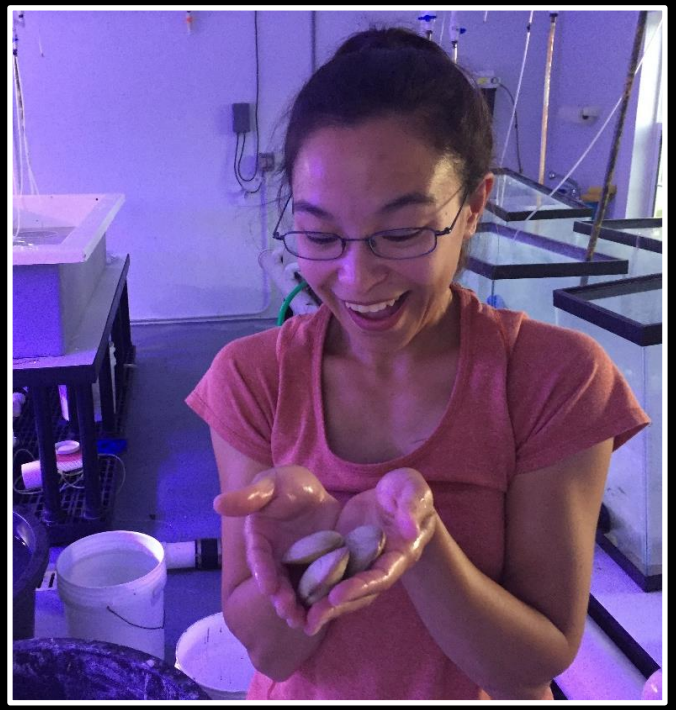
Dr. Kara Gadeken

What about within the sediments?



What role can organisms play in modifying *toxicity stress* to the benthic plant community?

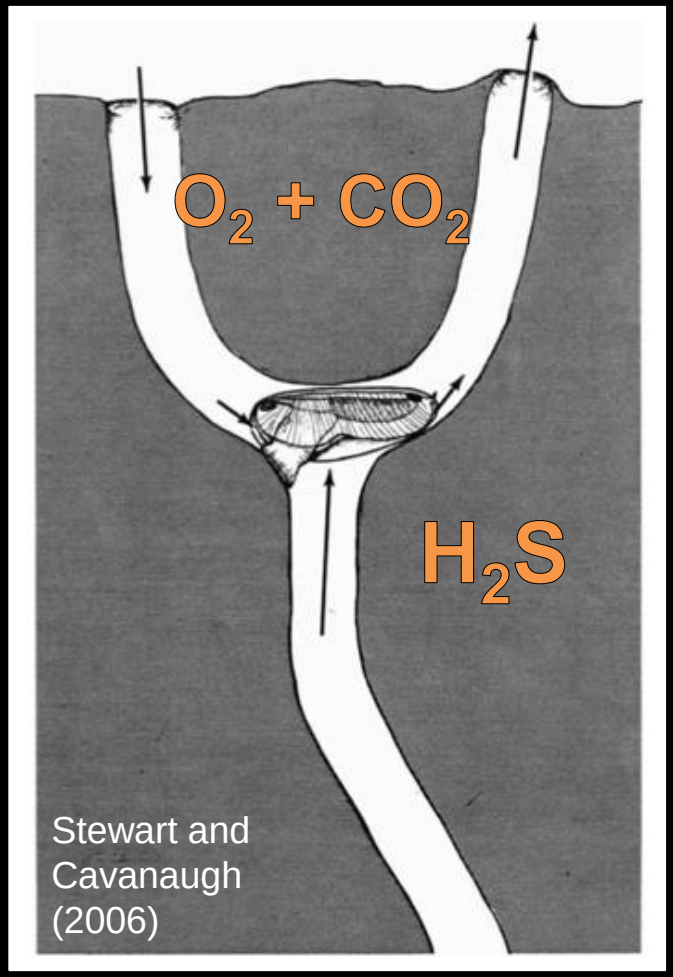
Chemosynthetic bivalves reducing sediment sulfide levels



Chin et al. 2021 J.of Ecology 109: 204-217

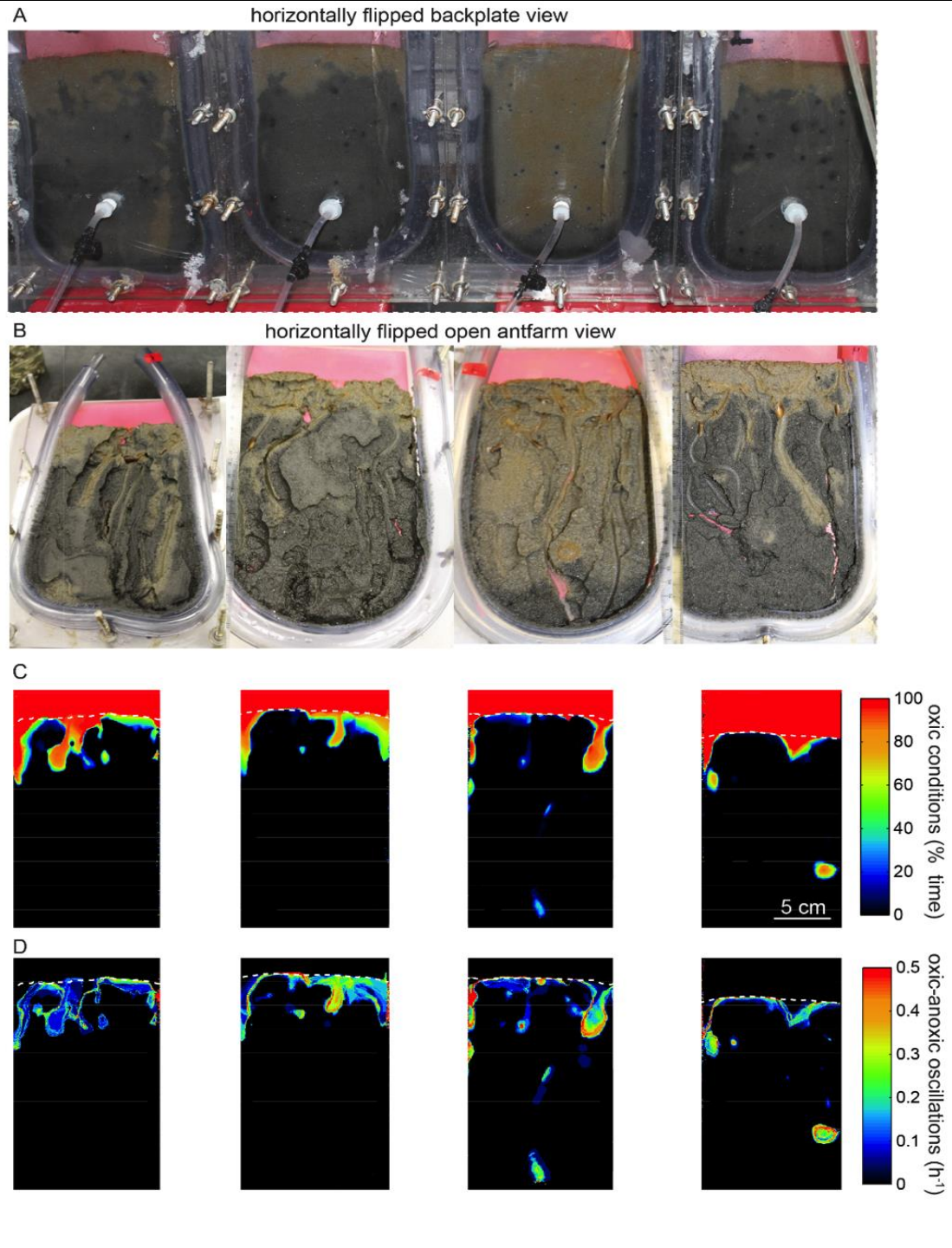
Solemya velum

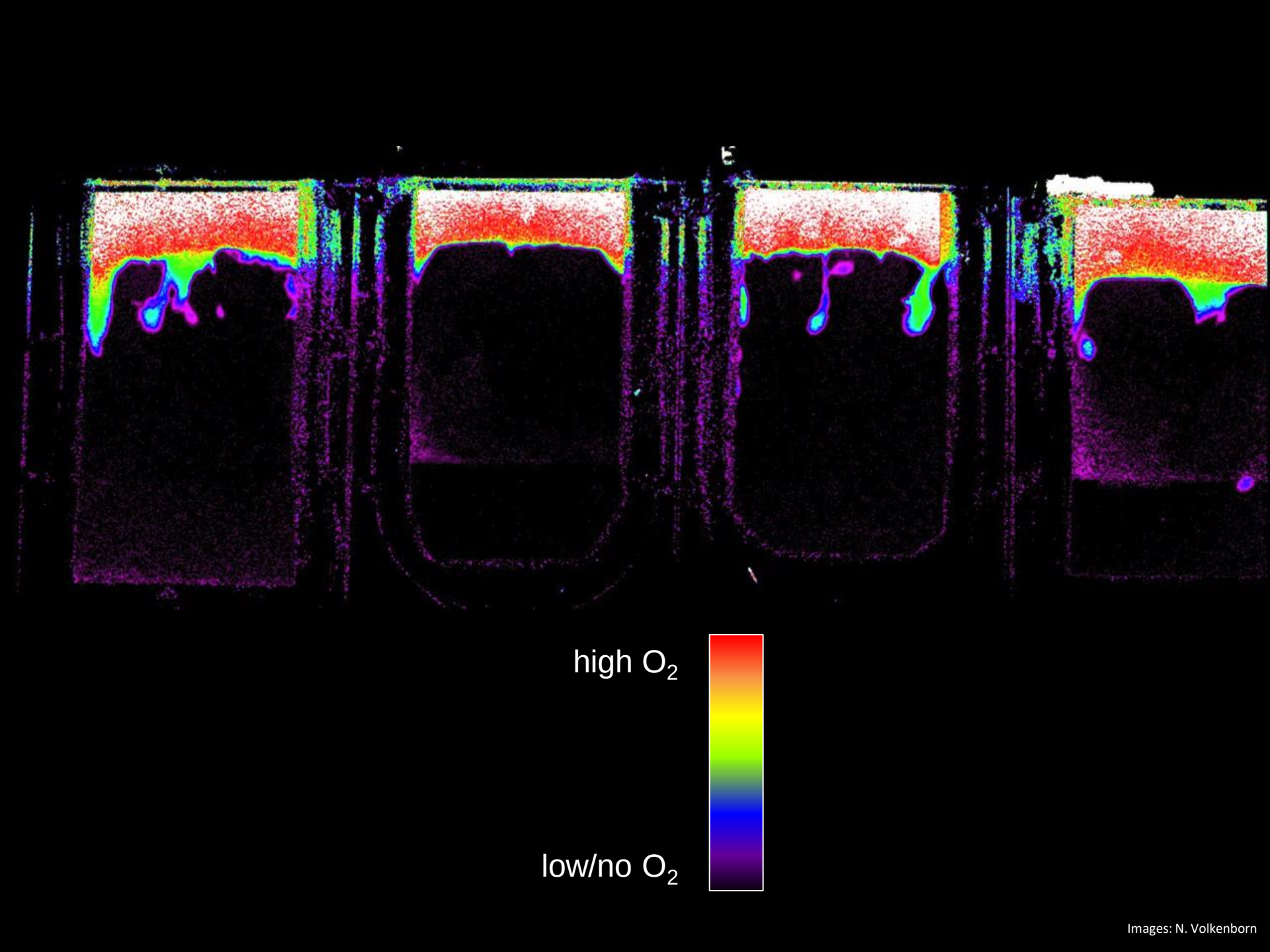
$H_2S + O_2 + CO_2 \rightarrow SO_4^{-2}$ + organic C



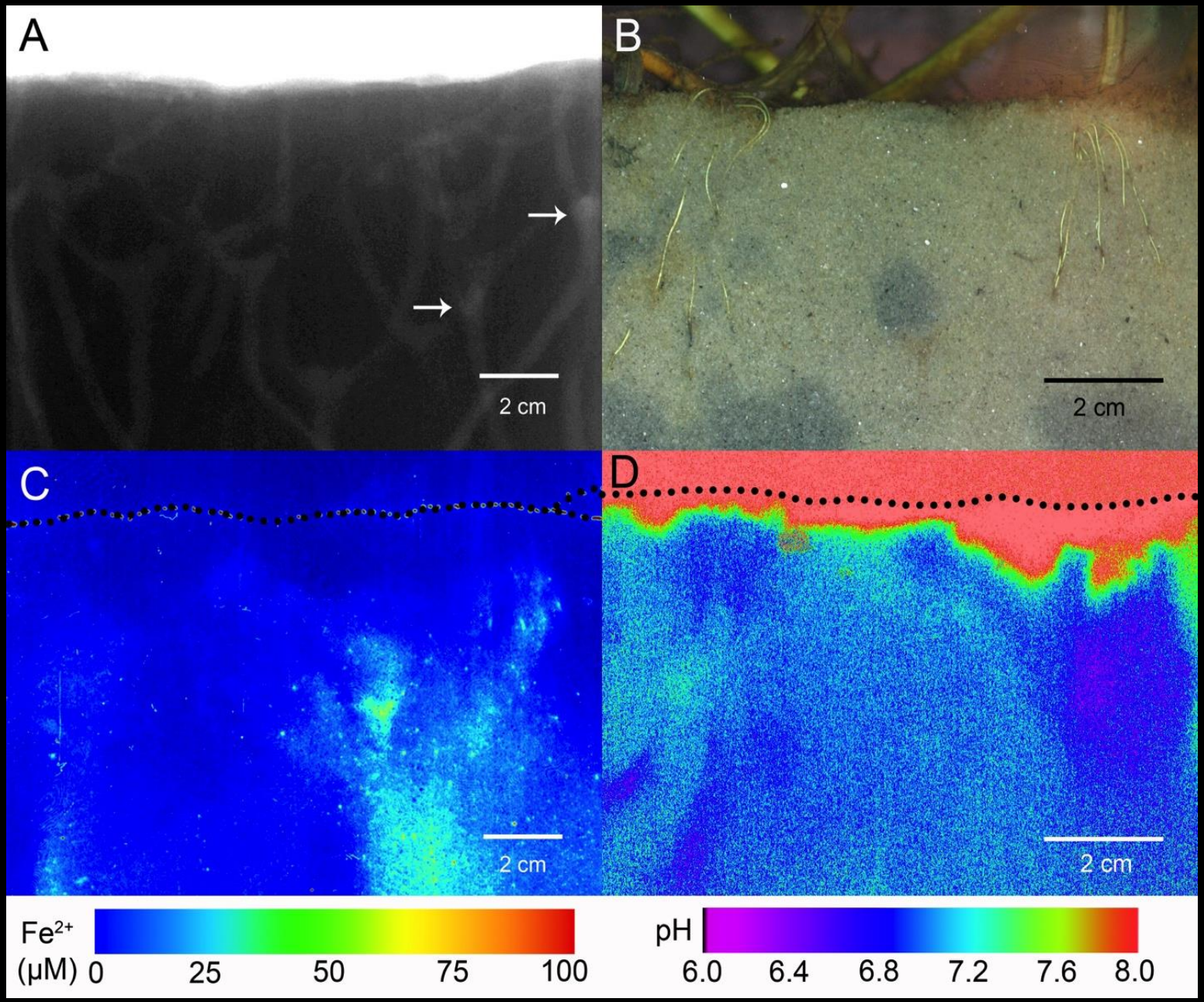
~97-98% of C requirement

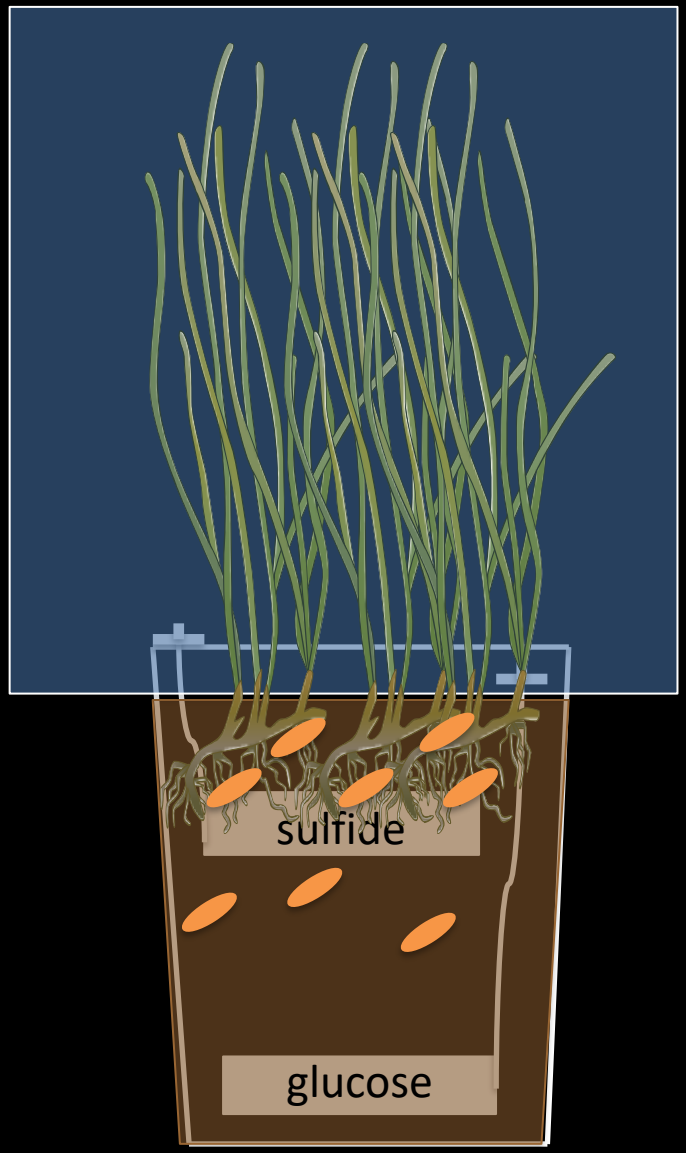
Conway et al. (1998), Krueger et al. (1992)


A
horizontally flipped backplate view
B
horizontally flipped open antfarm view
C
5 cm
100
80
60
40
20
0
oxic conditions (% time)
D
0.5
0.4
0.3
0.2
0.1
0
oxic-anoxic oscillations (h-1)



