Subaqueous Soils and Shellfish Aquaculture

Mark H. Stolt

University of Rhode Island
Natural Resources Science

Acknowledgements

Laboratory of Pedology & Soil Environmental Science

Soils Work!

Dr. Jose Amador

Chelsea Duball
Alex Salisbury
Dr. Brett Still

Oyster farmers!

NRCS Soil Scientists
Jim Turenne
Maggie Payne

Steven Brown (TNC)
Dave Beutel (CRMC)

Coastal Fellows
Shannon Cron, Mason Garfield, Kristopher Plante, Annie Ragan, Lauren Salisbury, Ed Tally, Marissa Theve

Sea Grant Rhode Island

NRCS

riaes
RI Agricultural Experiment Station

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

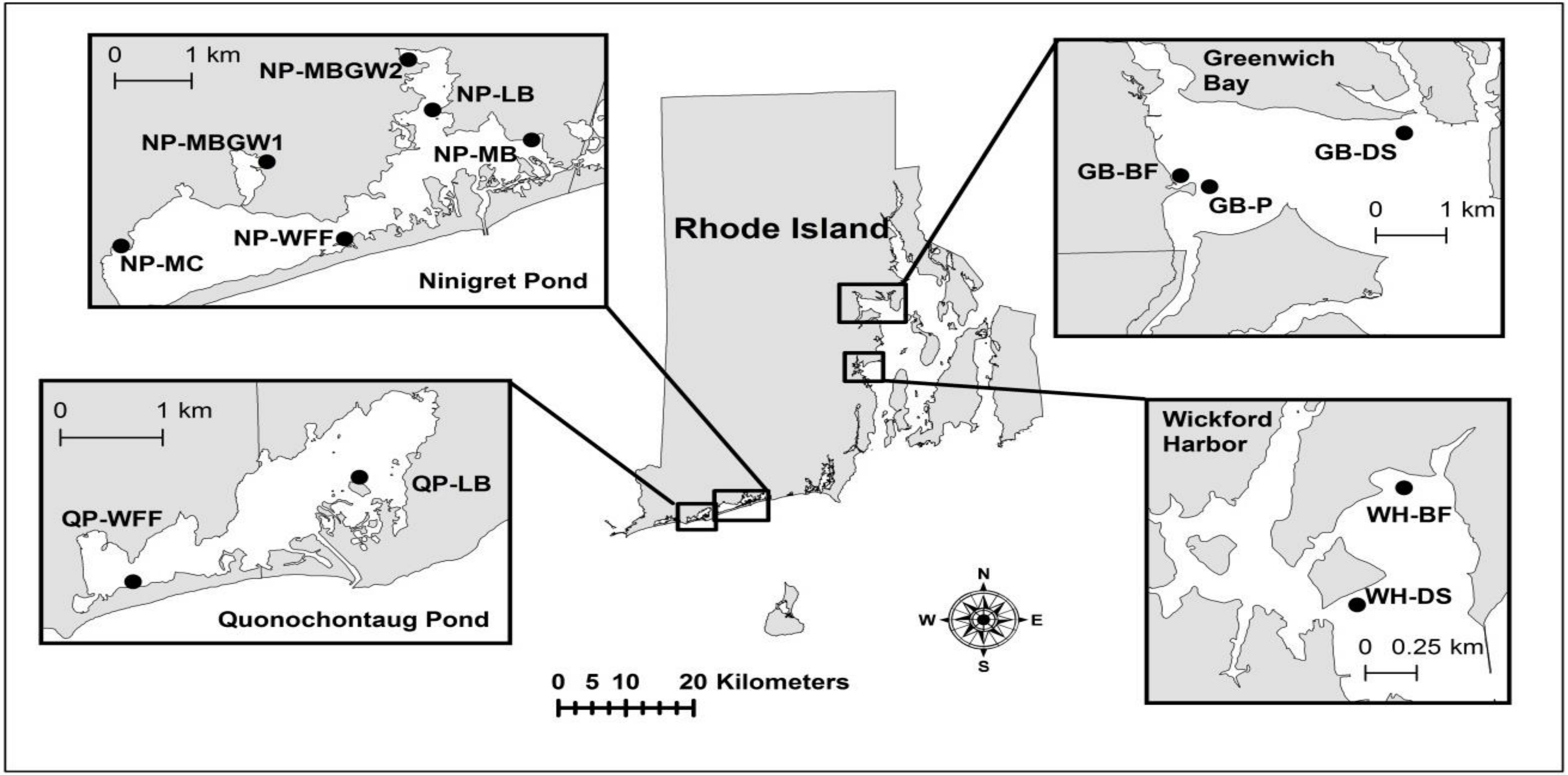
Rhode Island
NSF EPSCoR

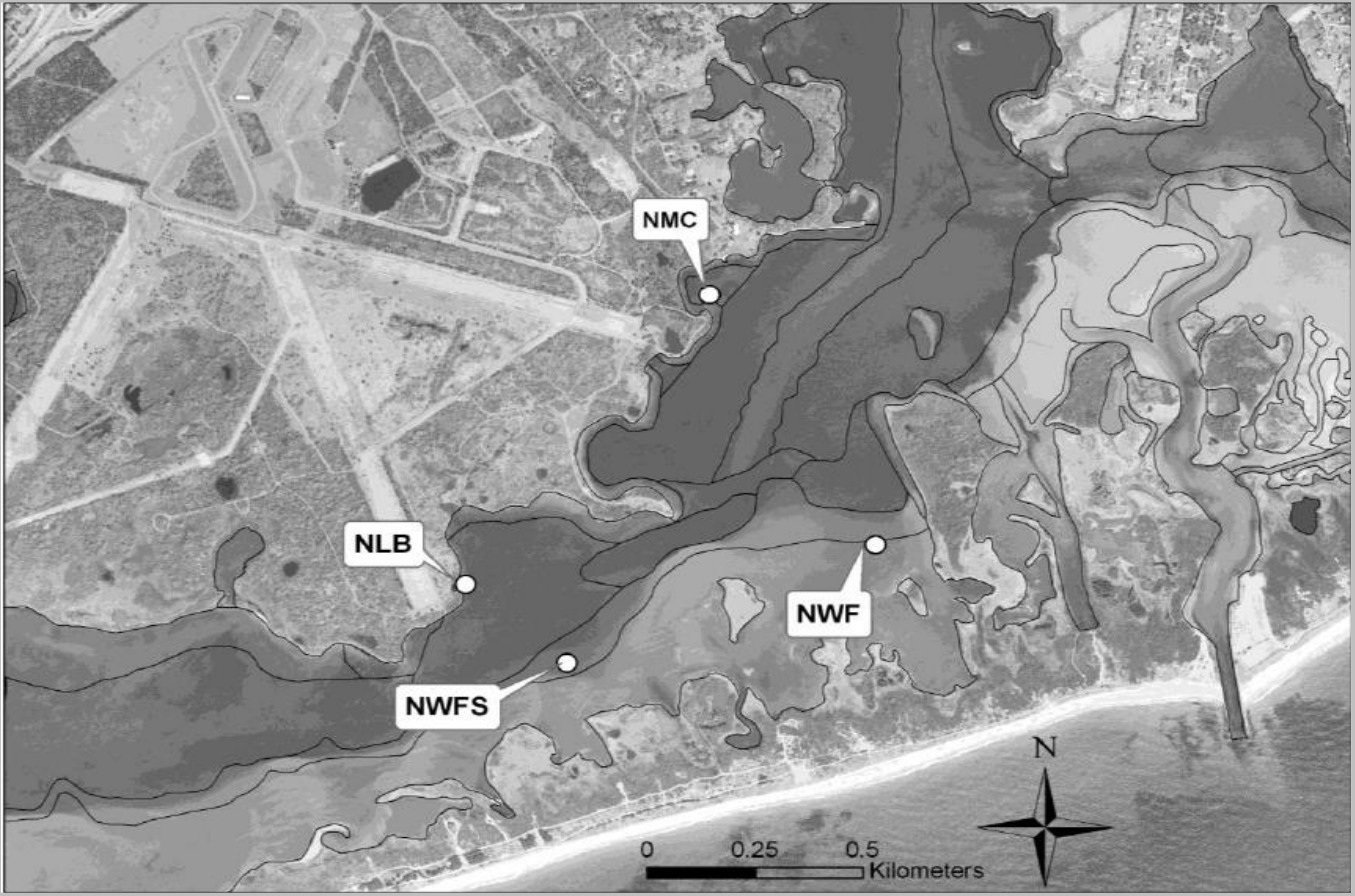
The Nature Conservancy

Aquaculture projects

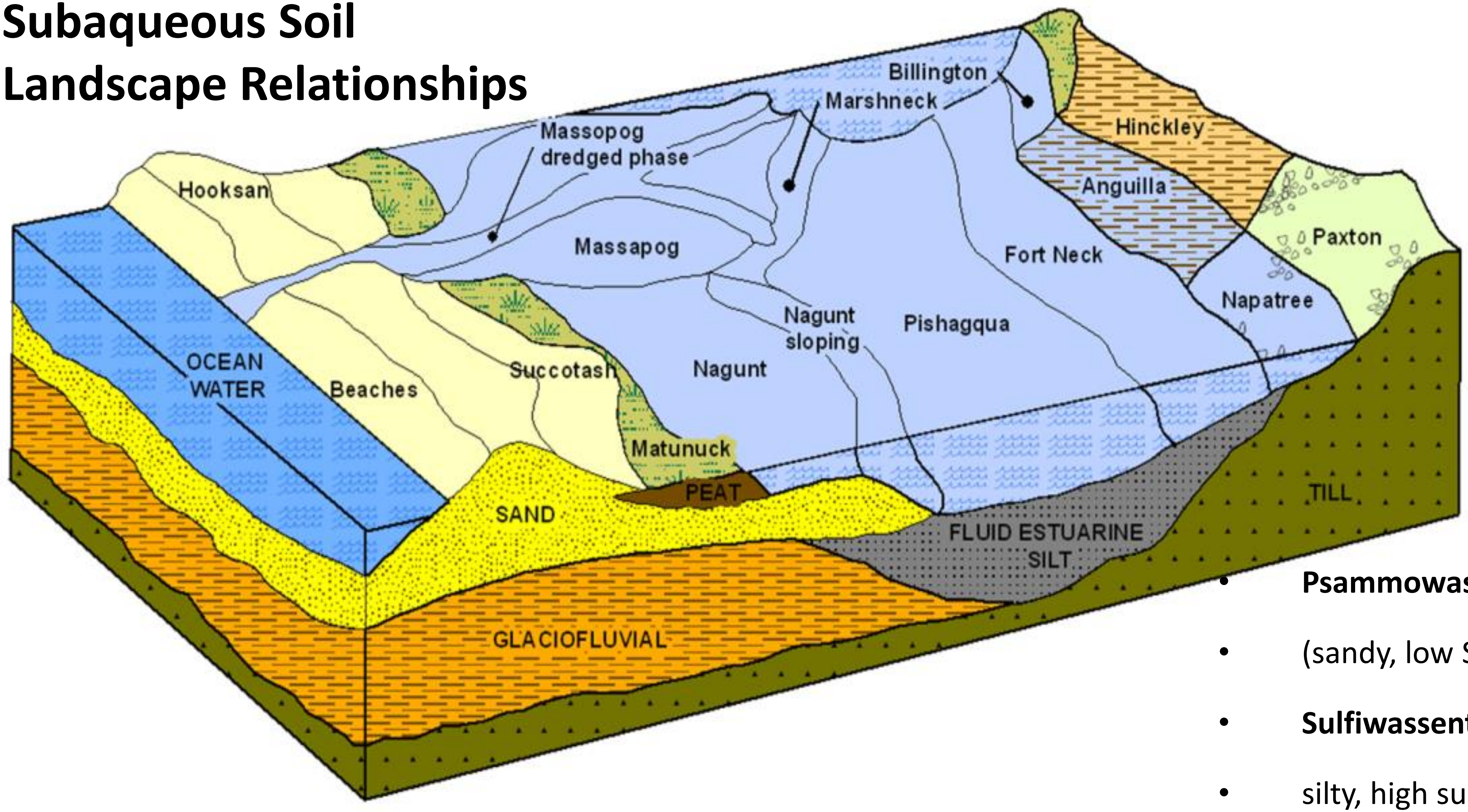
- **Aquaculture Productivity**
- **Effects of Aquaculture on Soils**
- **Coastal Acidification**
- **Balancing Aquaculture with Other Estuary Uses**

