# Nutrient Removal by Oysters:
## A Review of Where We Are

Mark W. Luckenbach
Virginia Institute of Marine Science
College of William & Mary

Chesapeake  Bay Program
Citizen's Advisory Committee
November 19, 2015

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# Outline

I. Nutrient and sediment removal pathways involving oysters

II. STAC review

III. New data and analyses since STAC review

IV. Scaling issues

# Removal Pathways

www.dnr.sc.gov

Oysters are filter-feeders. They filter *stuff* out of the water.

The *stuff* that most TMDLs seek to reduce is nitrogen (N).

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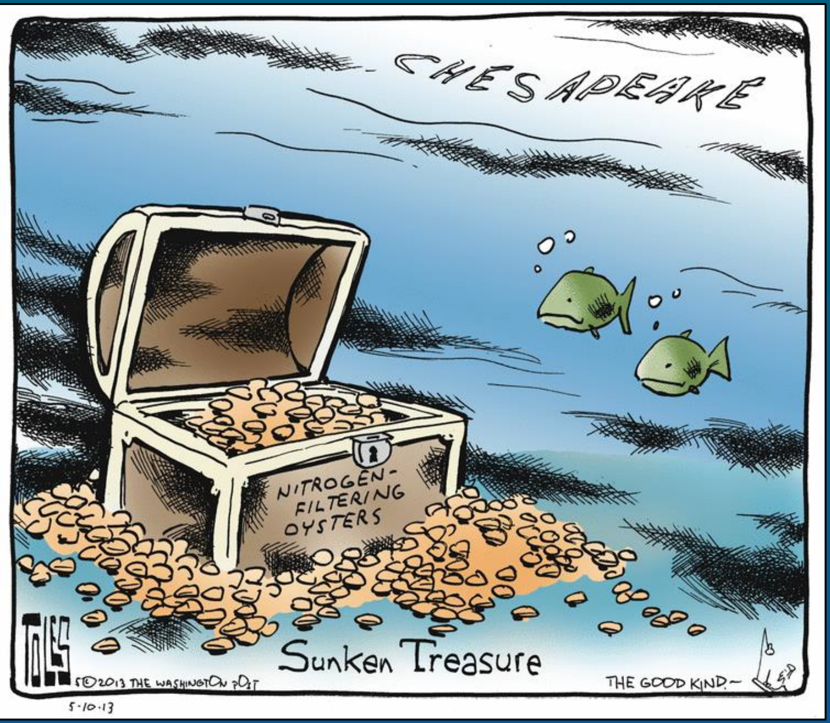
# Removal Pathways

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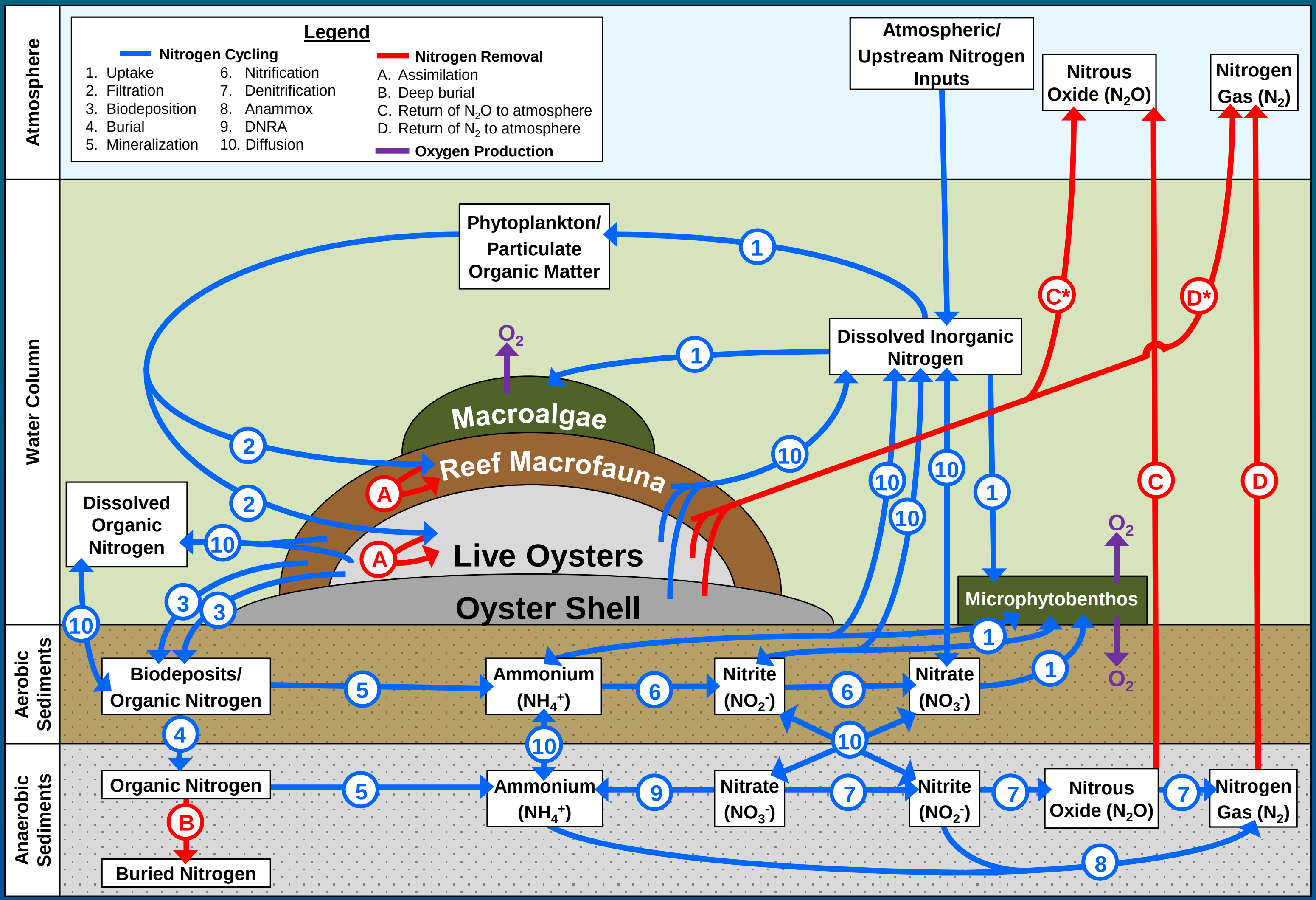
Oysters don't filter N, they filter phytoplankton that contain N (and P).

