The biogeochemistry of oyster restoration: Initial conditions determine potential mitigation

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BACKGROUND

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

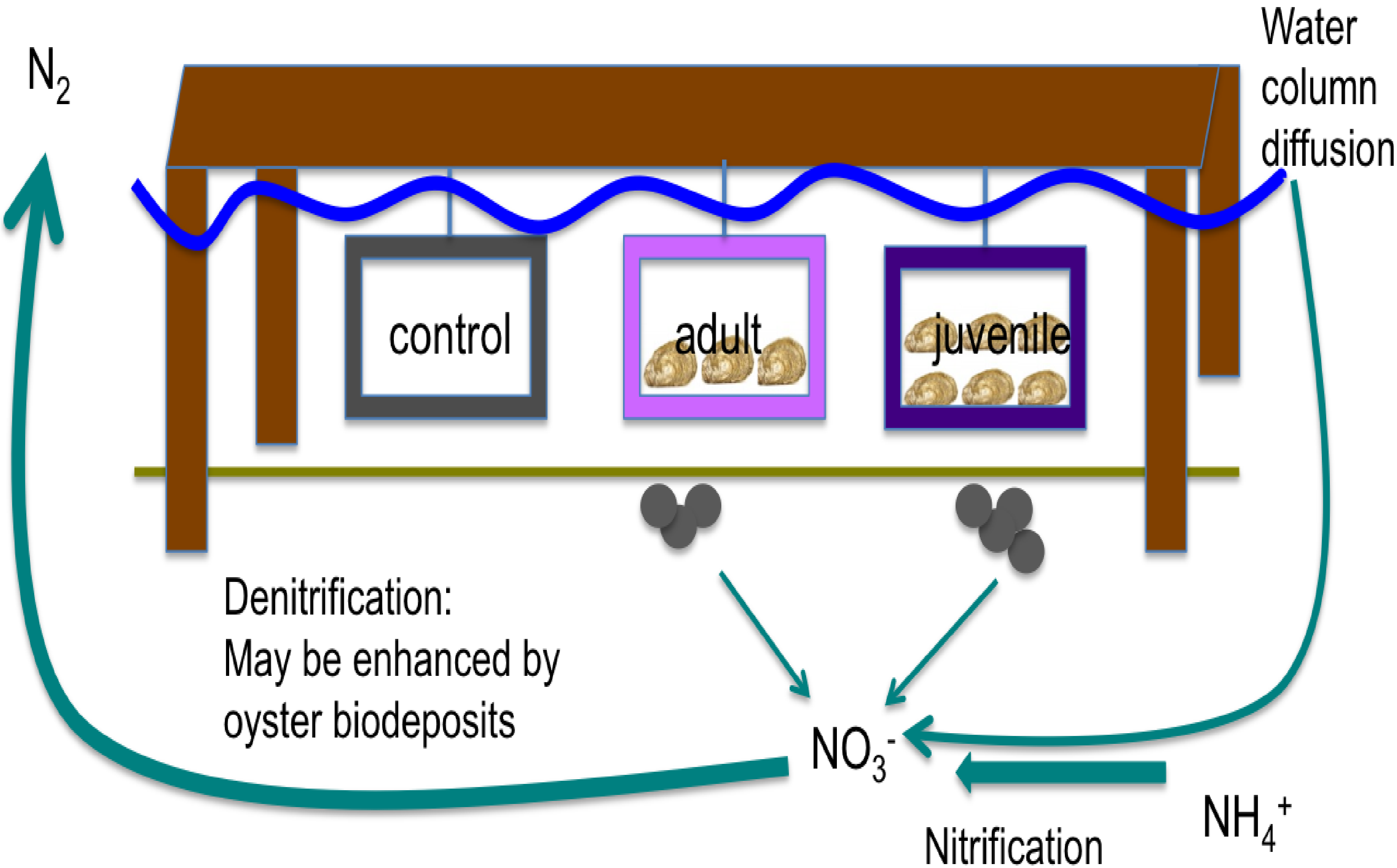
OBJECTIVE AND HYPOTHESIS

Objective: To determine the ability of oysters to indirectly remove excess N from the system

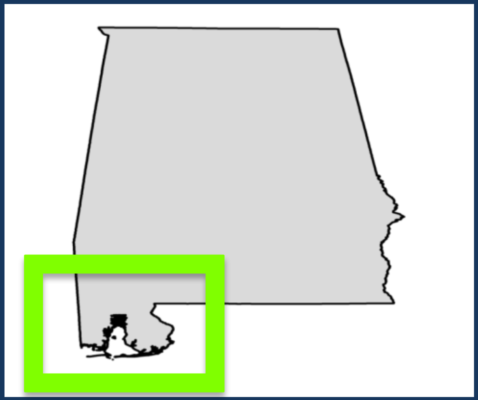
Many studies look at N content in tissue.
But what about interactions with sediment biogeochemistry?

