LUX ET SPES

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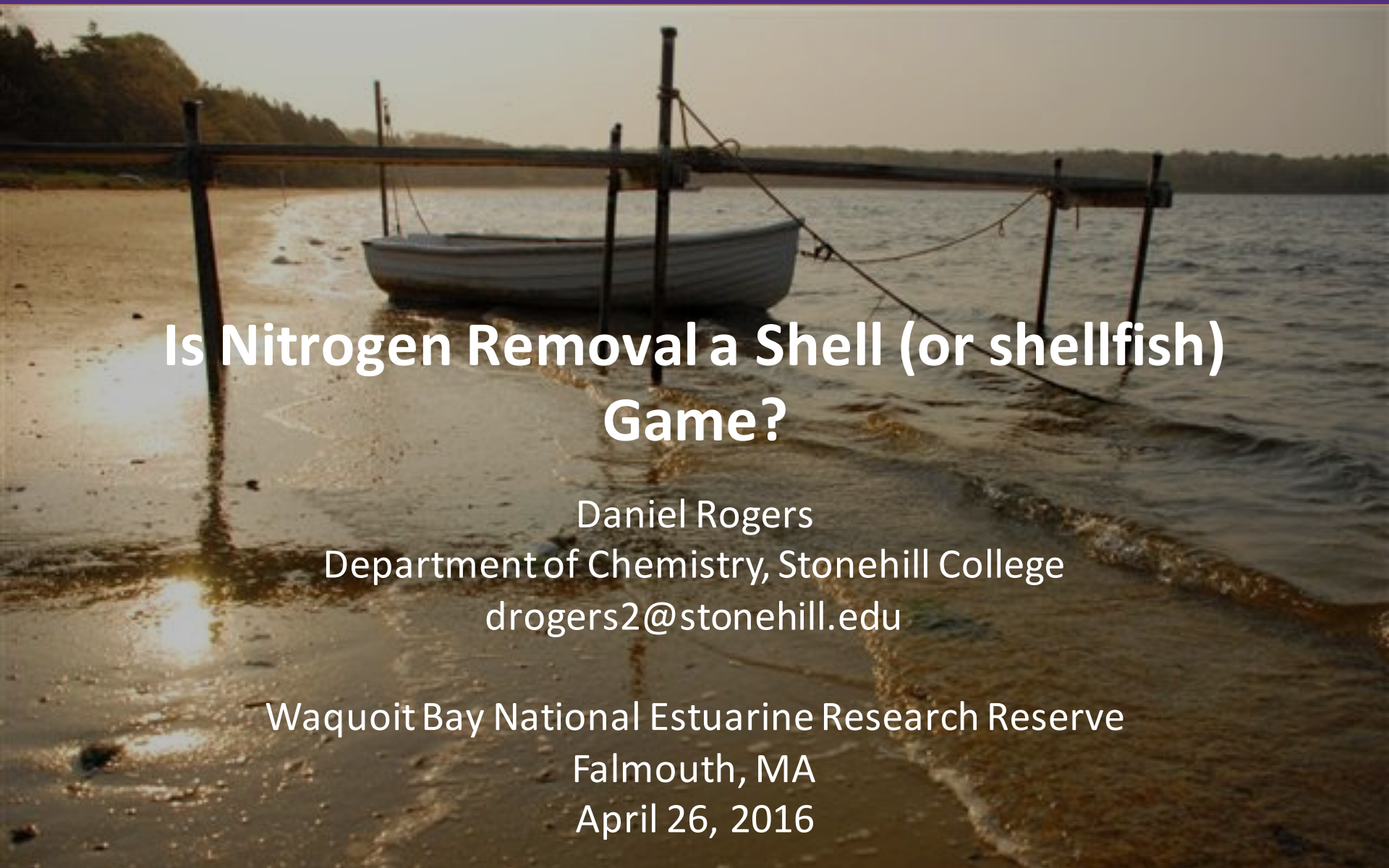
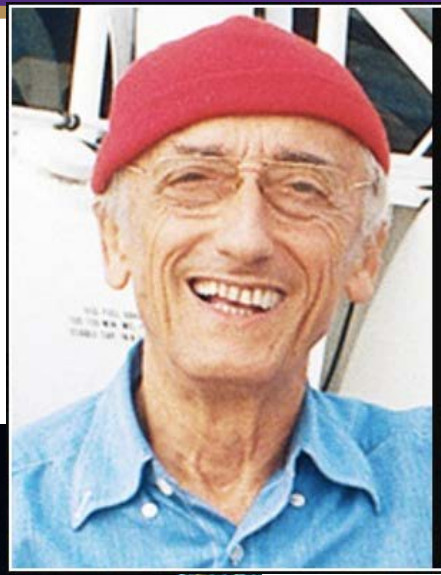


Is Nitrogen Removal a Shell (or shellfish) Game?

Daniel Rogers
Department of Chemistry, Stonehill College
drogers2@stonehill.edu

Waquoit Bay National Estuarine Research Reserve
Falmouth, MA
April 26, 2016

- **About Me**
  - How did you get here?
  - What are you interested in?
    - Very different environments but similar interaction between life and chemistry.
- **The Interplay between Life and Chemistry**
  - Nitrogen
  - Estuaries
  - Waquoit groundwater
  - Oysters
- **Can we use this information?**
  - Modeling work, future studies.

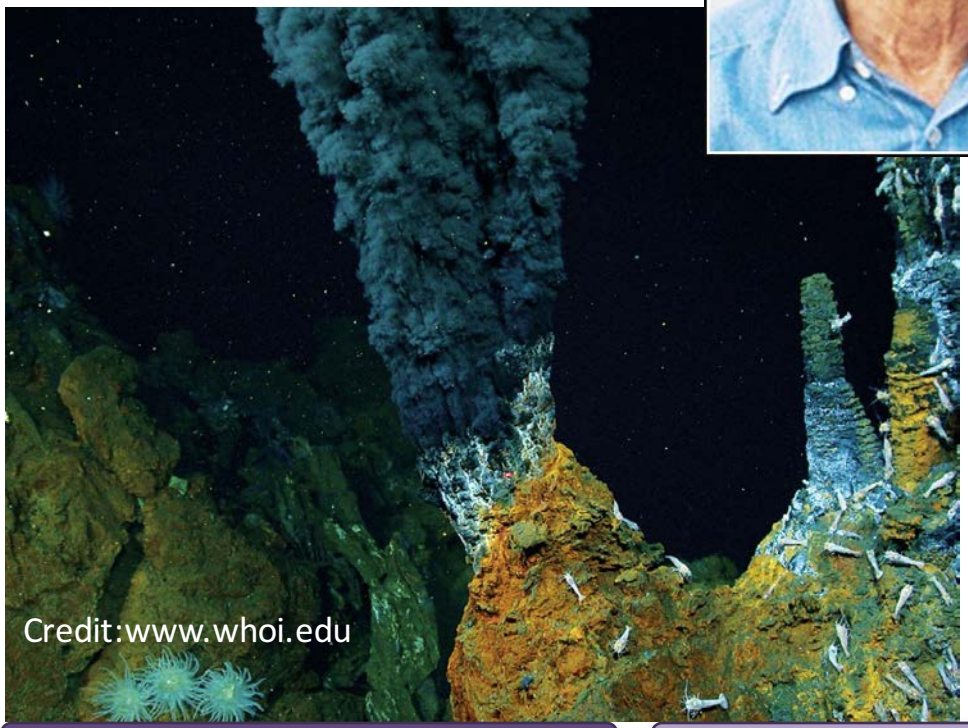


For most of history, man has had to fight nature to survive; in this century he is beginning to realize that, in order to survive, he must protect it.

— Jacques Yves Cousteau —

AZ QUOTES

Credit:www.azquotes.com



Credit:www.whoi.edu

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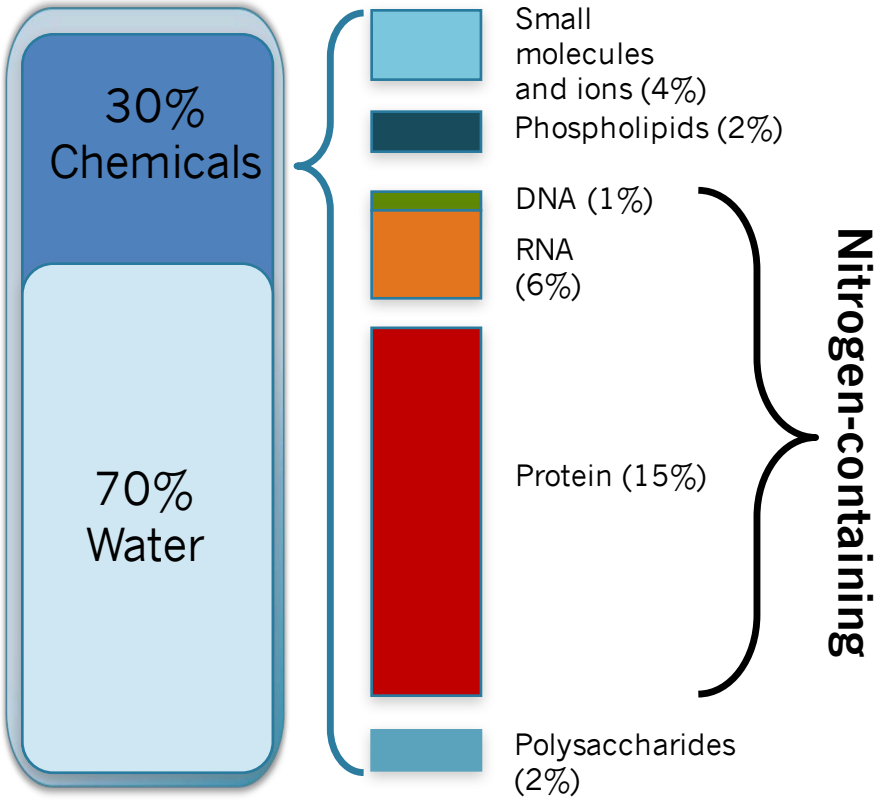
MIT-WHOI

JOINT PROGRAM IN OCEANOGRAPHY/APPLIED OCEAN SCIENCE & ENGINEERING

What is the relationship between biological processes and chemical environment?

- How does chemistry influence life?
- How fast are resources moved in an environment?
- What are the mechanisms involved?
- What signatures of life are consistent between environments?

Why do we care about nitrogen?