Shellfish Growth Experiment Locations




NMC
NLB
NWF
NWFS
N
0
0.25
0.5
Kilometers

Subaqueous Soil Landscape Relationships



- **Psammowassents**
- (sandy, low SOM and sulfides)
- **Sulfiwassents**
- silty, high sulfides, & SOM)
- **Haplowassents**
- (loamy, intermediate sulfides)

Hard-shell Clam Growth

Aquaculture Site ID	Final Size (mm)	Growth $\mu m/day^{-1}$	Number Recovered
NWFS	22.1^{a}	31.0	73
NWF	16.8^{b}	18.3	32
NMC	18.1^{b}	21.4	115
NLB	N/A	N/A	0
QWFS	17.6^{x}	20.6	109
QWF	19.1^{y}	24.3	126
QSMB	18.0^{x}	21.4	47
QLB†	15.9^{z}	16.3	243

Initial size 9 mm

300 clams/plot

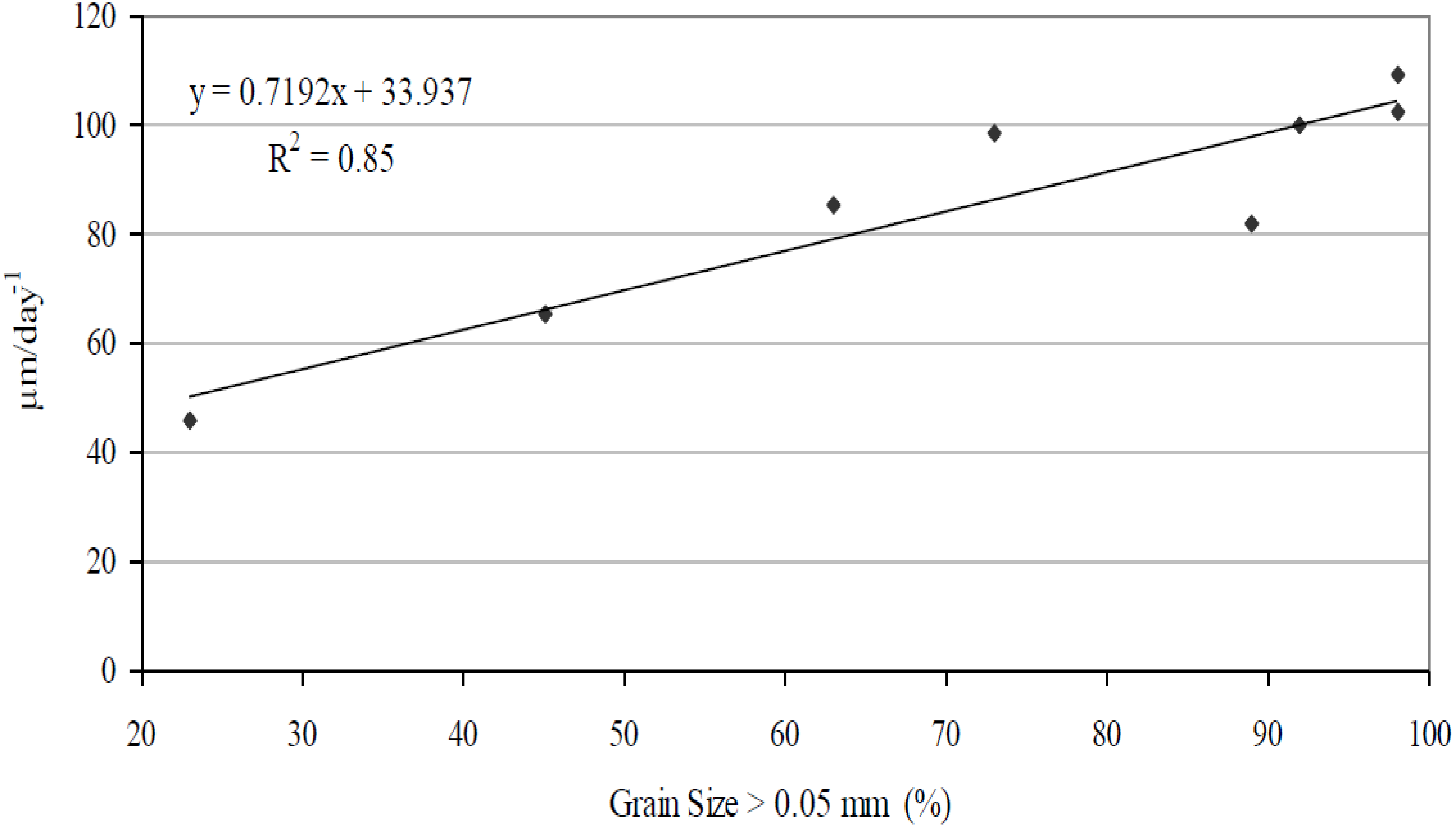
420 days

Oyster Growth

Initial size 30 mm long in June 2008

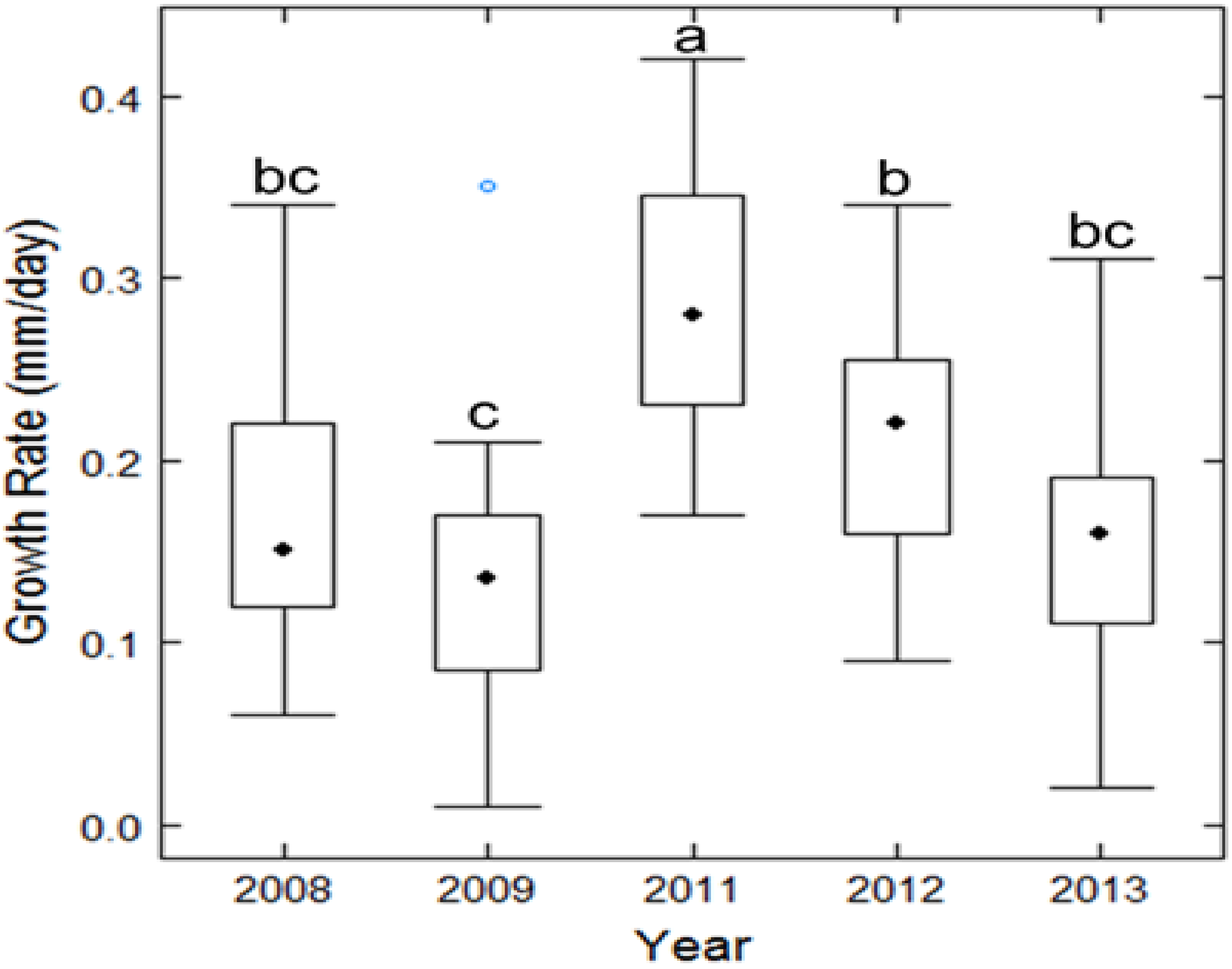
Aquaculture Site ID	October 2008 % ≥ 76 mm	June 2009 % ≥ 76 mm	October 2009 % ≥ 76 mm
NWFS	0	20	73†
NWF	0	30	44
NMC	0	13	45
NLB	0	0	1
QWFS	3	19	62
QWF	1	24	62
QSMB	2	16	61
QLB	N/A	3	24

