COLLABORATIVE SCIENCE FOR ESTUARIES
WEBINAR SERIES

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Can Oyster Aquaculture Help Restore Coastal Water Quality?

National Estuarine
Research Reserve System
Science Collaborative

Date: Tuesday, May 25, 2021
Time: 3:00-4:00 PM ET

Can Oyster Aquaculture Help Restore Coastal Water Quality? A collaborative study.

Webinar, May 25, 2021

Daniel Rogers, Paraskevi (Vivian) Mara, Tonna-Marie Surgeon-Rogers

LUX ET SPES
STONEHILL COLLEGE

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

TOWN OF FALMOUTH SUCKANESSET 1660 INCORPORATED 1686

WAQUOIT BAY NATIONAL ESTUARINE RESEARCH RESERVE

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

National Estuarine Research Reserve System Science Collaborative

Agenda

- Setting the Stage
- Motivation for This Study: The Cape Cod Context
- Using a Collaborative Research Approach: Our Team
- Target Audience
- Audience Poll
- Science Results & Management Application
- Project Resources

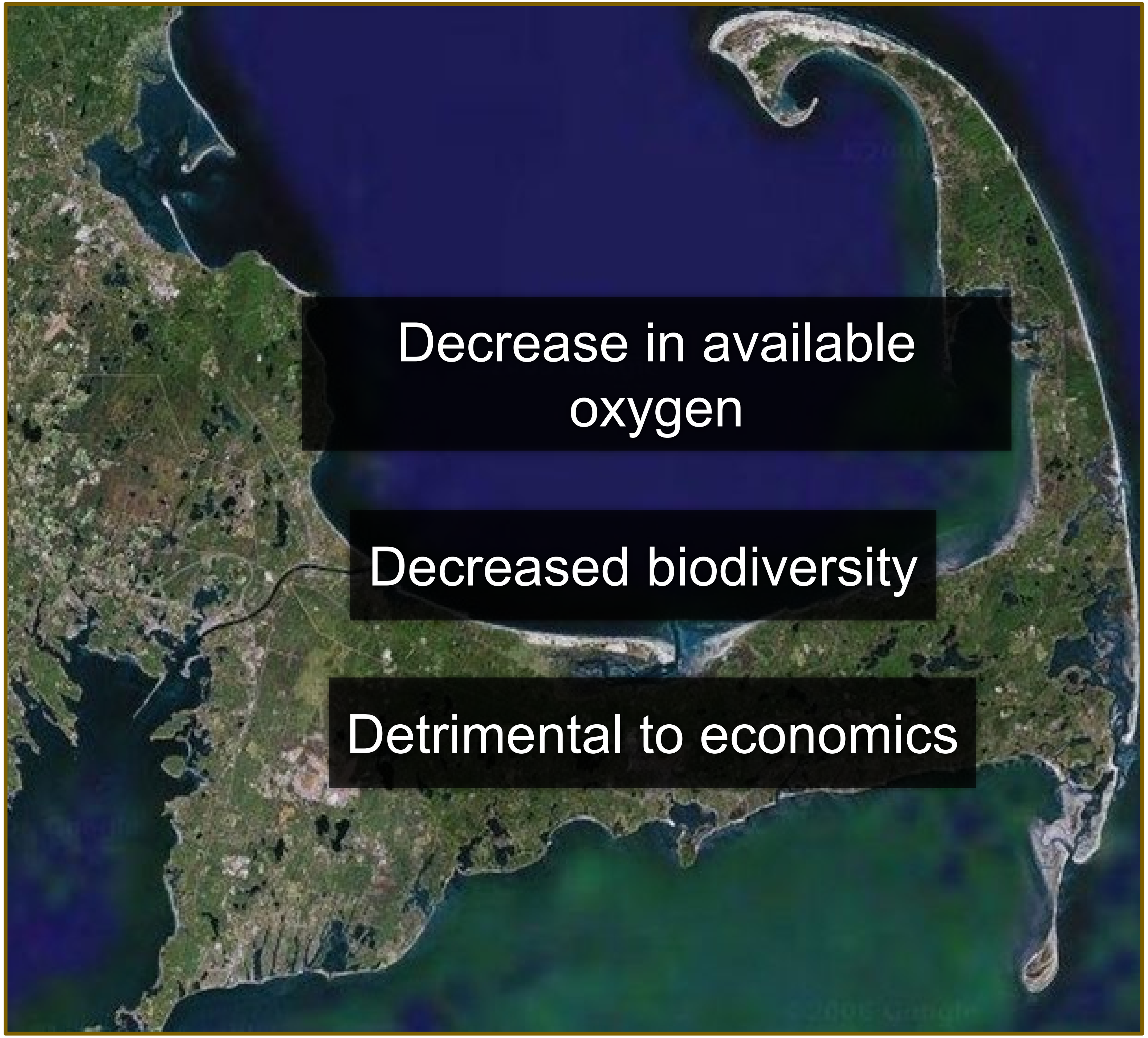
Imagine our coastal community.
What do you think of?

Human activity impacts our coastal waters.

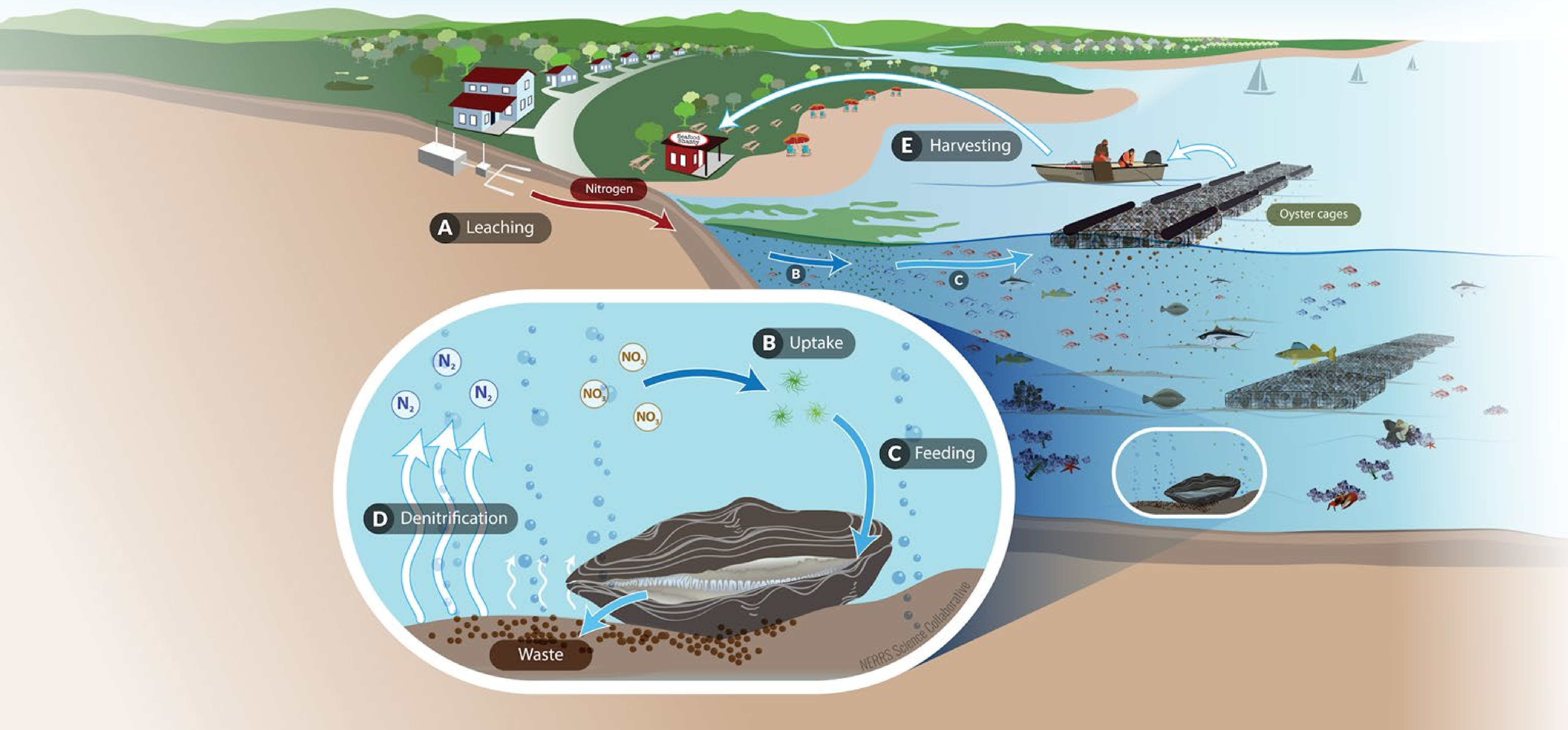
- Major cities located on waters or coasts
- Large population on the coasts
- Activities have altered the coastal ecosystem.
  - Overfishing of many species.
  - Loss of habitat
- Nitrogen pollution

http://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/pop_coastal_areas.pdf

