Nutrient Removal by Oysters

Evaluating the Potential of Oyster Aquaculture and Oyster Restoration as a BMP for Nutrient Reduction

STAC Review

Panel Members
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The study "*Shellfish Aquaculture: Ecosystem Effects, Benthic-Pelagic Coupling and Potential for Nutrient Trading*" by Roger Mann and Roger Newell was developed to analyze the nutrient assimilation of shellfish and their potential to assist in the Chesapeake Bay restoration activities.

Request

The Management Board requests that STAC review this, as well as other relevant studies, on the use of shellfish as a method of nutrient reduction and advise on how this can be incorporated into nutrient reduction practices.

12 Specific Questions to Consider

What are the nutrient removal efficiencies associated with oyster aquaculture and oyster reefs based on current science? (Questions 1, 4, 6, 7, 9, 12)

How can oysters (cultured, wild, or restored) be used as in situ *BMPs? Is our current knowledge of this representative throughout the Bay? How do environmental conditions affect the BMP efficiencies?* (Questions 2, 3, 7, 9)

When can nutrient reductions be counted towards Chesapeake Bay TMDL (annually, at harvest, by season)? (Question 10)

NCBO – Sponsored Workshop

Jan. 10 – 11, 2013

Wachapreague, VA

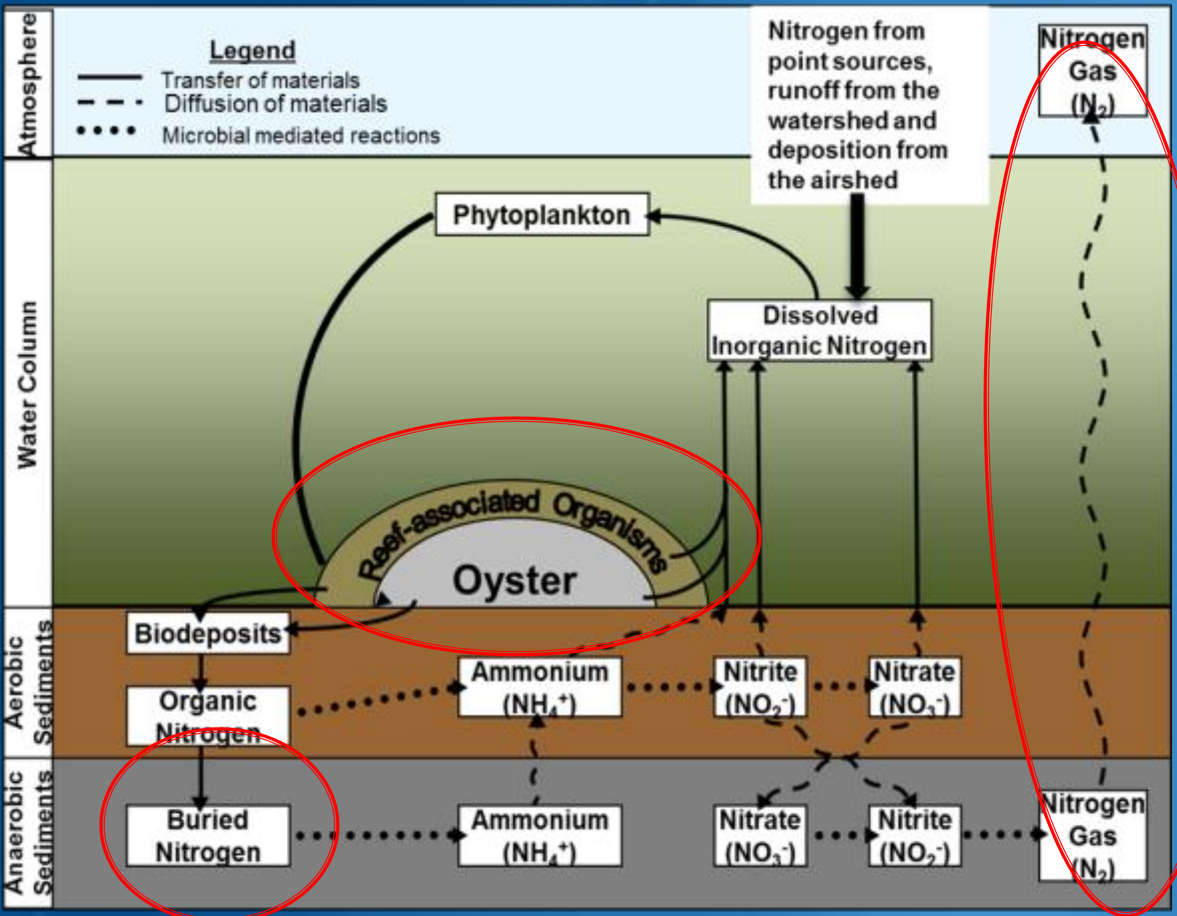
Purpose: To gather experts to determine: (1) the best available values for nitrogen removal by oysters; (2) the uncertainty associated with these estimates; and, (3) the data gaps necessary to reduce the uncertainty

