OYSTER RESTORATION, AQUACULTURE AND NITROGEN REMOVAL – A BIOGEOCHEMIST'S PERSPECTIVE

Jeffrey Cornwell, Michael Owens, Lisa Kellogg

Thanks to RIE Newell and K Paynter

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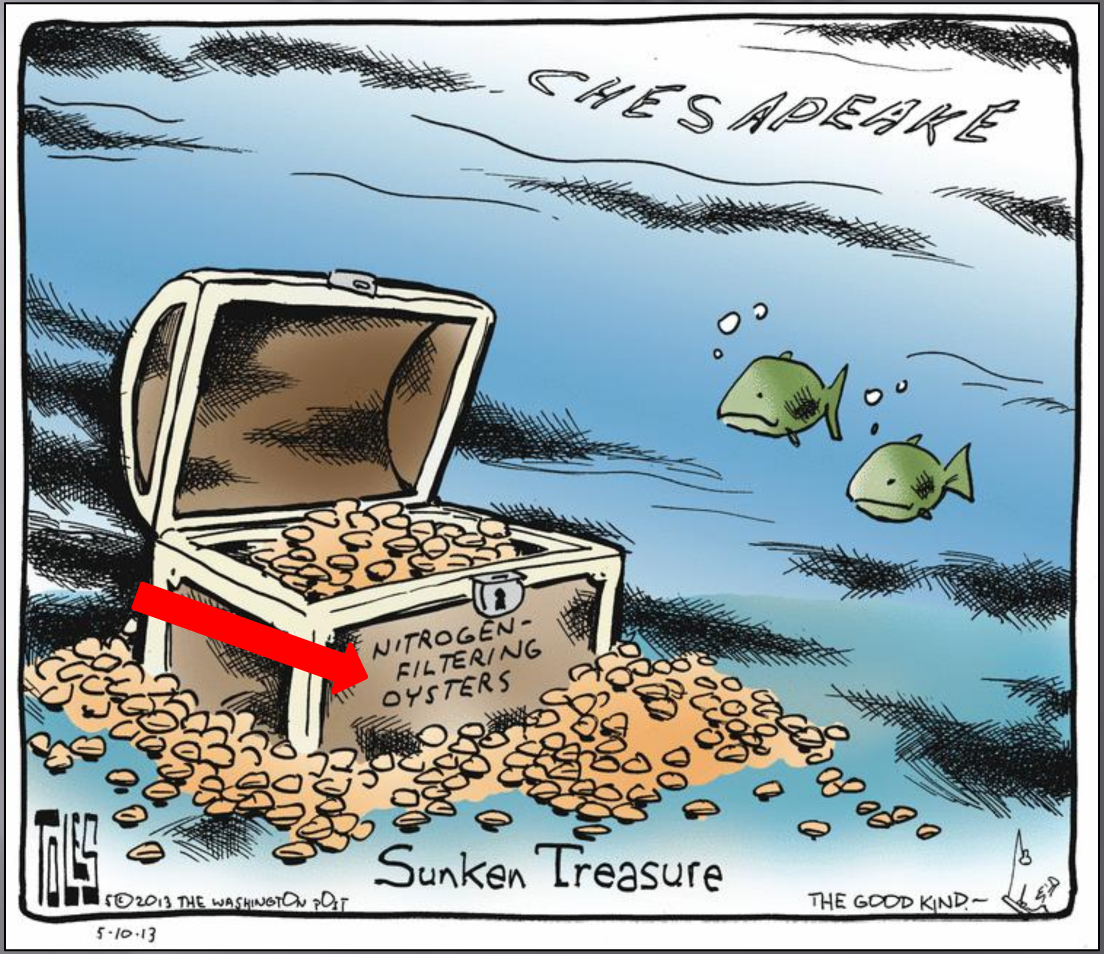
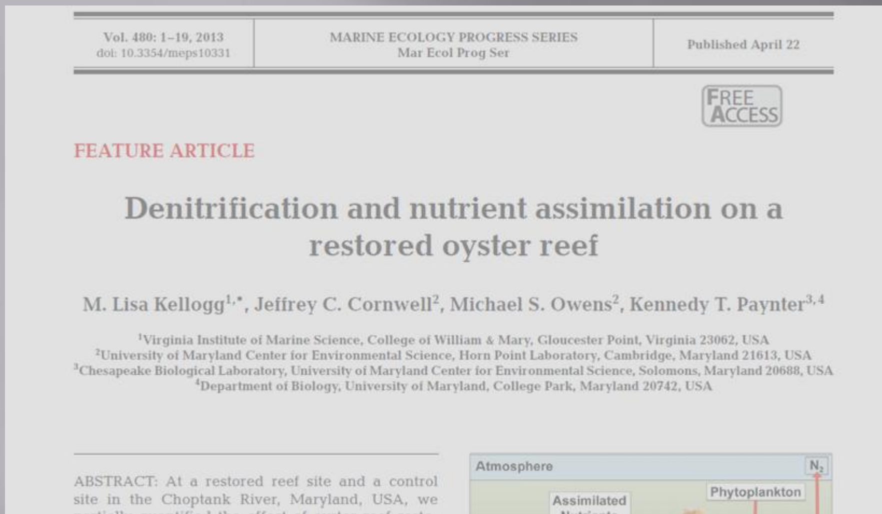
The Promise of Oyster Reef Restoration



Source: Tom Toles (2013) The Washington Post.

Resources



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FEATURE ARTICLE

Denitrification and nutrient assimilation on a restored oyster reef

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ABSTRACT: At a restored reef site and a control site in the Choptank River, Maryland, USA, we

Kellogg, M. L., J. C. Cornwell, M. S. Owens, and K. T. Paynter. 2013. Denitrification and nutrient assimilation on a restored oyster reef. Marine Ecology Progress Series **480:1-19.**

Kellogg, M. L., M. W. Luckenbach, B. L. Brown, R. H. Carmichael, J. C. Cornwell, M. F. Piehler, M. S. Owens, D. J. Dalrymple, C. B. Higgins, and A. R. Smyth. 2013. Quantifying nitrogen removal by oysters - workshop report. NOAA Chesapeake Bay Office.

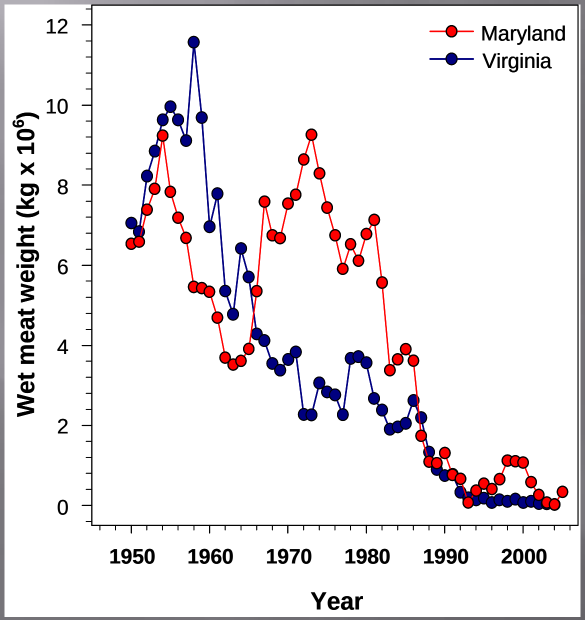
2014 Funding:

- NCBO Funding in Harris Creek MD, nutrient fluxes + benthic community assessment + fish utilization
- TNC funding to examine oyster biomass-driven differences in biogeochemistry
- Just completed: MD Sea Grant/NOAA funded research on aquaculture biogeochemical effects
- Just completed: 2 Virginia studies (bayside/oceanside) on oyster nutrient cycling.

Previous and Ongoing Studies

Outline

- Evolution of measurement approaches
- Prior studies
- Biogeochemical concepts
- Putting flux rates in an environmental context