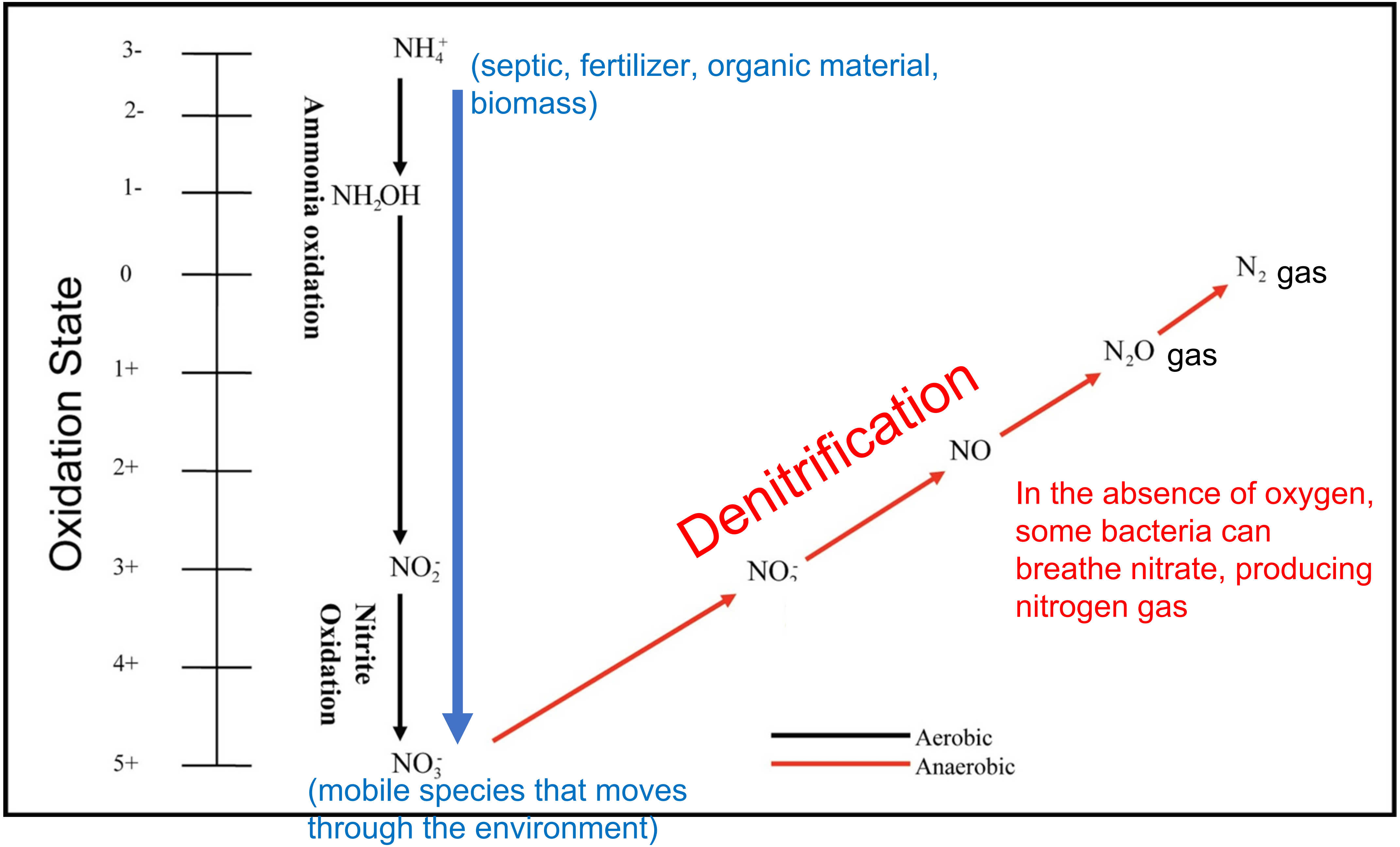
Too much nitrogen is bad for the health of the coastal ecosystem



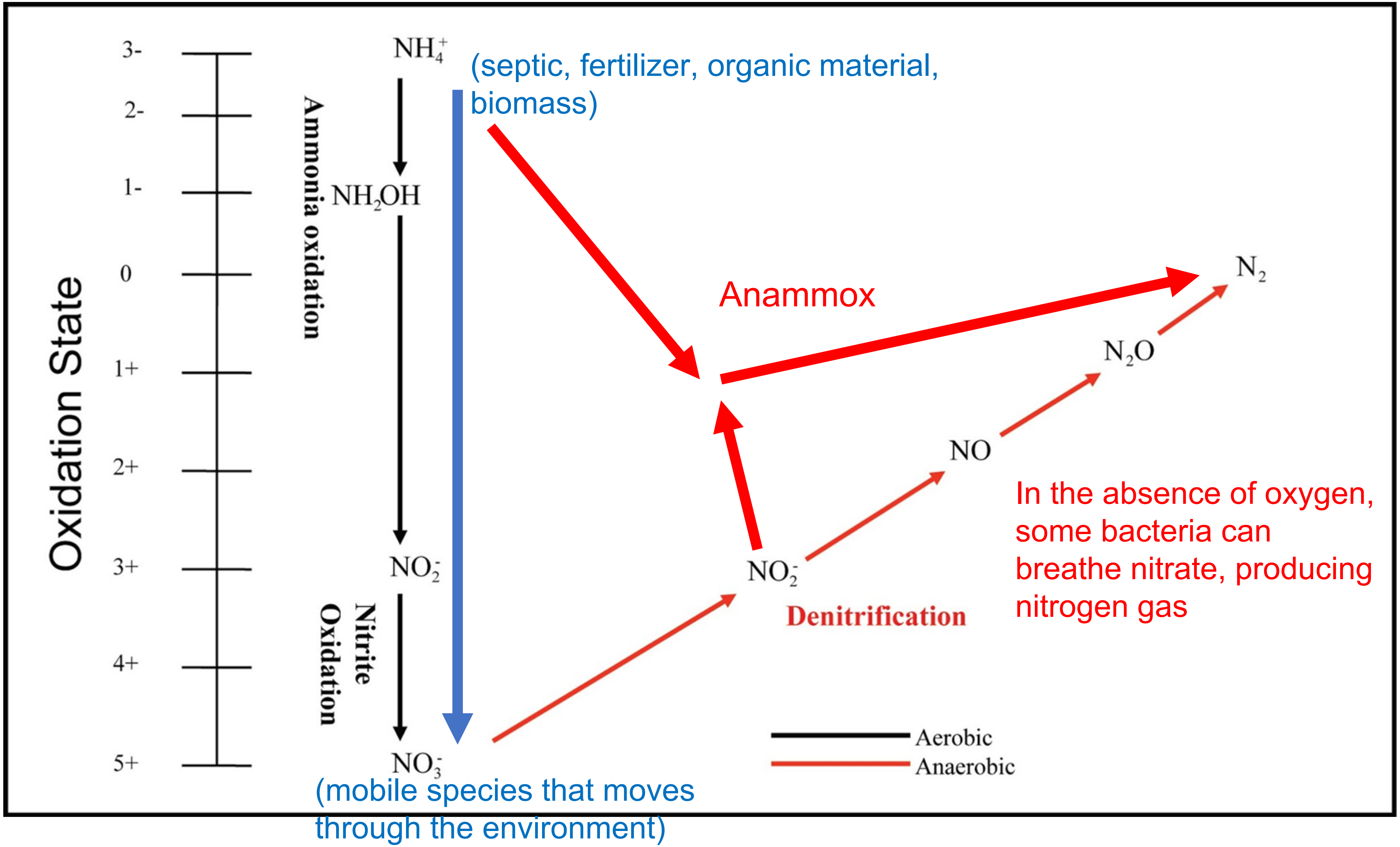
How oyster aquaculture may impact the N cycle



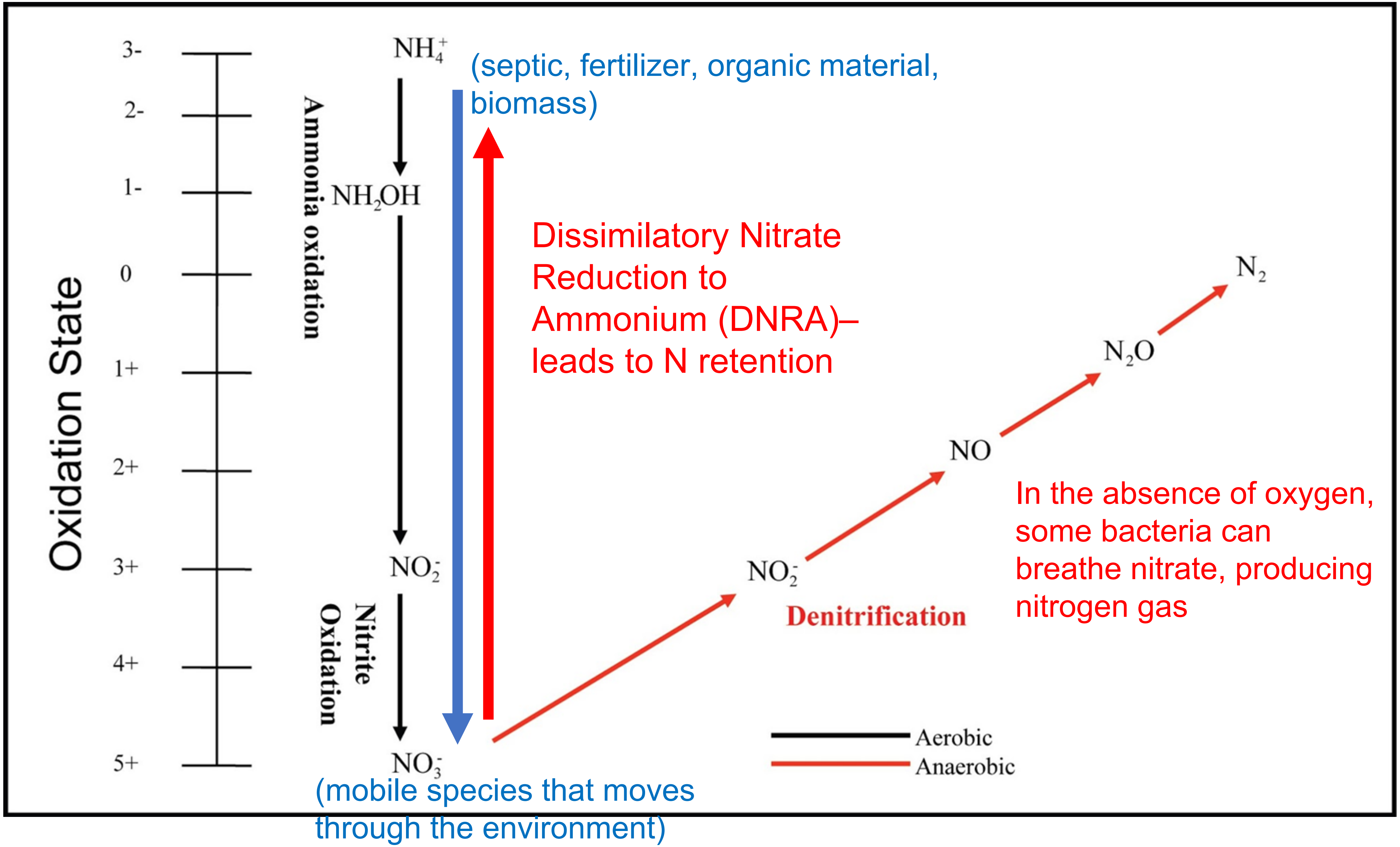
Nitrogen transformations in the environment



