Oyster BMP Expert Panel Update: Reduction Effectiveness Strategies of Oyster BMPs in Second Report

Fisheries GIT Meeting

December 17, 2018

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University of Maryland
Center for Environmental Science

Oyster Recovery Partnership | ORP

Chesapeake Bay Program
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Oyster BMP Expert Panel Charge

- Establish a nutrient and suspended sediment reduction effectiveness determination decision framework for oyster BMPs (completed and approved in first report).

- Determine the nutrient and suspended sediment reduction effectiveness of oyster practices using available science.
  - Does existing data support N and P reduction estimates for the various oyster practices occurring in Chesapeake Bay?
  - How can the reduction be quantified and verified given the variability in oyster growth and survival?

Decision Points from the Oyster BMP Reduction Effectiveness Decision Determination Framework

Step	Decision Points	Description
1	Identify practices and oyster-associated reduction processes suitable for BMP Consideration	Practice must include an enhancement activity that could result in the overall production of new oysters and reduction process must occur with practice
2	Sufficient science exists to determine reduction	Quality and scope of data can generate a reasonably constrained estimate
3	Estimate is verifiable	Practical method exists, or could be developed, to track reduction effectiveness
4	Identified unintended consequences are manageable	Negative effects can be addressed so they don't outweigh environmental benefits

Chesapeake Bay Oyster Practices												
Oyster Fate	Oysters removed (harvested) from Bay									Oysters remain in Bay		
Fisheries Management Approach	Oyster Cultivation									Conservation		
	Private Oyster Aquaculture					Licensed Public Oyster Harvest				Oyster Reef Restoration		
Description	Oyster harvest from State-issued water column and bottom leases to private entities					Oyster harvest from State-designated public grounds				No harvest allowed (e.g., sanctuaries)		
Access to Oysters	Lease-holder (e.g., specific entity who obtains the lease)					License-holder (e.g., any individual with the proper license)				State resource management agencies		
Oyster Culture Type	Hatchery-produced oysters (diploid or triploid)		Wild oysters (diploid)			Hatchery-produced oysters (diploid or triploid)	Wild oysters (diploid)			Hatchery-produced oysters (diploid)	Wild oysters (diploid)	
Activity	Hatchery-produced oysters grown off the bottom using some sort of gear (e.g., floating rafts near the surface or cages near the bottom)	Hatchery-produced oysters grown on the bottom using no gear	Moving wild oysters from one location to another	Addition of substrate to the bottom to enhance recruitment of wild oyster larvae	None	Addition of hatchery-produced oysters (e.g. spat-on-shell) to the bottom	Moving wild oysters from one location to another	Addition of substrate to the bottom to enhance recruitment of wild oyster larvae	None	Sanctuary creation followed by addition of hatchery-produced oysters	Sanctuary creation followed by addition of substrate	Sanctuary creation
Oyster Practice Title	**Off-bottom private oyster aquaculture using hatchery-produced oysters**	**On-bottom private oyster aquaculture using hatchery-produced oysters**	On-bottom private oyster aquaculture using transplanted wild oysters	**On-bottom private oyster aquaculture using substrate addition**	Private oyster aquaculture with no activity	**Licensed public oyster harvest using hatchery-produced oysters**	Licensed public oyster harvest using transplanted wild oysters	Licensed public oyster harvest using substrate addition	Licensed public oyster harvest with no activity	**Oyster reef restoration using hatchery-produced oysters**	**Oyster reef restoration using substrate addition**	Designated oyster reef no harvest area
Oyster Practice Category	**A**	**B**	C	**D**	E	**F**	G	H	I	**J**	**K**	L
Panel Recommends for BMP Consideration	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	TBD	No	**Yes**	**Yes**	TBD

Oyster Practices for BMP Consideration

First Report:

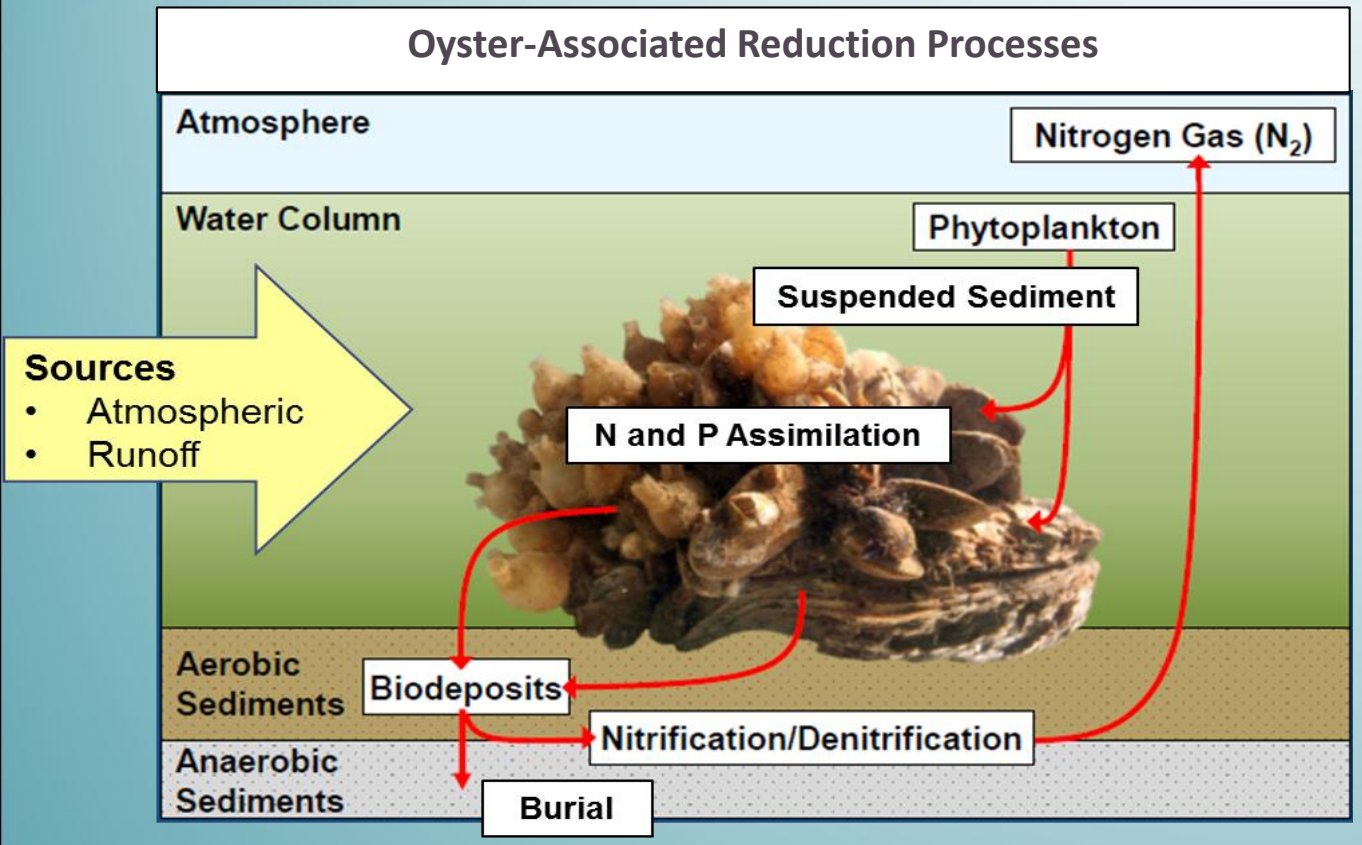
- Private Oyster Aquaculture: A, B, and D endorsed by Panel and approved by CBP.