So, what happens to the N when they filter phytoplankton?

# Nitrogen Cycling




* Nitrogen cycling pathways resulting in removal assumed to be similar to those shown for sediments

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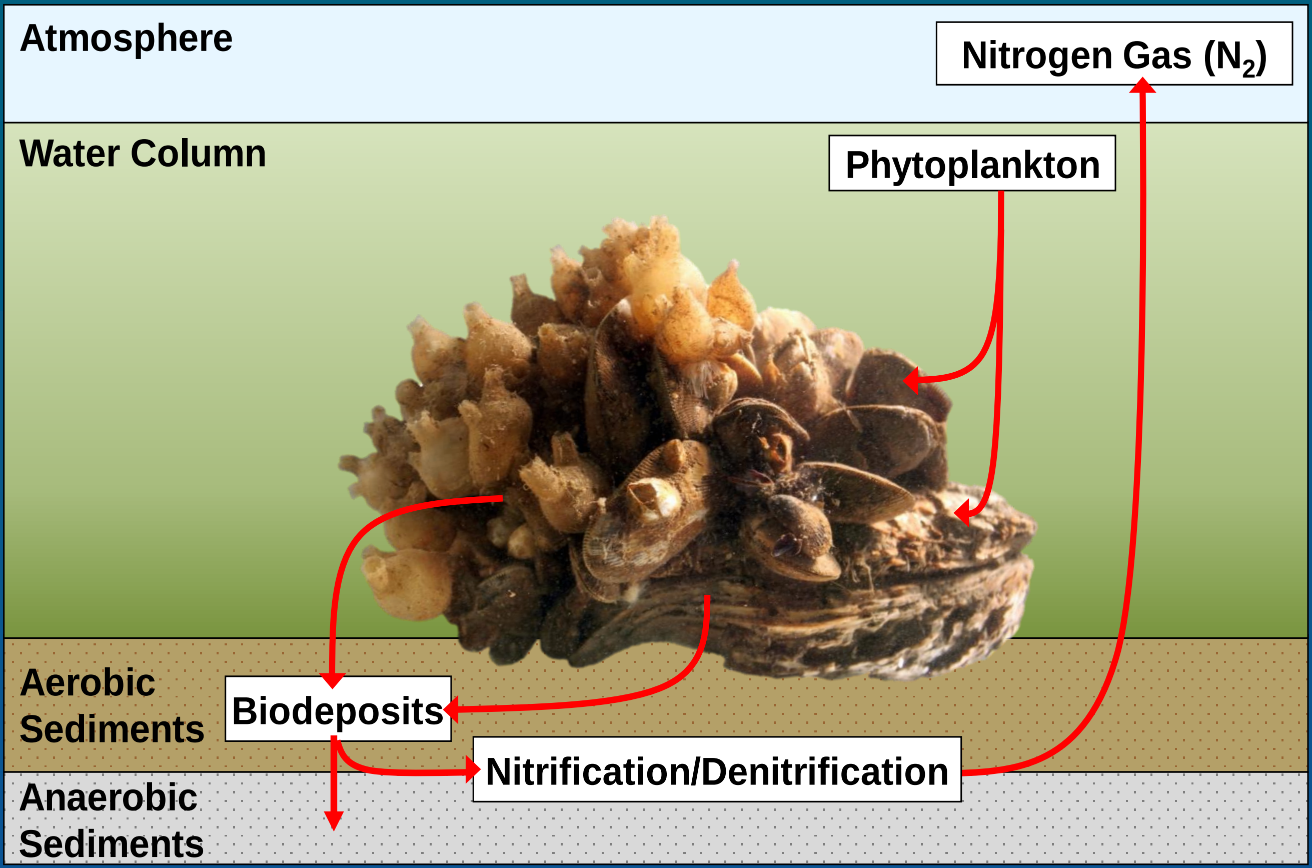
# Removal Pathways

Net N removal = assimilation + denitrification + burial

Enhanced removal = reef site – control site




<u>Assimilation</u>
8.2% tissue DW
0.2% shell DW

<u>Burial</u>
No field data

<u>Denitrification</u>
Variable

# Removal Pathways

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## Evaluation of the Use of Shellfish as a Method of Nutrient Reduction in the Chesapeake Bay

**A response to the request from the Management Board of the Chesapeake Bay Program**

**STAC Review Report**
**September 2013**

**STAC Publication 13-005**


**STAC Panel**

Mark Luckenbach
Donna Bilkovic
Charles Bott
Randy Chambers
Michael Ford
Jack Meisinger
Gene Yagow


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# NCBO – Sponsored Workshop
## Jan. 10 – 11, 2013
## Wachapreague, VA

Purpose: To gather experts to determine: (1) the best available values for nitrogen removal by oysters; (2) the uncertainty associated with these estimates; and, (3) the data gaps necessary to reduce the uncertainty