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

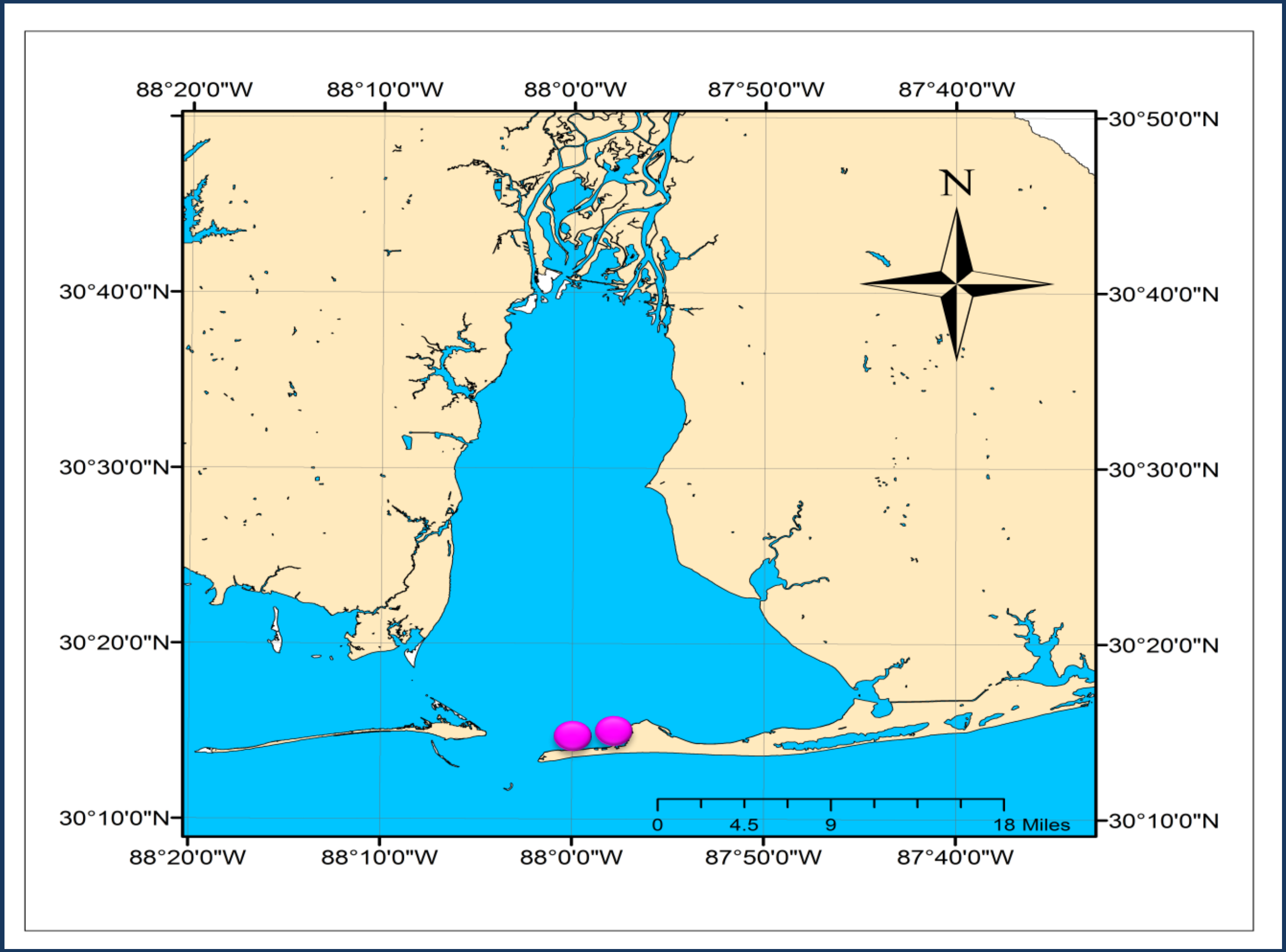
H_a: Oyster biodeposits will enhance rates of N removal via denitrification



N_2
Water column diffusion
control
adult
juvenile
Denitrification:
May be enhanced by oyster biodeposits
NO_3^-
NH_4^+
Nitrification