Oyster growth/day vs Sand Content

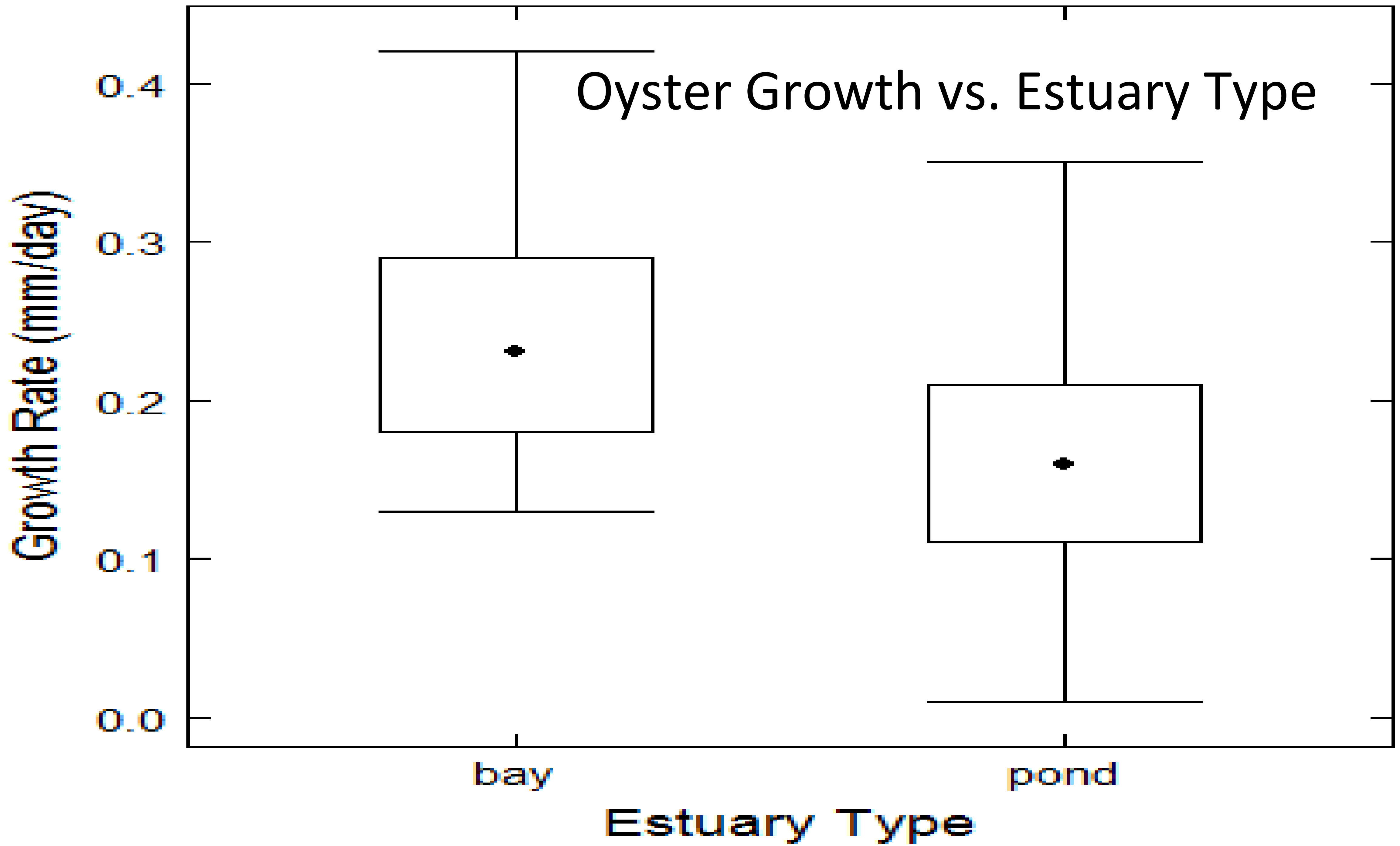


5 growing seasons (2008 – 2009, 2011 – 2013)

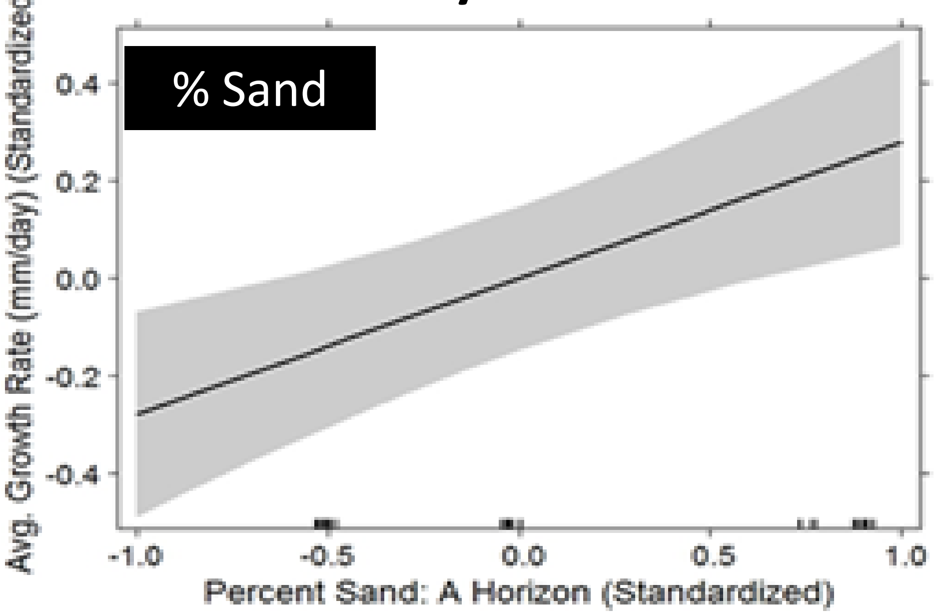
- 3 replicate aquatrays/site (250 oysters/m^2)
- Sampled 30 oysters from each tray
- Calculated growth rates (mm/day)

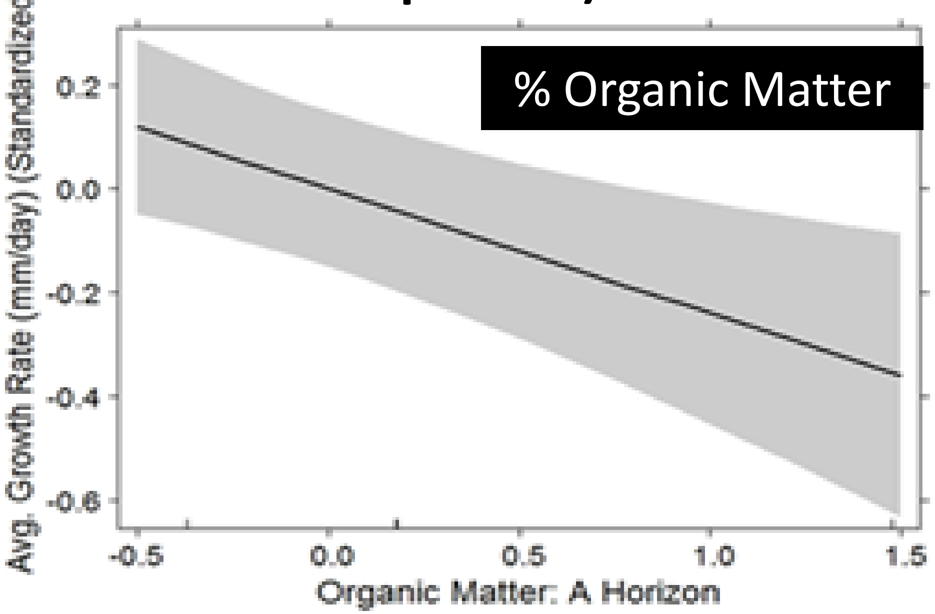


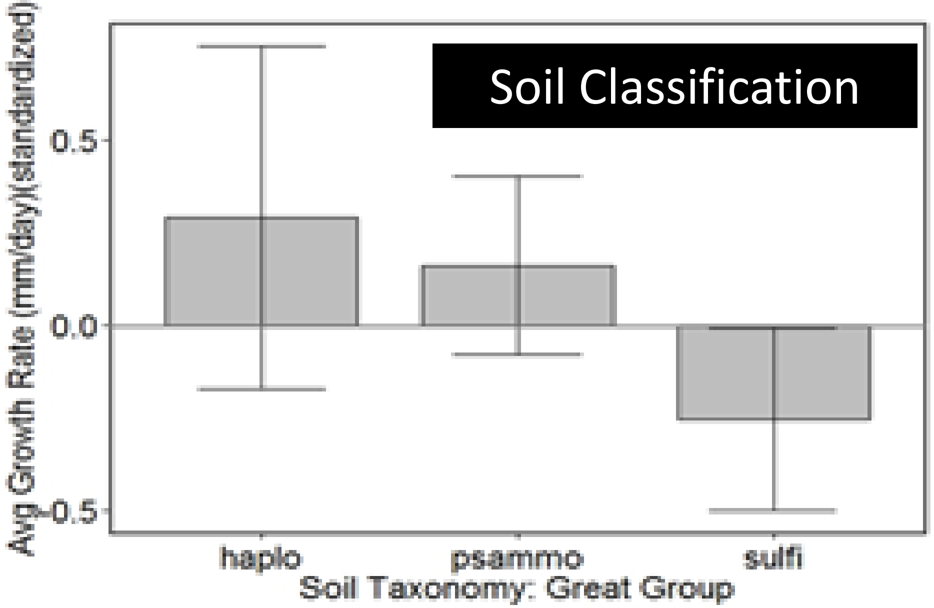
Oyster Growth vs. Year


Oyster Growth vs. Estuary Type
Growth Rate (mm/day)
0.4
0.3
0.2
0.1
0.0
bay
pond
Estuary Type

Oyster Growth (LMM effects plots)







Chl-a, and Avg. start size, were also significant in each candidate model, and explained a greater proportion of the variance in the growth data