Second Report:

- Licensed Public Oyster Harvest: F endorsed by Panel
- Oyster Reef Restoration: J and K endorsed by Panel

*Practice must include an enhancement activity that could result in the overall production of new oysters and reduction process must occur with practice.

Reduction Effectiveness Protocols based on Oyster-Associated Nutrient/Suspended Sediment Reduction Processes



Reduction Effectiveness Protocols
1. Nitrogen Assimilation in Oyster Tissue
2. Nitrogen Assimilation in Oyster Shell
3. Enhanced Denitrification Associated with Oysters
4. Phosphorus Assimilation in Oyster Tissue
5. Phosphorus Assimilation in Oyster Shell
6. Sediment Reduction Associated with Oysters
7. Enhanced Nitrogen Burial Associated with Oysters
8. Enhanced Phosphorus Burial Associated with Oysters

Incremental Recommendations "Roadmap"

	Private Oyster Aquaculture					Licensed Public Oyster Harvest				Oyster Reef Restoration		
Oyster Practice Category x Crediting Protocol	**A. Off-bottom private oyster aquaculture using hatchery-produced oysters**	**B. On-bottom private oyster aquaculture using hatchery-produced oysters**	**C. On-bottom private oyster aquaculture using transplanted wild oysters**	**D. On-bottom private oyster aquaculture using substrate addition**	**E. Private oyster aquaculture with no activity**	**F. Licensed public oyster harvest using hatchery-produced oysters**	**G. Licensed public oyster harvest using transplanted wild oysters**	**H. Licensed public oyster harvest using substrate addition**	**I. Licensed public oyster harvest with no activity**	**J. Oyster reef restoration using hatchery-produced oysters**	**K. Oyster reef restoration using substrate addition**	**L. Designated oyster reef no harvest area**
1. Nitrogen Assimilation in Oyster Tissue	**1st Approved**	**1st Approved**	1st Not Endorsed	**1st Approved**	1st Not Endorsed	**2nd Complete**	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
2. Nitrogen Assimilation in Oyster Shell	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
3. Enhanced Denitrification Associated with Oysters	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
4. Phosphorus Assimilation in Oyster Tissue	**1st Approved**	**1st Approved**	1st Not Endorsed	**1st Approved**	1st Not Endorsed	**2nd Complete**	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
5. Phosphorus Assimilation in Oyster Shell	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
6. Suspended Sediment Reduction Associated with Oysters	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later
7. Enhanced Nitrogen Burial Associated with Oysters	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later
8. Enhanced Phosphorus Burial Associated with Oysters	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later

1st Report (approved) 2nd Report (in draft) Future Report

Status of Policy Issues

- **Legality of in-water BMPs for nutrient sequestration from oysters that remain in the water (e.g., oyster restoration practices in sanctuaries)?**
  - Resolved—From EPA: Yes, *in-situ* BMPs are legal since pollutants are removed from water column.
    - Assumes practice involves native species.
- **How to count in-water BMPs toward load allocation?**
  - Resolved—From CBP: Not credited to specific source sector, but instead towards total nonpoint source load allocation.
- **Can conservation with no physical activity count towards reduction?**
  - Not resolved—Need to present issue to CBP Management Board
    - Designated oyster reef no harvest area does not include planting oysters or substrate; just creates a “no harvest” area to protect existing oysters.

2nd Report: Oyster Practice-Protocol Combinations with Complete Recommendations for Approval

- N reduction via **enhanced denitrification** (DNF) associated with oysters for **oyster reef restoration practices.**

- N and P **assimilation in whole live oysters** (tissue and shell) for **oyster reef restoration practices** (sequestration).

- N and P **assimilation in tissue of harvested oysters** from **licensed public harvest practices** that use hatchery-produced oysters.

