Micro-siting and Nitrogen Removal Efficiency of a Liquid Injection Permeable Reactive Barrier (PRB)

Jessica Thomas

MARTHA'S VINEYARD COMMISSION

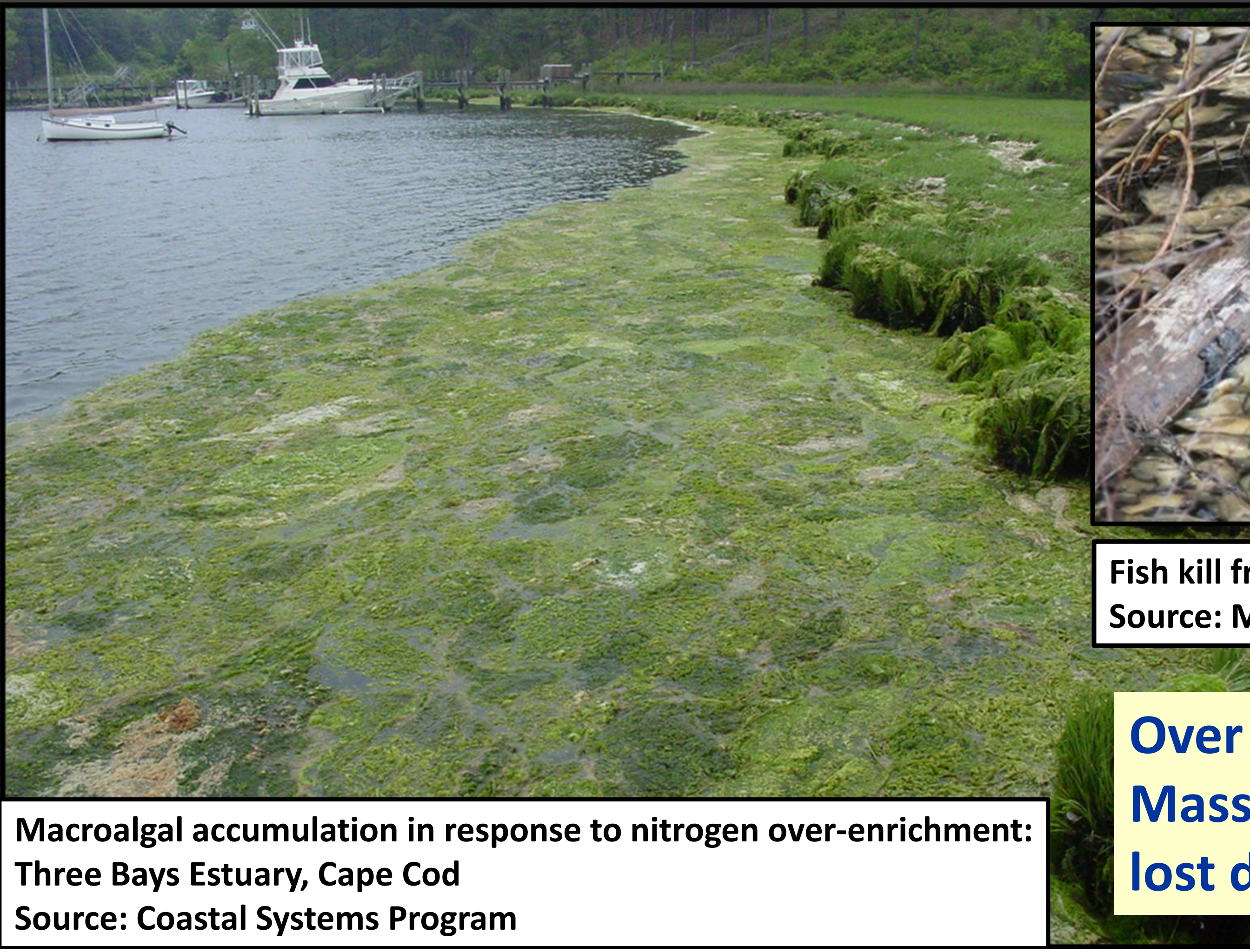
SNEP
Southeast New England Program

Coastal Systems Program
SMAST

Outline

- The Problem with Nitrogen
- Possible Solutions
- PRBs for Nitrate Reduction
- Micro-Siting
- Efficacy Testing
- Secondary Reactions
- Pros and Cons of PRBs

What is the Problem with Nitrogen?



Macroalgal accumulation in response to nitrogen over-enrichment: Three Bays Estuary, Cape Cod
Source: Coastal Systems Program

Fish kill from low dissolved oxygen levels
Source: Massachusetts Division of Fishery and Wildlife

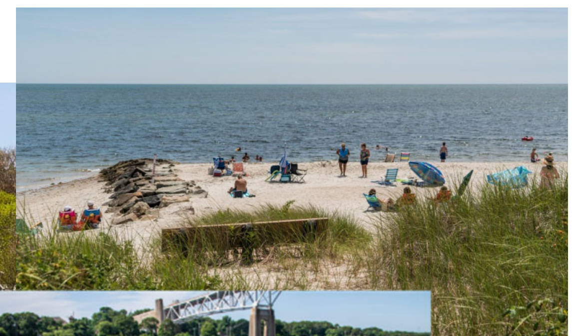
Over 50% of eelgrass coverage in Massachusetts waters has been lost due to N enrichment!

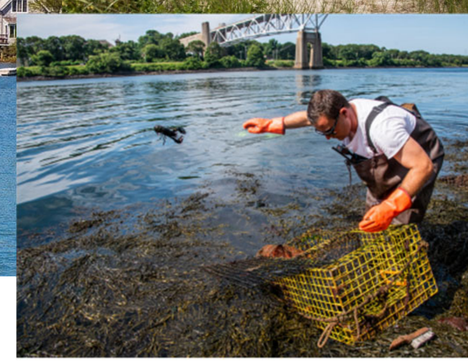
Problems with Nitrogen Enrichment

- Nitrogen inputs to estuaries can lead to eutrophication
- Estuarine eutrophication is a global environmental problem

Eutrophication in Coastal Communities Can Cause:

- Loss of water and habitat quality
- Financial Impact to
  - Tourism
  - Fisheries
  - Property Values
- Quality of Life
  - Beach Use
  - Native American Subsistence Rights





Nitrogen Enrichment

While eutrophication is a natural process, anthropogenic sources of nutrients can exacerbate the process

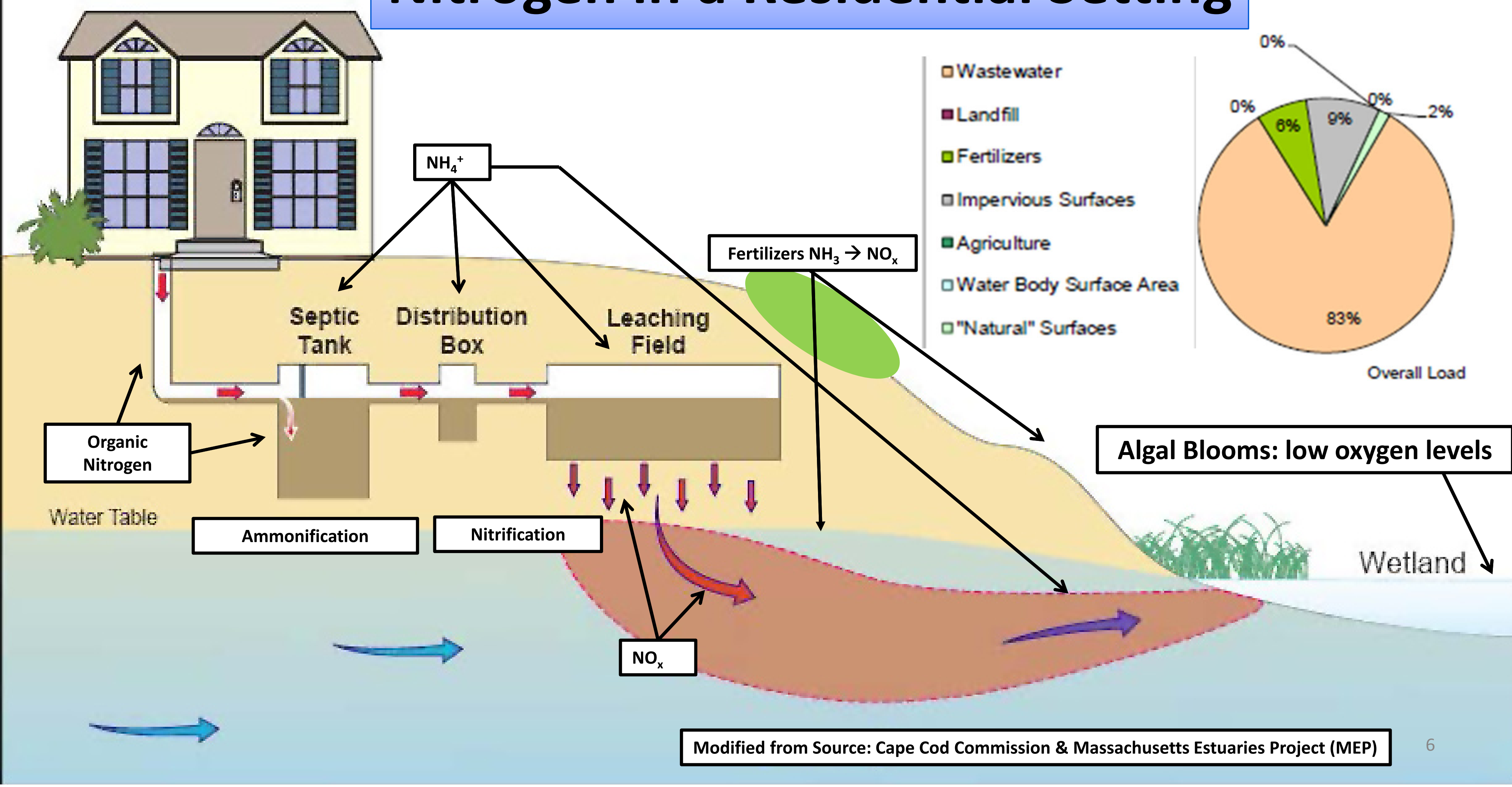
Point Sources:

- Wastewater Treatment Facility Discharges
- Stormwater Discharges

Non-Point Source:

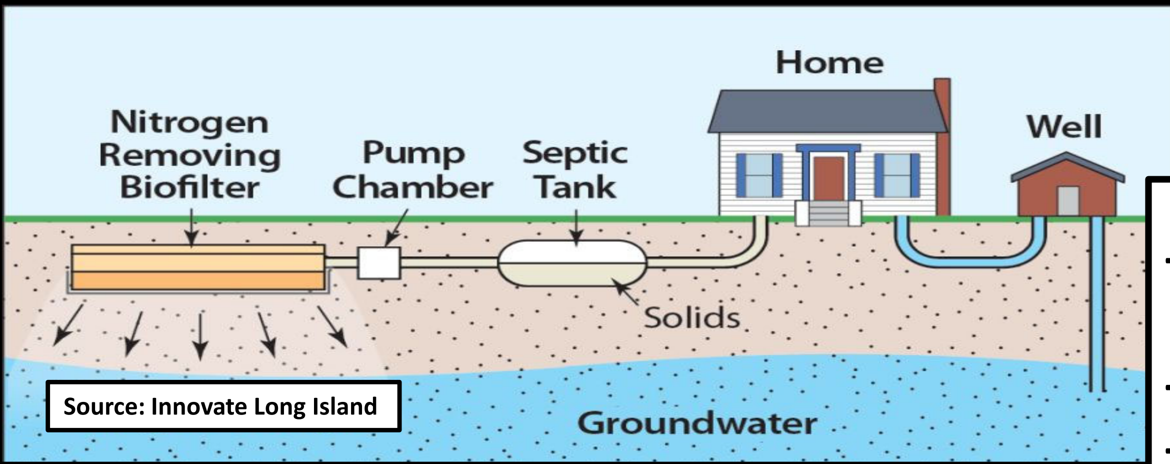
- Atmospheric Deposition
- Agricultural (Crop/Animals)
- Lawn Fertilization
- Septic Systems

Nitrogen in a Residential Setting



Modified from Source: Cape Cod Commission & Massachusetts Estuaries Project (MEP)

Solutions for Nitrogen Enrichment

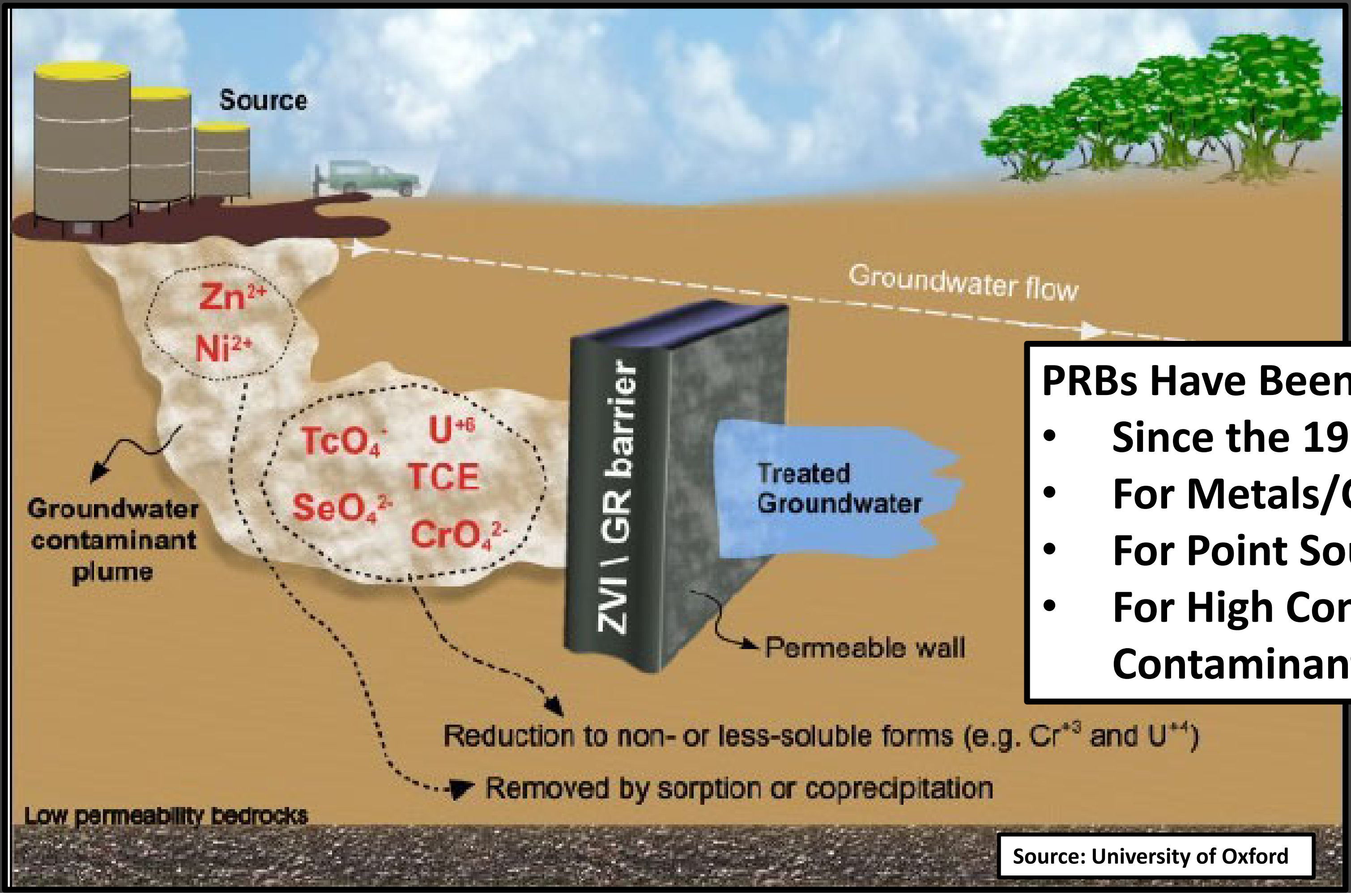


Source: Innovate Long Island

Source: Coastal Systems Program

- Advanced Wastewater Treatment Facilities
- Innovative N Removing Septic Systems
- Wetland Restoration/Construction
- Pond Construction/Modification
- Increased Tidal Flushing
- Aquaculture
- Permeable Reactive Barriers

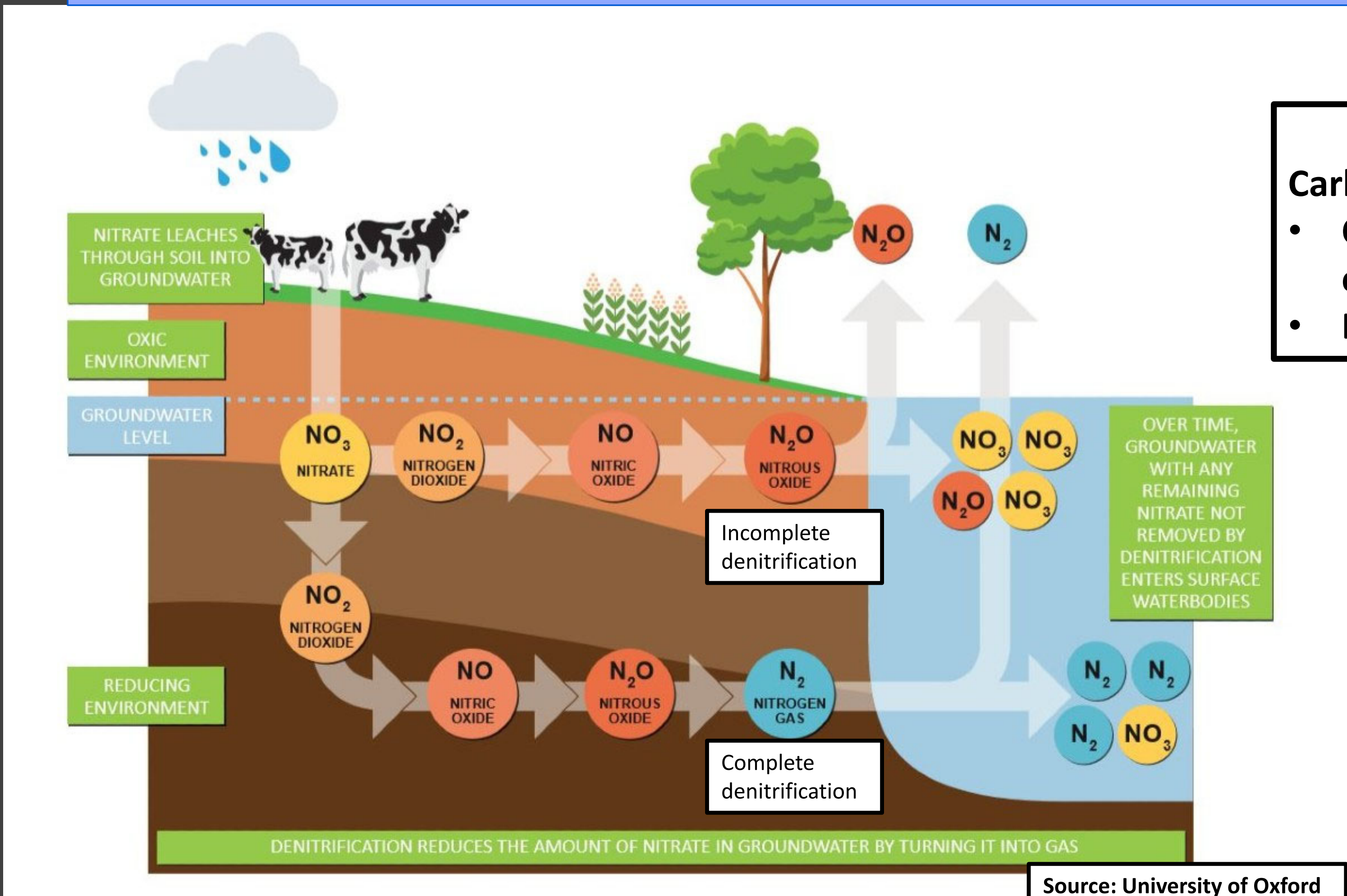
PRBs as a Mitigation Solution



PRBs Have Been Used:

- **Since the 1990s**
- **For Metals/Chlorinated Solvents**
- **For Point Sources (groundwater)**
- **For High Concentrations of Contaminants.**

PRBs as a Mitigation Solution



Source: University of Oxford

PRB

Carbon Source that is used for:

- **Creation of anaerobic conditions**
- **Bacterial substrate**

Carbon Source Pros and Cons

Solid Source

Pros

- Achieves high levels of denitrification
- Limited movement in groundwater
- Easily sourced

Cons

- Difficult construction
- High Cost
- High environmental disturbance

Liquid Source

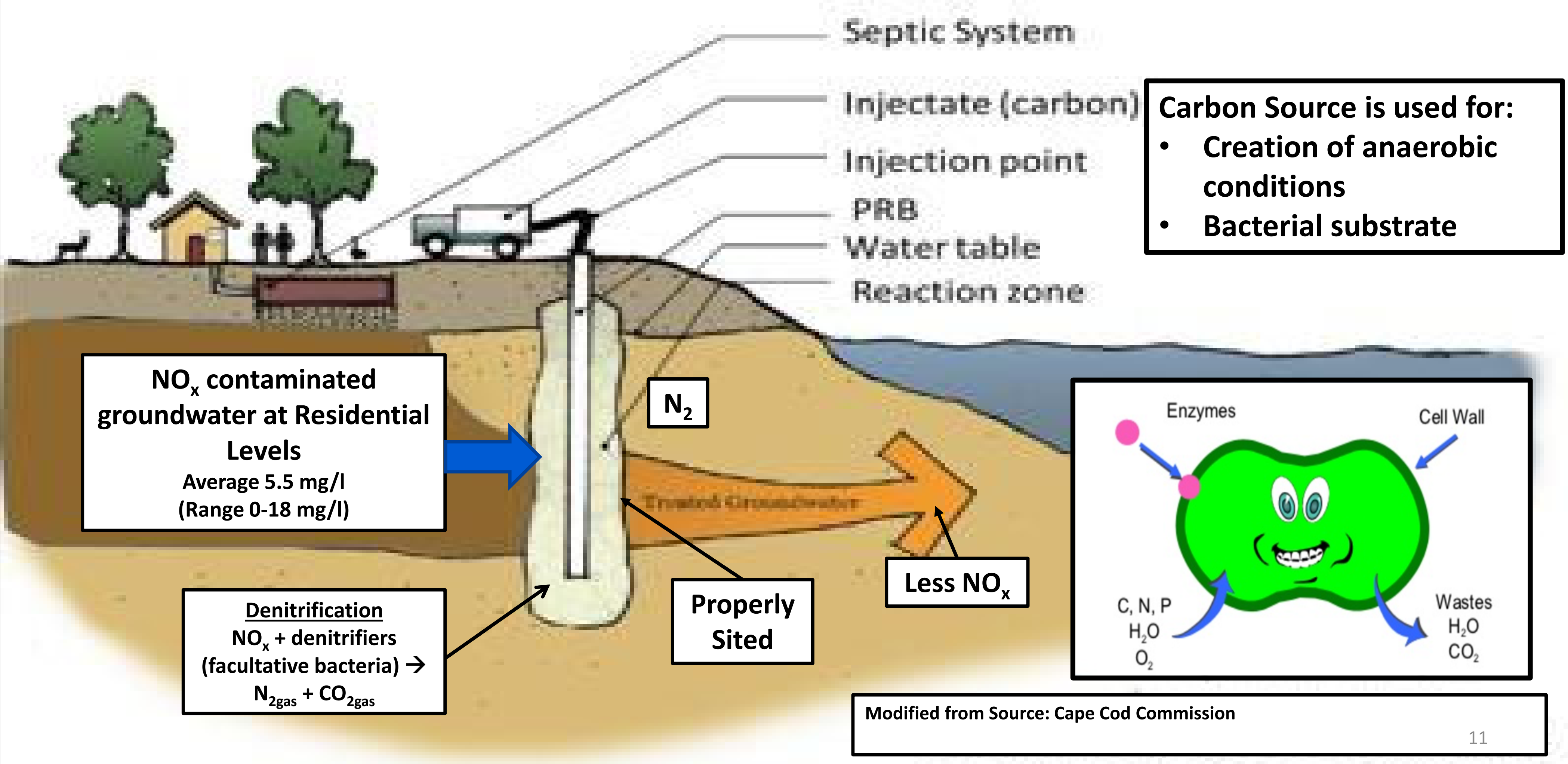
Pros

- Achieved high levels of denitrification
- Easy installation
- Relatively low cost
- Little environmental disturbance

Cons

- Some movement with groundwater
- May reduce groundwater conductivity

What is a Liquid Injection PRB?