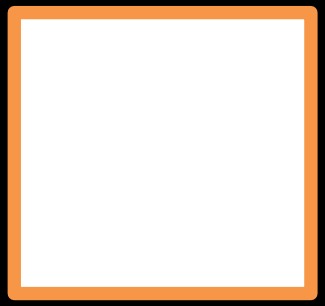
Images: N. Volkenborn

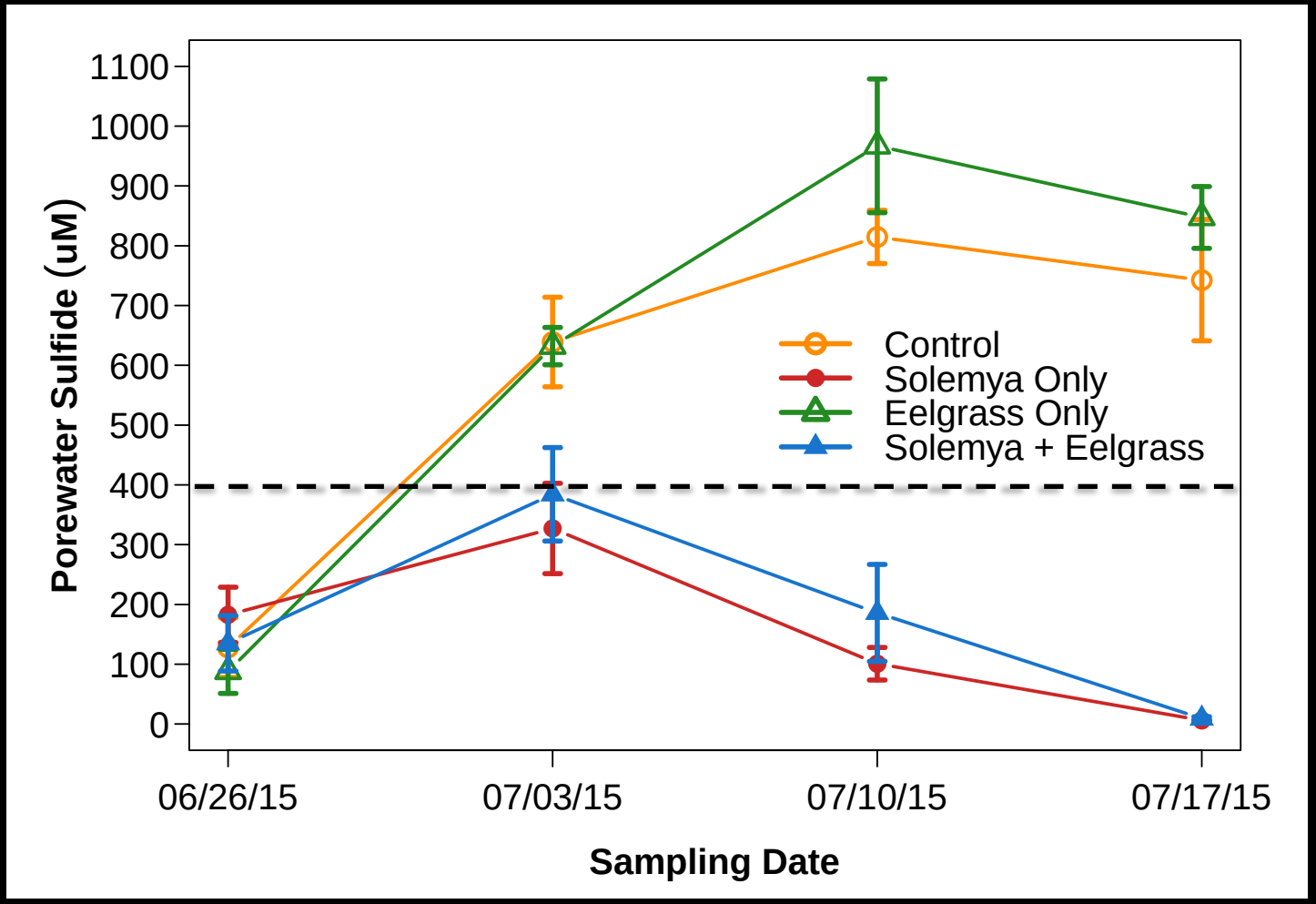

A
B
C
D
2 cm
2 cm
2 cm
2 cm
Fe2+
(μM) 0 25 50 75 100
pH
6.0 6.4 6.8 7.2 7.6 8.0



Images: D. Chin, www.marlin.ac.uk

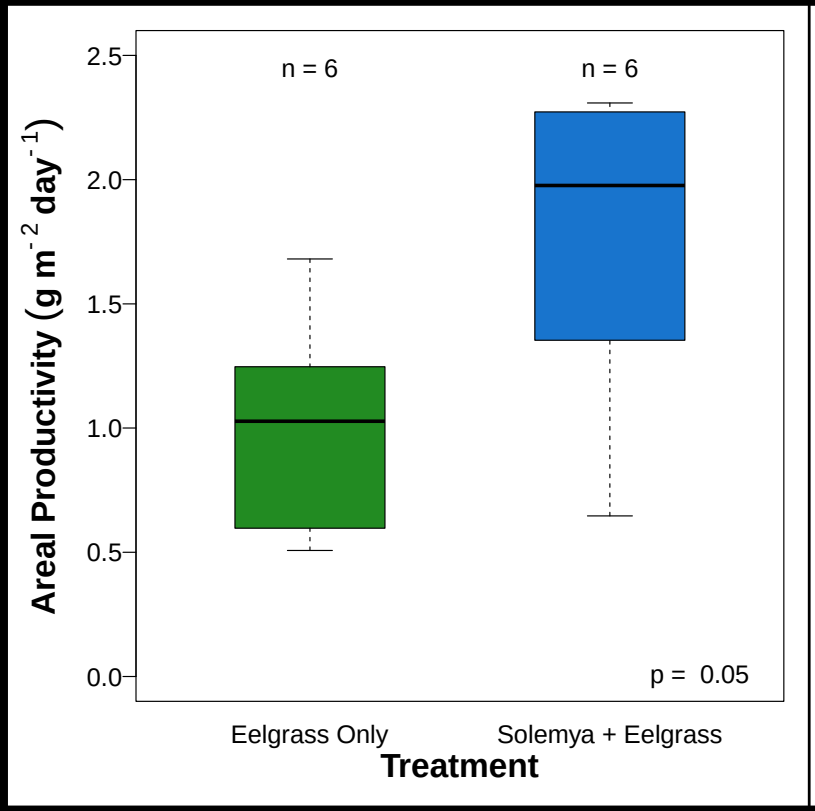
Porewater sulfide concentrations are lower when *Solemya* is present

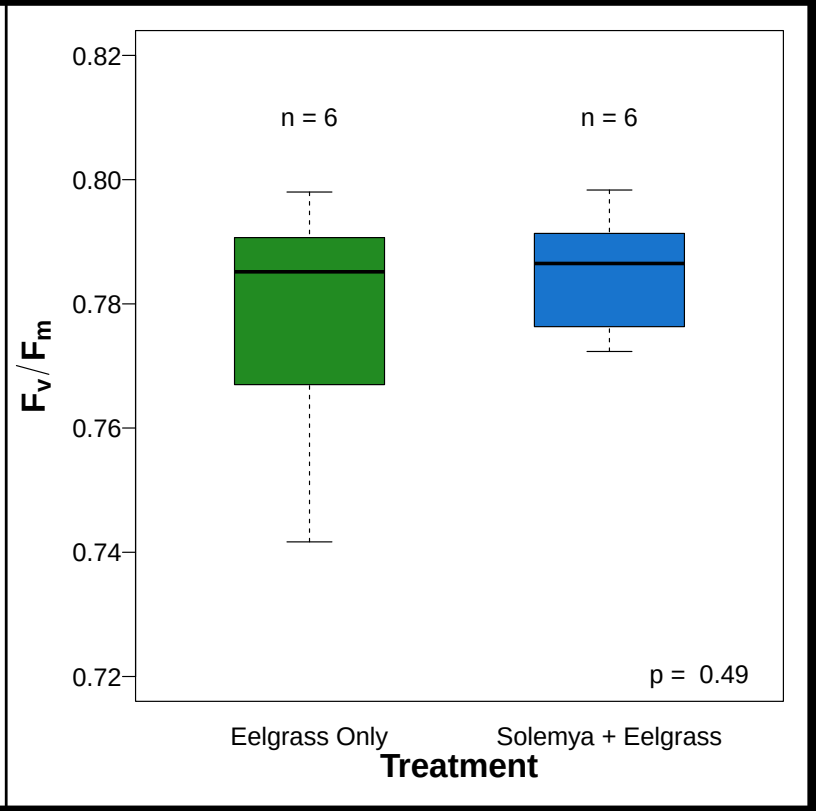




Images: D. Chin, www.marlin.ac.uk

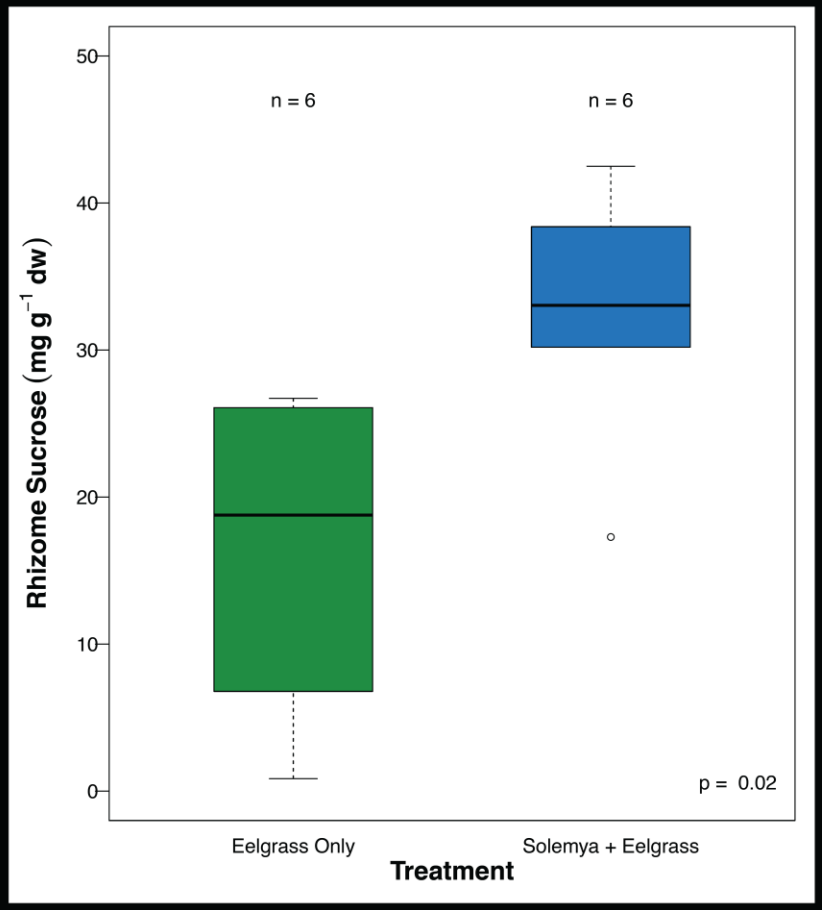
Eelgrass is more productive (by biomass) when *Solemya* is present but not more photosynthetically efficient





Images: D. Chin, www.marlin.ac.uk

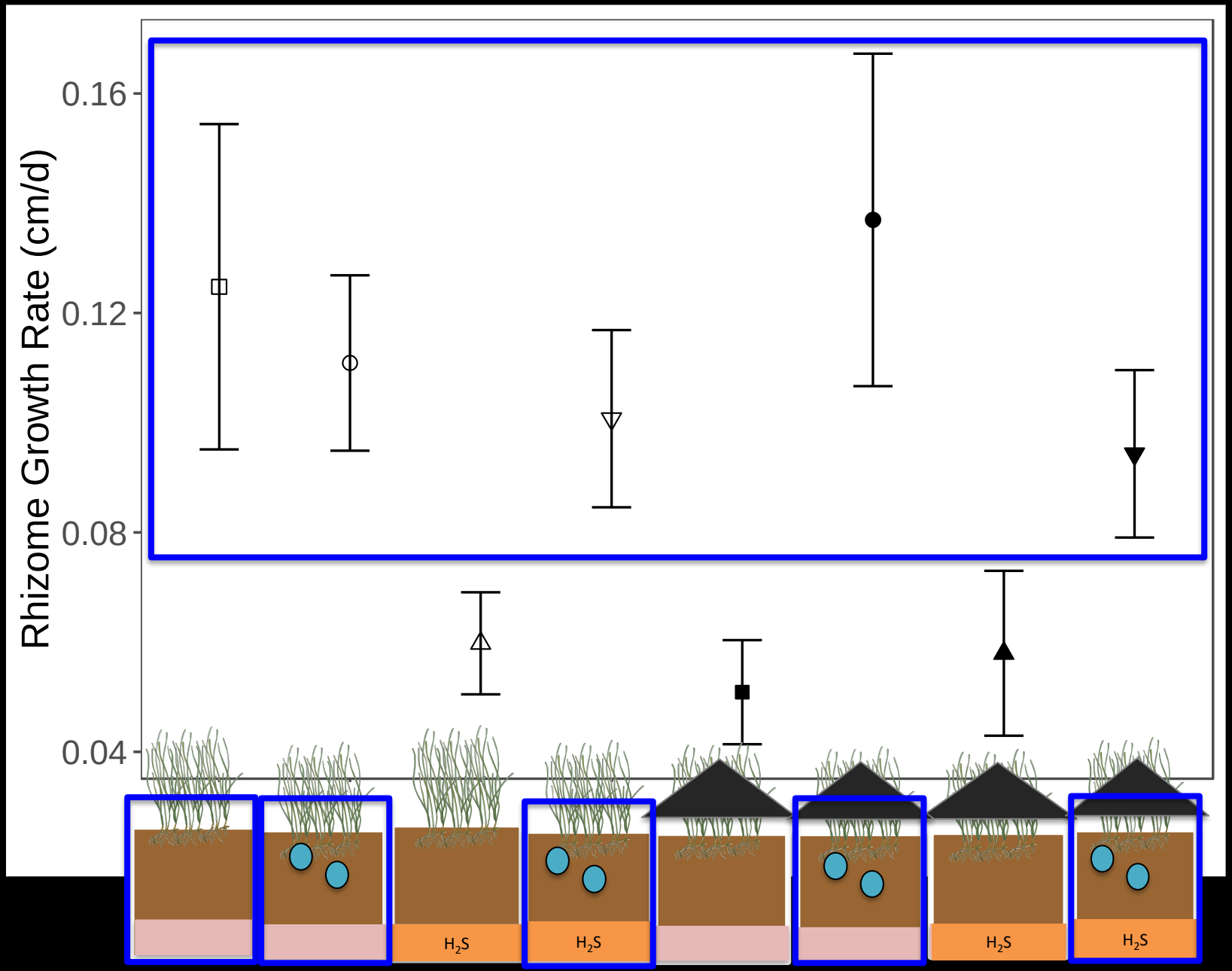
Eelgrass rhizomes have more soluble carbohydrates when *Solemya* is present



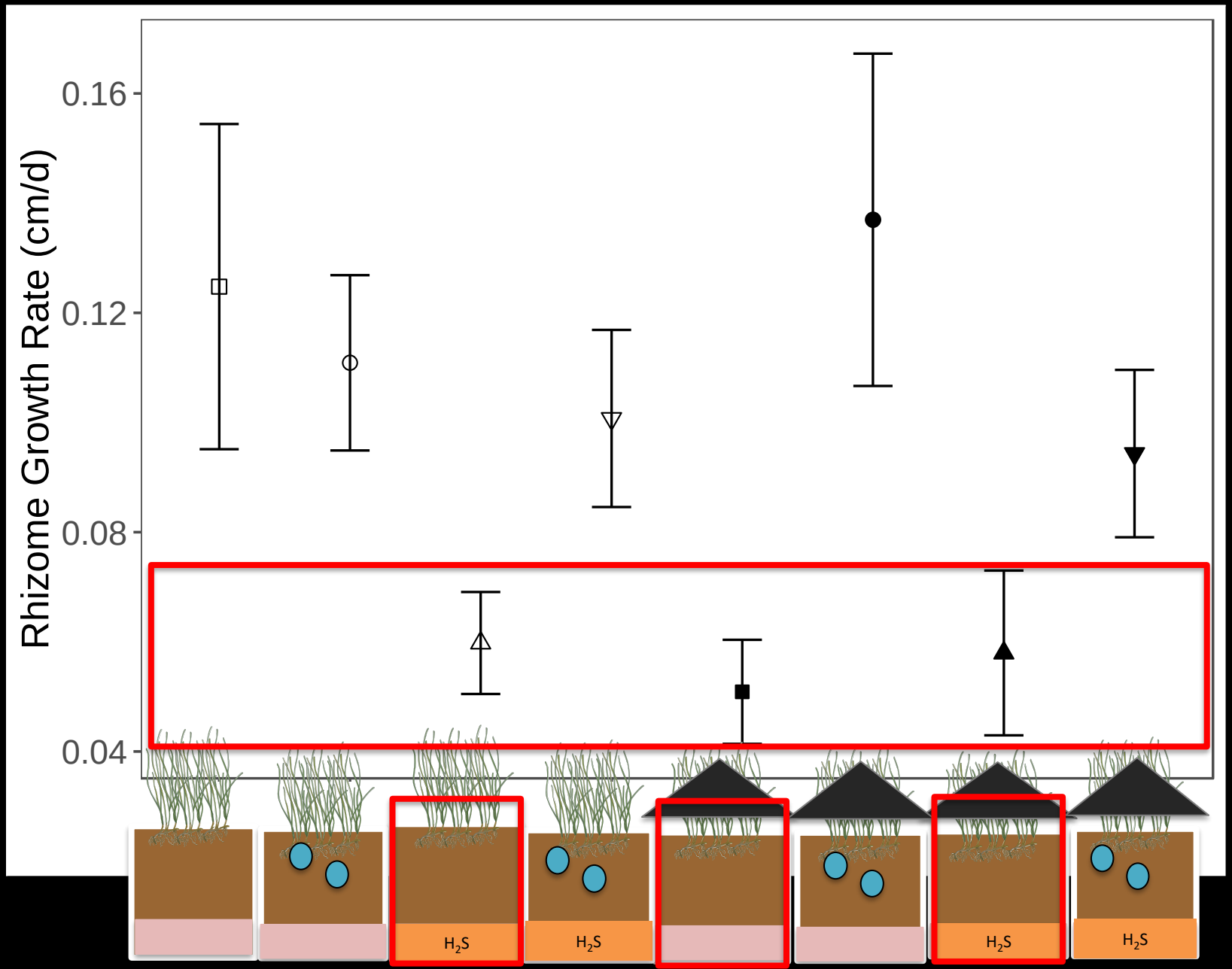
Images: D. Chin, www.marlin.ac.uk

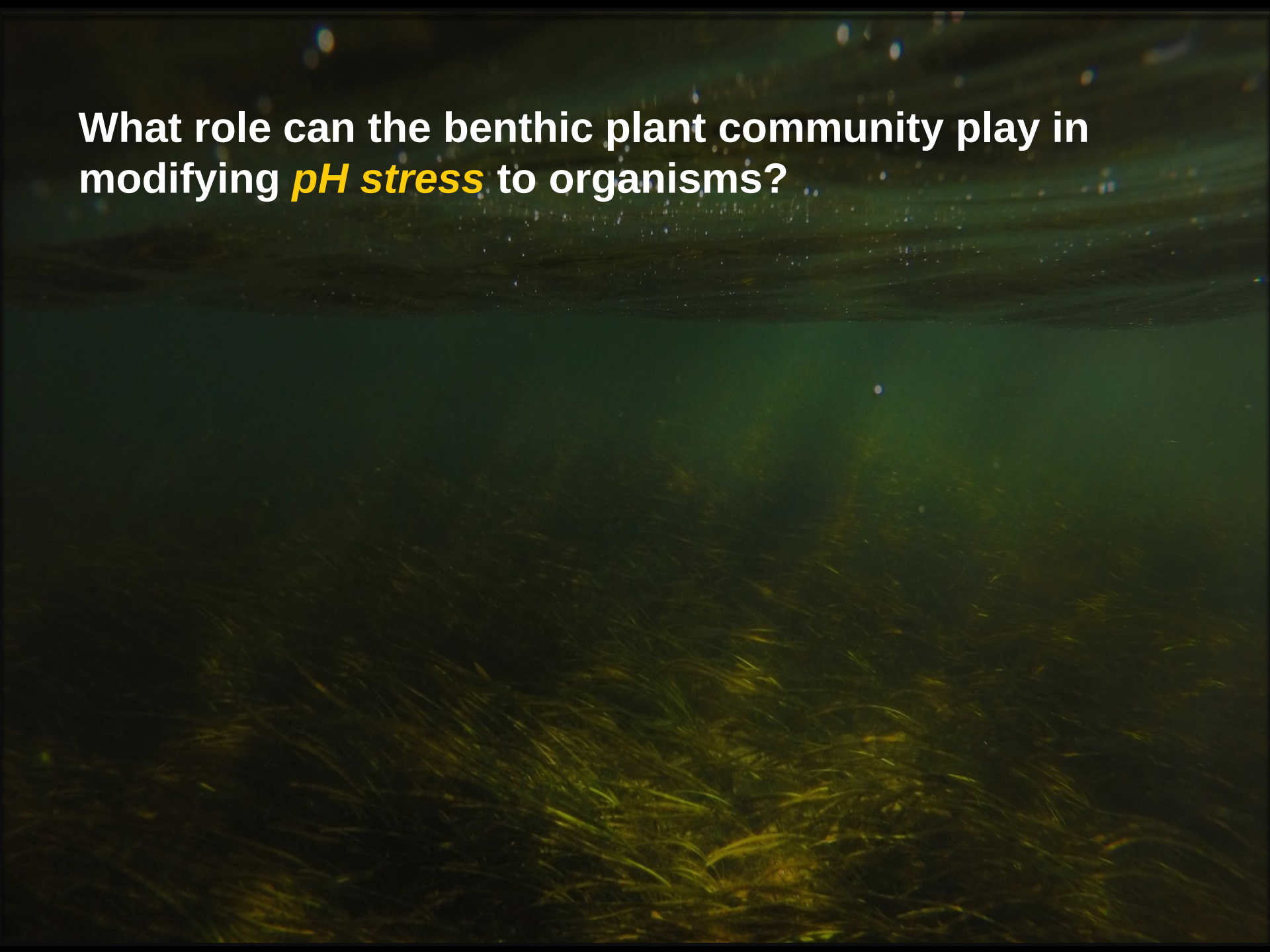
Codakia orbicularis

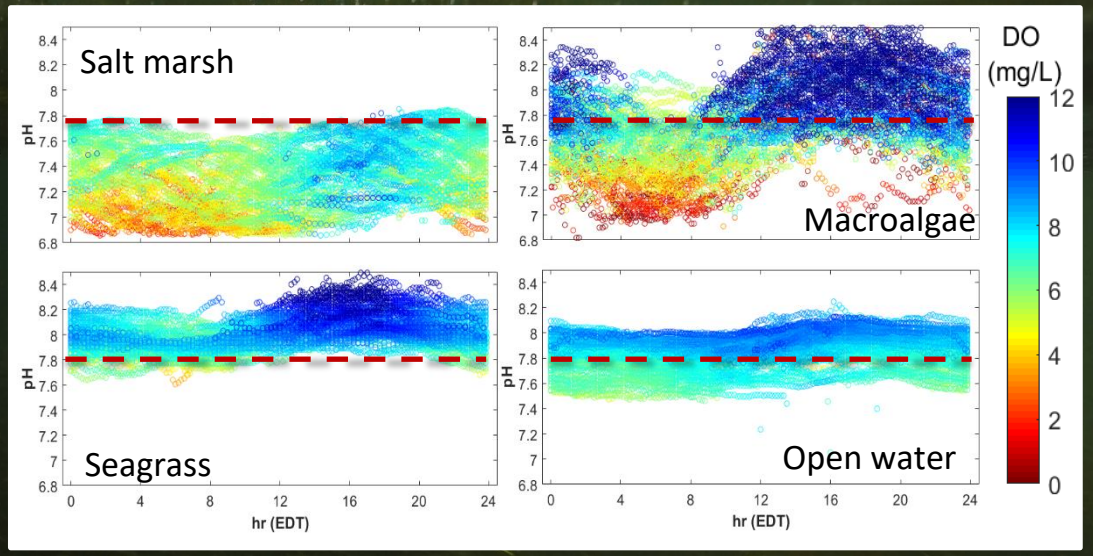
Lucinids helped *Thalassia* grow despite low light and/or high sulfide