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_2 fixation activity

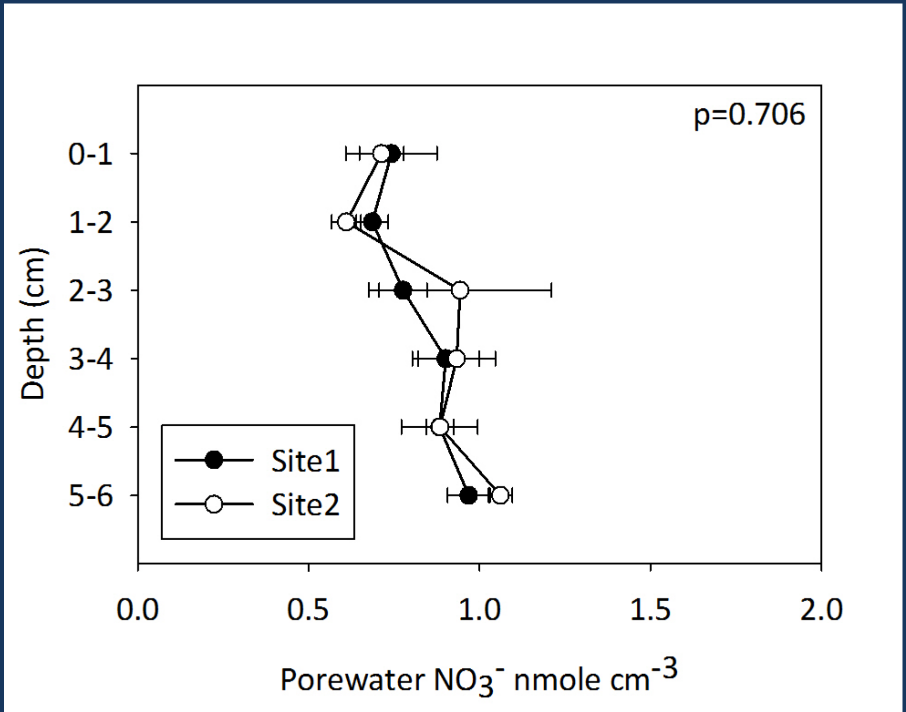
METHODS

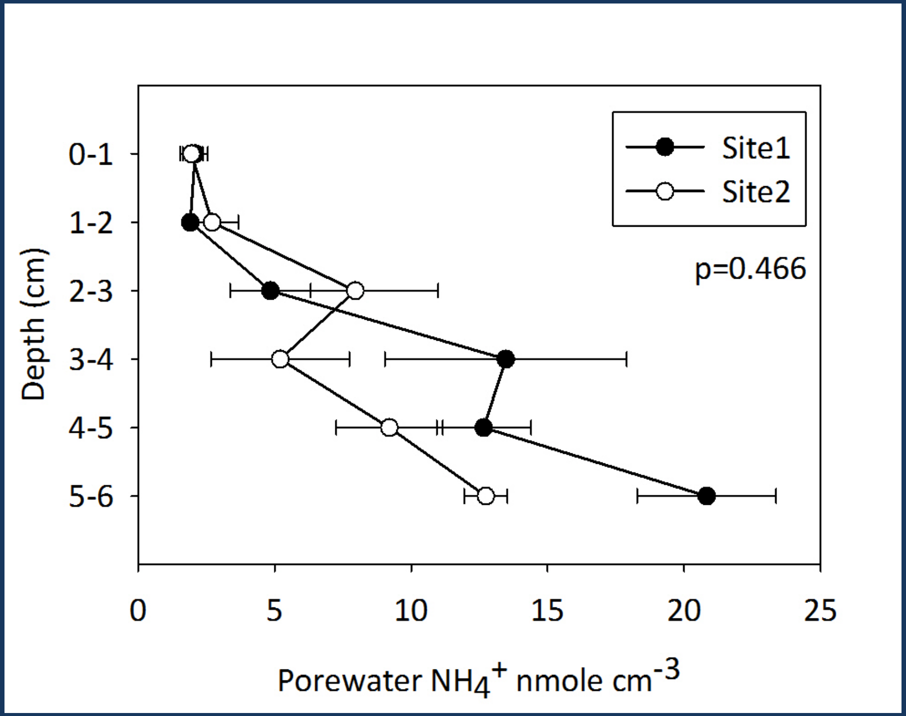
Net N_2 flux was measured using a flow-through system and membrane inlet mass spectromoter (MIMS)

HS^- and O_2 profiles were made from additional cores using microelectrodes and a UniSense multimeter.