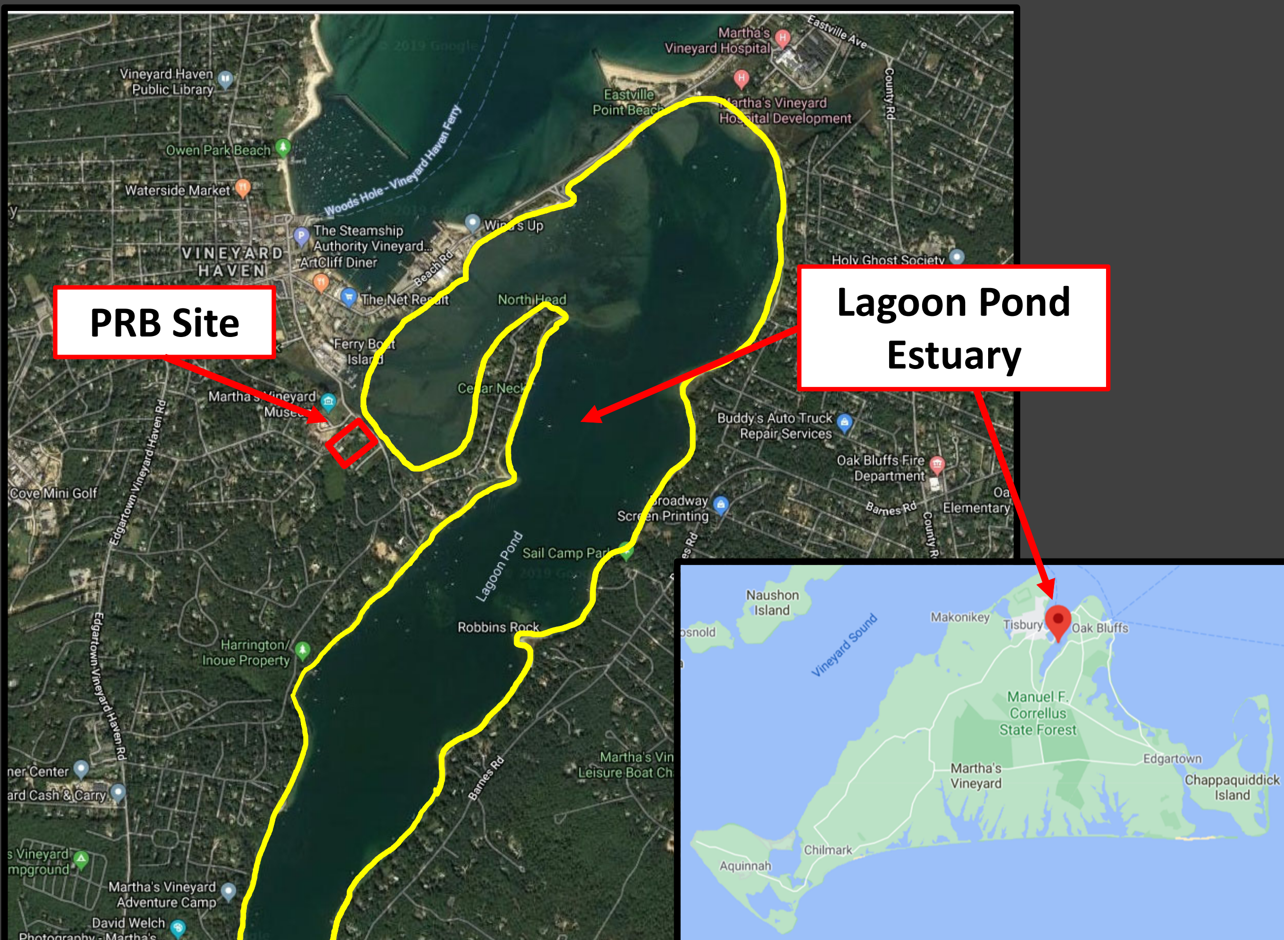


Modified from Source: Cape Cod Commission

Micro-Siting PRBs

✓ 1. Select desired Site
✓ 2. Determine depth to groundwater
✓ 3. Determine groundwater flow direction and hydraulic conductivity
✓ 4. Establish nitrogen concentration levels and vertical profiles
✓ 5. Establish soil type
✓ 6. Quantify any tidal influence on groundwater
✓ 7. Finalize PRB design and placement

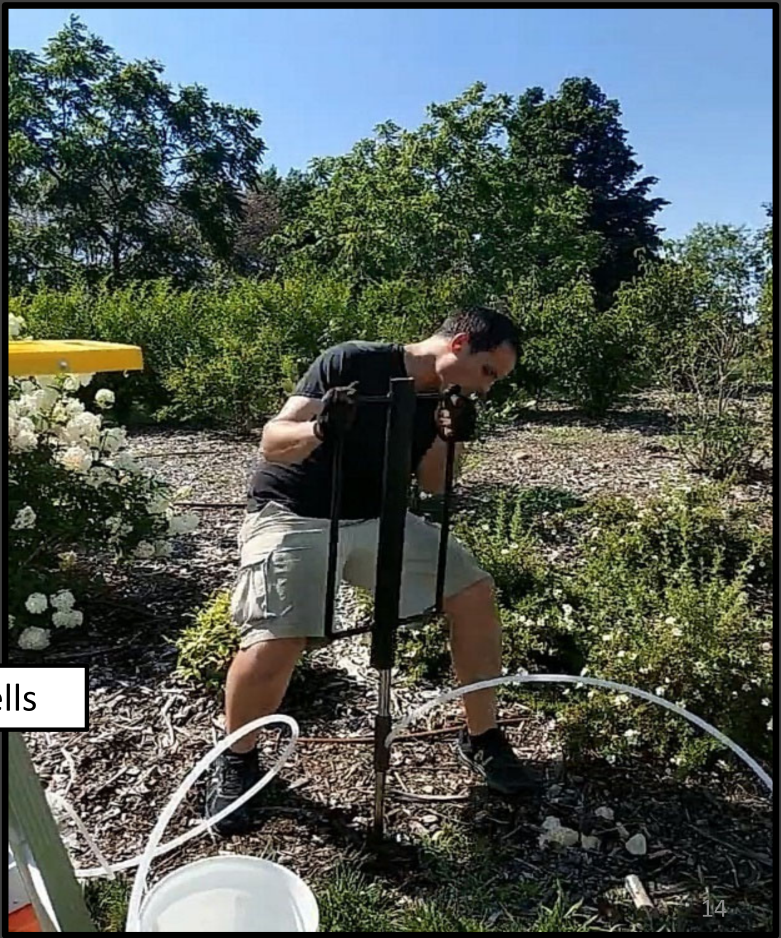
Site Selection: Locus Map



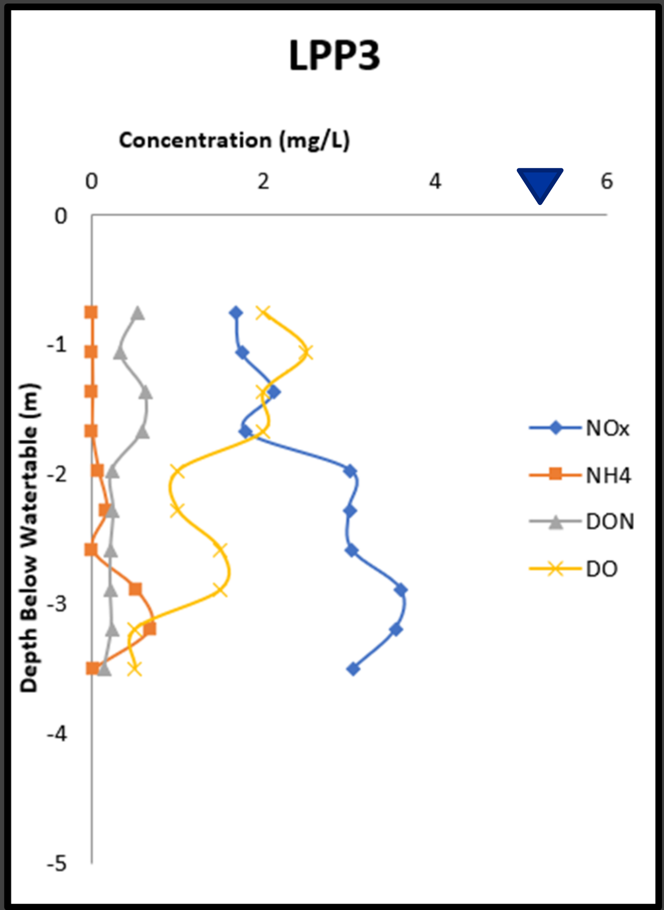
Lagoon Pond Estuary

- Coastal Systems Program (CSP): MEP Assessment
- Impaired by N enrichment:
  - TMDL [N] Target = 0.33-0.42 mg/L
- CSP N loading to meet TMDL for N:
  - 74.1 kg/day
- Nitrogen Removal Goal:
  - 5,900 kg/y
- Stewards:
  - Oak Bluffs
  - Tisbury
  - MV Commission

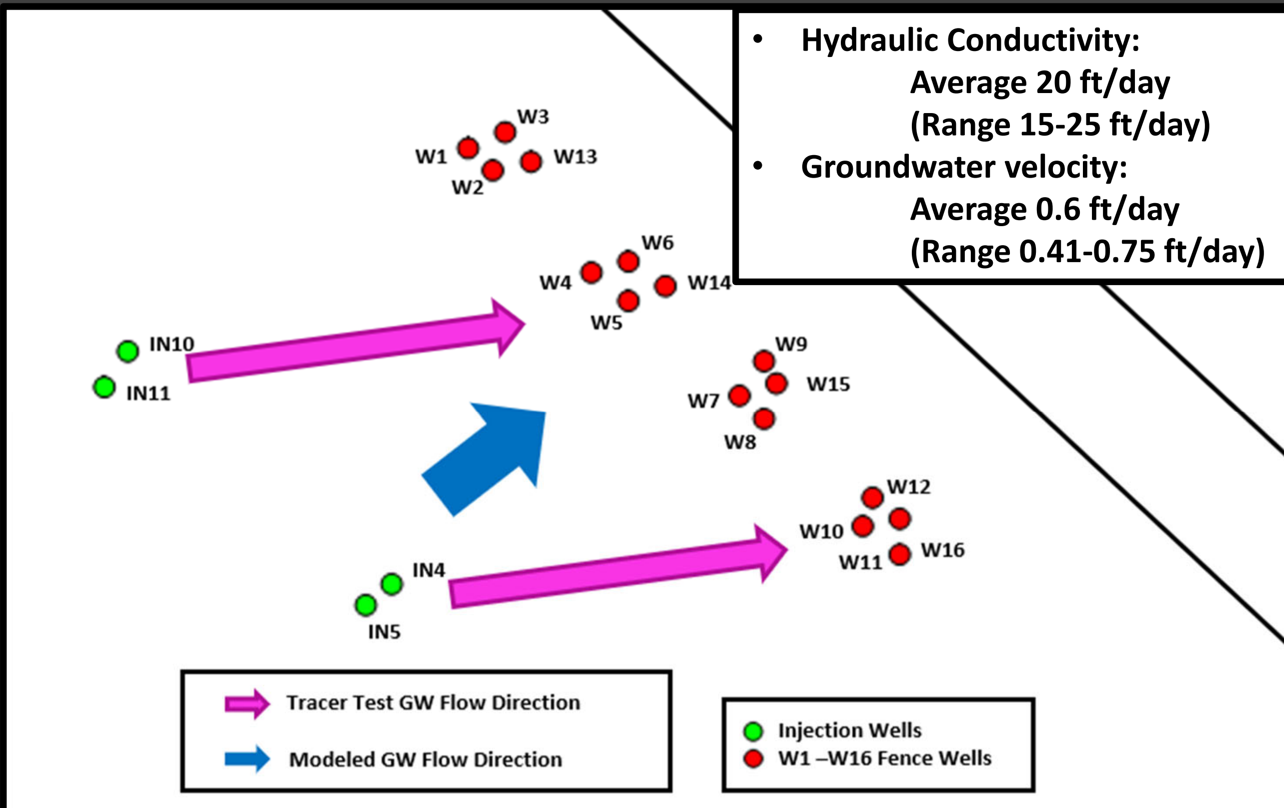
Site Selection: Site Map



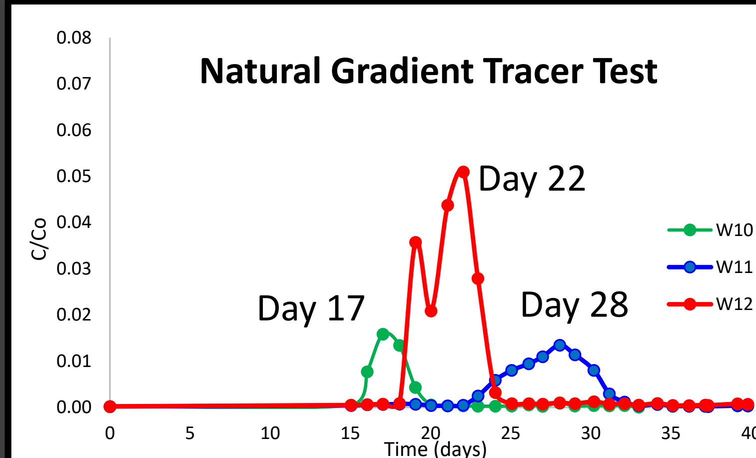
Groundwater Flow & Nitrate Profiles

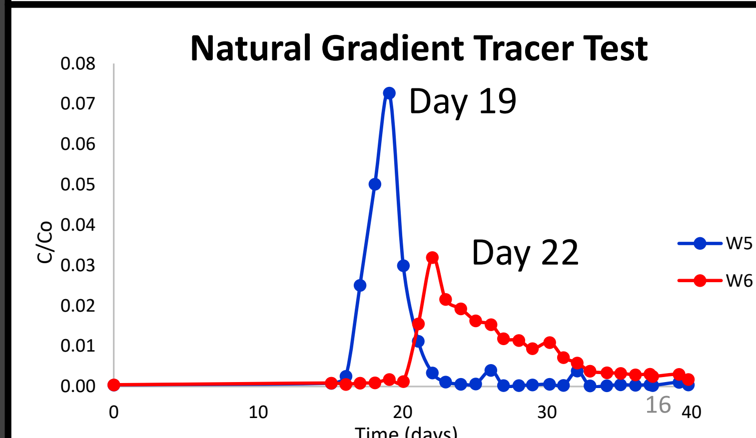


GW Flow: Natural Gradient Tracer Test

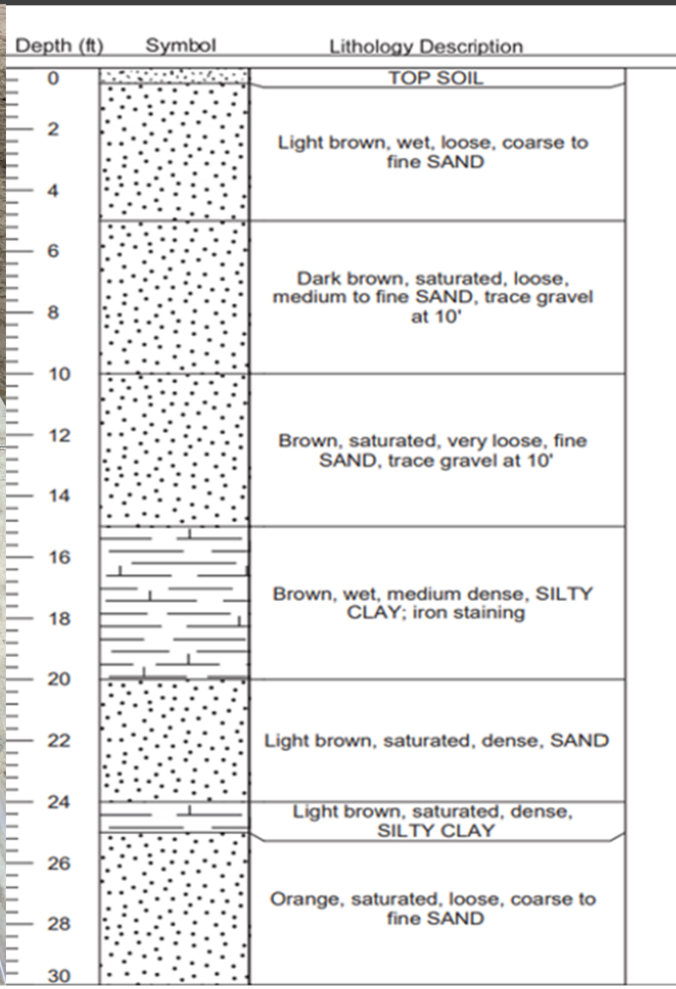


- **Hydraulic Conductivity:**
  Average 20 ft/day
  (Range 15-25 ft/day)
- **Groundwater velocity:**
  Average 0.6 ft/day
  (Range 0.41-0.75 ft/day)

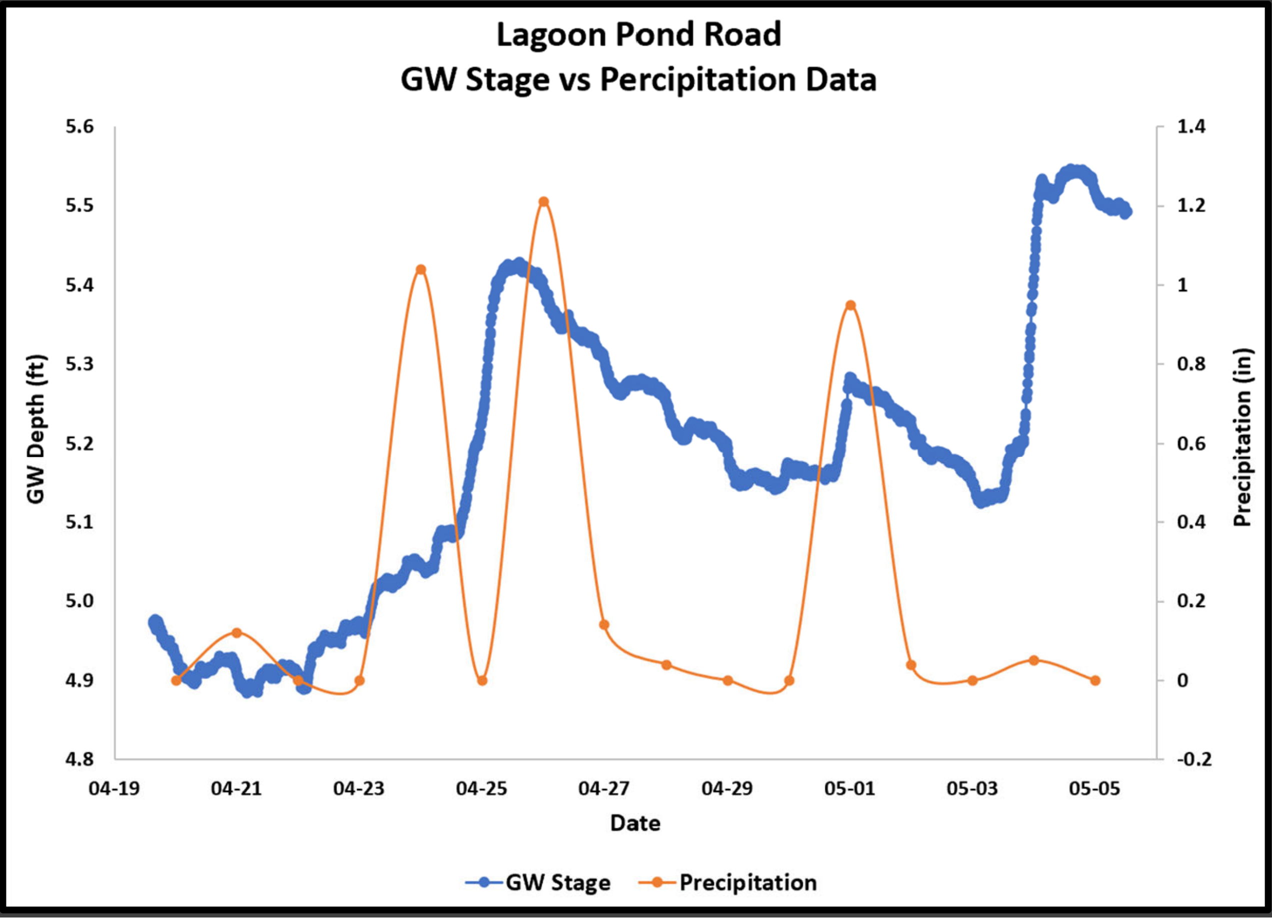




Establish Soil Type: Soil Borings



Determining a Tidal Influence: Fluctuations in Water Table Elevation



While some tidal influence is seen, dominant factor in changing groundwater elevation is recharge.