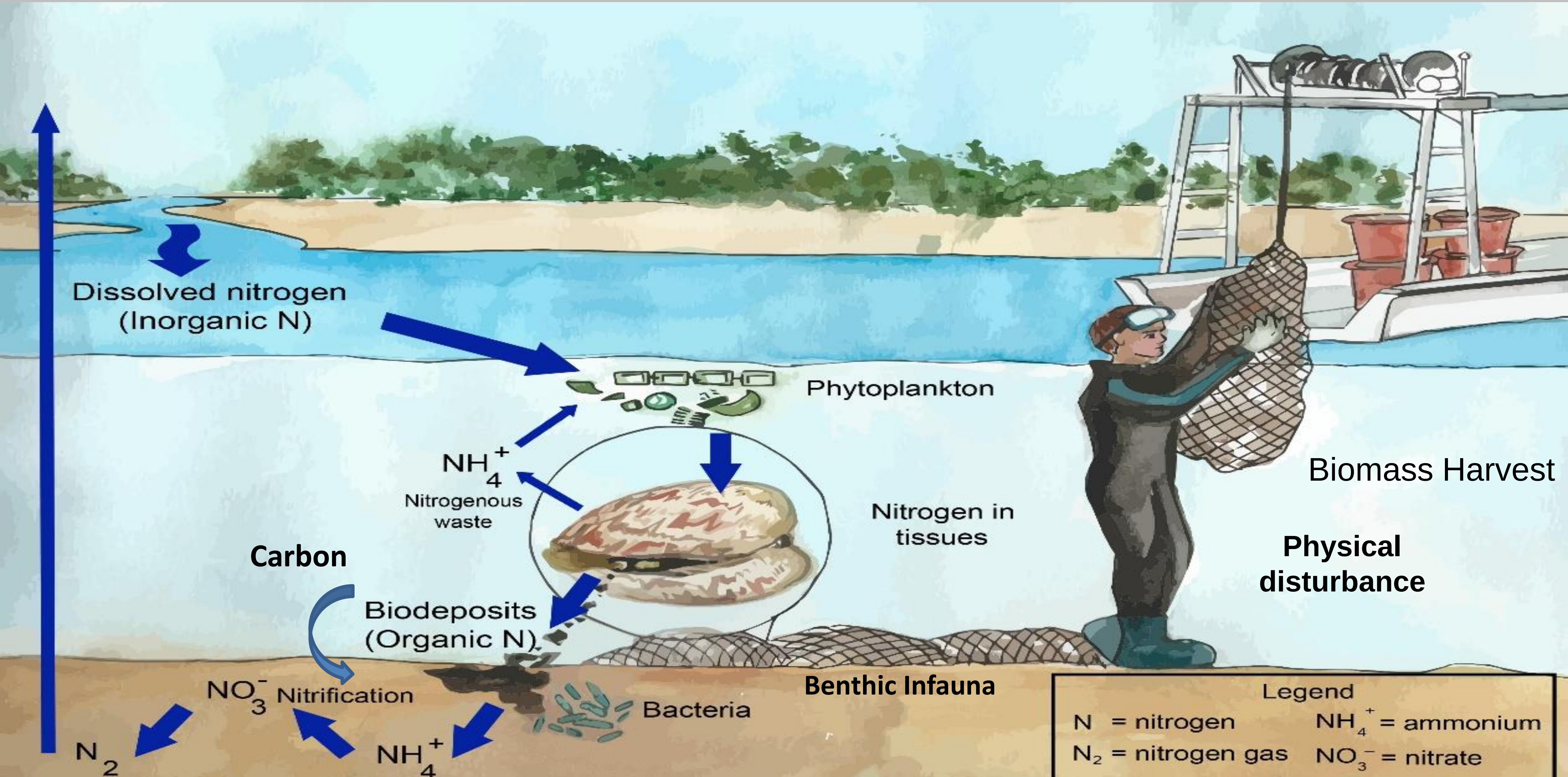
Oyster Aquaculture in Potter Pond, RI

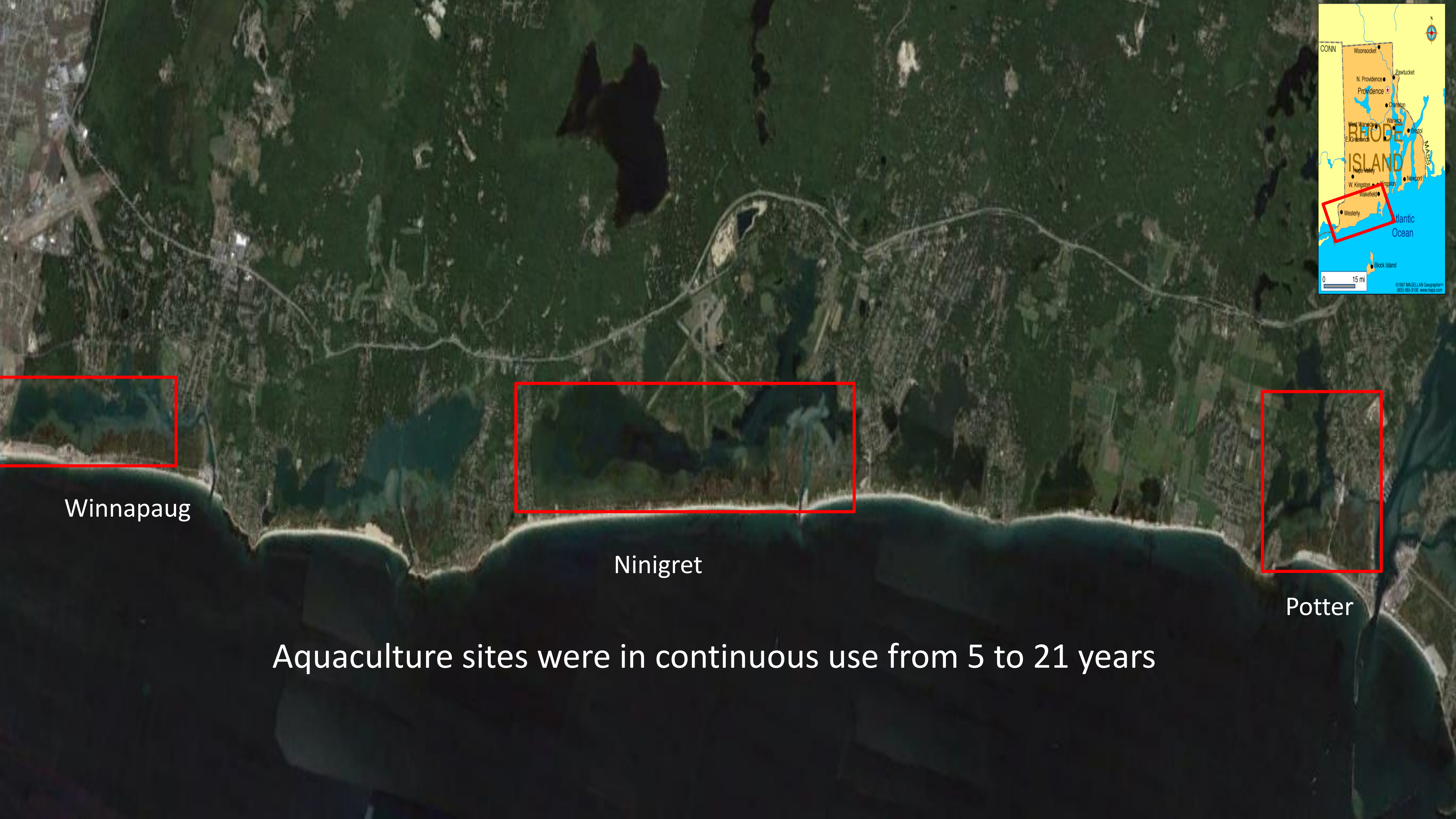
Oyster Aquaculture in Ninigret Pond, RI

Take Away Message

Our results are consistent with previous research that indicates course textured substrates support increased bivalve growth relative to fine textured substrates due to greater current velocity and seston flux

Effects of oyster aquaculture on the benthic environment

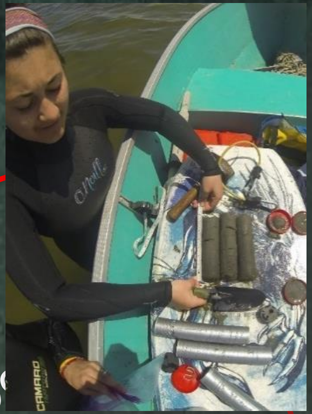



CONN
Woonsocket
Pawtucket
N. Providence
Providence
Cranston
West Warwick
Warwick
E. Greenwich
Bristol
RHODE
ISLAND
MASS.
Hope Valley
W. Kingston
Kingston
Wakefield
Newport
Westerly
Atlantic
Ocean
Block Island
15 mi
Winnapaug
Ninigret
Potter
Aquaculture sites were in continuous use from 5 to 21 years

Each site had a control not used for aquaculture

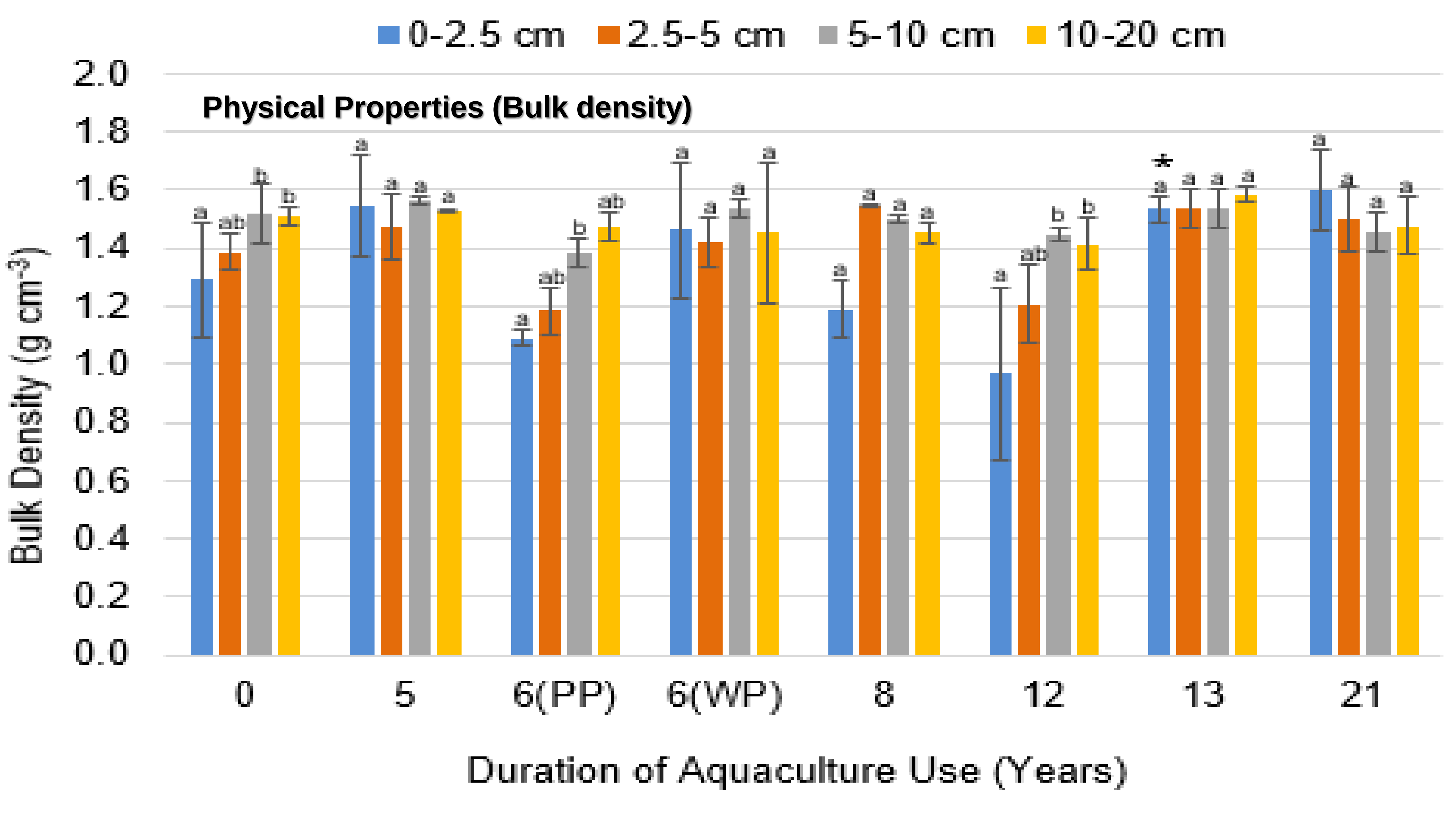
Soil Properties

- Particle size
- Electrical conductivity
- Bulk density
- Total N and C
- Pore-water sulfide levels