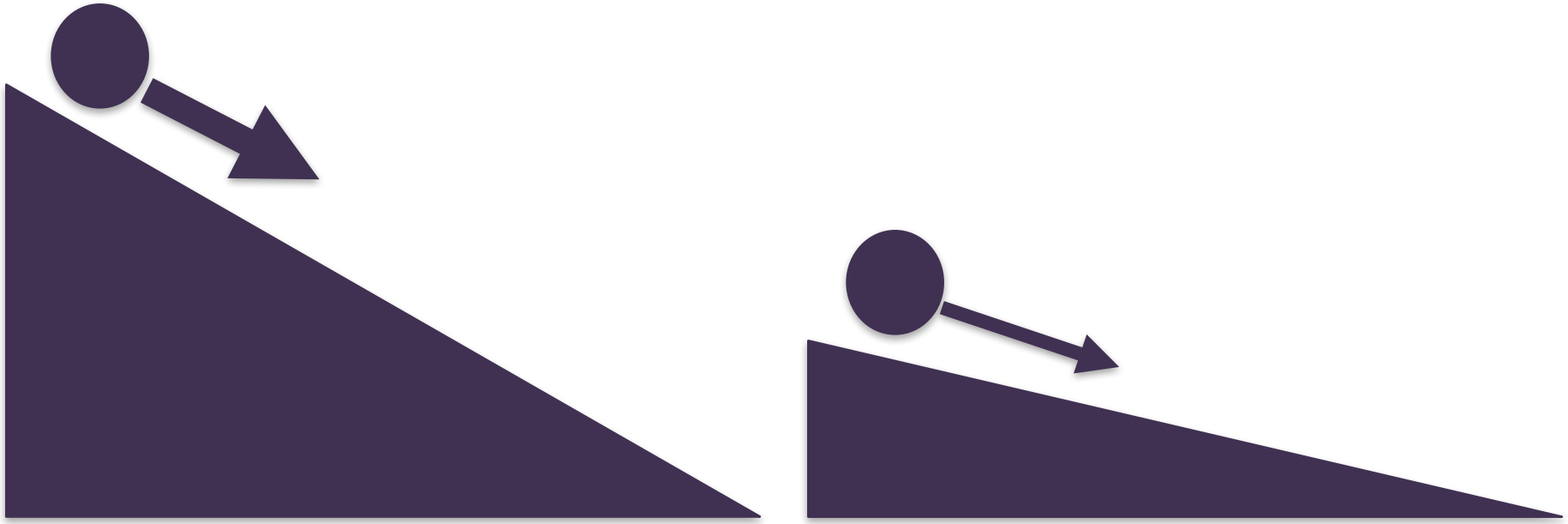
More than 20% of the cell weight is built with nitrogen.

- One of six elements required for all life (CHONPS).
- Its abundance. Nitrogen is everywhere!
- However, its lack of abundance in a usable form often limits life.
- Humans have gone to great lengths to produce more (anthropogenic) biologically available nitrogen.
- Anthropogenic nitrogen has altered the environment.

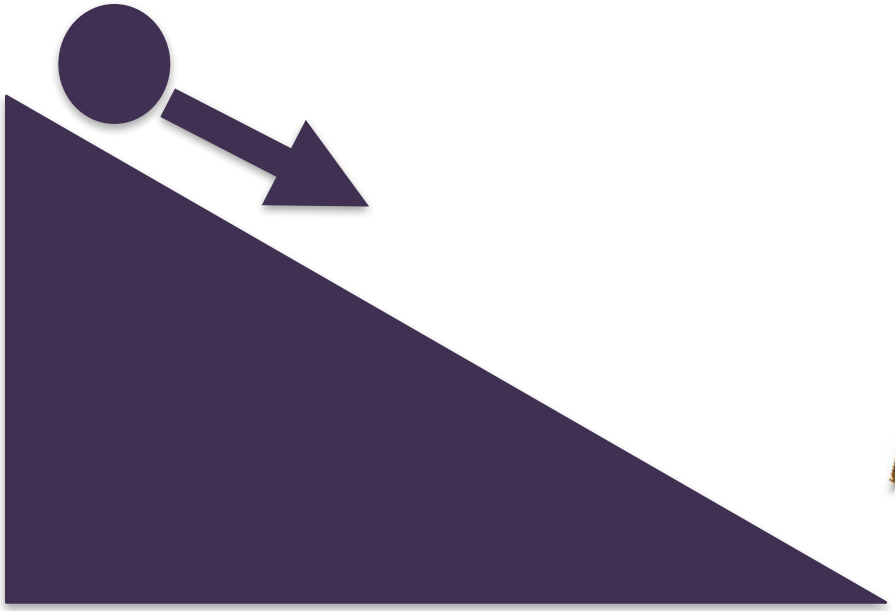
Life drives chemistry / Chemistry drives life

- Life
  - Requires energy source
  - In a race to harvest energy
  - In competition for energy
- Chemistry
  - Moves toward balance
    - giving off energy
    - The more out of balance the more energy will be available
  - Tends to move slowly, rates driven by the degree of difference

Steeper gradient mean more energy



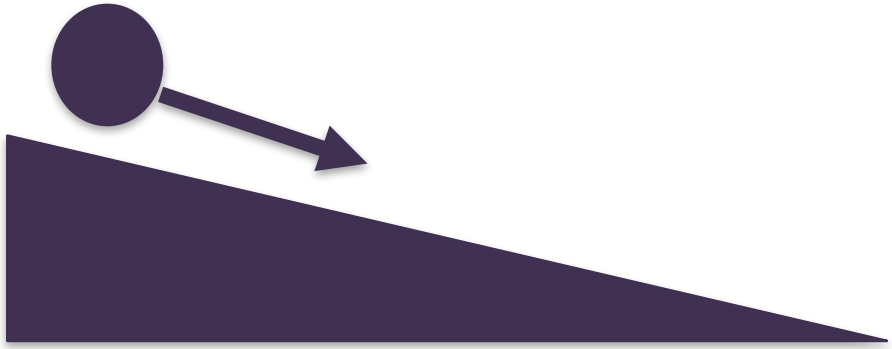
Steeper gradient mean more energy



/ Chemistry drives life


Credit:www.elephantfacts.com

Steeper gradient mean more energy



Without oxygen, other chemicals can be used.

Credit: iStockphoto.com

Microbes are metabolically diverse.

+

=

Credit: iStockphoto.com

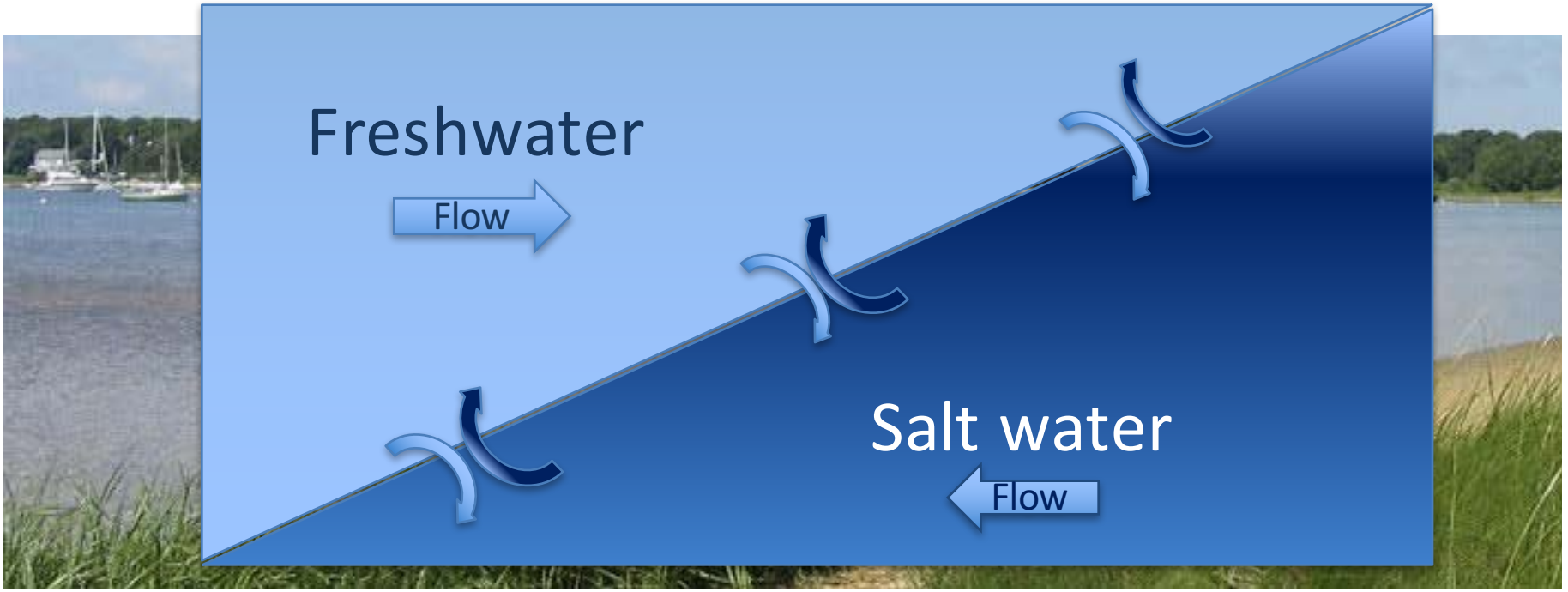
What else does nitrogen do?

Stimulates plant growth

Where does it come from

Land, septic tanks, fertilizer

Estuaries are environments where a chemical gradient persists: freshwater mixing with sea water.



Estuaries are zones where freshwater and sea water mix.