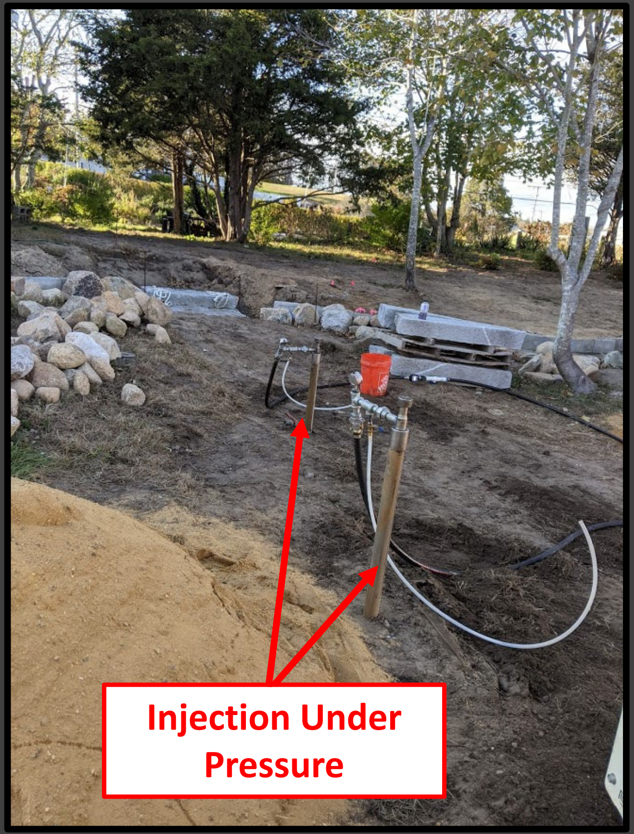
PRB Pre-Installation Findings

- **Groundwater only 0.5 – 2.5 m below ground surface**
- **Soils are coarse to fine sand with some silty/clay**
- **Nitrate is the dominant form of N and corresponds with typical residential levels**
  - **Total Dissolved Nitrogen: Average 6.0 mg/L (0-19 mg/L)**
  - **Nitrate + Nitrite: Average 5.5 mg/L (0-18 mg/L)**
  - **Ammonium: Average 0.3 mg/L (0-0.68 mg/L)**
- **Freshwater (Salinity <0.2 PSU)**
- **Hydraulic Conductivity: 20 ft/day (15-25 ft/day)**
- **Groundwater velocity: Average 0.6 ft/day (0.41-0.75 ft/day)**

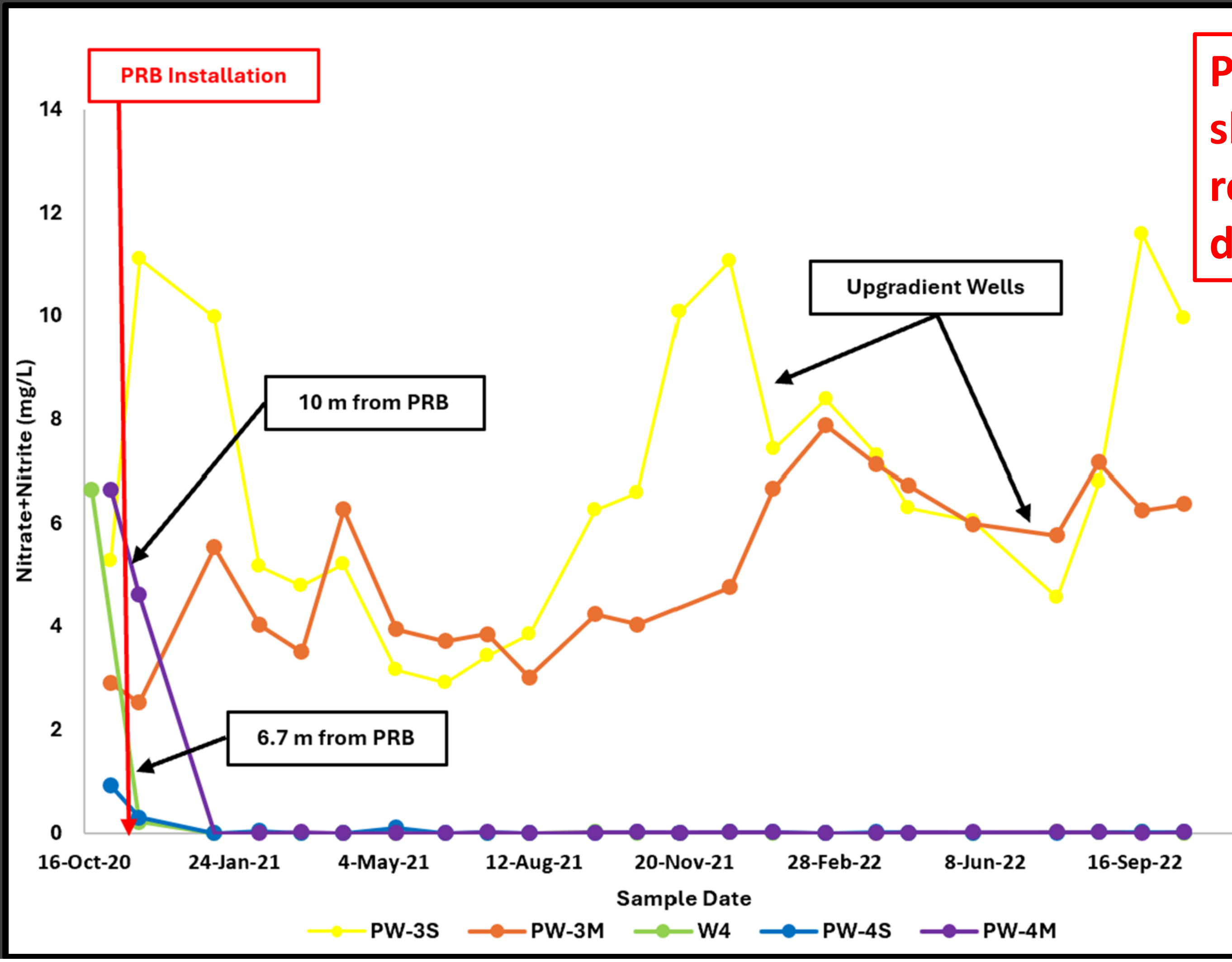
PRB Design

- 150 linear ft
- 80 ft from Pond
- Fence of Injections 10 ft & 15 ft apart
- 17,155-Gal Total Injected (4:1 Water:EVO)

Liquid Injection PRB Installation



Post Injection Findings



Preliminary results show a significant reduction of nitrate in downgradient wells.

Post Injection Findings

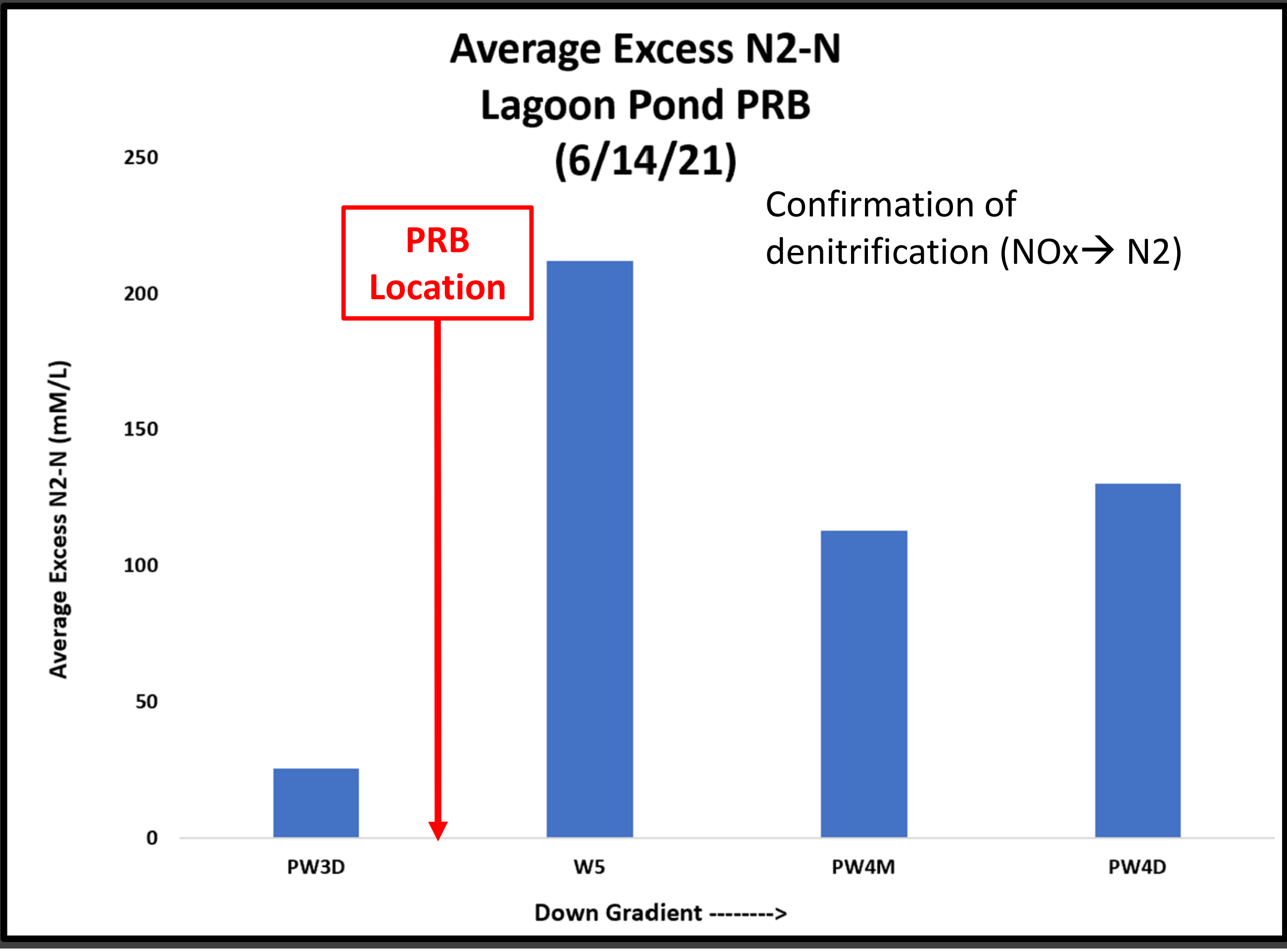
Winter

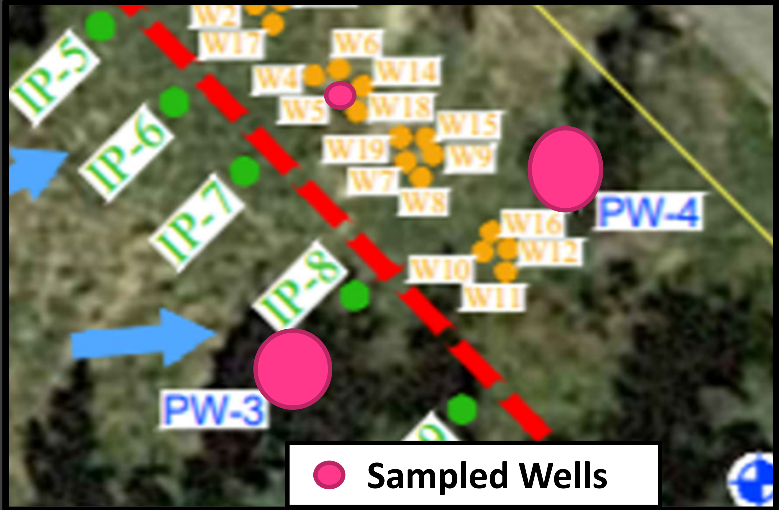
Depth (m)	Upgradient Concentration (mg/L)	Downgradient Concentration (mg/L)	% Reduction Nitrate+Nitrite	Kg NOx Removed / day
2	8.18	0.04	-99.5%	-0.07
4.5	5.73	0.05	-99.1%	-0.06
7.5	3.90	0.01	-99.7%	-0.04
Total	5.97	0.04	-99.3%	-0.16

Summer

Depth (m)	Upgradient Concentration (mg/L)	Downgradient Concentration (mg/L)	% Reduction Nitrate+Nitrite	Kg NOx Removed / day
2	7.23	0.04	-99.4%	-0.04
4.5	5.52	0.19	-96.6%	-0.05
7.5	4.09	0.01	-99.8%	-0.02
Total	5.61	0.12	-97.9%	-0.11

Post-Injection Findings



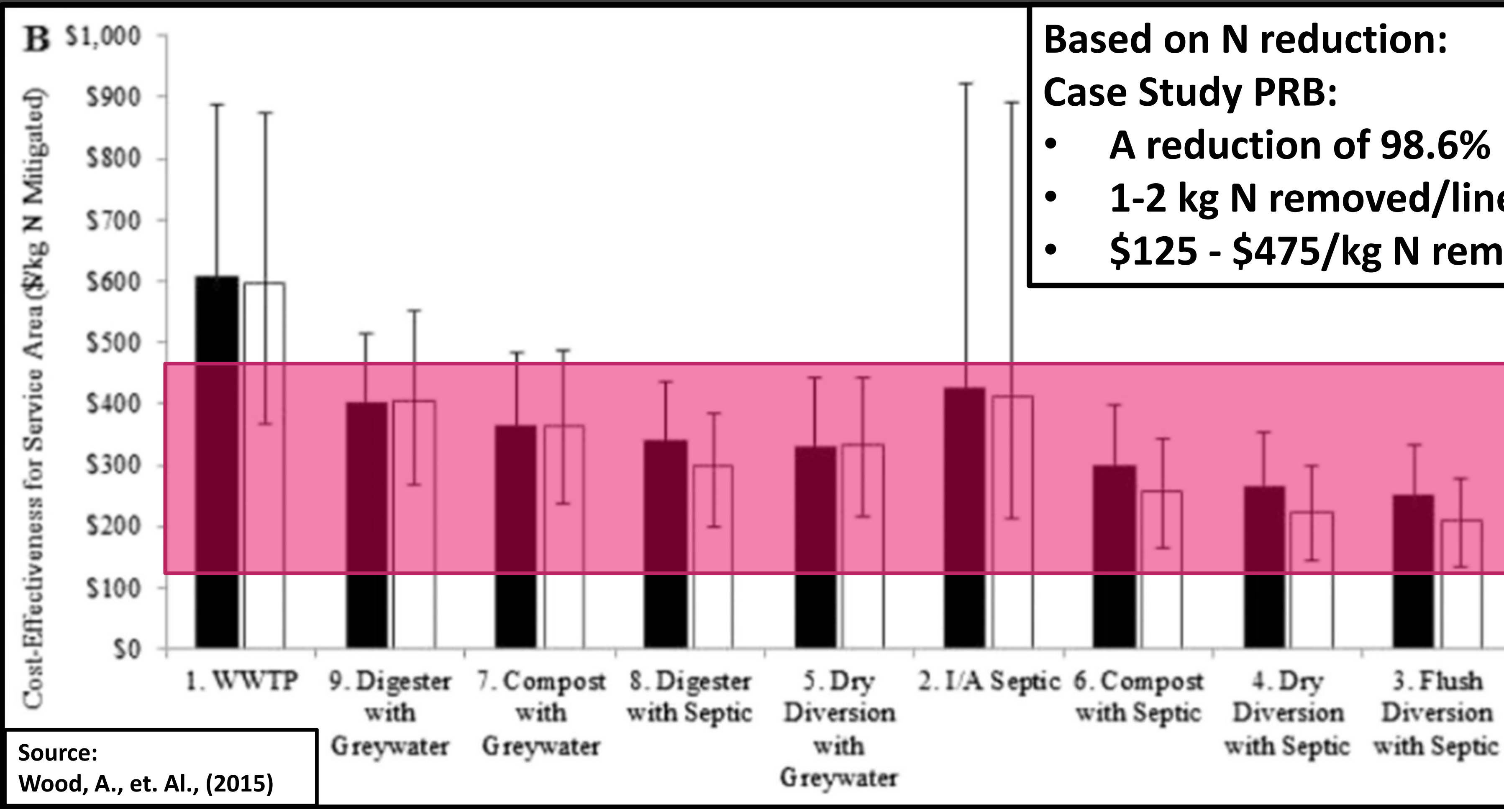


A mass balance approach will be utilized to confirm amount of denitrification.

Conclusions

- Installation of the liquid injection PRB was straightforward
- The PRB began removing Nitrate within days of installation
- Nitrate was reduced to very low levels

Potential PRB Impact



Based on N reduction:

Case Study PRB:

- **A reduction of 98.6%**
- **1-2 kg N removed/linear m year**
- **$125 - $475/kg N removed**

Source:
Wood, A., et. Al., (2015)

Thank You!

Martha's Vineyard Commission
Adam Turner and Sheri Caseau
EPA's Southeast New England Program
Amy Hambrecht and Dan Greening
ES&M
Terra Systems, Inc.
Coastal Systems Program

United States Environmental Protection Agency

Enhanced onsite wastewater treatment for significant nitrogen removal
a neighborhood-scale demonstration study in Barnstable, MA (Cape Cod)

Erban L.[1], Wigginton S.[2], Olmsted E.M.[2], Horsley B.[2], Gleason T.[1], Baumgaertel, B.[2]

[1] US Environmental Protection Agency, Office of Research and Development,
Atlantic Coastal Environmental Sciences Division, 27 Tarzwell Dr, Narragansett, RI, 02882
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Presented by: Laura Erban, PhD

Office of Research and Development
Center for Environmental Measurement and Modeling, Atlantic Coastal Environmental Sciences Division

SNEP Symposium
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Acknowledgments

Local farmers and other landowners

Disclaimer: *The views expressed in this presentation are those of the author(s) and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency. Any mention of trade names, products, or services does not imply an endorsement by the U.S. Government or the U.S. Environmental Protection Agency. The EPA does not endorse any commercial products, services, or enterprises.*

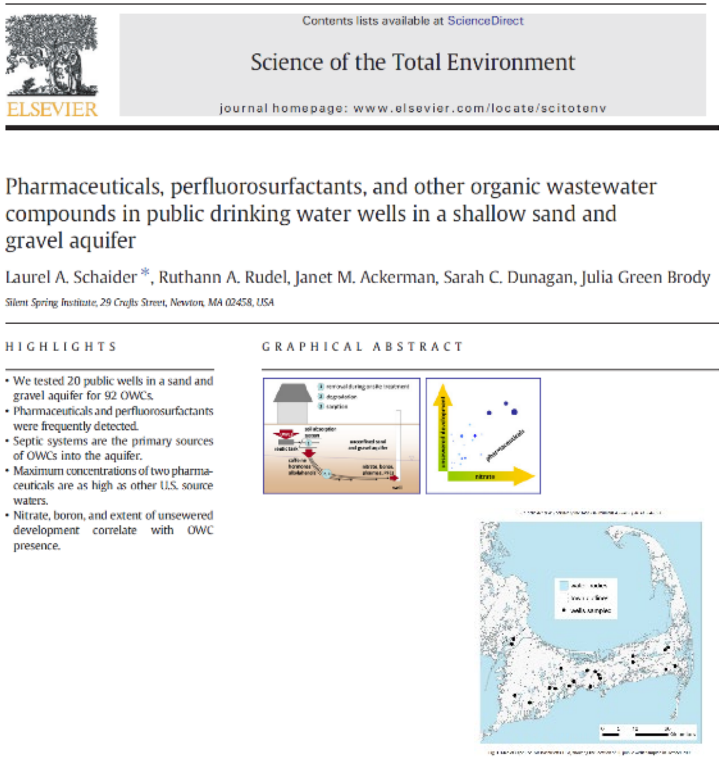
Nutrients and co-pollutants in onsite wastewater can overload water resources


The New York Times

A Toxic Stew on Cape Cod: Human Waste and Warming Water

Climate change is contributing to electric-green algae blooms. Massachusetts wants a cleanup of the antiquated septic systems feeding the mess, but it could cost billions.

Ashley Fisher, director of the Mashpee Department of Natural Resources in Massachusetts, took samples from the bed of the Mashpee River earlier this month.


Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

ELSEVIER

Pharmaceuticals, perfluorosurfactants, and other organic wastewater compounds in public drinking water wells in a shallow sand and gravel aquifer

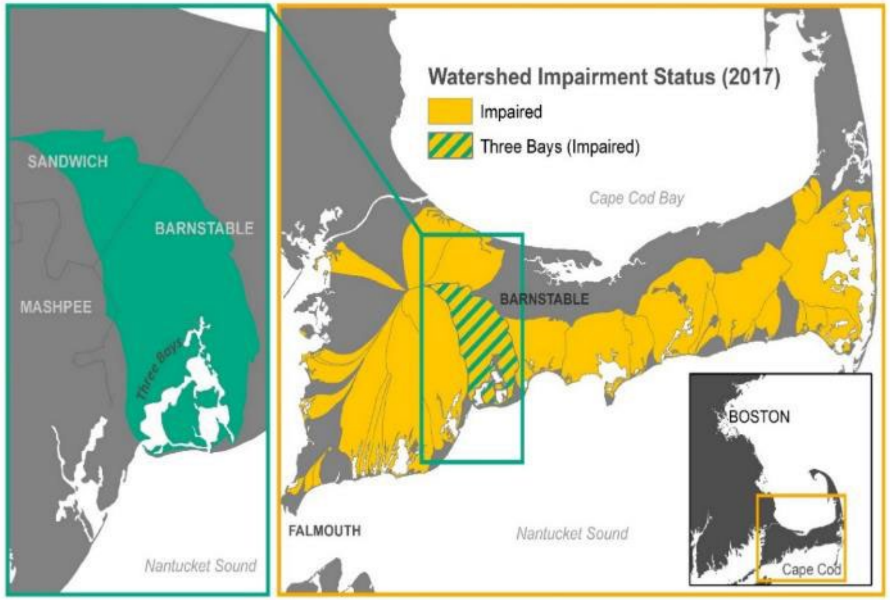
Laurel A. Schaider *, Ruthann A. Rudel, Janet M. Ackerman, Sarah C. Dunagan, Julia Green Brody

Silent Spring Institute, 29 Crafts Street, Newton, MA 02458, USA

HIGHLIGHTS

- We tested 20 public wells in a sand and gravel aquifer for 92 OWCs.
- Pharmaceuticals and perfluorosurfactants were frequently detected.
- Septic systems are the primary sources of OWCs into the aquifer.
- Maximum concentrations of two pharmaceuticals are as high as other U.S. source waters.
- Nitrate, boron, and extent of unsewered development correlate with OWC presence.

