The biogeochemistry of oyster restoration: Initial conditions determine potential mitigation

Rebecca J Bernard $^{1, 2, x}$ and Behzad Mortazavi $^{1, 2}$

$^{1}$ The University of Alabama Department of Biological Sciences Box 870344, Tuscaloosa, Alabama 35487
$^{2}$ Dauphin Island Sea Lab 101 Bienville Blvd Dauphin Island, Alabama 36528
$x$ Corresponding author
Ecosystem Services of oyster restoration include improved water quality and foraging and nursery habitats.

Oysters connect water column processes to the sediment.

Indirectly mediate N removal from a system by stimulating nitrification-denitrification processes in microbes.

Eastern Oyster (*Crassostrea virginica*)
Oyster Gardening in Mobile Bay

masgc.org

The Mobile Bay Oyster Gardening Program works with local volunteers ("Oyster Gardeners") to rear juvenile oysters in protected gardens from private wharfs.

Each Oyster Gardener grows oysters in up to four gardens from late June to November. During this time, the juvenile oysters grow from a few millimeters to more than 2 inches.
Oyster Gardening in Mobile Bay

masgc.org

When the oysters are large enough they are collected and returned to restoration reefs within Mobile Bay.

The protection and maintenance provided by Oyster Gardeners allow the oysters to attain a larger size more rapidly than they would in the wild.

This larger size improves the survival rate and increases the probability of restoration success.
**Objective:** To determine the ability of oysters to indirectly remove excess N from the system

Many studies look at N content in tissue. But what about interactions with sediment biogeochemistry?

**H⁰:** N removal from the system will not be stimulated by oyster biodeposits

**Hₐ:** Oyster biodeposits will enhance rates of N removal via denitrification
Denitrification: May be enhanced by oyster biodeposits

Water column diffusion

N₂

control

adult

juvenile

NO₃⁻

Nitrification

NH₄⁺
SAMPLING SITES

• Bon Secour Bay, Alabama

• Two spatially close docks part of the Oyster Gardening program

• April to September 2011
METHODS

Control, Juvenile, Adult oyster hanging cages

Triplicate sediment cores were collected from sediment below each cage

Slurry incubations for potential nitrification, denitrification, and N\textsubscript{2} fixation activity
METHODS

Net $N_2$ flux was measured using a flow-through system and membrane inlet mass spectromoter (MIMS).

$H$ and $O_2$ profiles were made from additional cores using microelectrodes and a UniSense multimeter.

Sediment Chl-$\alpha$ measured using a Turner Designs TD-700 fluorometer.
INITIAL CONDITIONS

NO significant difference between porewater NO$_3^-$ and NH$_4^+$ at the two sites
INITIAL CONDITIONS

No difference between sites for NO$_3^-$, NH$_4^+$ and N$_2$ fluxes

Site 1 had higher pw [NH$_4^+$], thus higher NH$_4^+$ flux

Both sites had N$_2$ uptake by the sediments
Initial chl-α as an indicator of bioavailable nutrients

Initial chl-α values were significantly different at the two sites

Site 1 had higher values than site 2 indicating more phytoplankton biomass to support oyster growth
Initial O$_2$ HS$^-$ Profiles

Initial [HS$^-$] differed significantly between the two sites.

Site2 had undetectable HS$^-$ at the beginning of the experiment.
Did the Oyster biodeposits stimulate denitrification?

Site ($p=0.020$) and treatment ($p=0.055$) had significant responses.

At site 1, Adult and Juvenile differed from each other ($p=0.002$) but not from the control.

At site 2, Juvenile significantly differed from control ($p<0.001$).
What could explain the difference in $N_2$ fluxes between sites and treatments?

Initial porewater nutrient and N fluxes at the two sites were not significantly different, yet at the end of the experiment only site2 Juvenile had an efflux of $N_2$

Initial chl-α and [HS-] differed significantly at the two sites and may explain why the N fluxes differed at the end of the experiment.
The diagram illustrates the nitrogen cycle in an aquatic environment, showing the interactions between various nitrogen species.

**INPUT**

1. **Solubilization**
2. **Ammonification**
3. **N₂ fixation**
4. **Nitrification**
5. **Assimilatory nitrogen reduction**
6. **Denitrification**
7. **Anammox**
8. **Dissimilatory nitrate reduction to ammonium (DNRA)**

**Oxic**

- **N₂(g)**
- **NH₄⁺**
- **NO₂⁻**
- **NO₃⁻**

**Suboxic/Anoxic**

- **A**
- **N₂(g)**
- **N₂O(g)**
- **NO**

**BURIAl**

- **Σ Input = Σ Export + Burial + Denitrification + Anammox**

**EXPORT**
Site1 Juvenile had higher HS\textsuperscript{−} relative to the control (391 ± 0.81 and 232 ± 0.44 SE μM, respectively) while in the adult treatment HS\textsuperscript{−} was undetectable. In contrast, at site2, HS\textsuperscript{−} was not detectable by the study end.
Site and treatment were significantly different

Site 1: Juvenile and Adult chl-α increased significantly by study end; indication of OM buildup

Site 2: had no change from initial conditions
Porewater profiles indicate that by the experiment end, site2 had less NO$_3^-$ and NH$_4^+$ than site1

Site1 NH$_4^+$ stays in system

Site2 NH$_4^+$ is nitrified/denitrified
Site 1 had NO$_3^-$ uptake and NH$_4^+$ efflux indicating the DNF pathway was HS$^-$ inhibited.

Site 2 Juvenile had NO$_3^-$ efflux, supporting the DNF rates found with the MIMS.
CONCLUSION

Sites were spatially close, BUT contrasting results indicated that initial redox conditions in the sediments determined the amount of N removed from the system.

Site1 had a strong HS\(-\) influence and net N\(_2\) uptake regardless of treatment due to inhibition of denitrification by HS\(-\).

In contrast, site2 had undetectable HS\(-\) by study end and detectable rates of denitrification in the juvenile treatment, likely due to their faster growth rate and greater biodeposits than the adult treatment.

These results indicate that when not HS\(-\) inhibited, associated oyster biodeposits stimulated N removal, suggesting that the potential for oyster restoration to remediate excess N depends on initial redox conditions.
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