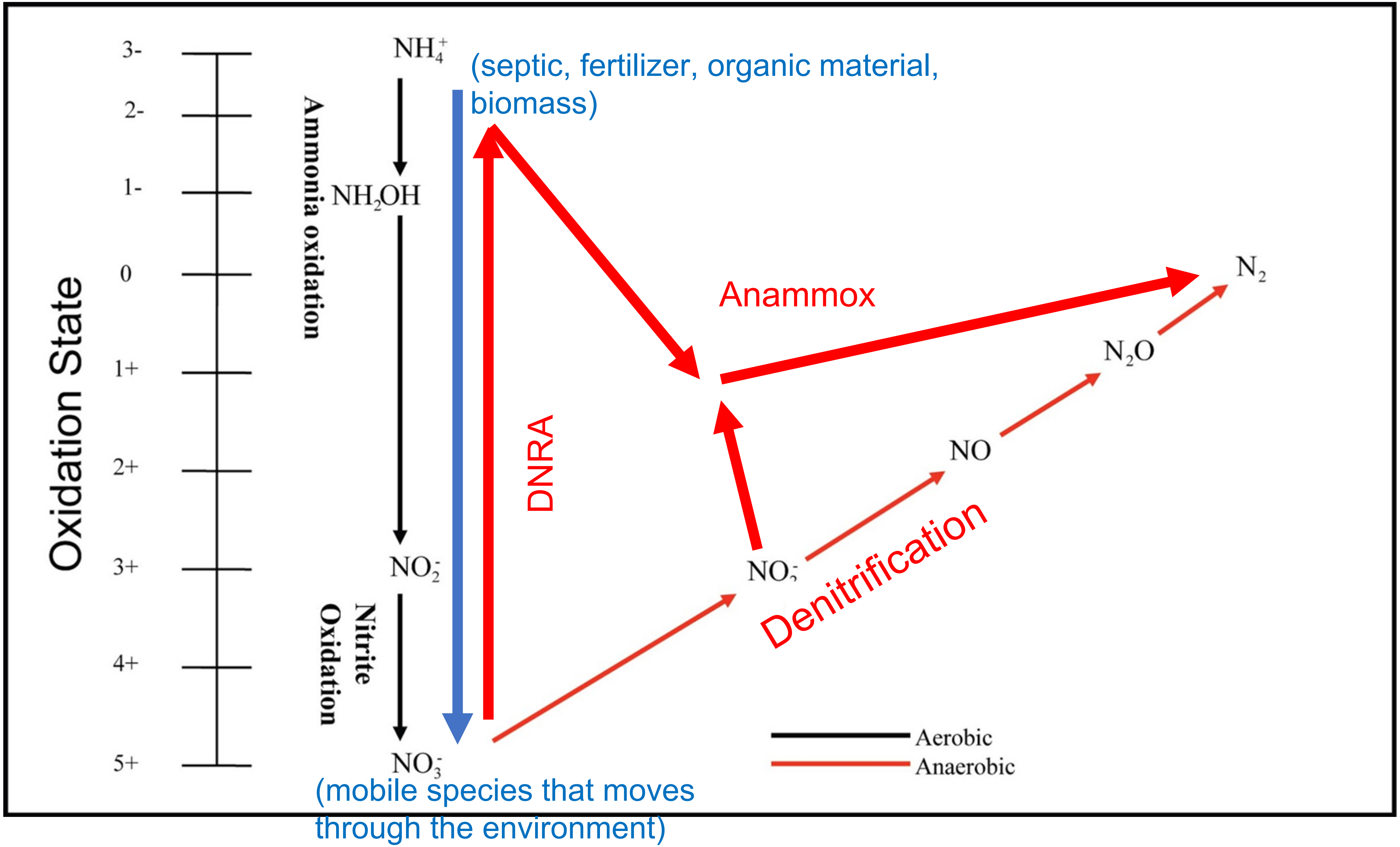
Nitrogen transformations in the environment



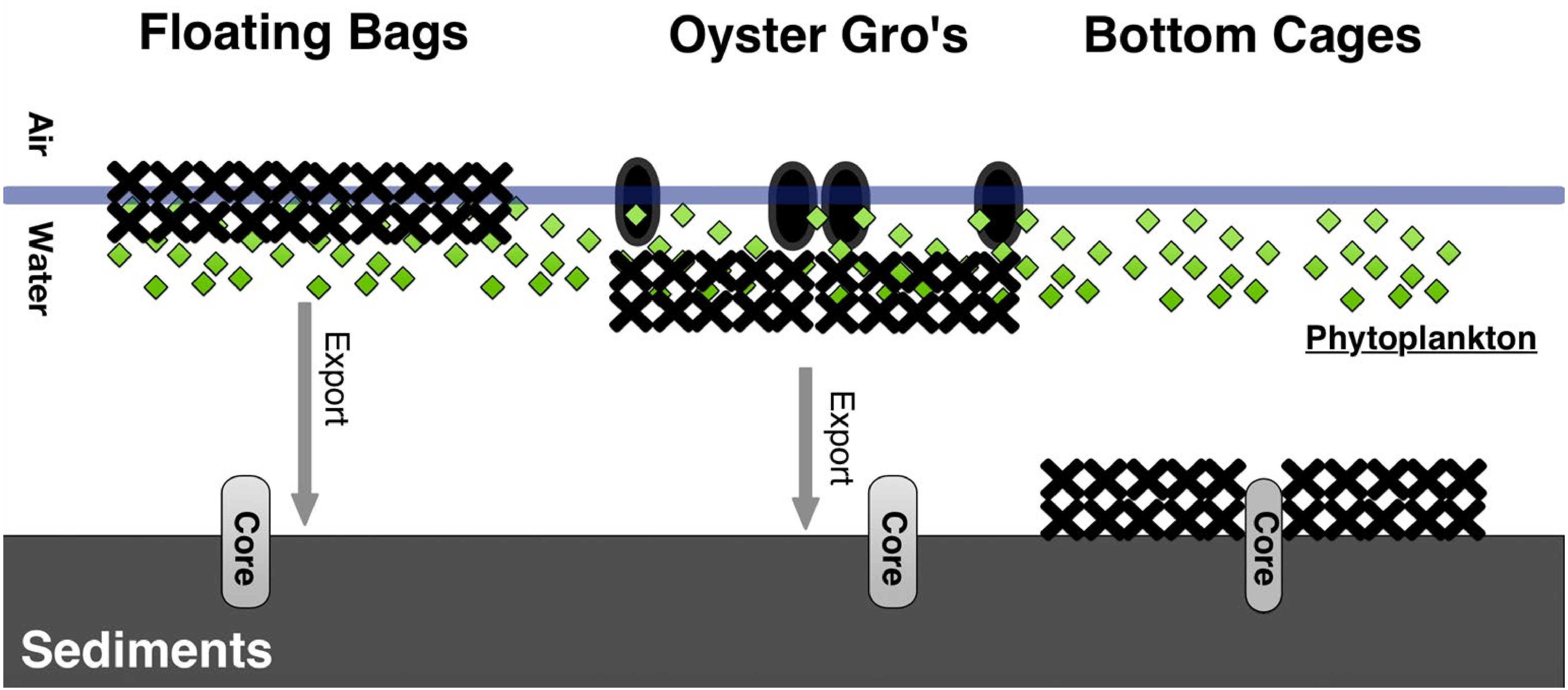
Nitrogen transformations in the environment



Nitrogen transformations in the environment



Project Overview:



N
50 m
Waquoit Bay National Estuarine Research Reserve
Control
Oyster Gro'
Floating Bags
Bottom Cages
Waquoit Bay
Falmouth, MA

The Big Questions

- Does aquaculture activity change N_2 release (flux) from the sediments?
- Are the microbial communities in the underlying sediments changed?
- Are the activities of these communities changed in the presence of aquaculture?
- Is the amount of N_2 released enough to be included in water quality management planning?