GRAPHICAL ABSTRACT



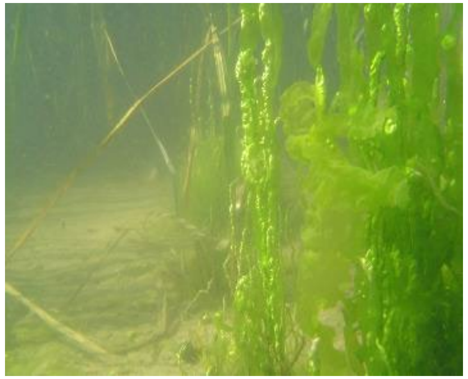
More than 30 Cape Cod watersheds have Total Maximum Daily Loads (TMDLs) for nitrogen.
Source: Twichell et al., 2019. EPA/600/R-19/107

EPA United States Environmental Protection Agency

Cape Cod communities are pursuing multiple means of load reduction

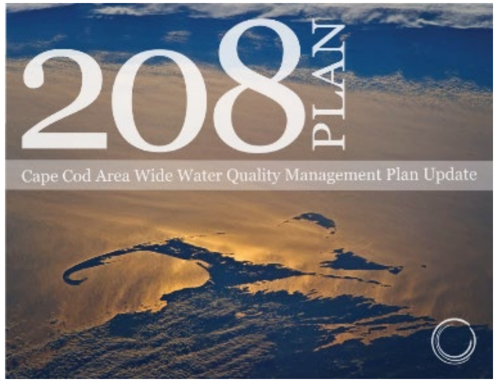
- TMDLs call for >50% reduction in nitrogen (N) loading from septic systems Cape-wide.
- Sewer expansion and complementary approaches for recurring and legacy pollution.
- Clean Water Act Section 208 Plan Update Technologies Matrix identifies many interventions, including enhanced decentralized or onsite wastewater treatment.


USGS


Buzzards Bay Coalition


NYTimes


Town of Mashpee



Cape Cod Commission, 2015

United States Environmental Protection Agency

Improving wastewater treatment takes time

- Innovative/Alternative (I/A) septic systems in Massachusetts have historically sought to meet a performance goal of 19 mg/L total nitrogen (TN) in effluent.

- New regulations (2023) set a more stringent goal for best available nitrogen reducing technologies of 10 mg/L TN

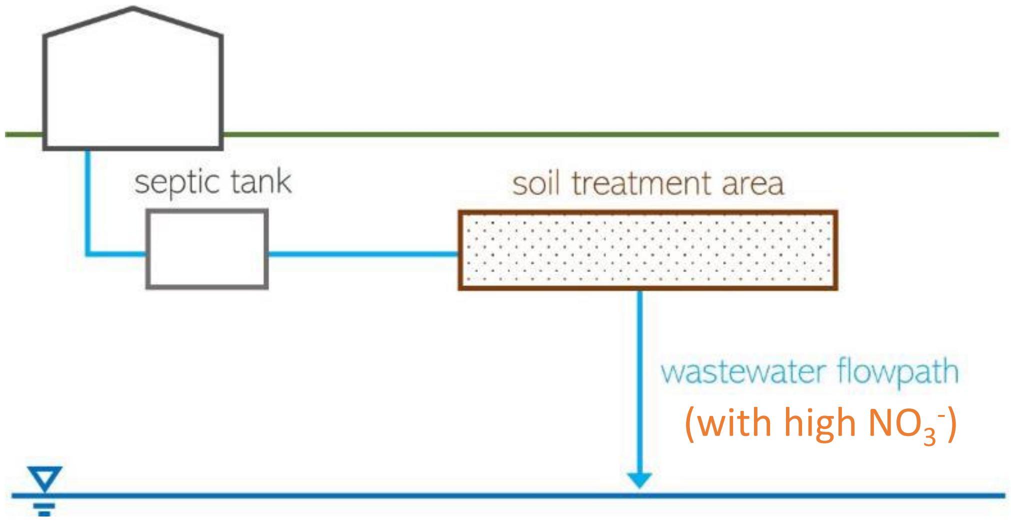
- 50 installations and 3 years of monitoring are required for general use approval.

- Few high-performing options (EIA) are available to users.

Sampling by MASSTC photo: L. Erban

Enhancing onsite wastewater treatment

conventional septic system



* Note that the diagram is simplified and not to scale!

alternatives

- separate waste streams
  (urine diversion, composting toilets, tight tanks)
- add treatment stage(s) for mixed effluent


Agronomy for Sustainable Development (2021) 41: 56
https://doi.org/10.1007/s13593-021-00675-2

RESEARCH ARTICLE

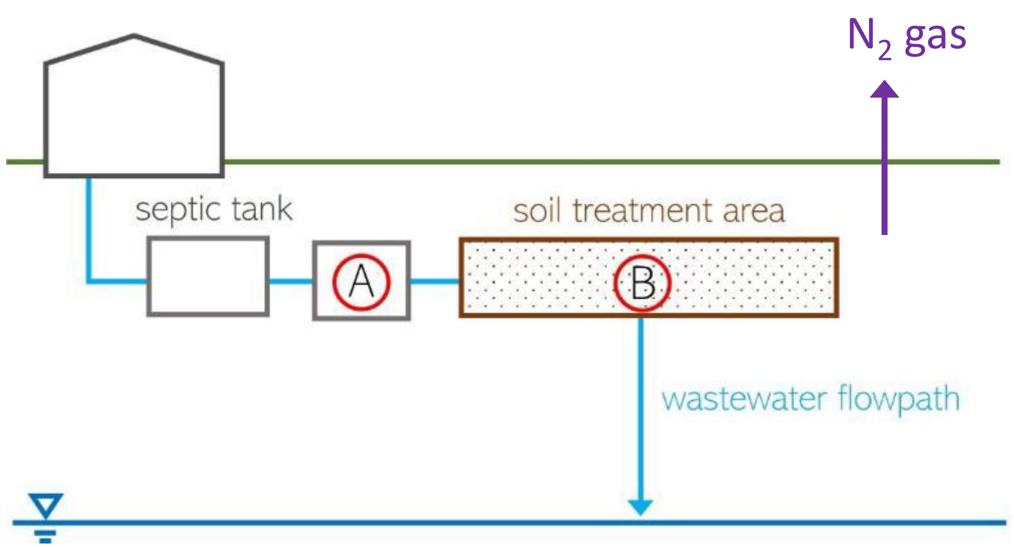
Sanitized human urine (Oga) as a fertilizer auto-innovation from women farmers in Niger

Hannatou O. Moussa[1] · Charles I. Nwankwo[2] · Ali M. Aminou[3] · David A. Stern[4] · Bettina I. G. Haussmann[5] · Ludger Herrmann[2]

Accepted: 29 January 2021 / Published online: 29 July 2021

Enhancing onsite wastewater treatment of nitrogen

alternative septic system



* Note that the diagram is simplified and not to scale!

Septic systems designed for nitrogen removal:

A) add a treatment unit after the septic tank and before soil treatment area (a.k.a. leach field)

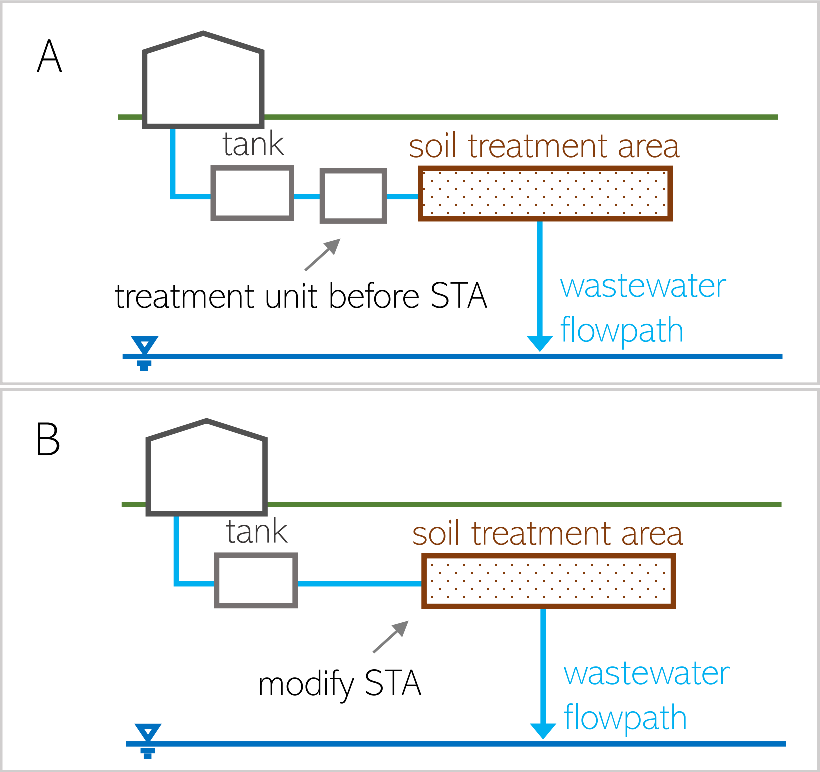
OR

B) modify the soil treatment area

(in general terms)

Enhancing onsite wastewater treatment of nitrogen

alternative septic systems



* Note that the diagram is simplified and not to scale!

- Designs with a lignocellulosic <u>carbon source</u> can provide a high degree of N removal.
- Two designs (proprietary and non-proprietary) use <u>woodchips</u> in this demonstration effort.

A

NiTROE® treatment unit
by KleanTu LLC

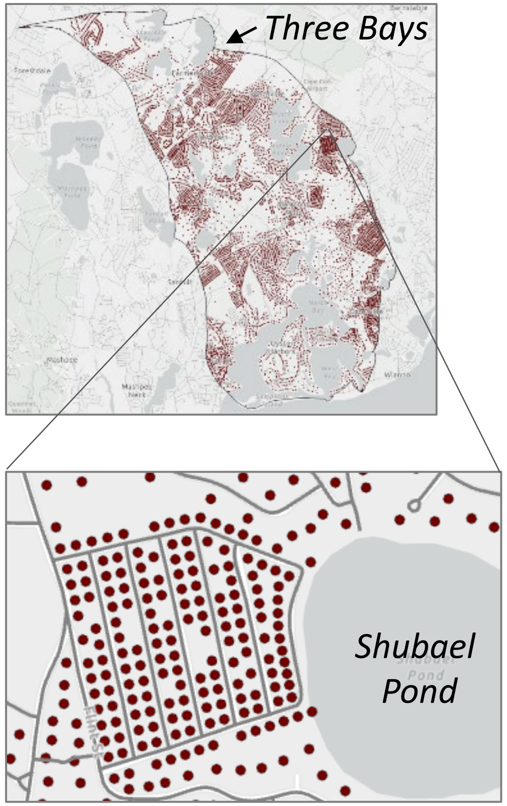
B

modified STA
by MASSTC

United States Environmental Protection Agency

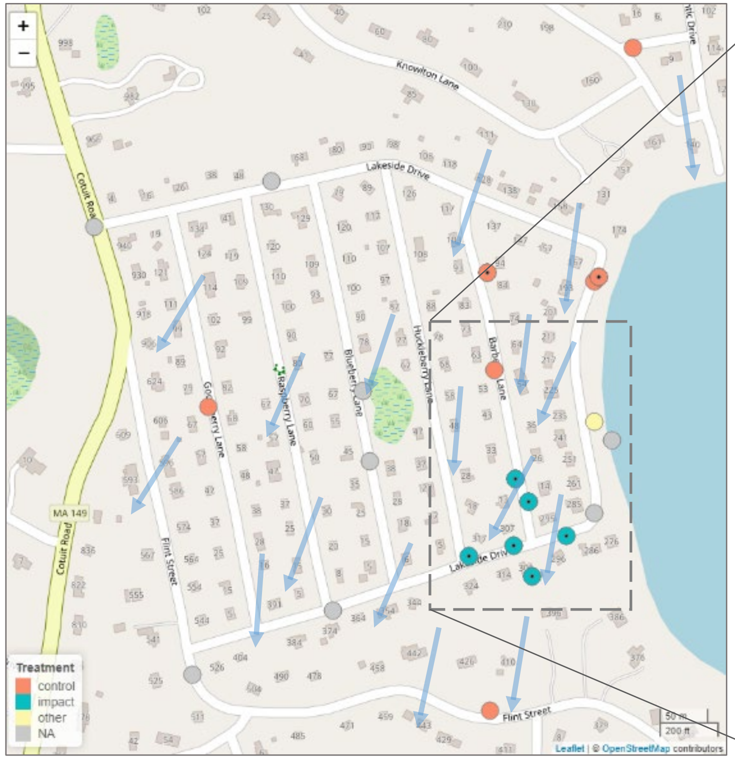
Demonstration setup

watershed screening



● onsite wastewater treatment system

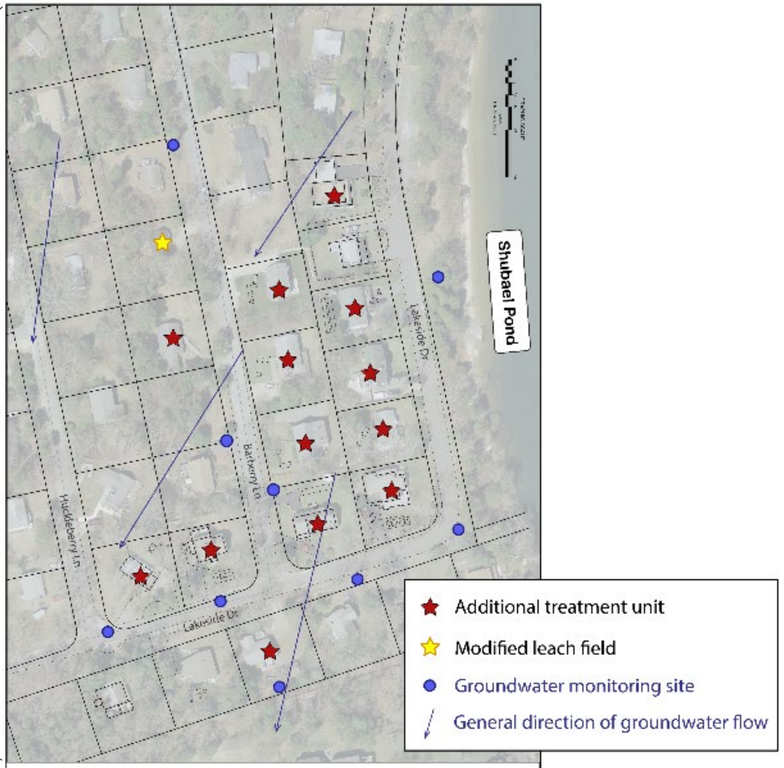
well network



• Indicates multiple sampling depths at site

General direction of groundwater flow

EIA septic systems (n = 14)



Homes participating in the enhanced septic system study.

Partners

Barnstable Clean Water Coalition

USGS science for a changing world

EPA

TOWN OF BARNSTABLE

United States Environmental Protection Agency

Performance monitoring: nitrogen concentration

Monthly samples for more than 2 years

Continuous flow metering

Order of magnitude reduction in TN

Effluent samples:

83% < 10 mg/L

50% < 3 mg/L

TN = 10 mg/L

Partners

Barnstable Clean Water Coalition

MASSTC The Massachusetts Alternative Septic System Test Center

EPA

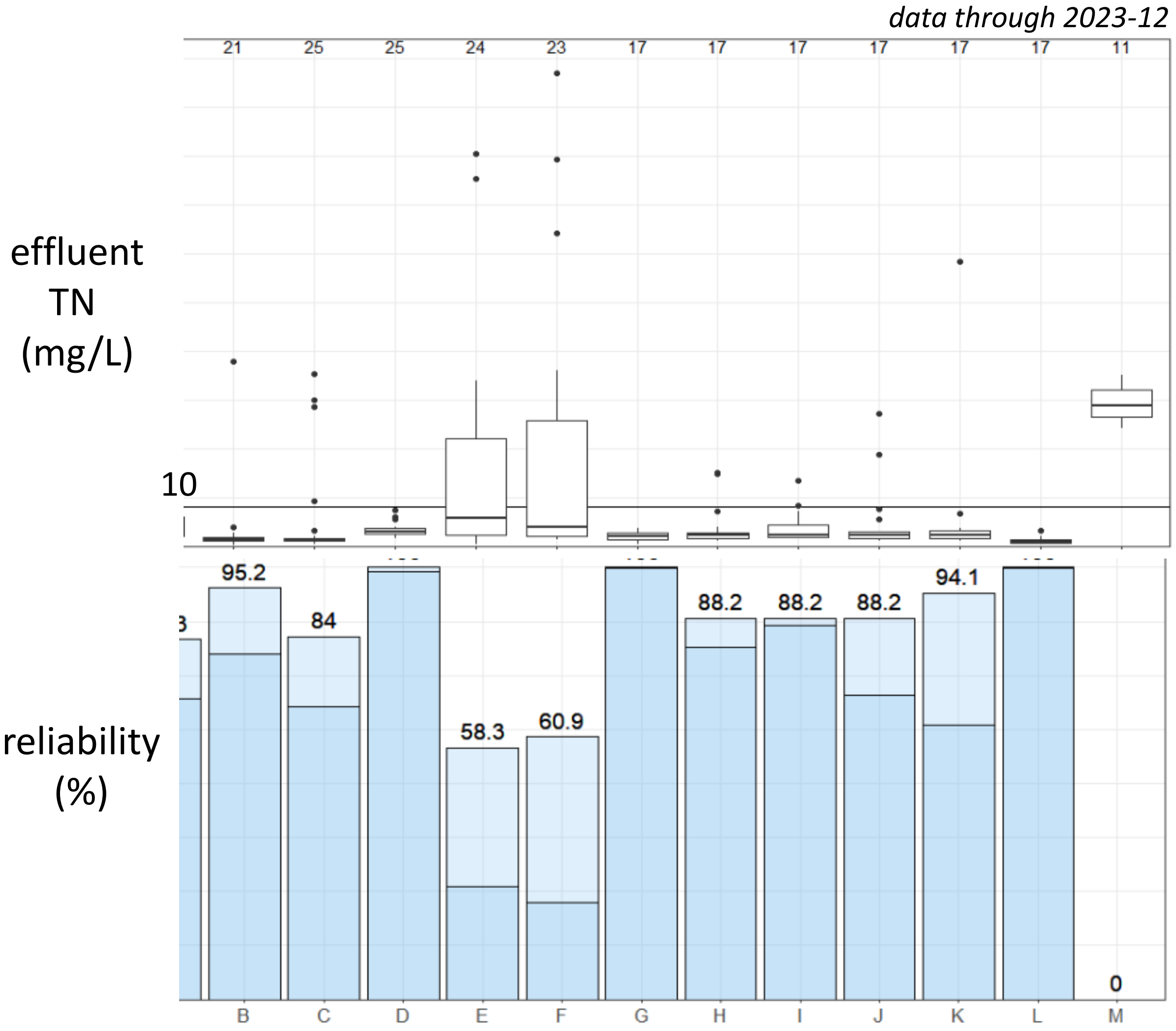
homeowners

Preliminary Information-Subject to Revision. Not for citation.

United States Environmental Protection Agency

Reliability of individual systems

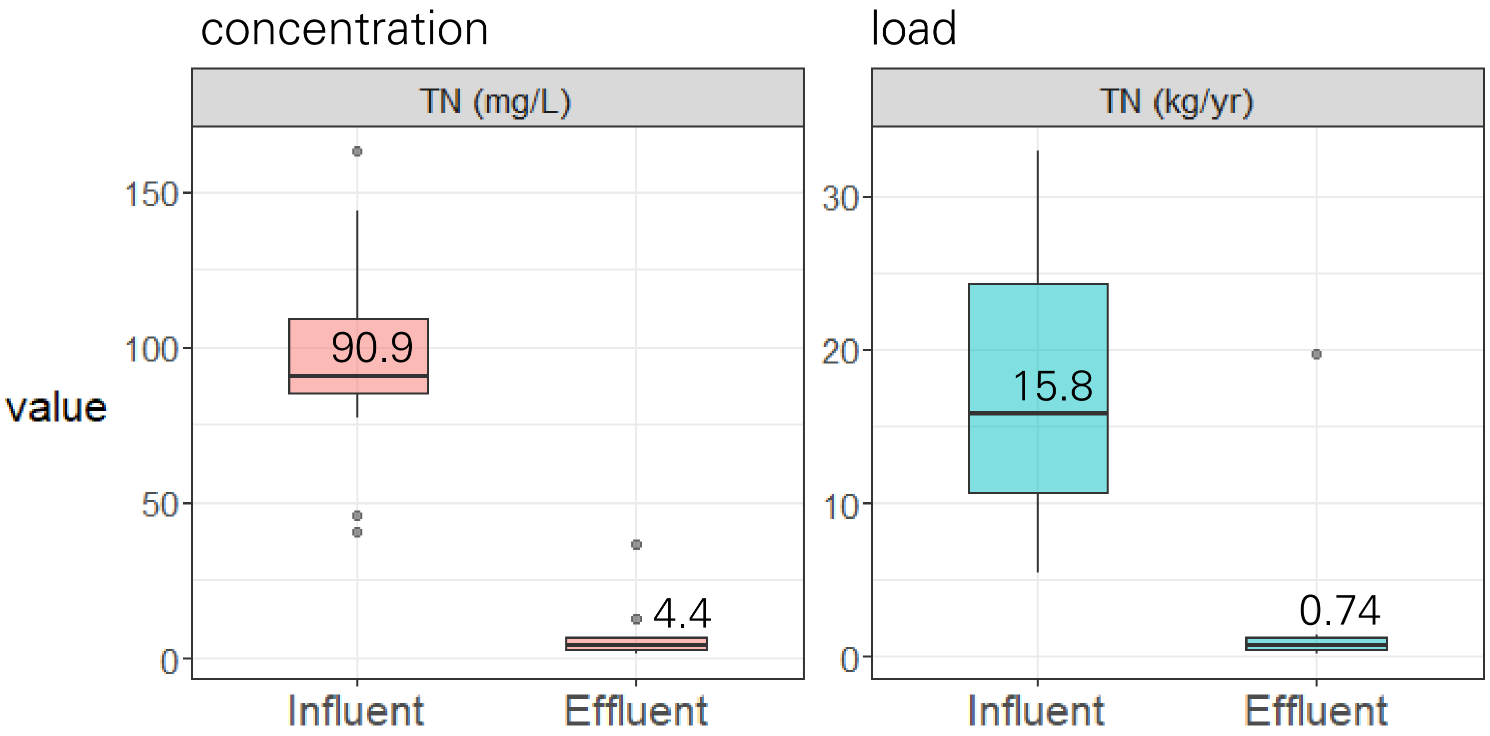
- Varies by household, technology, system adjustments.
- High performance requires good design, use, and maintenance.
- Monitoring and maintenance costs scale with number of systems.
- How might we implement cluster systems and/or responsible management entities (RME)?