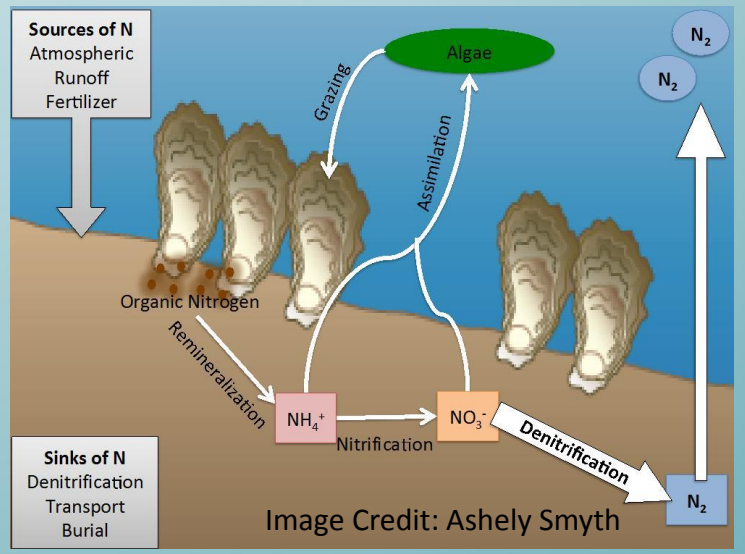


Image Credit: Ashely Smyth

Enhanced Denitrification-Oyster Reef Restoration Strategy to Determine Reduction Effectiveness

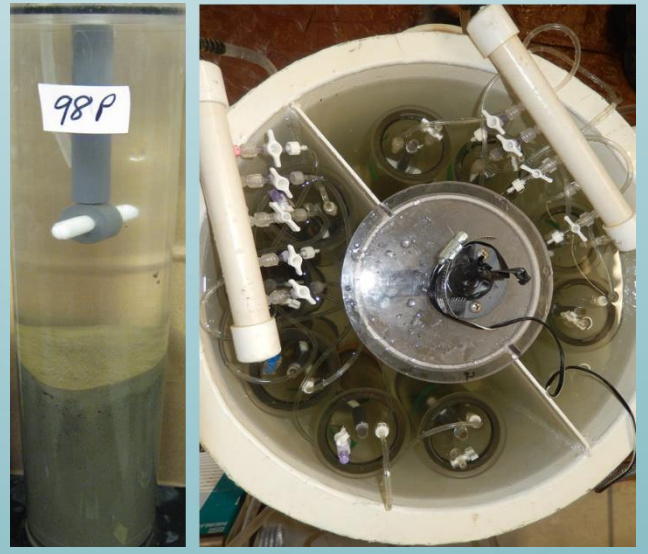
Fisheries Management Approach	Reduction Effectiveness Strategy (Crediting based on Live Oysters)
Denitrification-Related	
Oyster Reef Restoration **(Oysters not removed from areas planted with hatchery-produced oysters or substrate; e.g., sanctuaries)**	**Reduction Effectiveness Determination:** • Determine **site-specific seasonal denitrification rates under known oyster tissue biomass** for dark and/or light hours using acceptable measurement techniques. **Verification:** • Use established shell height to tissue dry weight regression equation or measured tissue biomass at site as a proxy for verification of denitrification rates. Apply corresponding qualifying conditions for DNF measurement used (chamber or core).

Enhanced Denitrification-Oyster Reef Restoration
Acceptable Methods to Measure DNF Rates

Reef Sample Method	Sample Type	Incubation Method	DNF Assessment Method
Chamber	Whole Community	Batch	N_2:Ar
	Sediment Only	Batch or Flow Through	N_2:Ar or ^{15}N Isotope Pairing
Core	Sediment Only	Batch or Flow Through	N_2:Ar or ^{15}N Isotope Pairing

Chamber:

- Directly relatable to oyster tissue biomass
- Can adjust DNF rate proportionally
- Whole community option allows DNF value to be close to actual



Core:

- Unknown if relatable to oyster tissue biomass
- Cannot adjust DNF rate proportionally
- Does not capture whole community—underestimates DNF value

Enhanced Denitrification-Oyster Reef Restoration
Components of Site-Specific DNF Rate

- **Reference Rate (Baseline Determination)**
  - Measure denitrification (DNF) rates at oyster site and nearby reference site
    - Consult with expert to determine appropriate number of sampling points (minimum of 3)
  - Enhanced Rate = Oyster Site – Reference Rate

- **Light and/or Dark Incubation**
  - If bottom gets sufficient light for photosynthesis (≥ 2% of incident sunlight):
    - Light incubations are needed to incorporate daylight hours for DNF rate
    - If only have dark incubations, then only dark hours can be incorporated for DNF rate
  - If no light reaches bottom then dark DNF rate can apply to full 24 hours