Evaluating N removal and oyster aquaculture

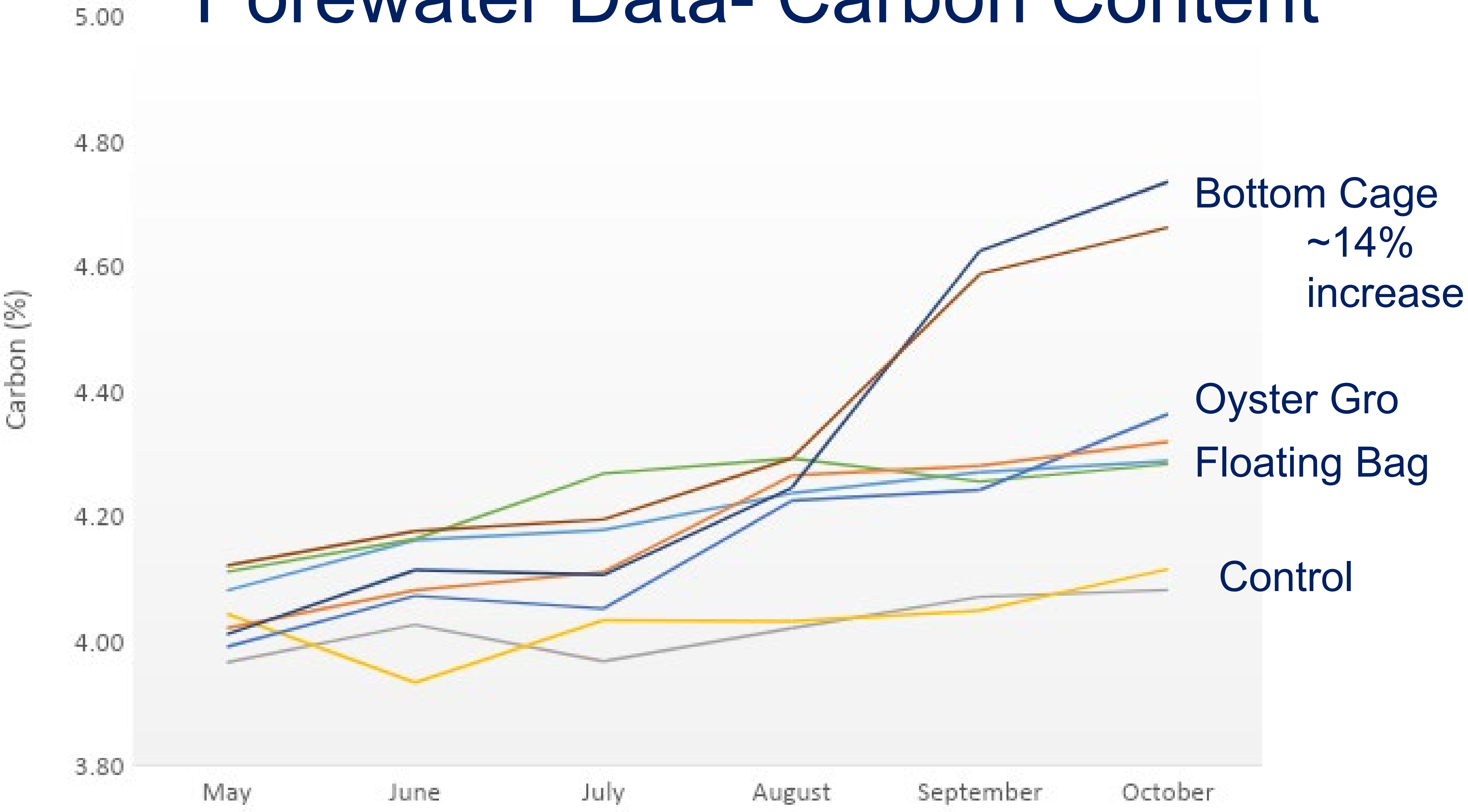
- A story in three parts

1. Chemistry and N_2 release (flux) from the sediments.

2. Characterizing the microbial community and activity.

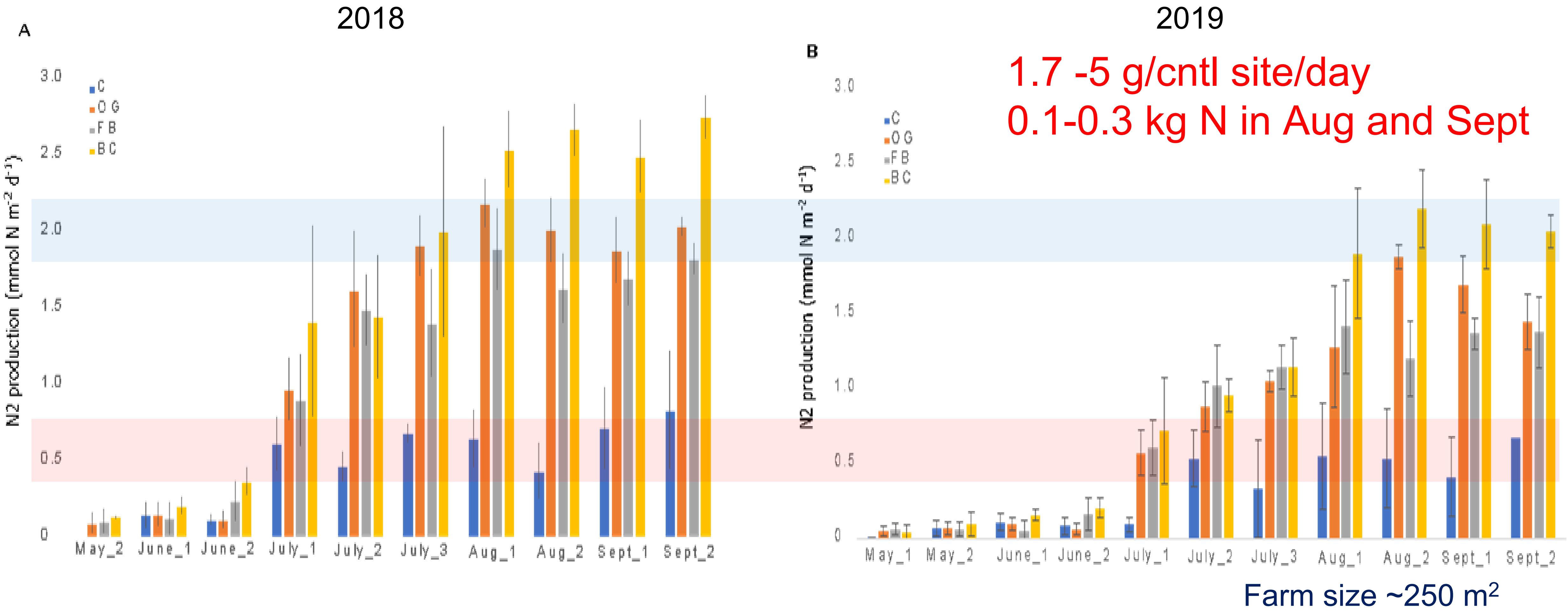
3. Lessons learned, take home or extrapolating to future studies.

Porewater Data- Carbon Content



N_2 release Data

14 -17 g/site/day
0.8-1 kg in N Aug and Sept at each farm



Increase in net N_2 production from late July/August through September

Part 2: Microbial Activity

iTAG (which microbes are present at the time of sampling)

- Collect the total DNA pool
- Describes community structure
- Moderate expense
- Won’t be covered today

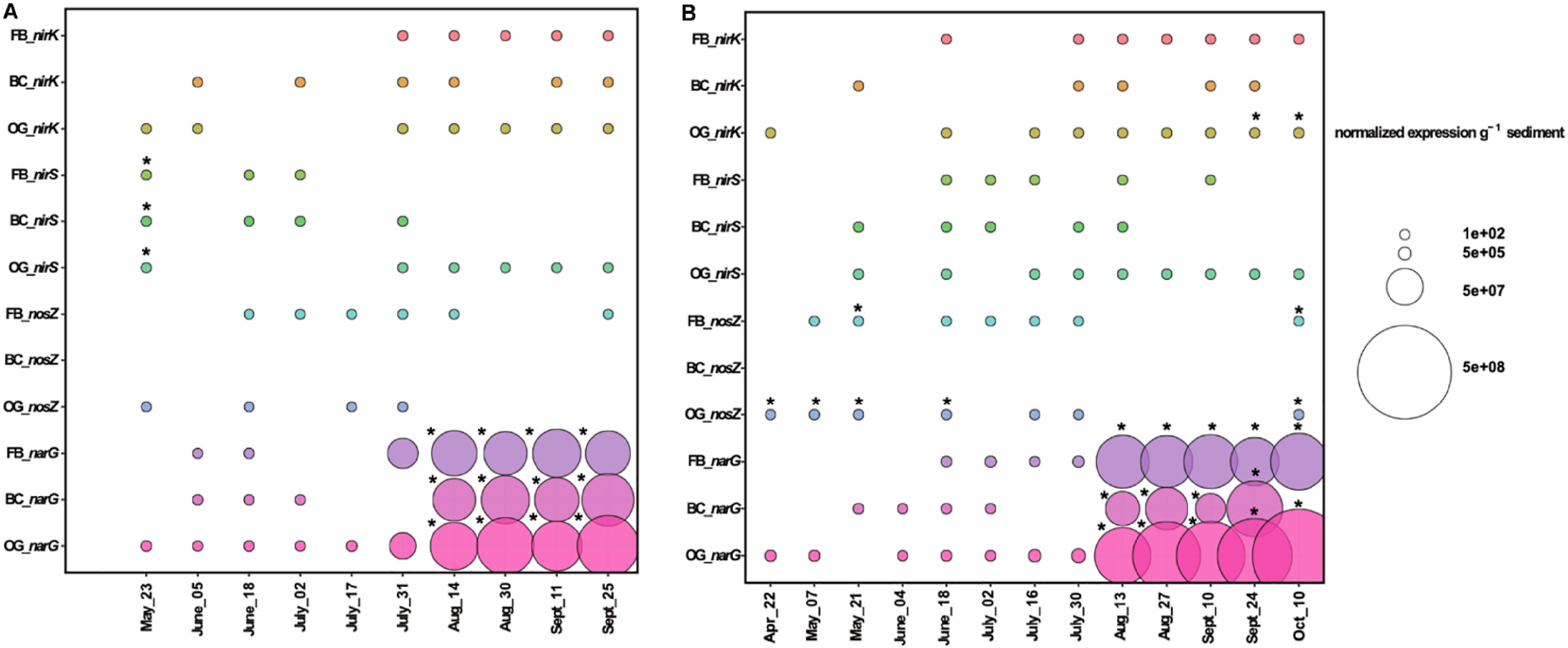
Metatranscriptomes (which genes are expressed at the time of sampling