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)

Summary of what we know.



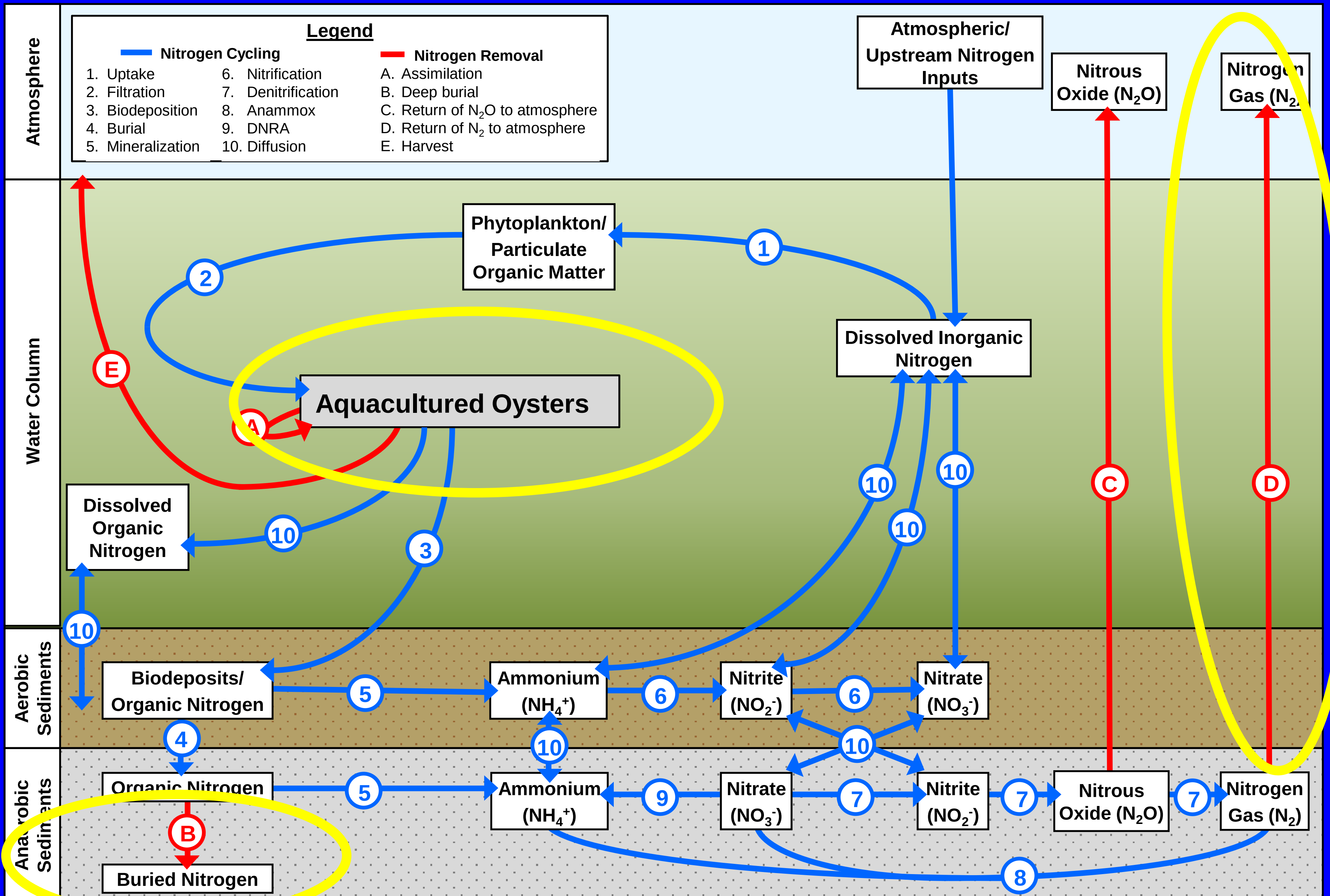
Adapted from: Newell RIE, Fisher TR, Holyoke RR, Cornwell JC (2005) Influence of eastern oysters on nitrogen and phosphorus regeneration in Chesapeake Bay, USA. In: Dame RF, Olenin S, (eds). The comparative roles of suspension feeders in ecosystems, NATO ASI Sci Ser 4 Earth Environ Sci, Springer-Verlag, Berlin, p 93–120.