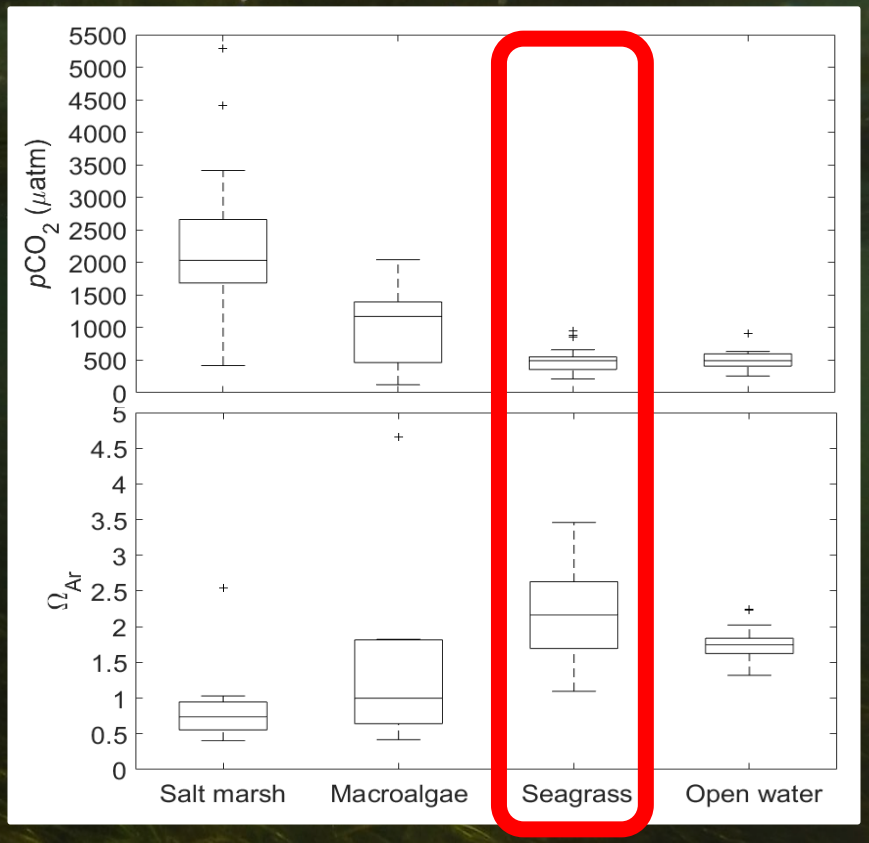
Lucinids helped *Thalassia* grow despite low light and/or high sulfide



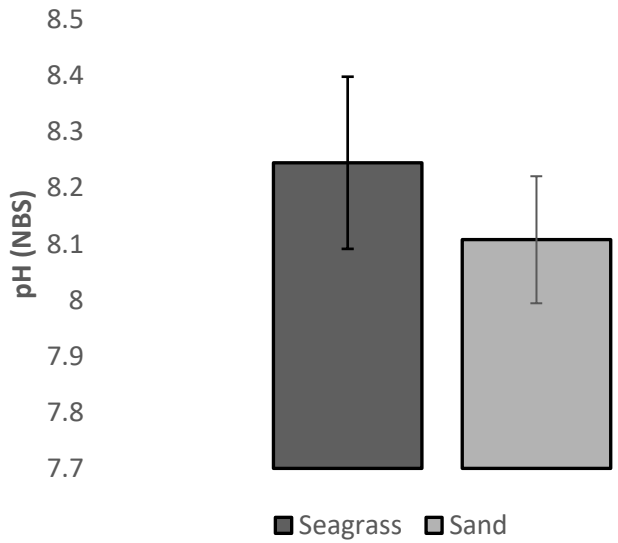

What role can the benthic plant community play in modifying *pH stress* to organisms?



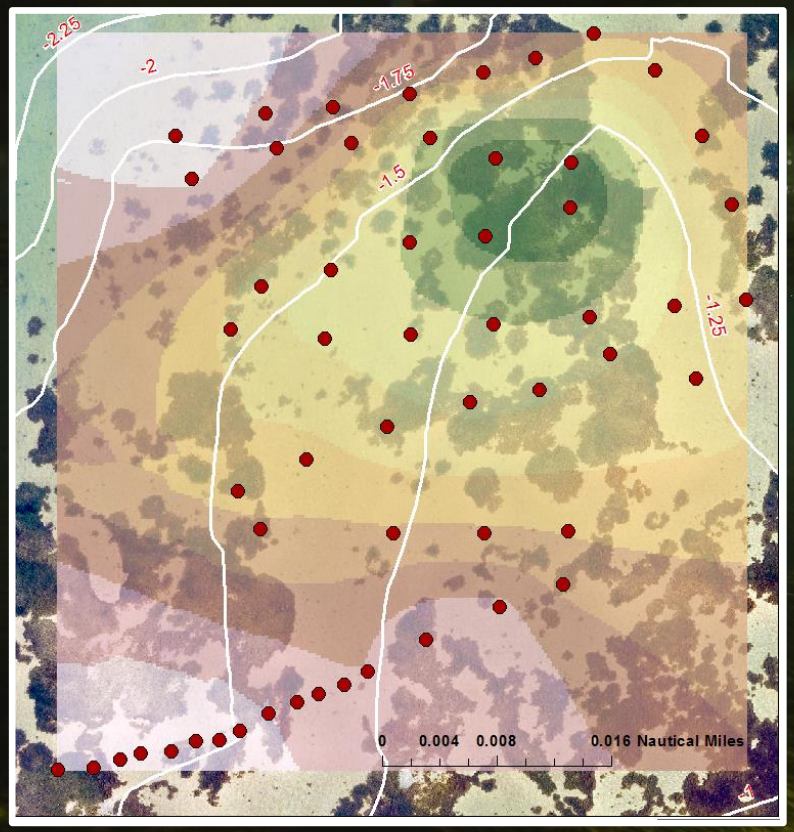
Wallace et al. 2021 Front Mar Sci 8:611781

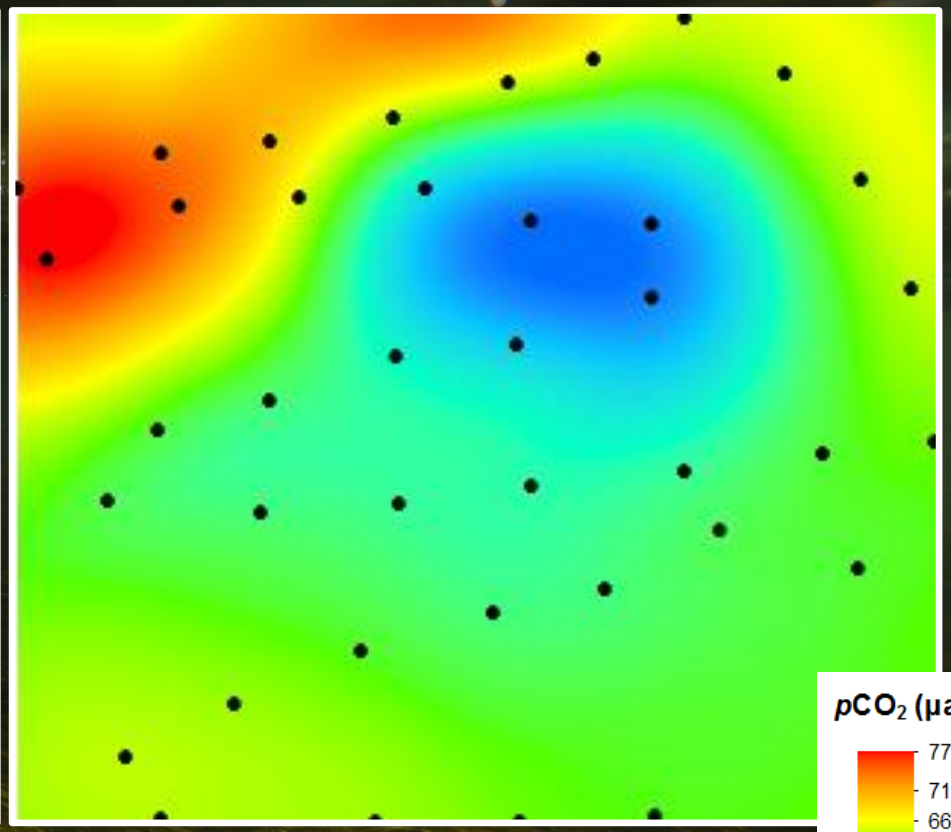


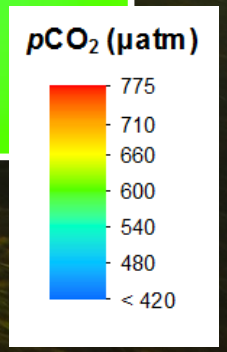
Wallace et al. 2021 Front Mar Sci 8:611781

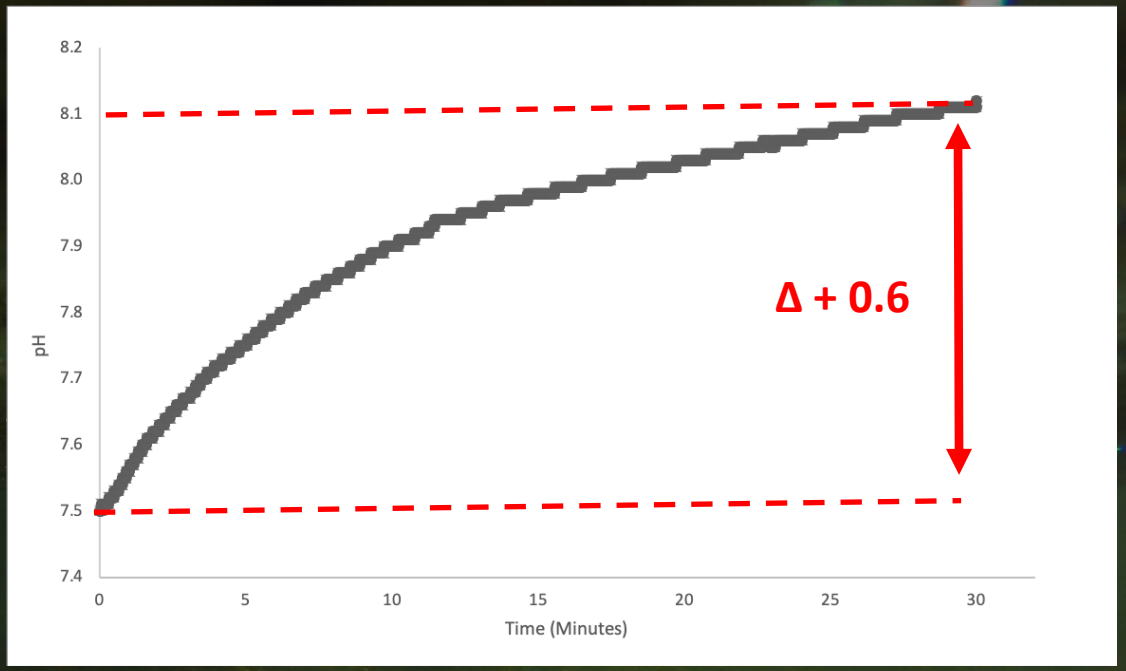


pH in relation to Substrate. A comparison of pH values taken from within the canopy to unvegetated sediments (p = 0.002).


-2.25
-2
-1.75
-1.5
-1.25
-1
0 0.004 0.008 0.016 Nautical Miles



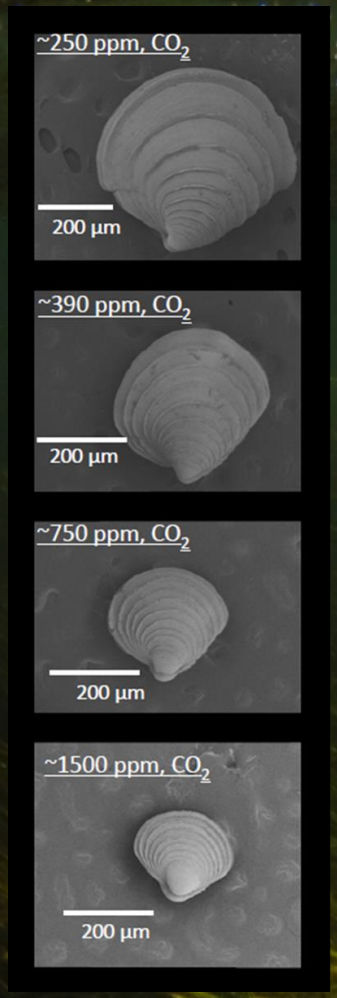

pCO_2 (µatm)
775
710
660
600
540
480
< 420


8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
pH
0
5
10
15
20
25
30
Time (Minutes)
Δ + 0.6

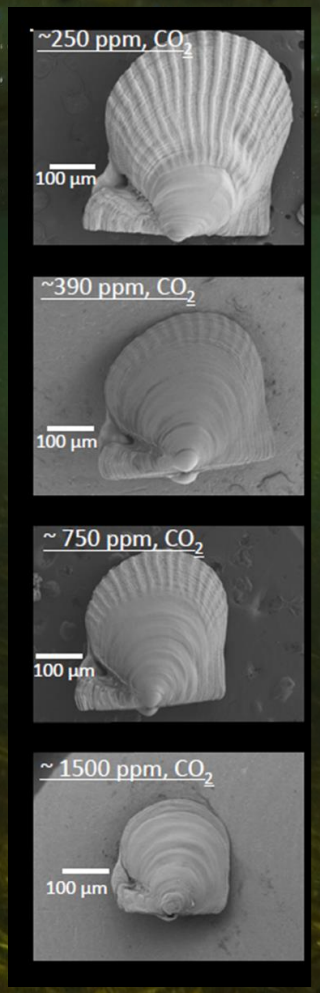
Low CO_2

High CO_2

Hard clam

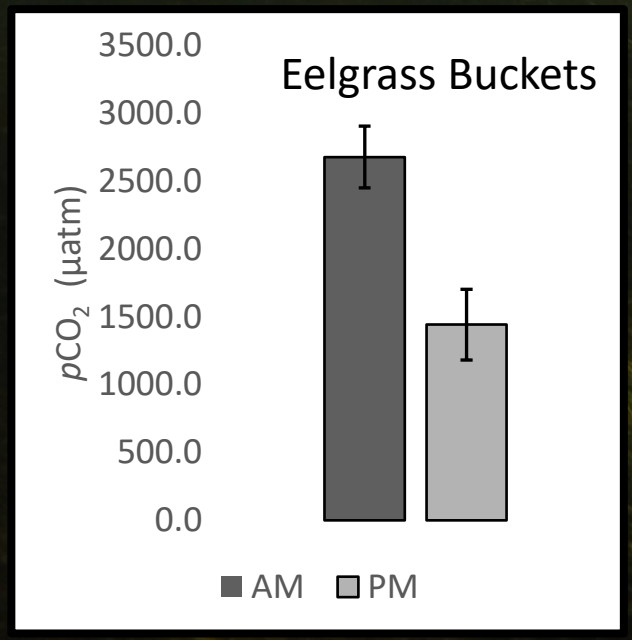


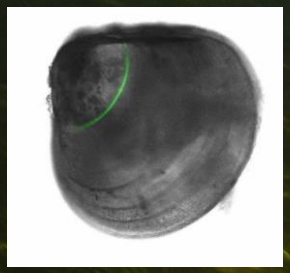
Bay scallops

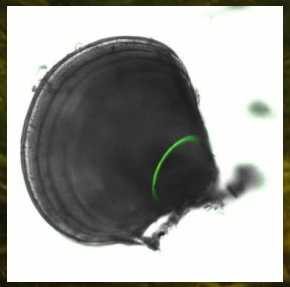


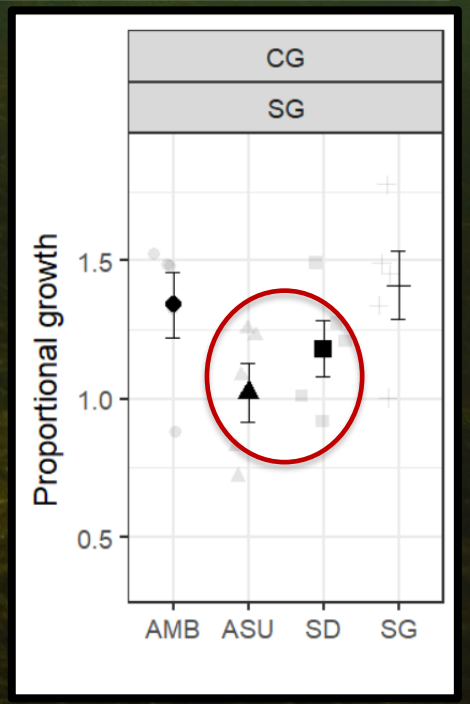
Talmage & Gobler 2010 PNAS 107: 17246

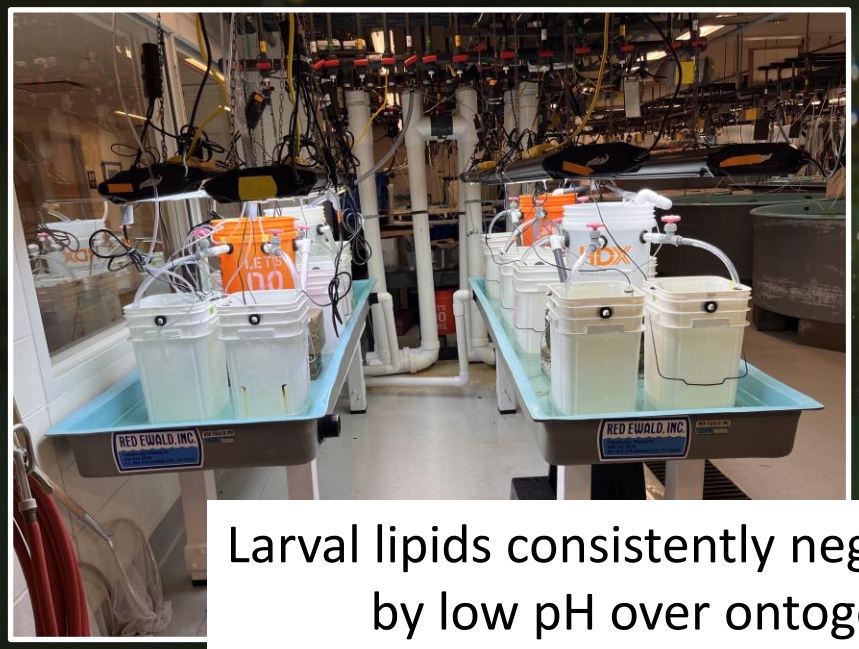

RED EWALD, INC.
RED EWALD, INC.