Moderated by Kevin Sellner (CRC)

Participants –

Lisa Kellogg (VIMS)
Mark Luckenbach (VIMS)
Jeff Cornwell (UMCES)
Mike Owens (UMCES)
Line zu Ermgassen (Cambridge)
Peter Bergstrom (NCBO)
Howard Townsend (NCBO)
Susan Connor (ACOE)
Doug Lipton (MD Sea Grant)
Troy Hartley (VA Sea Grant)
Steve Brown (TNC)

Mike Piehler (UNC)
Ruth Carmichael (USAB)
Bonnie Brown (VCU)
Wally Fulweiller (U. Mass)
Ken Paynter (UMD)
Stephanie Westby (NCBO)
Steve Allen (ORP)
Eric Weissberger (MD DNR)
Fredrika Moser (MD Sea Grant)
Boze Hancock (TNC)

Mark Brush (VIMS)
Iris Anderson (VIMS)
B.K. Song (VIMS)
Suzy Avvasian (EPA)
Annie Murphy (VIMS)
Bruce Vogt (NCBO)
Angie Sowers (ACOE)
Jim Wesson (VMRC)

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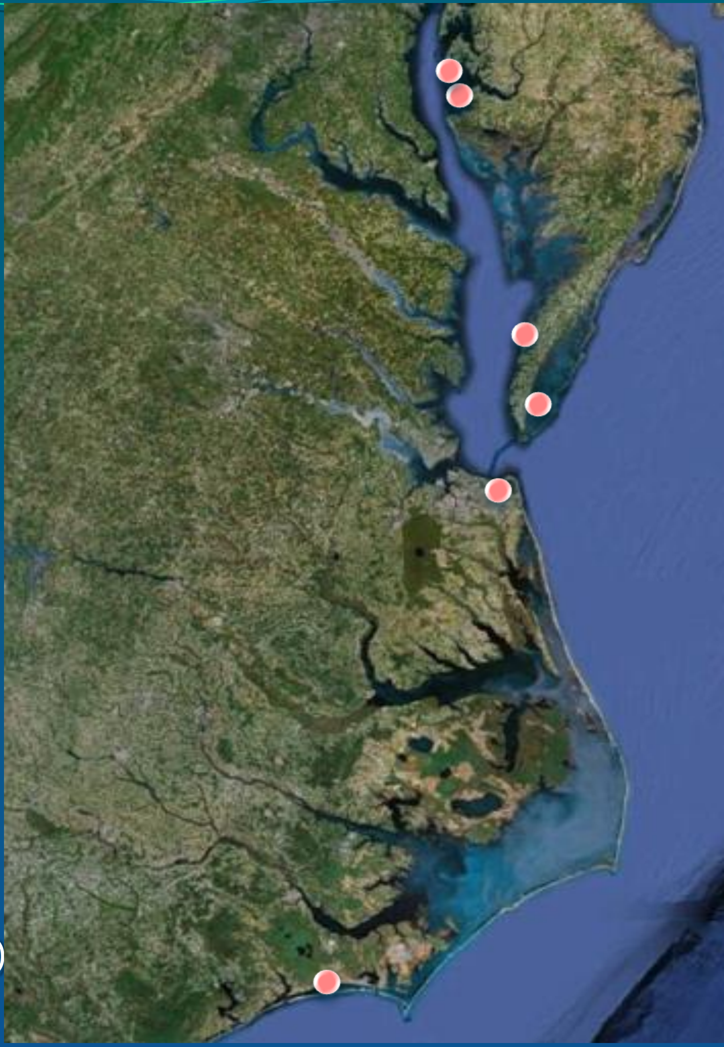
# Denitrification studies

1. Choptank River, MD (Kellogg et al. 2013)
   - Restored oyster reef vs. non-restored site
   - Subtidal, salinity ~7-11
2. Lynnhaven River, VA (Sisson et al. 2011, Kellogg in prep)
   - Existing reefs varying in oyster density
   - Intertidal and subtidal, salinity ~20
3. Onancock Creek, VA (Kellogg et al. in prep)
   - Experimental reefs with range of oyster density
   - Shallow subtidal, salinity ~15
4. Hillcrest Oyster Sanct., VA (Kellogg et al. in prep)
   - Experimental reefs with range of oyster density
   - Intertidal, salinity ~30
5. Bogue Sound, NC Piehler & Smyth 2011; Smyth et al 2013)
   - Intertidal, natural reefs
6. Harris Creek, MD (Cornwell, Kellogg et al. Ongoing)
   - Tributary-scale oyster reef restoration effort
   - Subtidal, salinity 11-18



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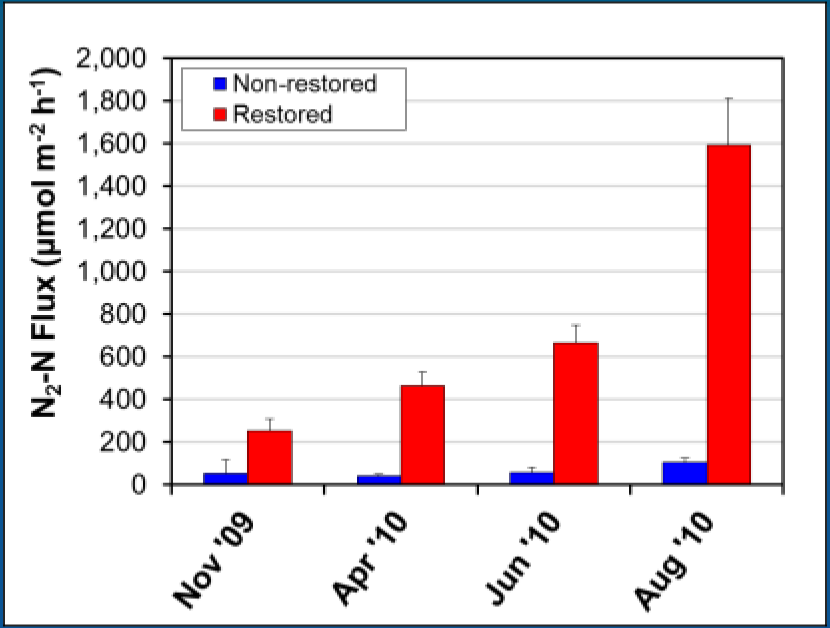
# Denitrification studies – Choptank