- Chemically complex – lots of energy sources for microbes
- Lots of nutrients for the base of the food chain
- Lots of higher biomass because the base is supported

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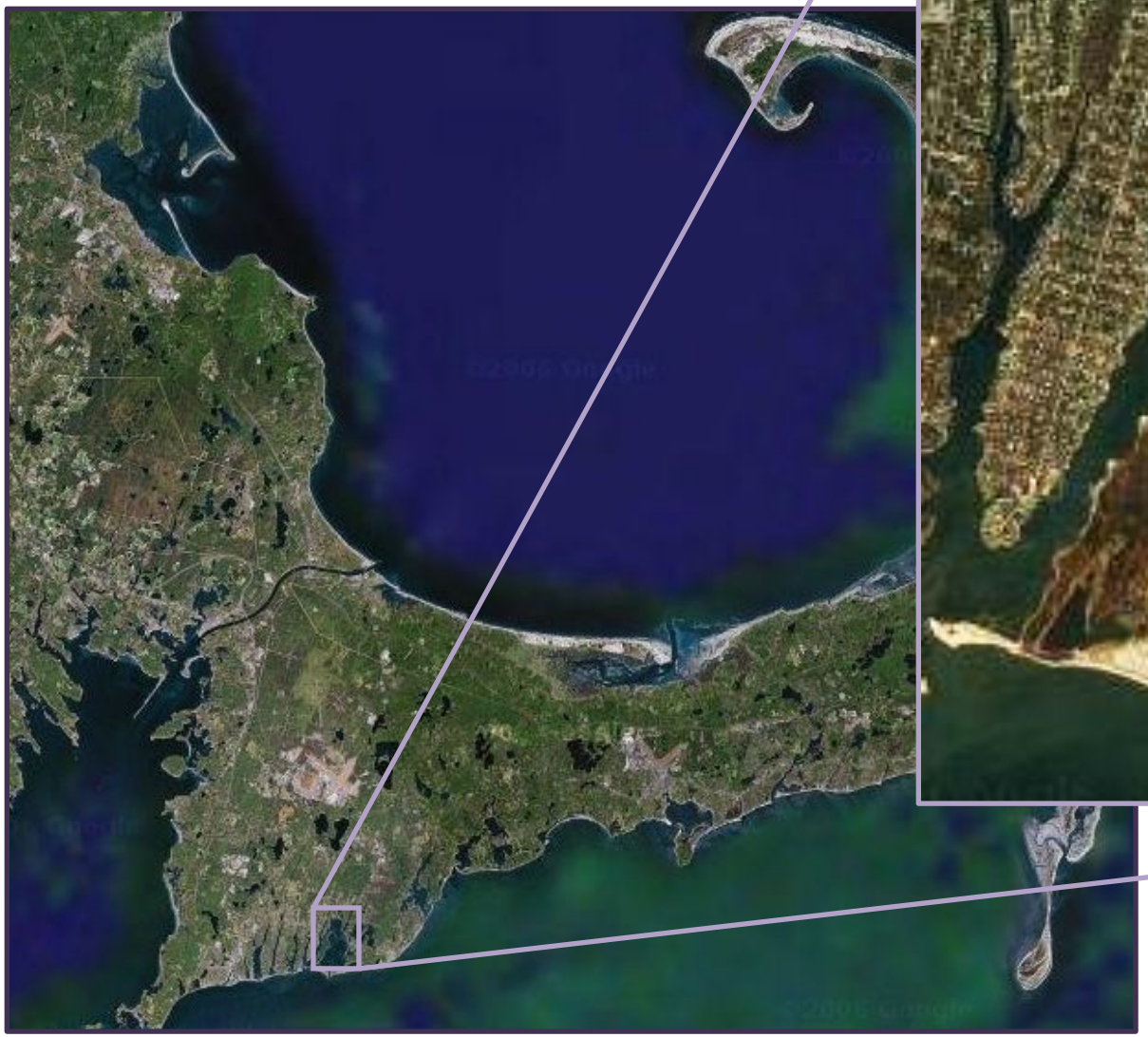
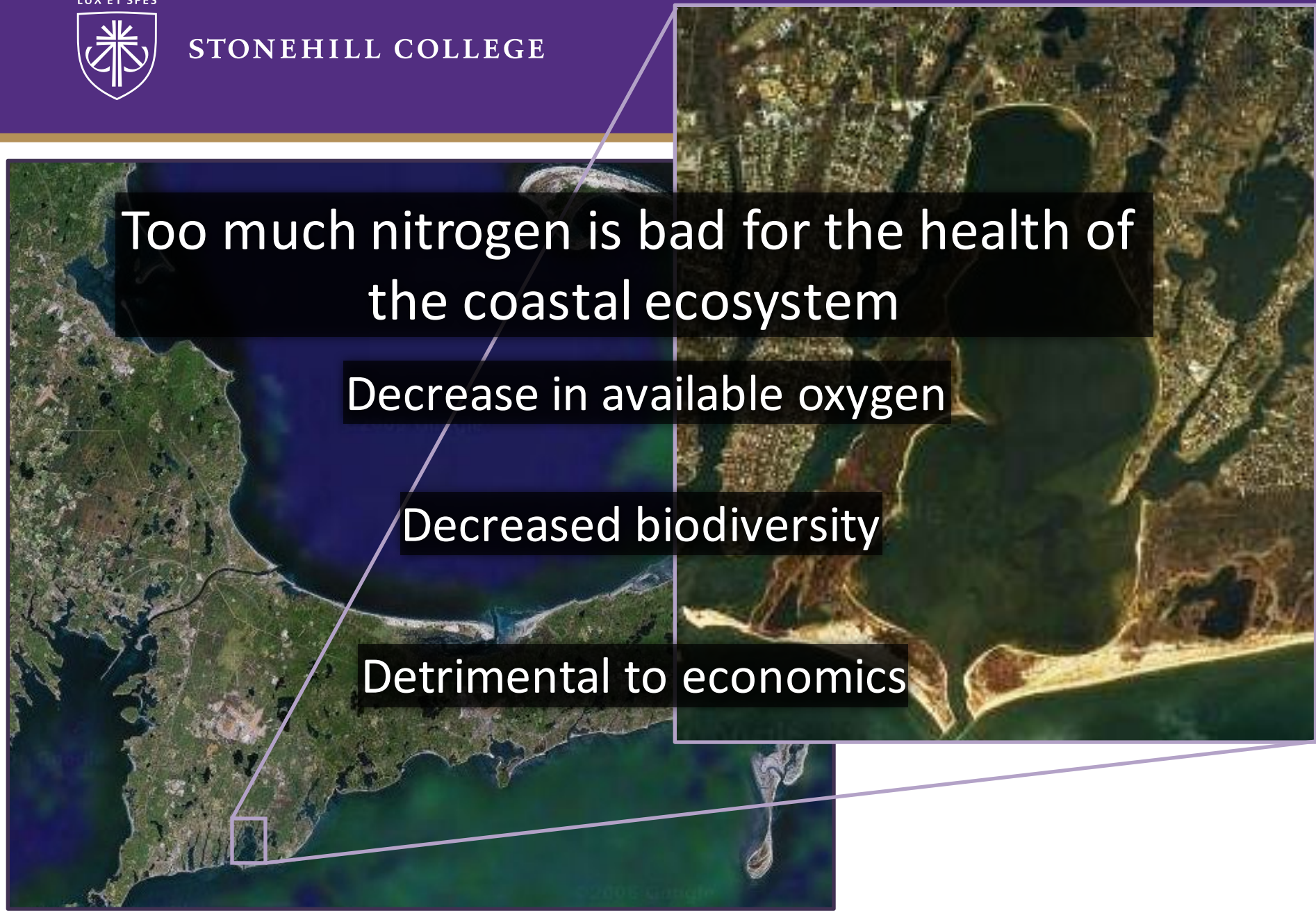




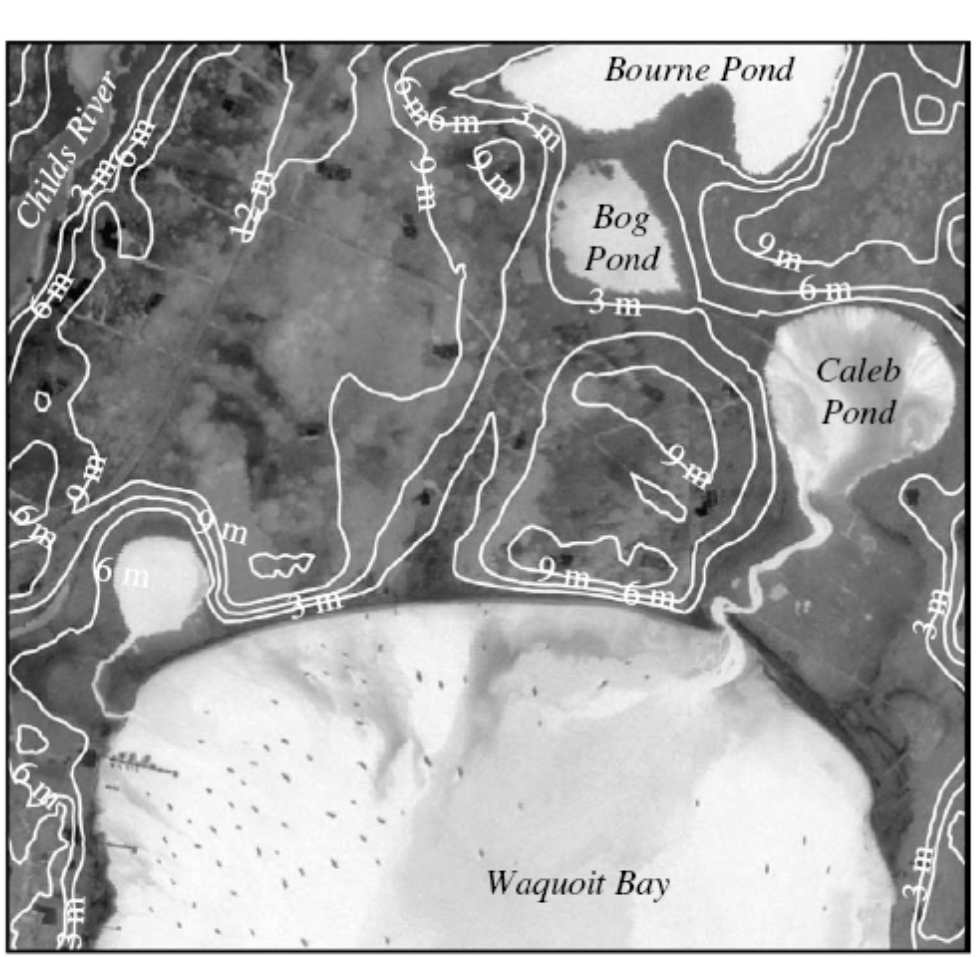
Too much nitrogen is bad for the health of the coastal ecosystem