- **QA/QC of DNF Rate**

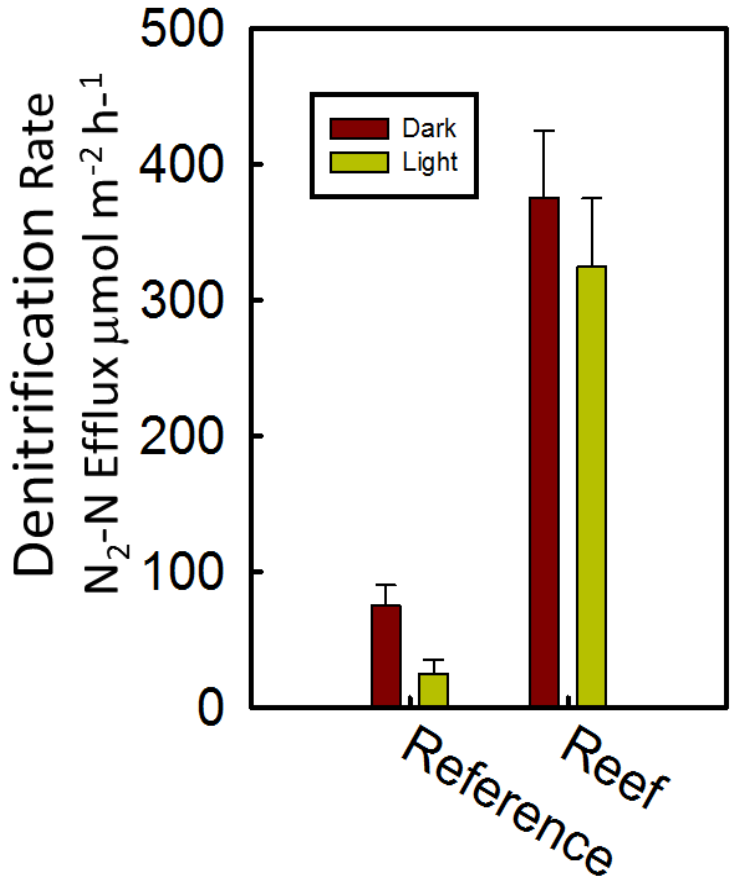
Enhanced Denitrification-Oyster Reef Restoration Components of Site-Specific DNF Rate Cont.

- **Seasonality**
  - Used defined time periods to address seasonal variability
    - Spring—Mar-May (92 days total)
    - Summer—Jun-Aug (92 days total)
    - Fall—Sep-Nov (91 days total)
    - Winter—Dec-Feb (90 days total)
  - Can receive partial annual credit for seasons with measured DNF rates; full annual credit if there are DNF rates for all seasons

- **Oyster Tissue Biomass Associated with DNF Rate**
  - Define “oyster presence” for verification later
    - Chamber Method: Measure oyster tissue biomass in chamber
    - Core Method: Determine average tissue biomass of designated BMP site

Enhanced Denitrification-Oyster Reef Restoration
DNF Rate Calculation Example: Light & Dark Rates (Light Reaches Bottom)

Summer Season
Jun-Aug (92 days total)



Mean Reference Rate: Dark = 60 ± 15 µmol N m^{-2} h^{-1}
± SD Light = 20 ± 5 µmol N m^{-2} h^{-1}

Mean Reef Rate: Dark = 375 ± 75 µmol N m^{-2} h^{-1}
± SD Light = 325 ± 75 µmol N m^{-2} h^{-1}

Daily rate if location and date is 14 hours light, 10 hours dark

Reference = (60*10 + 20*14) = 880 µmol m^{-2} d^{-1}
Reef = (375*10+ 325* 14) = 8,300 µmol m^{-2} d^{-1}

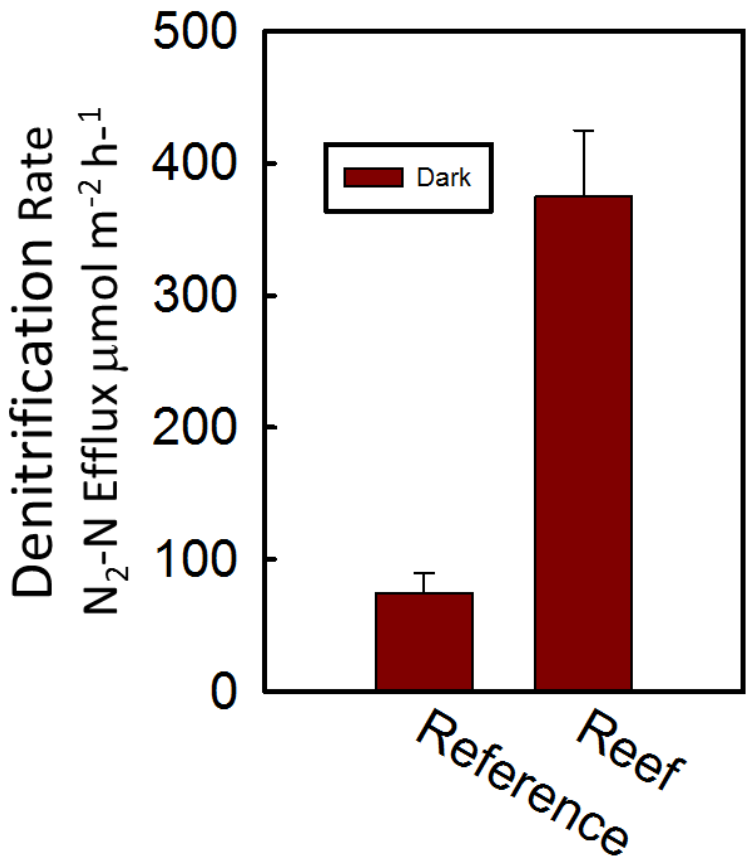
Daily Enhanced Denitrification Rate:
Reef – Reference = 7,420 µmol N m^{-2} d^{-1}
= 0.10388 g N m^{-2} d^{-1}
= 0.93 lbs N $acre^{-1}$ d^{-1}

Example Assumptions:

- **Light reaches the bottom and light and dark rates assessed**
- Rates are typical warm season rates that can be observed in the summer season (e.g., July)
- Mean reference oyster tissue biomass = 0 g m^{-2}
- Mean reef oyster tissue biomass = 50 g m^{-2}

Enhanced Denitrification-Oyster Reef Restoration
DNF Rate Calculation Example: Dark Rate Only (Light Reaches Bottom)

Summer Season
Jun-Aug (92 days total)



Mean Reference Rate: Dark = 60 ± 15 µmol N m^{-2} h^{-1}
± SD Light - unassessed

Mean Reef Rate: Dark = 375 ± 75 µmol N m^{-2} h^{-1}
± SD Light - unassessed

Daily rate if location and date is 14 hours light, 10 hours dark

Reference = (60*10) = 600 µmol m^{-2} d^{-1}
Reef = (375*10) = 3,750 µmol m^{-2} d^{-1}