We have some good numbers on the incorporation of N & P into oyster tissues.

We do not have any data on enhanced nutrient burial rates.

We have data from a few recent and ongoing studies.

Aquaculture – Aerobic Sediments – Below Euphotic Zone



Graphic produced by Lisa Kellogg

Nitrogen content of soft tissue and shell

Source	Location	Conditions	% N
Newell 2004	Choptank River, Chesapeake Bay	Natural oyster reef	Soft tissue: 7.0 Shell: 0.3
Higgins et al. 2011	2 tributaries in Chesapeake Bay	Cultured oysters in floats Oyster density = 286 m^{-2} High and low energy sites	Soft tissue: 7.86 Shell: 0.19
Carmichael et al. 2012	5 estuaries on Cape Cod	Cultured oysters in floats Oyster density = 429 m^{-2} Variation in N loading across watersheds	Soft tissue: 8.6
Carmichael et al. unpublished	2 locations in Mobile Bay	Cultured oysters in cages	Soft tissue: 12
Kellogg et al. 2013	Restored reef in Choptank	Subtidal oyster reef Hatchery-produced spat 2 -7 year-old oysters Oyster density = 131 m^{-2}	Soft tissue: 9.2 Shell: 0.21

1) Tight range of %N content in soft tissue (7.00 - 9.27%) and shell (0.19 – 0.3%) in Atlantic estuaries.
2) ~50% of the N is contained in shells
3) Similar pattern for P

Studies on denitrification at reef sites

1. Bogue Sound – M. Piehler and Smyth (2011), Symth et al. (2013)

   Intertidal natural oyster reefs

2. Choptank River, MD – Kellogg et al. (2013)

   Restored oyster reef vs. non-restored site. Subtidal (~4 m), below euphotic zone, salinity ~7-11