- Collect the total RNA pool
- Proxy for microbial activity
- Expensive and technically challenging

RT-qPCR (targets specific genes of interest)

- Uses the total RNA pool
- Quantifies specific target genes.
- Quick, inexpensive if protocol developed

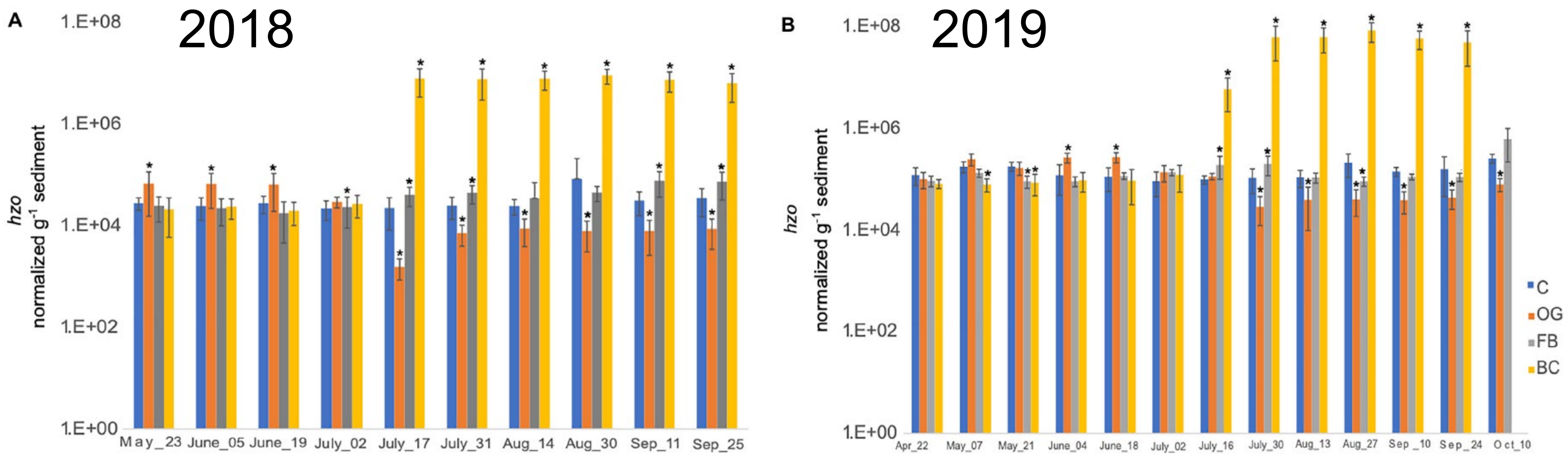
Nitrogen cycling: Denitrification (N_2 release)



Detection of higher expression of denitrification genes (nirK, nirS, nosZ and narG) under the treatments when compared to the control

- Control
- Oyster Gro'
- Floating Bag
- Bottom Cage

Nitrogen cycling: anammox (N_2 release)

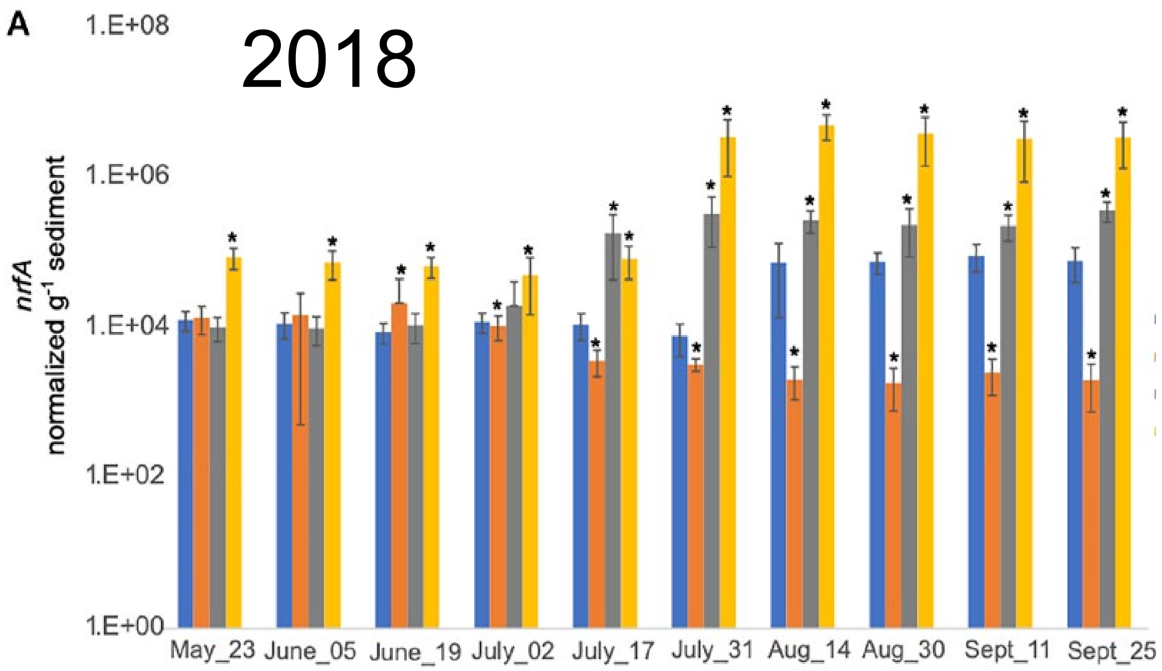


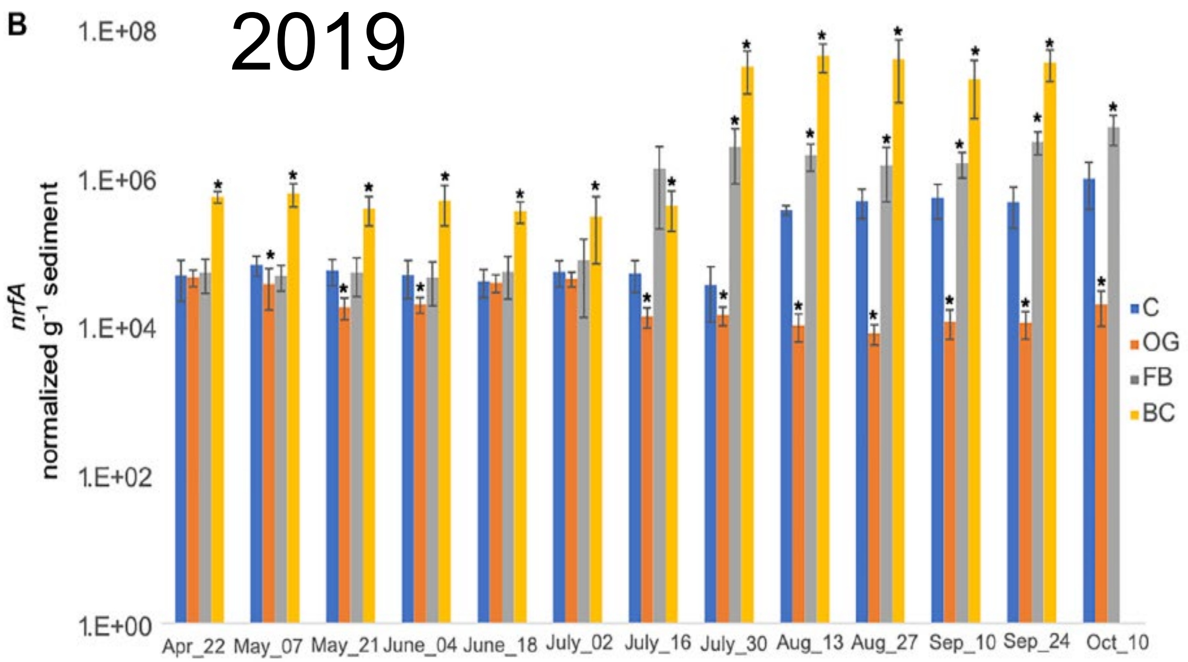
hzo gene: marker for anammox

- High hzo expression in the Bottom Cages compared to the control
- Similar hzo expression between Floating Bags and the control
- Decreased expression (below the control levels) in the Oyster Gro' treatments