Decrease in available oxygen

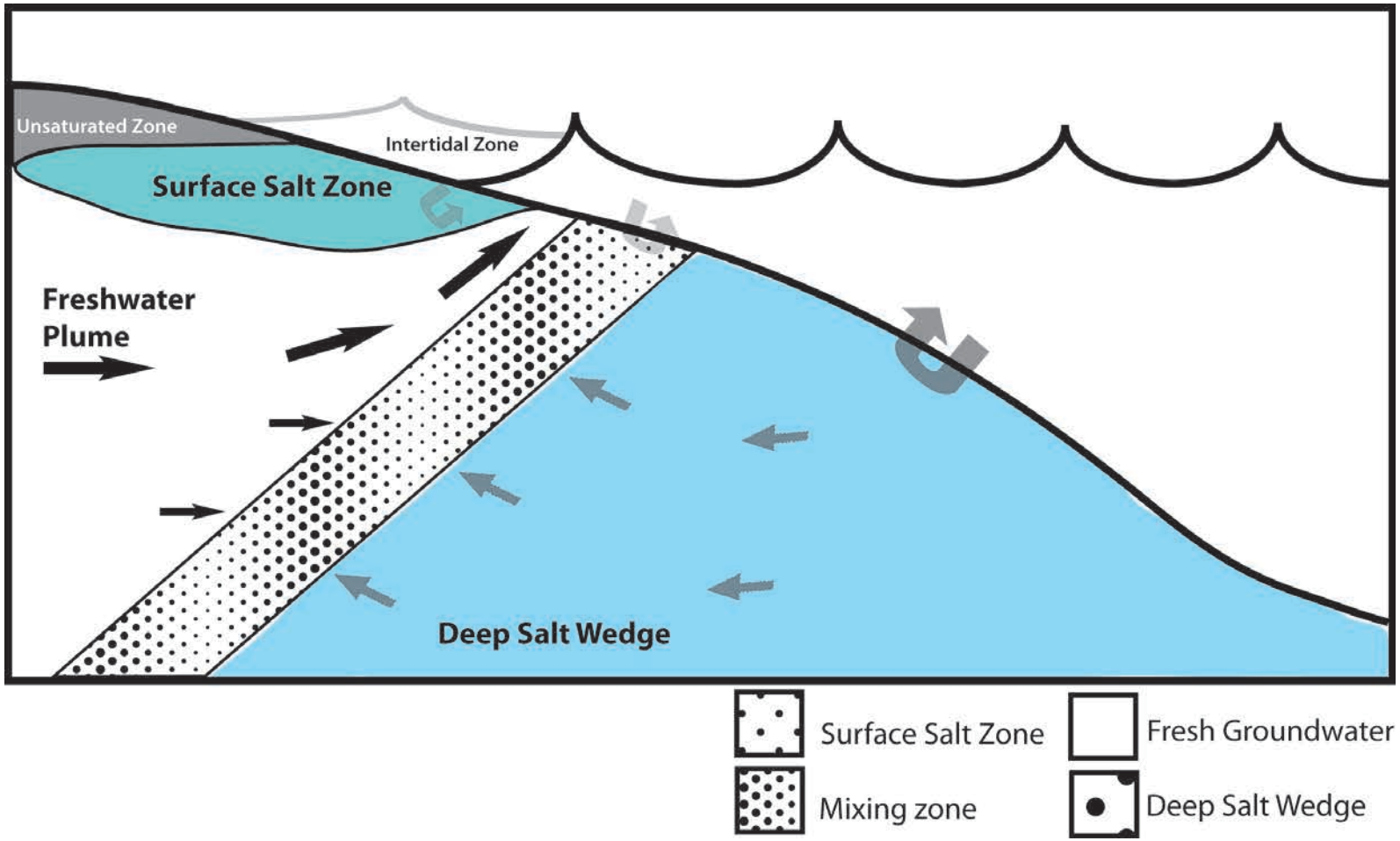
Decreased biodiversity

Detrimental to economics

About half of the freshwater entering Waquoit Bay is groundwater

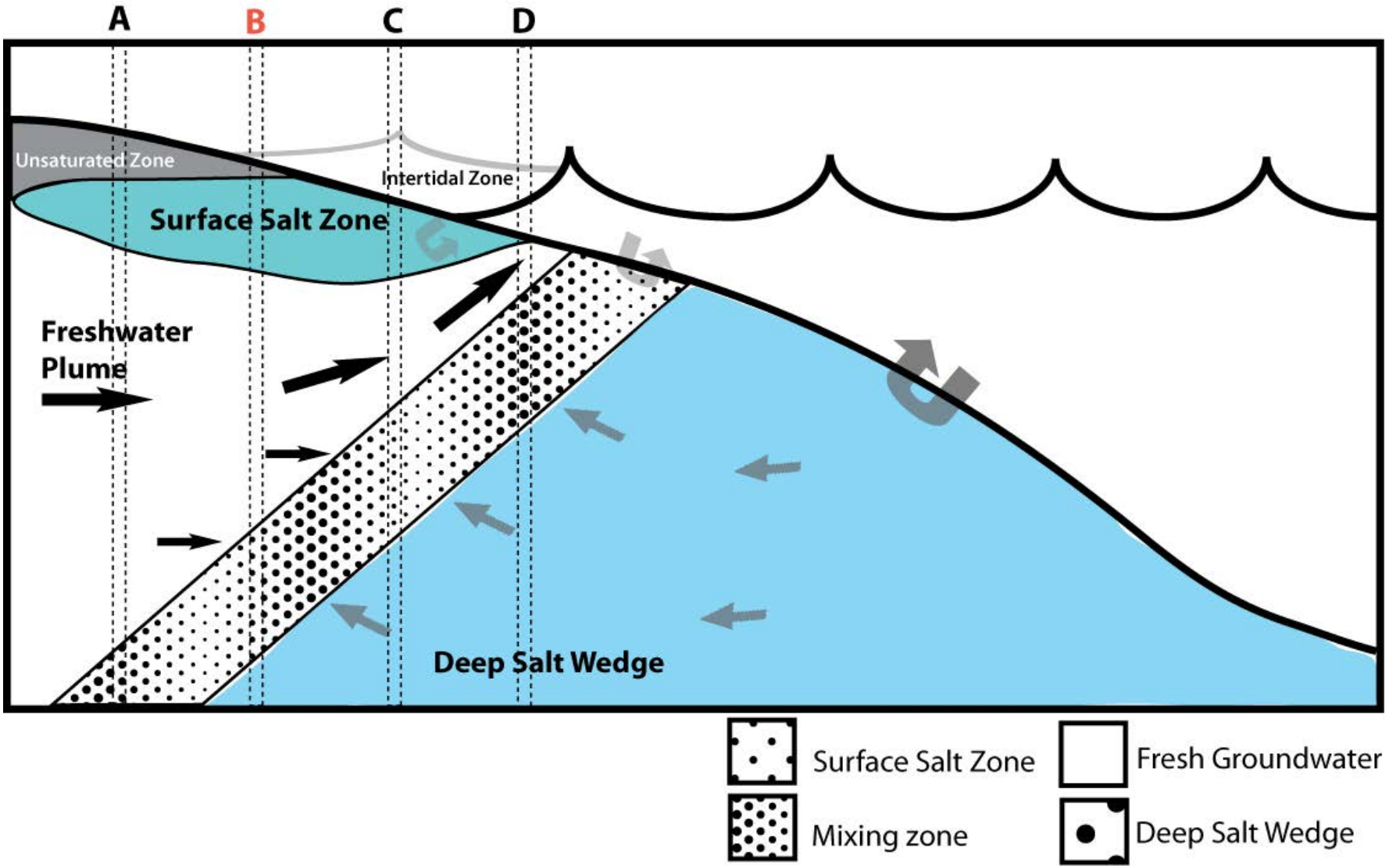


(Mulligan and Charette, 2006)