Sediment Chl-α measured using a Turner Designs TD-700 fluorometer

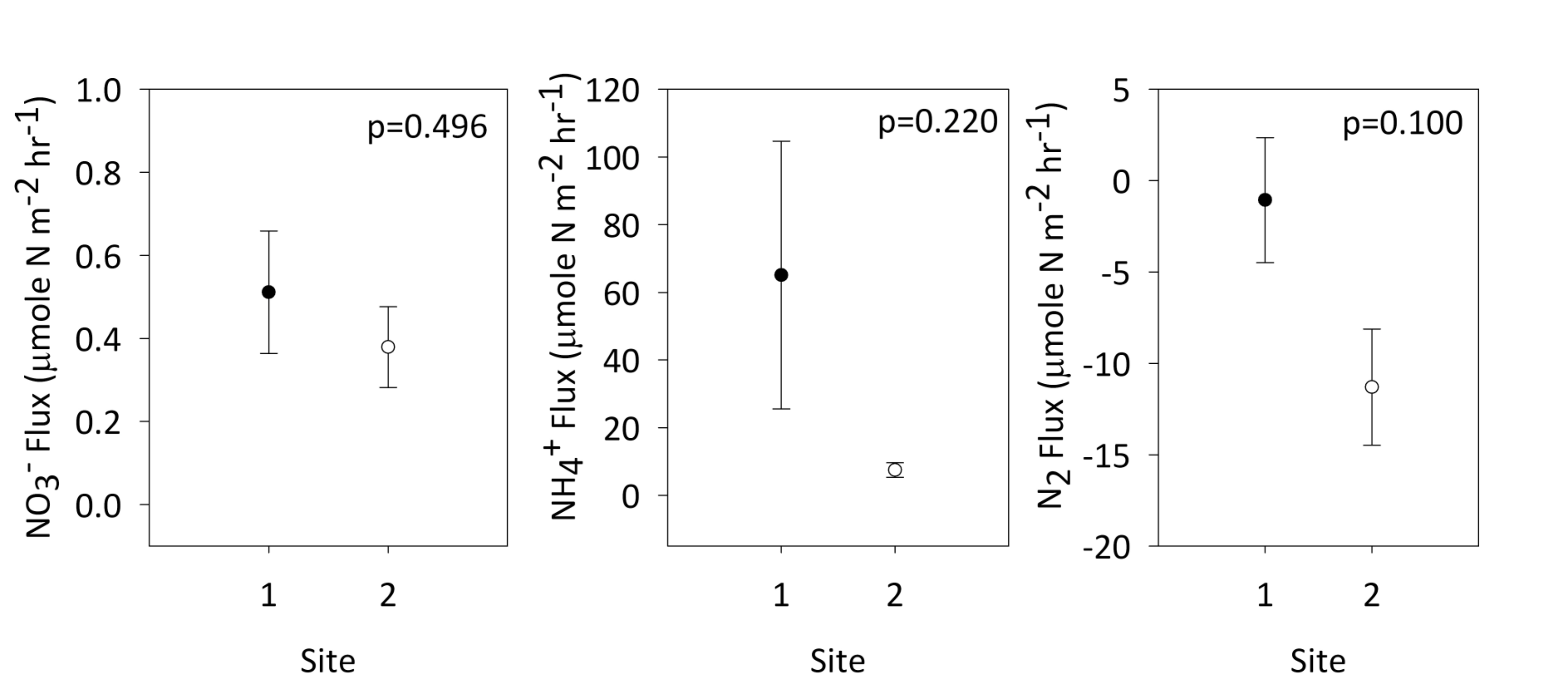
INITIAL CONDITIONS





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

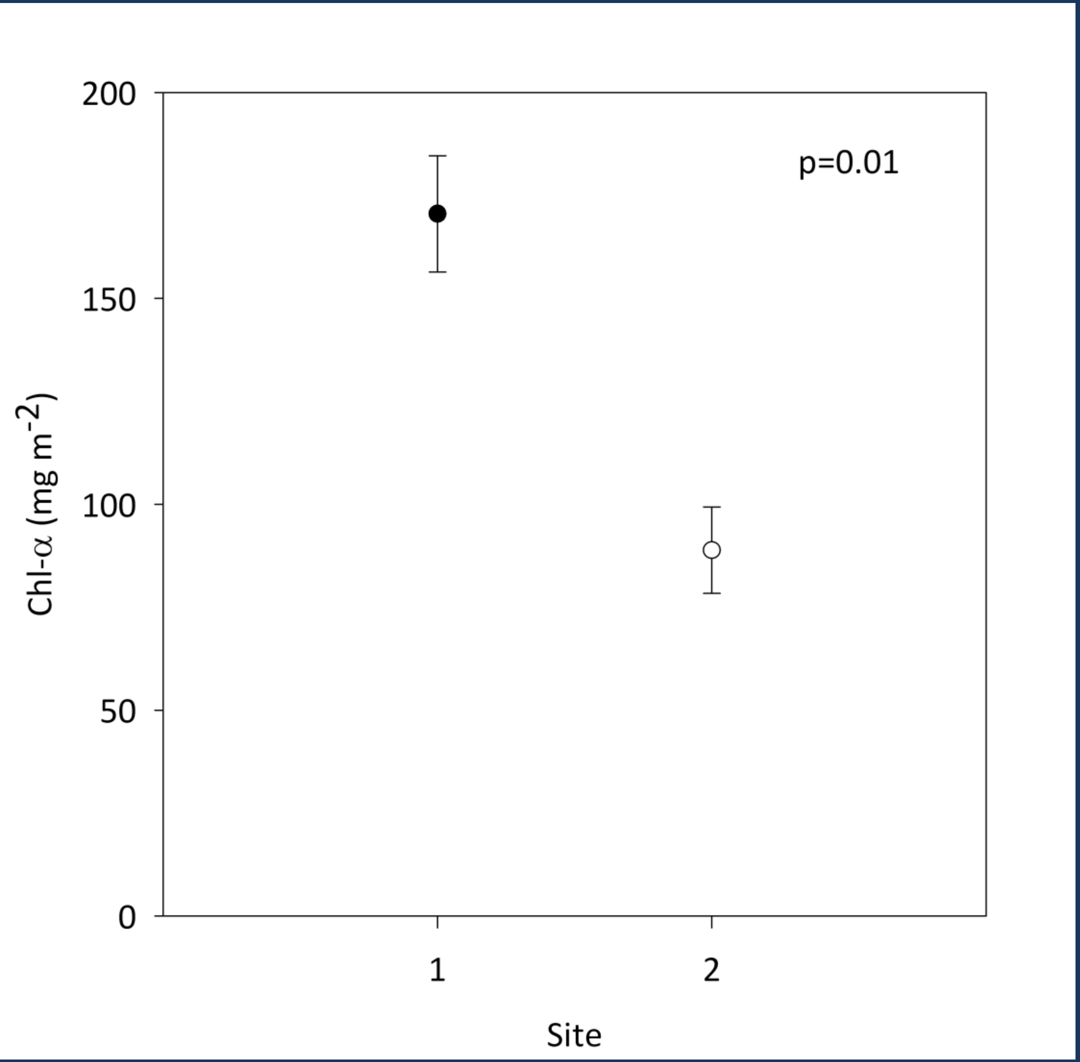
Site1 had higher pw [NH_4^+], thus higher NH_4^+ flux

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

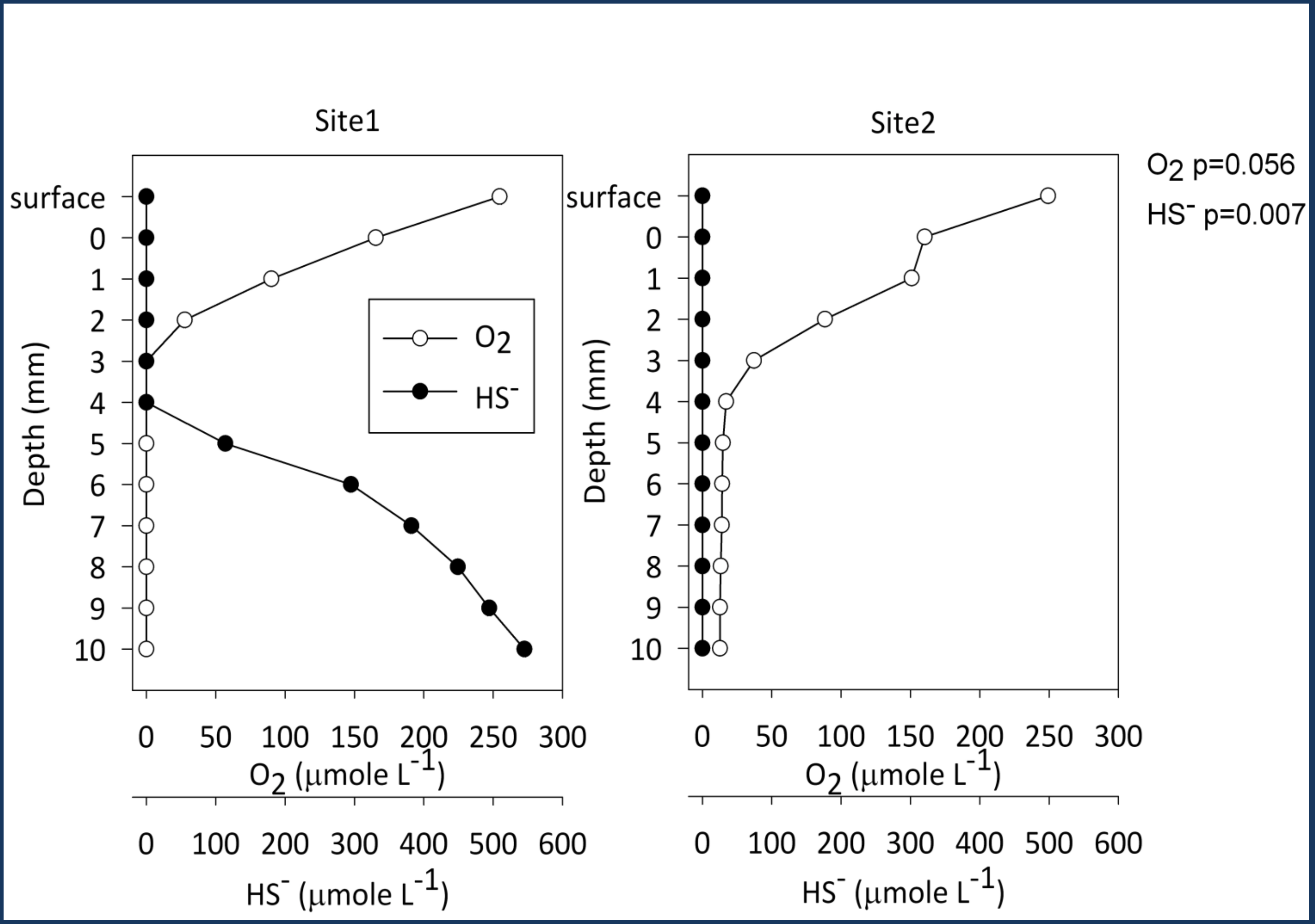
Site1 had higher values than site2 indicating more phytoplankton biomass to support oyster growth