Control
Oyster Gro'
Floating Bag
Bottom Cage

Nitrogen cycling: DNRA (ammonium retention)





nrfA gene: marker for DNRA

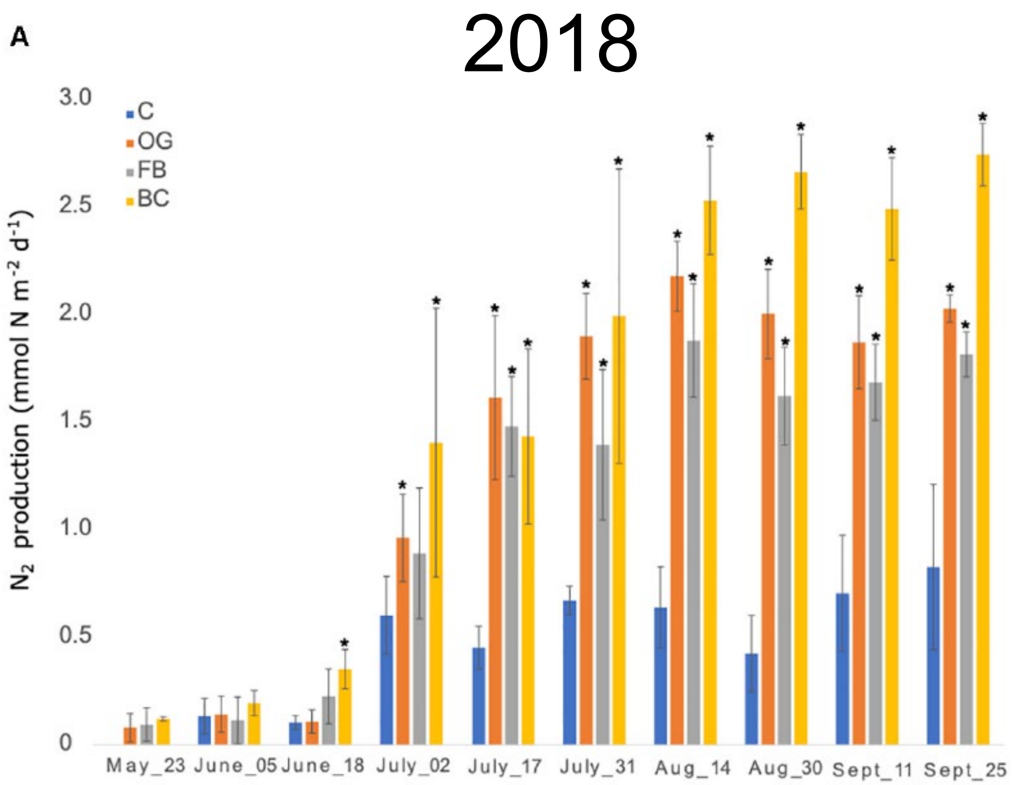
- High expression nrfA under the Bottom Cages when compared with the control
- Similar nrfA expression between Floating Bags and the control
- Decreased expression (below the control levels) in the Oyster Gro' treatment

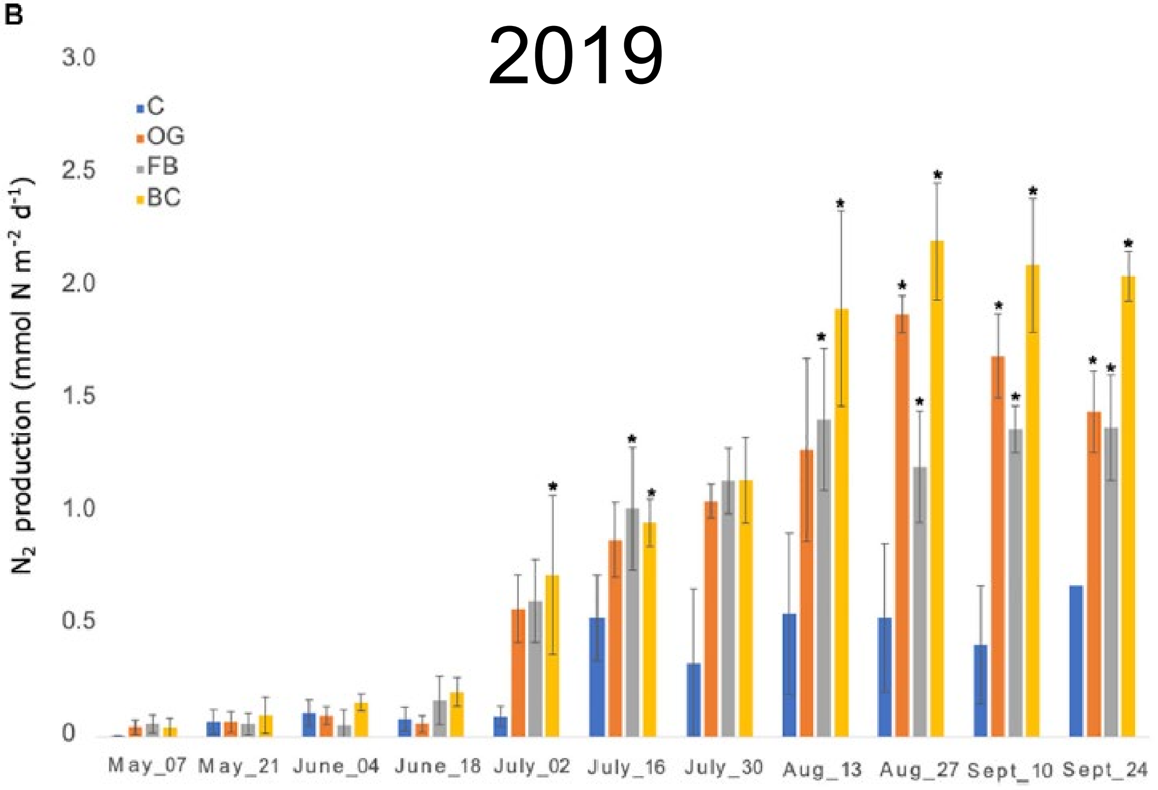
Part 3: Lessons Learned
Circling back to our big questions

- Does aquaculture activity change N_2 release (flux) from the sediments?
- Are the microbial communities in the underlying sediments changed?
- Are the activities of these communities changed in the presence of aquaculture?
- Is the amount of N_2 released enough to be included in water quality management planning?

Control
Oyster Gro'
Floating Bag
Bottom Cage

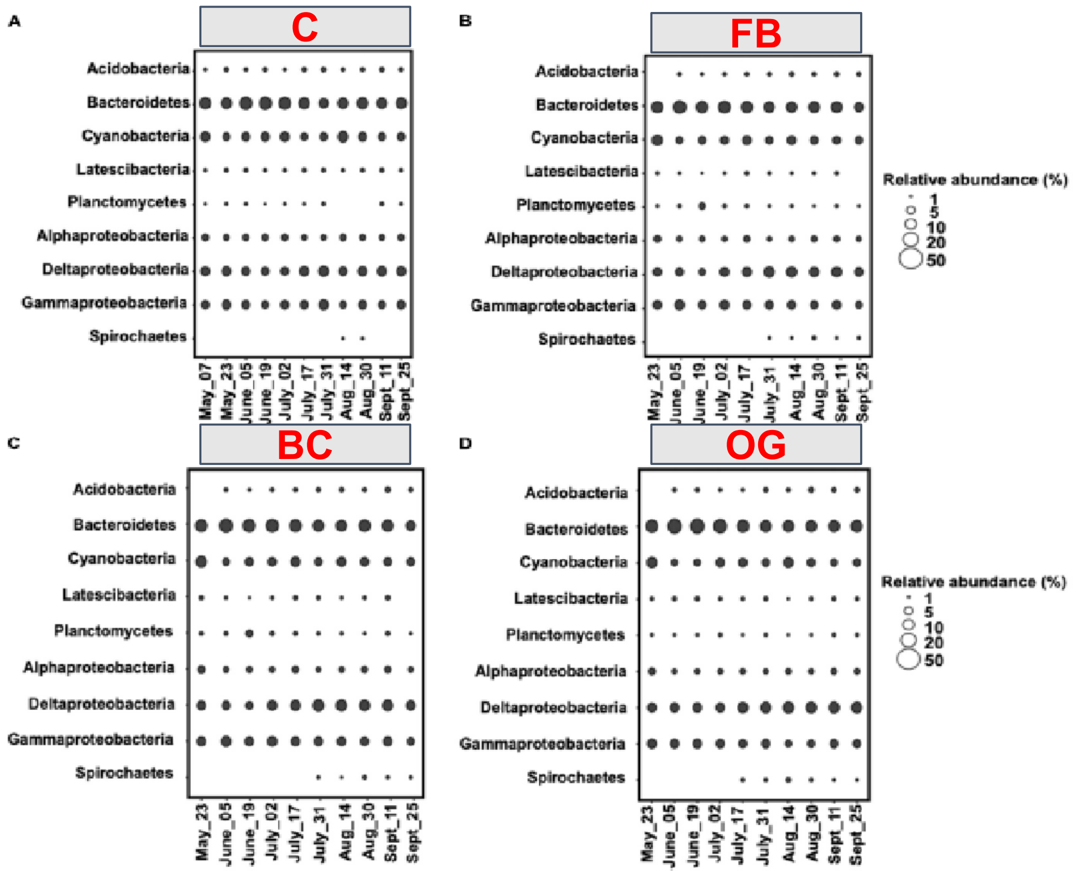
Does aquaculture activity change N_2 release (flux) from the sediments? YES





