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.

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Specific Questions to Consider

1.What would be the nutrient removal efficiencies of nitrogen by oyster aquaculture and oyster reefs as described in the current state-of-science?

2. Does the current science support using oyster aquaculture or oyster reefs as best management practice in the Chesapeake Bay?

3. Is the current oyster aquaculture BMP research representative of all Chesapeake Bay watersheds? (If not, how so?)

4. What would be the most appropriate nitrogen removal efficiency based upon the current science?

5. What are your recommended baseline conditions for an oyster aquaculture and for a natural reef site?

6. How should nutrient efficiencies be calculated based on best available data? Which site-specific factors (e.g. salinity, temperature, water flow, nutrient load) should be considered in the calculations?

7. Should BMP efficiencies be based on nutrient assimilation, biogeochemistry (denitrification and burial processes), or both?).

Specific Questions to Consider

8. How would on-bottom reef, on-bottom caged, and in-column aquaculture nutrient removal differ from one another? How would these differences impact BMP efficiencies?

9. How will efficiencies change seasonally? How will fluctuations in filtration rate due to low/high temperatures or algae concentrations impact BMP efficiencies?

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

11. Should tissue sampling, water quality data or other methods be used to verify reductions? If so, what would be the measuring protocols?

12. Taking into account the above questions, what are STAC's recommended nutrient reduction efficiencies for oyster aquaculture? How might those efficiencies translate for oyster restoration projects?

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 –

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Mark Luckenbach (VIMS)
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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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Nitrogen content of soft tissue and shell

Source	Location	Conditions	Measured value	Values	Comments
Higgins et al. 2011	2 tributaries in Chesapeake Bay	Cultured oysters in floats Oyster density = 286 m^{-2} High and low energy sites	N content of soft tissue as % of DW N content of shell as % of DW	7.86% (SE =0.11) 0.19% (SE = 0.01)	%N in soft tissue and shells did not differ between sites.
Carmichael et al. 2012	5 estuaries on Cape Cod	Cultured oysters in floats Oyster density = 429 m^{-2} Variation in N loading across watersheds	N content of soft tissue as % of DW	8.6% (SE = 0.2	%N in soft tissue did not vary in relation to N loading to the estuary
Carmichael et al. unpublished	2 locations in Mobile Bay		N content of soft tissue as % of DW	12%	%N in soft tissues and did not differ between sites.
Kellogg et al. 2013	Restored reef in Choptank	Subtidal oyster reef Hatchery-produced spat 2 -7 year-old oysters Oyster density = 131 m^{-2}	N content of soft tissue as % of DW N content of shell as % of DW	9.27% 0.21%	56% of oyster N is in the shell. Non-oyster macrofauna account for 37% of the sequestered N

Findings: 1) Tight range of %N content in soft tissue (7.86 - 9.27%) and shell (0.19 – 0.21%) in Atlantic estuaries.

2) > 50% of the N is contained in shells

3) Oyster growth rates highly variable. Need harvest biomass.

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Denitrification – Floating Oyster Aquaculture

Source	Location	Conditions	Measured value	Values	Comments
Higgins et al. 2013	2 tributaries in Chesapeake Bay	Cultured oysters in floats Oyster density = 286 m^{-2} High and low energy sites	N_2 flux in cores with sediment collected below aquaculture and reference sites	Reference site = 1.26 mmol N m^{-2} d^{-1} Oyster culture site 0.89 mmol N m^{-2} d^{-1}	Denitrification <u>not</u> enhanced under floating aquaculture relative to a reference site.
Holyoke 2008	3 locations in the Choptank River	Cultured oysters in floats	N_2 flux in cores with sediment collected below aquaculture and reference sites	Reference site = 26.6 µmol N m^{-2} d^{-1} Oyster culture site 23.1 µmol N m^{-2} d^{-1}	Denitrification <u>not</u> enhanced under floating aquaculture relative to a reference site.

Finding: 1) Currently no evidence supporting enhanced denitrification under floating oyster aquaculture.