Initial O_2 HS^- Profiles

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

Site2 had undetectable HS^- at the beginning of the experiment

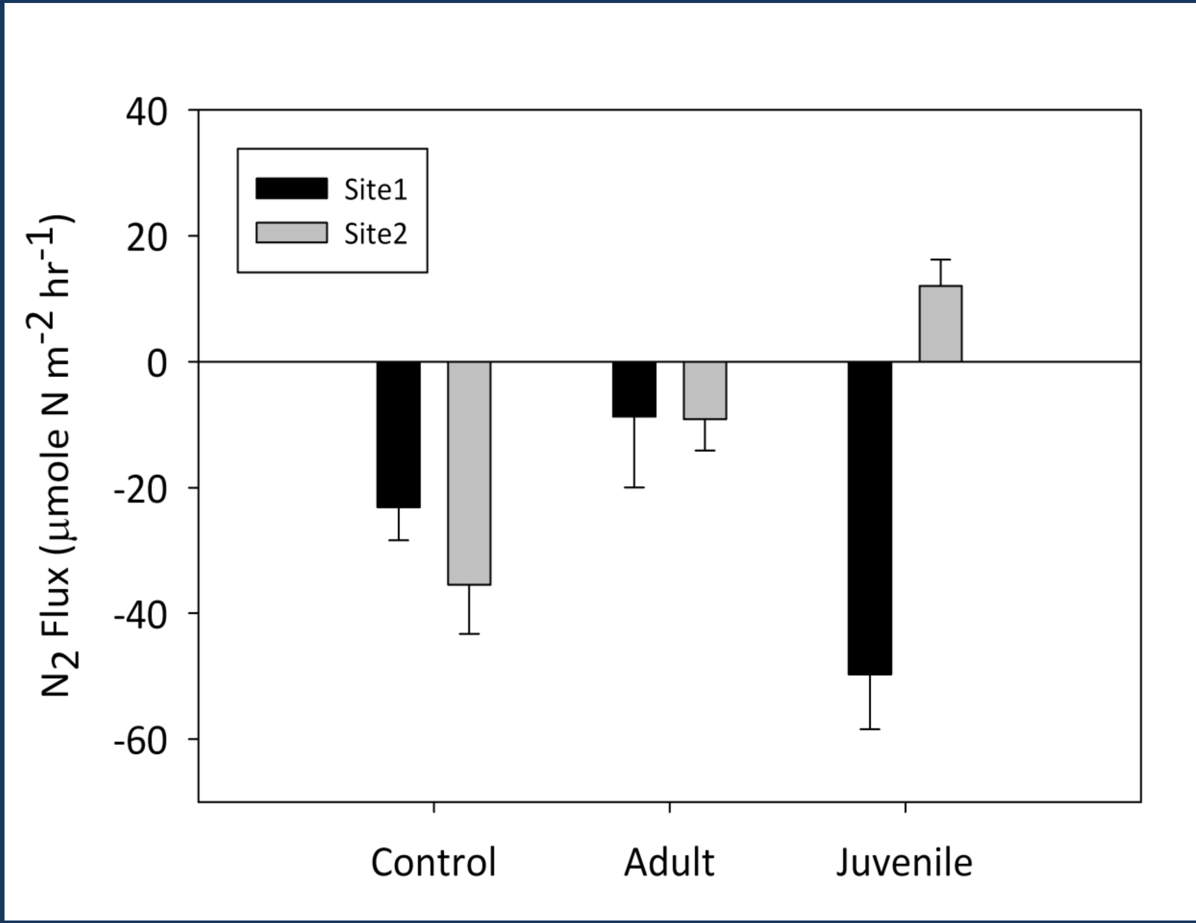


Did the Oyster biodeposits stimulate denitrification?

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

At site1, Adult and Juvenile differed from eachother ($p=0.002$) but not from the control

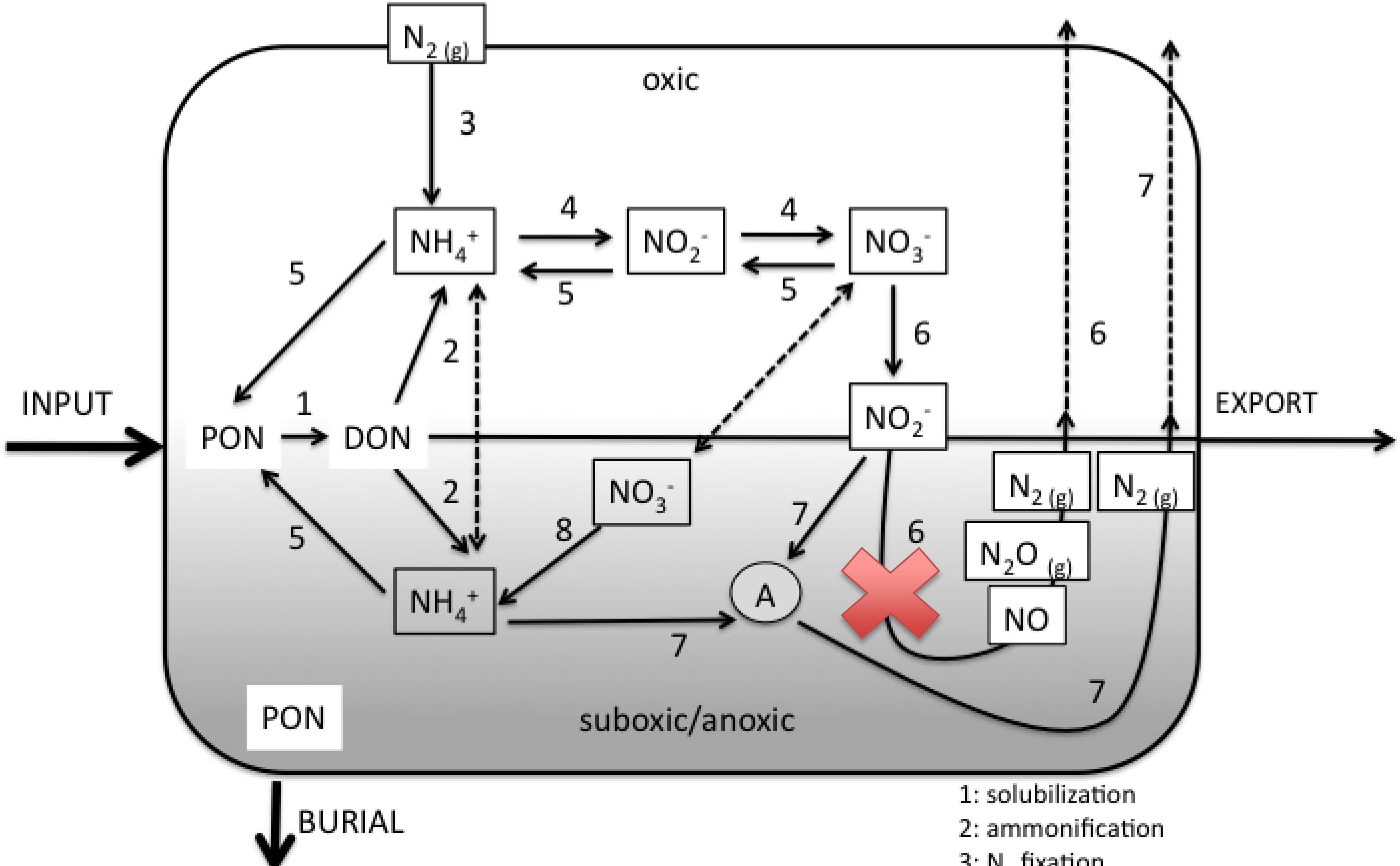
At site2, Juvenile significantly differed from control ($p<0.001$)