3. Lynnhaven River, VA – Sisson et al. (2012)

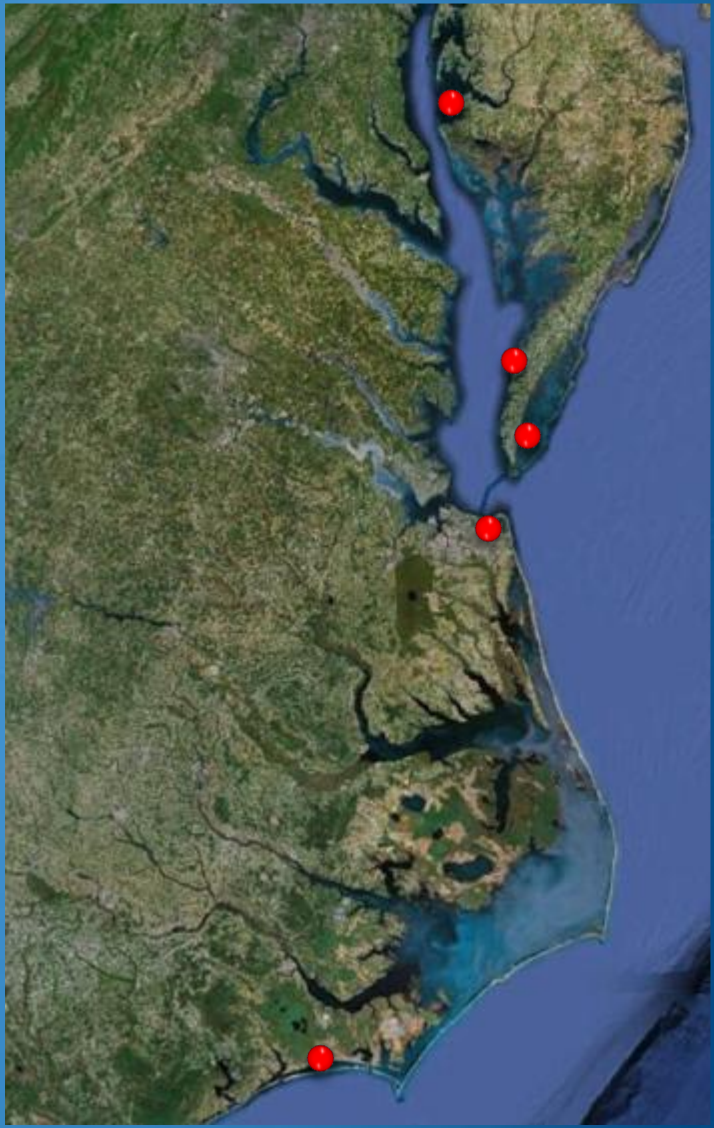
   Existing reefs varying in oyster density; Intertidal and shallow subtidal; within euphotic zone; salinity ~20

4. Onancock Creek, VA – Kellogg et al. (in prep.)

   Replicate experimental reefs of varying oyster density; Shallow subtidal (~1 m); within euphotic zone, salinity ~15