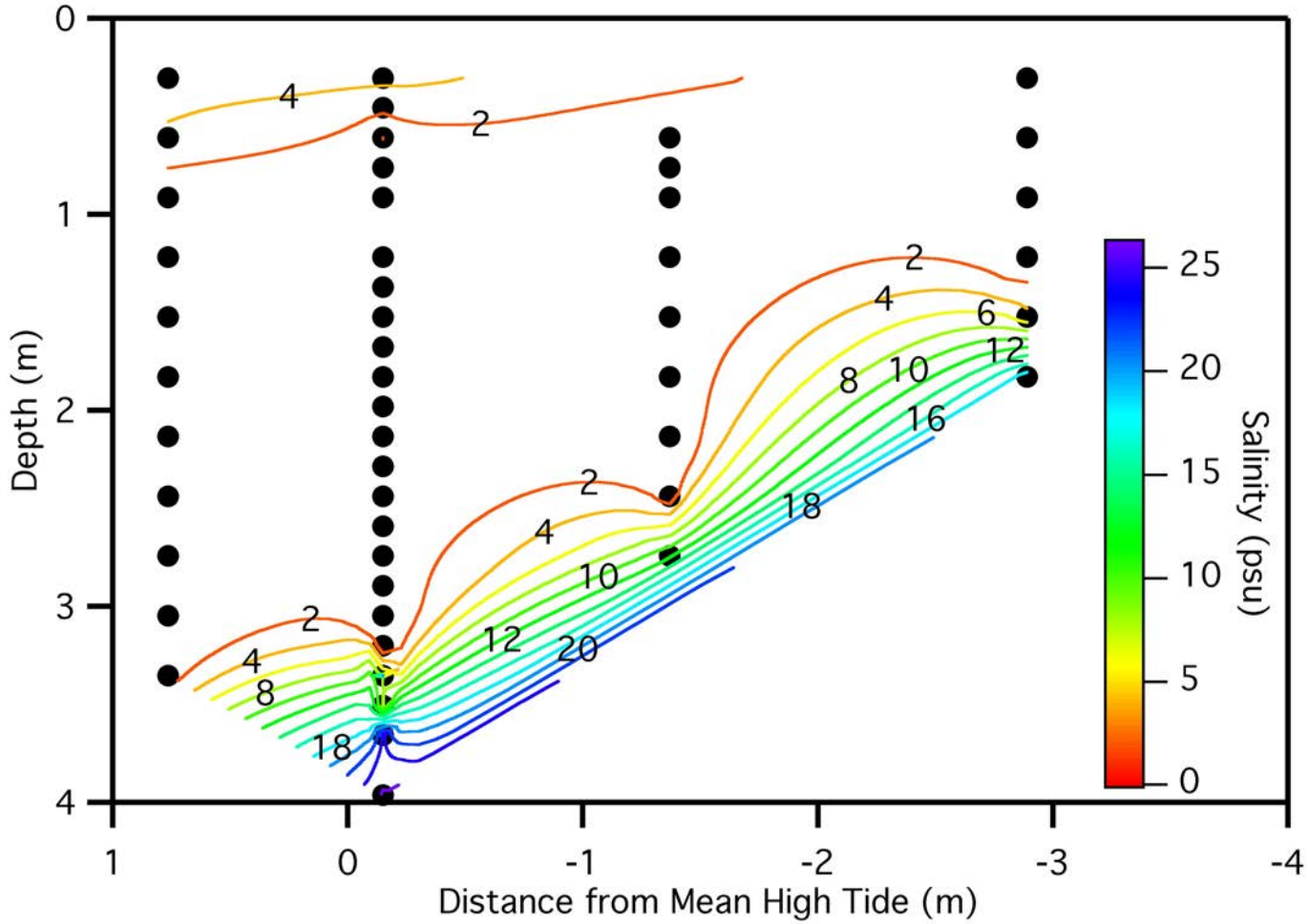


Atlantic, 2-4 x 10^{13} m^3 yr^{-1},

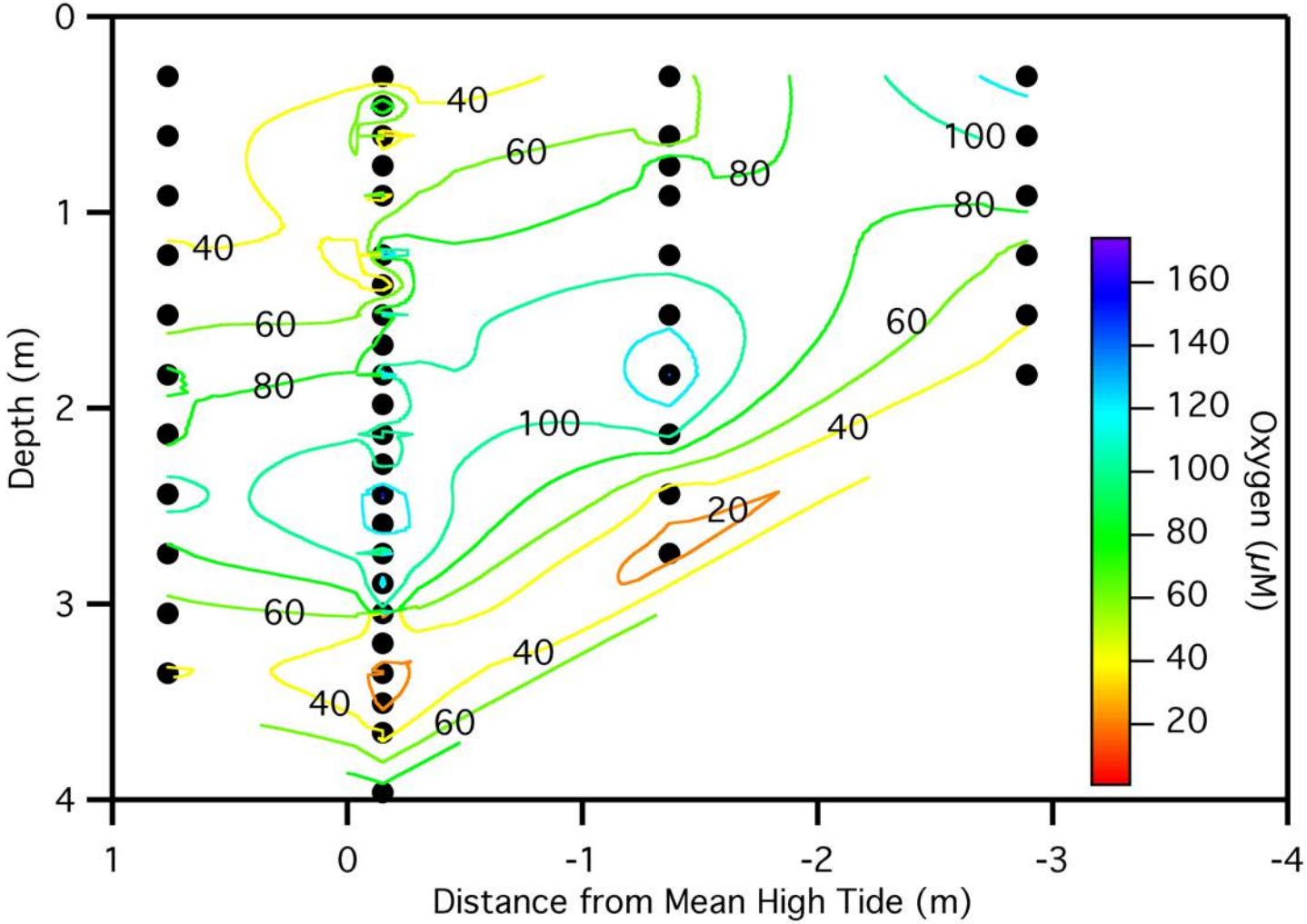
80-160% of river flow (Moore et al., 2008)


A
B
C
D
Unsaturated Zone
Intertidal Zone
Surface Salt Zone
Freshwater
Plume
Deep Salt Wedge
Surface Salt Zone
Fresh Groundwater
Mixing zone
Deep Salt Wedge

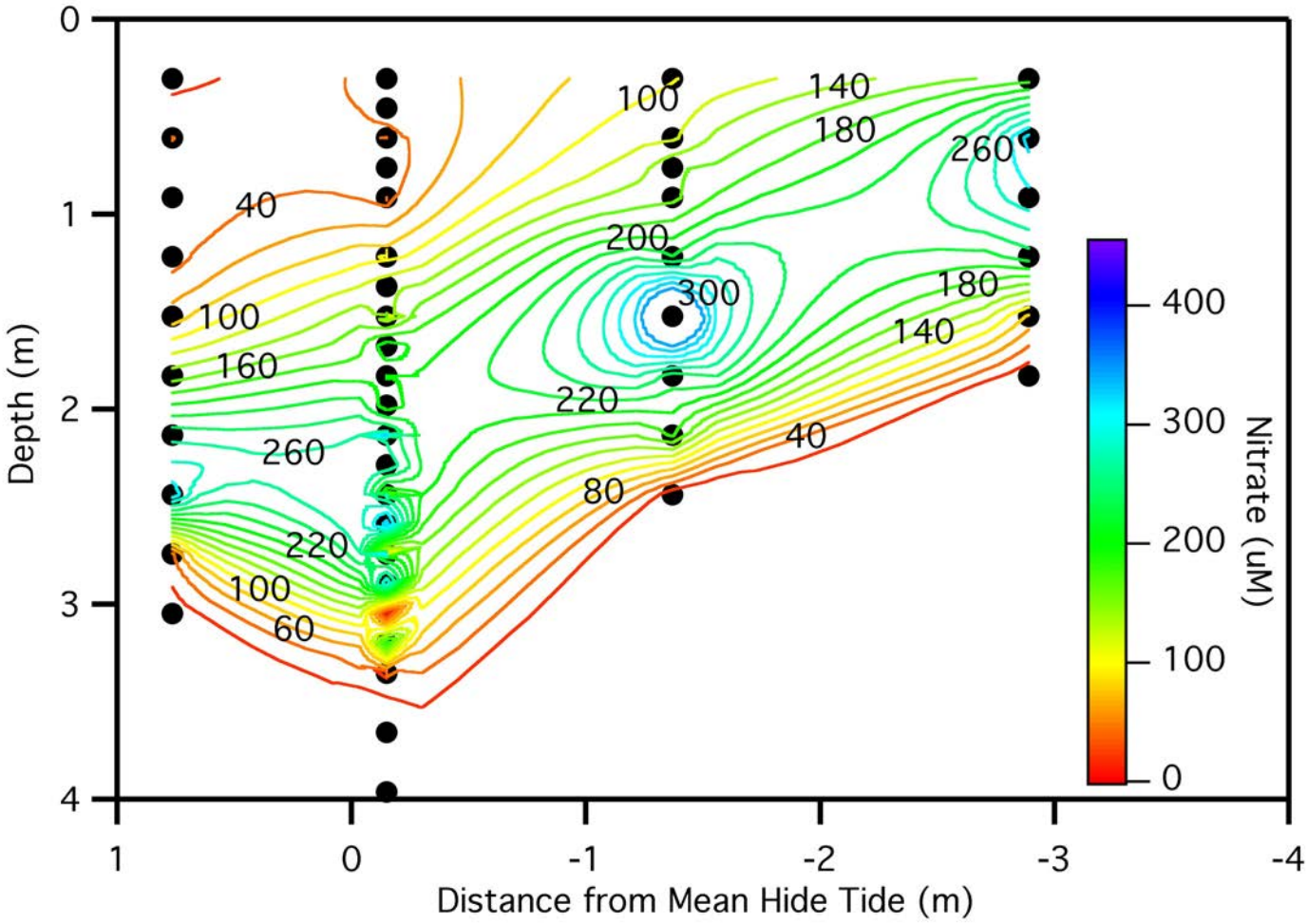
Salinity


Depth (m)
0
1
2
3
4
1
0
-1
-2
-3
-4
Distance from Mean High Tide (m)
Salinity (psu)
25
20
15
10
5
0
2
4
6
8
10
12
16
18
20

Oxygen

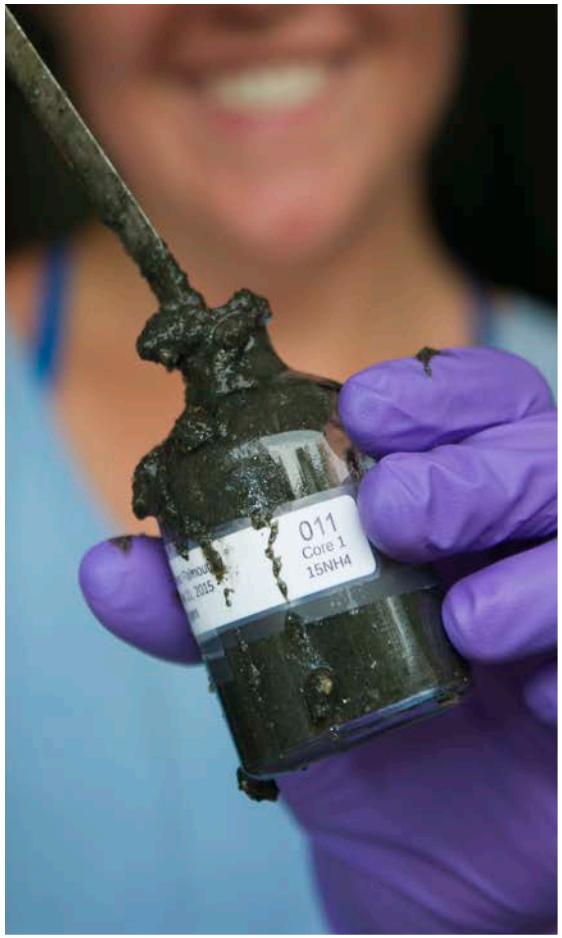

Depth (m)
0
1
2
3
4
1
0
-1
-2
-3
-4
Distance from Mean High Tide (m)
40
60
80
100
80
40
60
80
100
60
40
20
60
40
40
60
160
140
120
100
80
60
40
20
Oxygen (μM)

Nitrate


Depth (m)
0
1
2
3
4
1
0
-1
-2
-3
-4
Distance from Mean Hide Tide (m)
Nitrate (uM)
400
300
200
100
0
40
100
160
260
220
100
60
100
200
300
220
80
140
180
260
180
140
40