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

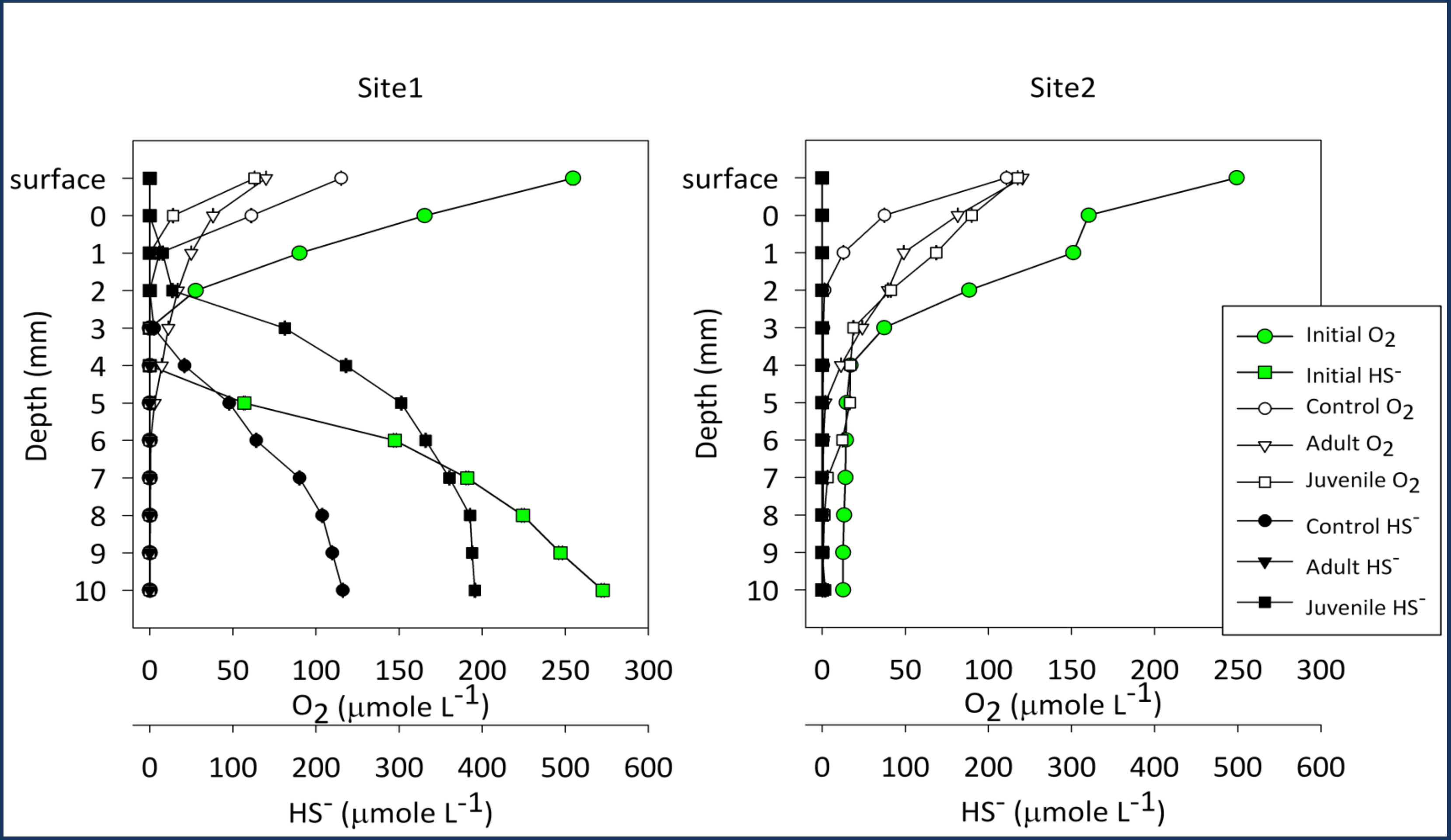
Initial chl-α and [HS-] differed significantly at the two sites and may explain why the N fluxes differed at the end of the experiment



Σ Input = Σ Export + Burial + Denitrification + anammox

1: solubilization
2: ammonification
3: N_2 fixation
4: nitrification
5: assimilatory nitrogen reduction
6: denitrification
7: anammox
8: dissimilatory nitrate reduction to ammonium (DNRA)

Oxygen and Hydrogen Sulfide Profiles



Site1 Juvenile had higher HS^- relative to the control (391 ± 0.81 and 232 ± 0.44 SE µM, respectively) while in the adult treatment HS^- was undetectable.