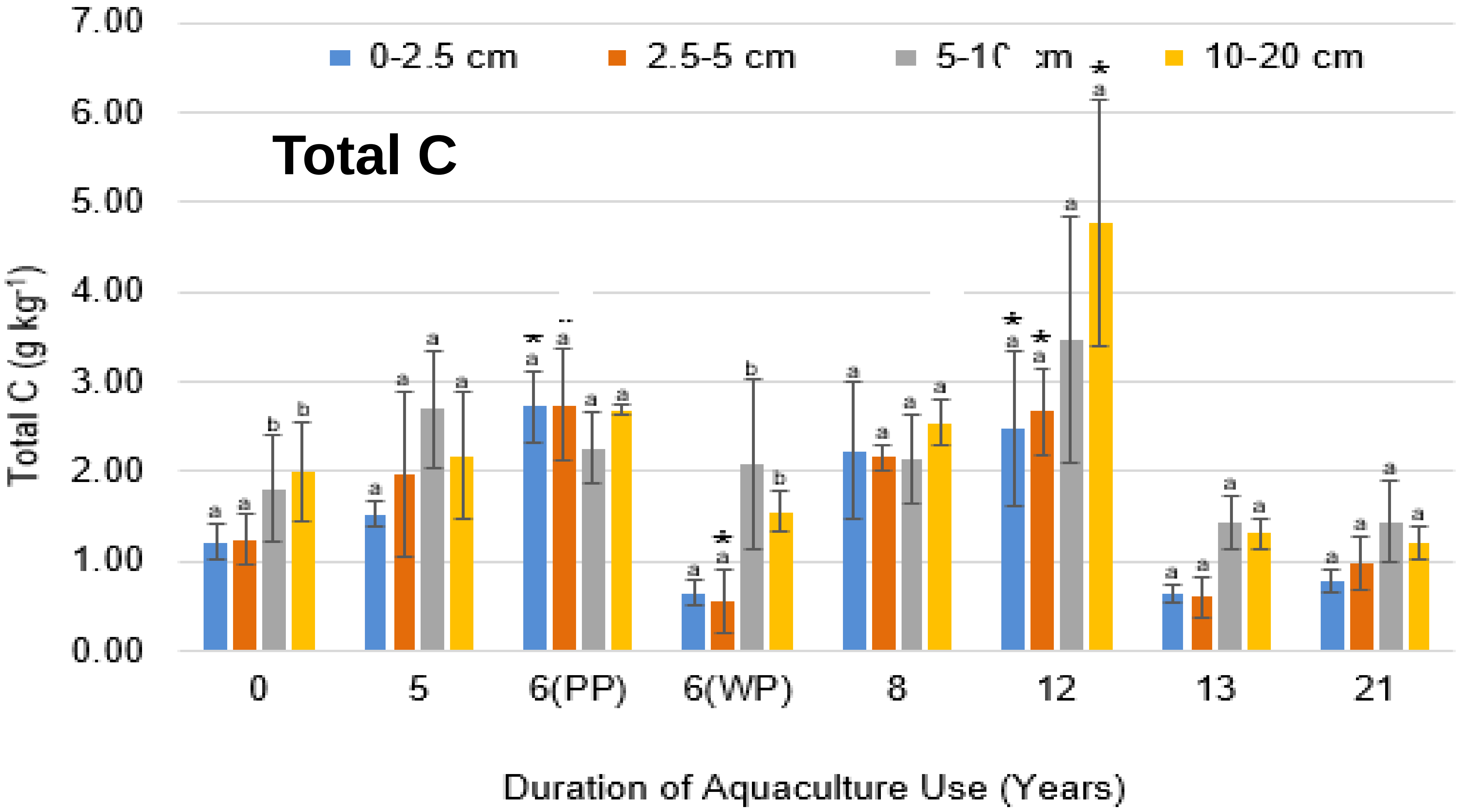


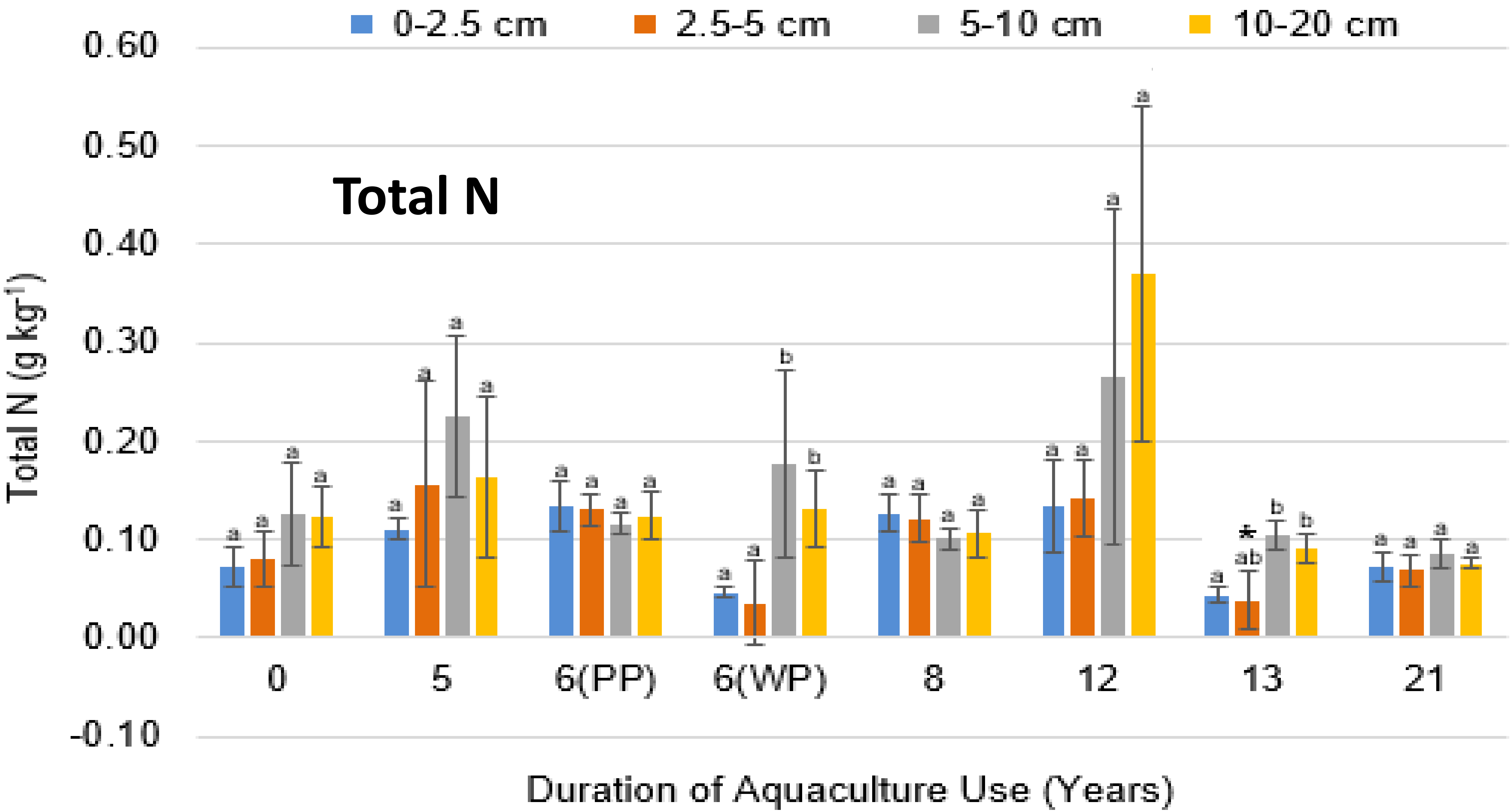
Benthic Infauna

- Species analysis
- Functional feeding group analysis
- Functional diversity of infauna



0-2.5 cm
2.5-5 cm
5-10 cm
10-20 cm
Physical Properties (Bulk density)
Bulk Density (g cm-3)
Duration of Aquaculture Use (Years)
0
5
6(PP)
6(WP)
8
12
13
21


Total C
0-2.5 cm
2.5-5 cm
10-20 cm
Total C (g kg-1)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
5
6(PP)
6(WP)
8
12
13
21
Duration of Aquaculture Use (Years)



0-2.5 cm
2.5-5 cm
5-10 cm
10-20 cm
Total N
Total N (g kg-1)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
5
6(PP)
6(WP)
8
12
13
21
Duration of Aquaculture Use (Years)

Back of the envelope N budgets

- N in the water column
- N stored in the oyster tissue (6 to 10% of dry weight)
- Denitrification in the oyster (maybe as much as 3%)
- N in the biodeposits (1 to 2 g of N per day per aquaculture rack)
- N sequestered in the soil
- Denitrification in the soil
- N resuspened into the water column