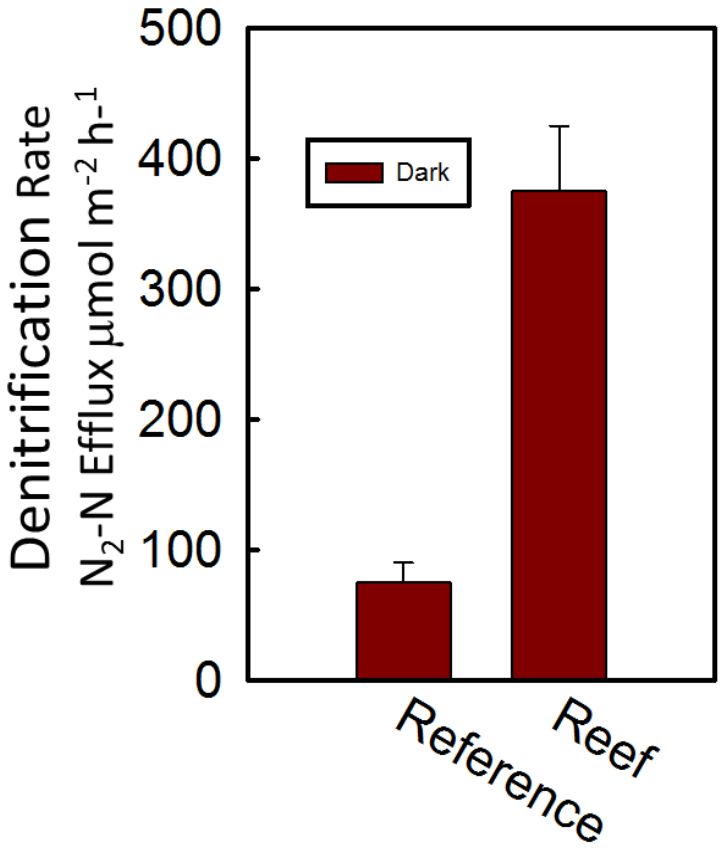
Reef – Reference = 3,150 µmol N m^{-2} d^{-1}
= 0.044 g N m^{-2} d^{-1}
= 0.39 lbs N $acre^{-1}$ d^{-1}

Example Assumptions:

- **Light reaches the bottom, but light rates not assessed**
- Rates are typical warm season rates that can be observed in the summer season (e.g., July)
- Mean reference oyster tissue biomass = 0 g m^{-2}
- Mean reef oyster tissue biomass = 50 g m^{-2}

Enhanced Denitrification-Oyster Reef Restoration
DNF Rate Calculation Example: Dark Rate (No Light at Bottom)

Summer Season
Jun-Aug (92 days total)



Mean Reference Rate: Dark = 60 ± 15 µmol N m^{-2} h^{-1}
± SD

Mean Reef Rate: Dark = 375 ± 75 µmol N m^{-2} h^{-1}
± SD

Daily rate if location and date is 14 hours light, 10 hours dark

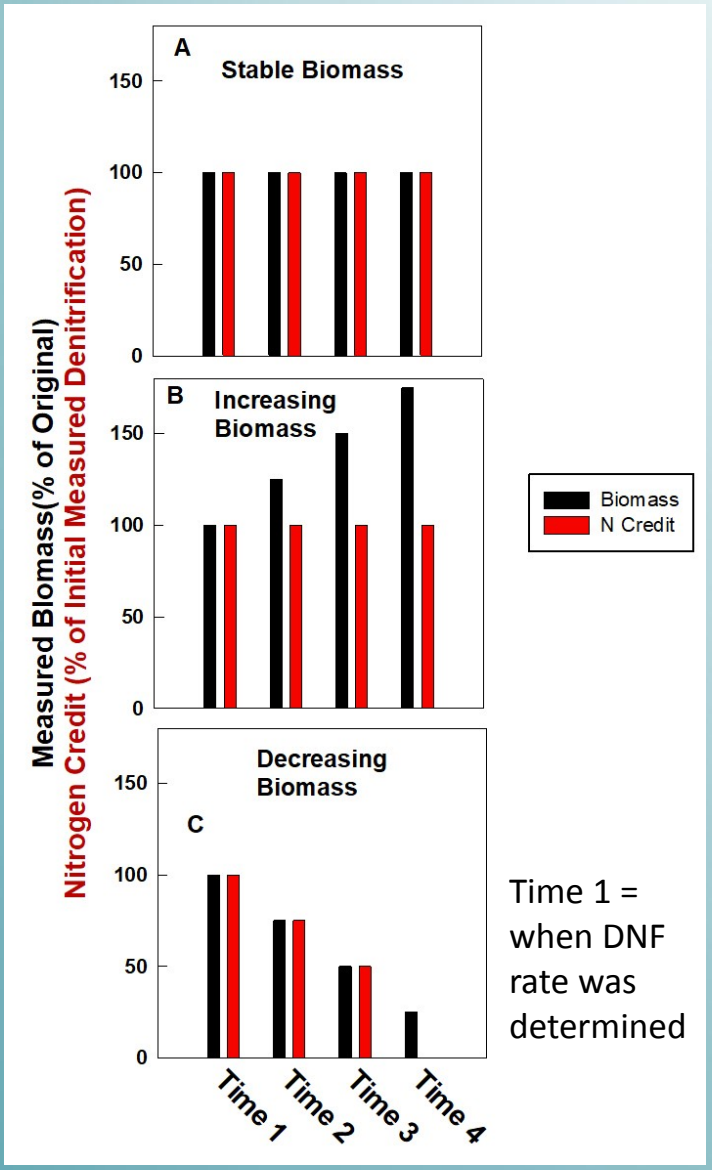
Reference = (60*24) = 1,440 µmol m^{-2} d^{-1}
Reef = (375*24) = 9,000 µmol m^{-2} d^{-1}