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Study Sites

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

   Intertidal natural oyster reefs compared to other estuarine habitats

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. Virginia Coastal Bay, VA – Kellogg et al. (Ongoing)

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

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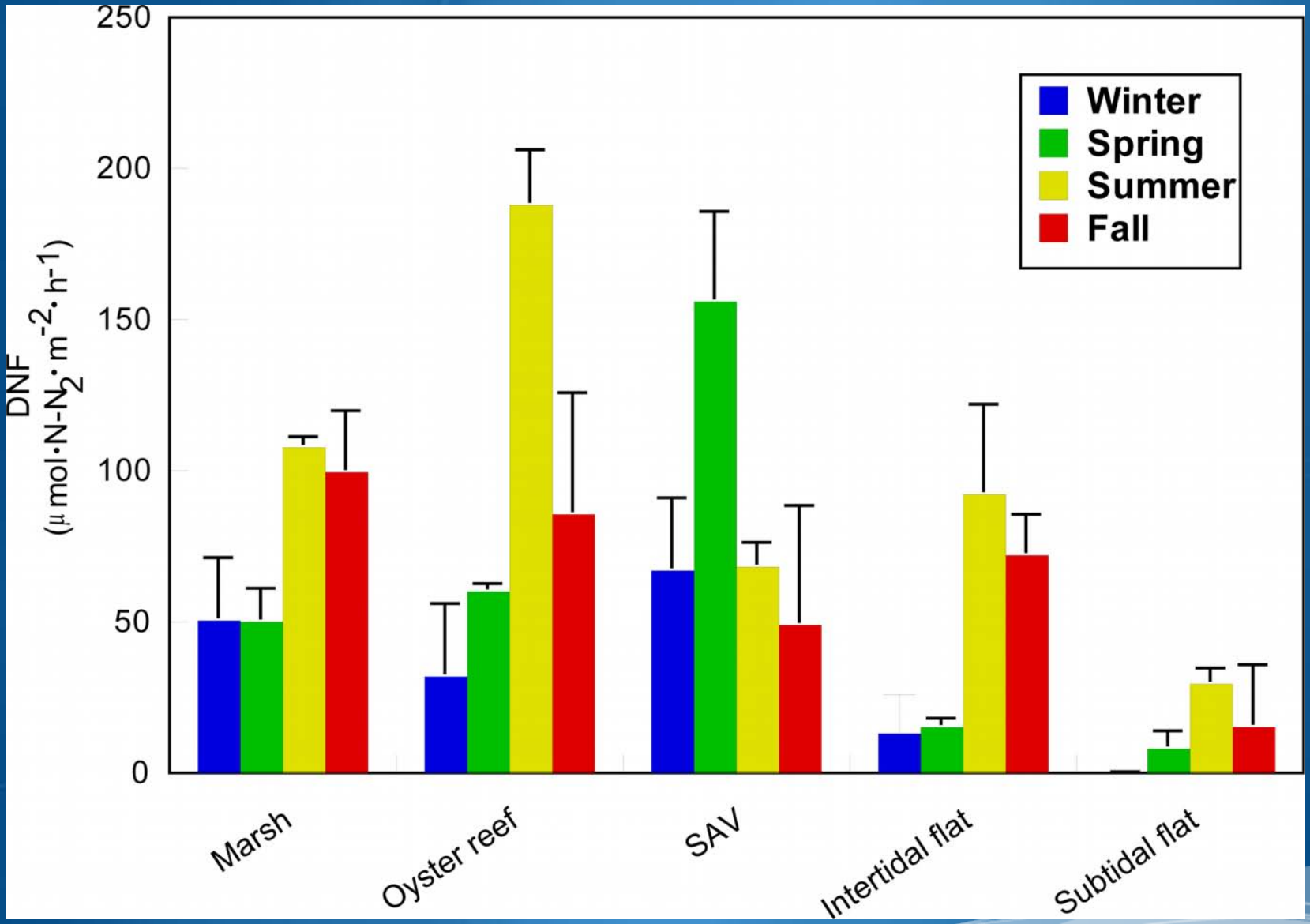
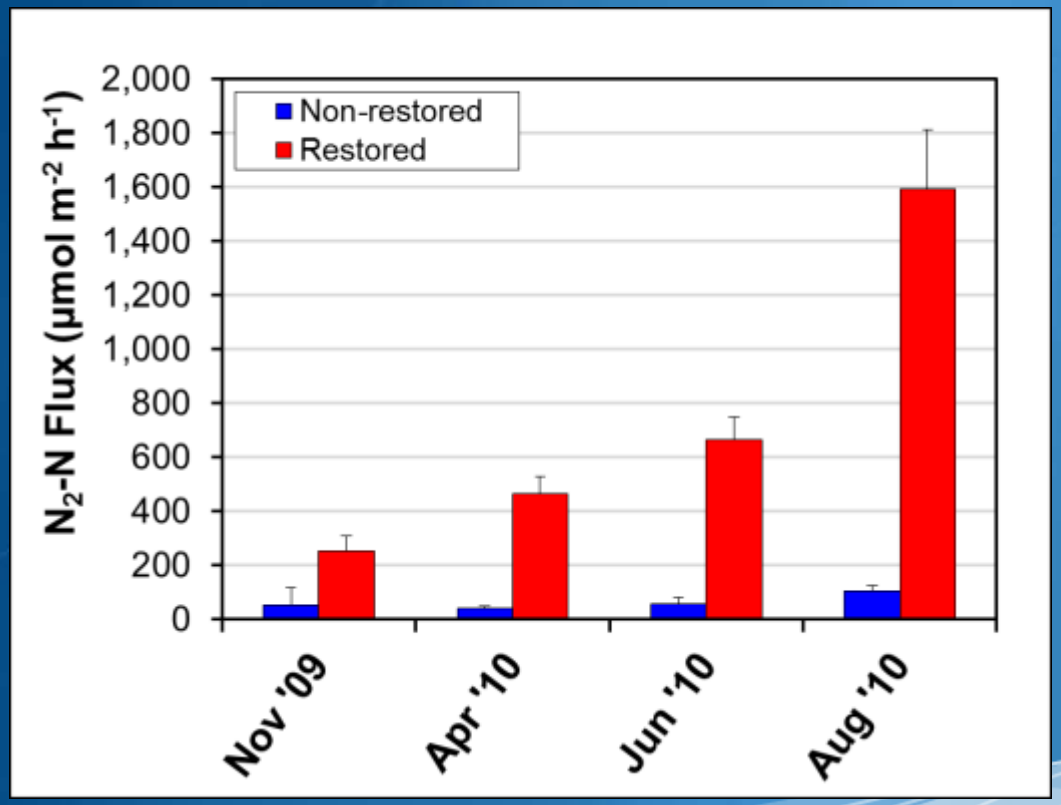