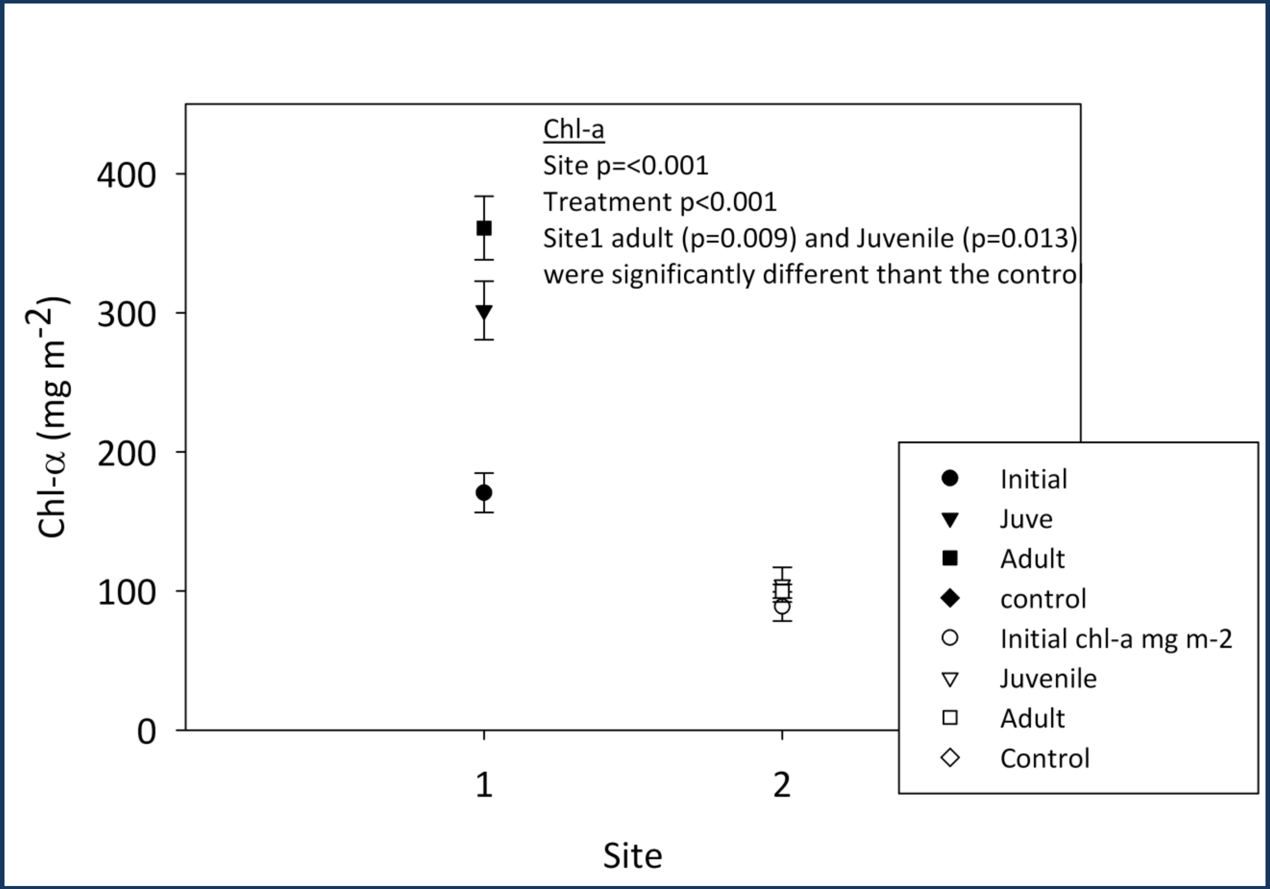
In contrast, at site2, HS^- was not detectable by the study end.

Chl-α values at study end

Site and treatment were significantly different

Site1 Juvenile and Adult chl-α increased significantly by study end; indication of OM buildup

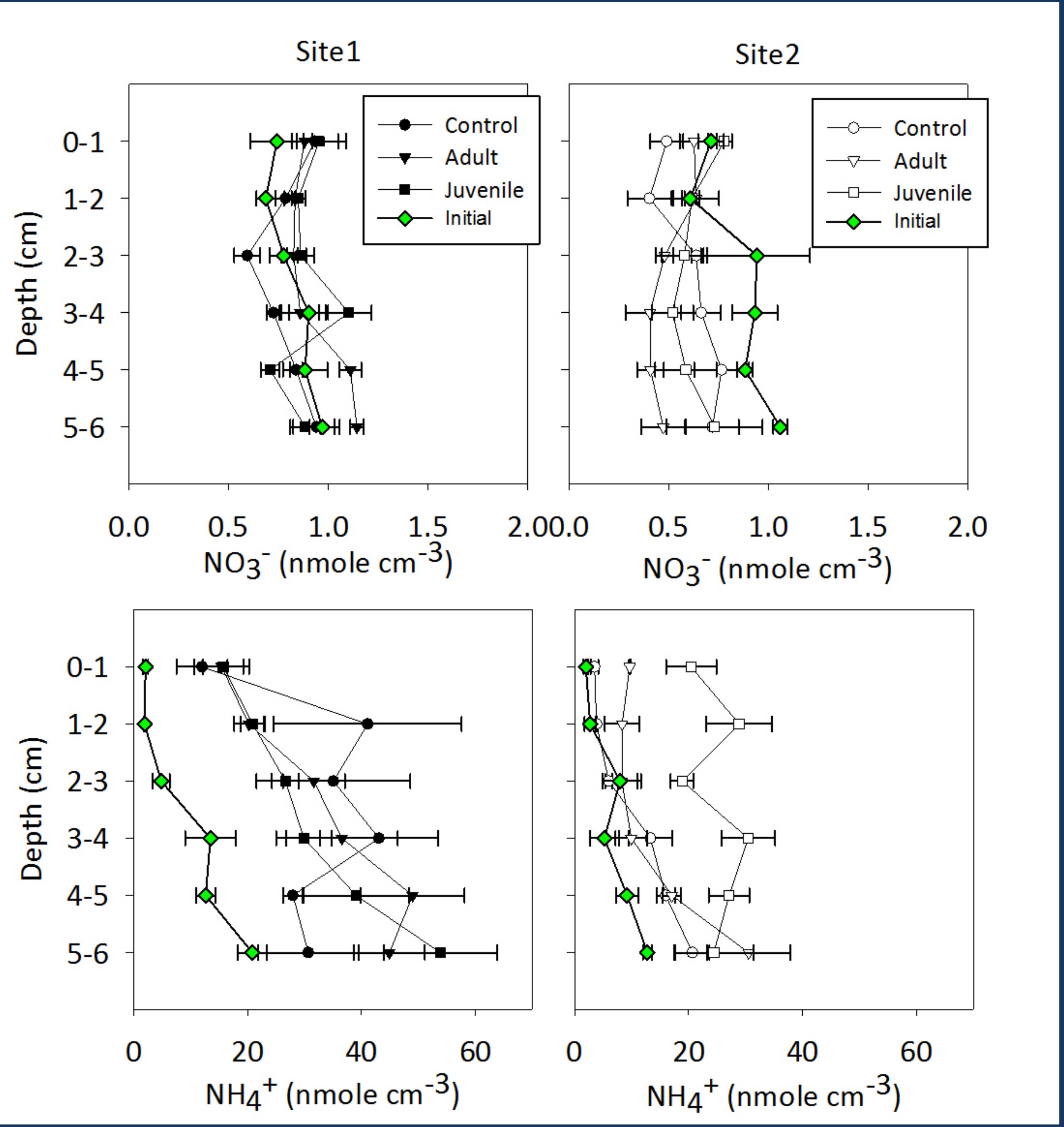
Site2 had no change from initial conditions