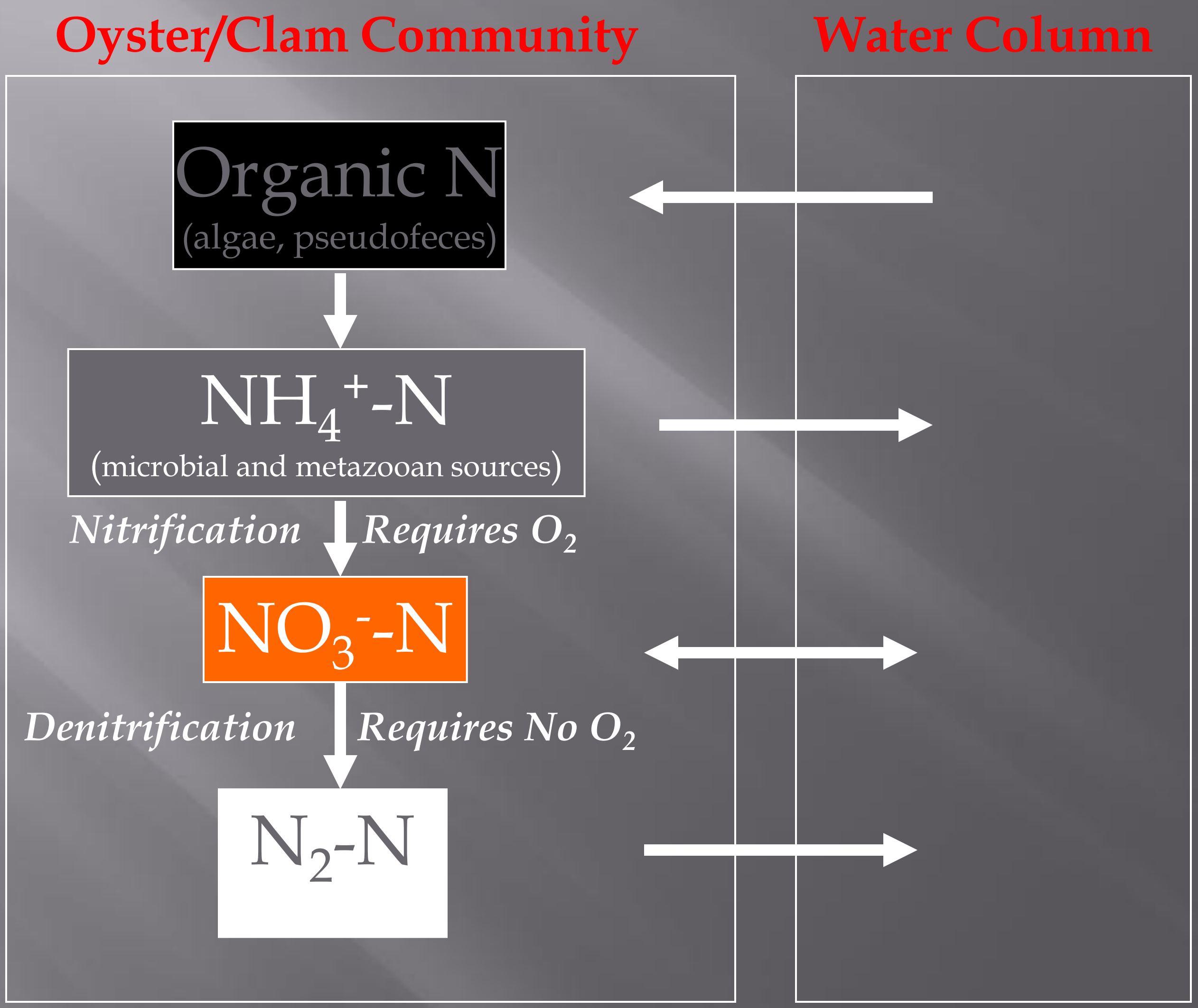
Data

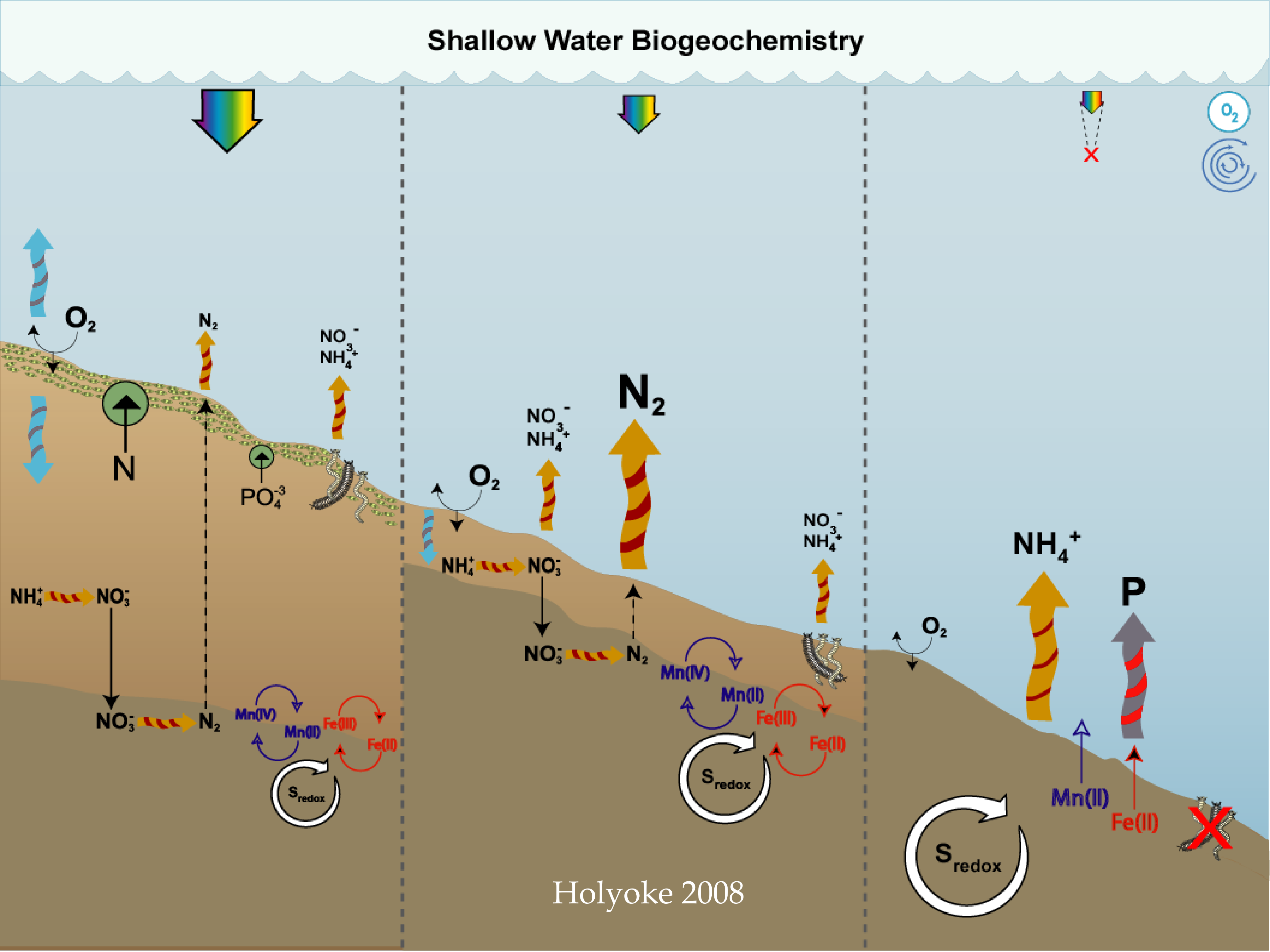
- Simulation of organic matter additions: Newell et al. 2002; Holyoke 2008
- Aquaculture-related studies: Holyoke 2008; current MDSG work in Chesapeake, Maine; clam work in MD Coastal Bays
- Reef measurements – Kellogg et al. 2013

Talk Sections

- Biogeochemical fundamentals
- Restoration sites
- Aquaculture
- Modeling

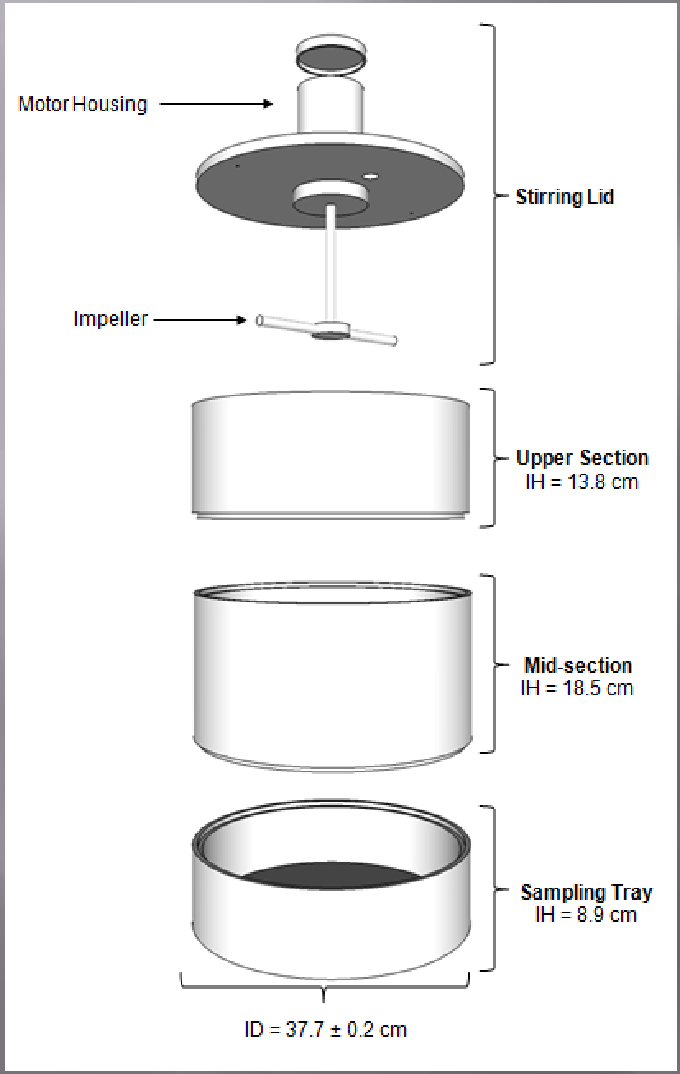
Denitrification




Shallow Water Biogeochemistry
O2
O2
N2
NO3-
NH4+
N
PO4-3
NH4+
NO3-
NO3-
N2
Mn(IV)
Mn(II)
Fe(III)
Fe(II)
Sredox
O2
NO3-
NH4+
N2
NH4+
NO3-
NO3-
N2
NO3-
NH4+
Mn(IV)
Mn(II)
Fe(III)
Fe(II)
Sredox
NH4+
P
O2
Mn(II)
Fe(II)
Sredox
Holyoke 2008