Kellogg et al. (2013) studied a restored oyster reef in the Choptank River, MD

251 kg N per acre were stored in the tissues and shells of oysters, but this included high densities of oysters up to 7 years old.

225 kg N per acre per year is lost through denitrification.




At this rate, if 23% of the suitable bottom in the Choptank River were restored with comparably healthy oyster reefs, it would equal the entire nutrient reduction target for that tributary.

**Wow!**

# Denitrification studies - Reefs

| Source | Location | Conditions | Measured value | Values | Comments |
|---|---|---|---|---|---|
| Piehler and Smyth 2011 | Intertidal oyster reefs in NC | Feb., May, July & Oct. measurements; intertidal mudflat reference sites | $N_2$ flux in cores containing reef sediments, but no shell. | Reference site<br>-4.5 µmol N $m^{-2}$ $d^{-1}$<br>Oyster reefs<br>17.8 µmol N $m^{-2}$ $d^{-1}$ | Denitrification significantly enhanced on intertidal oyster reefs |
| Kellogg et al. 2013 | Subtidal restored reef in the Choptank River | Oyster density – 131 $m^{-2}$ | N2 flux in chambers with reef materials | Reference site<br>39-105 µmol N $m^{-2}$ $d^{-1}$<br>Oyster reefs<br>252-1592 µmol N $m^{-2}$ $d^{-1}$ | Denitrification greatly enhanced on restored reef |
| Sisson et al. 2010 | Natural and restored reefs in Lynnhaven River. Intertidal & shallow subtidal | 7 small reefs with varying oyster density: 47 – 576 $m^{-2}$ | $N_2$ flux in chambers with reef materials | Reference site:<br>0 µmoles $m^{-2}$ $hr^{-1}$<br>Reef sites:<br>0 -324 µmoles $m^{-2}$ $hr^{-1}$ | Positive relationship between denitrification and total oyster biomass |
| Kellogg et al. (in prep.) | Shallow subtidal experimental oyster reefs | Experimental oyster reef densities = 0 to 250 oysters $m^{-2}$ | $N_2$ flux in chambers with reef materials | Reference site:<br>65 µmoles $m^{-2}$ $hr^{-1}$<br>Reef sites:<br>298-800 µmoles $m^{-2}$ $hr^{-1}$ | Positive, asymptotic relationship between oyster soft tissue biomass and denitrification |
| Kellogg et al. (on-going study) | Intertidal experimental oyster reefs | Experimental oyster reef densities = 0 to 250 oysters $m^{-2}$ | $N_2$ flux in chambers with reef materials | Reference site:<br>87-123 µmoles $m^{-2}$ $hr^{-1}$<br>Reef sites:<br>139-814 µmoles $m^{-2}$ $hr^{-1}$ | Weak relationship between DNF rates and oyster biomass. Lower than subtidal rates. |

1) DNF rates on oyster reefs are generally greater than those at reference sites.
2) The amount of DNF enhancement is highly variable.