250
200
150
100
50
0
DNF
(μmol·N-N2·m-2·h-1)
Winter
Spring
Summer
Fall
Marsh
Oyster reef
SAV
Intertidal flat
Subtidal flat

Results – Choptank River – Denitrification

Rates 4.7-15.1x higher on restored reefs than non-restored site

- Maximum rate: 1592 µmol N m^{-2} h^{-1}
- Rates change with season
- NO_{2+3} fluxes had similar pattern and magnitude



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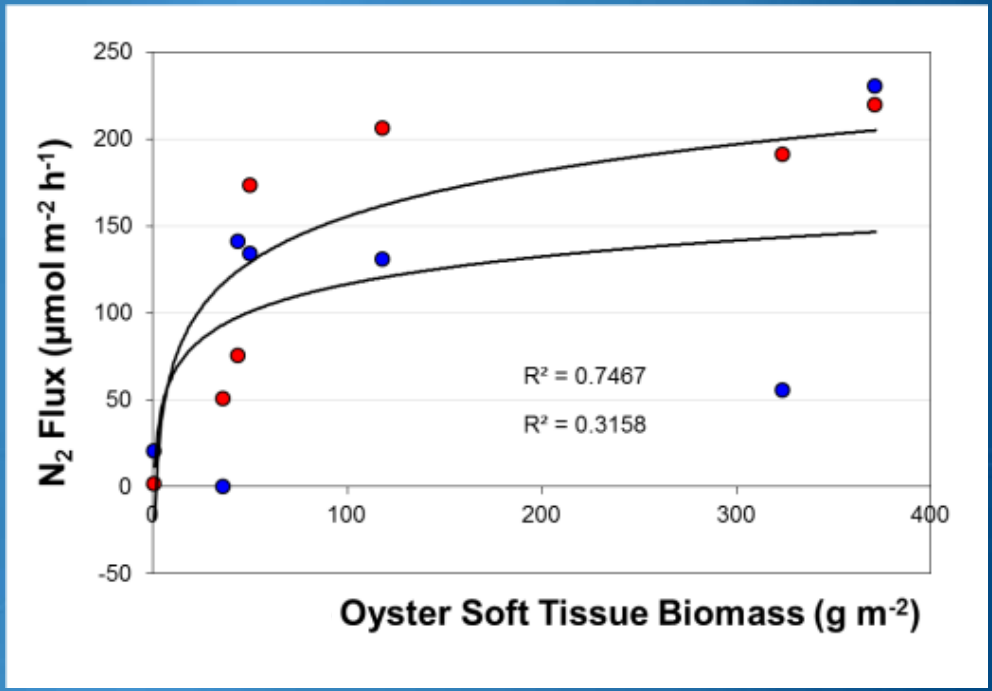
Lynnhaven River – Denitrification