Soil pore-water sulfides

Control Sites

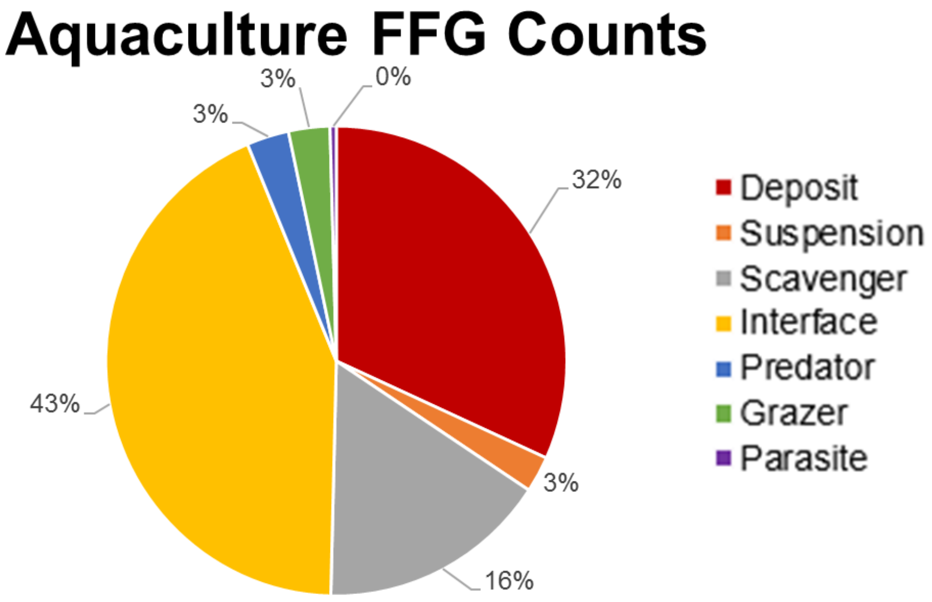
Depth

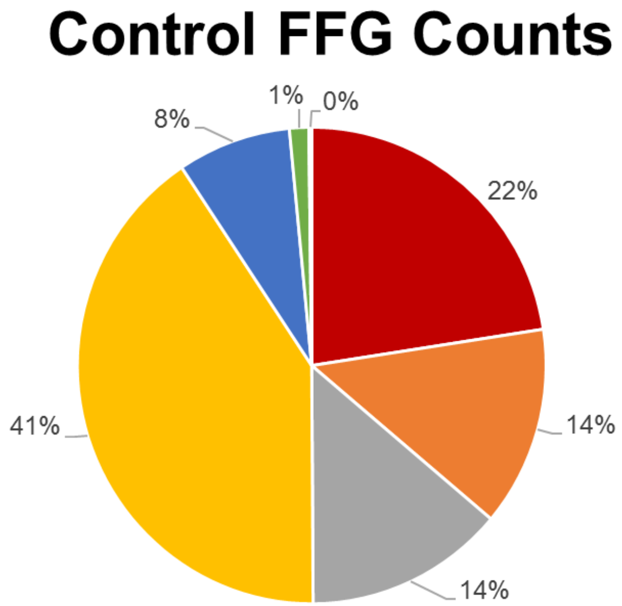
- 0 cm -

-10 cm-

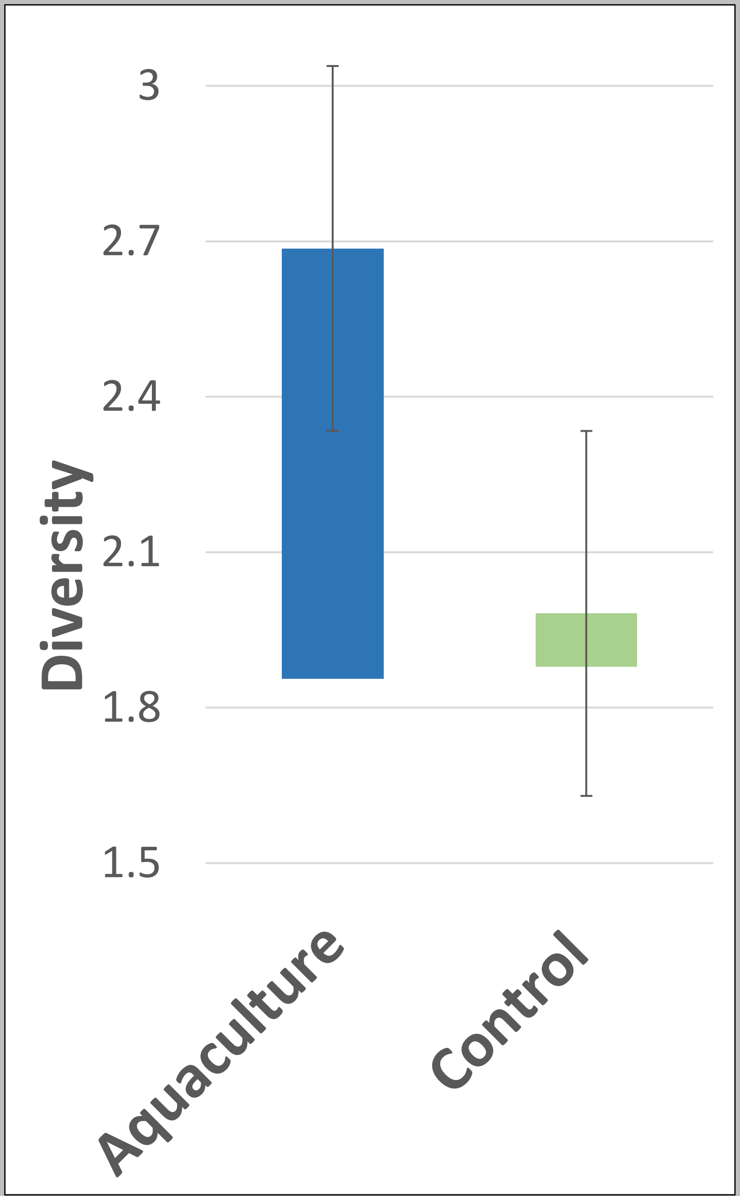
-20 cm-

Aquaculture Sites





Benthic Infauna Diversity



Organism	FFG	Aquaculture Abundance	Control Abundance
Benthic copepods	Scrapers	0	1
Gemma gemma	Suspension	6	20
Capitellid polychaetes	Deposit	88	28
Spionid polychaetes	Interface	95	74

November 19, 2010, 7:55 am | Comment

A Call to Action on Ocean Acidity

By JOHN COLLINS RUDOLF

st for Marine Life

IGTON and JANE LUBCHENCO

Published: June 18, 2012

Ocean Acidification: It's Time to Act

Post

How Climate Change I
Oyster Business

by JESSICA CAMI

EDITORIAL

The Oceans' Shifting Balance

Study: (

UN: Oceans are 30 percent more acidic than before fossil fuels

Posted by David Braun of National Geographic on December 15, 2009

The Great (D
Coral Cover

Posted by Michael Conathan of Cent

evels to
Oyster Die-Offs

By LESLIE KAUFMAN

Climate Change an
Countries Most Vulnerable to Ocean Acidification

Posted by Michael Conathan of
2012

Acid In The Oceans: A Growing Threat To Sea Life

Is Your SUV Killing Ocean Coral Reefs?

Ocean Ac
Scientists

Posted by David B

Can Shellfish Adapt to More Acidic Water?

by LAUREN SOMMER

Acidification and Commercial Bivalves

Negative responses to acidification

Low pH (**< 7.6**), Ωar, saturation (**< 1**)

- Larval development
- Recruitment
- Growth
- Survival
- Shell dissolution

Early Development Stages

Green et al., 2009

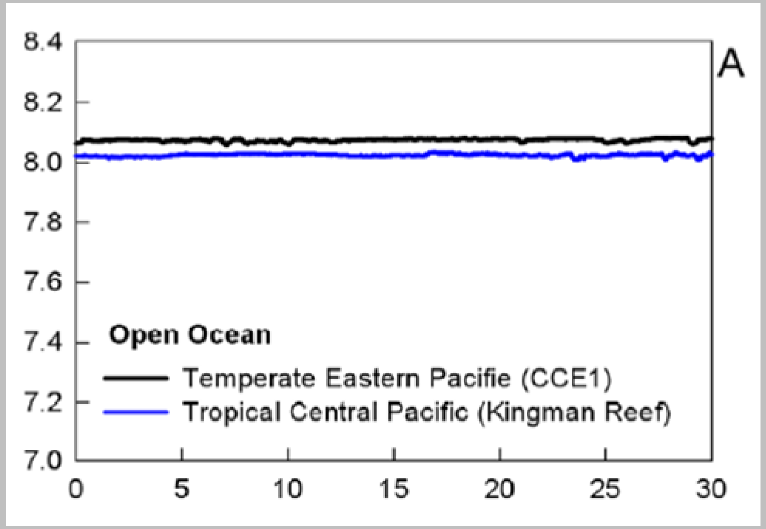
Ocean vs. Coastal Acidification

pH in the coastal zone is much more variable when compared to the open ocean

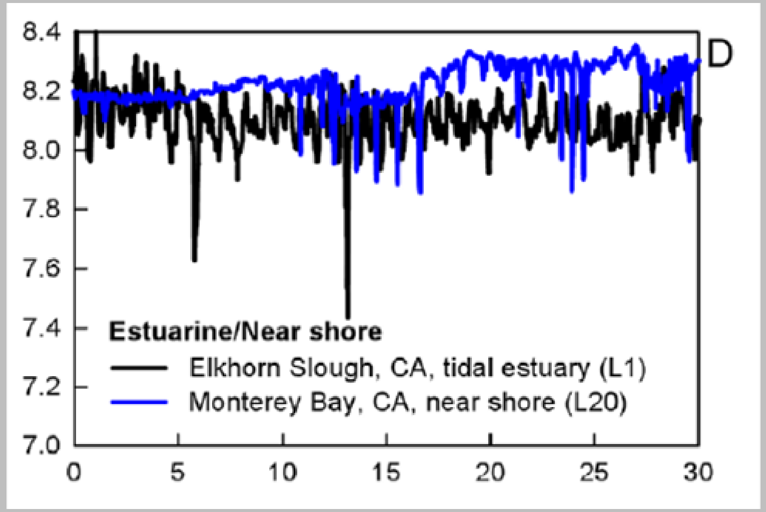
Additional Sources of Acidity

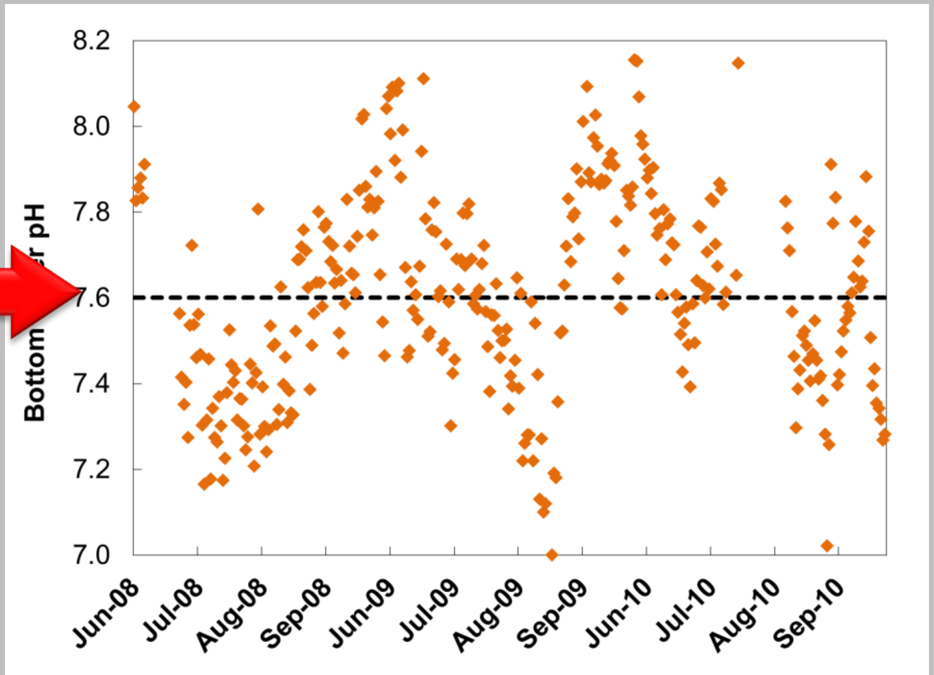
- **Nutrient enrichment**
- **Freshwater inputs**
- **Sediment biogeochemistry**
  - Sulfide chemistry
  - Organic matter oxidation