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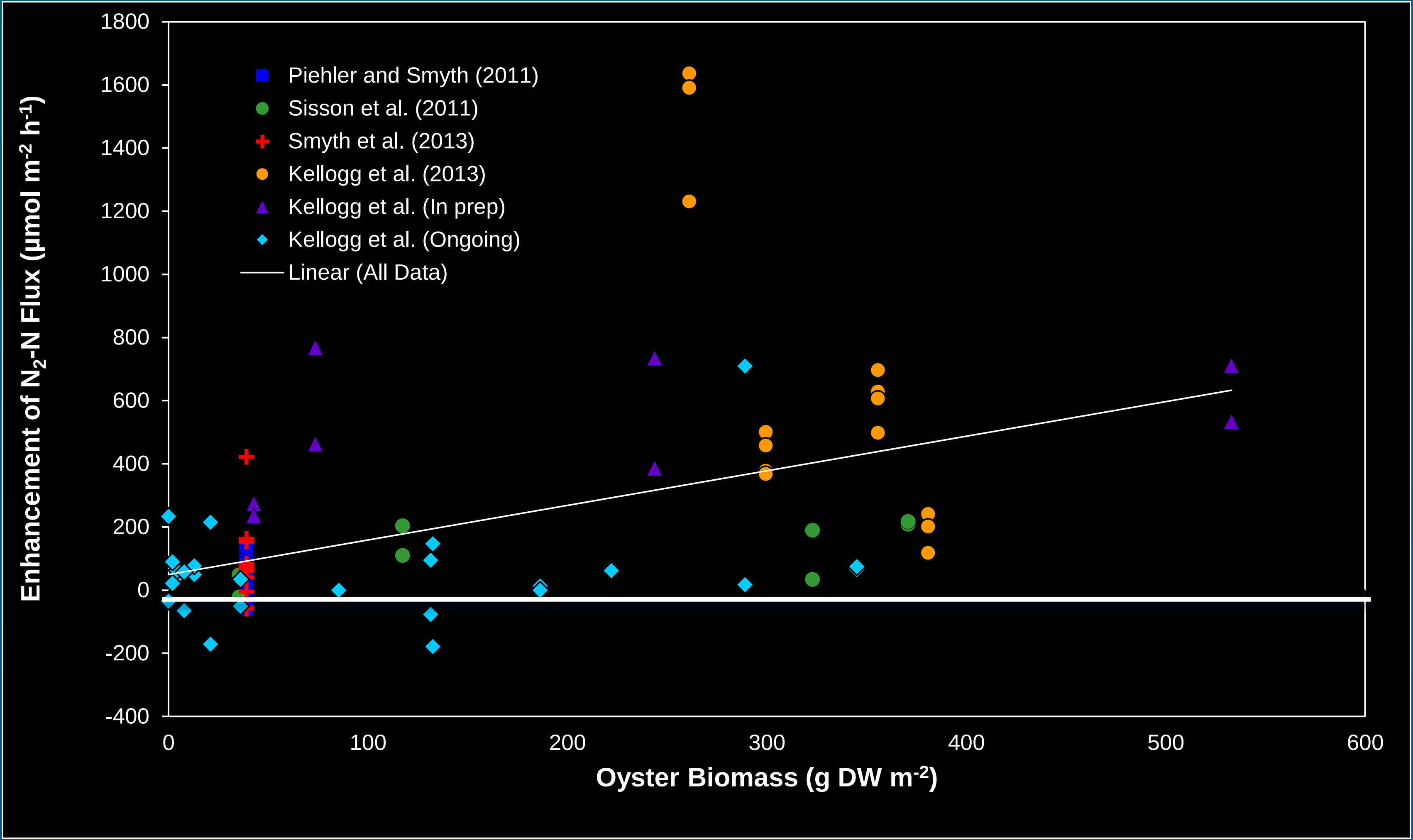
# Denitrification studies - Reefs



# Denitrification studies - Aquaculture

1. Choptank River, MD

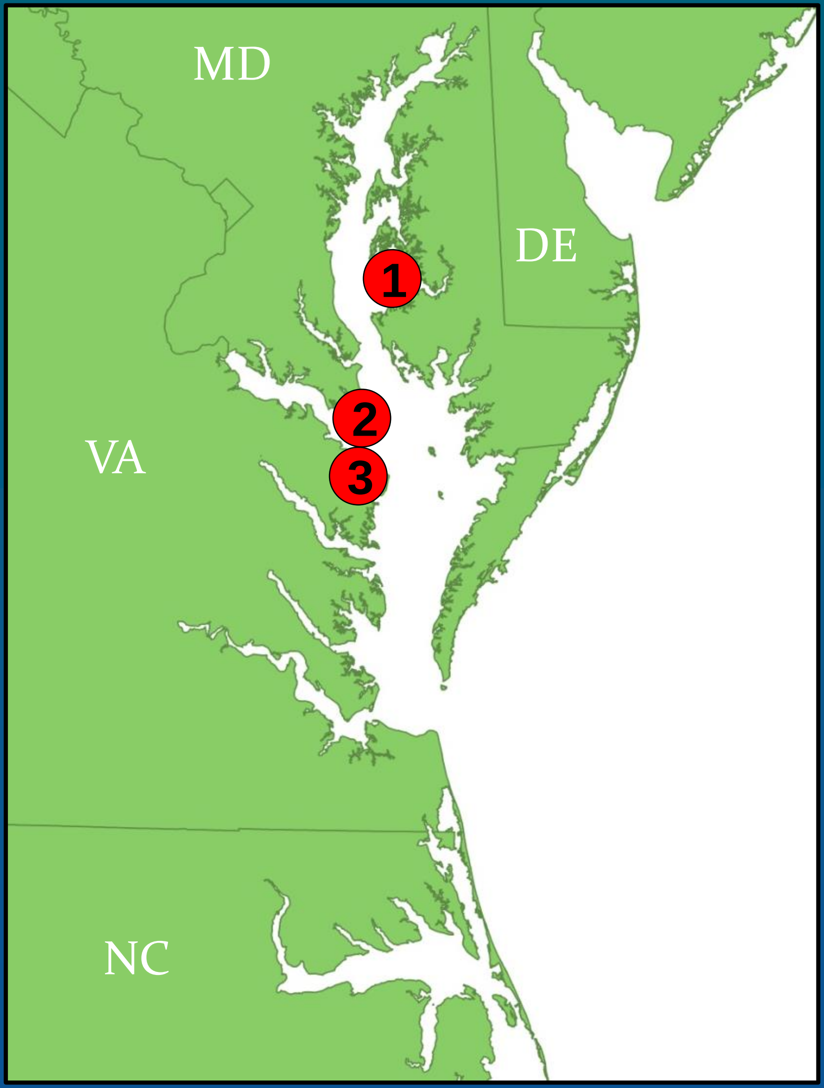
   Rebecca Holyoke (2008) Ph.D. Thesis, UMD.

   No increase in denitrification at 4 floating oyster aquaculture sites.

2. St. Jerome Creek, MD
3. Spencer Creek, VA

   Colleen Higgins et al. (2013)

   No increase in denitrification at 2 floating oyster aquaculture sites

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# STAC Panel Findings

Finding 1: Average nitrogen content in oysters can be estimated as 8.2% of tissue dry weight and 0.21% of shell dry weight.

Finding 2: Average phosphorus content can be estimated as 1.07% of tissue DW and 0.06% of shell dry weight.

Finding 3: Reliable estimates of total nutrient removal attributable to harvest of cultured oysters requires harvest data.