Eelgrass Buckets
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
pCO2 (µatm)
AM
PM

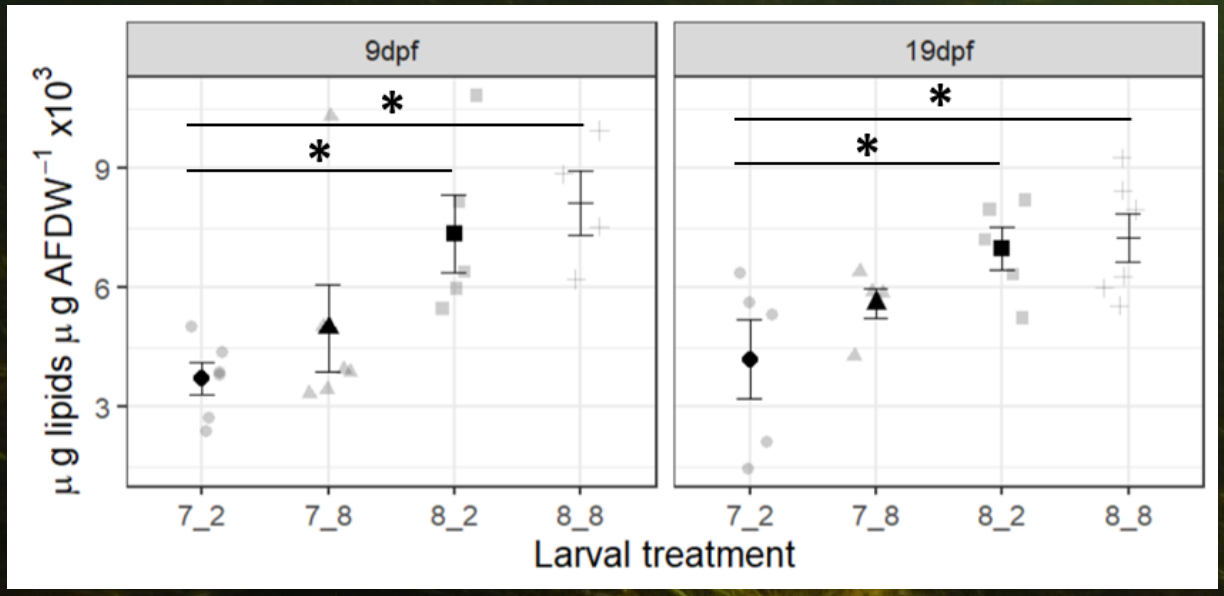




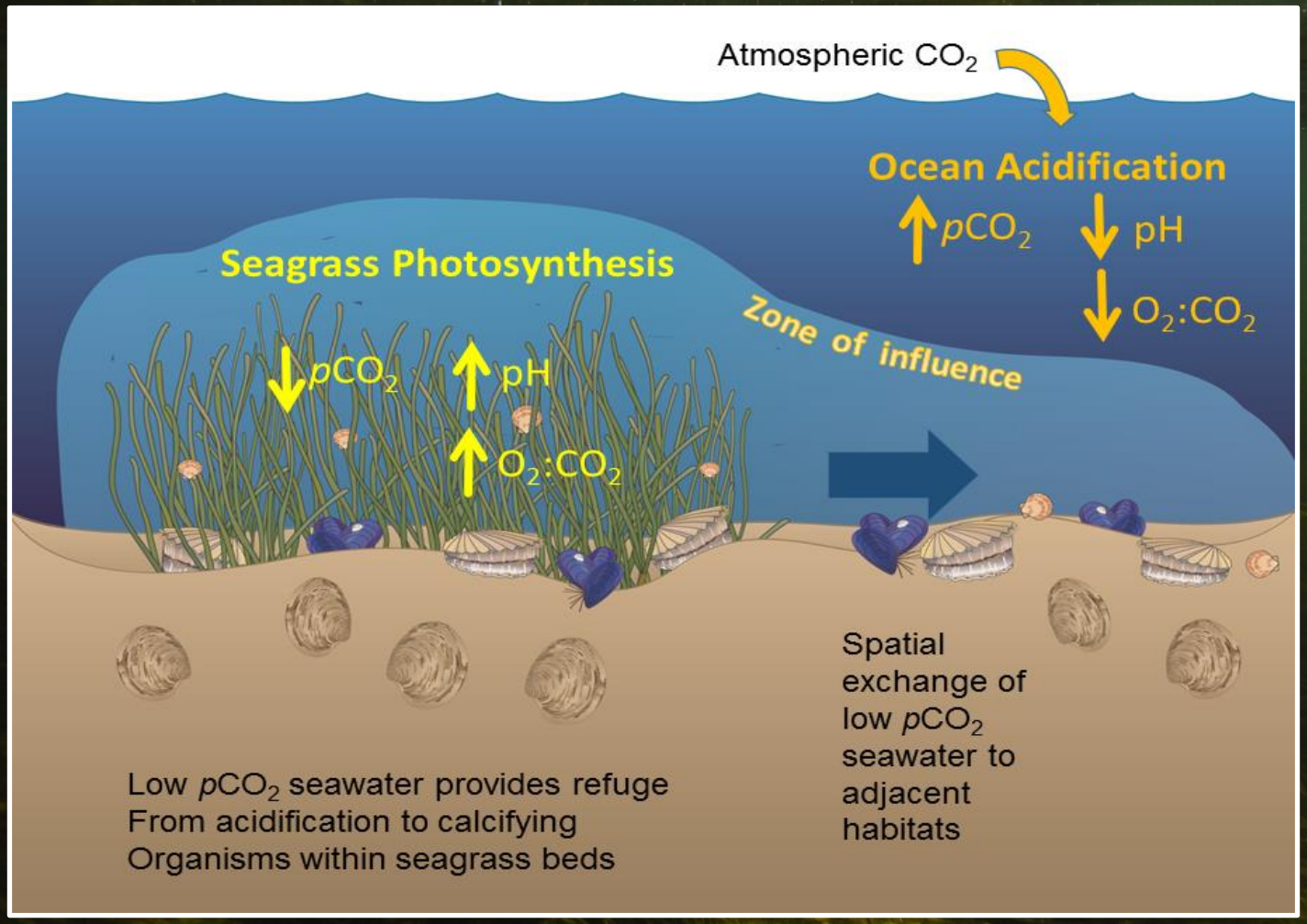

CG
SG
Proportional growth
1.5
1.0
0.5
AMB
ASU
SD
SG

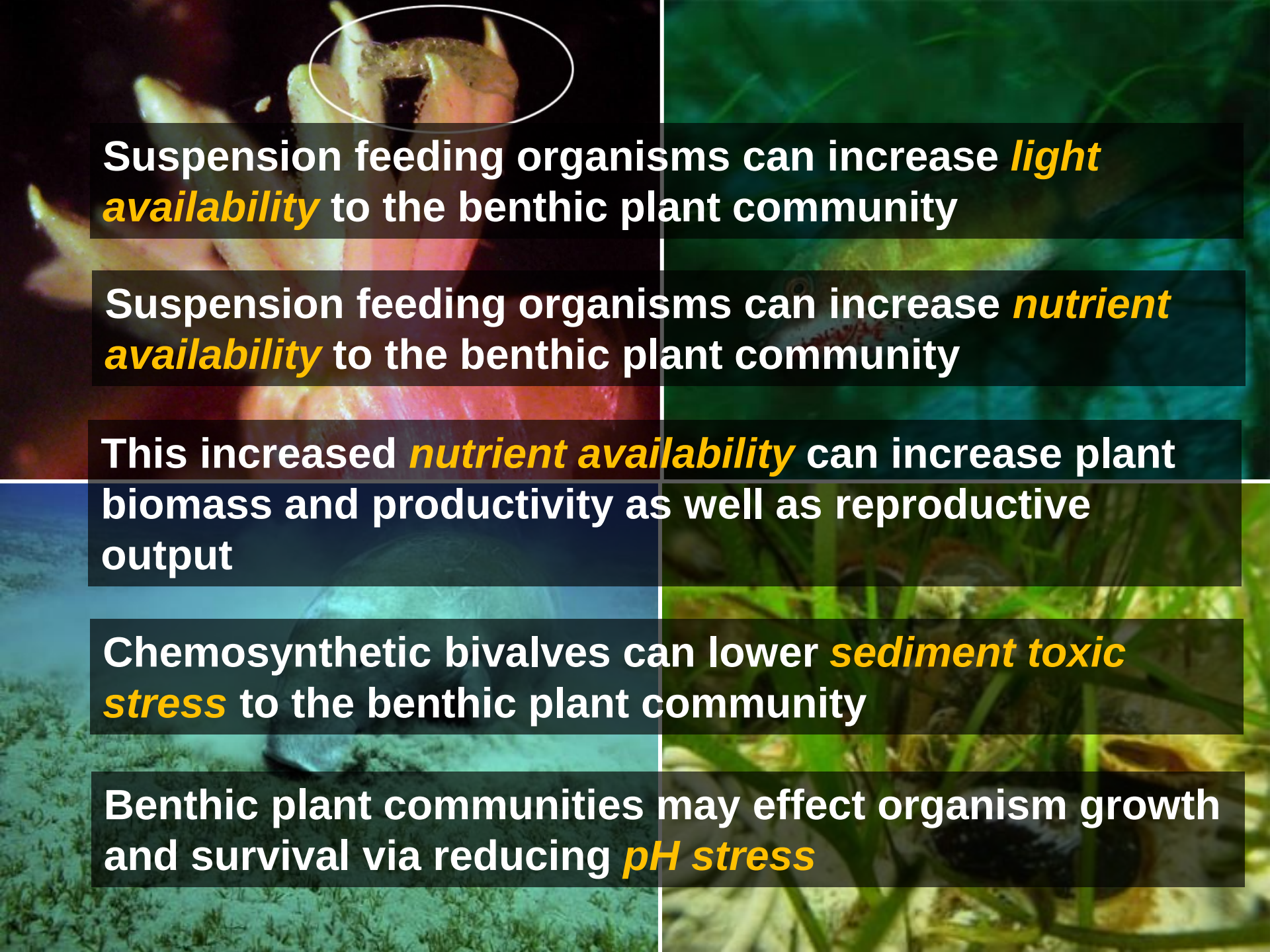


Larval lipids consistently negatively affected by low pH over ontogeny



Seagrass OASiS:
Ocean Acidification Sanctuaries and Subsidies





Suspension feeding organisms can increase *light availability* to the benthic plant community

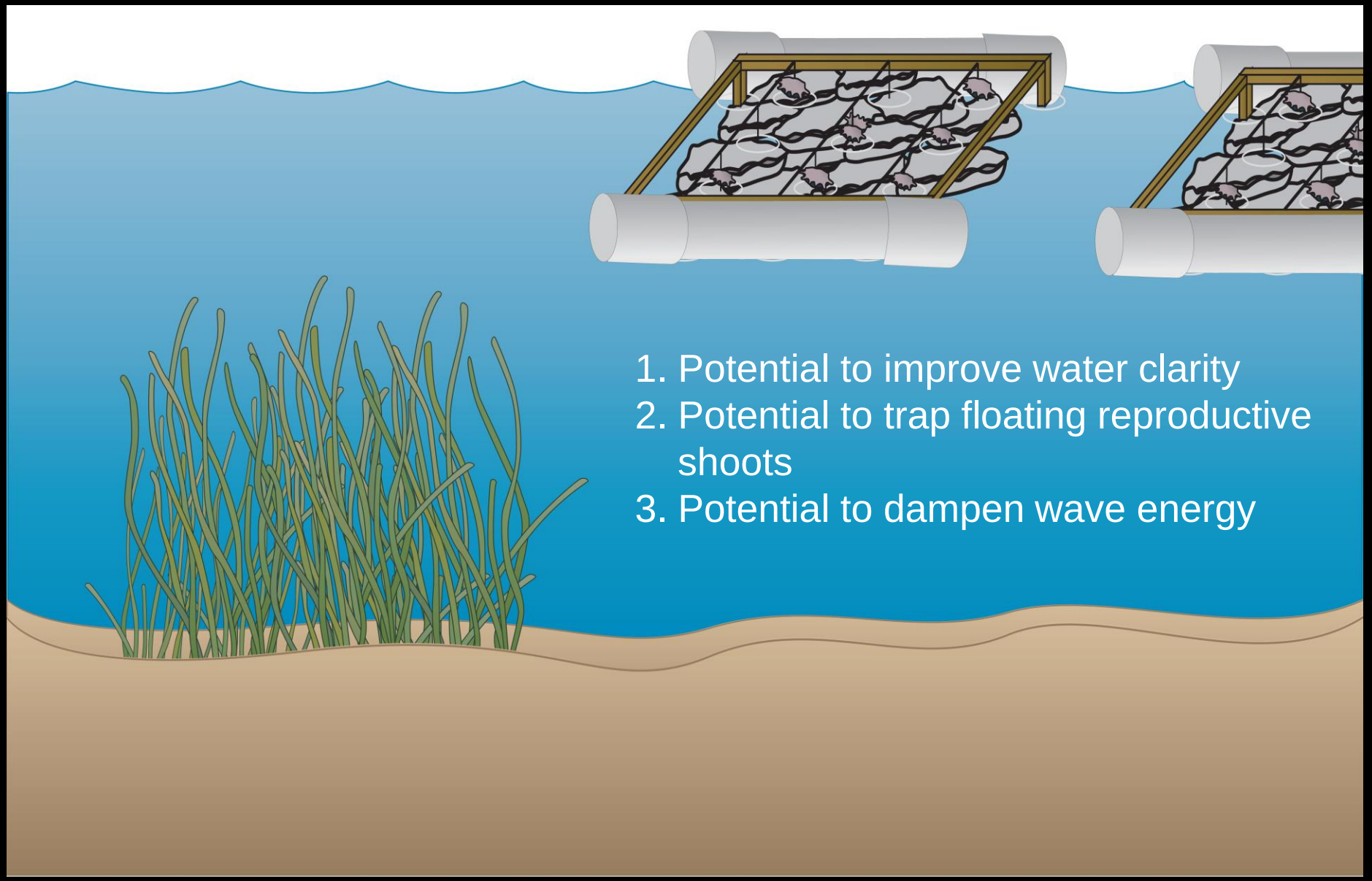
Suspension feeding organisms can increase *nutrient availability* to the benthic plant community

This increased *nutrient availability* can increase plant biomass and productivity as well as reproductive output

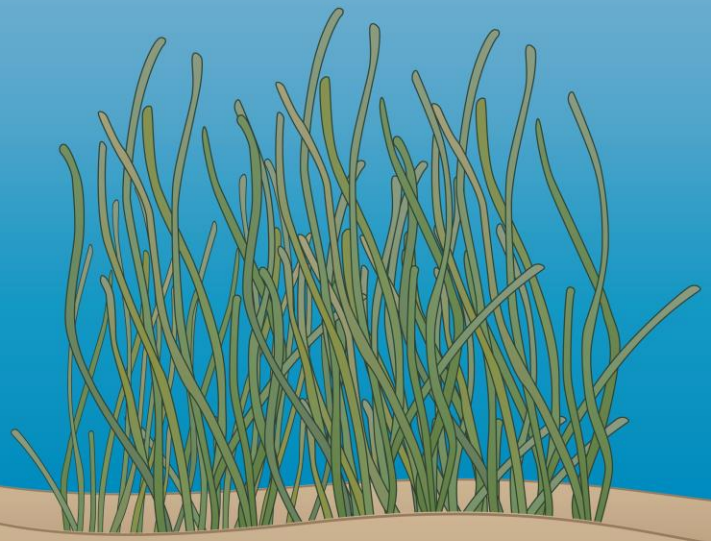
Chemosynthetic bivalves can lower *sediment toxic stress* to the benthic plant community

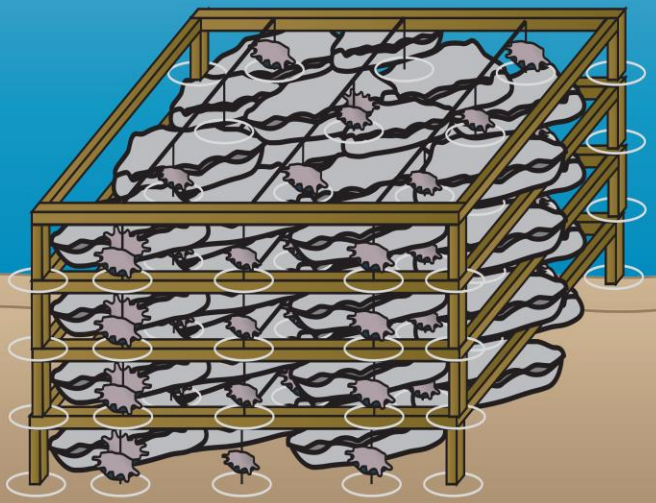
Benthic plant communities may effect organism growth and survival via reducing *pH stress*

Dr. Jennifer Reusnik


1. Potential to improve water clarity
2. Potential to trap floating reproductive shoots
3. Potential to dampen wave energy

1. Potential to improve water clarity
2. Potential to trap reproductive shoots and seeds
3. Potential to dampen wave energy
4. Potential to increase sediment nutrient pool