Restoration

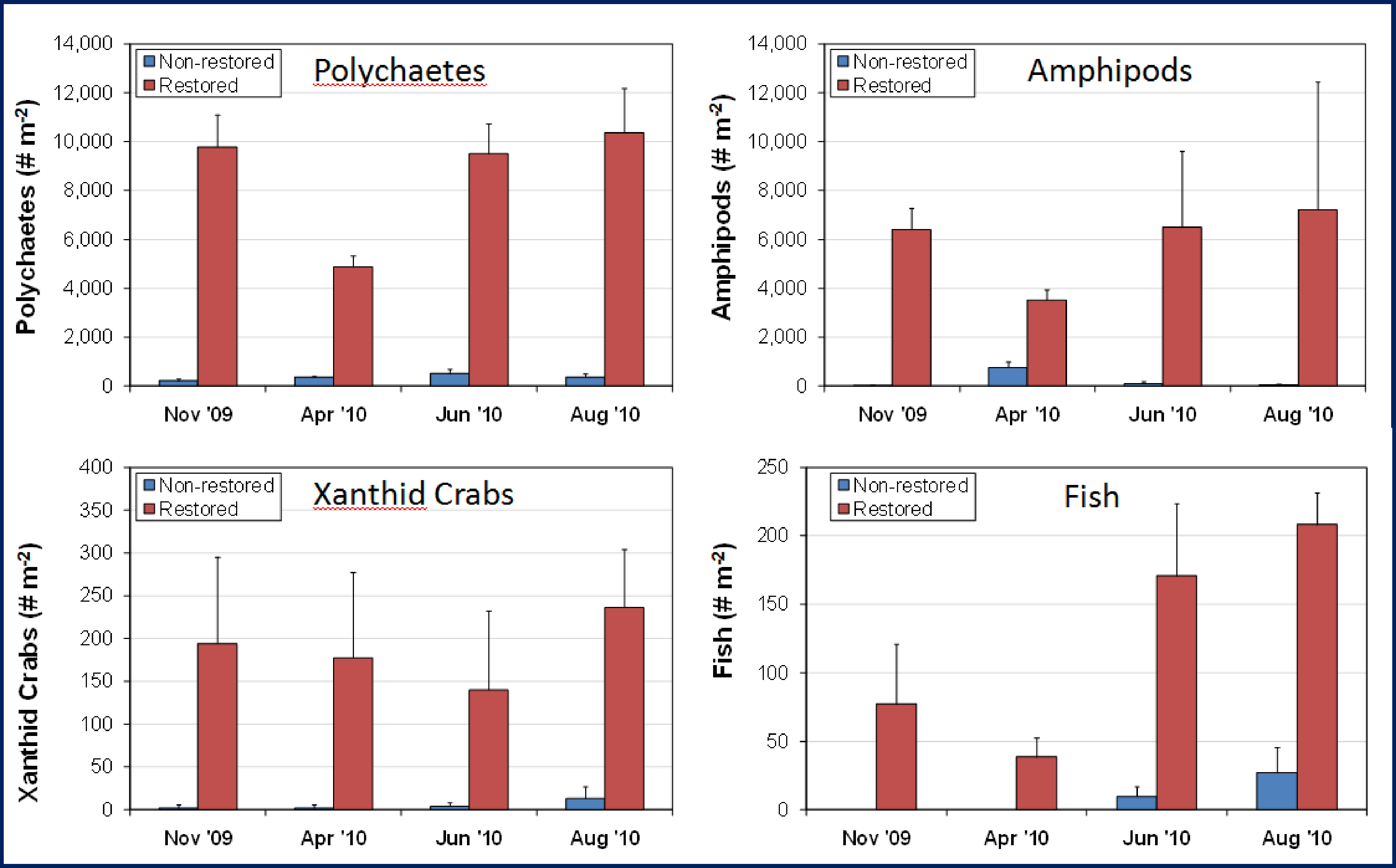
Choptank River Study



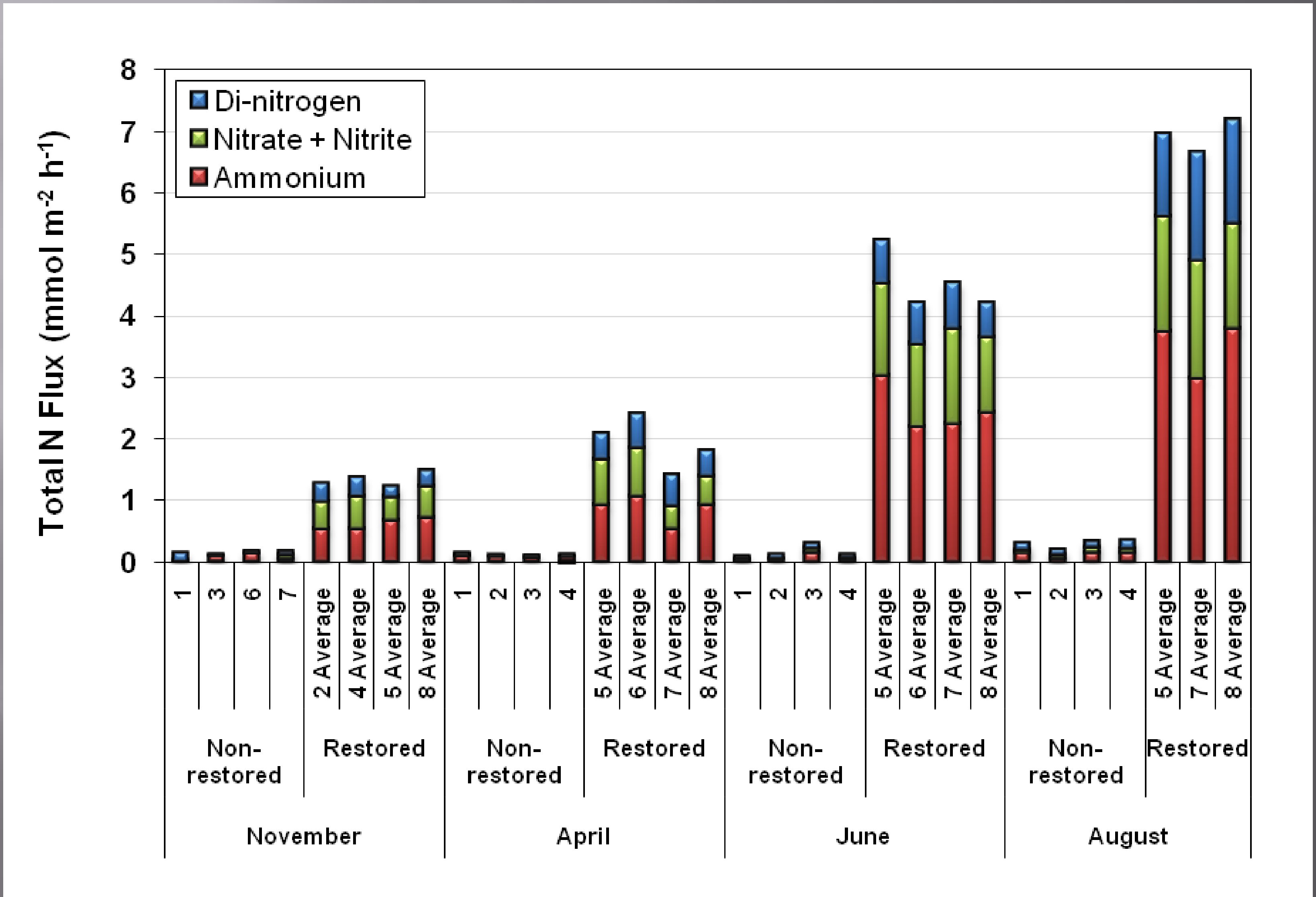
Funding from GenOn Energy with ORP

Faunal Abundance – Choptank River

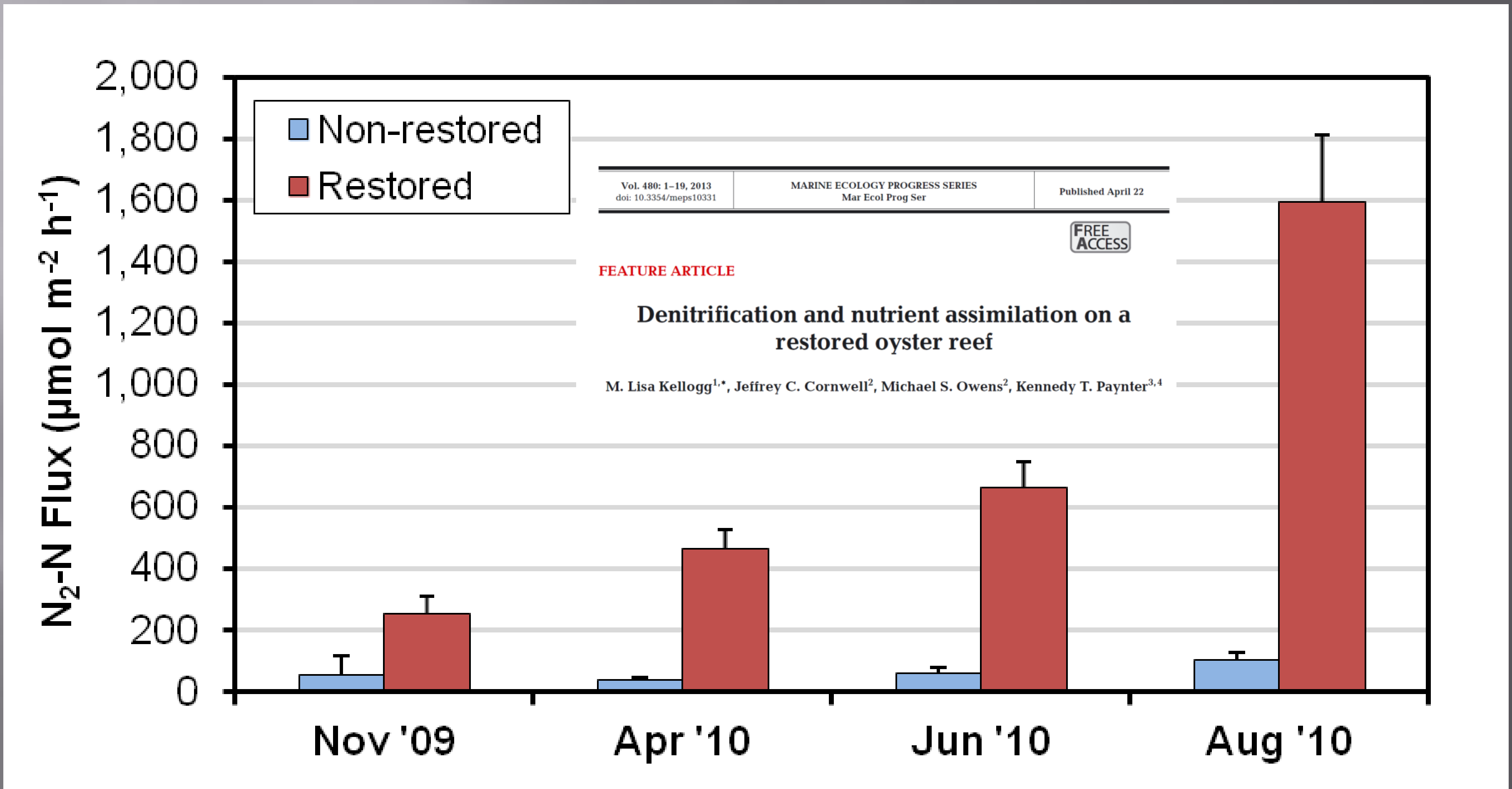
- **Higher abundances of most organism types on restored oyster reefs**



Small tray to tray variability!



Highest Chesapeake Rates Excluding Waste Water Plants



Impacts on WQ: Choptank River, MD Example

- Measured denitrification rates for a successfully restored oyster reef