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# STAC Panel Findings

Finding 4: Burial rates of nutrients associated with oyster biodeposits have not been quantified and cannot at this time be assigned values for nutrient reduction.

Finding 5: Denitrification rates at sites with suspended oyster aquaculture have not been observed to be elevated relative to control sites.

# STAC Panel Findings

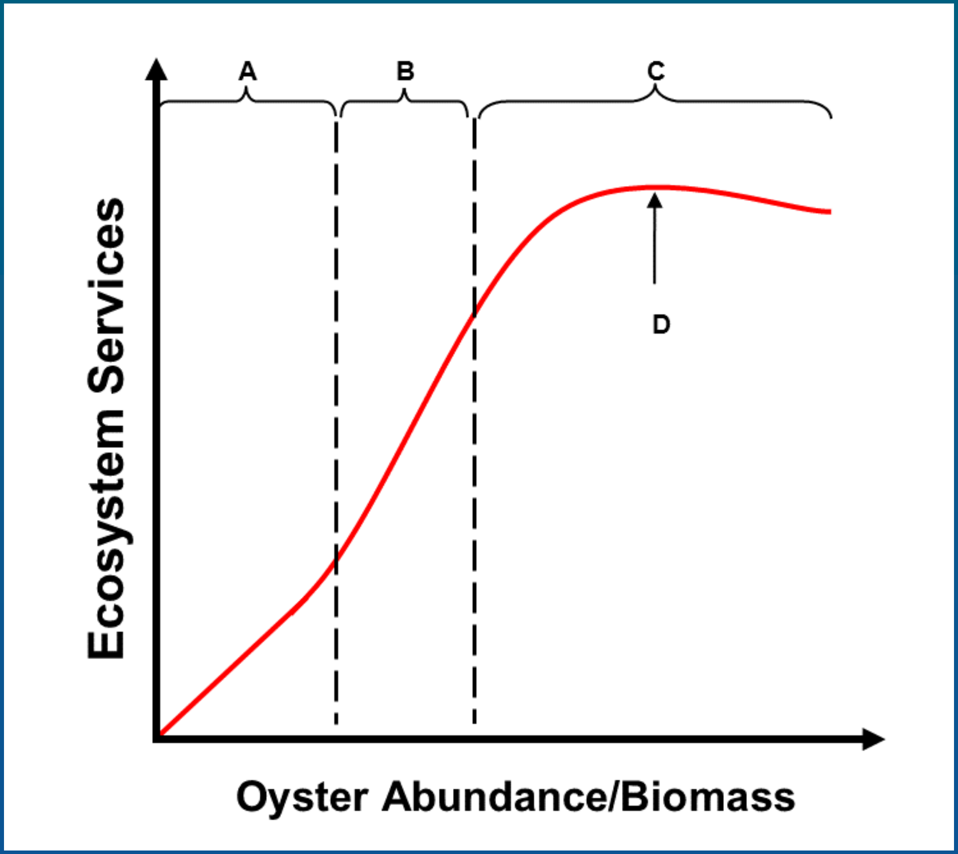
Finding 6: Denitrification rates measured for oyster reefs typically exceed background levels in control sites with reefs generally exhibiting rates of denitrification that are 1.5- to 14-fold increases above reference sites.

However, several factors including oyster biomass, tidal exposure, depth relative to the photic zone, and other unknown environmental factors affect these rates in ways that have not yet been fully quantified.