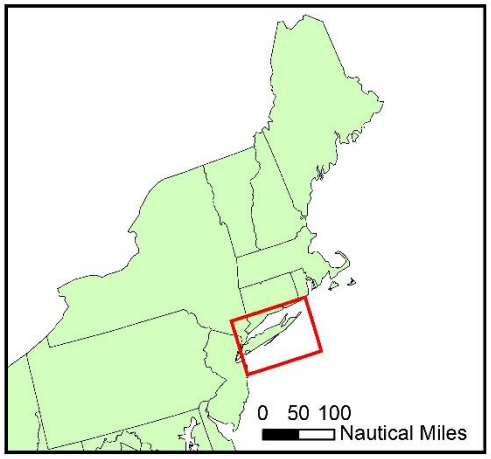


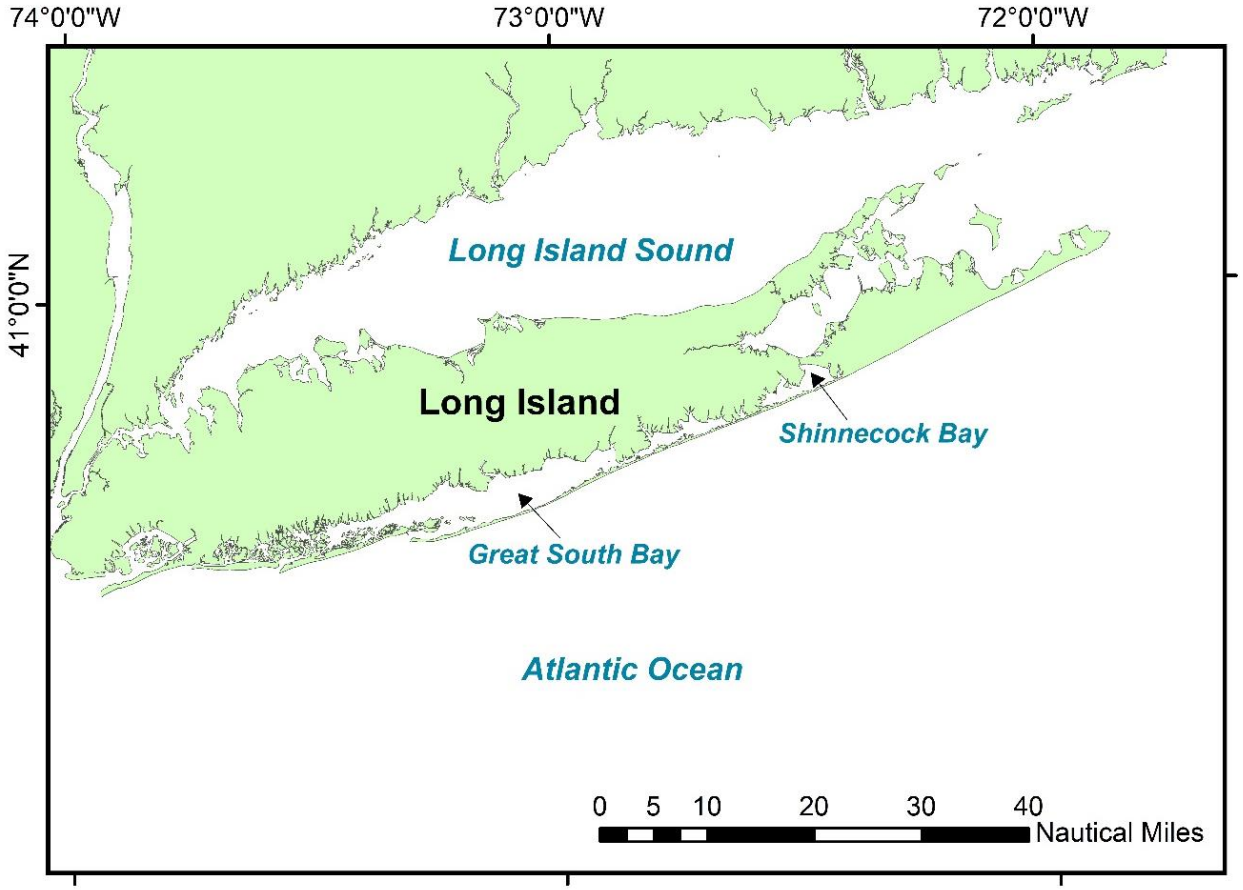
SHINNECOCK BAY
RESTORATION PROGRAM

Chris Gobler

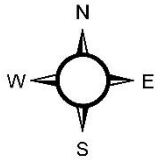
Mike Doall

South Shore Estuaries in Long Island, NY



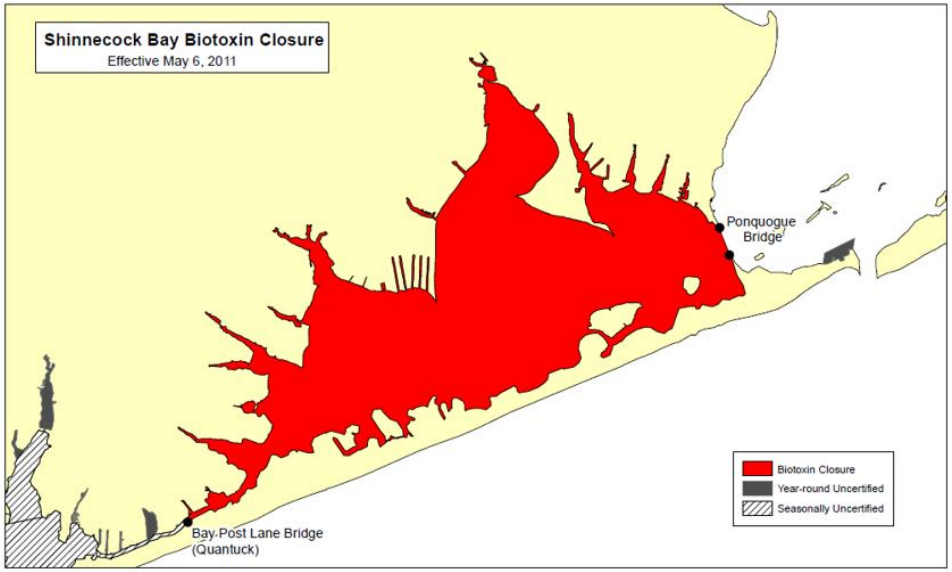


Stony Brook University

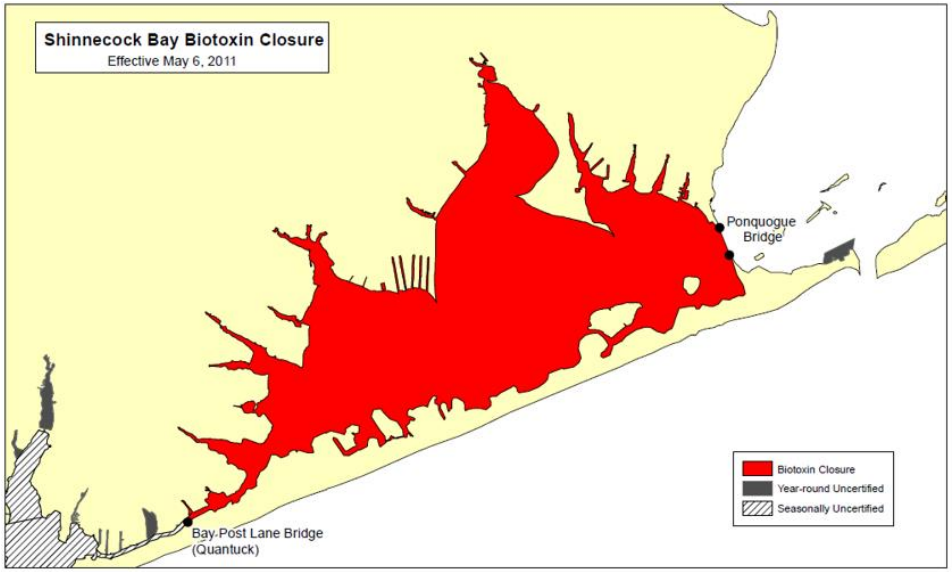


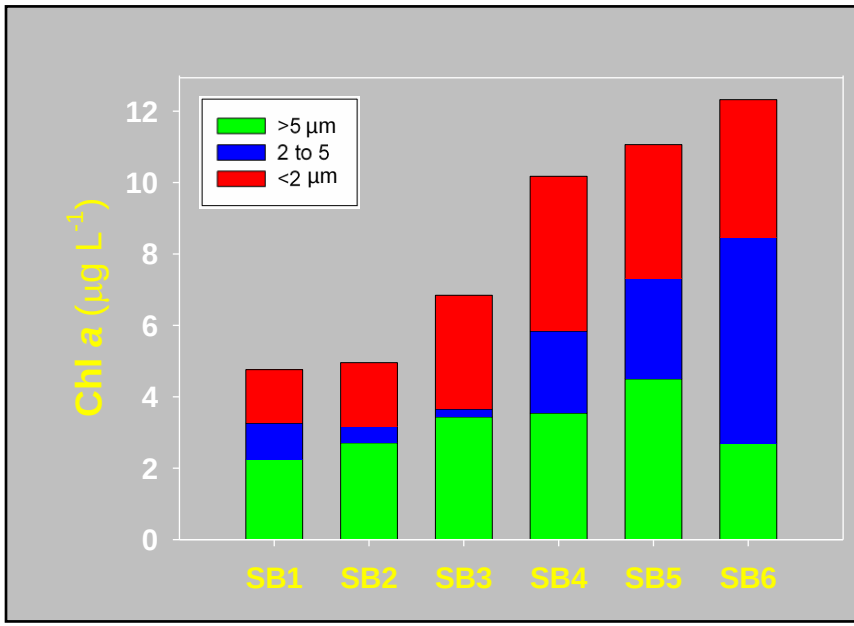
Coordinate System: NAD 1983 UTM Zone 18N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
Author: Peter Larios

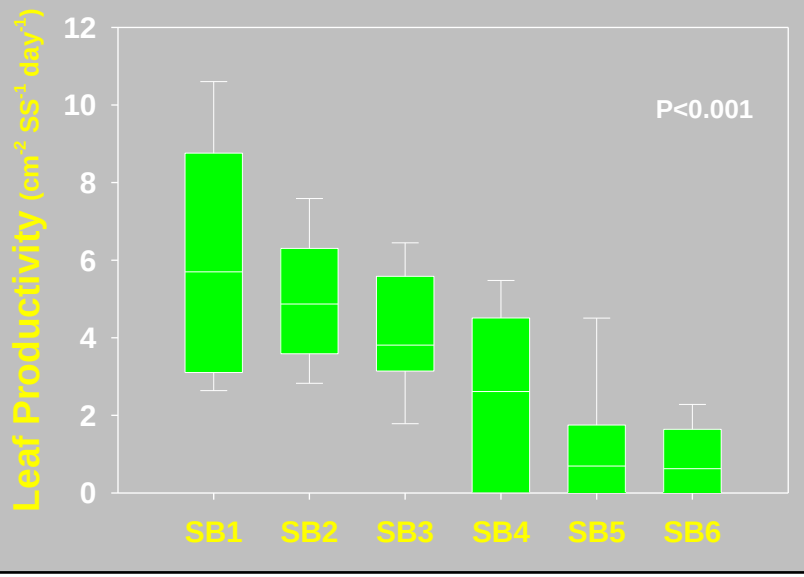
Shinnecock Bay, 2010



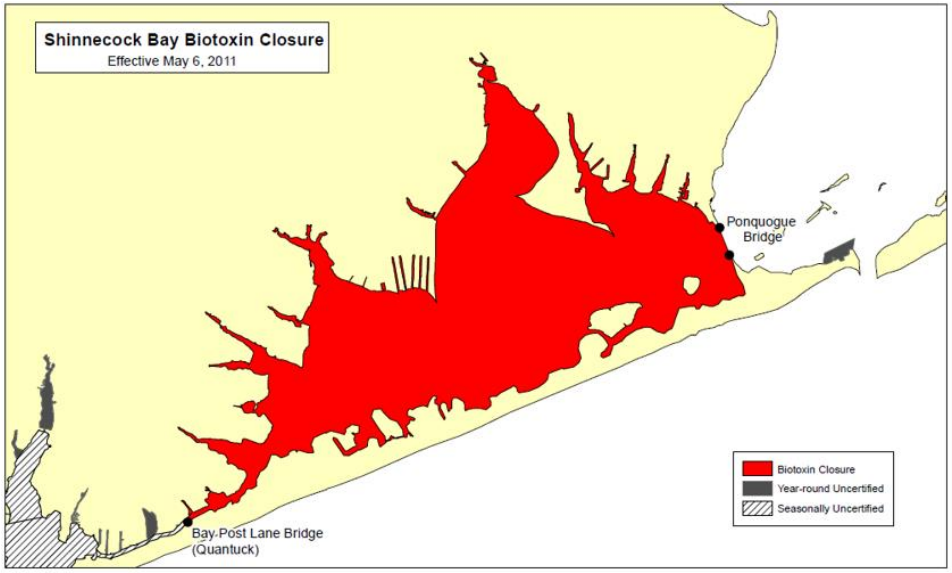
Shinnecock Bay, 2010

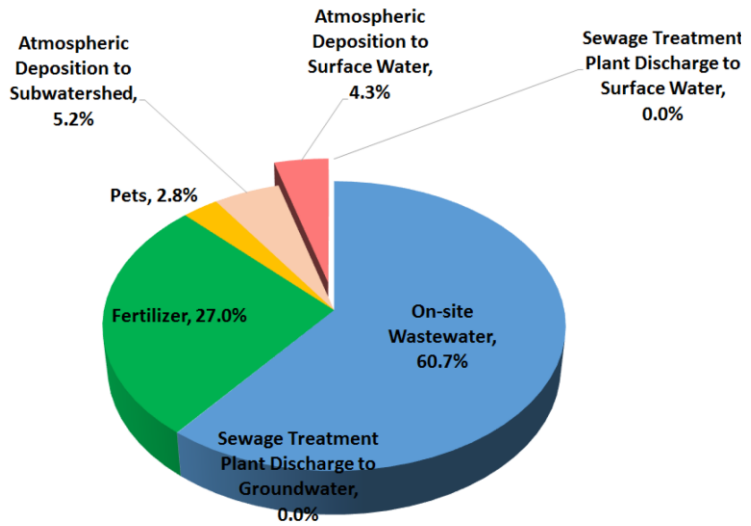


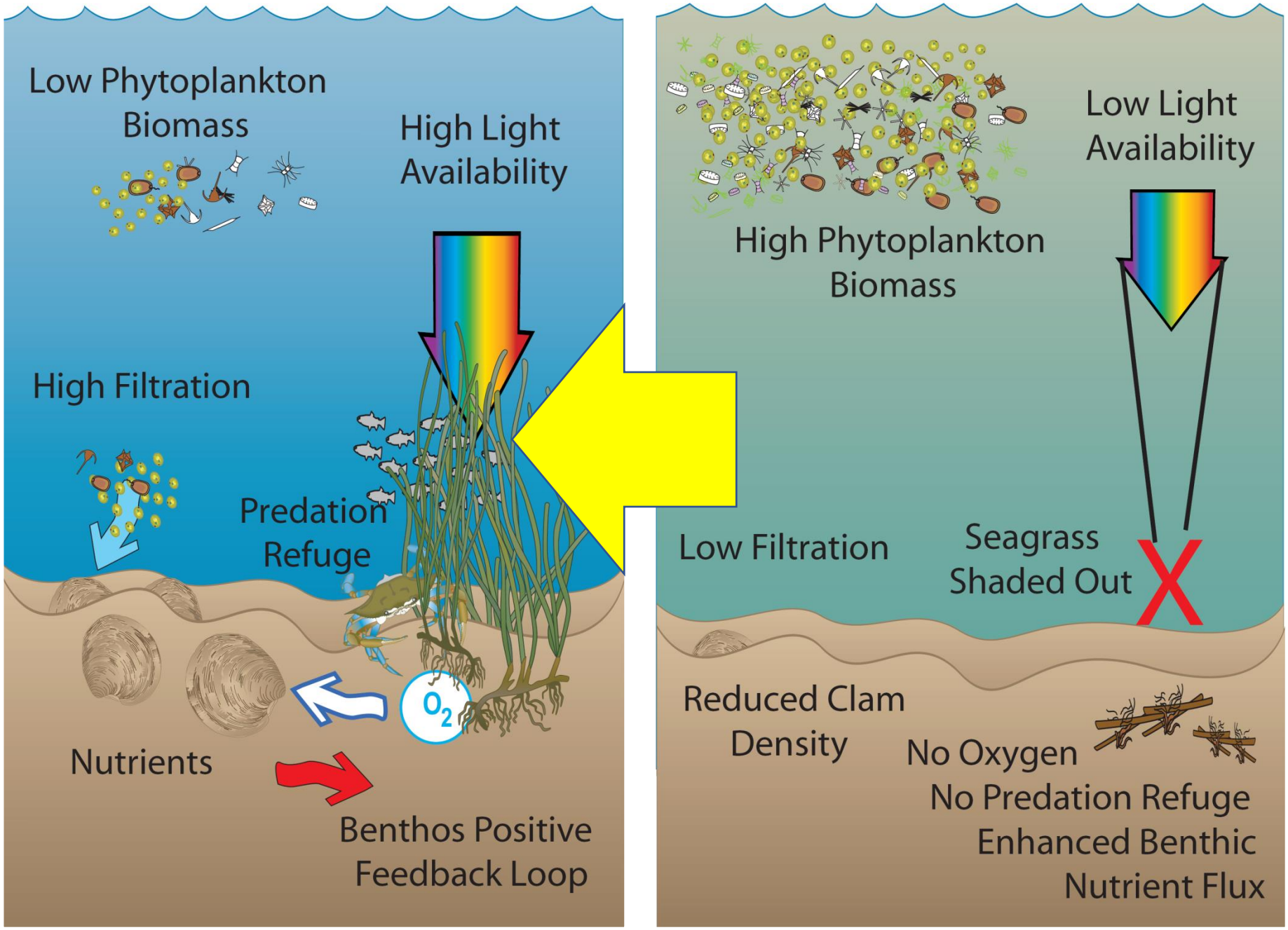




Shinnecock Bay, 2010

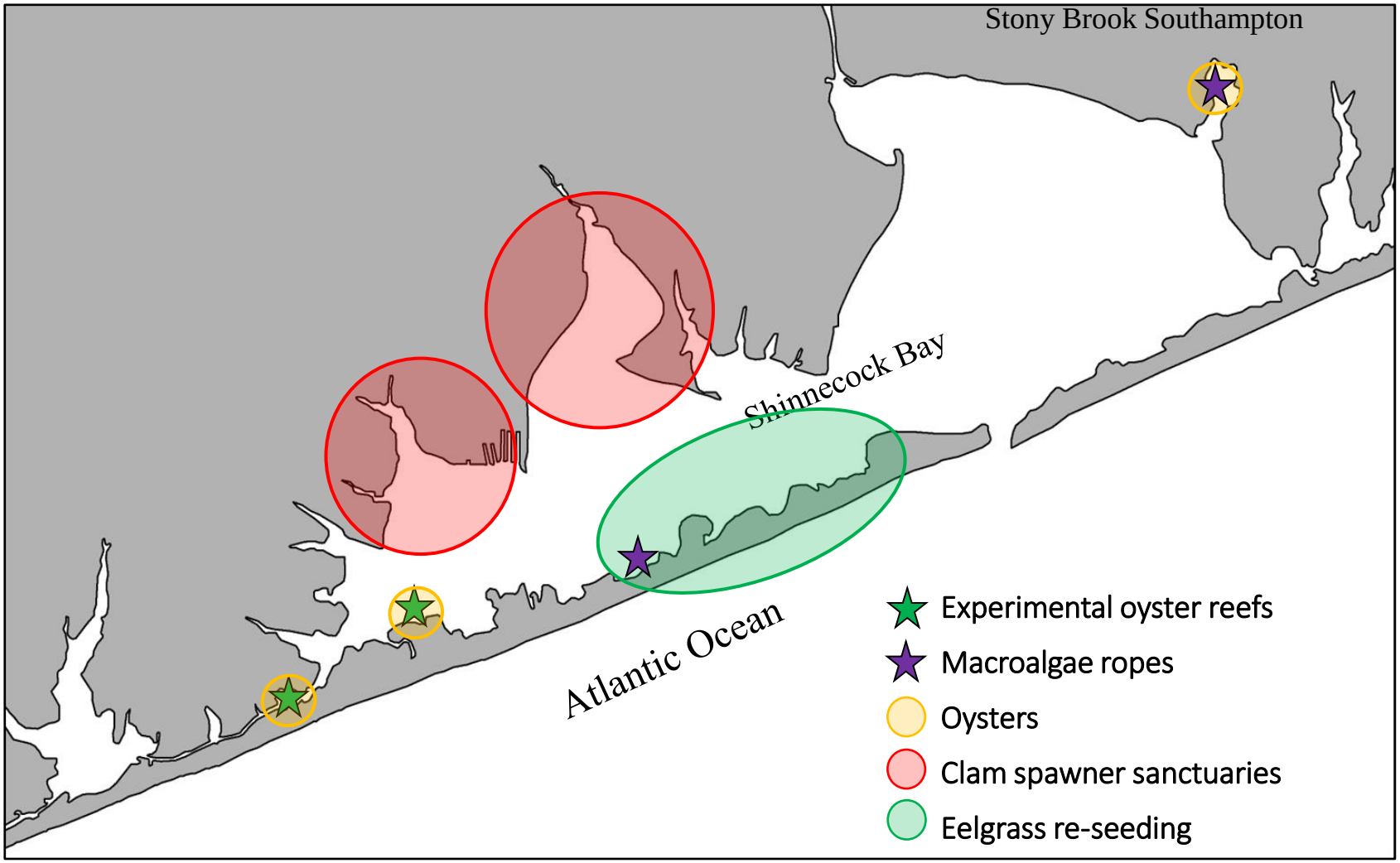




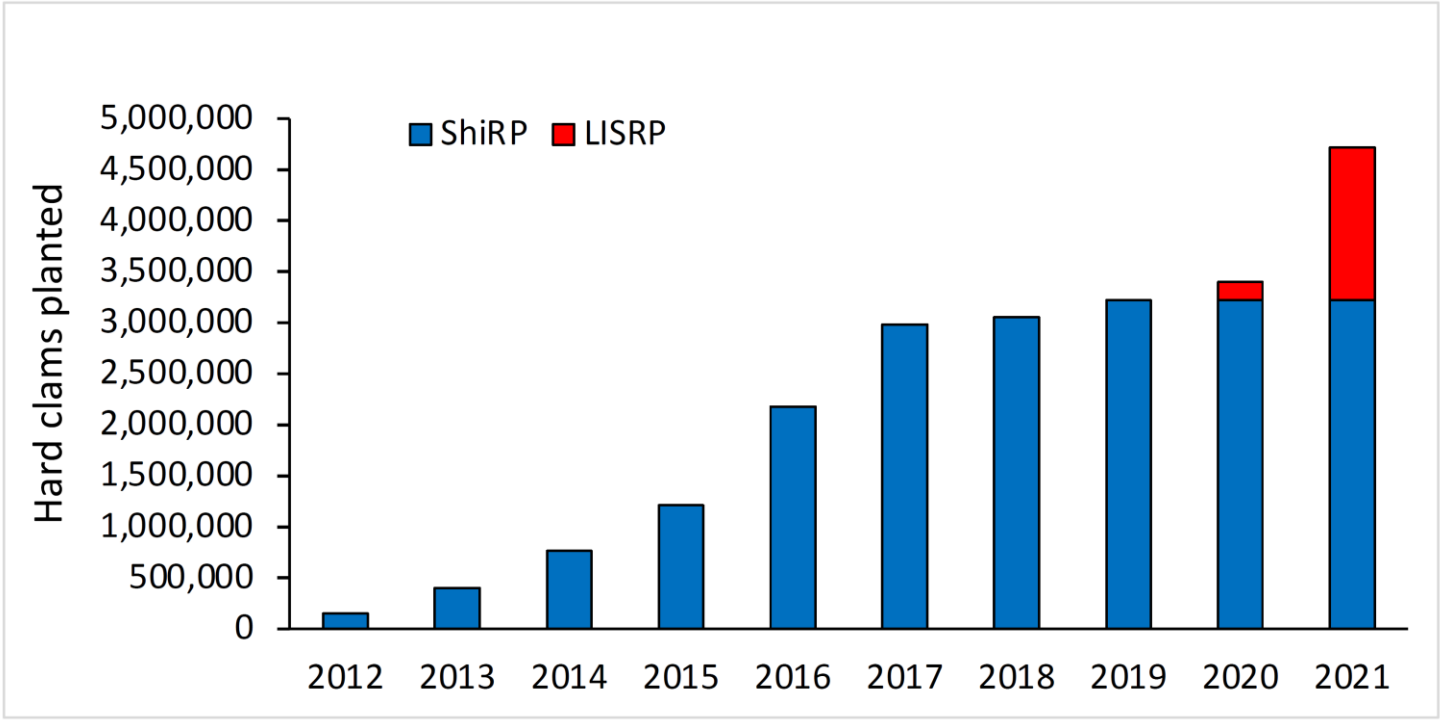

Low Phytoplankton Biomass
High Light Availability
High Filtration
Predation Refuge
O_2
Nutrients
Benthos Positive Feedback Loop
High Phytoplankton Biomass
Low Light Availability
Low Filtration
Seagrass Shaded Out
Reduced Clam Density
No Oxygen
No Predation Refuge
Enhanced Benthic Nutrient Flux