5. VA Coastal Bays, VA – Kellogg et al. (ongoing)

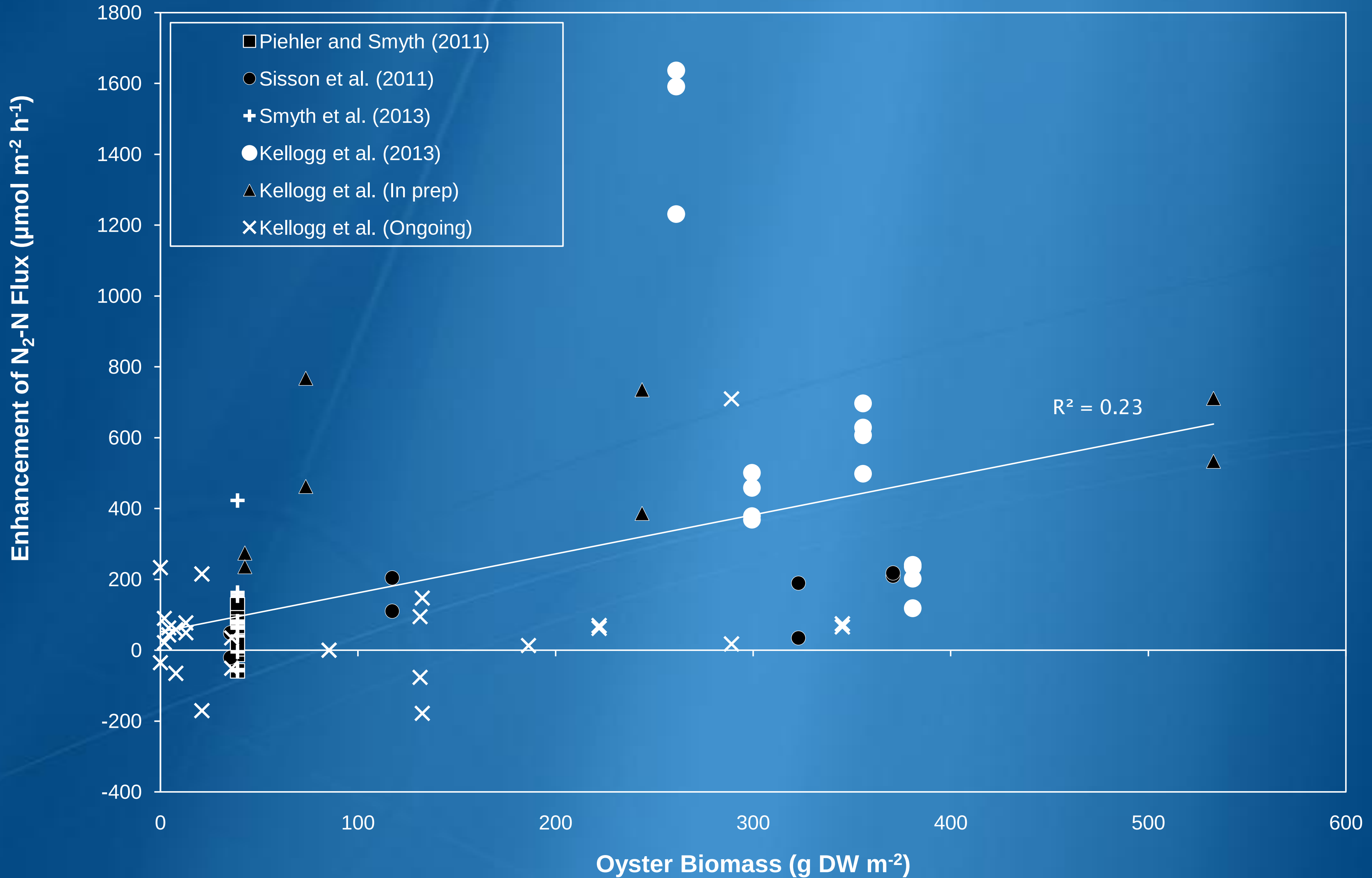
   Replicate experimental reefs of varying oyster density; Intertidal, salinity ~30



Denitrification – Oyster 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 --4.5 µmol N m^{-2} d^{-1} Oyster reefs 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 39-105 µmol N m^{-2} d^{-1} Oyster reefs 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: 0 µmoles m^{-2} hr^{-1} Reef sites: 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: 65 µmoles m^{-2} hr^{-1} Reef sites: 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: 87-123 µmoles m^{-2} hr^{-1} Reef sites: 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.



Enhancement of N_2-N Flux (µmol m^{-2} h^{-1})
1800
1600
1400
1200
1000
800
600
400
200
0
-200
-400
Piehler and Smyth (2011)
Sisson et al. (2011)
Smyth et al. (2013)
Kellogg et al. (2013)
Kellogg et al. (In prep)
Kellogg et al. (Ongoing)
R^2 = 0.23
0
100
200
300
400
500
600
Oyster Biomass (g DW m^{-2})