Reef – Reference = 7,420 µmol N m^{-2} d^{-1}
= 0.106 g N m^{-2} d^{-1}
= 0.95 lbs N $acre^{-1}$ d^{-1}

Example Assumptions:

- **Light does not reach bottom, dark rate applies to 24 hours.**
- Rates are typical warm season rates that can be observed in the summer season (e.g., July)
- Mean reference oyster tissue biomass = 0 g m^{-2}
- Mean reef oyster tissue biomass = 50 g m^{-2}

Enhanced Denitrification-Oyster Reef Restoration Chamber Reduction Verification Crediting Approach



Time 1 = when DNF rate was determined

- Full credit = Same or increased biomass as measured denitrification rate (A and B).
- Proportional credit = Lower biomass, but equal to or above 50% of original biomass (C, Time 2 and 3).
- No credit = Biomass lower than 50% of original biomass (C, Time 4).
- Reduction credit only applies when oyster tissue biomass is verified (via regression equations or direct measurements).

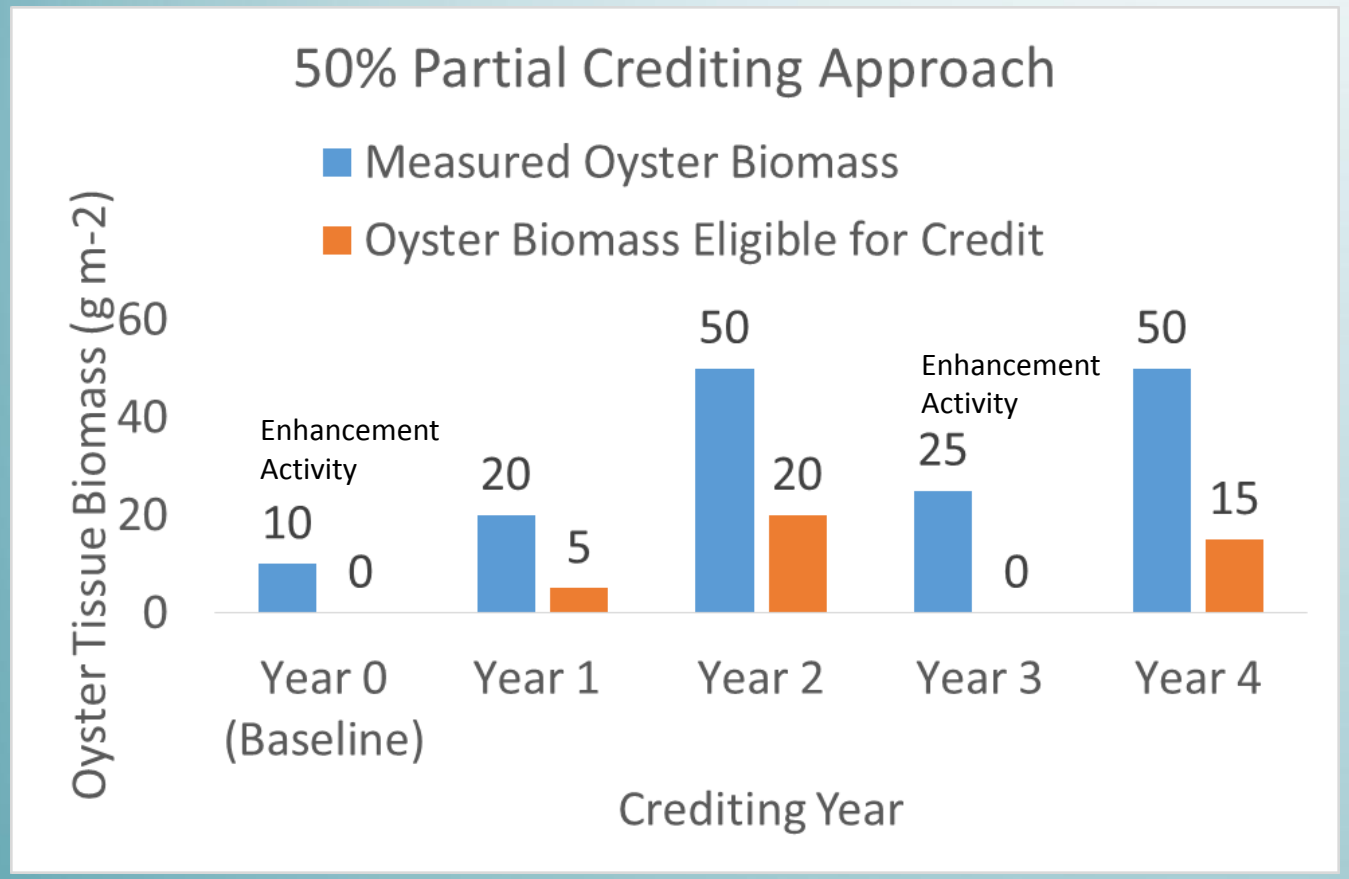
Enhanced Denitrification-Oyster Reef Restoration Core Reduction Verification Crediting Approach

- Full credit = Same or increased biomass as measured denitrification rate.
- No credit = Biomass decreases from when DNF rate was determined.
- Reduction credit only applies when oyster tissue biomass is verified (via regression equations or direct measurements).