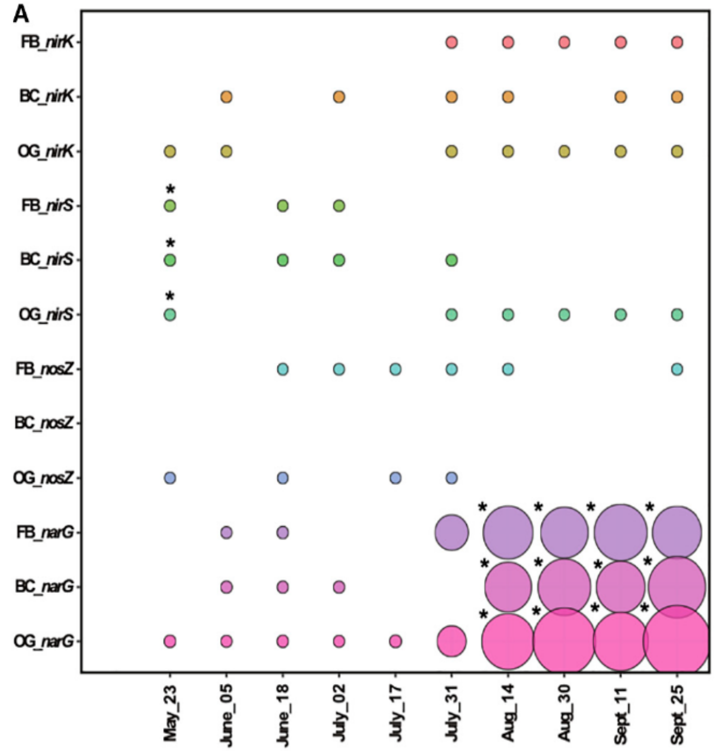
Are the microbial communities in the underlying sediments changed?

No, but activity changed



Community composition stays the same

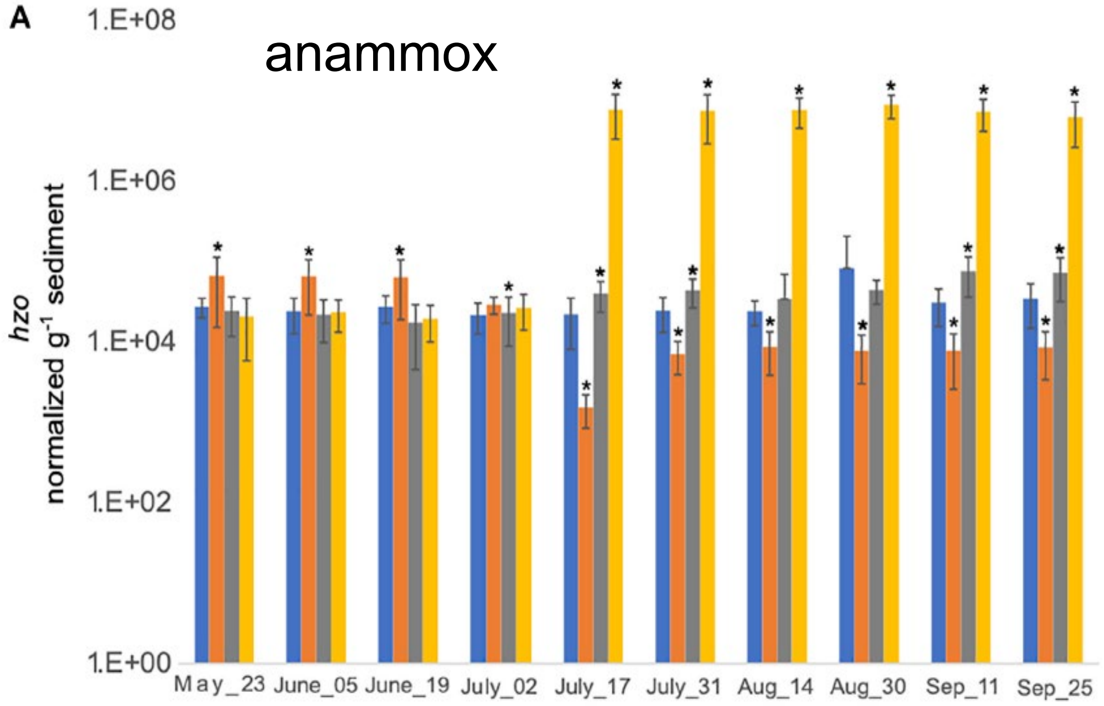
DNF

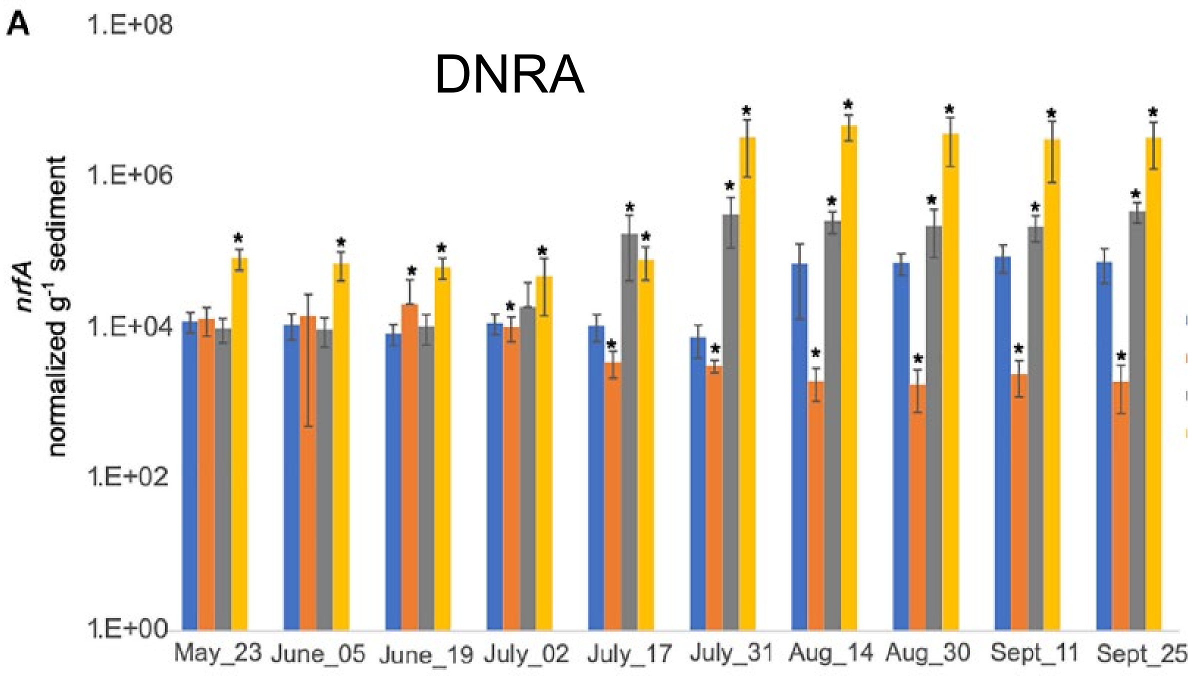


Expression of genes associated with denitrification stimulated!

Control
Oyster Gro'
Floating Bag
Bottom Cage

Are the activities of these communities changed in the presence of aquaculture?

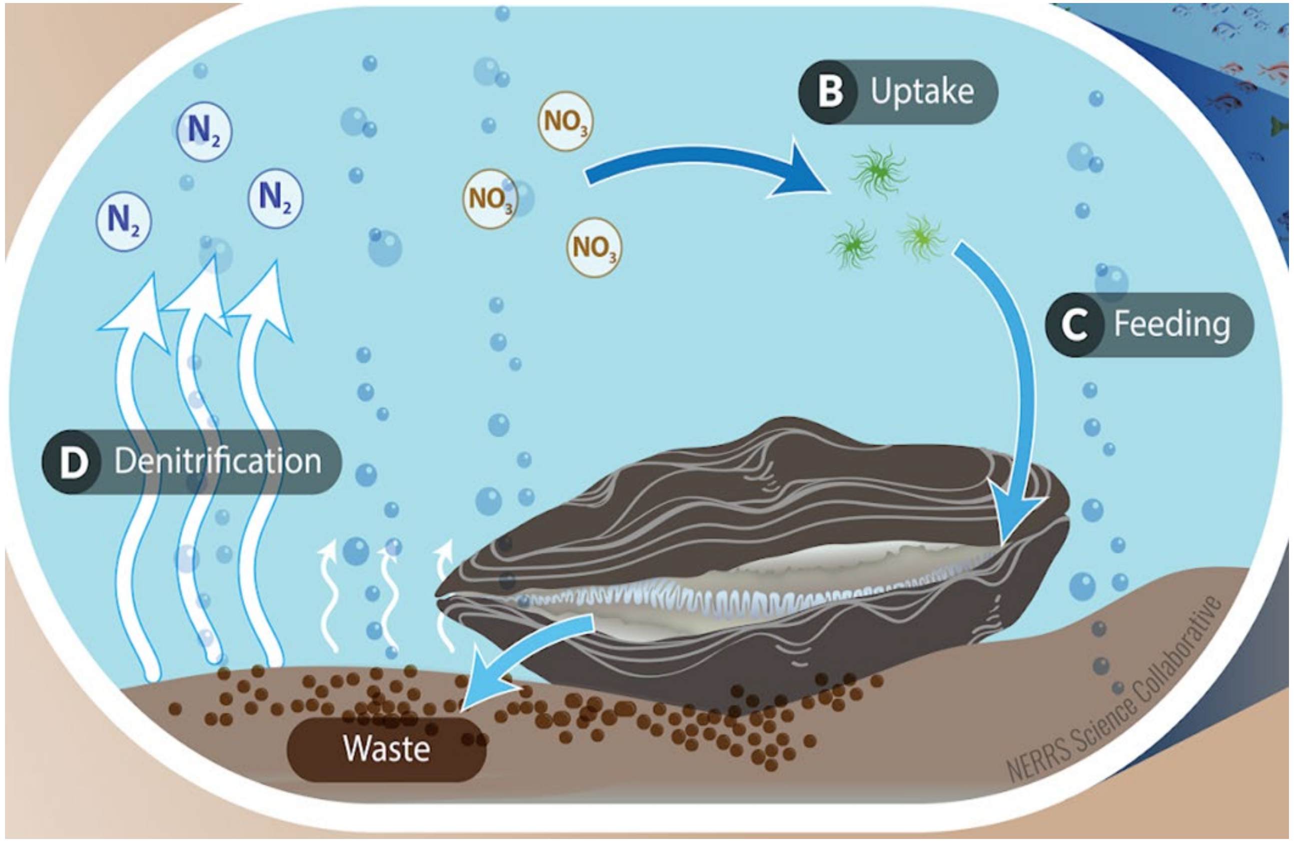




Anammox is stimulated under BC because of the organic matter accumulation

DNRA is sensitive to O_2, is stimulated under the BC and repressed under OG (piston pump activity).