Preliminary Information-Subject to Revision. Not for citation.

EPA United States Environmental Protection Agency

Overall, N concentration and load reductions exceed 90%



as of 2023-12 (11 to 25 months of sample data)
Labels are median values for the group of systems (n=12)

Preliminary Information-Subject to Revision. Not for citation.

Load estimates based on mean daily flow, mean monthly concentrations for systems with flow meters and a least one calendar year of data.

Boxes depict spread in estimates across systems.

Median total nitrogen (TN) reduction:*

concentration: 95%
load: 95%

* values are sensitive to samples included and method of estimation

Partners

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MASSTC The Massachusetts Alternative Septic System Test Center

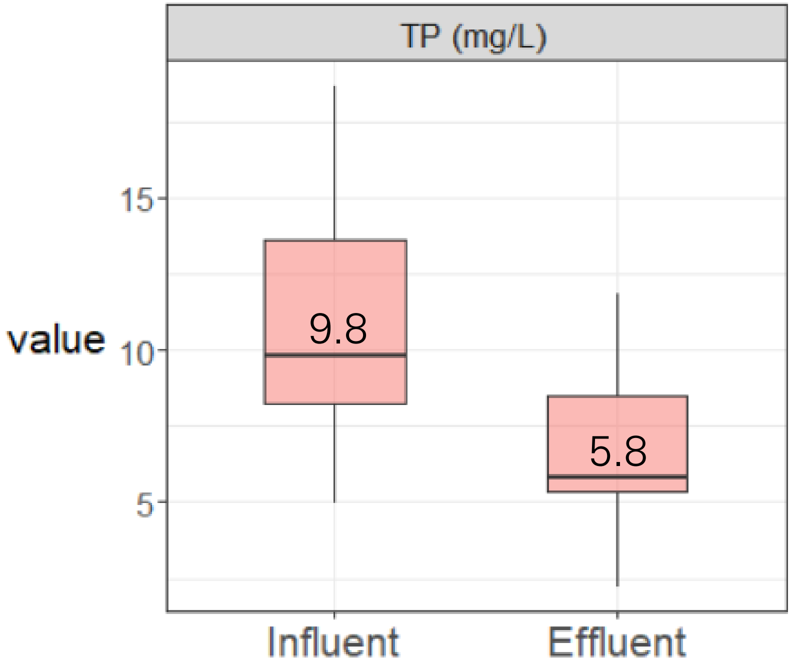
EPA

homeowners

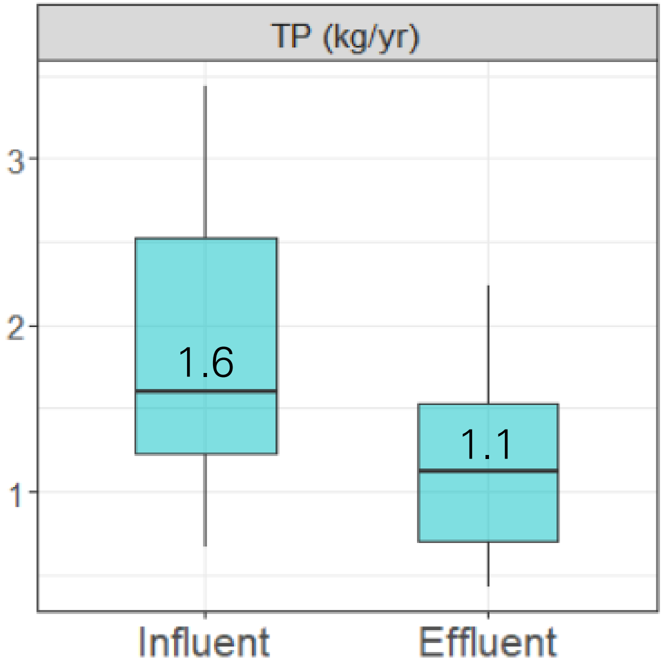
United States Environmental Protection Agency

P reductions are lower (note: systems were not designed for this purpose)

concentration



load



as of 2023-12 (11 to 25 months of sample data)
Labels are median values for the group of systems (n=12)

Preliminary Information-Subject to Revision. Not for citation.

Load estimates based on mean daily flow, mean monthly concentrations for systems with flow meters and a least one calendar year of data.

Boxes depict spread in estimates across systems.

Median total phosphorus (TP) reduction:*

concentration: 41%
load: 31%

* values are sensitive to samples included and method of estimation

Partners

homeowners

EPA United States Environmental Protection Agency

EIA septic system performance: beyond nutrients

frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 23 May 2023
DOI 10.3389/fmars.2023.1069599

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Factors in homeowners' willingness to adopt nitrogen-reducing innovative/alternative septic systems

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Removing 80%–90% of nitrogen and organic contaminants with three distinct passive, lignocellulose-based on-site septic systems receiving municipal and residential wastewater

Christopher J. Gobler[a,b,*], Stuart Waugh[a], Caitlin Asato[a], Patricia M. Clyde[a,b], Samantha C. Nyer[a,b], Molly Graffam[a,b], Bruce Brownawell[b], Arjun K. Venkatesan[a,c], Jennifer A. Goleski[b], Roy E. Price[a,b], Xinwei Mao[a,c], Frank M. Russo[a,c], George Heufelder[d], Harold W. Walker[a,1]

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EIA septic systems in context

- One of many solutions
- Total mass of pollutants
- Values and perceptions of people
- Limitations and co-benefits

Wetland restoration site. Photo: K. Canfield

legacy wastewater pollution

	Site Scale	Neighborhood	Watershed	Cape-Wide
Reduction	Standard Title 5 System	Cluster Treatment System: Single or Two-stage	Conventional Treatment	Fertilizer Management ❖
Reduction	I/A Title 5 Systems	Satellite Treatment	Advanced Treatment	Compact and Open Space Development ❖
Reduction	Enhanced I/A Systems	Nutrient Reducing Development ❖		
Reduction	Toilets: Composting, Incinerating, Packaging, Urine Diverting	Transfer of Development Rights ❖		
Reduction	Hydroponic Treatment			
Remediation		Constructed wetlands		Stormwater: Best Management Practices (BMPs) ❖
Remediation		Phytoirrigation		
Remediation	Permeable Reactive Barriers (PRB)			
Remediation	Phytoremediation			
Remediation	Stormwater: Bioretention/ Soil Media Filters	Fertigation Wells: Turf, Cranberry Bogs		
Remediation		Stormwater: Constructed Wetlands		
Restoration		Aquaculture/Shellfish Farming		
Restoration		Coastal Habitat Restoration		
Restoration		Inlet/Culvert Widening		
Restoration		Constructed Wetlands: Floating		
Restoration		Pond and Estuary Circulators		
Restoration		Surface Water Remediation Wetlands		
Restoration		Pond and Estuary Dredging		

❖ Policy

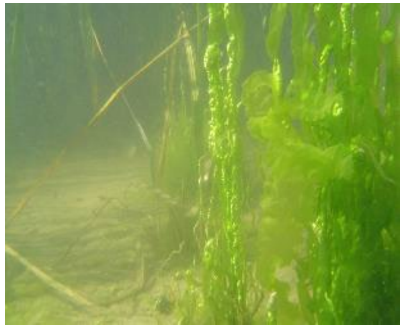
Adapted Technologies Matrix from Cape Cod Area Wide Water Quality Management ("208") Plan Update (2015)

United States Environmental Protection Agency

Summary and directions

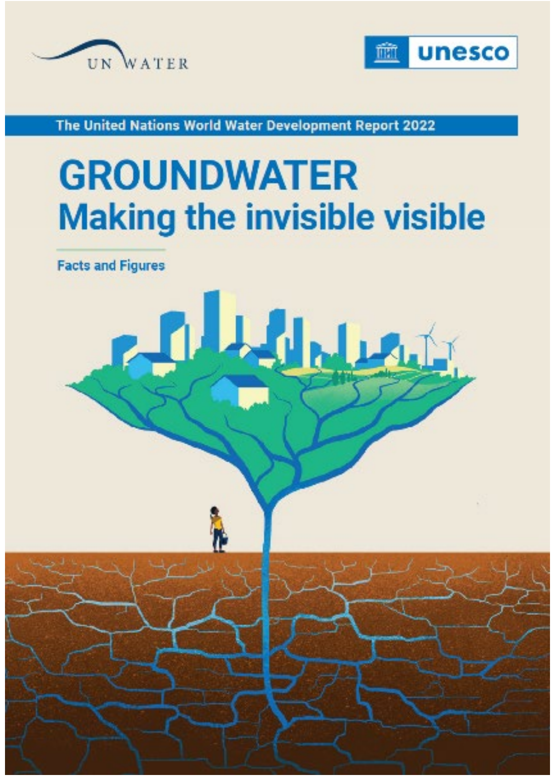
- Significant reduction of onsite wastewater N loads is possible
- Incentives are limited
- Consequences of the status quo are indirect and remote
- Design and (redesign) for resilience
- Center equity: who pays, who benefits?


USGS


Buzzards Bay Coalition


NYTimes


Town of Mashpee



"…once groundwater becomes contaminated, it can be extremely difficult and costly to remedy."

United States Environmental Protection Agency

Questions?

erban.laura@epa.gov

Laura Erban, PhD

Office of Research and Development
Center for Environmental Measurement and Modeling, Atlantic Coastal Environmental Sciences Division

Enhancing Rhode Island's estuaries through oyster habitat conservation and restoration planning

SNEP
Southeast New England Program

RESTORE AMERICA'S ESTUARIES

JA Macfarlan, **Eric Schneider*,** Jon Grabowski, Randall Hughes, Heather Kinney, Will Helt

Principal Marine Fisheries Biologist
Rhode Island Department of Environmental Management
Division of Marine Fisheries
Pronouns: He, Him, His

Recognize Current Partners, Contributors, and Funding Sources

Div. of Marine Fisheries: Eric Schneider (*PI*), JA Macfarlan, Patrick Barrett, Blake Busch, Conor McManus

Northeastern University: Jonathan Grabowski, A. Randall Hughes

Rhode Island Chapter of TNC: William Helt, Heather Kinney, Sara Paulson

USDA NRCS: Melissa Hayden, Jim Turenne, Gary Casabona, Brunilda Velez

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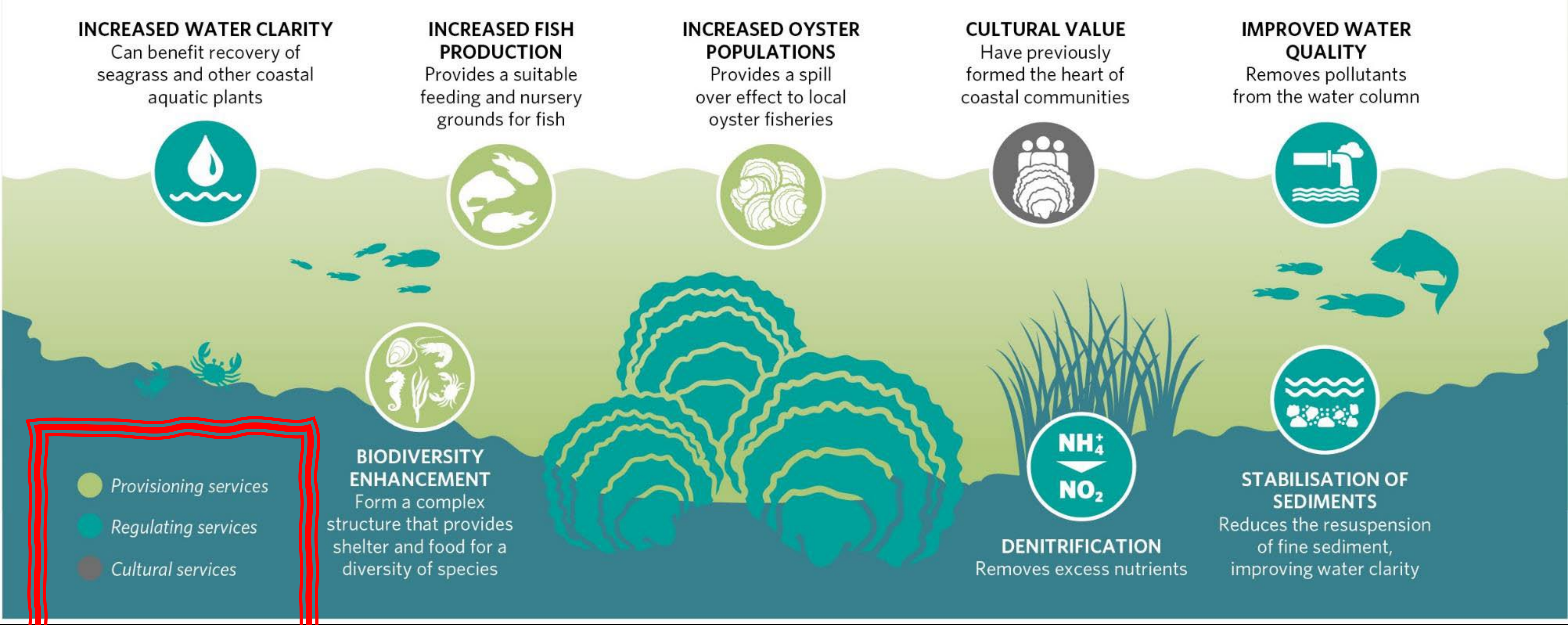
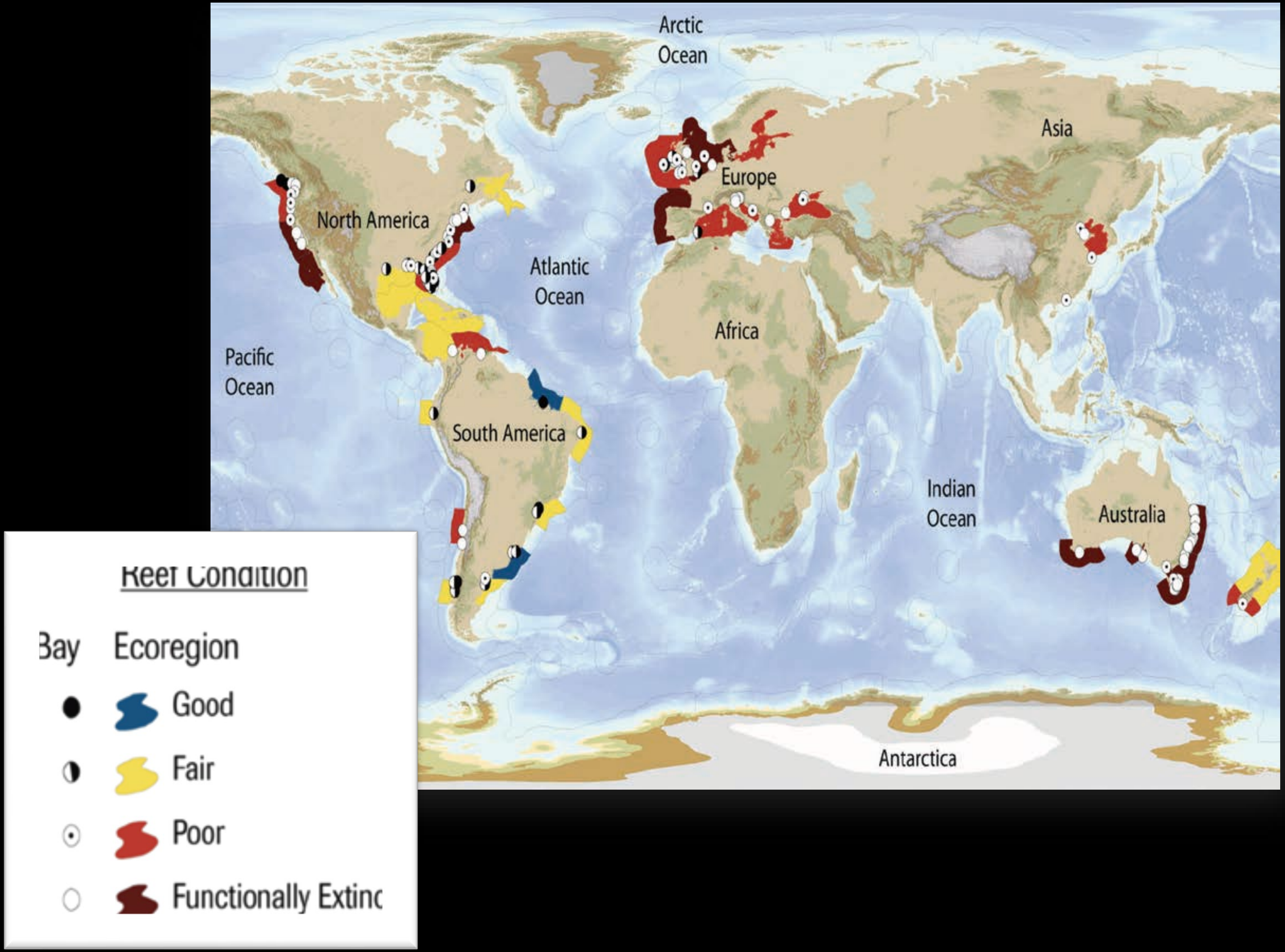
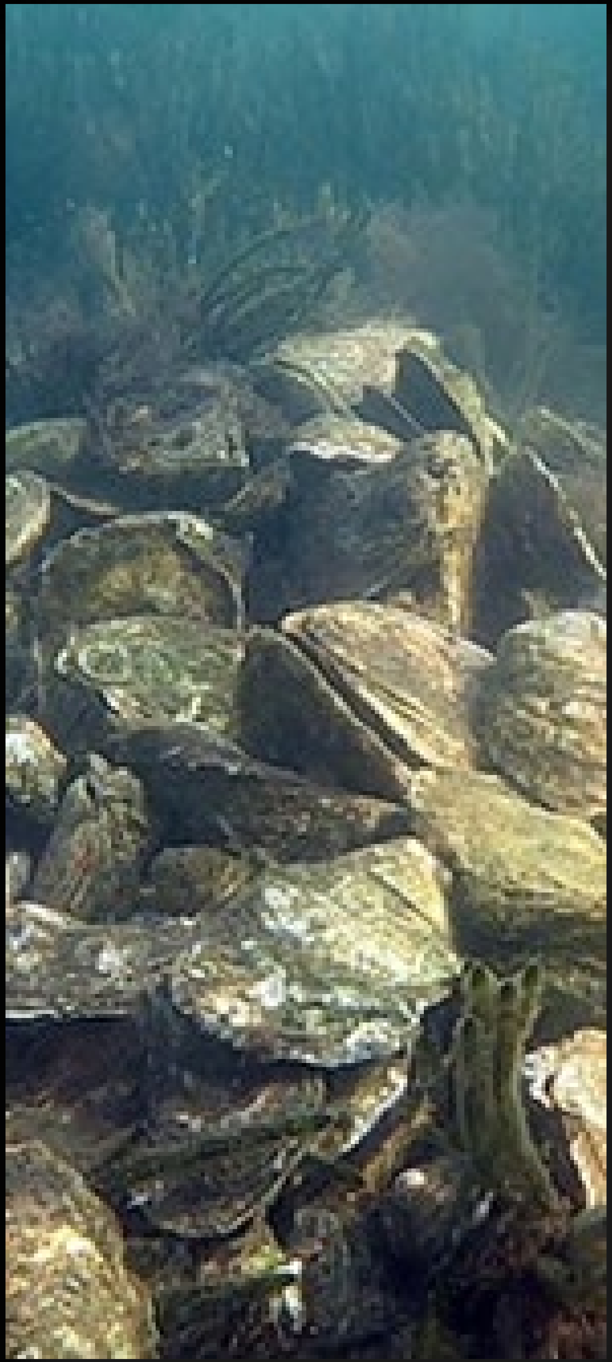
Why are oyster reefs important?



Oyster Reductions Worldwide





What Contributes to Oyster Decline?

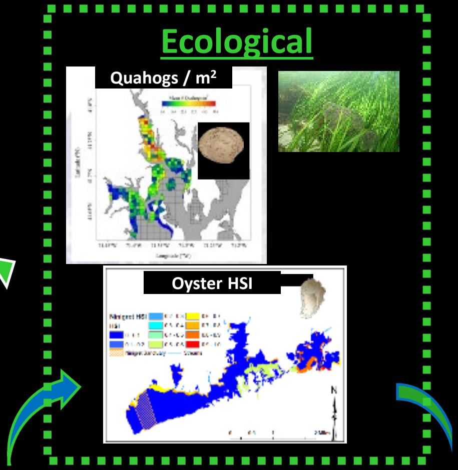
- Pollution
- Overfishing
- Habitat Destruction
- Disease
- Changes in Water Conditions

Justification

What are the overarching motivations for our project?