  - Subtidal reef
  - Oysters 3-7 years old
  - High oyster biomass m^{-2}
- Estimated annual enhancement:
  - 55.6 g N_2-N m^{-2} y^{-1}

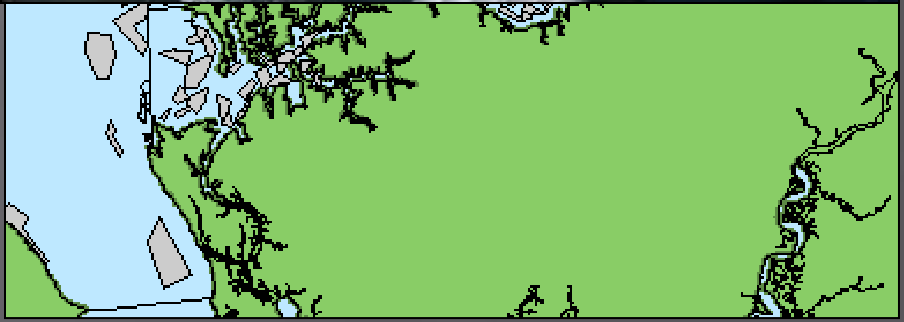
  (496 lbs. N $acre^{-1}$ y^{-1})

Restoring all suitable bottom:

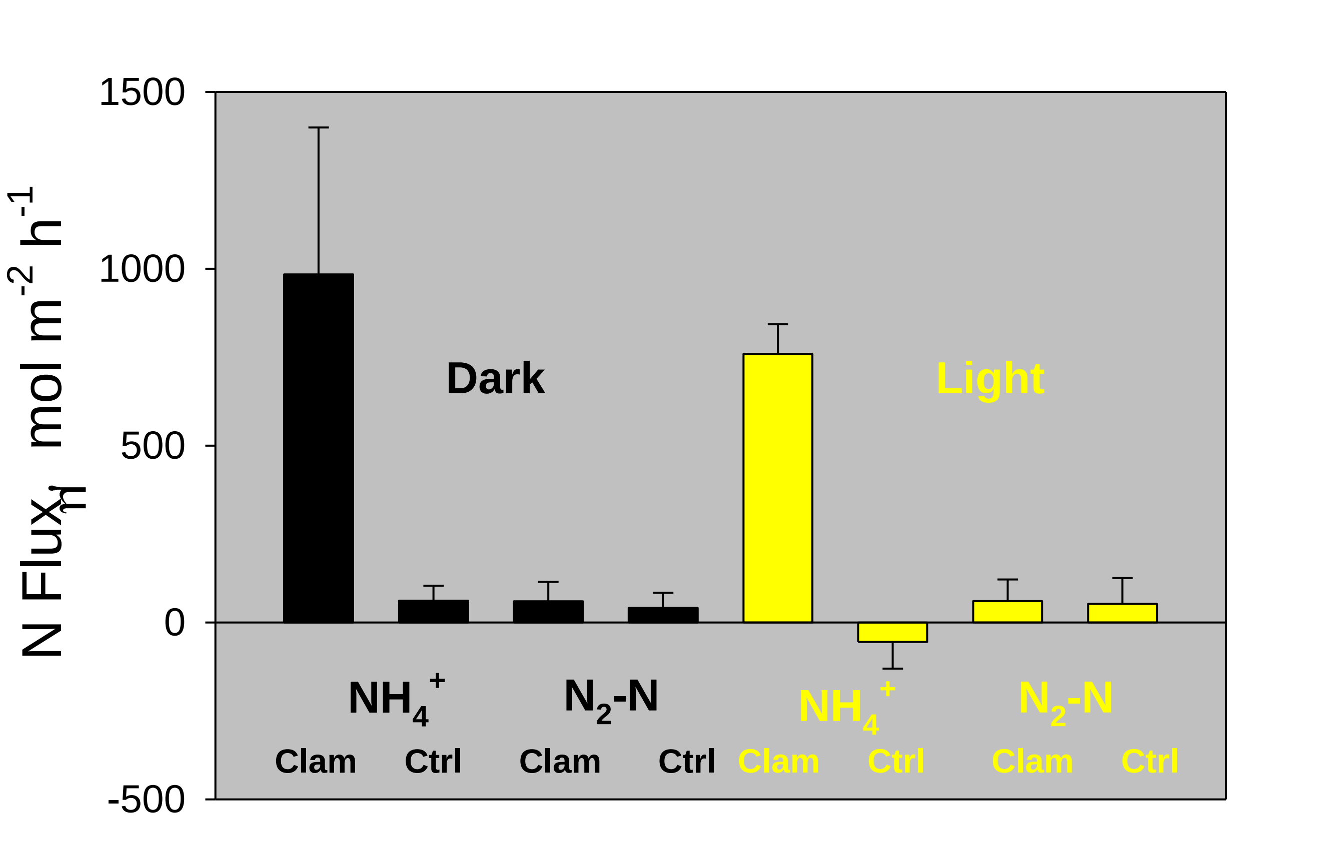
- “Suitable bottom” based on sonar surveys and fine-scale sampling of substratum
- 48% of total external N removed

Restoration needed to meet TMDL requirements:

- 23% of suitable bottom



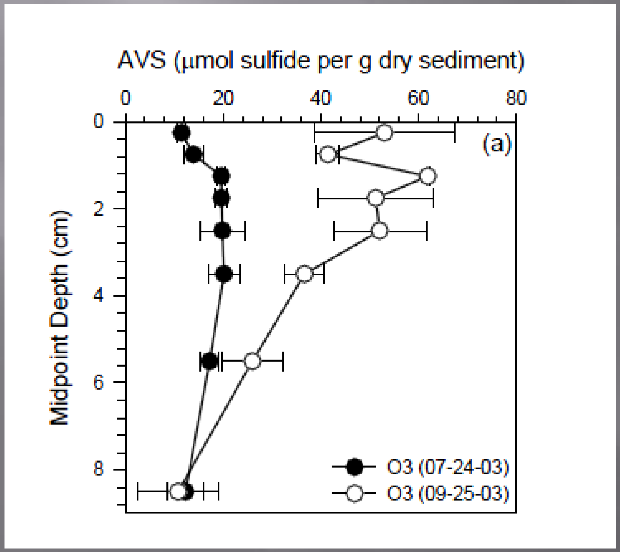
Coastal Bays Clams

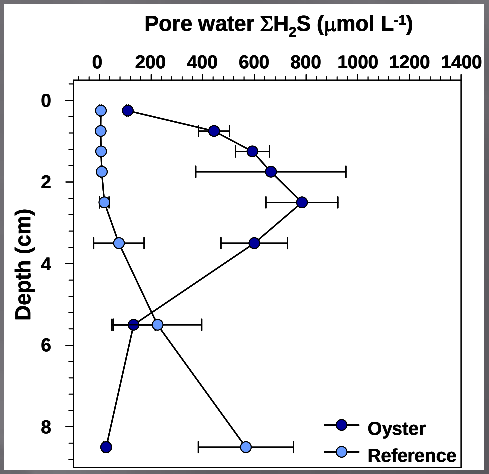


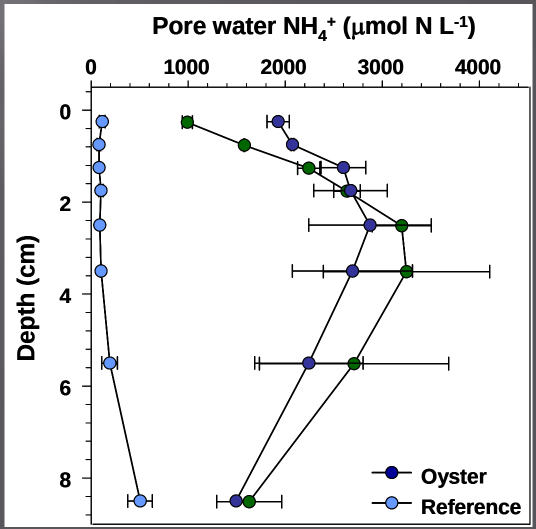
Aquaculture

La Trappe Creek Taylor Floats

•Low flow, shallow water turbid system. Large changes in P, Fe, S chemistry, loss of benthic animals.
•Changes in N flux were dramatically attenuated by benthic microalgal uptake of remineralized N
•Denitrification not a big sink for N







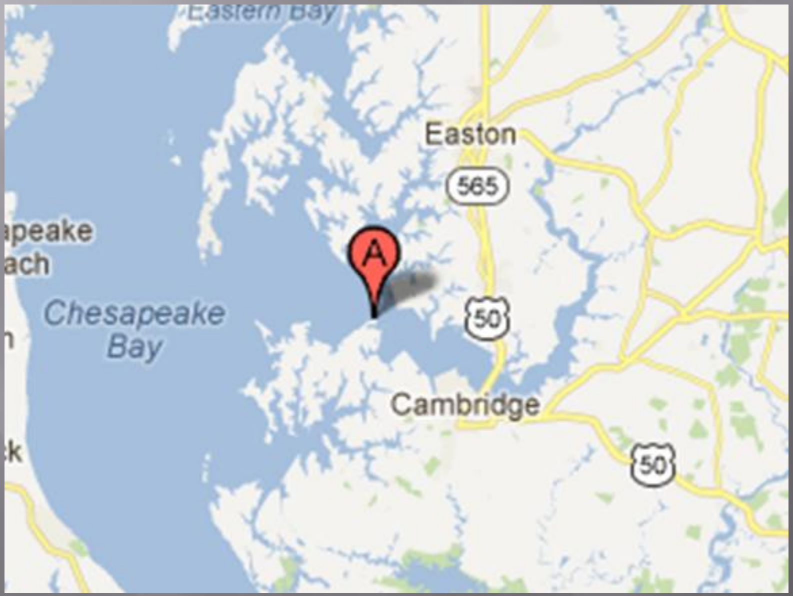
INVESTIGATIONS OF BIVALVE BIODEPOSIT DISPERSAL FROM AQUACULTURE FARMS

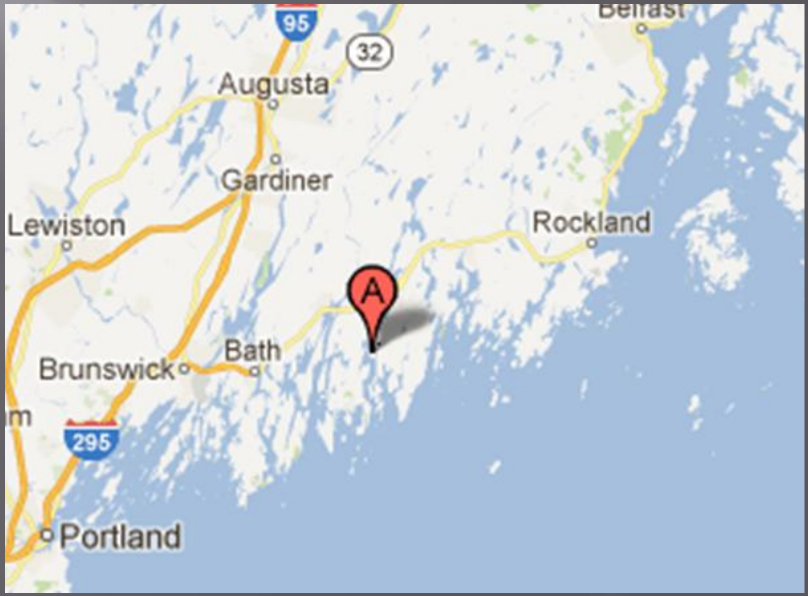
Larry Sanford, *Roger Newell, Jeff Cornwell, Carter Newell, John Richardson, Jeremy Testa, Damian Brady, Steve Suttles, Abbas Haghshenas, Mike Owens, and Sarah Kwon*

Funding from the NOAA National Sea Grant Office is gratefully acknowledged, as is the ready cooperation of Marinetics Oyster Farm (MD) and Mooks Oyster Farm (ME)

Study Sites

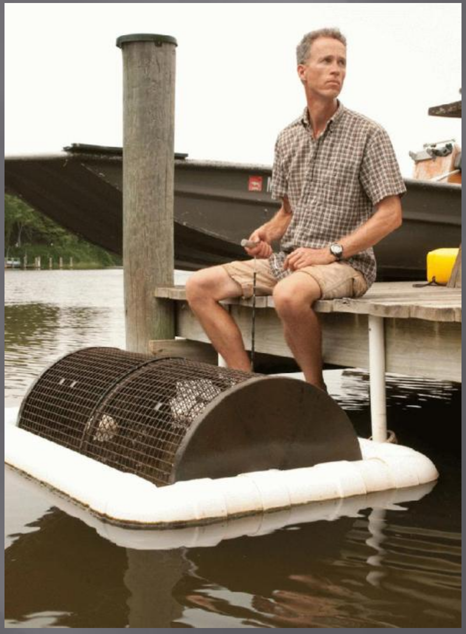
We carried out 4 intensive field studies at the Marinetics oyster farm at Castle Haven in the lower Choptank River, MD, during April, June, August, and September 2011, and 2 intensive field studies at a mussel farm and an oyster farm in the Damariscotta River, ME, during July 2012. These studies covered a wide range of temperatures, depths, tidal ranges, tidal currents, food supply, and farm design.





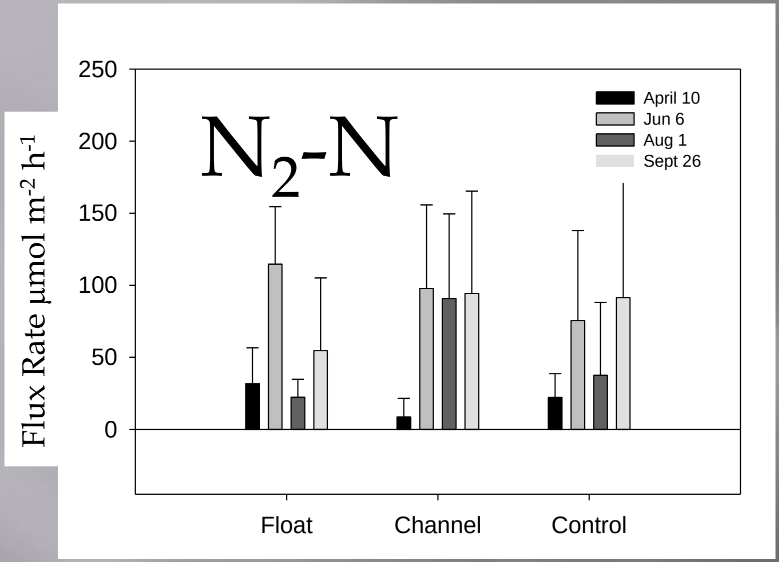
Measurements of sediment biogeochemical fluxes