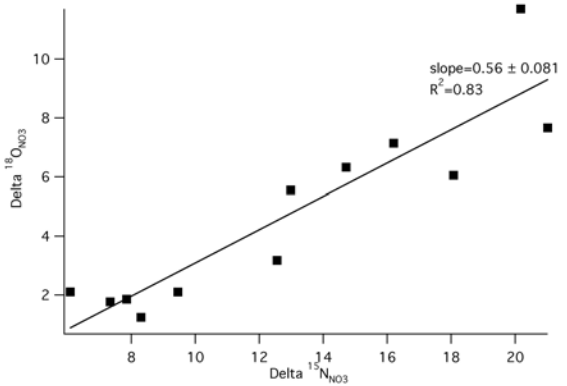
Collect Sediments

Add tracers



Credit: Thomas Kleindinst, WHOI

Look for N-removal



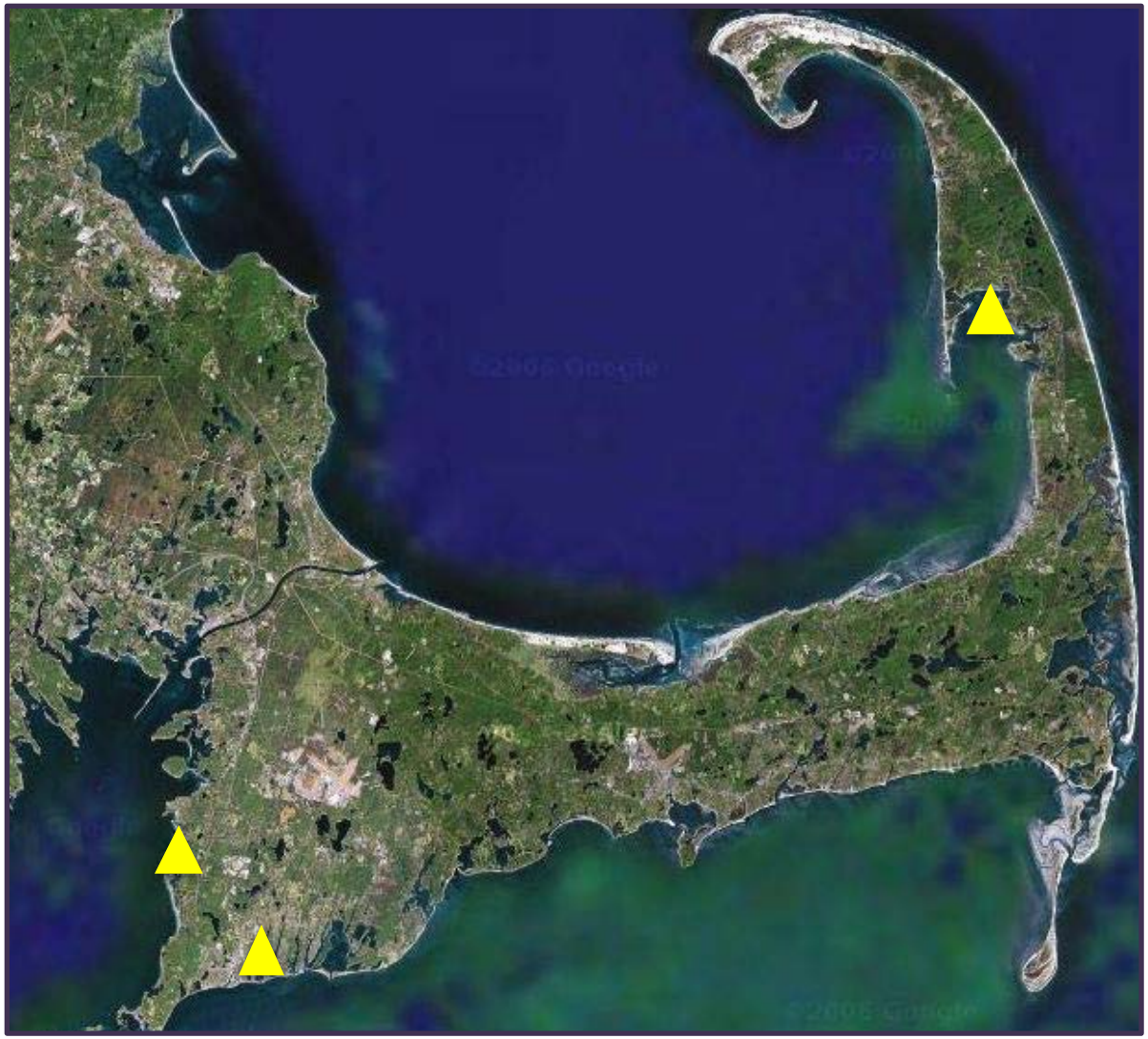
Why low rates of N-removal in ground water?

- Small zone where oxygen is absent
- Relatively short time for the groundwater to move through that zone
- Sediments in this zone are low in food (carbon)

Why Oysters?

- Economically desirable
- Incorporate nitrogen into biomass
  - ~0.5% of dry weight
  - ~12% of dry weight of tissue
- **May move a lot of nitrogen and carbon to the sediments**

Credit:Seafood.maryland.gov



How valuable are shellfish?

- >$60M for Barnstable alone in 2013*.
- Shellfish Farming is increasing.
  - ~250 growers on Cape Cod*.

- Little Pond, Falmouth
- Snug Harbor, West Falmouth
- Wellfleet Harbor, Wellfleet

- Floating Bags (3 m), benthic cages or a combination

(*Josh Reitsma and Diane Murphy, Cape Cod Cooperative Extension)

Little Pond

Credit:maps.google.com

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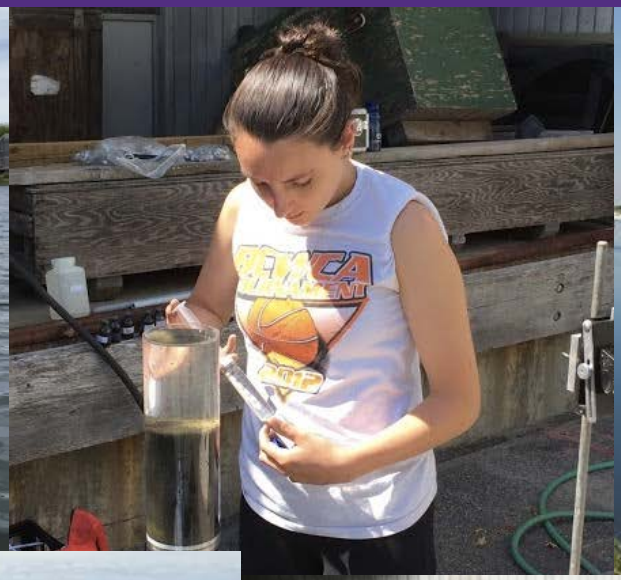

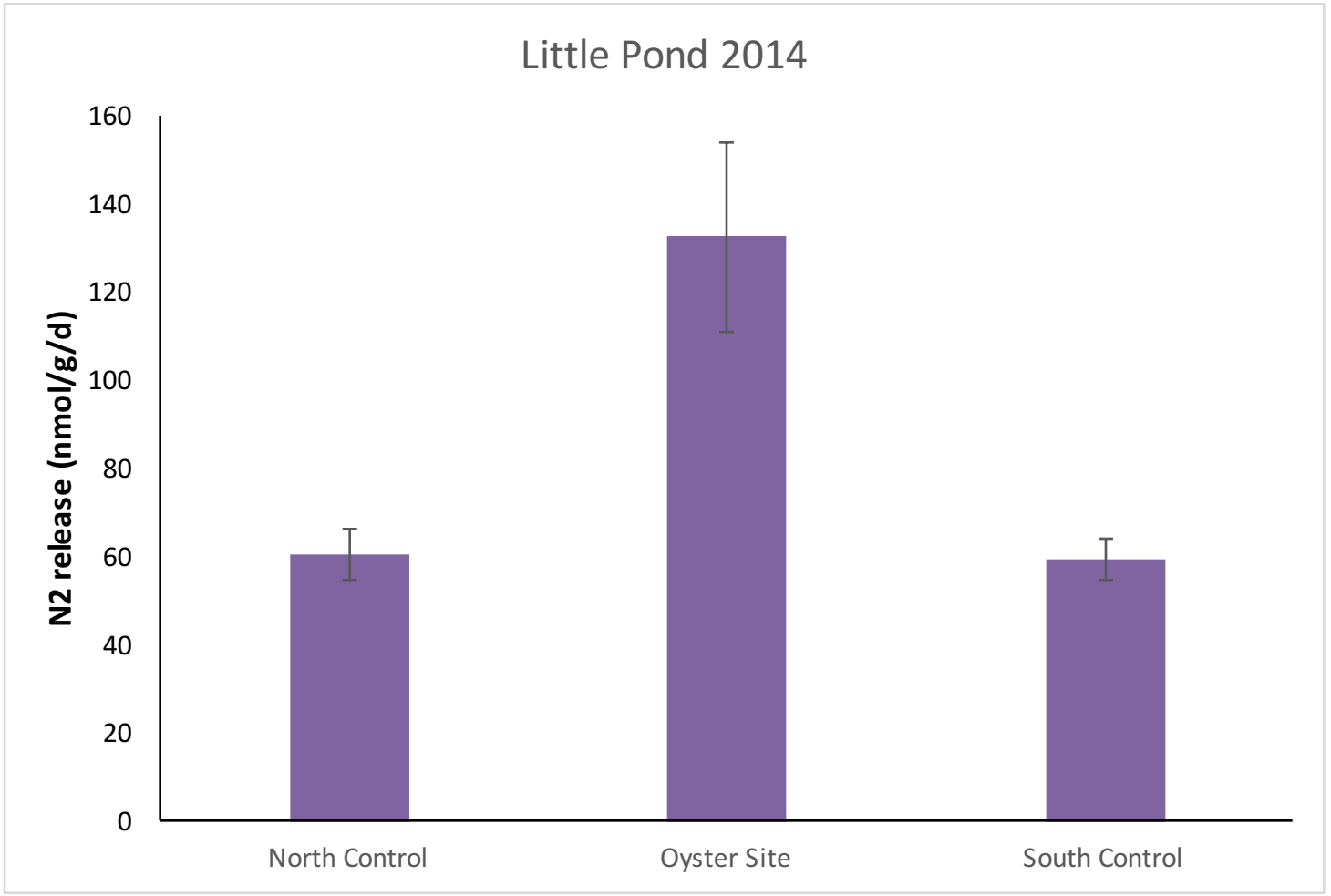
Little Pond 2014
N2 release (nmol/g/d)
160
140
120
100
80
60
40
20
0
North Control
Oyster Site
South Control