Correlation between denitrification and oyster biomass

Conclusions:

1) Generally lower fluxes than in the Choptank
2) Significant variation between sites within region
3) Still many unknown sources of variation



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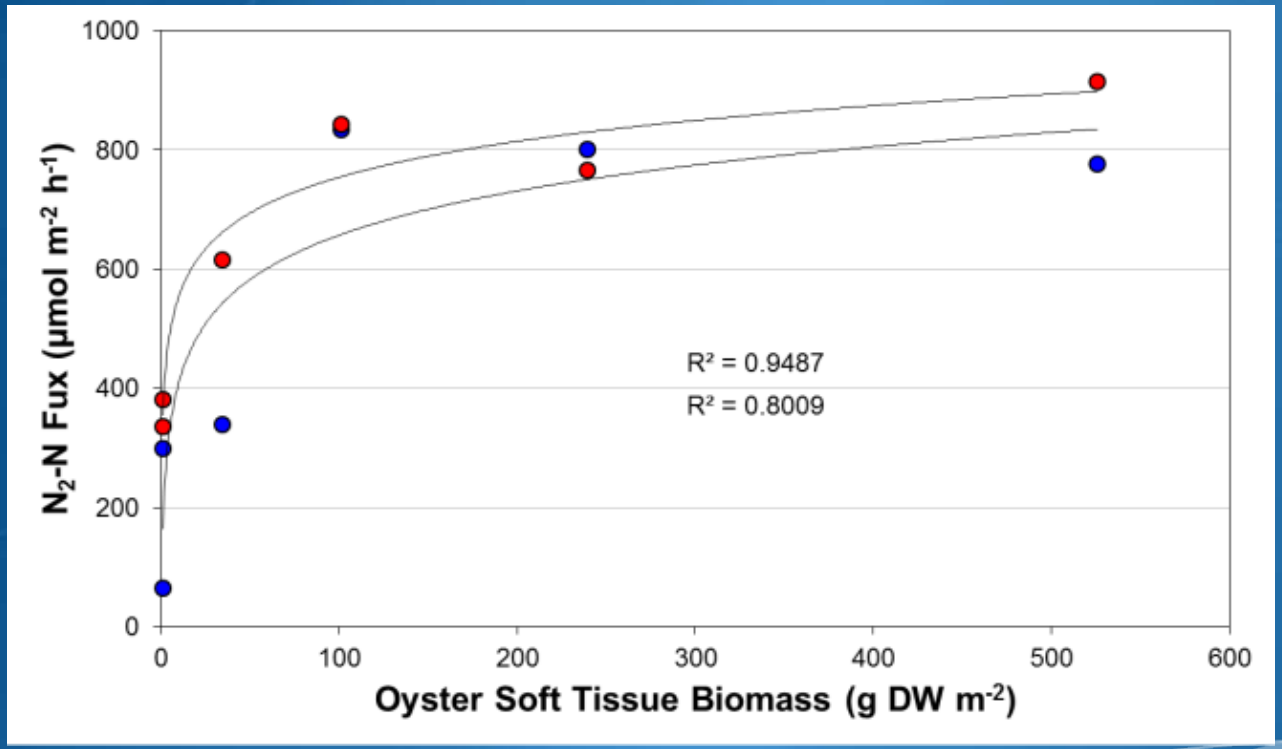
Onancock Creek, VA – Denitrification