Hard clam restoration as a means of *Ecosystem Manipulation*

ShiRP zones of activity since 2012

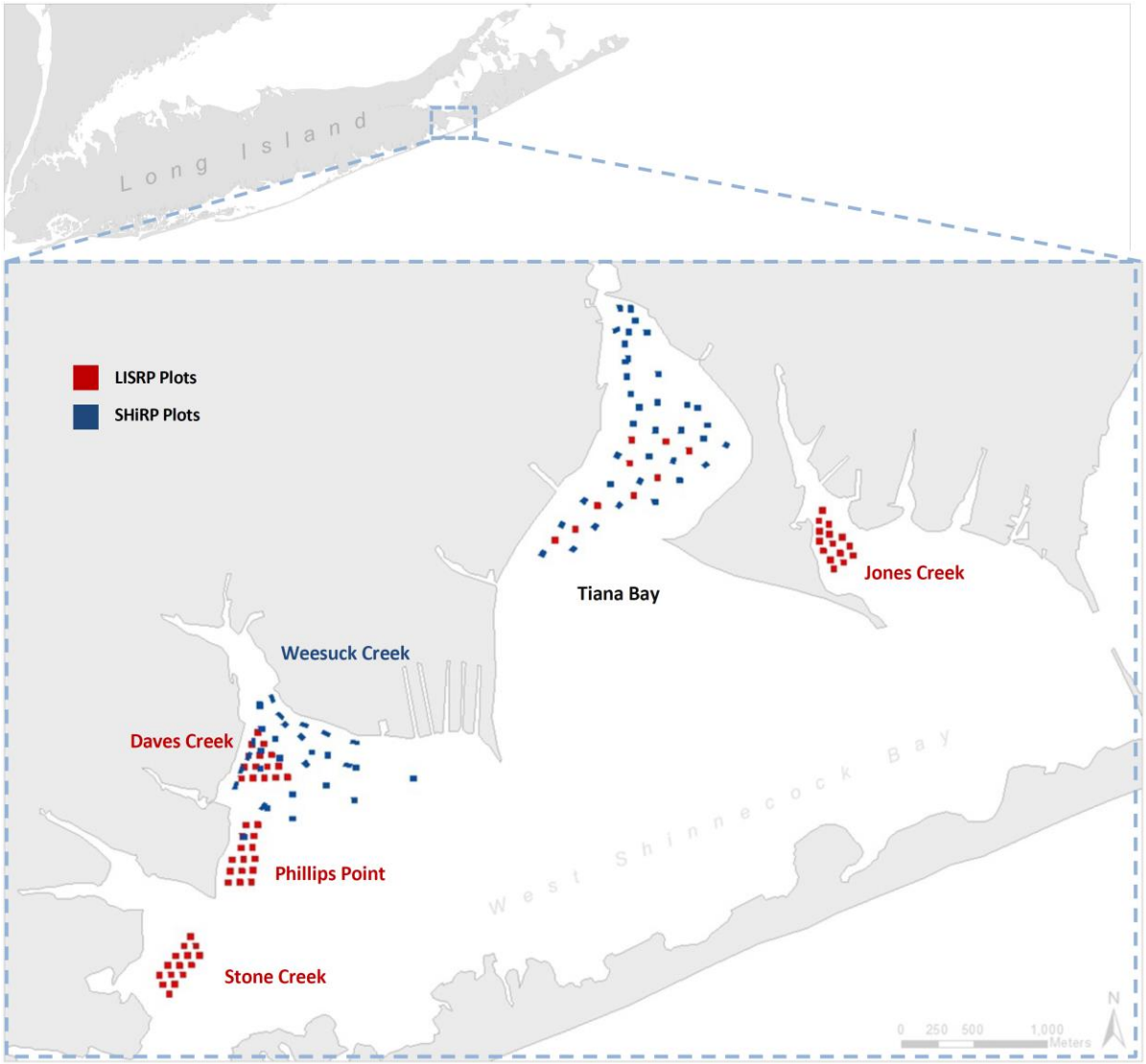


Hard Clam Plantings



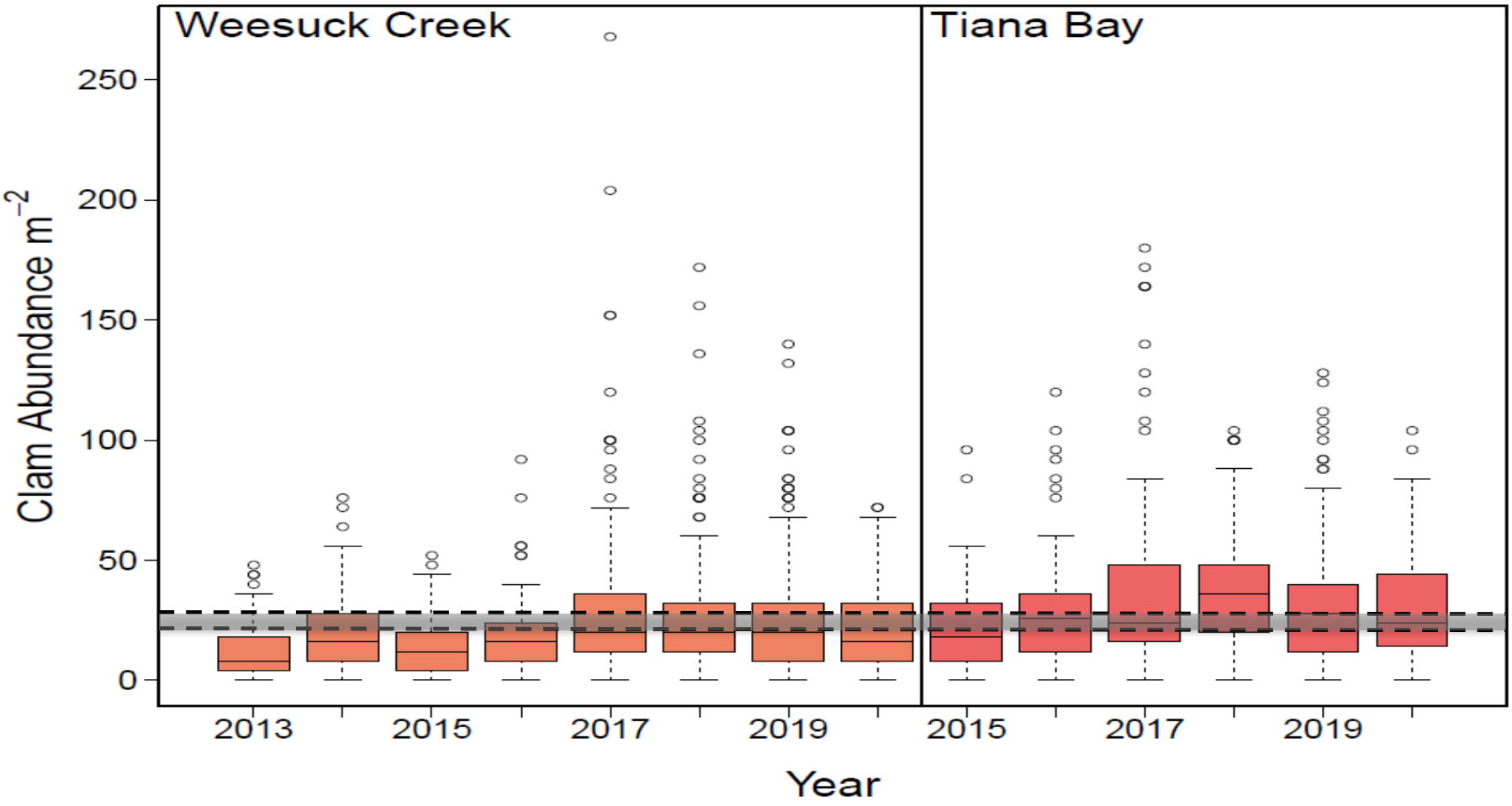
Shinnecock Bay Restoration Program

Since 2012, ShiRP has planted >4,719,250 adult clams in 124 half-acre plots within spawner sanctuaries in Weesuck Creek, Tiana Bay and Jones Creek

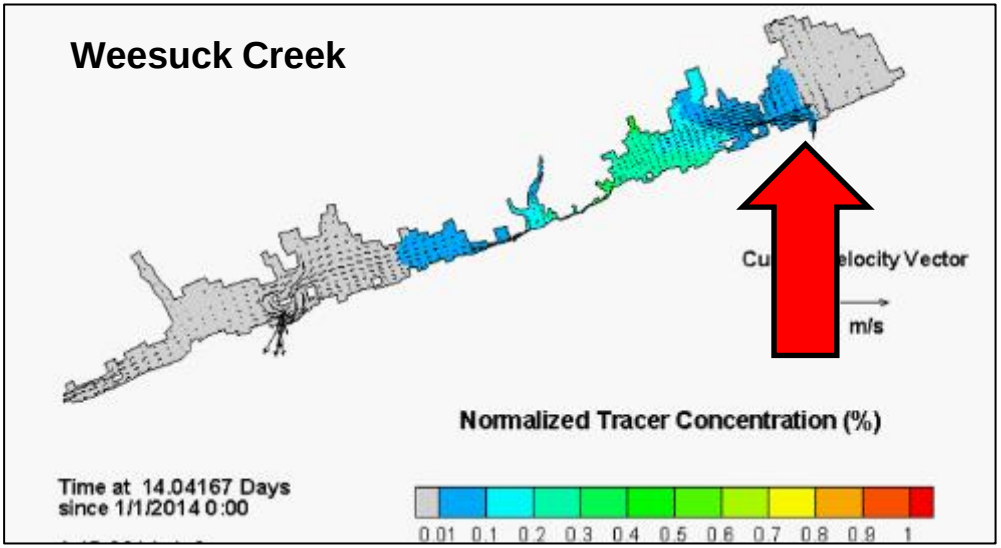


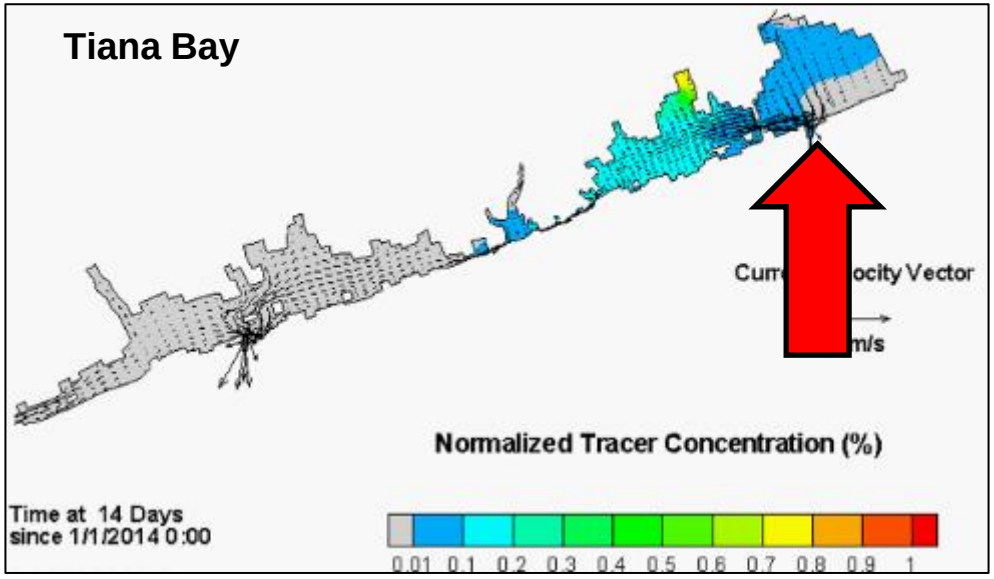
High survivorship

Target Density (25-35 clams m^{-2})



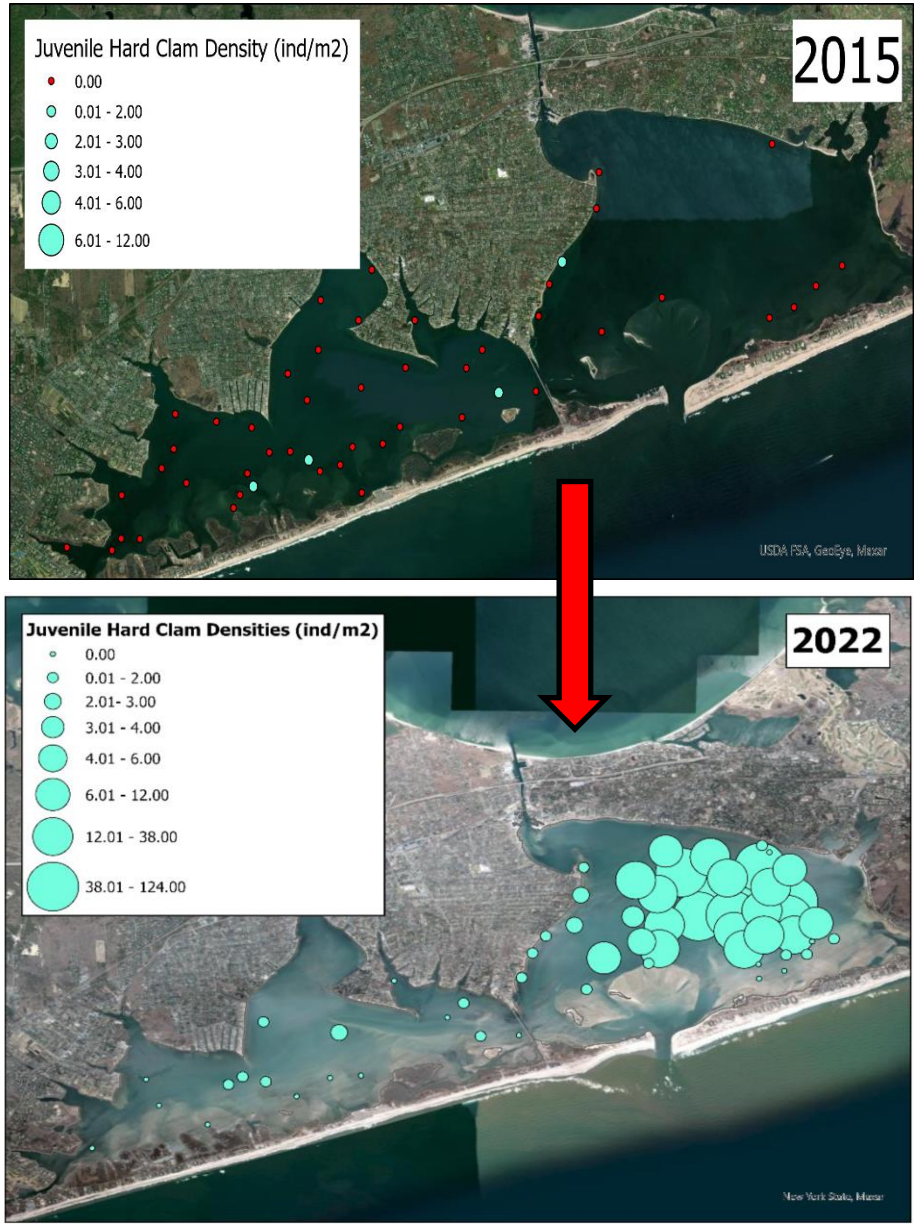
Larval Transport & Recruitment: Shinnecock Bay



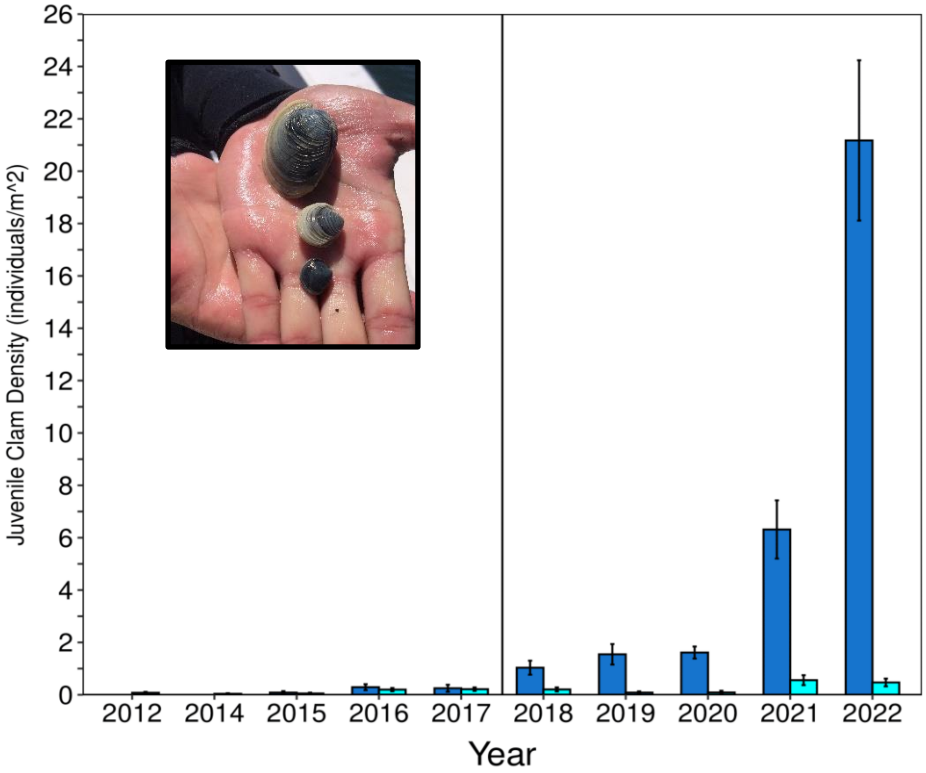


- Hydrodynamic models show both eastward and westward transport

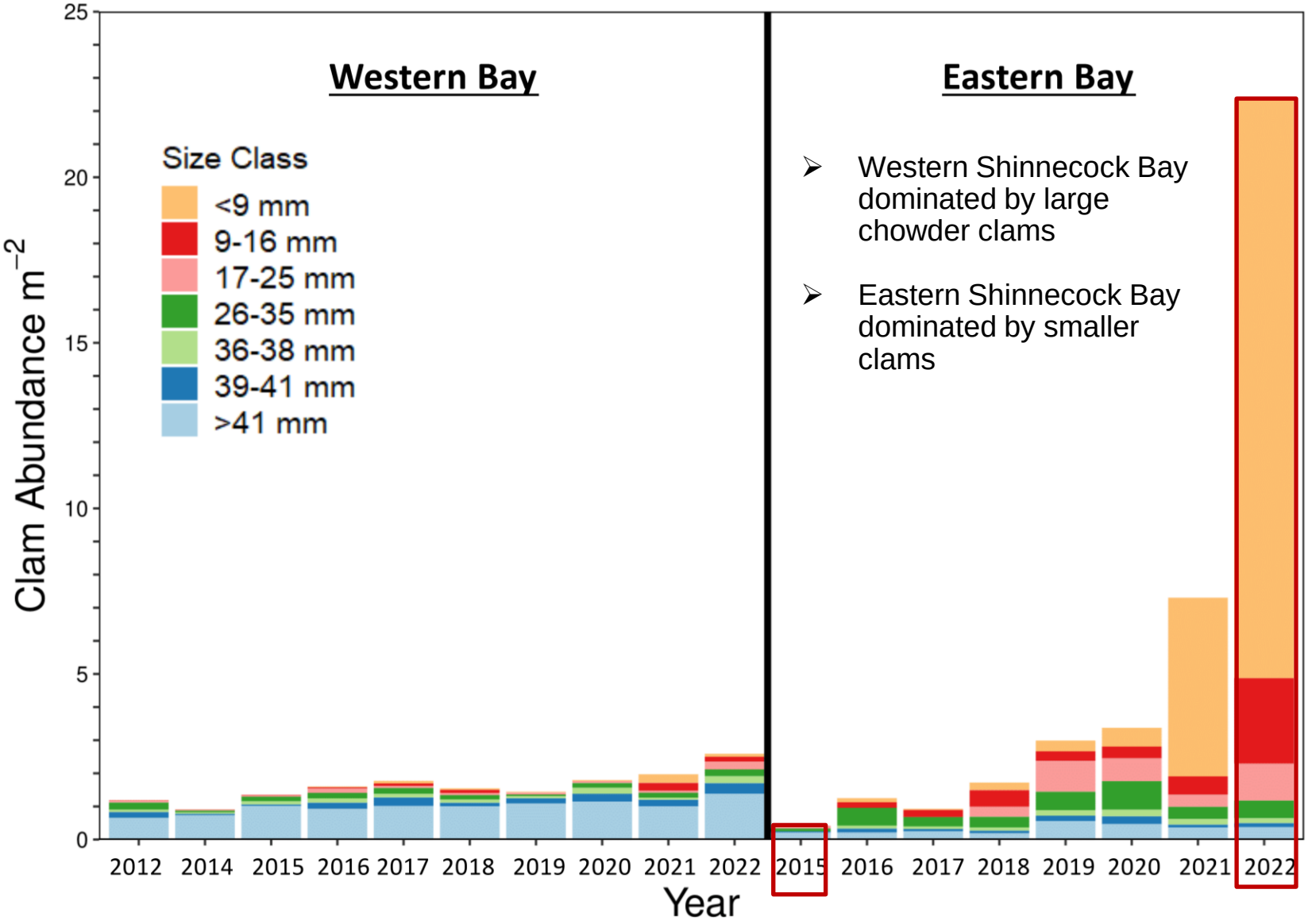
Large increase in hard clam recruitment since onset of ShiRP