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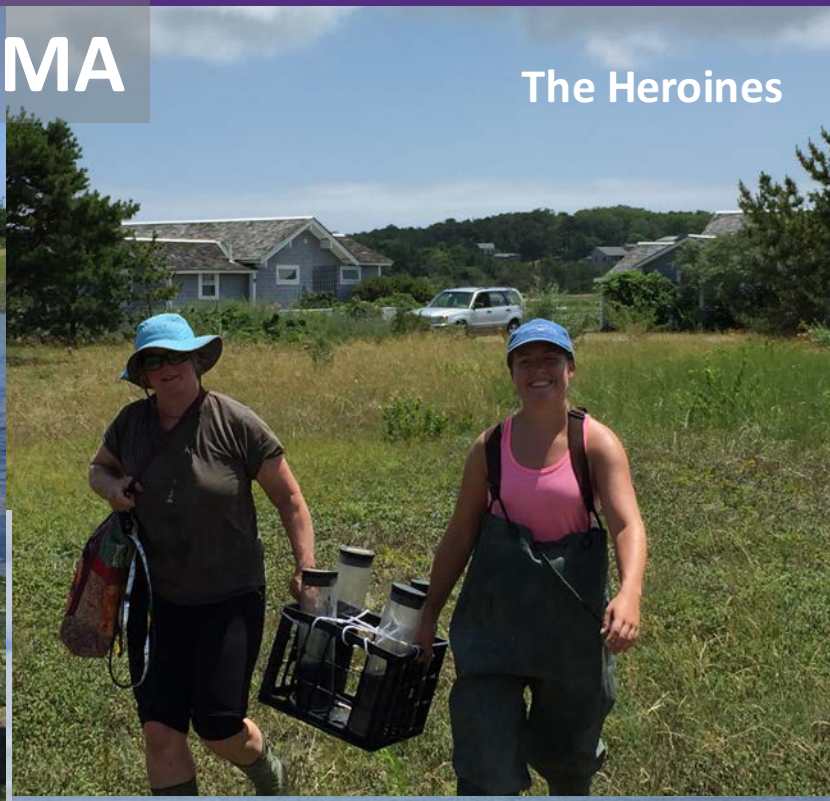
Wellfleet, MA

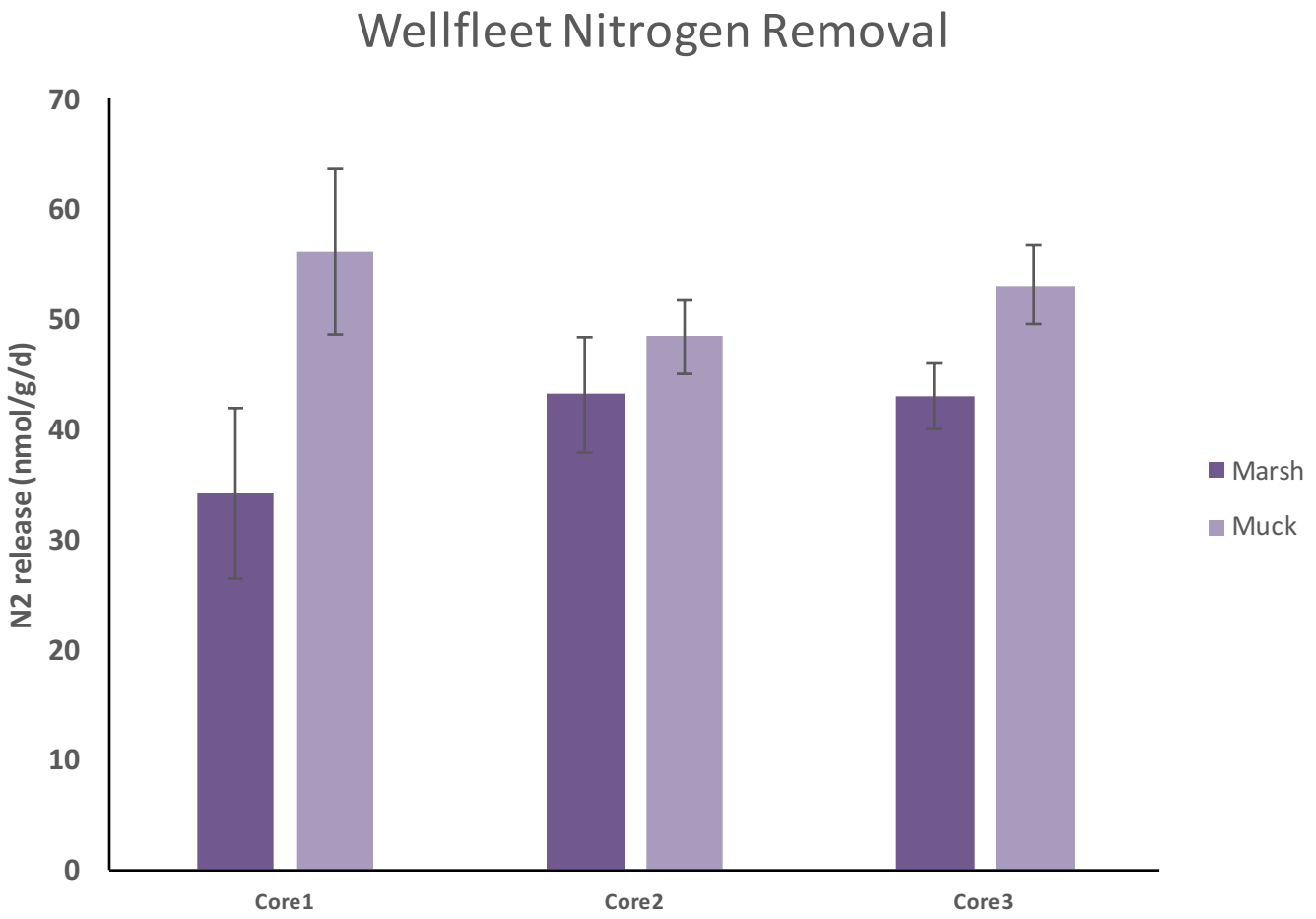
Marsh

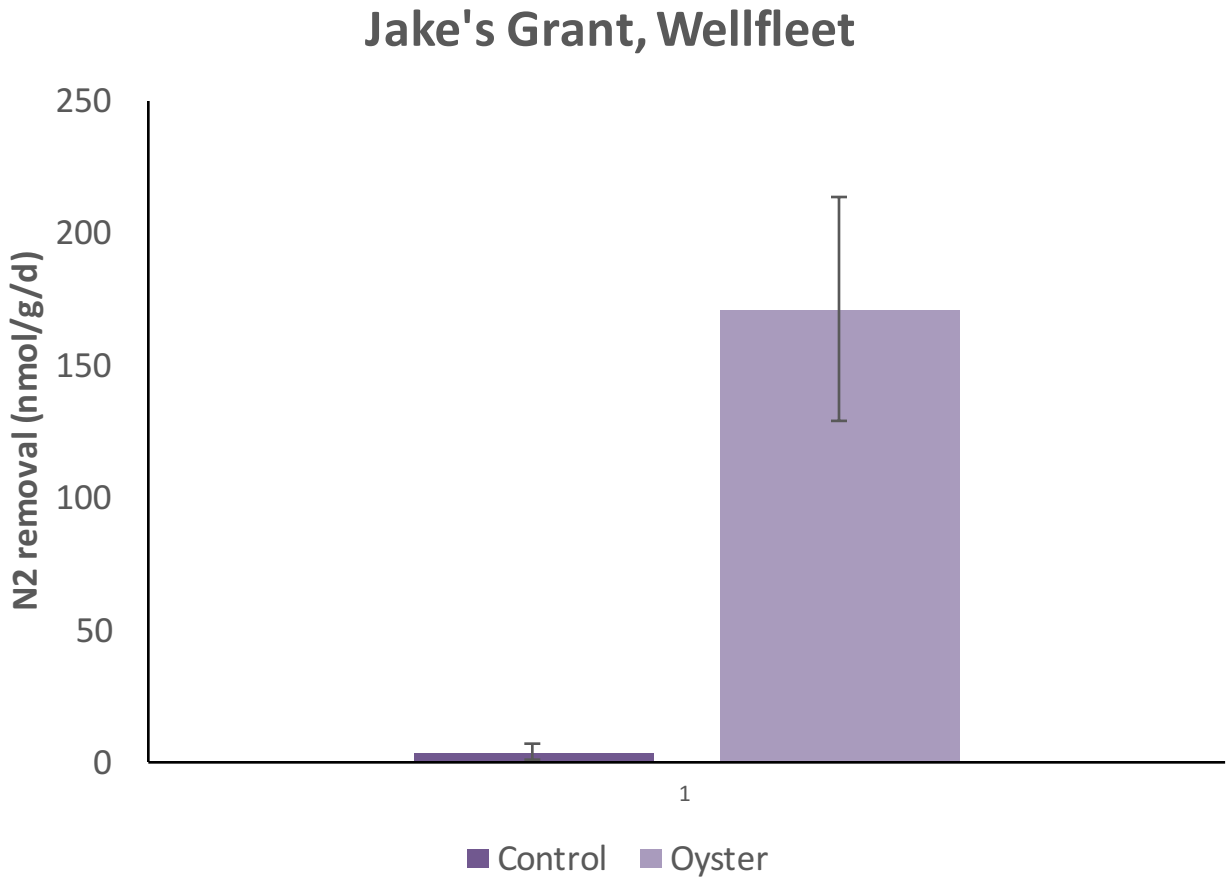
The Heroines



Muck

Jake's Grant


Wellfleet Nitrogen Removal
N2 release (nmol/g/d)
70
60
50
40
30
20
10
0
Core1
Core2
Core3
Marsh
Muck


Jake's Grant, Wellfleet
250
200
150
100
50
0
N2 removal (nmol/g/d)
1
Control
Oyster