Clear relationship between oyster soft tissue biomass and denitrification

Good fit in light and dark

>99% of oysters died in June 2012 of unknown causes



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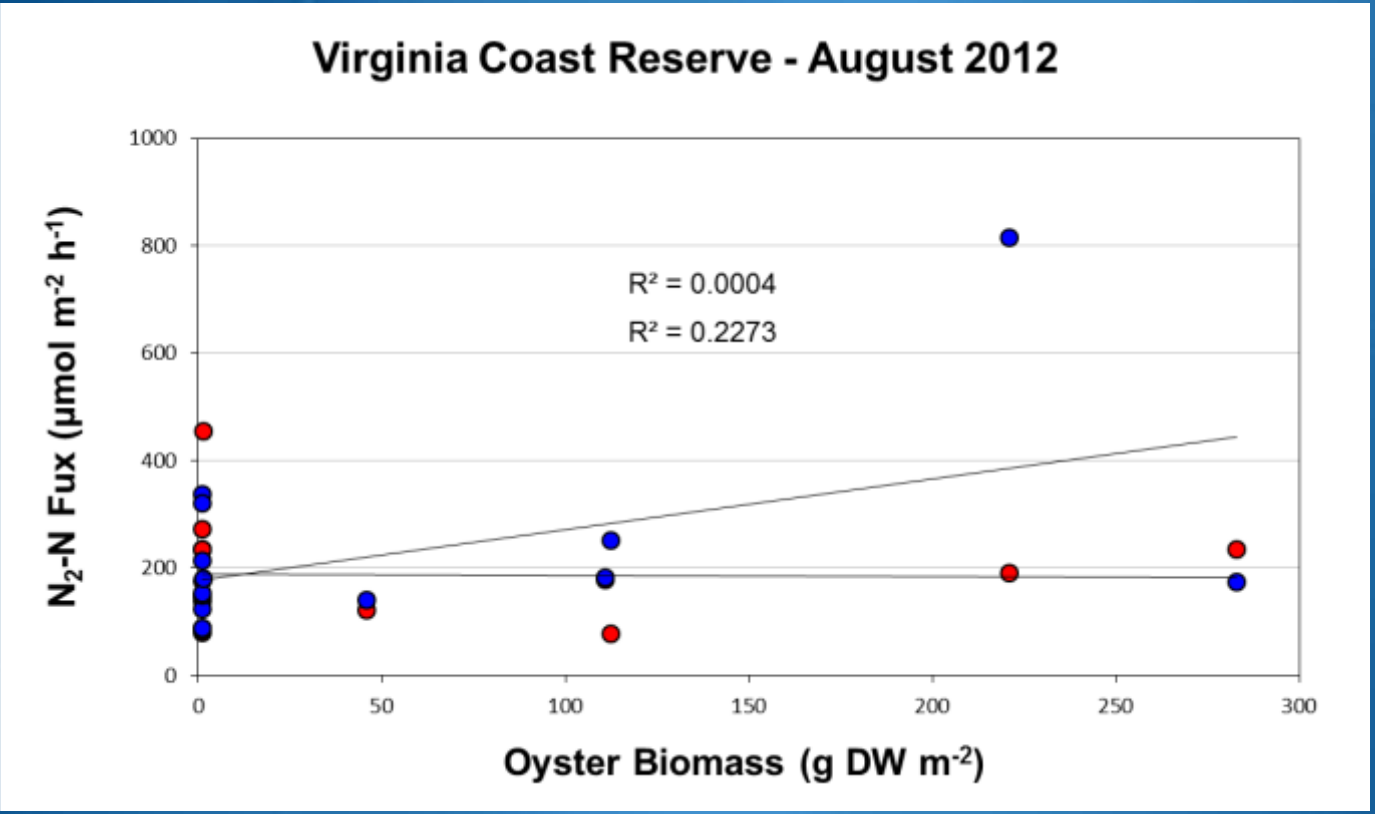
Virginia Coastal Bays

Preliminary analysis: no clear relationship between oyster biomass and denitrification