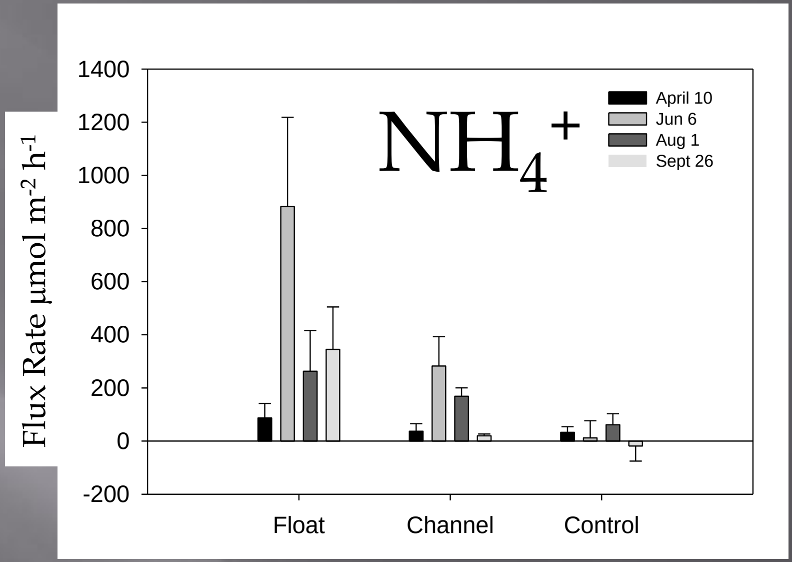
Different oyster aquaculture methods in the Chesapeake (most photos by David Harp in articles by Rona Kobell in the Chesapeake Bay Journal)



Measurements of currents, waves, tides, and water properties

Nitrogen Fluxes

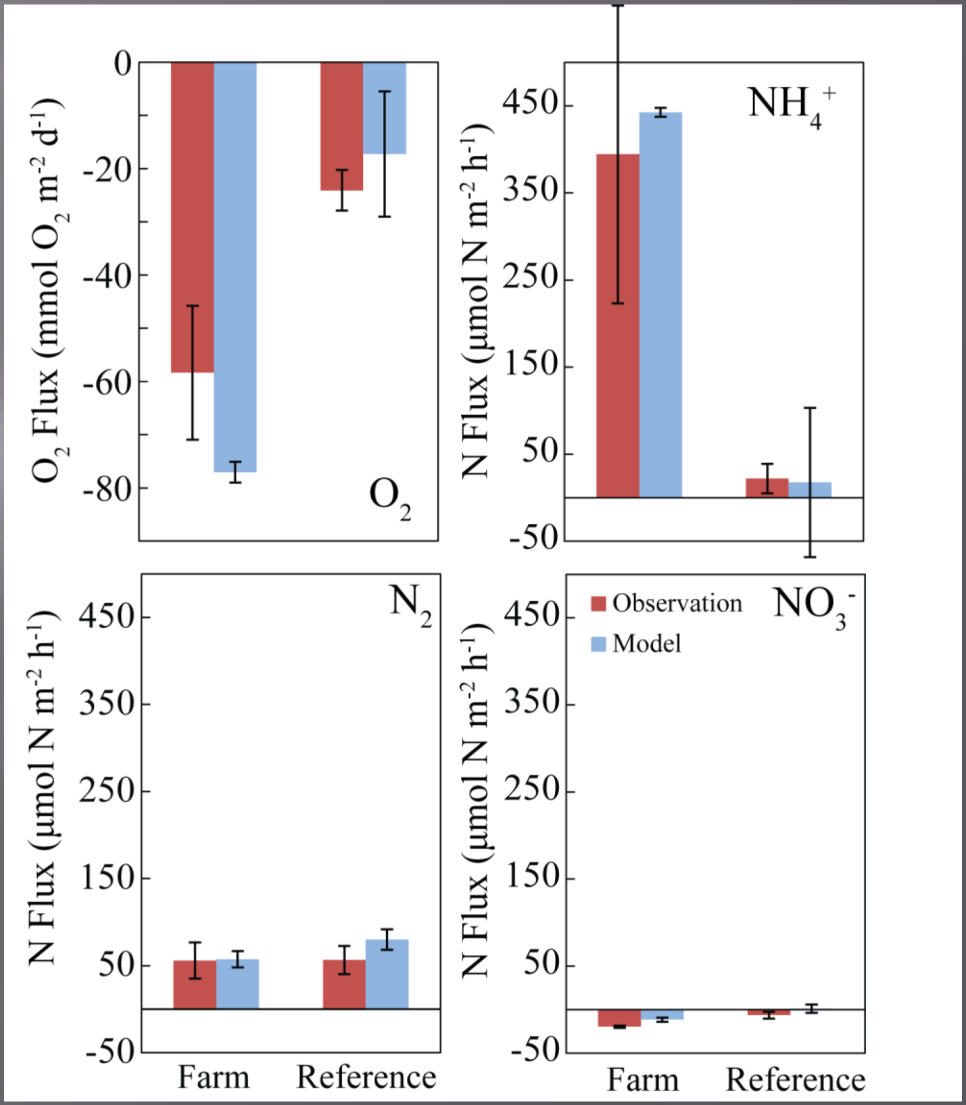


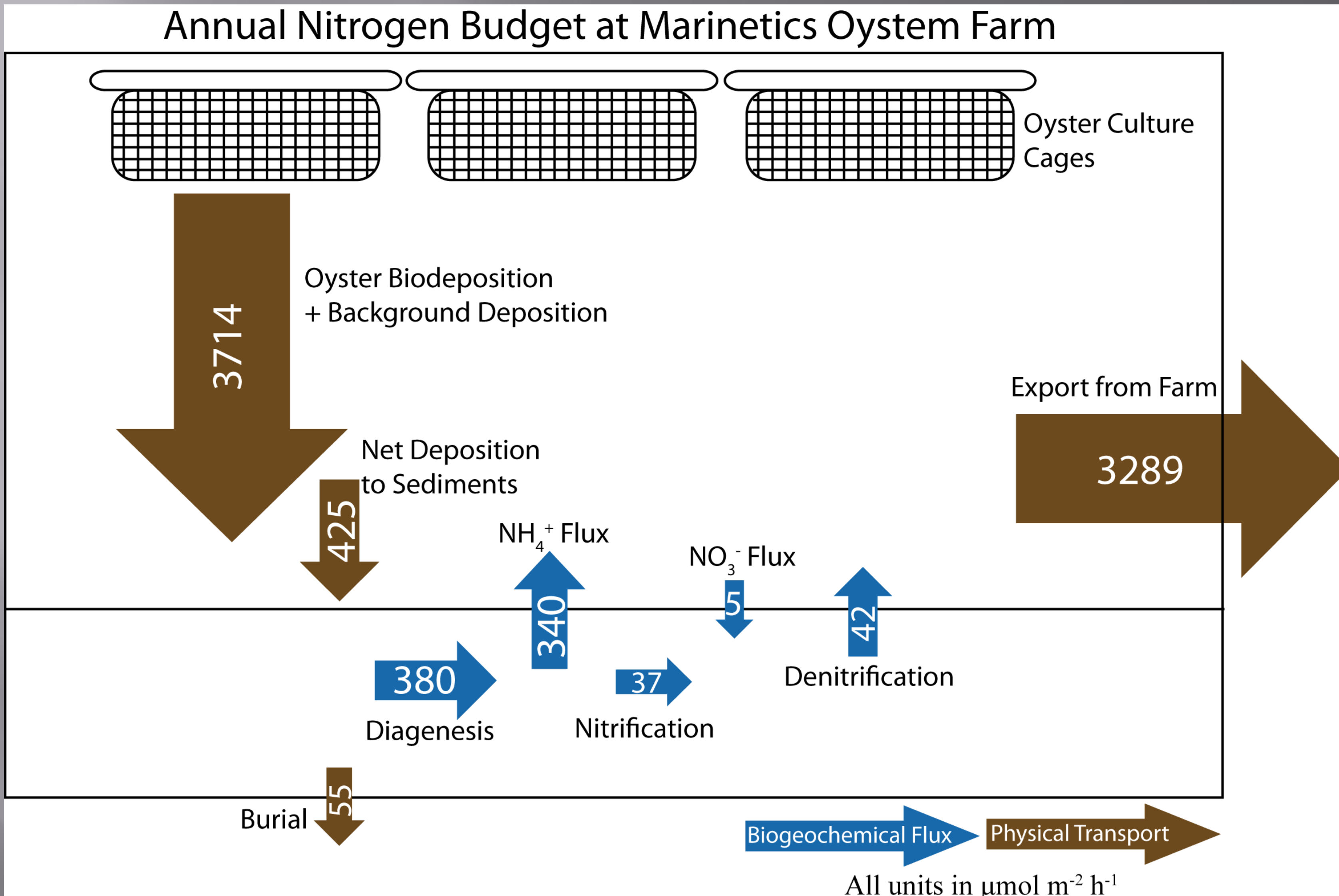


- High ammonium efflux rates occurred in June; at other times fluxes were higher than controls, but not extreme.
- Denitrification rates were relatively high at Channel and Control sites, somewhat attenuated at times under the oyster floats.
- The efficiency of denitrification relative to total N remineralization was 10-20% under the oysters, 20-70% at the other sites

SFM Modeling Results, Marinetics

- < 5% of oyster-generated organic matter was processed beneath the floats in the summer.
- Ammonium and oxygen fluxes are enhanced at farm site
- Denitrification, nitrate, and phosphate flux not enhanced below farm (although the model predicts significant reductions in aerobic layer depth)