- To find the best planning process to support co-development of the Shellfish Restoration and Enhancement Plan(SREP)
- To find the social and ecological information needed to develop spatially specific restoration goals

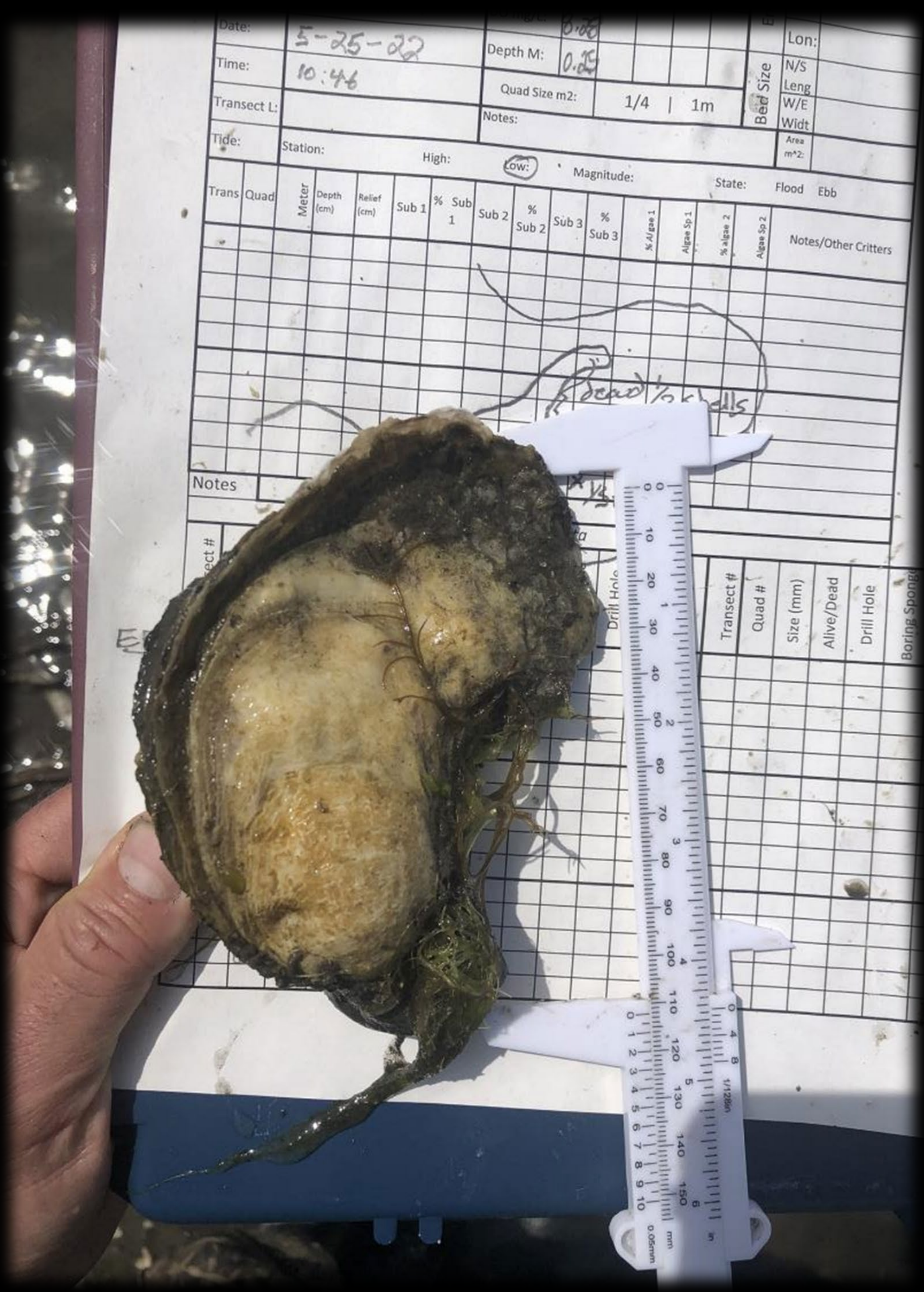
Develop Process → Information Collection & SES Analysis → Draft Plan Development → Final Plan



Develop Process

Starting at the Endpoint: SREP and the HSI

- SREP: requires shellfish data to inform future work
- Model building efforts will result in a "Habitat Suitability Index"
  - Siting of future restoration and enhancement projects
- Gathering a portion of those data is the subject of our discussion today



Simple Questions

1. Where are the remaining oysters?
2. What oyster densities are typical?
3. What is their size distribution?
4. What are the habitat characteristics typical of RI oyster beds/reefs?
5. What are the water conditions where these natural oysters are found?

Spatial Coverage

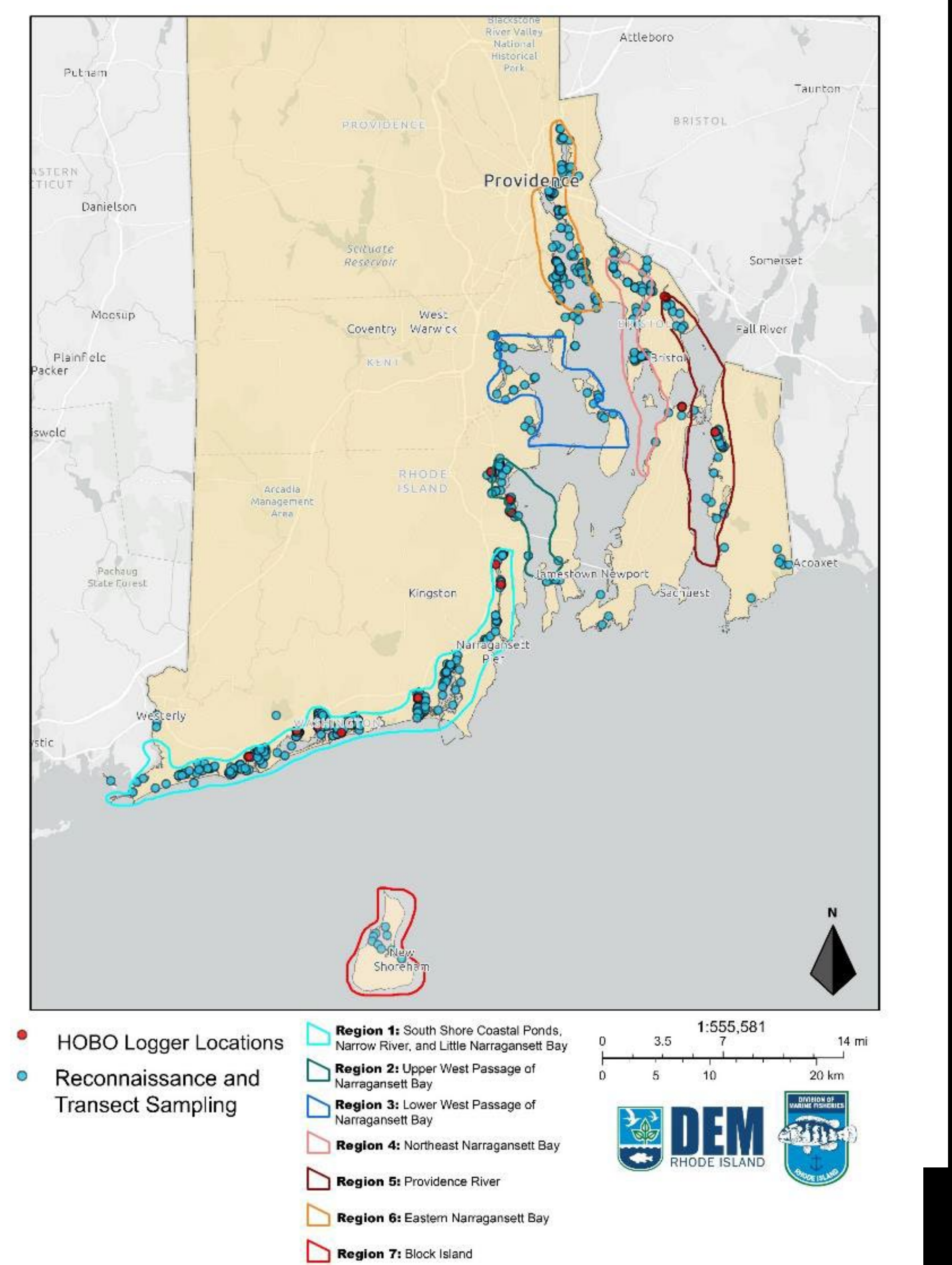
How do we know where to look?

- Historical records
- Personal Observations
- Local Knowledge
- Institutional knowledge
- Other Surveys
- Recon

Coastlines

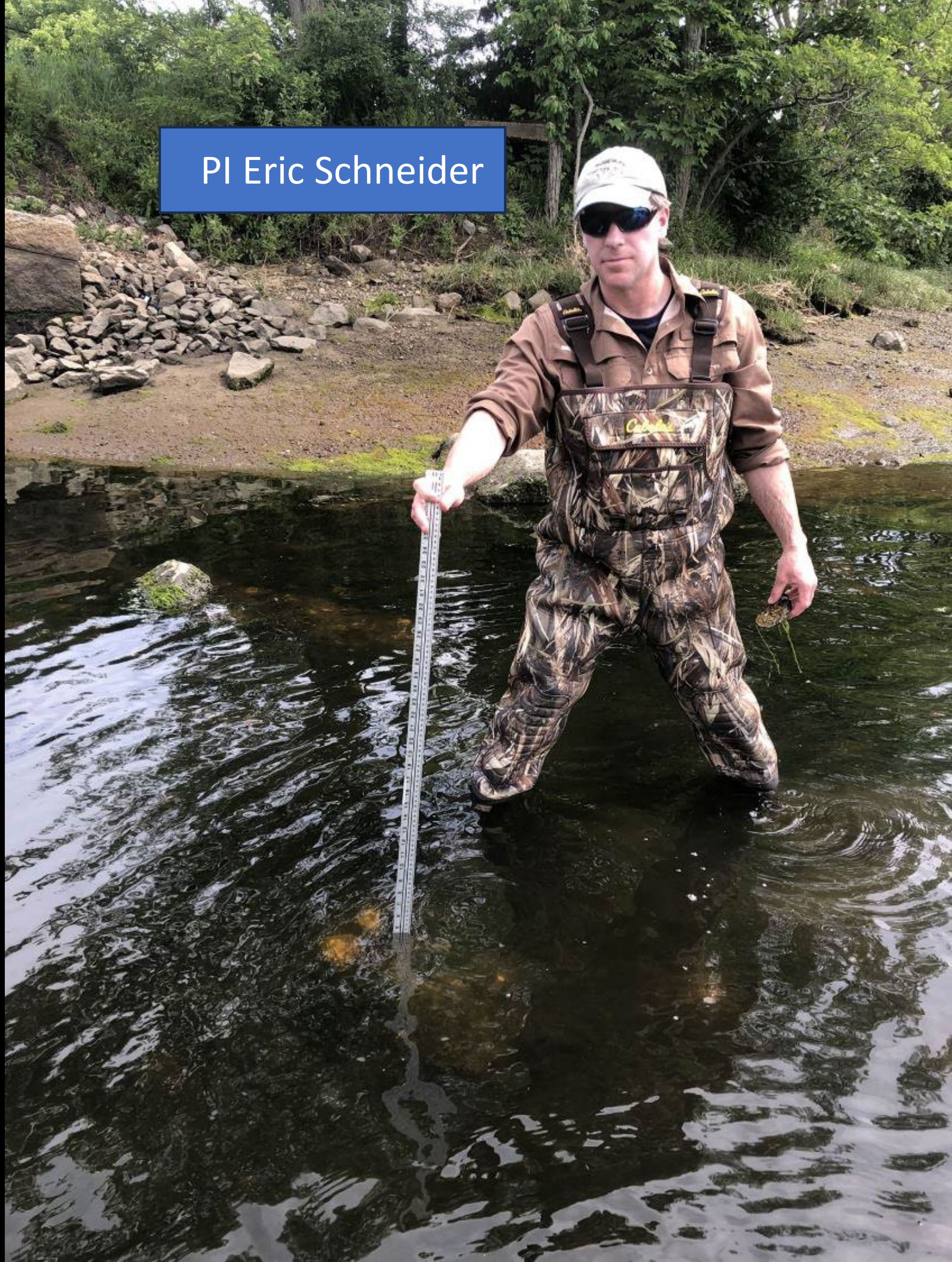
Regional Approach

- Areas grouped based on shared characteristics
- Unfunded partnerships greatly enhanced coverage



Field Protocols

- Waders, wetsuits, snorkels and determination
- Progressive Sampling based on density thresholds:
  - Site Recon
    - Efficiently cover large areas within a **system**
  - Full Census
    - Low density, count and measure all at the **site** level
  - Expanded Sampling
    - Conduct 1-2 **site** level surveys
    - Transects and Quadrats



Methodology

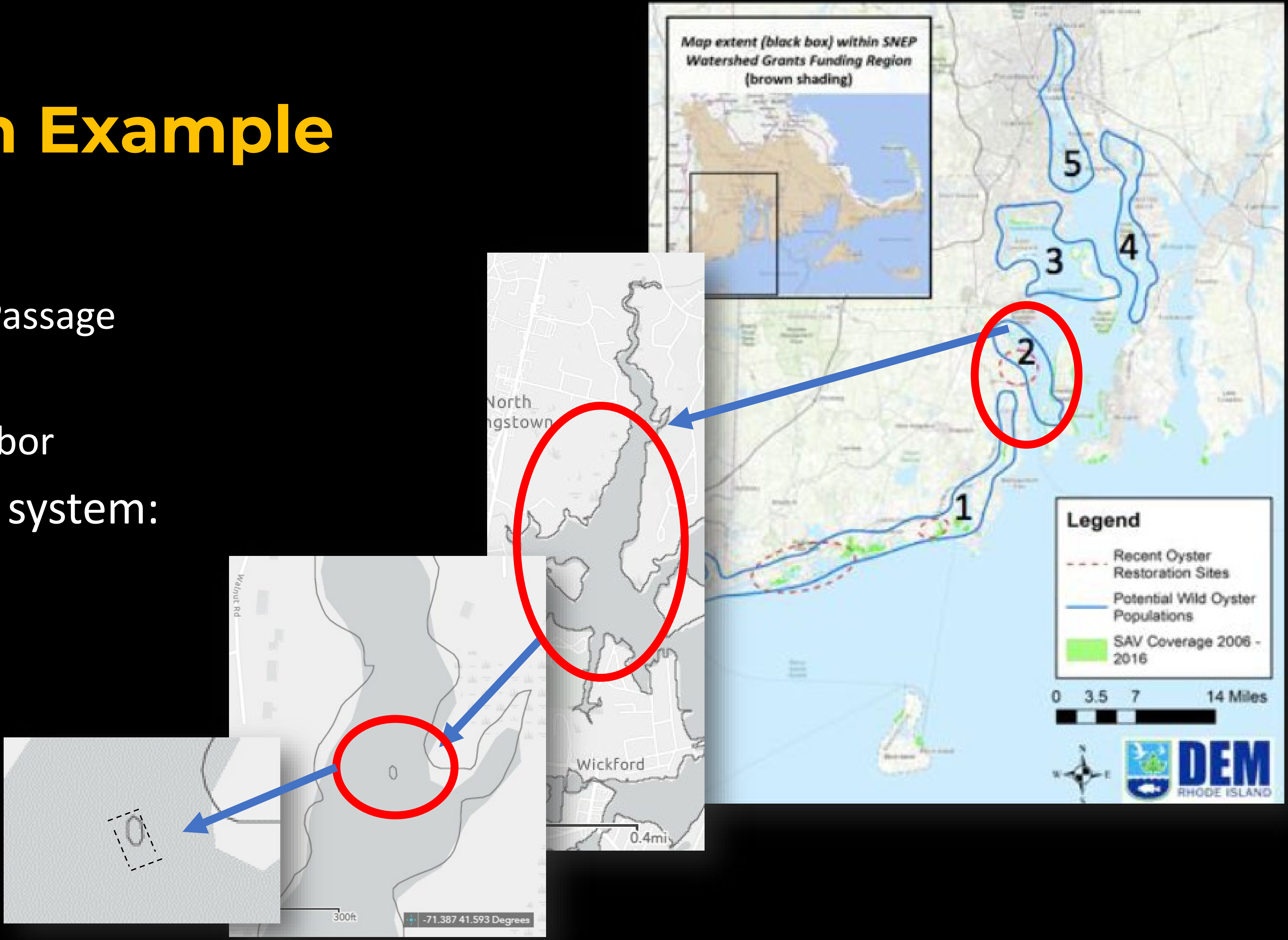
Site Recon: Rapid Collection of Site Characteristics

- Rapid Assessment
  - Oyster presence/absence
  - Measurements
  - Fouling
  - Substrate type
  - Subaqueous soils
  - Fresh water inputs
  - YSI
  - Algae presence/ID to species
  - Pics and GPS points/Delineate the bed
  - Representative measurements of largest and smallest
  - Density estimates based on haphazard quadrat placement
  - Water depth
  - Tide state

TLDR

Scale an Example

- Regions: #2,
  - Lower West Passage
- System:
  - Wickford Harbor
- Feature within system:
  - Mill Creek
- Site:
  - Rock Island
- Within Site:
  - Transect



Field Methodology

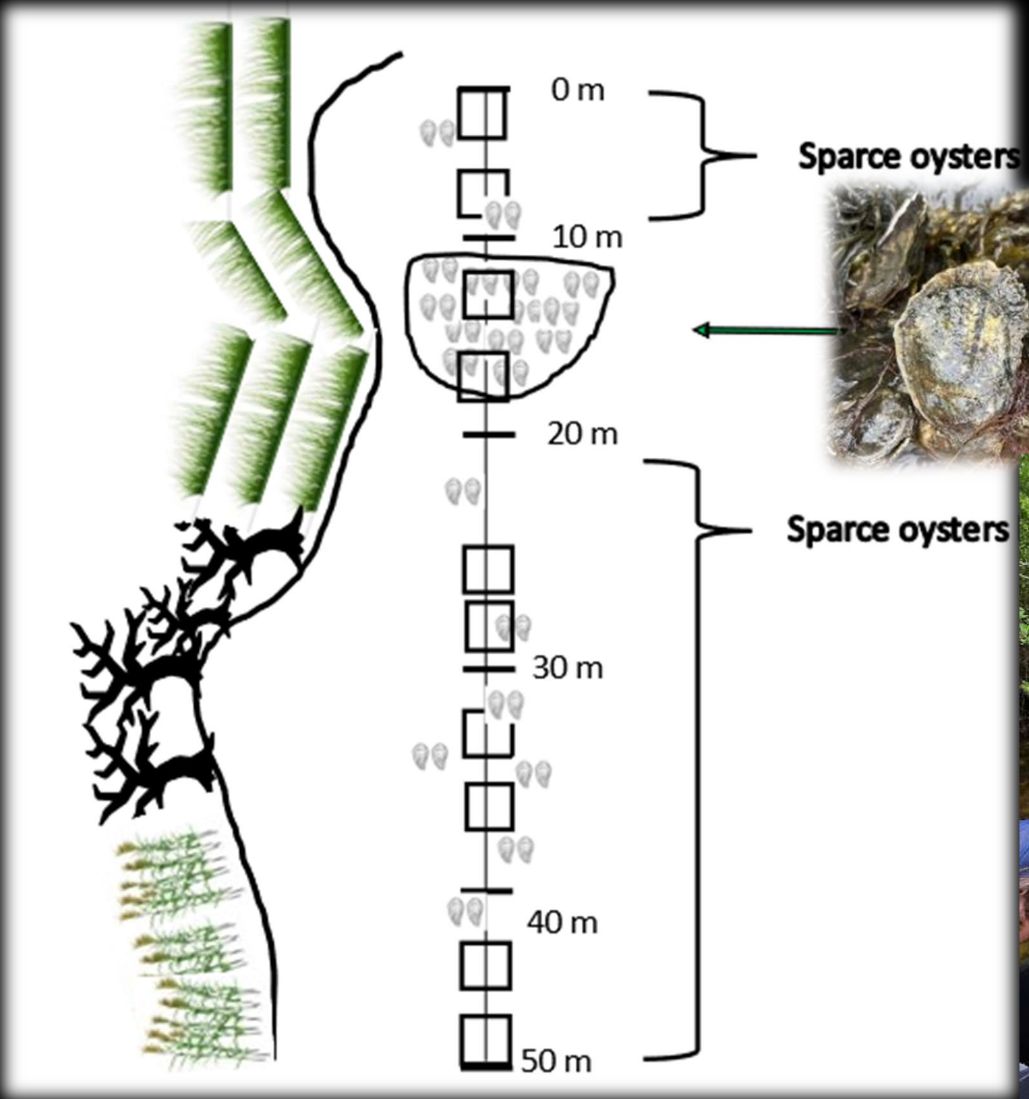
Protocols

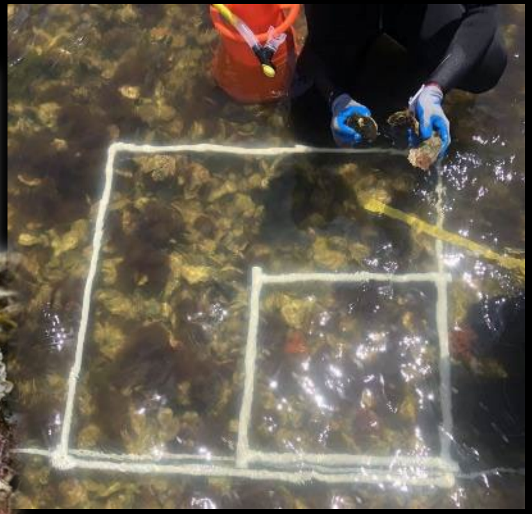
- Progressive Sampling based on density thresholds:
- Site Recon
  - Efficiently cover large areas within a **system**
- Full Census
  - Low density, count and measure all at the **site** level
- Expanded Sampling
  - Conduct 1-2 **site** level surveys
  - Transects and Quadrats

Is expanded Sampling Needed?