Hofmann et al. 2011



Hofmann et al. 2011

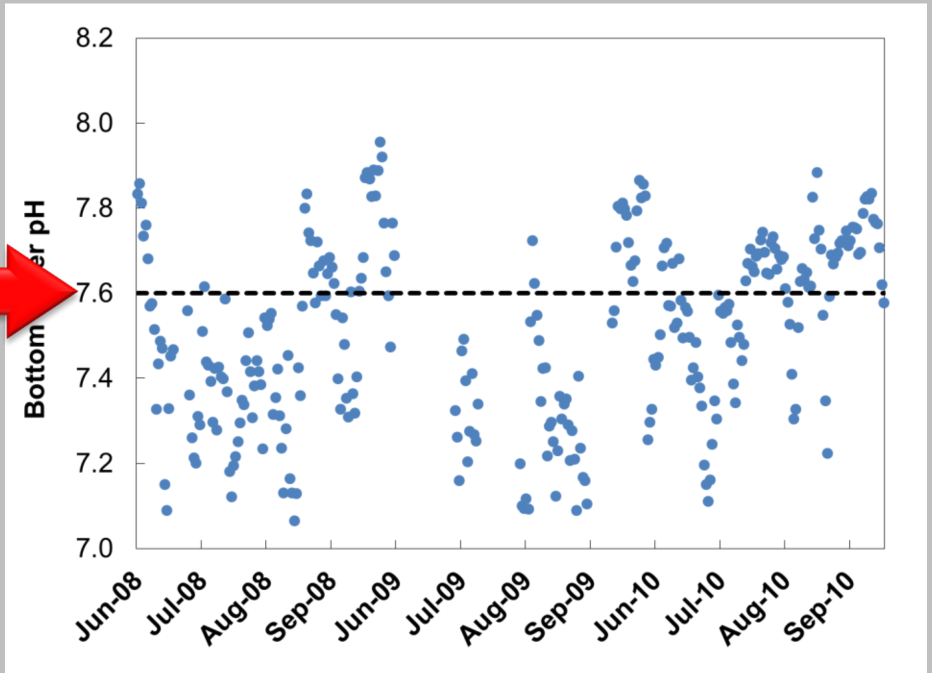




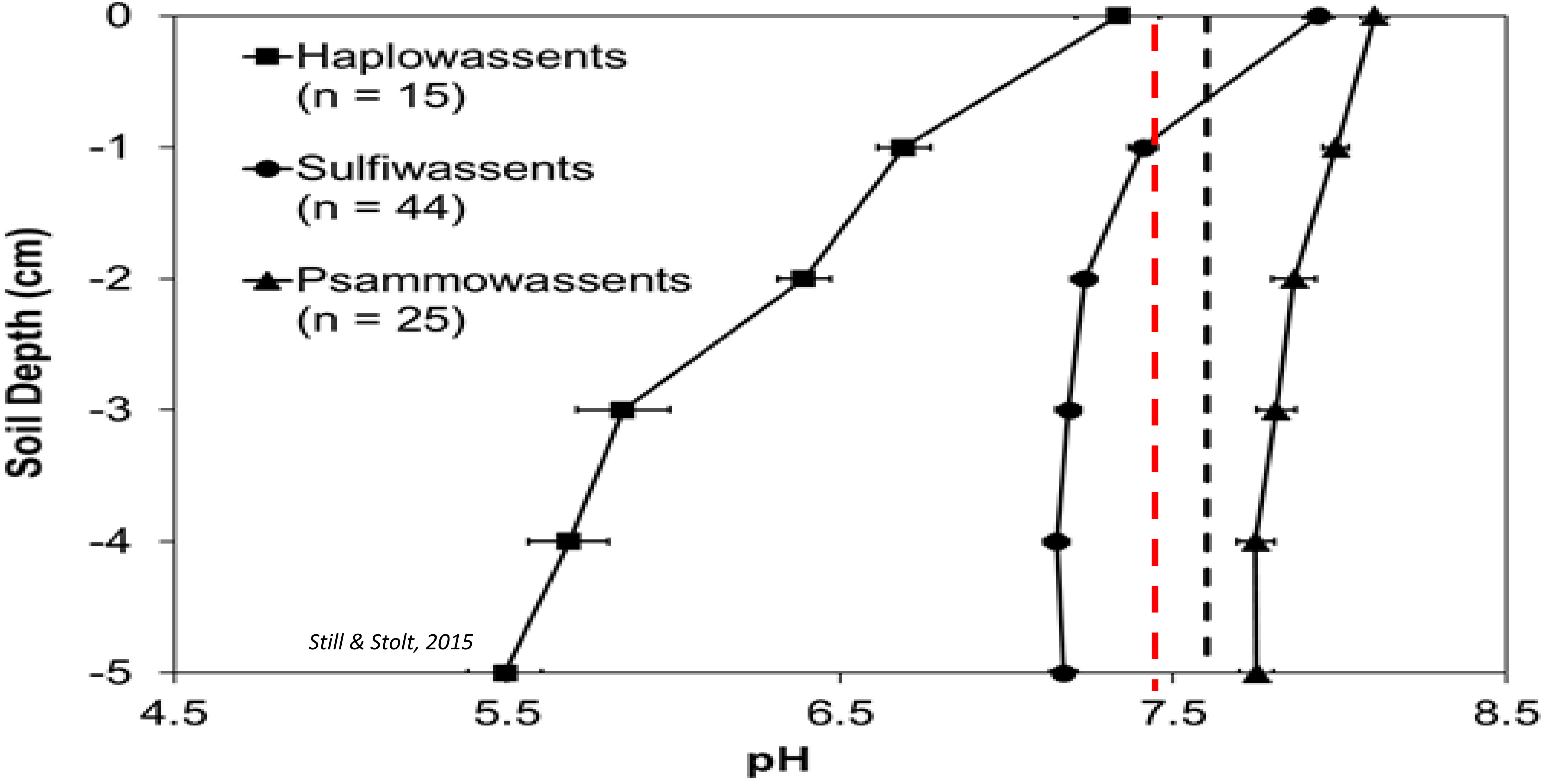
Bottom water conditions

June – Sept

2008 – 2010

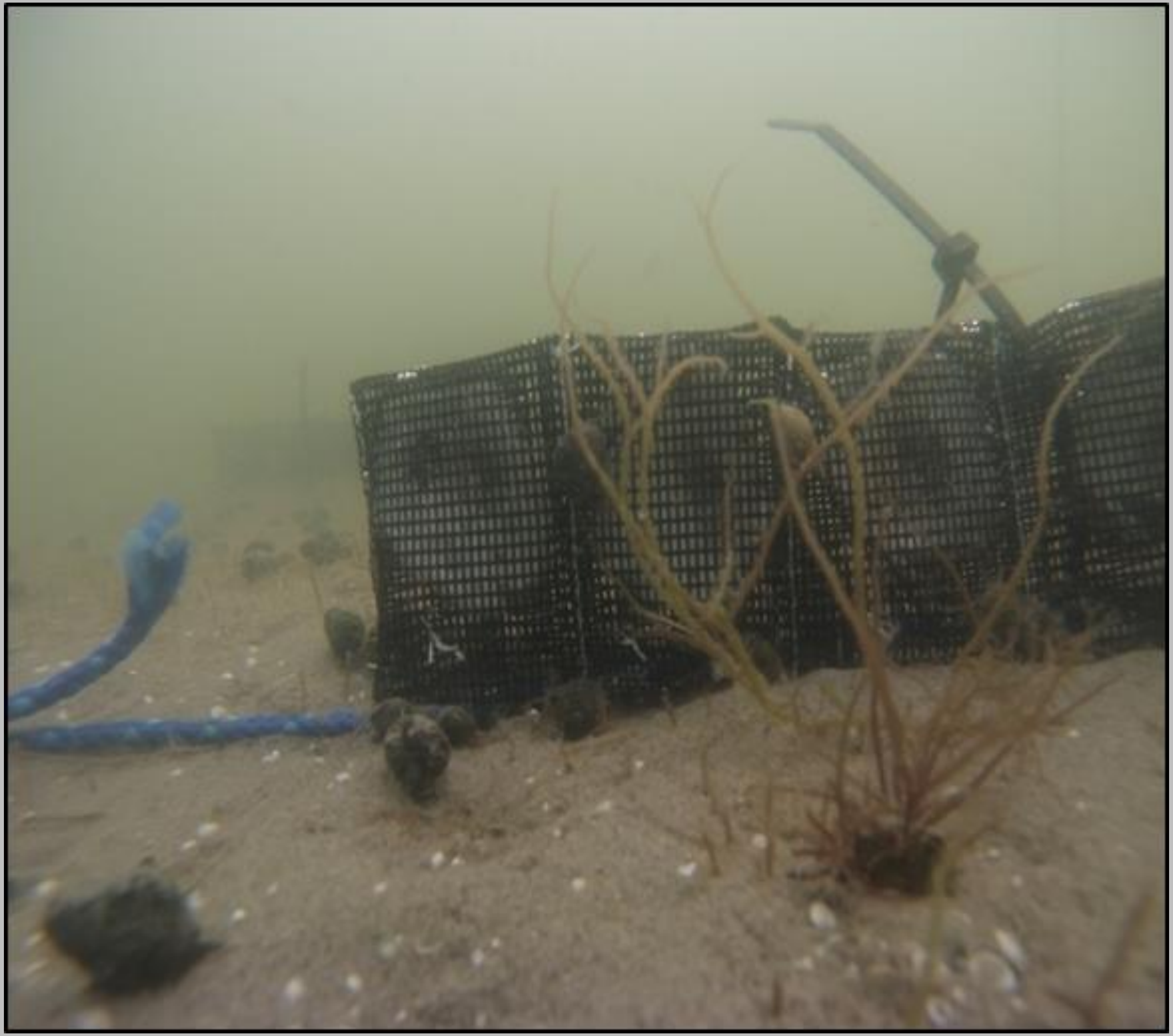


Soil pH Depth Profiles

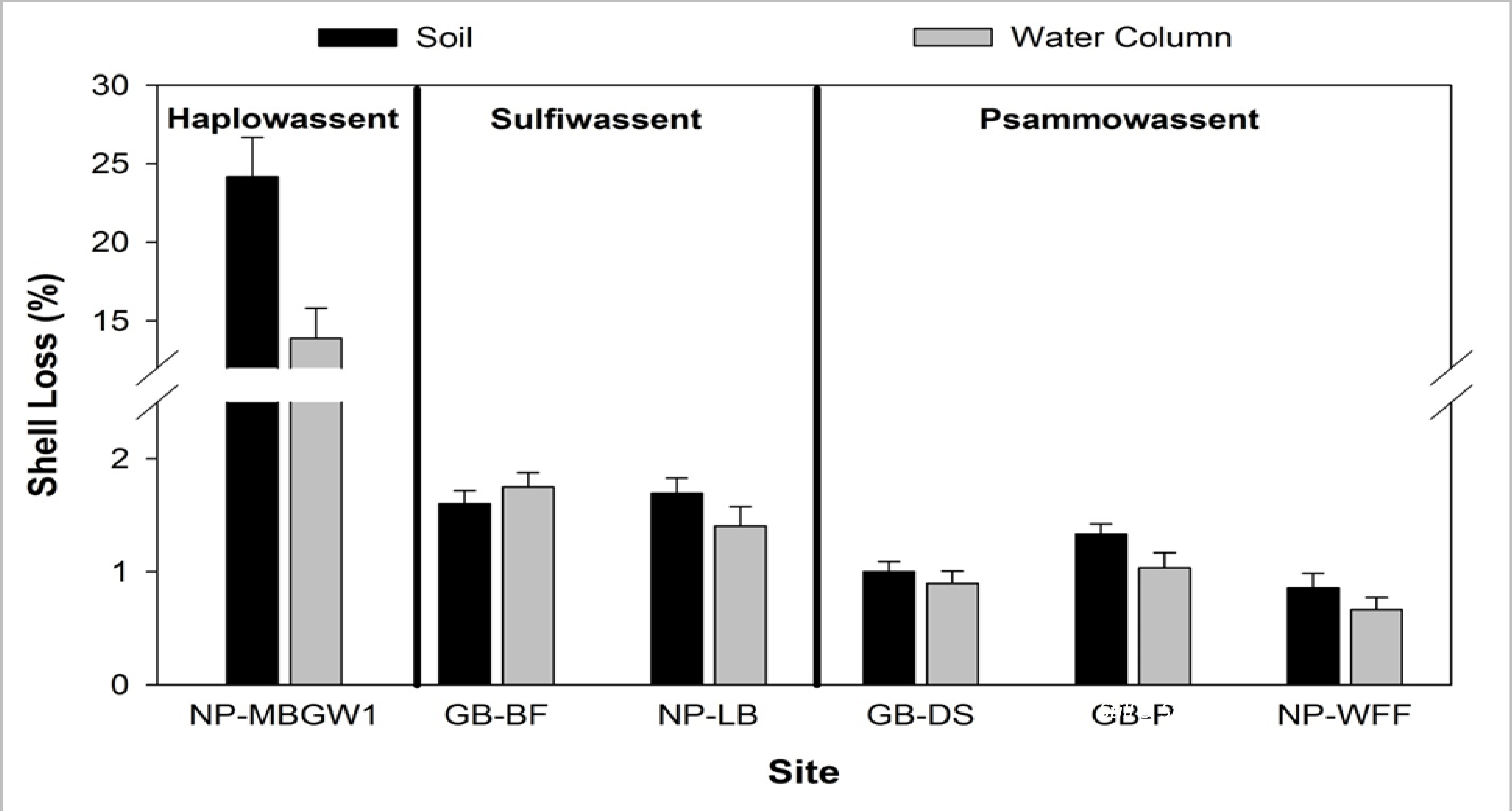


In-situ Oyster Shell Dissolution

- Shells were oven dried at 105°C
- Bags were deployed for four weeks (August)
- Shells were washed and oven dried at 105°C
- % shell loss was calculated



Shell loss across sites/treatment



Aquaculture Management in Rhode Island

*In the **coastal salt ponds** the area occupied by aquaculture shall **not exceed five percent (5%)** of the total open water surface area of the coastal pond below MLW. (CRMC Red Book 300.11(E)(6)*

The 5% rule

CRMC Red Book

The State of Rhode Island

Coastal Resources
Management Program

As Amended

LEGAL COUNSEL

GOLDMAN Law Offices
681 Smith Street
Providence, RI 02908

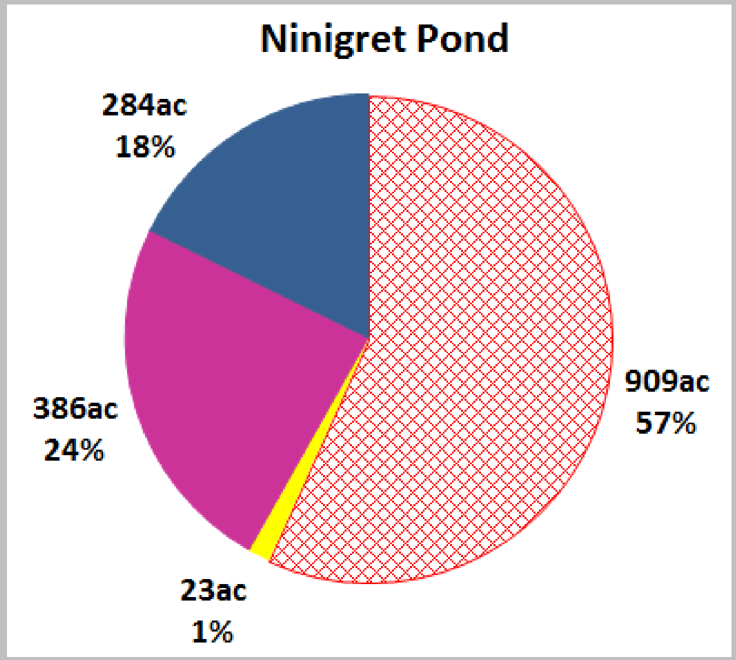
This document replaces Chapters 1 through 5 of the program adopted by the Coastal Resources Management Council in 1977.

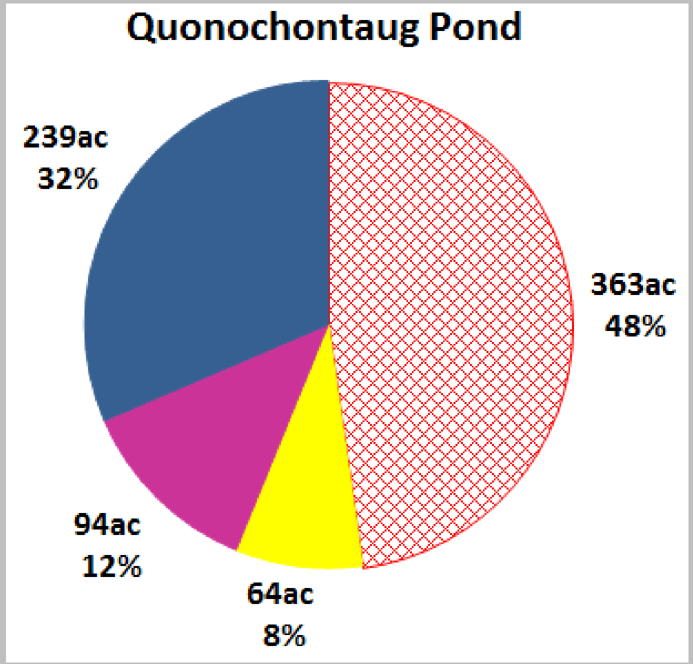