Annual Nitrogen Budget at Marinetics Oystem Farm
Oyster Culture Cages
3714
Oyster Biodeposition + Background Deposition
Export from Farm
3289
Net Deposition to Sediments
425
NH$_4^+$ Flux
340
NO$_3^-$ Flux
5
42
380
Diagenesis
37
Nitrification
Denitrification
55
Burial
Biogeochemical Flux
Physical Transport
All units in µmol m^{-2} h^{-1}

Challenges in Modeling the Water Quality Benefits of Oyster Reef Restoration: Harris Creek, MD

M. Lisa Kellogg, Mark J. Brush and Younjoo Lee*

*Bigelow Laboratory for Ocean Sciences

Harris Creek Model

User inputs for each segment

- Area of reef
  - Upper bound set by total amount of suitable bottom in each segment
- Oyster per unit area
- Mean oyster biomass or length

2. Specify the density of restored oysters (#/acre) in each spatial element.

Restored Oyster Density

Oyster density[1]	0
Oyster density[2]	0
Oyster density[3]	0
Oyster density[4]	0
Oyster density[5]	0

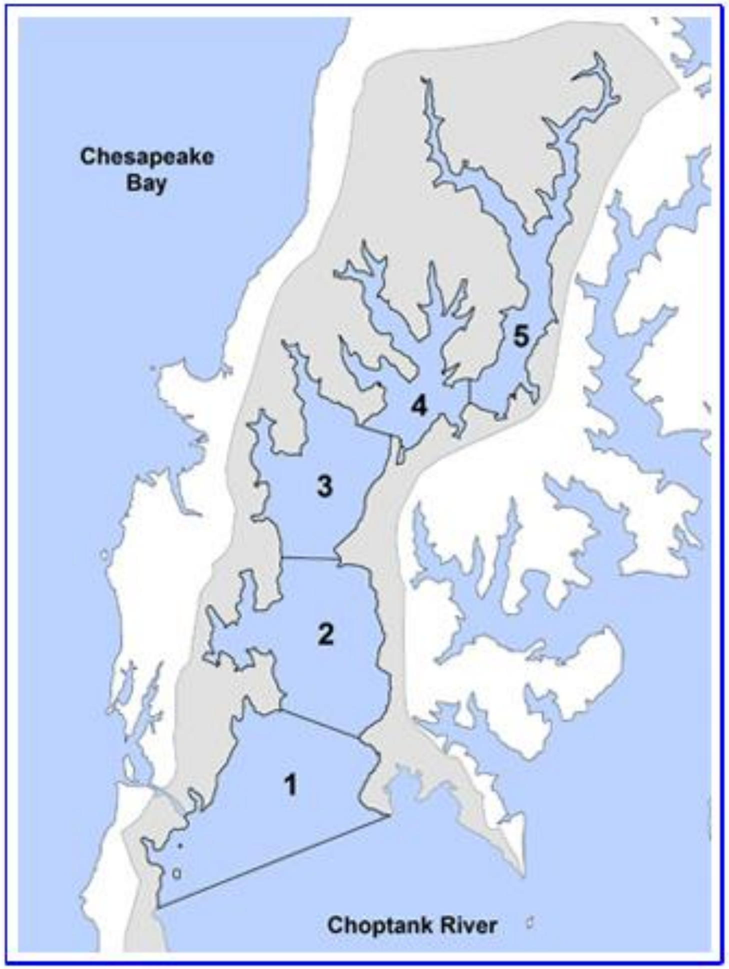
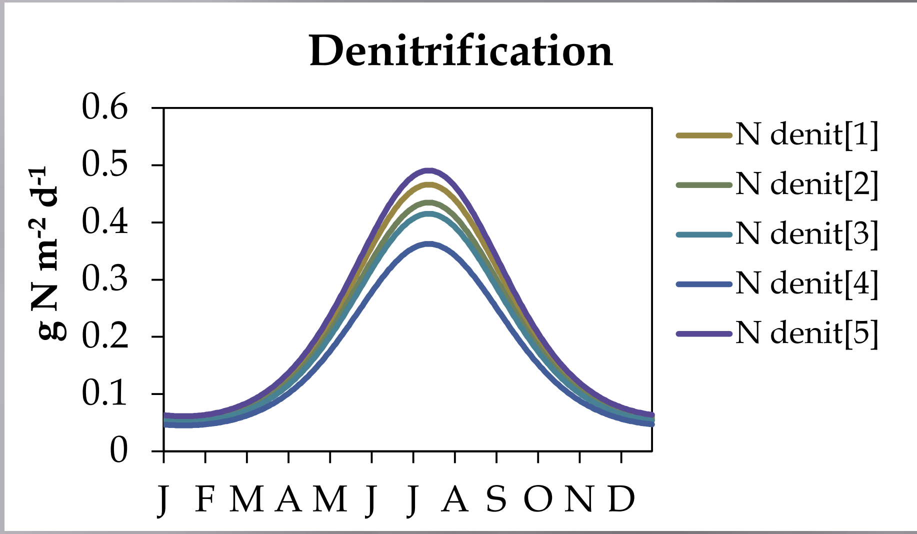
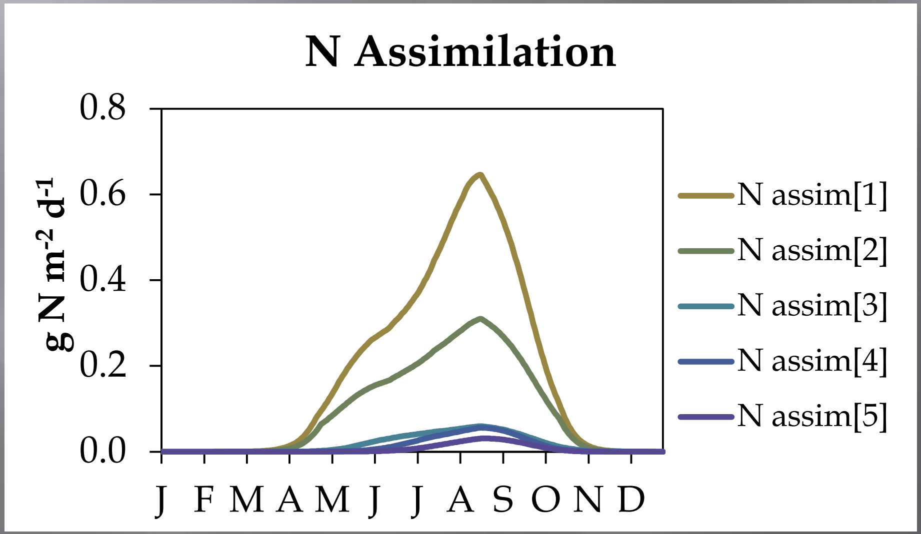


Fig. 1: Spatial elements (1-5) of the Harris Creek model. Watershed boundary is shown in light grey.

Harris Creek Model





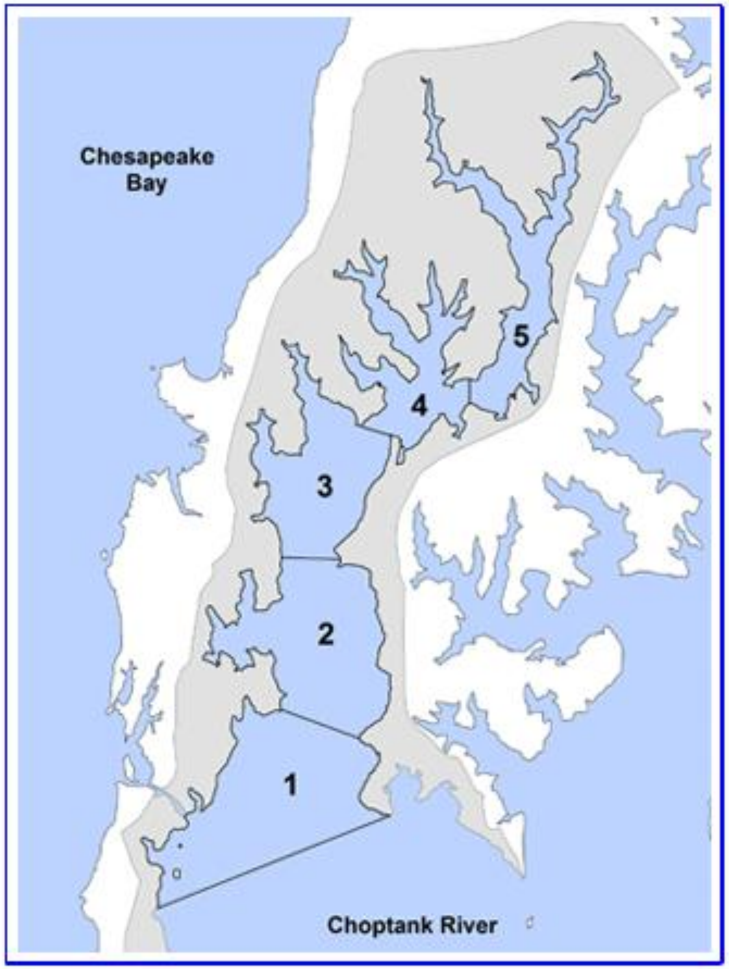
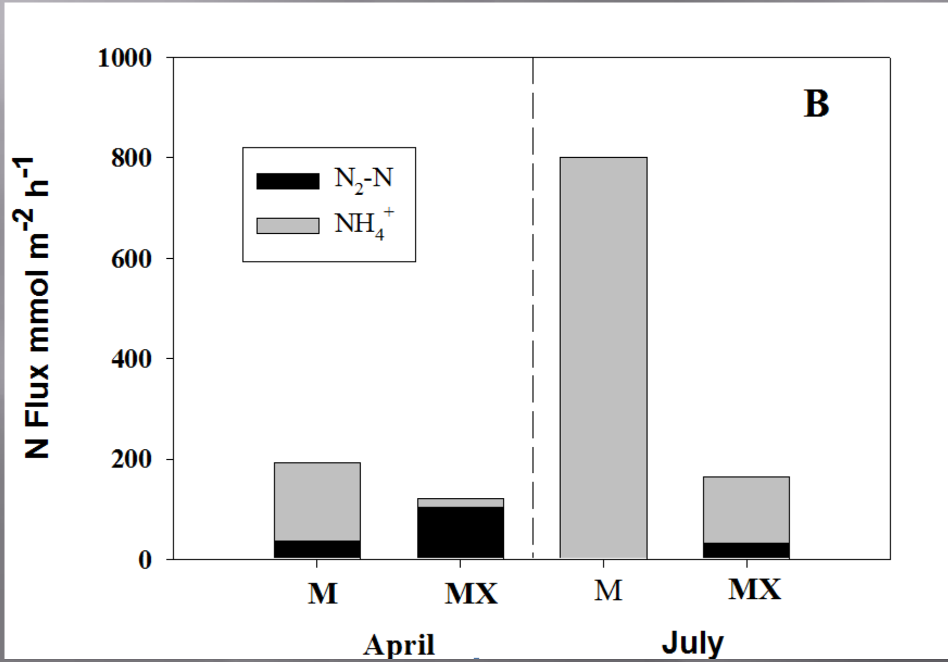