- Most of increase in hard clam recruitment is in eastern Shinnecock Bay



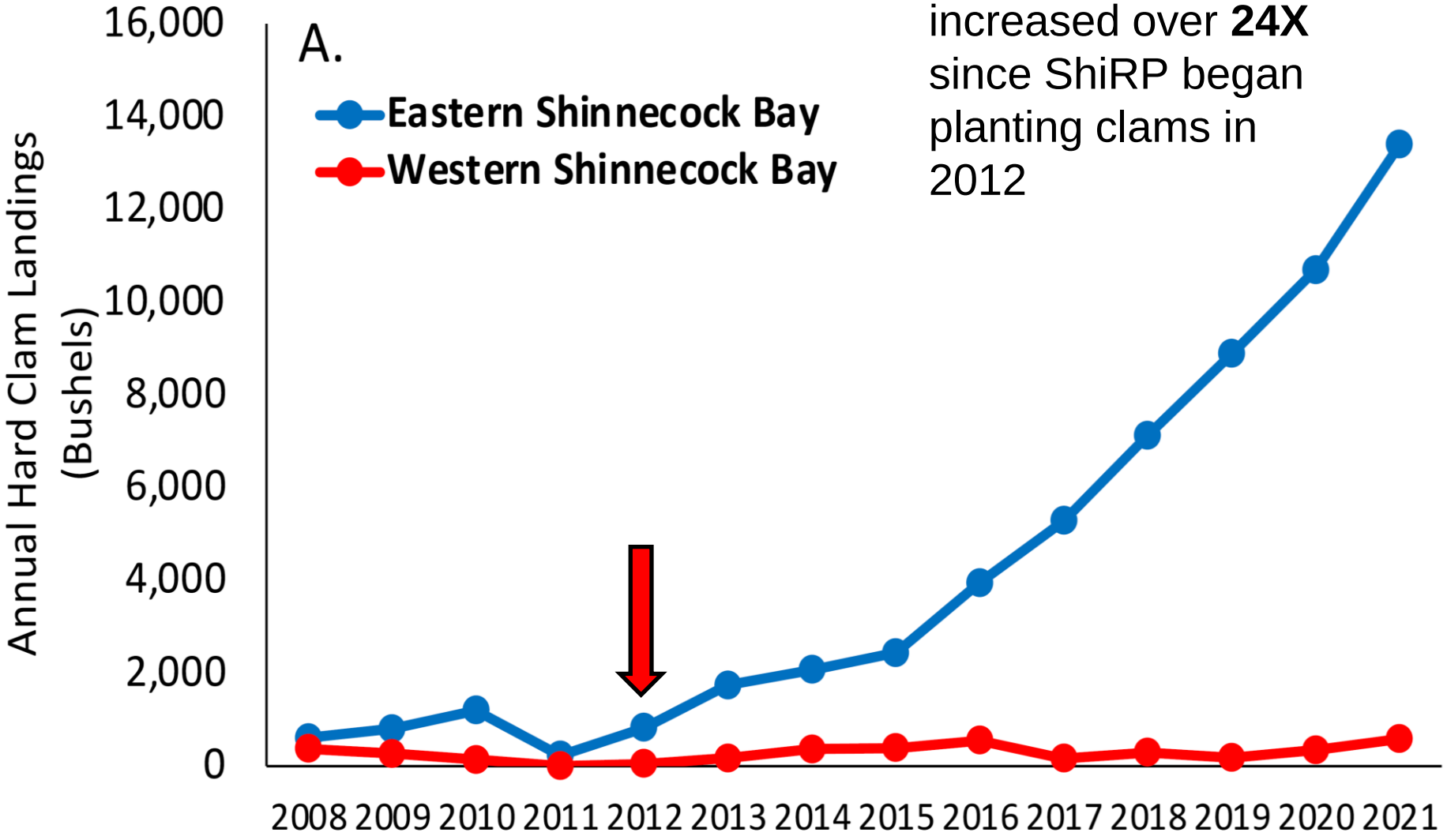
Very different population size/age structures between eastern and western Shinnecock Bay



- Western Shinnecock Bay dominated by large chowder clams
- Eastern Shinnecock Bay dominated by smaller clams

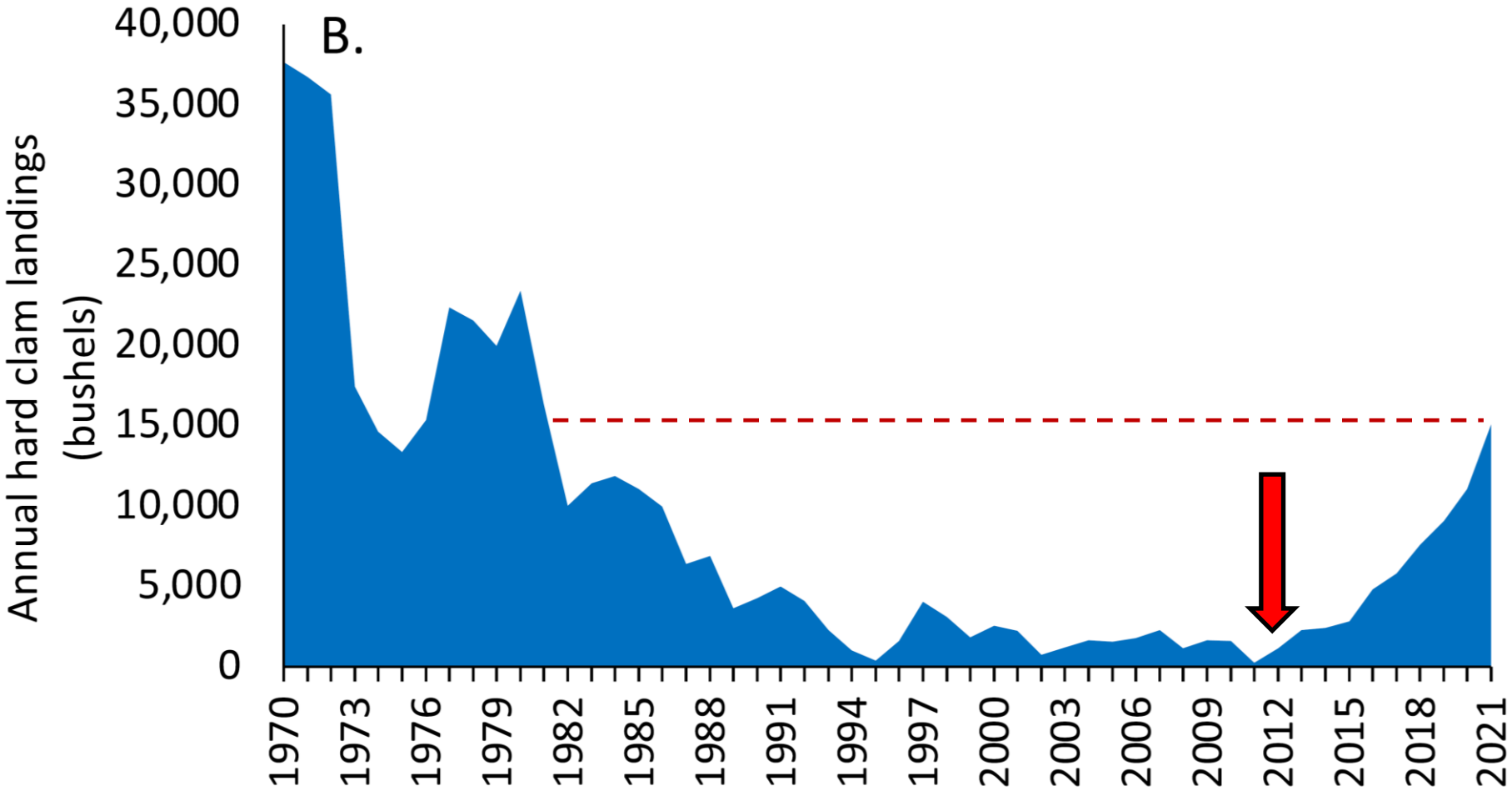
Commercial harvest has skyrocketed since onset of ShiRP

- Annual landings have increased over **24X** since ShiRP began planting clams in 2012



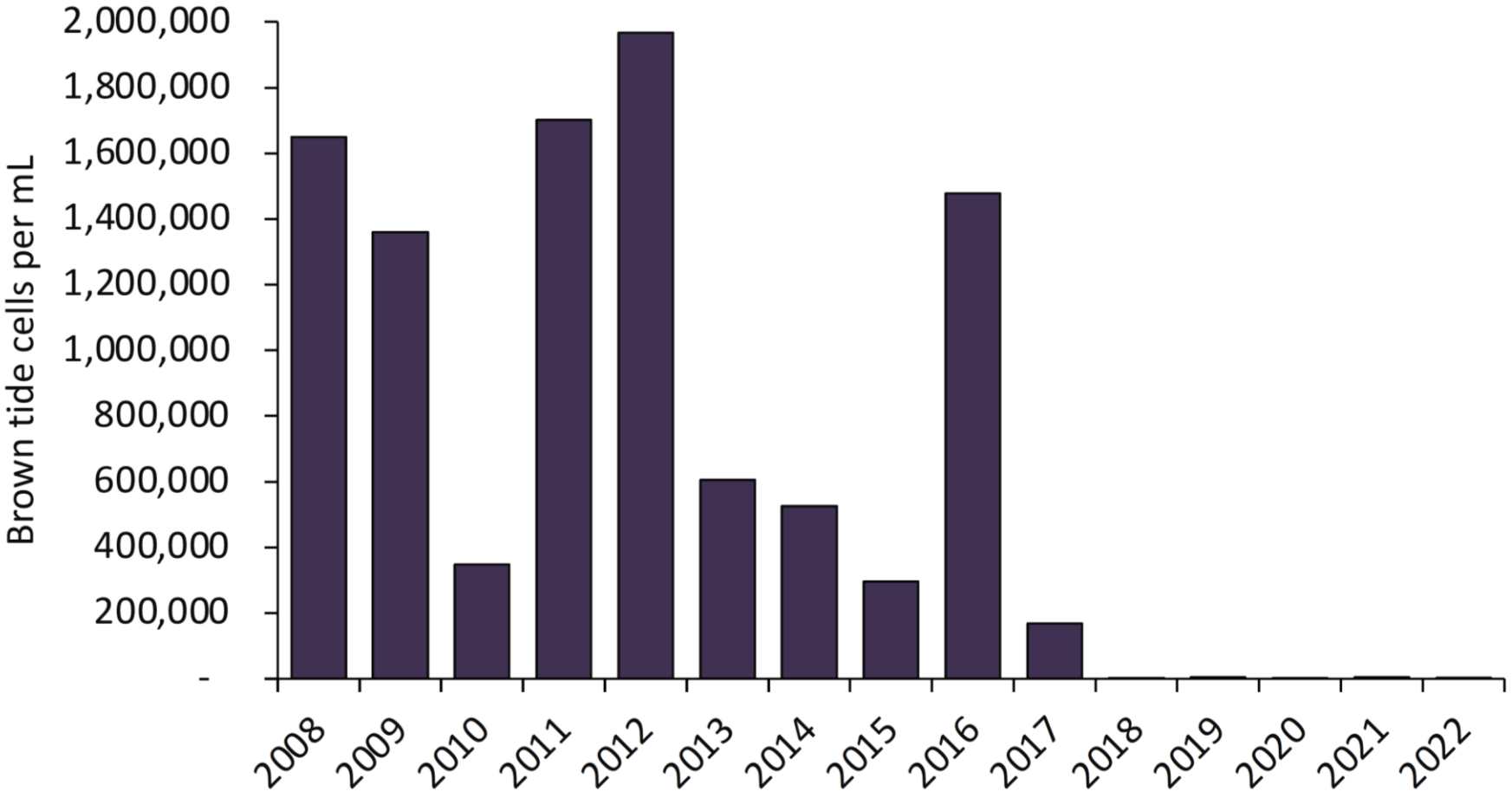
2018 & 2019 were best hard clam harvest years in Shinnecock Bay in over 40 years!

NYSDEC report on landings



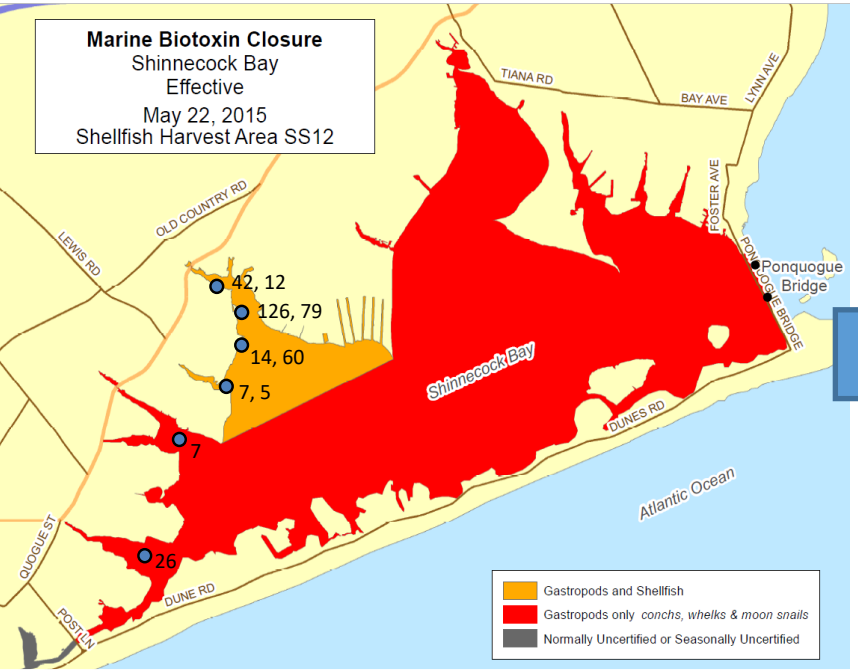
How has this increase impacted Shinnecock Bay?