1. Density $\geq$ 10 per m^2 &
2. $\geq$ 2 size classes(+/- 30mm)

- Yes = Intensive Quads
- No = Transect OR Census





Water Condition Data

- <u>Snap shots</u>:
  - YSI ProSolo Multiparameter Tool
- <u>Contemporary short term</u>:
  - HOBO U24 Loggers
  - Short term deployments
    - ~120 day sampling period, 15 minute intervals, rotating throughout the regions
- <u>Longer Term</u>:
  - Existing Datasets: SPC, WW, other Surveys

THE UNIVERSITY OF RHODE ISLAND

URI Watershed Watch

Volunteer Water Monitoring

SALT PONDS COALITION

2021-23 Field Sampling

Recon Sites	~350
Expanded Sampling Sites	~30
Hobo Loggers currently deployed	~18

<10%

Back to our Simple Questions

1. Where are the remaining oysters?
2. What oyster densities are typical?
3. What is their size distribution?
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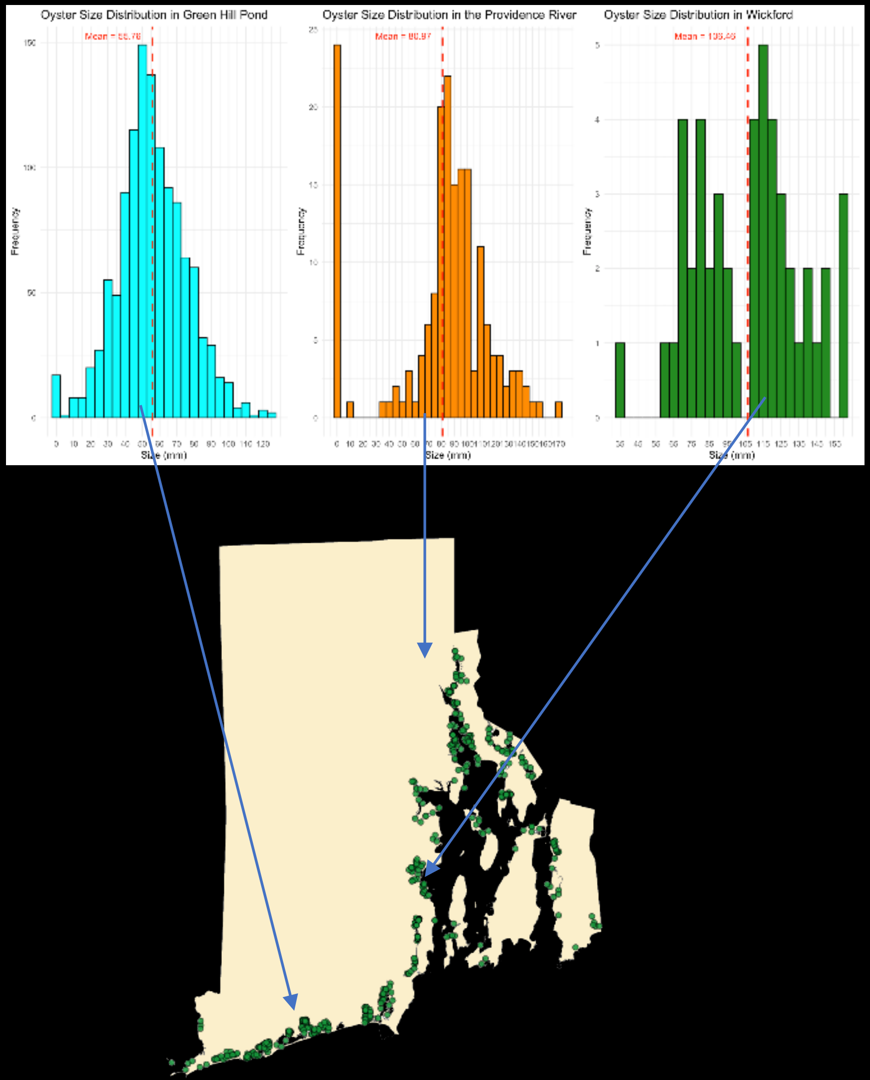
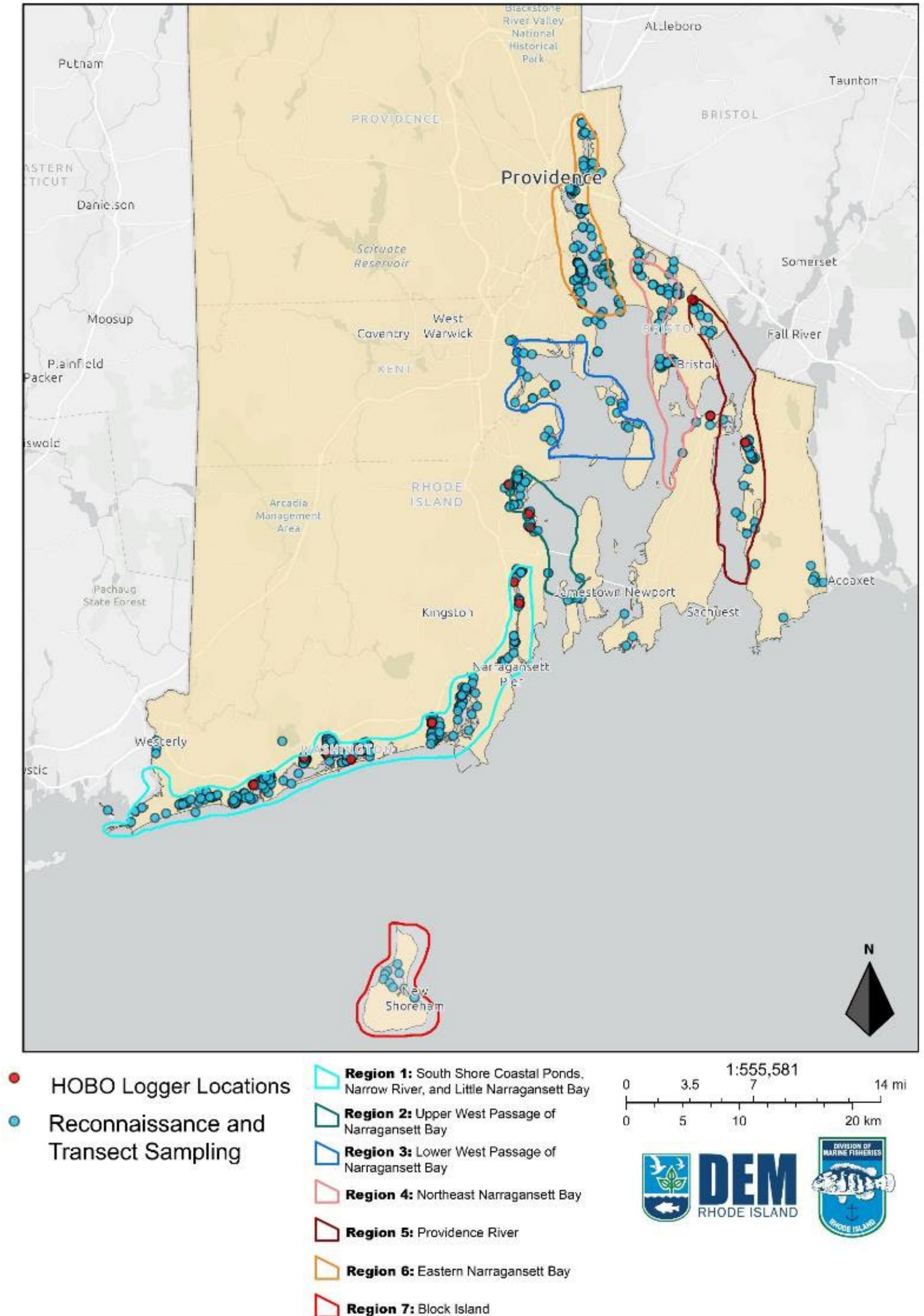


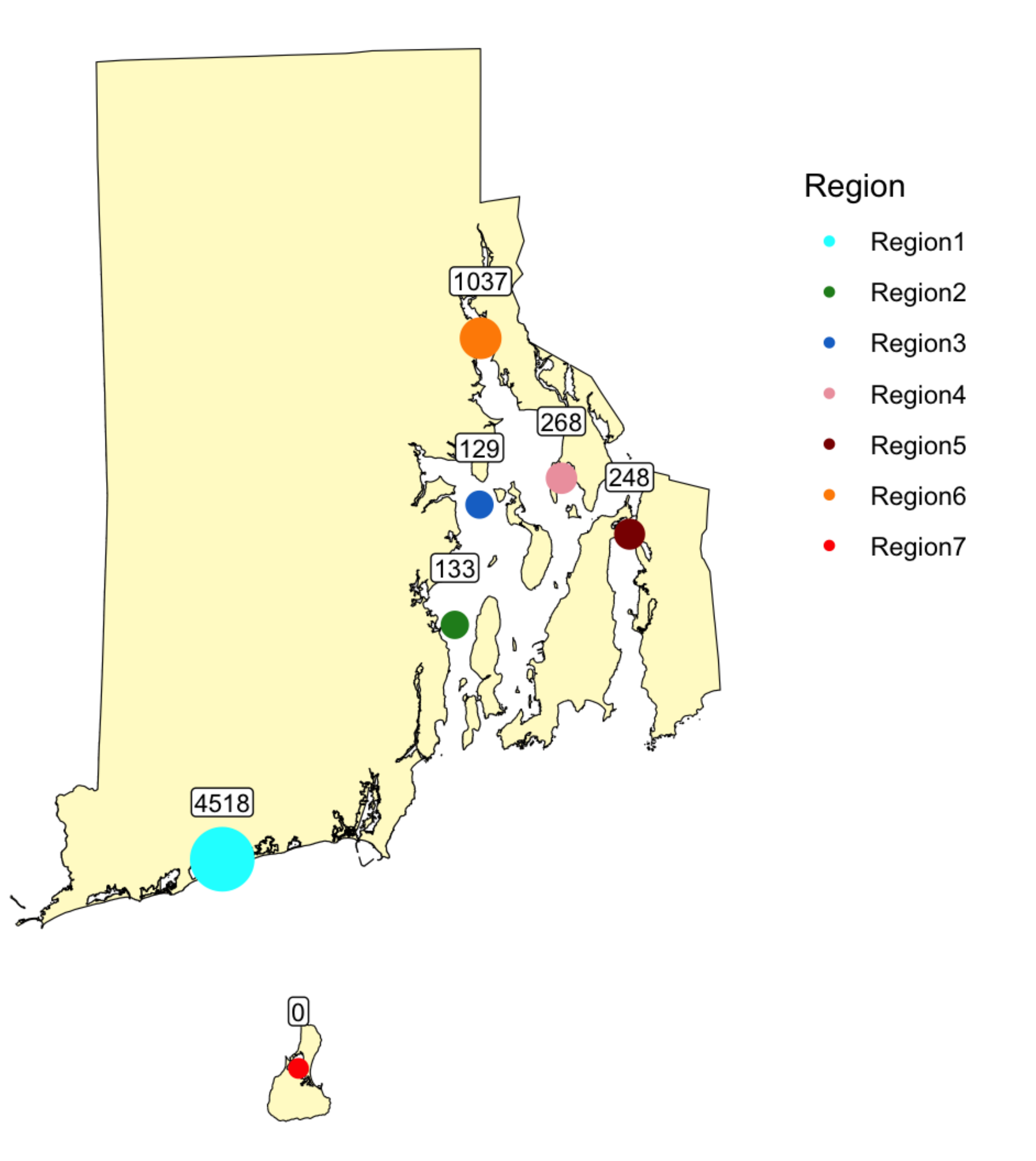
Where are the remaining oysters?

- Upper Bay
- Salt Ponds



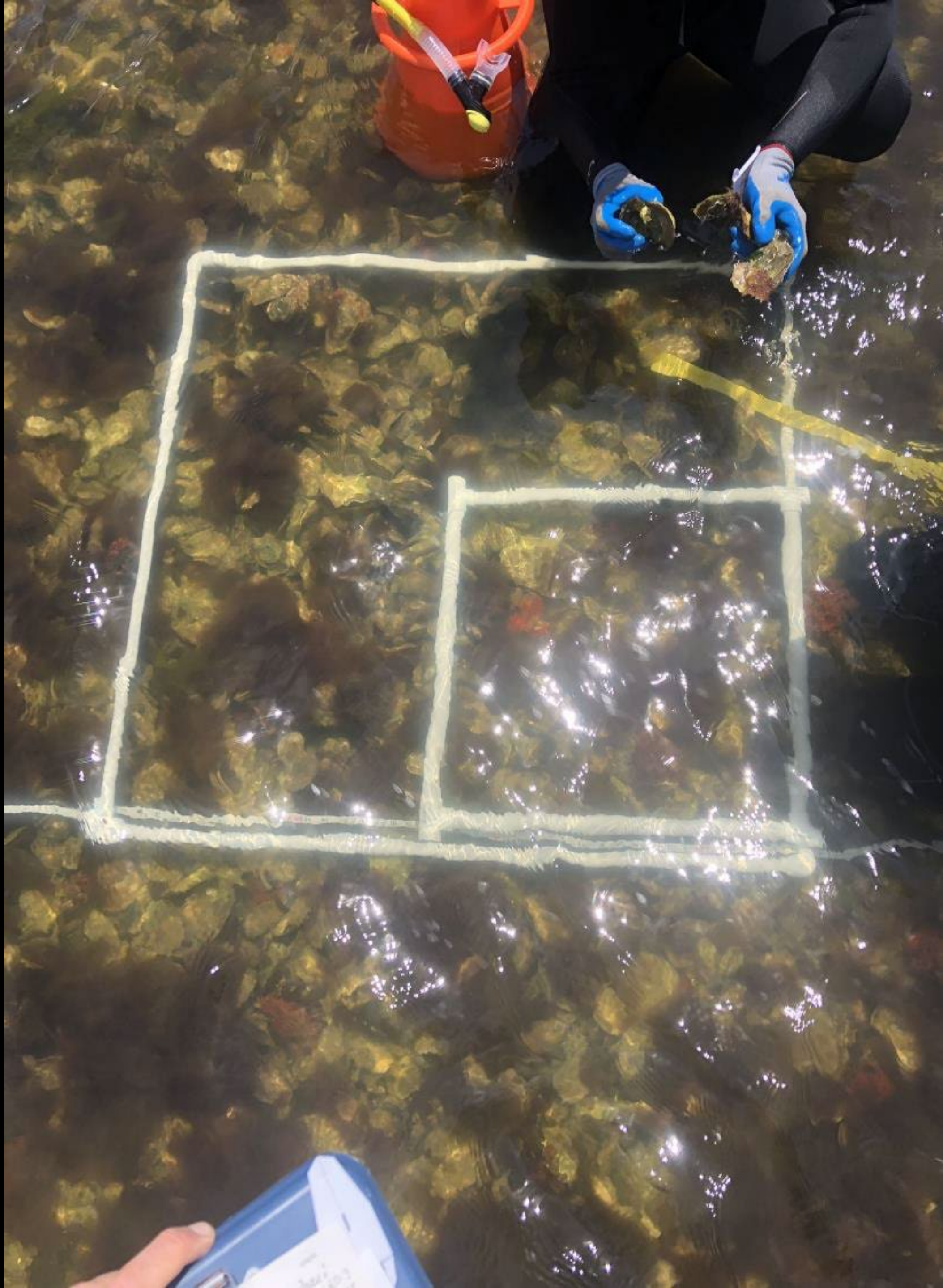
Where are the remaining oysters?

Spatial Coverage and Oysters Measured



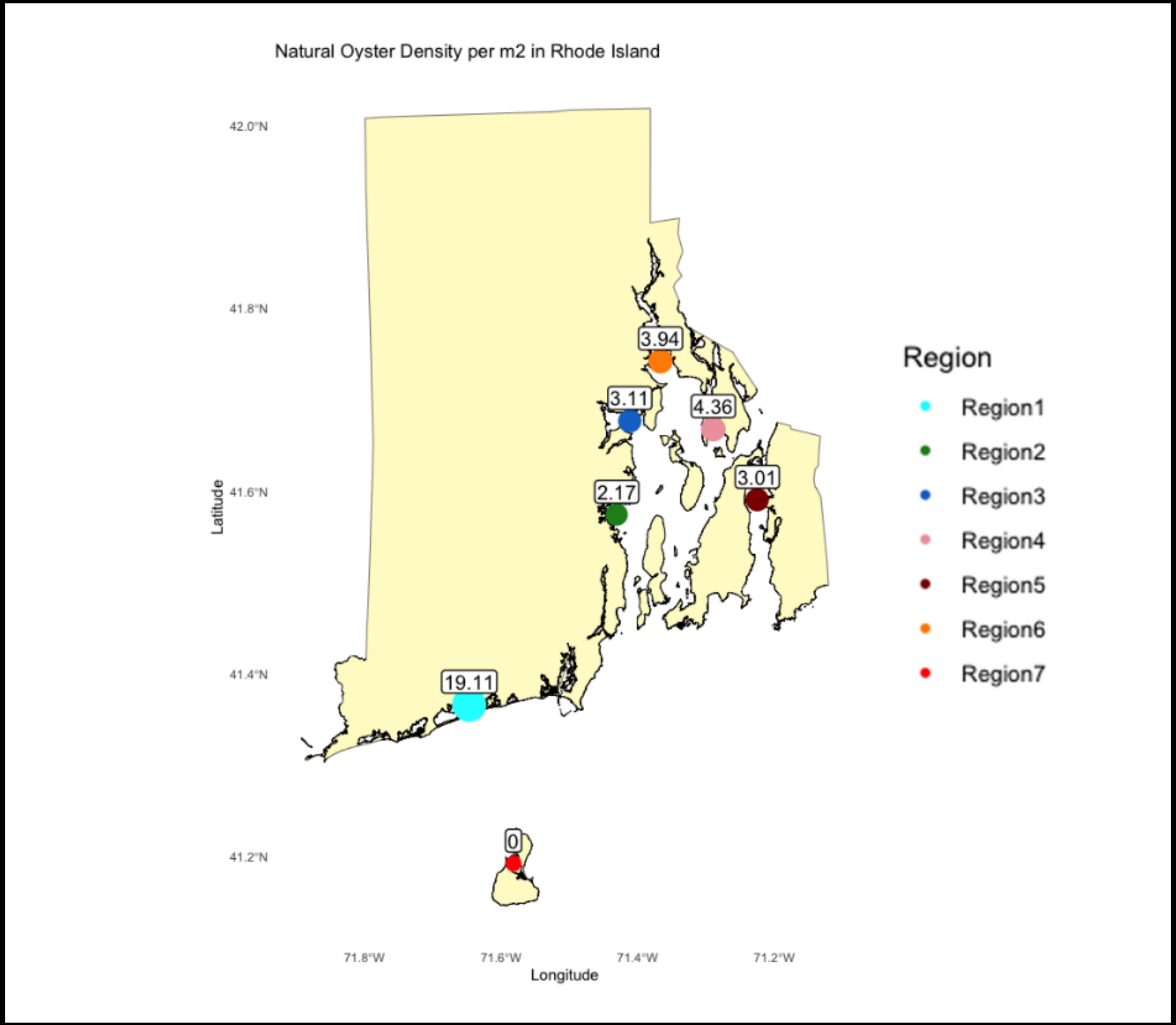
Oysters per M²

- Mostly very low
- What can we expect for a biologically appropriate, self sustaining density to be?
  - 5 or more per m^2
  - Multiple age classes



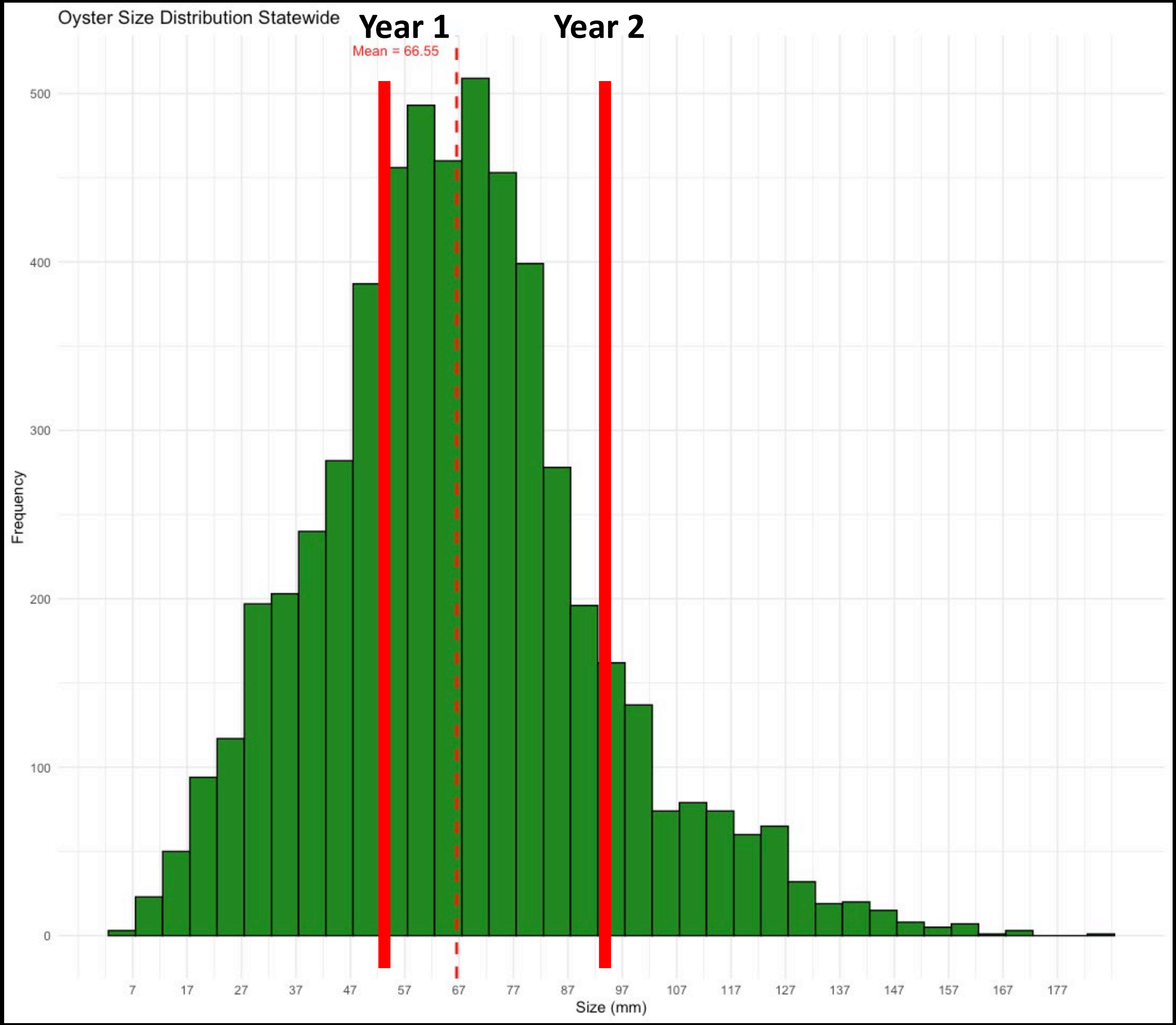
Density Across Regions

- >5 per m2 across most of the state with exception to the Salt Ponds and Narrow river region
- In general that is low



What is their size distribution?