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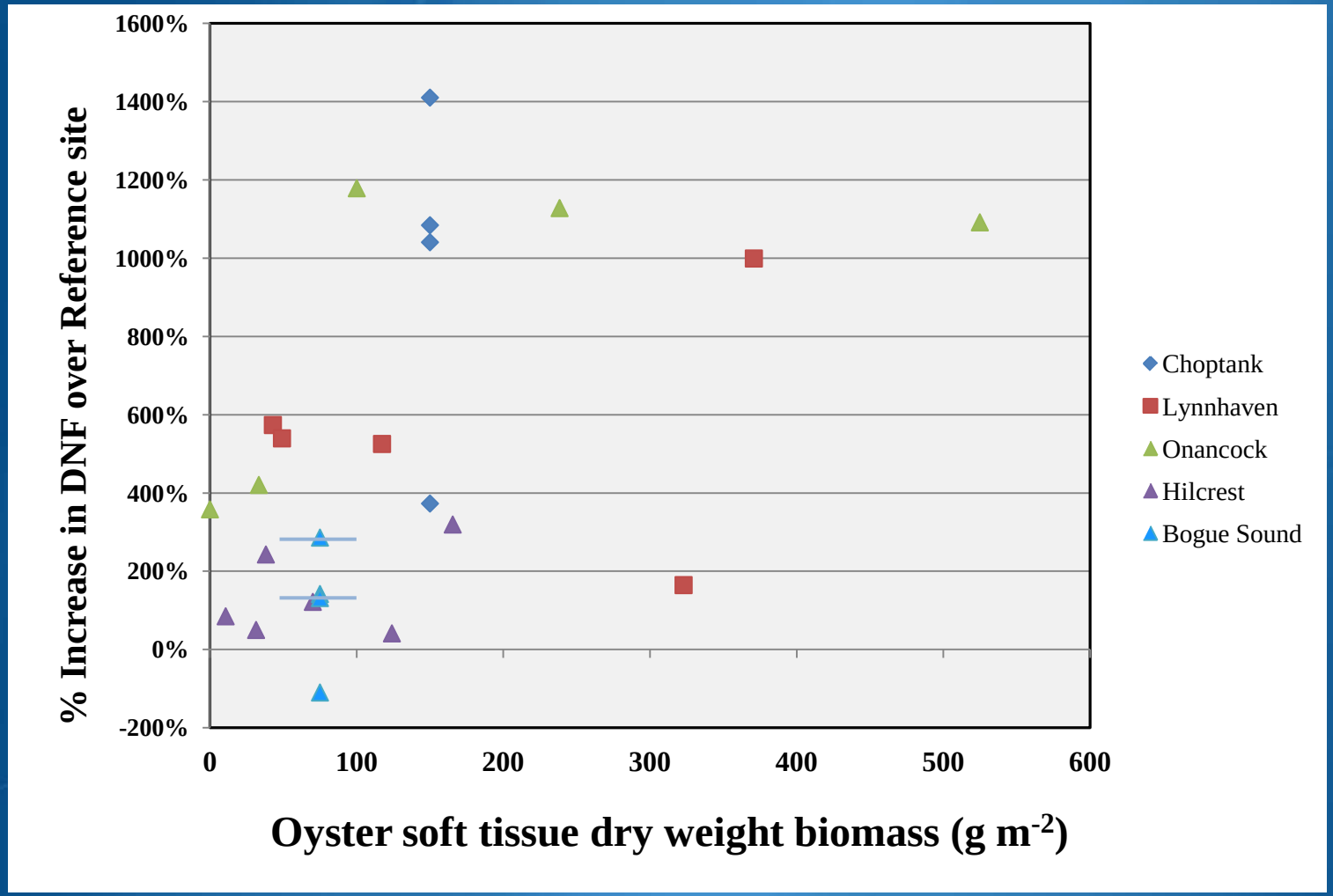
Meta-analysis: Increase in DNF



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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.

Findings:

1) DNF rates on oyster reefs are generally greater than those at reference sites.
2) DNF rates on shallow, subtidal reefs are reduced under light relative to dark conditions.
3) DNF rates in intertidal reefs are lower and more variable than on subtidal reefs

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Findings

Finding #1 A. N content of oysters can reasonably be estimated as ~8.5% of DW for soft tissue and ~0.2% of DW for shells

B. > 50% of N is contained in shells

C. Oyster production rates are highly variable, so harvest data needed.

Finding #2 A. Currently no evidence supporting enhanced denitrification (DNF) under floating oyster aquaculture.

B. No direct evidence for enhanced DNF with other methods of oyster culture.

Finding #3 A. DNF rates on oyster reefs are generally greater than those at reference sites.

B. DNF rates on shallow, subtidal reefs are reduced under light relative to dark conditions.

C. Factors contributing to high variability in DNF rates not currently quantified.

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Recommendations

Some obvious ones:

1. Can use N (and P) content of oyster tissues of harvested aquacultured oysters in computing nutrient removal.
2. Based on current knowledge cannot count any enhanced denitrification from aquaculture.
3. More research is needed to better quantify the relationship between denitrification and environmental conditions on oyster reefs.

The question for the panel here is how far we are willing to go in making recommendations and answering the questions more broadly related to the use of oysters as BMP's

Timeline

February 2013 - Panel conference call to discuss charge and review approach

March 11, 2013 – Panel meeting to discuss data and findings

April 1, 2013 – Draft report with findings and recommendations circulated within the panel.

early May 2013 – Panel conference call to finalize recommendations

early June 2013 – Draft report circulated within STAC for comments

July 2013 – Presentation of report to the Management Board