Brown tides in Shinnecock Bay, 2008 - 2022

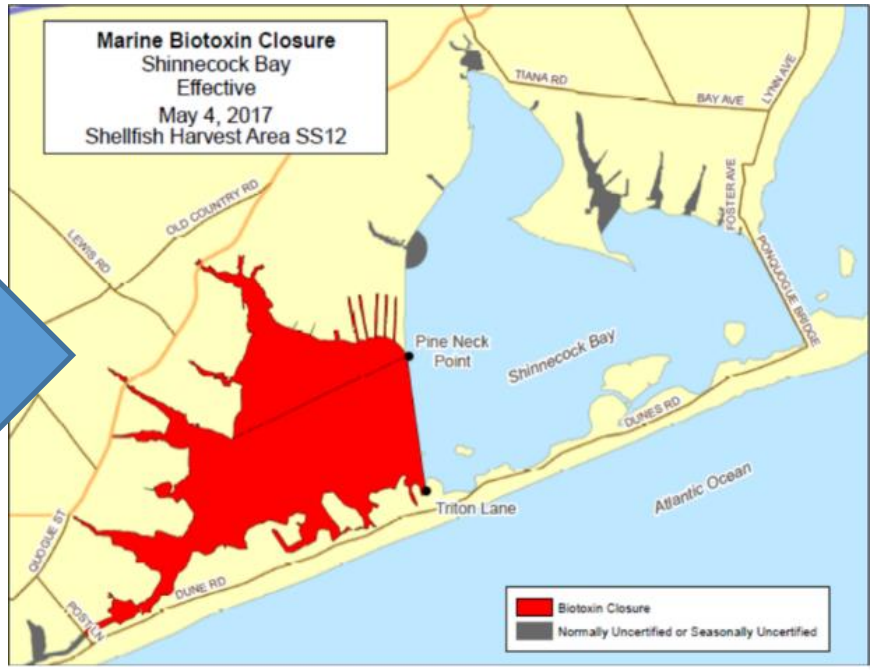


PSP closures

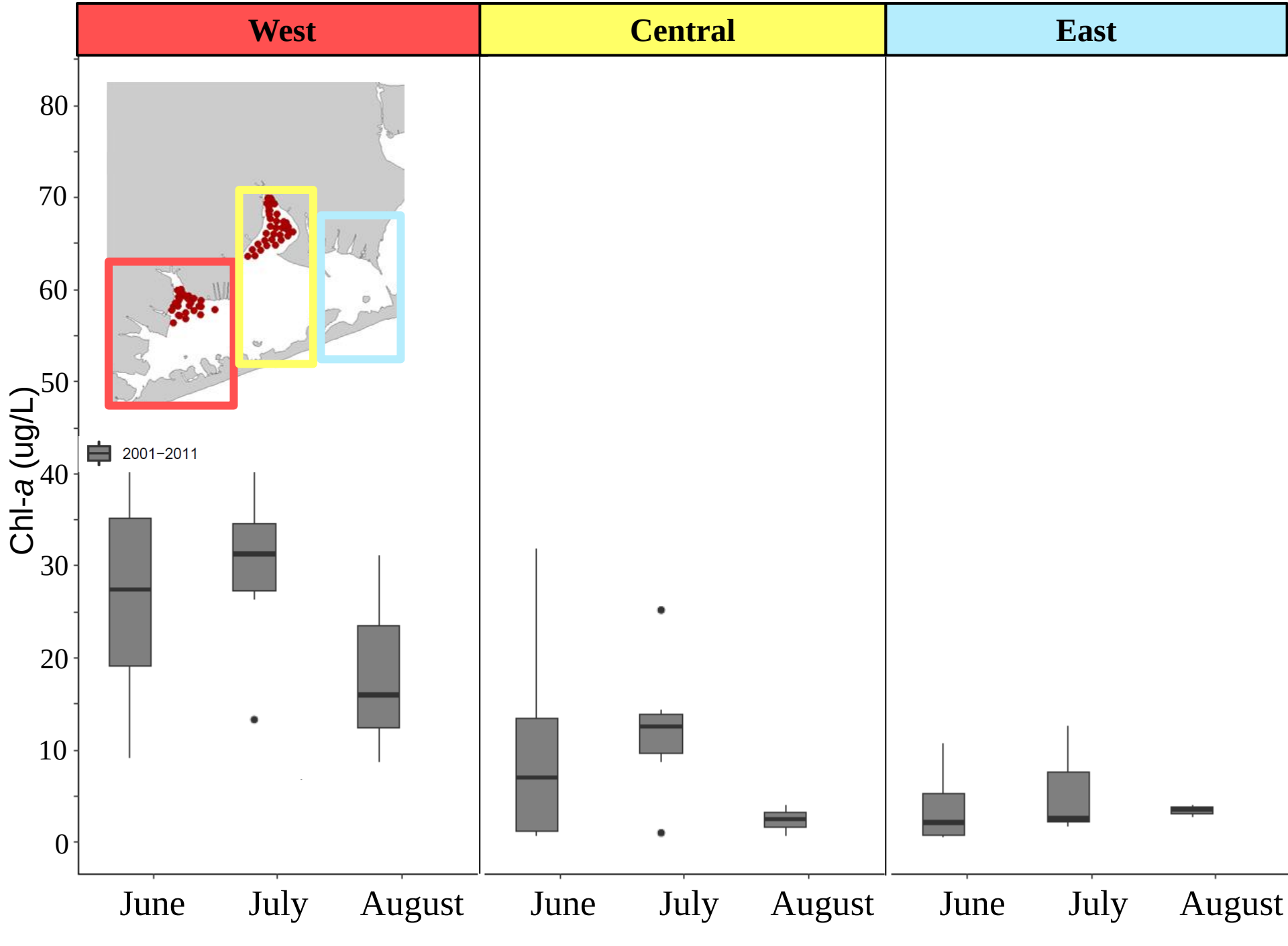
2011, 2014, 2015: 4,000 acres



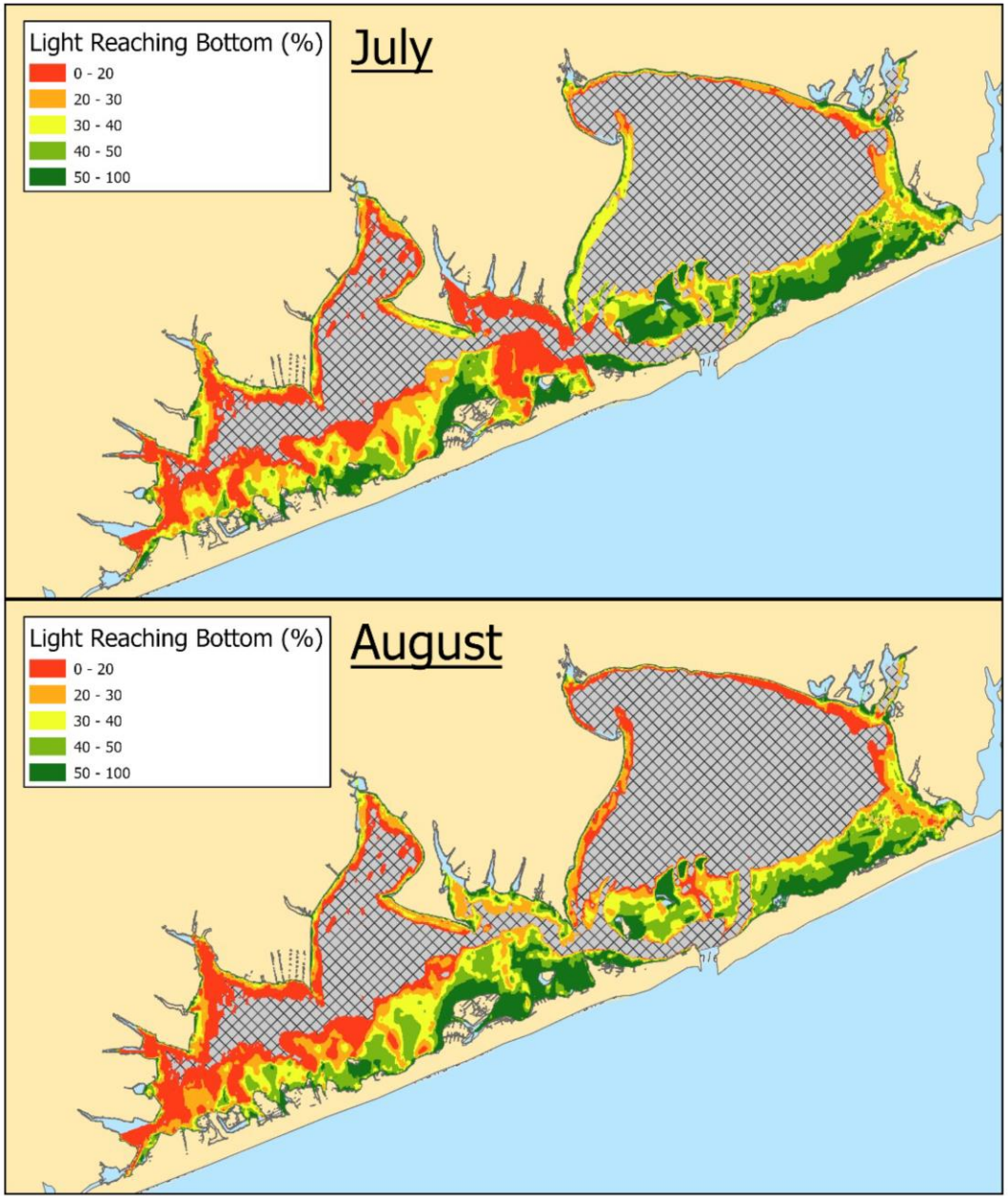
2017, 2018: 2,000 acres

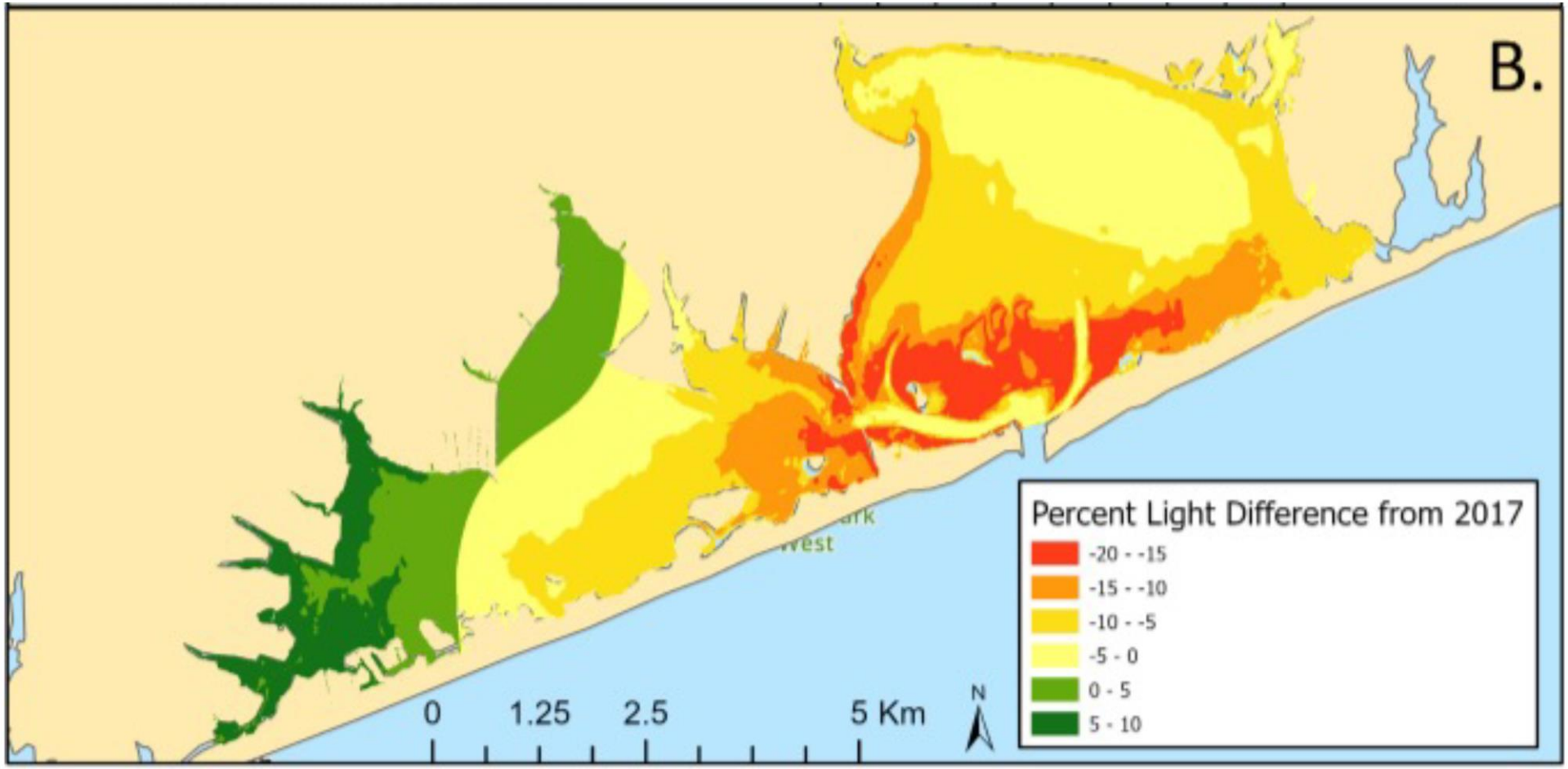


No NYS Shellfish closures since 2019


West
Central
East
Chl-a (ug/L)
0
10
20
30
40
50
60
70
80
2001−2011
June
July
August
June
July
August
June
July
August

Bio-Optical Modeling





In 2012, resident time in Western Shinnecock was greater than 3 weeks, now it is 8.5 days


West BRUV Aug 28 2014


West BRUV Aug 29 2019

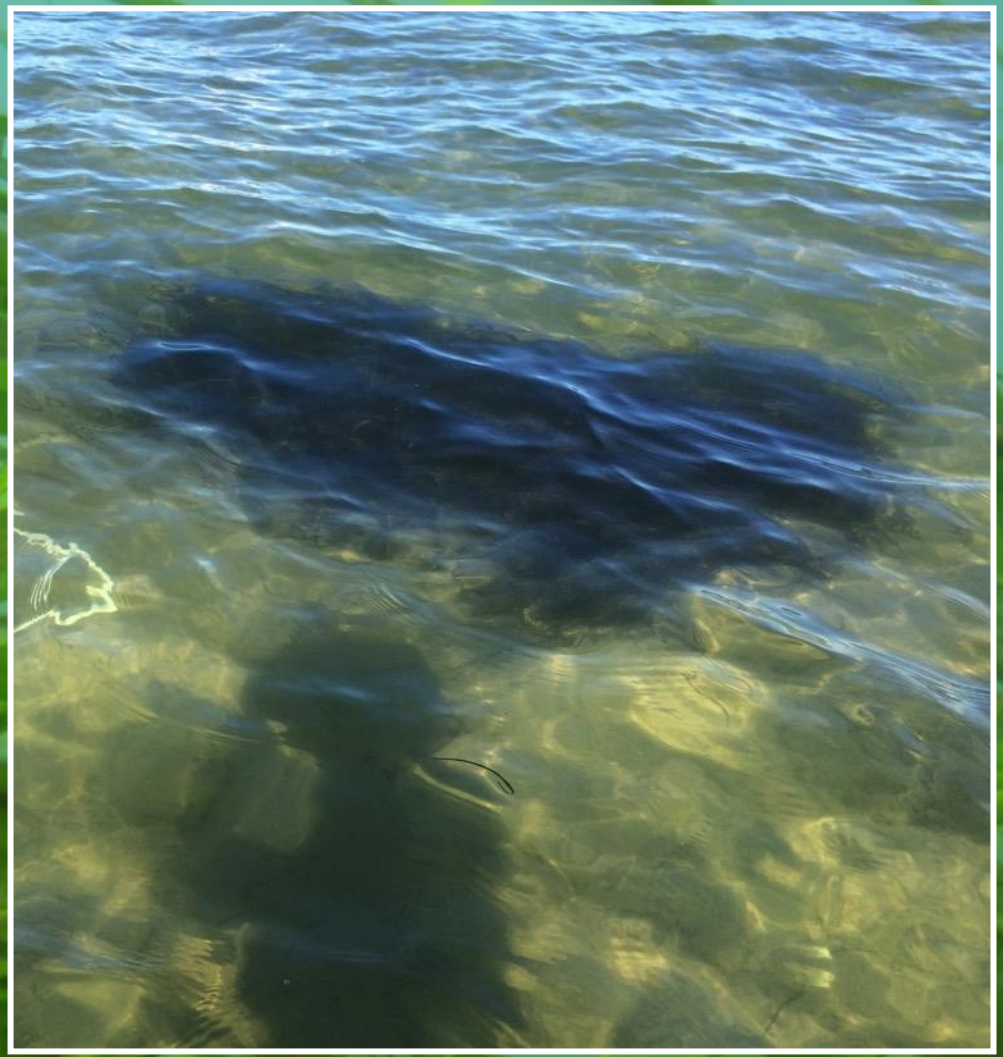

Seagrass Restoration
through ecosystem change


SUZUKI


KEEP
CLAM

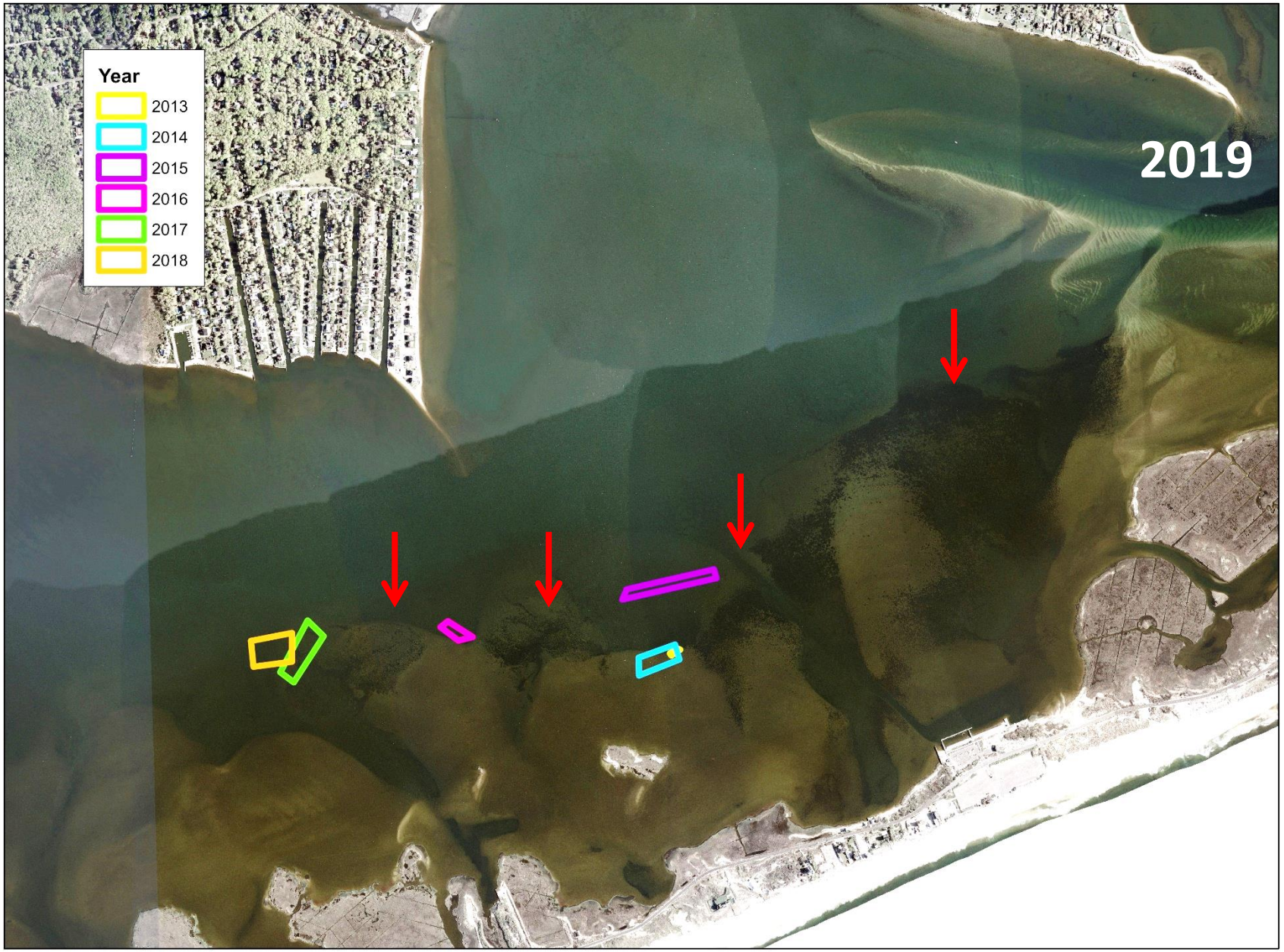

KEEP
CLAM

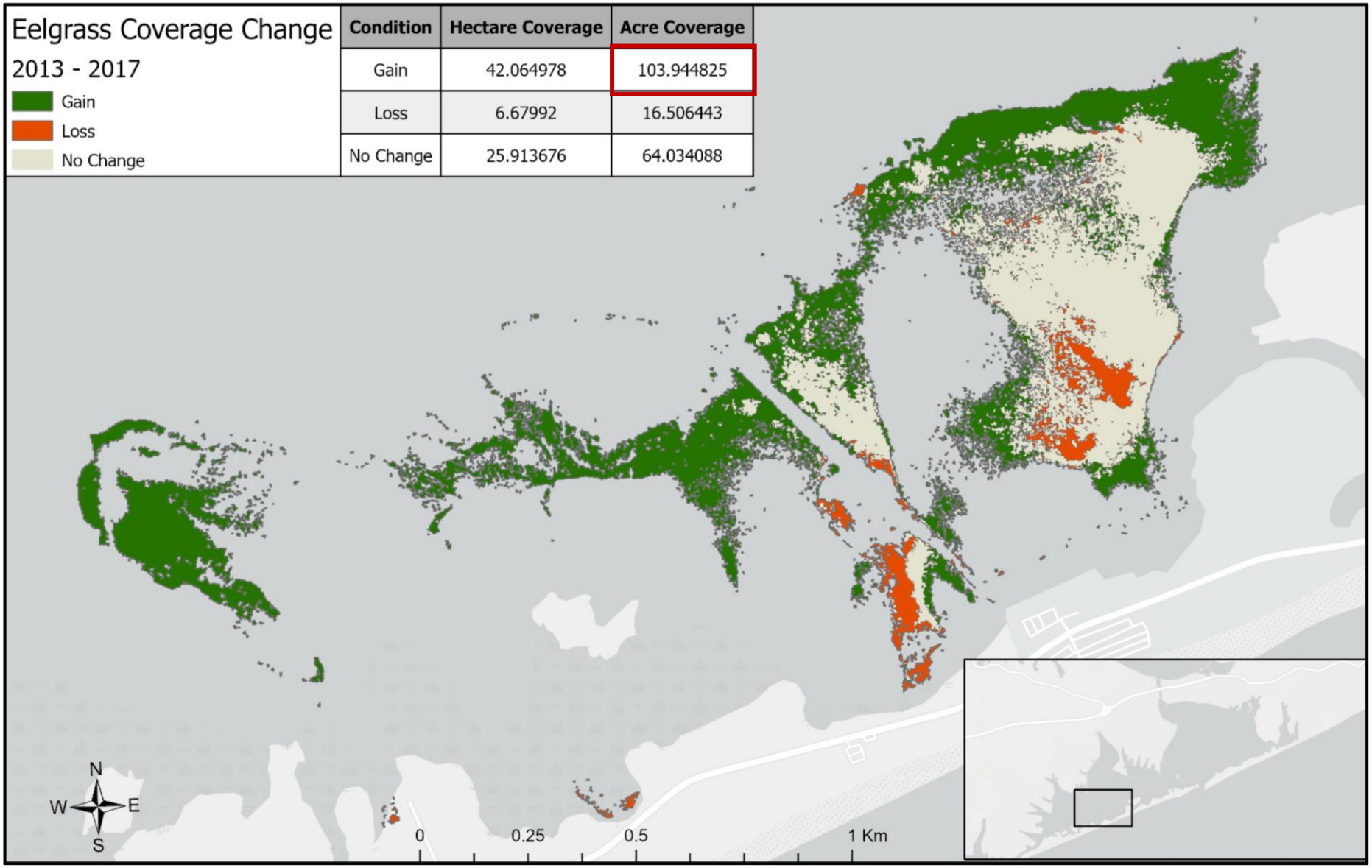

KEEP
CLAM



hand broadcasting and burlap bags


Year
2013
2014
2015
2016
2017
2018
2013


Year
2013
2014
2015
2016
2017
2018
2019



Condition	Hectare Coverage	Acre Coverage
Gain	42.064978	103.944825
Loss	6.67992	16.506443
No Change	25.913676	64.034088

Net gain estimate: 104 acres

eelgrass-dominated habitat between Pine Neck Point and East Point

Estimated cost to create: $25,480,000

URI estimated restoration cost analysis: $245,000/acre

frontiers | Frontiers in Marine Science

ORIGINAL RESEARCH
published: 30 August 2022
doi: 10.3389/fmars.2022.911731

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Rebuilding A Collapsed Bivalve Population, Restoring Seagrass Meadows, and Eradicating Harmful Algal Blooms In A Temperate Lagoon Using Spawner Sanctuaries

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