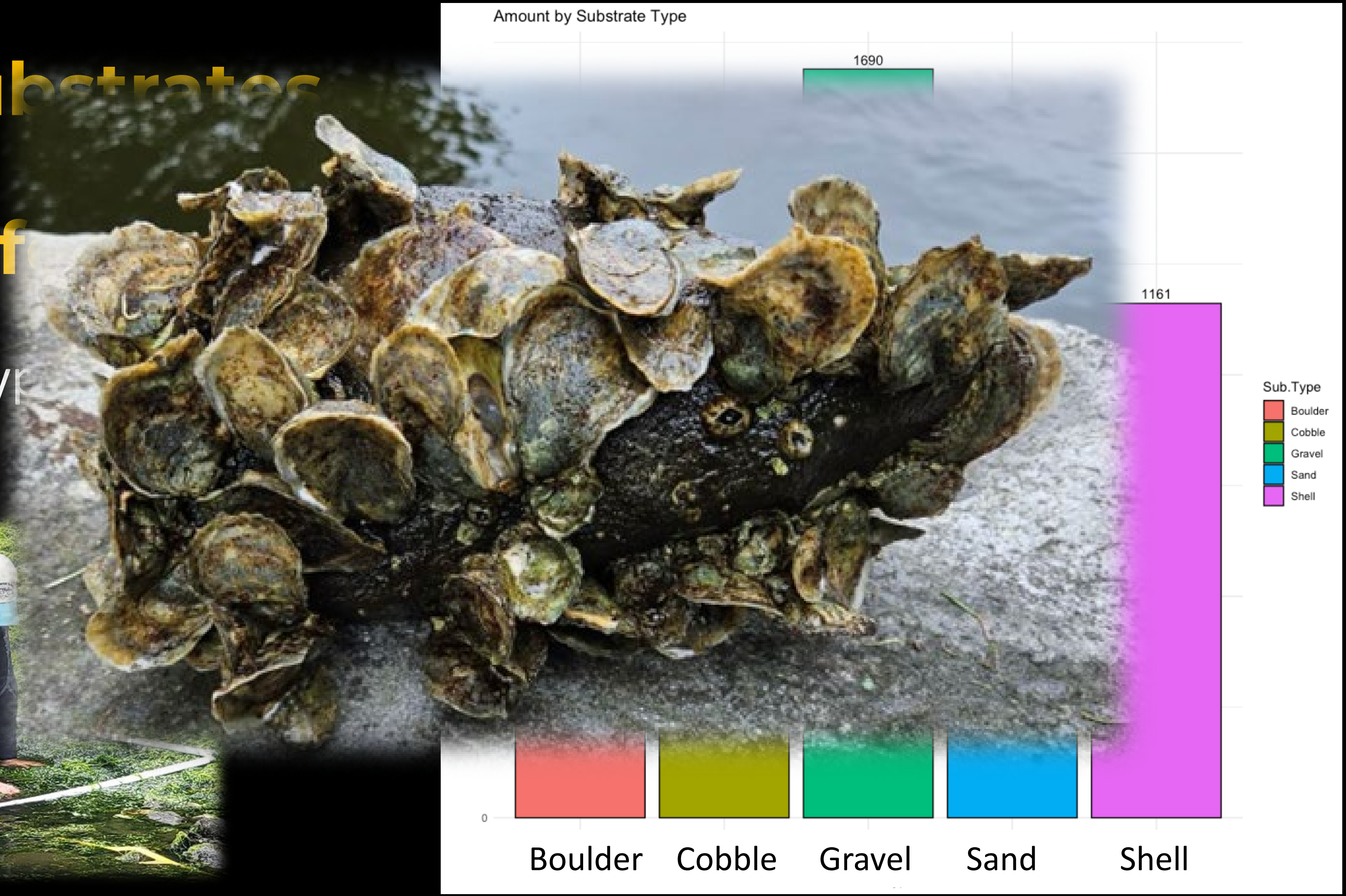
Size Frequency Across Regions



What are the habitat characteristics typical of RI oyster beds/reefs?

On what substrates are oysters commonly f

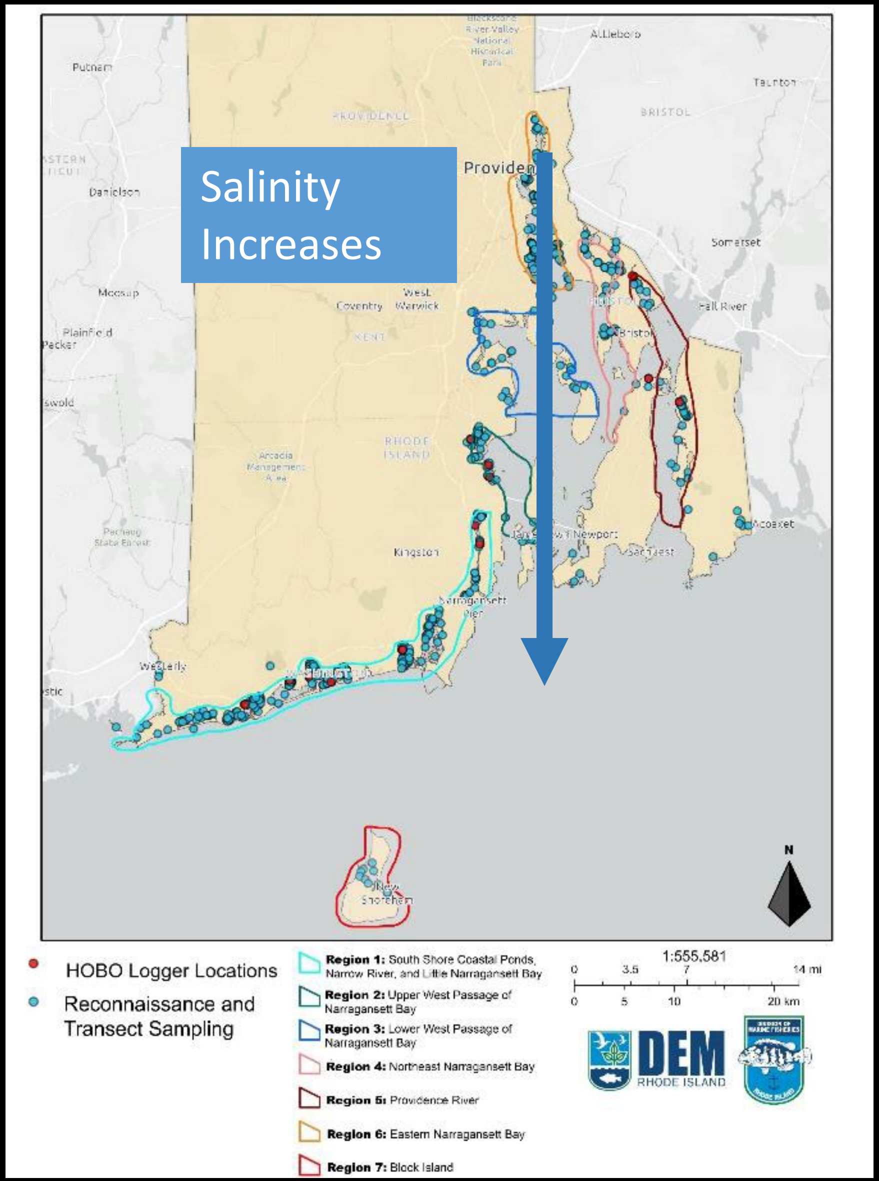
- Hard substrates typ
  glacial deposits



What are the water conditions where these natural oysters are found?

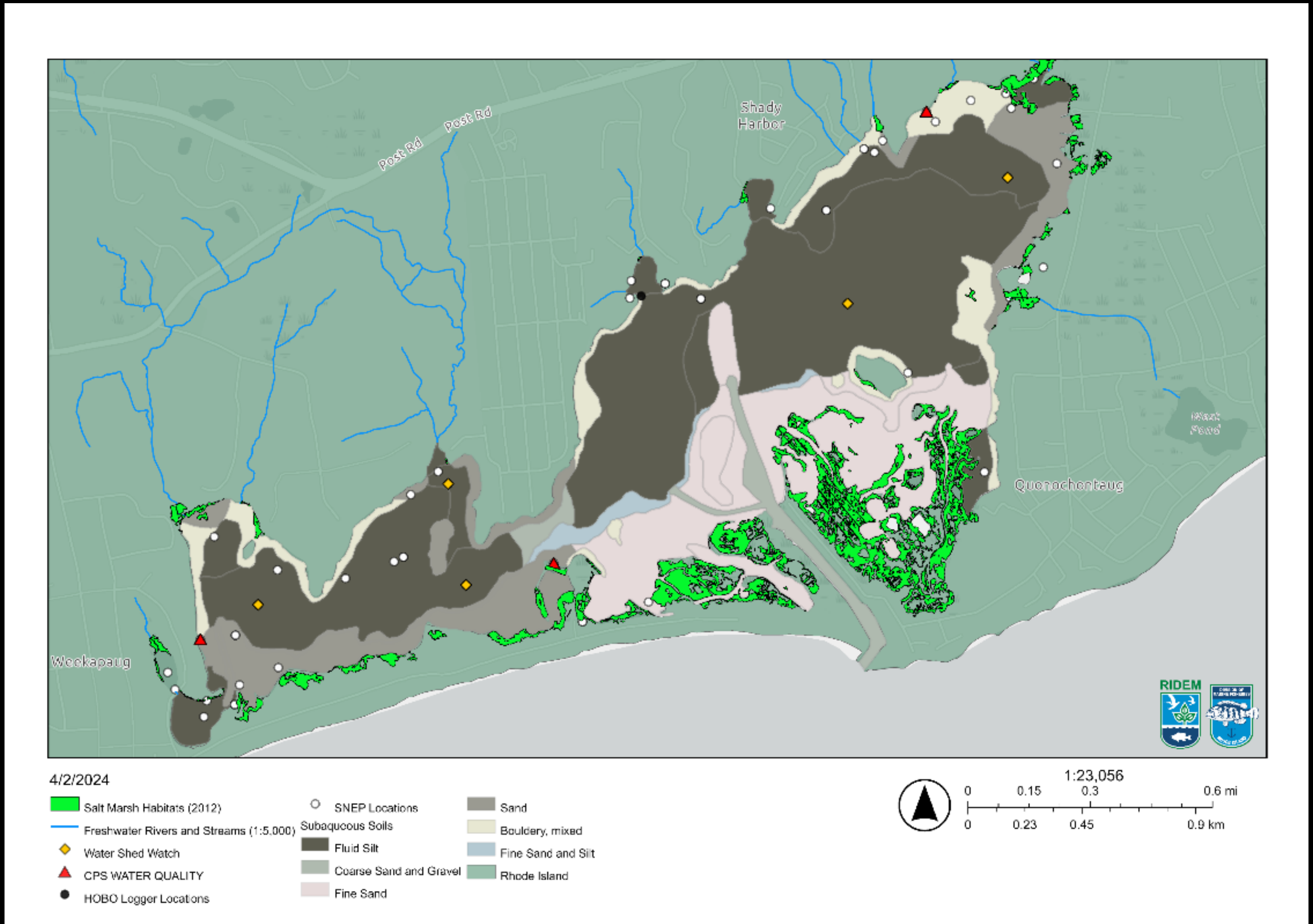
Salinity, Temp, DO…

- A work in progress
- Narragansett Bay is a large estuary
- The Salt Ponds are mostly coastal lagoons
- Data from Many Sources are currently being examined



What have we done and what will we do with all those Data?

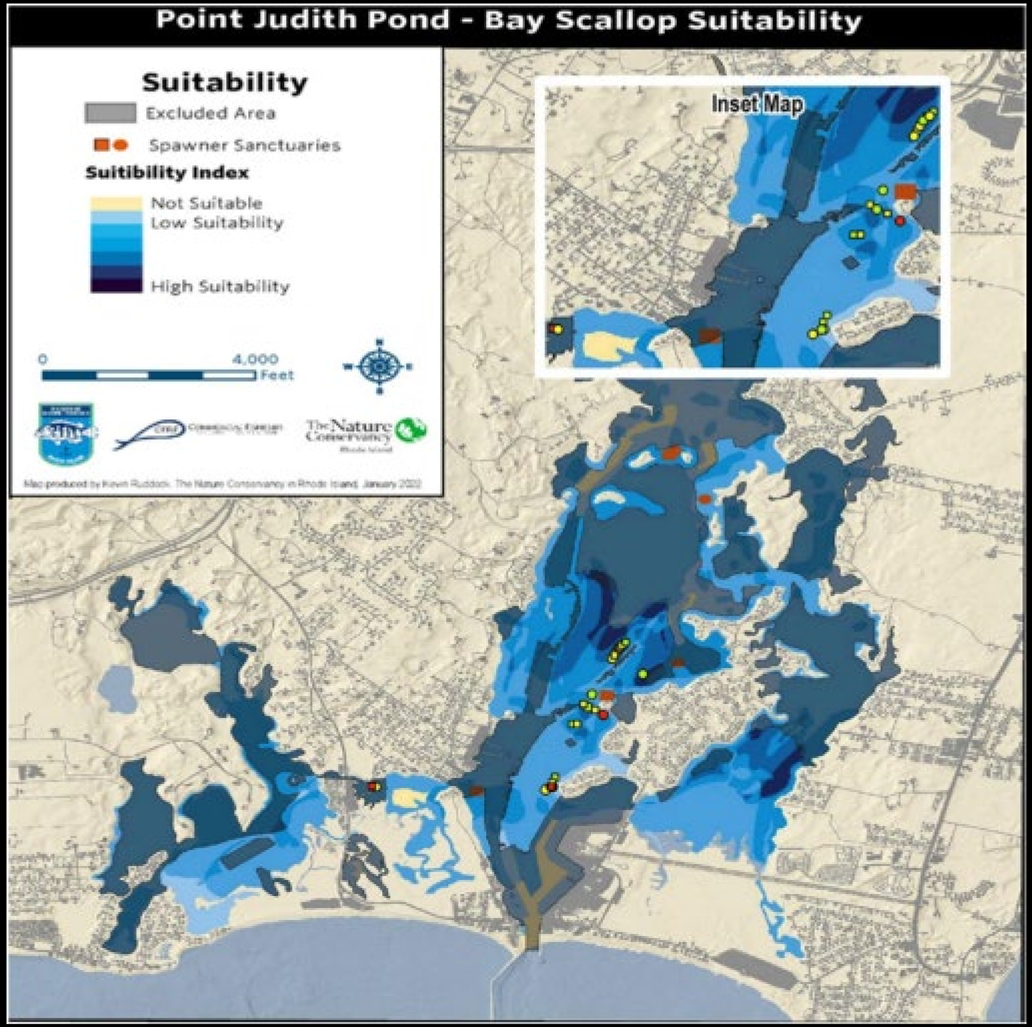
- Build a Geodatabase
- House all of our spatially explicit data in one place
- Use that to model where we can best achieve restoration goals



Develop Process → Information Collection & SES Analysis → Draft Plan Development → Final Plan

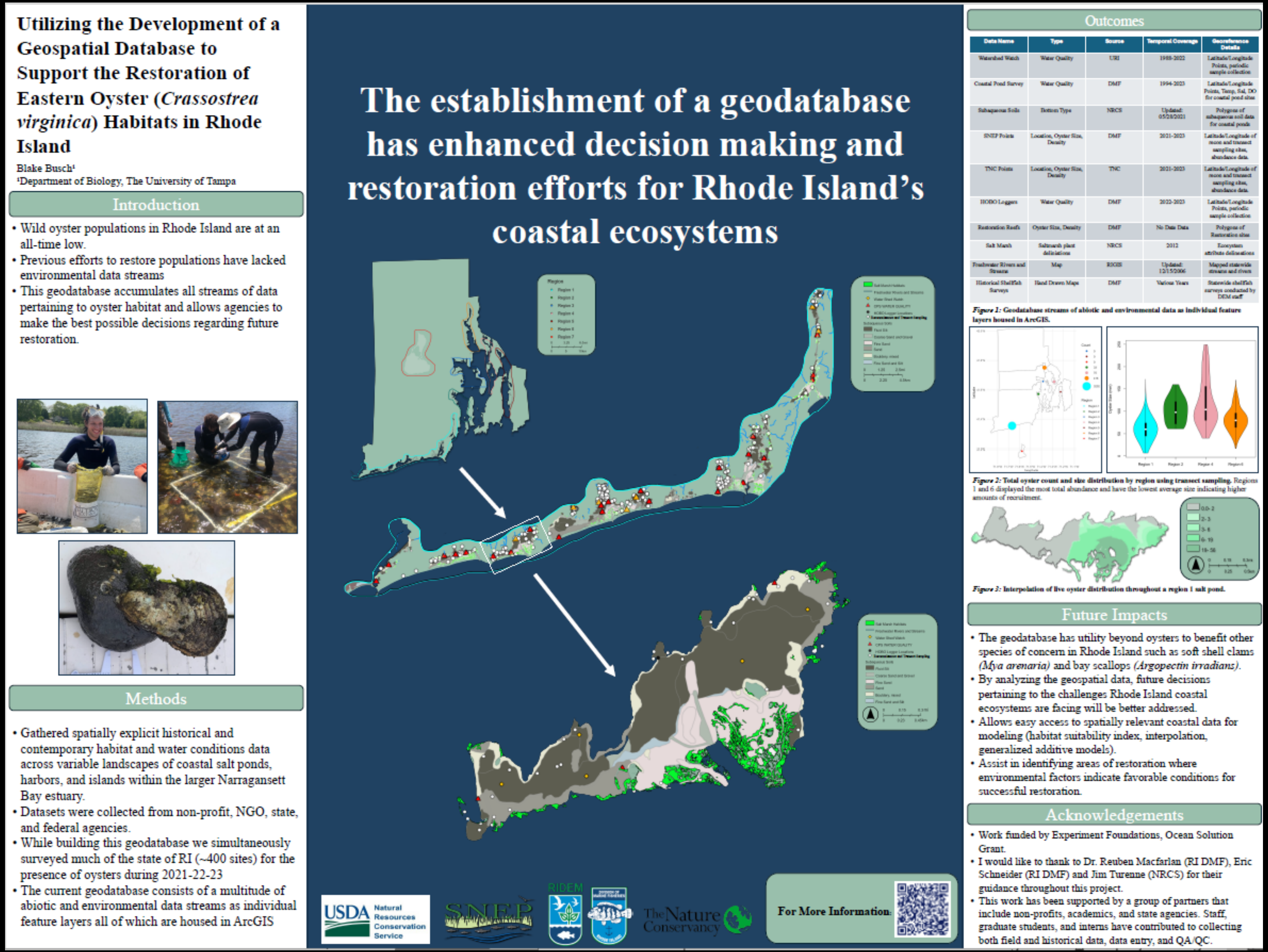
2024-25-Data Integration

- Onward to the HSI Model
- Geodatabase(s)



Verkamp et al 2022

Go see this poster!



Special Thanks…

Individuals	Institution	Program/Funding	Contributions	Year
Natalia Jaworski, (Masters Candidate)	Florida Atlantic University	Yale Environmental Fellows Program	Fieldwork, data entry and QA/QC, historical data.	2022
Madeline Armstrong, (PhD candidate)	Central Michigan University, Nowheresville	Yale Environmental Fellows Program	Field work, data entry, loggers.	2023
Blake Busch, (Undergraduate, BS)	University of Tampa, DMF Seasonal Intern	RIDEM(2022), Experiment.com-Ocean Solutions Challenge Grant (2023)	Fieldwork, mapping, data entry, outreach materials.	2022-23
Olivia Chatowsky, Postbaccalaureate	DMF-Seasonal	RIDEM	Fieldwork	2021
Erin Drumm, Post baccalaureate	DMF-Seasonal	RIDEM	Fieldwork	2021
Jess Rugeri, Postbaccalaureate	DMF Seasonal	RIDEM	Fieldwork, data entry	2023
Courtney Caccomo, Postbaccalaureate	DMF-Seasonal	RIDEM	Fieldwork, data entry	2023

Acknowledgements

SNEP
Southeast New England Program

RESTORE AMERICA'S ESTUARIES

USDA NRCS
Natural Resources Conservation Service

Northeastern
Marine Science Center

DEM
RHODE ISLAND
DIVISION OF MARINE FISHERIES
RHODE ISLAND

LUX ET VERITAS
YALE
YALE

The Nature Conservancy
Protecting nature. Preserving life.

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Abstract:

- Oyster reefs provide a multitude of ecosystem services such as critical nursery and foraging habitat for fish, stabilization of coastal shorelines, and nitrogen removal from estuaries.
- Oyster reef habitat has been reduced globally to 15% of its historic extent due to destructive harvesting, disease, bottom water hypoxia, and sedimentation. Wild populations of the native eastern oyster (Crassostrea virginica) in Rhode Island (RI) have been even more severely degraded, with oyster reef habitat currently estimated at less than 1% of its historic abundance.
- With funding provided by the Southern New England Estuary Program, the RI Division of Marine Fisheries, in collaboration with The Nature Conservancy, Northeastern University, and the RI Natural Resources Conservation Service, extensive field surveys were conducted to assess and document the spatial extent, habitat properties, and environmental characteristics of restored and wild reef habitats in coastal RI.
- A team of dedicated interns, partners, and research fellows searched for, mapped, counted and measured thousands of oysters, collected habitat characteristics, and water conditions data at 375 sites from 2021-2023, employing transect and quadrat methods.
- Across the state we found that when present oysters occur in two modes (1) low density (<5 per/m2) patches showing ephemeral recruitment patterns and a single age class or (2) high density (100s per/m2) beds with multiple age classes.
- Oysters were more frequently found in areas with stable substrates of sand, boulder and cobble, and where salinity averaged ~28 ppt with seasonal variation. Information collected by this project will improve ongoing and future oyster restoration practices, inform the development of a habitat suitability index model of oyster habitat, and will be incorporated into a Statewide Shellfish Restoration Planning process.