Other adopted elements of the Rhode Island Coastal Resources Management Program include the Energy Amendments of 1979, Management Procedures, Right-of-Ways to the Shore, Special Area Management Plans for selected areas, and the Guidelines for the Development of Municipal Harbor Management Plans. These documents may be obtained from the Council's offices.

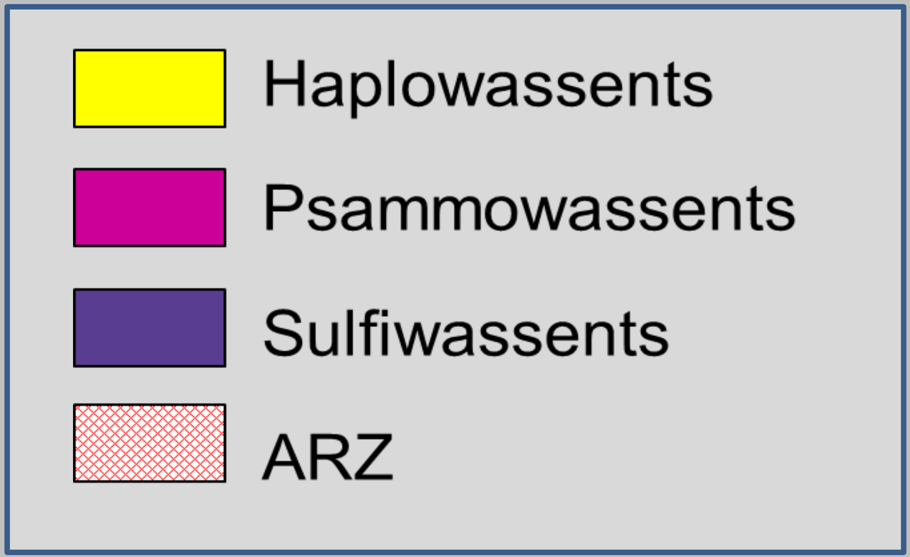
Data Layers	Source	Description
Docks/Piers	Generated (this study)	25 ft buffer established around all doc/pier structures within each pond
Navigation Centerline	Generated (this study)	150 ft navigation corridor established for heavily used areas of each pond.
Mooring/Anchorage	Generated (this study)	Mooring/anchorage areas identified by digitizing from summer period aerial imagery
Potential SAV areas	RIGIS	Combined footprint of submerged aquatic vegetation from 2009 and 2012 collected by the RI Eelgrass Mapping Taskforce
Recreational Shellfishing	RI SMP	Recreational shellfishing areas identified on the RI Shellfish Management Plan user maps
RIDEM Spawner Sanctuary	RIDEM	Shellfish Spawner Sanctuaries designated by RI Department of Environmental Management
RIDEM Shellfish	RIGIS	RI Department of Environmental Management regulatory shellfish areas. Data includes areas prohibited from the harvesting of shellfish

Uses incompatible with shellfish aquaculture

Aquaculture Restriction Zone (ARZ)







43 to 69% restricted use