Nitrogen and Phosphorus Assimilation-Oyster Reef Restoration Strategy to Determine Reduction Effectiveness

Fisheries Management Approach	Reduction Effectiveness Strategy (Crediting based on Live Oysters)
N and P Assimilation-Related (Tissue and Shell)	
Oyster Reef Restoration **(Oysters not removed from areas planted with hatchery-produced oysters or substrate; e.g., sanctuaries)**	**Reduction Effectiveness Determination:** Determine whole oyster estimates (tissue and shell) using established **shell height to tissue and shell dry weight quantile regression equations** or site measured biomass multiplied by the average nitrogen and phosphorus percent contents from existing data to represent sequestered nitrogen and phosphorus. **Verification:** Only credit 50% of appreciated oyster biomass at a time. Remaining 50% can be credited if oyster biomass stays the same or increases in a following year.

Nitrogen and Phosphorus Assimilation-Oyster Reef Restoration Reduction Effectiveness Verification Strategy



Enhancement Activity = Planting hatchery-produced oysters or substrate (e.g., shell)

When Oysters are Not Removed (Sequestered N an P)

- Use either established shell height to tissue dry weight regression equations or measured biomass at site.
- When oyster biomass appreciates, 50% of the assimilated nitrogen and phosphorus in the oyster tissue and shell is eligible for credit.
- The remaining 50% becomes eligible when oyster biomass remains the same or increases.
- If oyster biomass decreases, then no credit.
- Reduction credit only applies when oyster biomass is verified (via regression equations or direct measurements).

Nitrogen and Phosphorus Assimilation-Licensed Public Oyster Harvest Strategy to Determine Reduction Effectiveness

Fisheries Management Approach	Reduction Effectiveness Strategy (Crediting based on Live Oysters)
N and P Assimilation-Related (Tissue Only)	
Licensed Public Oyster Harvest Using Hatchery-Produced Oysters **(Oysters removed from public grounds by licensed fishers where hatchery-produced oysters were planted)**	**Reduction Effectiveness Determination:** • Use approved diploid estimates from 1st report • *Oyster Harvest Allowance*: Harvest claimed for reduction credit can be no more than 15% of planted hatchery-produced oysters. • *Reduction Credit Time Lag*: Oyster harvest becomes eligible for reduction credit 2 years after the planting. • *Lifespan of Oyster Harvest Allowance*: Max of 5 years after planting • *Lifespan of BMP*: Subsequent plantings must occur within 5 years for the BMP to remain active

Note: Shell N and P content not credited at this time due to research gap of what happens to N an P in shell when returned to the water.

Nitrogen and Phosphorus Assimilation-Licensed Public Oyster Harvest Reduction Estimates for N and P Assimilated in Harvested Oyster Tissue

BMP Name	Lbs N Reduced/1,000,000 Oysters Harvested	Lbs P Reduced/1,000,000 Oysters Harvested
Diploid Hatchery-Produced Oyster Licensed Public Oyster Harvest 2.25 Inches	110	22
Diploid Hatchery-Produced Oyster Licensed Public Oyster Harvest 3.0 Inches	**198**	**22**
Diploid Hatchery-Produced Oyster Licensed Public Oyster Harvest 4.0 Inches	331	44
Diploid Hatchery-Produced Oyster Licensed Public Oyster Harvest 5.0 Inches	485	44
Diploid Hatchery-Produced Oyster Licensed Public Oyster Harvest ≥ 5.5 Inches	683	66
Site-Specific Monitored Licensed Public Oyster Harvest	NA	NA

1 pound (Lbs) ~ 0.45 kg

Above BMPs would be reported annually and are only eligible in tidal waters (to qualify oysters had to be < 2 inches when planted and alive when removed).

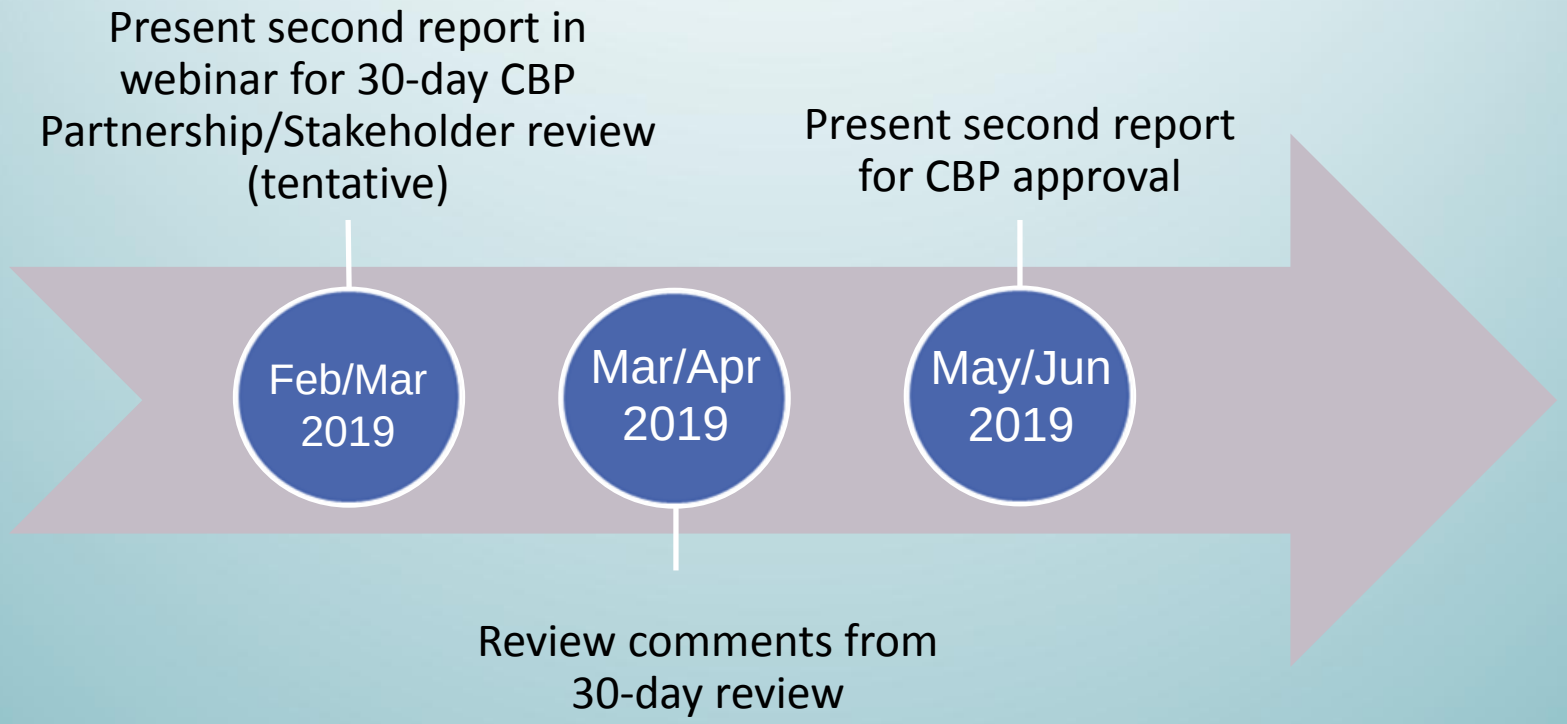
2nd Report: Oyster Practice-Protocol Combinations with Informational Recommendations