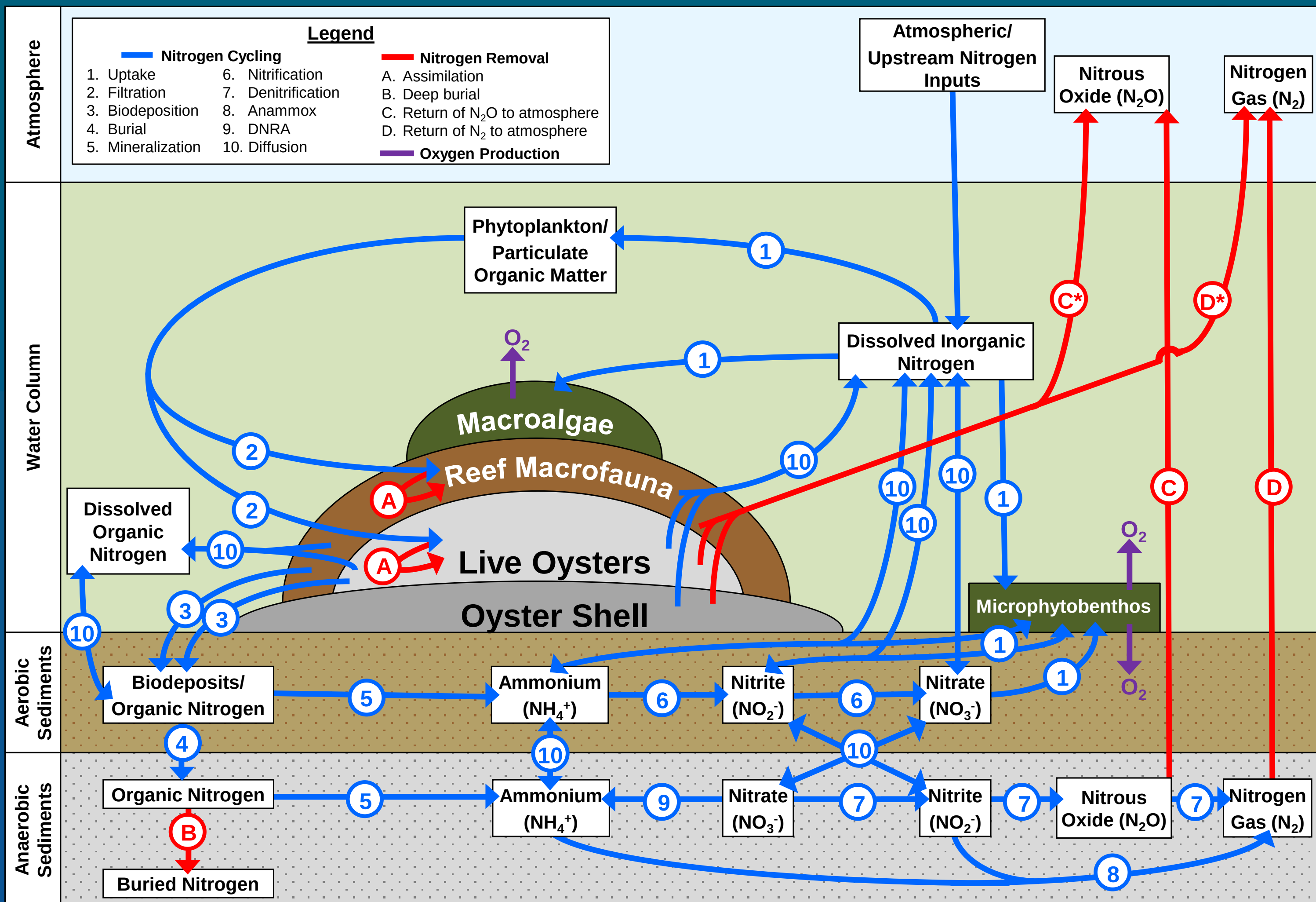
# Beyond STAC

Hypothesis 1: Positive relationship between oyster biomass and DNF

Hypothesis 2: DNF reduced in photic zone due to competition with benthic microalgae.



# Beyond STAC

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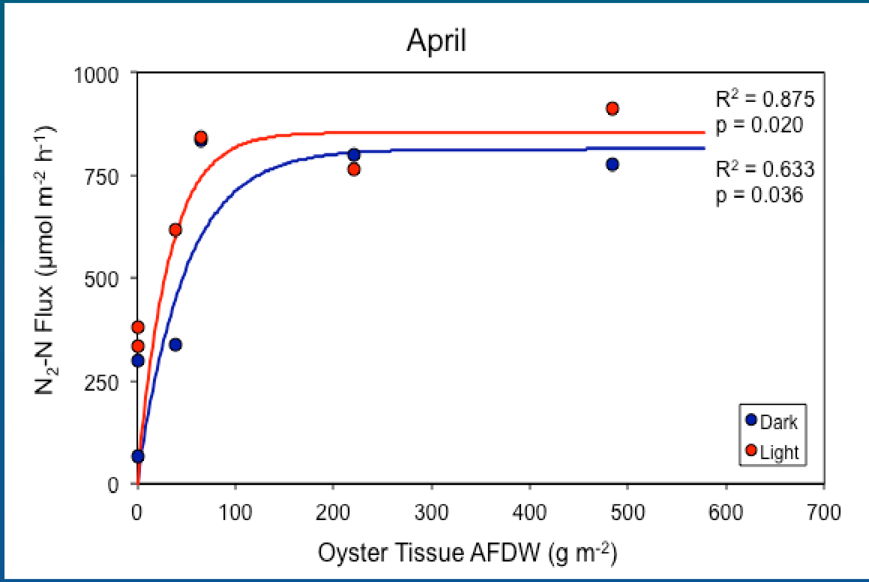
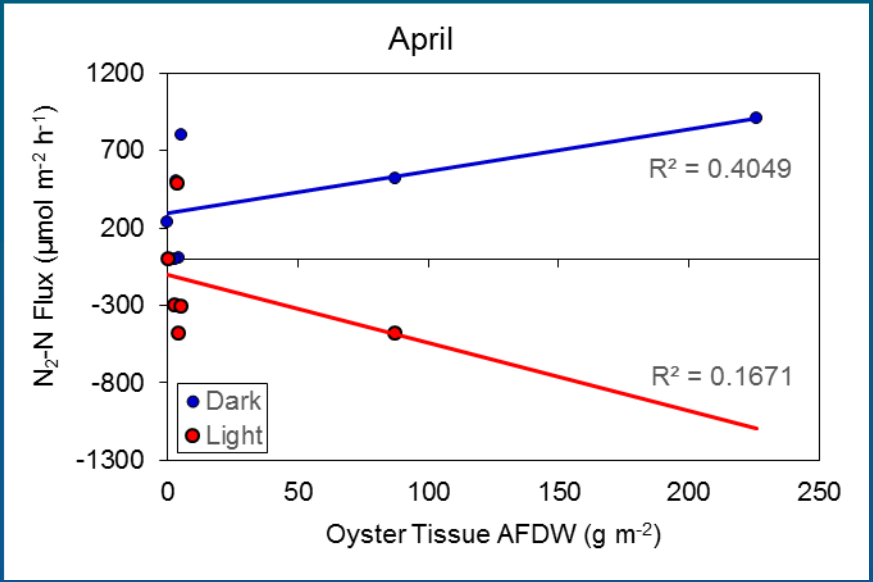
# Beyond STAC

Does DNF vary with oyster biomass and reef location in the tidal zone?