Fig. 1: Spatial elements (1-5) of the Harris Creek model. Watershed boundary is shown in light grey.

Large Scale Changes????

The Simple Case

If the fate of algal N is removal in shallow oyster reefs versus deep, anaerobic sediments, reef denitrification is a true net water quality benefit



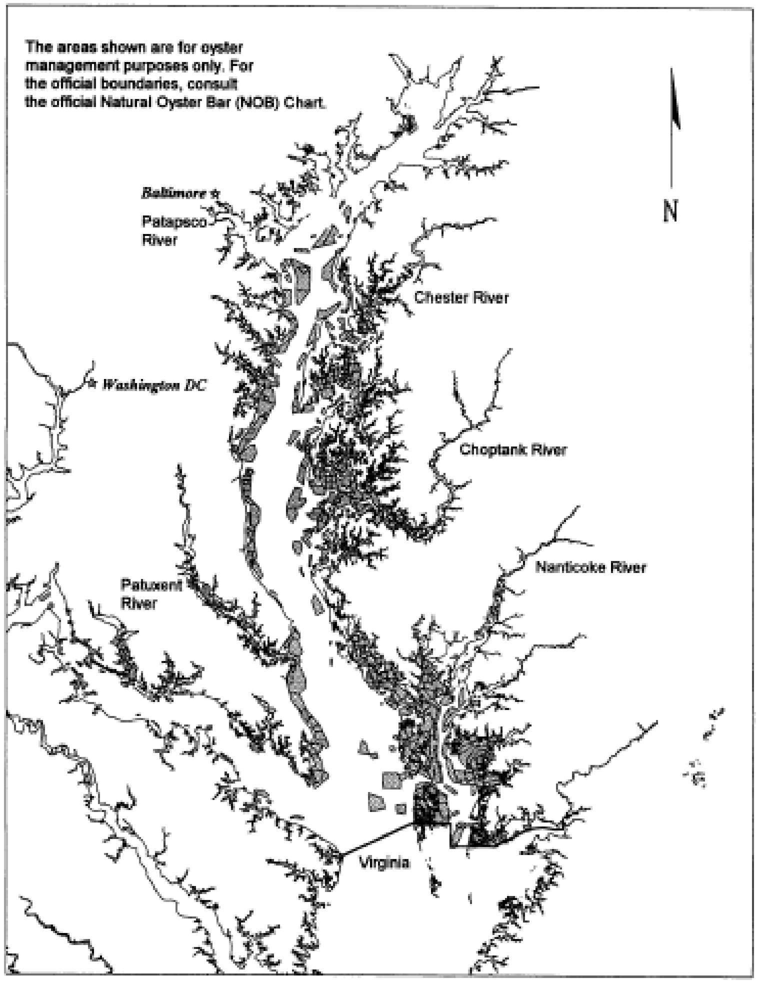
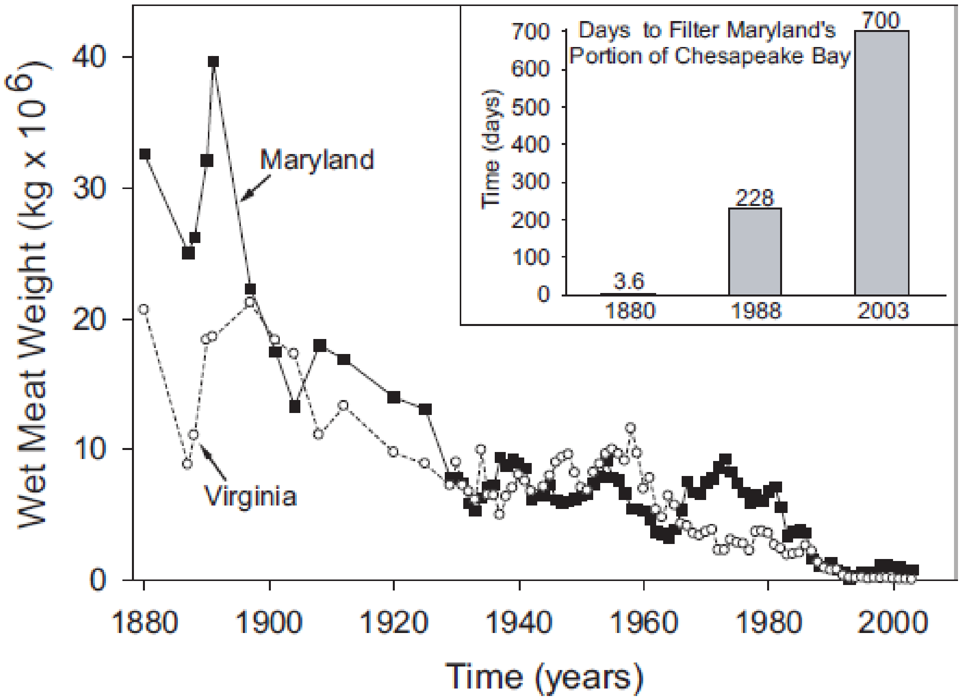
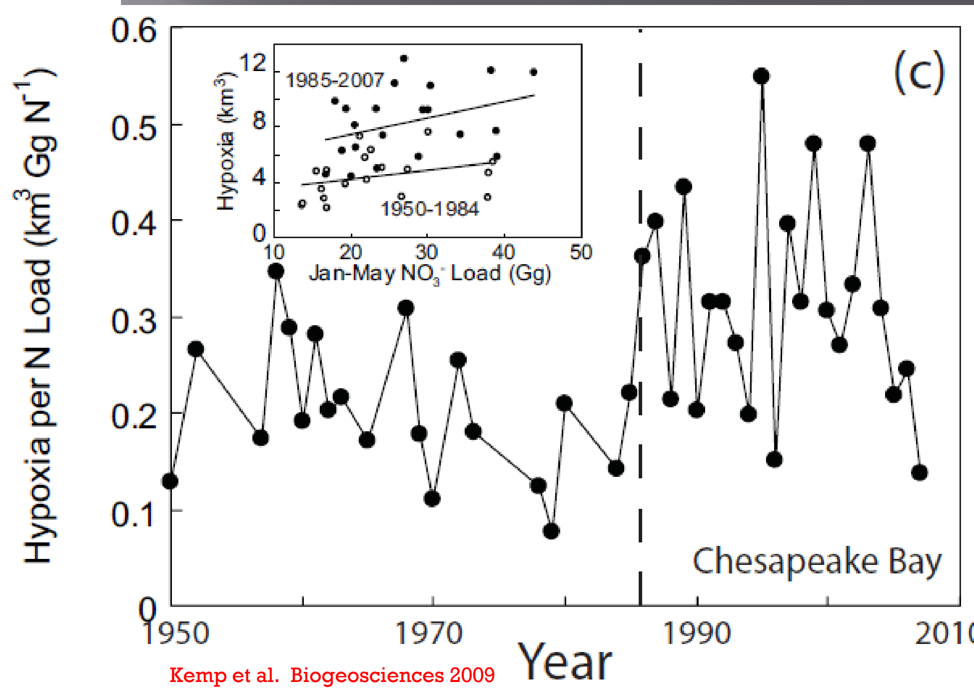


Figure 1. Maryland Historic Oyster Bottom. Depiction based on the MDNR spatial data file - MDOYSBRS. Shaded regions are named oyster bottom.



Kemp et al. MEPS 2005



Kemp et al. Biogeosciences 2009