Is there enough N_2 generated to be included in water quality management planning?



microbial N_2 released from under oyster aquaculture is about 10% of the amount of N removed in oyster biomass

Aug-Sept: ~1 kg of N per farm ($250 m^2$)
vs.
0.1-0.3 kg of N_2 at the control site

Implications of the science for management

Relaying oysters at the end of the season

- Choice of gear will depend on priorities: ease of management, cost, hydrodynamics, wind and wave exposure, and whether N removal is a priority
- If N removal is a priority BC give most benefit but NOT if conditions go too sulfidic (> 2 ppm)
- If sediments are already organic-rich (approaching 7-8% total organic carbon), FB and OG gear may be better choices for N benefits, and consider site rotation!

Implications of the science for management

$200

- Denitrification dominates but it is possible to push sediments to DNRA if organic matter and sulfide accumulate too much, which is counter-productive
- Hydrodynamic setting, the method and the stocking density can all affect nitrogen cycling
- Site Selection
  - Measure sulfide prior to farm installation
  - Measure organic matter content (~$20/sample)

Sulfide test kit
www.Lamotte.com

Argument for site rotation in some areas?

Conclusions

- All three systems increase sediment N removal compared to the control
- Bacterial community structure controlled by season and not by aquaculture method
- N removal consistent with upregulation of genes associated with denitrification
- You can push the system toward DNRA and increase retention of N, decreasing your N removal benefits

Additional Resources:

- Mara et al. Front. Mar. Sci., 2021.
- Best Practices Guide
- Video series (8 parts, mix and match)

Q&A

Q: The design of the experiment may have some bias on the results, for example the currents may carry water back forth. How would you quantify and remove the bias caused by currents?

- **A**: Currents can push nutrients back and forth between them, so one way we tried to attenuate that was by spreading them out. At high tide, we're in about a 1.5 meters of water, and there's about 5 meters of space between each type. The way the bay is structured, most of the currents closer to shore are wind-driven. We also had some trouble with green crabs messing with the sediment.

Q: I'm wondering if any cores were taken in the area surrounding the farms? In other words, in addition to the cores you took at the center of your control, Oyster Gro', floating bags, and bottom cage plots, were any cores taken at a distance from the farms to see the geographic extent of nitrogen removal?

- **A**: We sampled the control site as a bare sediment site outside the influence of the aquaculture systems. We did not do anything like a transect to see how it looked deeper out; our sites were about a meter and a half deep at most.

Q: From a policy perspective, does the state have a nutrient trading program whereby aquaculture farms can sell credits to nitrogen sources such as local waste water treatment plants? This would be another revenue stream for growers.

- **A**: The idea of nutrient trading has been discussed on the Cape for a long time, but there isn't one in place right now. Communities are mostly focused on comprehensive water quality plans that could involve aquaculture, and what kinds of credits they could receive for using potential options.

Q: A couple questions: - 1) we see attenuation of denitrification with illumination with nitrifiers losing out to autotrophs, do you think this might diminish denitrification? - 2) what about on-bottom oyster culture, lots of evidence for high rates of denitrification?

- **A**: In our system, the nitrate is already coming out of the groundwater system. With illumination, stimulating phytoplankton will cause them to assimilate nitrogen faster than nitrifiers, which move nitrogen from ammonium to nitrate, but we already have it in that nitrate pool, and we're trying to move it to the sediment where it can be removed.

Q: Did the control site get the same amount of foot traffic and stirring up of sediments as the aquaculture sites throughout the study period and on non-sampling days? Was foot traffic consistent and the same among gear type sites?

- **A**: Foot traffic between sites was similar. The Town of Falmouth managed the farms in a manner consistent with how a private grower would. Scientifically we wanted to replicate actual methods.

Q: How did you extract porewater from the sediment cores for analysis? How did you decide on sampling depth for porewater nutrients?

- **A**: We focused on the upper 3-cm of the sediment column. We extracted them a couple different ways; e.g., centrifuge, calcium chloride wash.

Q&A

Q: Is there any evidence to suggest that other prolific but less desirable /invasive species, such as zebra mussels, can also contribute to denitrification?

- **A**: That's a tough question. I think about this in terms of how we could get the nitrogen to the anaerobic zone of the sediment. Could we do this with other shellfish: absolutely. Denitrification as a process only constitutes about 30% of the nitrogen removal in the ecosystem, the rest is removed through oyster biomass as oysters grow, so it's best from a nitrogen-removal perspective if the species can be harvested. Any type of bivalve that can filter feed on nitrogen can remove nitrogen from the water column.

Q: Could you imagine a scenario where too many oysters could lead to a reduction of water quality?

- **A**: From what we found, there's a risk of high hydrogen sulfide in the sediment, which we considered an undesirable outcome. There are a lot of parameters to consider for a given location; e.g., local sediment geochemistry, how oysters interact with the geochemistry, etc.

Q: Were the rates normalized for the biomass of the oysters?

- **A**: Each system was started with the same biomass of oysters. The rate measured were the net flux of N2 across the sediment water interface and are normalized to this area. We did not test different biomasses of the oysters as we wanted to examine effects between systems. We did monitor the oyster biomass throughout the experiment.

Q: Did you use diploid or triploid oysters in the study?

- **A**: Diploid.

Q: Did you say the bottom caged oysters were more productive in removing nitrogen? But couldn't that be due to their waste being delivered "directly" to the sediment whereas the floating oysters could be removing just as much N but it's being moved laterally from the system by currents as it falls to the bottom? If so, could the water column be sampled to see if that's occurring?

- **A**: This is the idea we talked about. Unfortunately, our sediments did not function well in this setting and were unable to measure particle flux between the systems and the sediments. Advection may be an important term to consider, as it would result in OM movement to/from other areas. In the sites we worked in, given the shallow waters and anecdotal observations transport onshore may be worth considering but along shore looks to be less interesting.

Q: You mentioned septic systems. What are other nitrogen sources - agriculture, point sources such as wastewater treatment plants? Are there regulatory programs in place to address nitrogen loading?

- **A**: For us, the bulk of the nitrogen impacting the coastal bays and estuaries comes from septic systems, so that's where efforts have largely focused. Other sources include fertilizer use and atmospheric deposition. There are state and county level efforts to address nitrogen loading, which are covered by the Massachusetts Department of Environmental Protection. Towns have developed total maximum daily loads (TMDLs) of nitrogen that they're trying to achieve, and most communities are developing comprehensive water quality management plans to achieve specified levels of nitrogen removal.

Q&A

Q: Were there any notable natural phenomena that happened during your experiments that affected it?

- **A**: We noted that the denitrification in the sediment in these communities continued for extended time periods even after the oysters were removed. We had expected that the sediment would return to the same state it had been in prior to exposure to oysters, but it turned out that the bacteria in the sediment effectively learned to remove more nitrogen, and faster.

Q: How does scaling up aquaculture influence the overall nitrogen budget of the Bay? How much aquaculture would be needed to impact say 30% of anthropogenic nitrogen loads from septic systems and how would this impact other habitats such as eelgrass?

- **A**: You could not install these aquaculture systems if eelgrass is present. Unfortunately, eelgrass is absent from most of the bay and other coastal waters in the region. The amount of oysters needed to remove 30% of the N loading is water body dependent and may require a careful site selection (eg. where is the groundwater source).

Q: Is that NH_4 that does get assimilated into sediments by DNRA utilized or broken down during the winter season when Oysters were not present?

- **A:** NH4+ tends to reflux out of the sediments later, where it can stimulate a phytoplankton bloom.

Q: Does the quality of the oyster itself change? Will the oysters be safe to eat?

- **A**: The oysters are safe to eat. All the oysters we grew were histology-checked for pathogens and relayed out where they can be harvested by recreational fishermen. This is just a normal function of oysters – there's nothing special about it. There is a difference between oysters that were grown in the bottom cages versus the floating bags. The floating bag oysters were prettier, but showed less growth. The bottom cage oysters grew more abundantly, but they were maybe less attractive than the floating bags.

Q: Have you investigated similar activities in Chesapeake Bay to see if they have similar results?

- **A**: We have not worked in Chesapeake Bay but other groups have.

Q: Do the type and levels of nitrogen in the water column matter too? Did the study look at levels in water column?

- **A**: We monitored the ammonium and nitrate levels in the water column. The water column is well mixed (and shallow) so there isn't typically a gradient in the N compounds in the water.