Shallow subtidal




Intertidal

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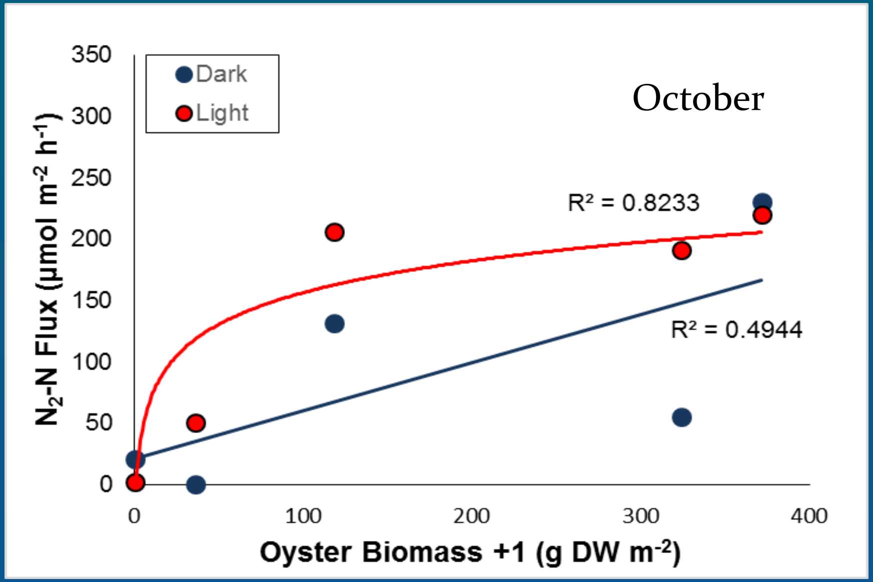
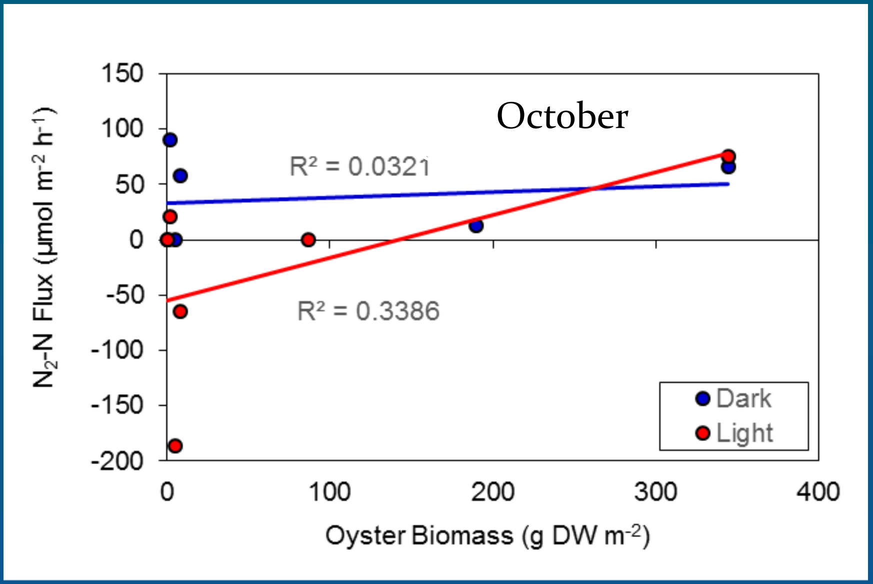
# Beyond STAC

Does DNF vary with oyster biomass on intertidal at different locations ?

Lynnhaven




Hillcrest

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# Scaling Issues

1 Million market-sized oysters contain about 290 lbs. of N.

| Tributary | Load reduction requirements (lbs. N per year) | # oysters harvested to meet 1% of requirement annually |
|---|---|---|
| Choptank River, MD | 475,682 | 16 million |
| Rhode River, MD | 4,126 | 0.14 million |
| Lynnhaven River, VA | 1,409,078 | 49 million |
| Mobjack Bay, VA | 87,628 | 3 million |

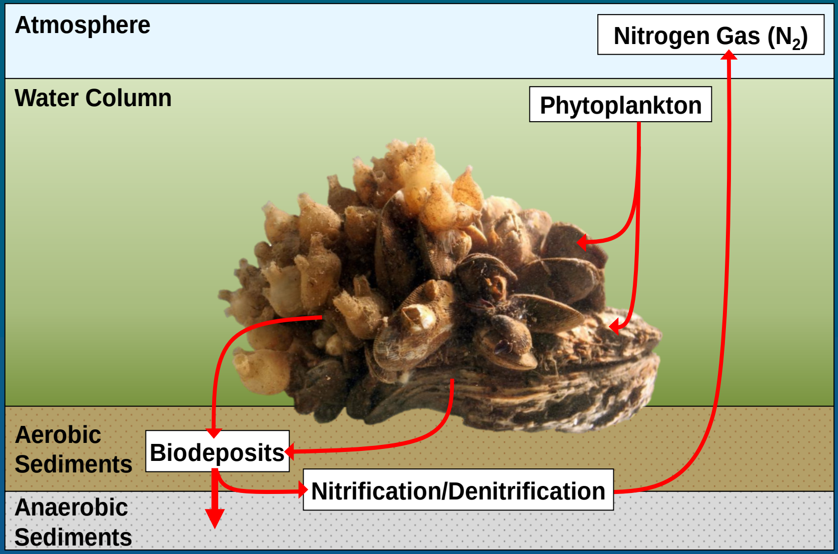
About half of this N is contained in shells, so if the shells are returned to the water, we don't get to count them.

But, 1% reduction may be worth something to local government

50 million oysters ≈ $20 M dockside value at today's prices

# Scaling Issues

Nitrogen removal does not always increase with increasing scale




At high levels of organic loading (oyster poop) the first steps in Nitrification/Denitrification may shut down.

In that case the nitrogen removal by harvesting of oysters must be discounted by the reduction in denitrification.

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