Studies on denitrification at aquaculture sites

1. Choptank River, MD

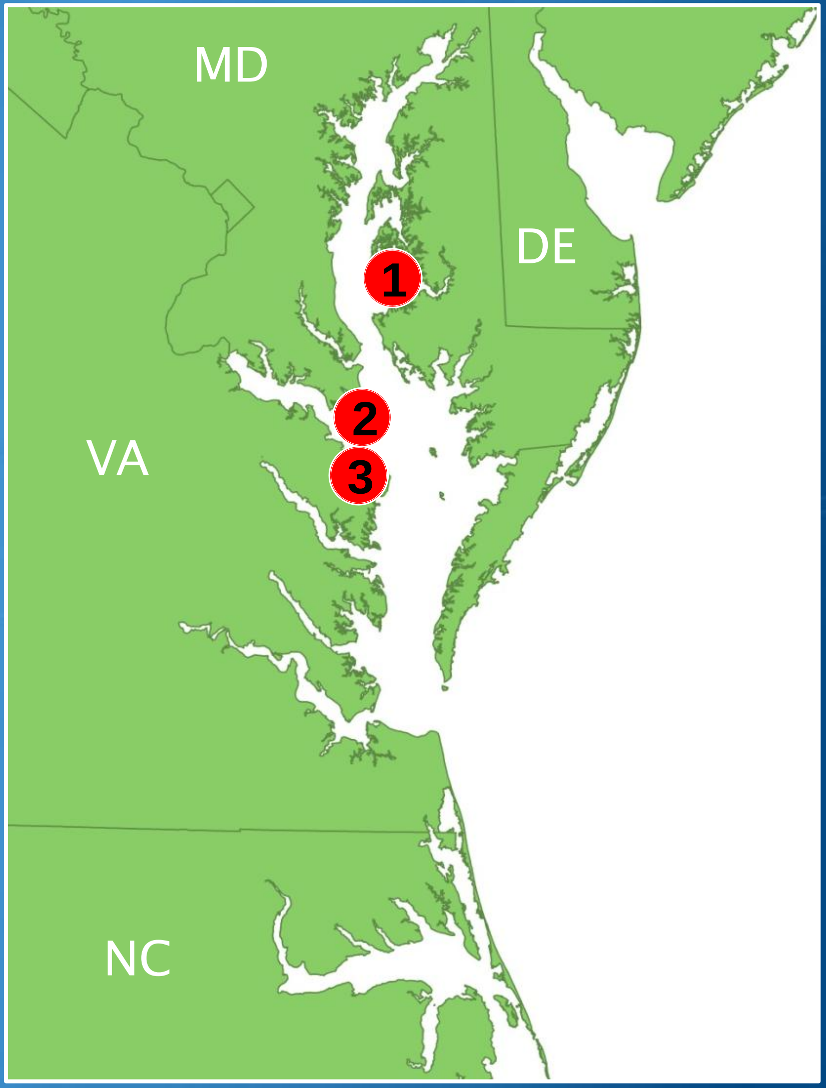
Rebecca Holyoke (2008) Ph.D. Thesis, UMD. No increase in denitrification at 4 floating oyster aquaculture sites.

2. St. Jerome Creek, MD

3. Spencer Creek, VA

Colleen Higgins et al. (2013) No increase in denitrification at 2 floating oyster aquaculture sites

Bottom line: For aquaculture we only get to count the N removed at harvest.



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.

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 comparable sites without aquaculture.

STAC Panel Findings:

Finding 6: Denitrification rates measured for oyster reefs typically exceed background levels in adjacent non-structured environments, with most, but not all, reefs 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 euphotic zone, and other unknown environmental factors affect these rates in ways that have not yet been fully quantified.

Oyster Aquaculture as a BMP

Oyster aquaculture increases the flux of organic nitrogen to the bottom and thus has the potential to enhance rates of denitrification (DNF).

Limited studies to date do not reveal enhanced DNF. We need additional studies to understand the conditions under which enhancement occurs.

Under conditions of high bio-deposition rates and low flushing rates oyster aquaculture may reduce DNF.

Inclusion of oysters in Bay TMDLs

N & P removal resulting from the harvest of aquacultured oysters can be reliably incorporated into Bay TMDLs at this time.

Insufficient data exist at this time to incorporate nitrogen removal resulting from burial and denitrification into the TMDL process.

A better understanding of the environmental conditions and processes affecting denitrification associated with oysters would permit improved model estimates of the role of this pathway.

My Commentary – A reality check

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.