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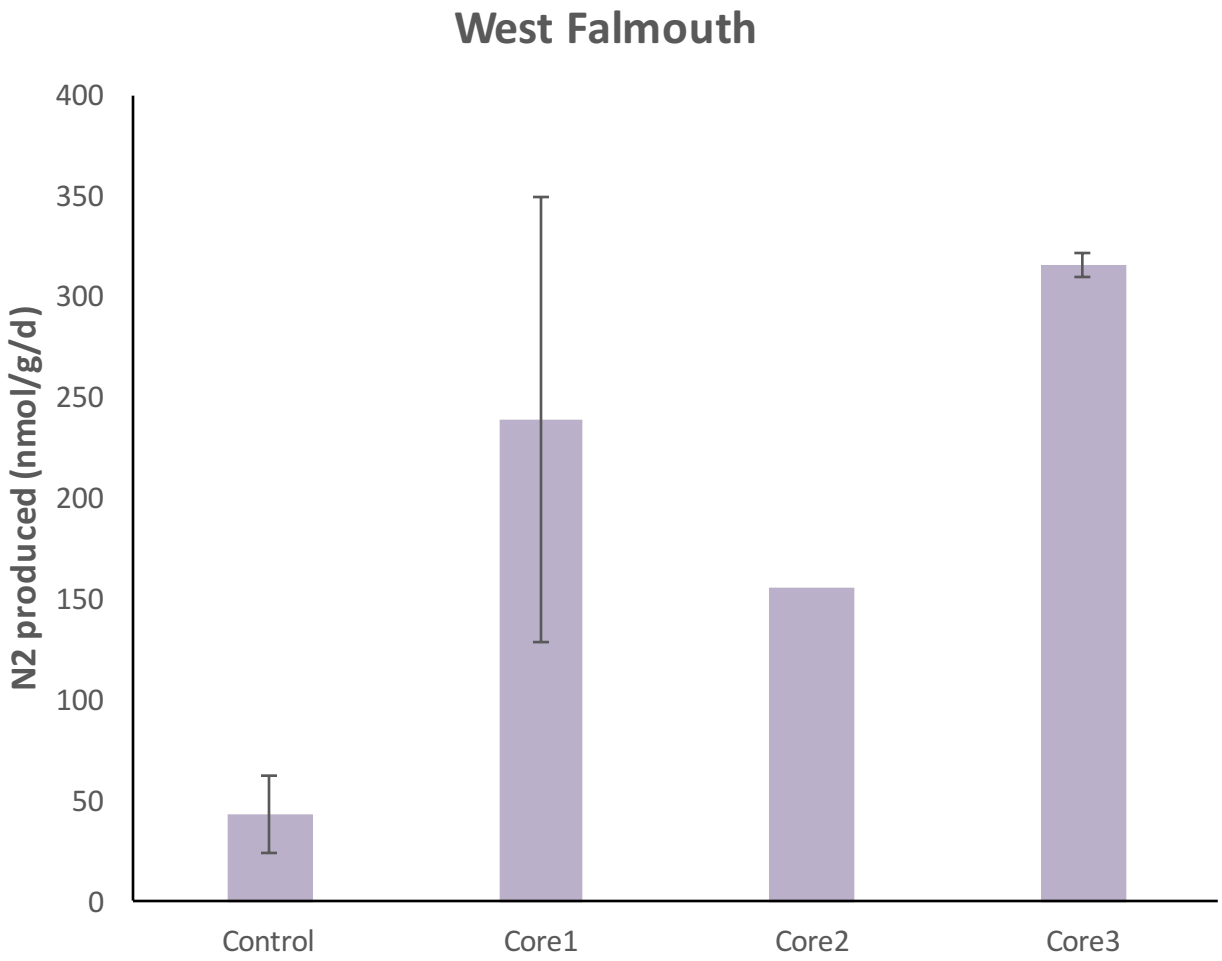
Snug Harbor, West Falmouth

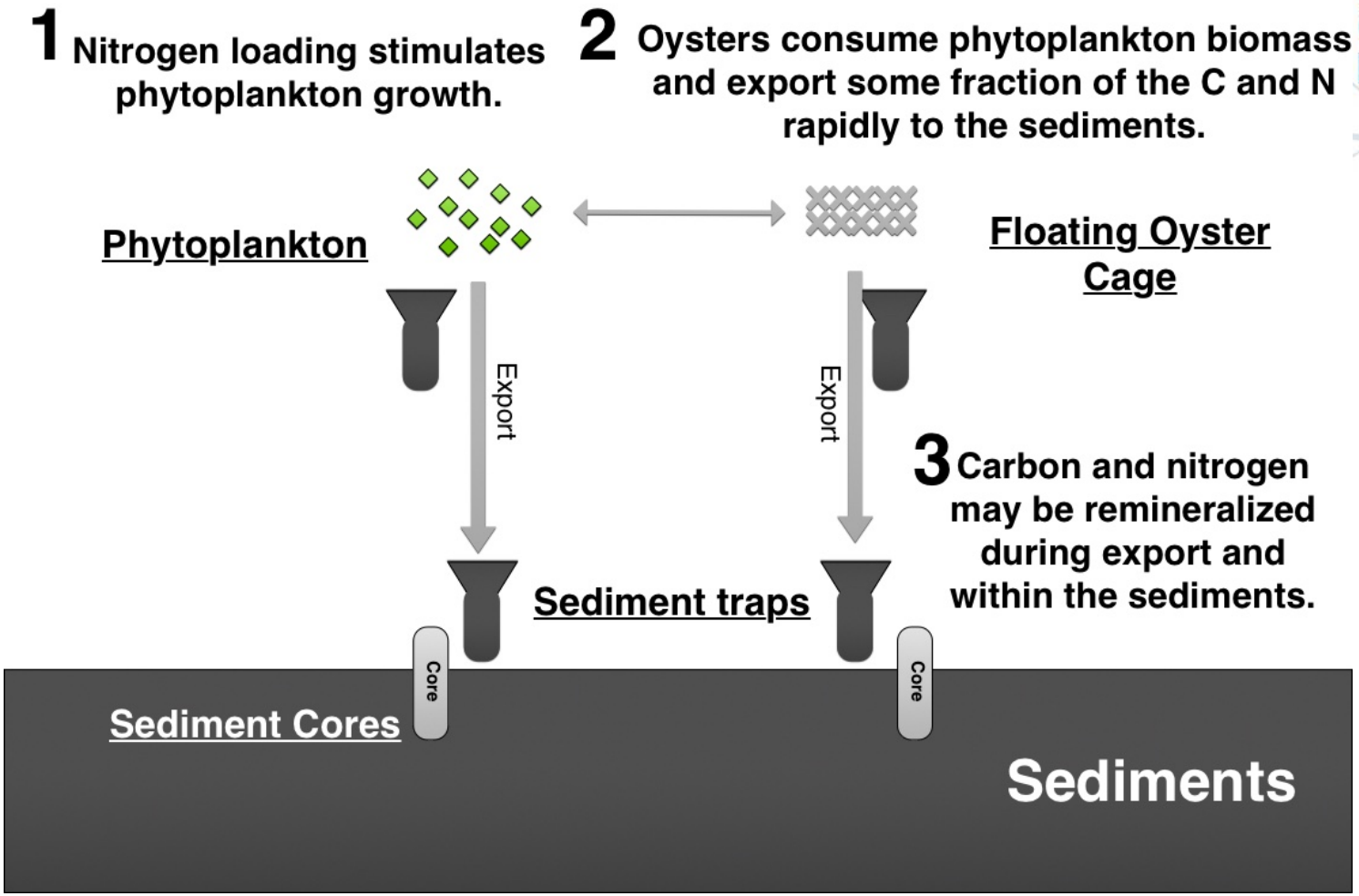

West Falmouth
N2 produced (nmol/g/d)
400
350
300
250
200
150
100
50
0
Control
Core1
Core2
Core3

Conclusions:

- Oyster activity does seem to increase removal of nitrogen from the underlying sediments.
  - increase may be more significant in well ventilated environments
- Increase in nitrogen is relatively well coordinated with the presence of the oysters (data not shown)
- Different oyster farming strategies may also influence impact on nitrogen removal

What is the next step in application:

Woods Hole Sea Grant

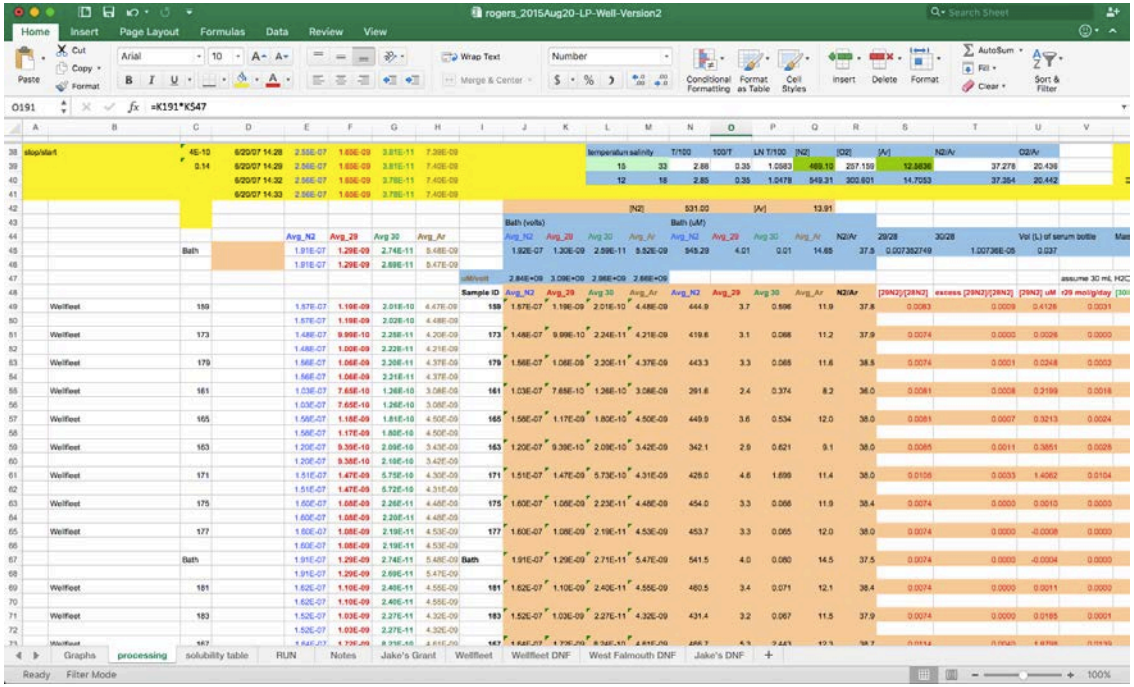


Model the movement of nitrogen to the sediment, given a particular oyster biomass in Little Pond.

Drive model with oyster biomass, sedimentary C and N content

Extrapolate to similar estuaries on Cape and test the model.

Distribute model to towns to help management of coastal waters

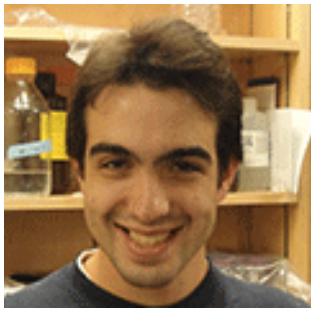


Acknowledgements:

Funding Agencies:

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930
COASTAL OCEAN INSTITUTE
Woods Hole Sea Grant





Charette Lab – WHOI
Casciotti Lab – WHOI/Stanford

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