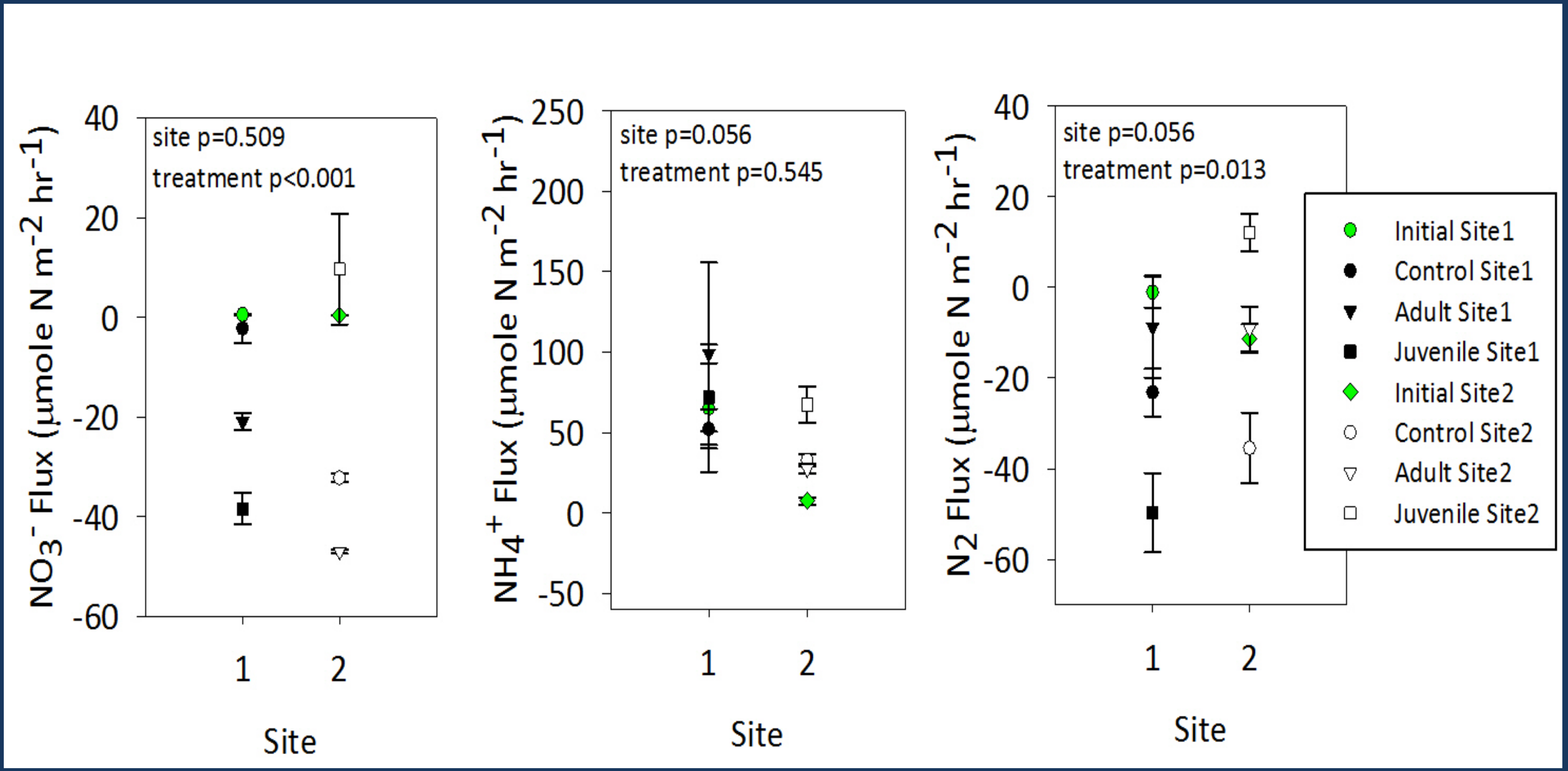
Porewater profiles indicate that by the experiment end, site2 had less NO_3^- and NH_4^+ than site1

Site1 NH_4^+ stays in system

Site2 NH_4^+ is nitrified/denitrified



N flux rates support HS^- inhibition



Site1 had NO_3^- uptake and NH_4^+ efflux indicating the DNF pathway was HS^- inhibited

Site2 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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