2nd Report includes informational recommendations on the following practice-protocol combinations where there are knowledge gaps (not seeking approval at this time):

- N and P **assimilation in shell of harvested oysters** from **private oyster aquaculture** and **licensed public harvest practices**
  - Potential framework to determine reduction effectiveness once more is known about shell dissolution when shells are returned to Bay

- N reduction via **enhanced denitrification** associated with oysters for **private oyster aquaculture** and **licensed public harvest practices**
  - Research fate of biodeposits
  - Understand how disturbance from harvesting affects denitrification rates

Panel Next Steps



How to Keep Informed of Panel Efforts

ORP webpage summarizing Panel effort

oysterrecovery.org/water-quality-improvement

First report available at

oysterrecovery.org/oyster-bmp-first-report/

Contact Information: jreichert@oysterrecovery.org

QUESTIONS?

Approved Oyster BMPs

- **Several private oyster aquaculture BMPs were approved by the Chesapeake Bay Program on December 19, 2016 (details in the Panel's 1st report):**
  - Provides estimates for the amount of nitrogen and phosphorus stored in oyster tissue for various sized harvested oysters from private oyster aquaculture practices.

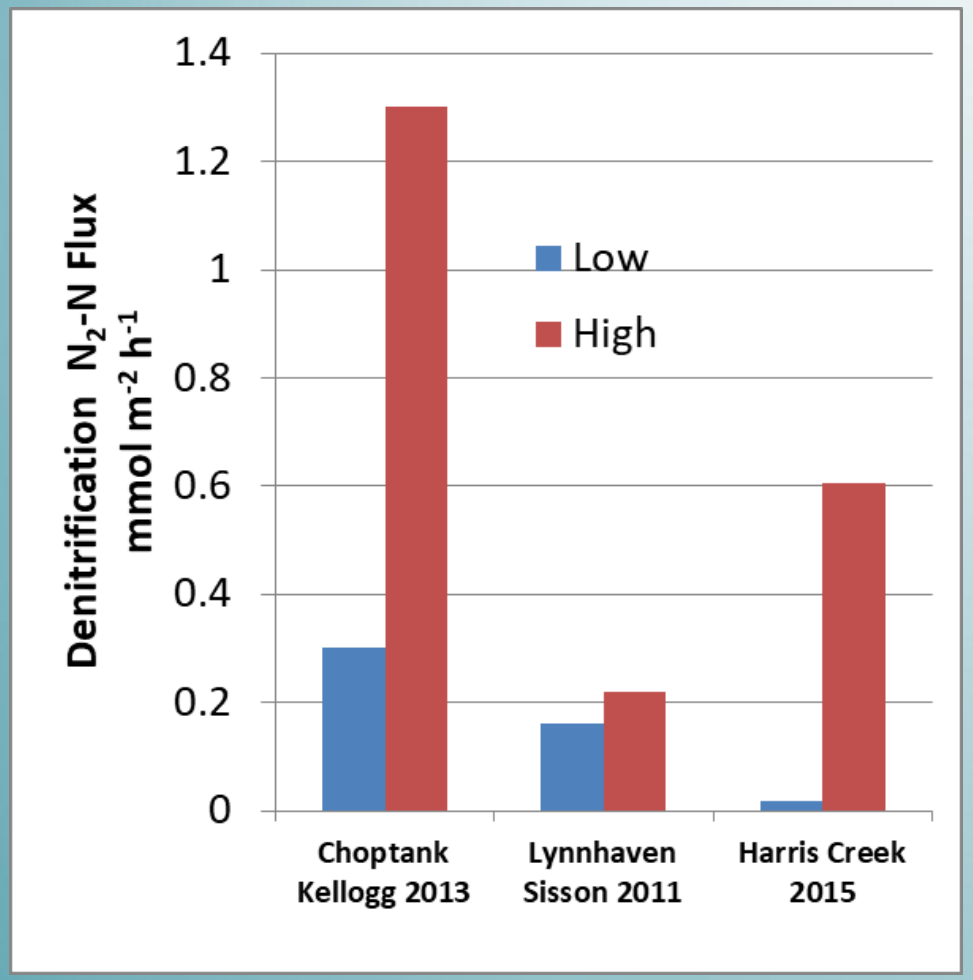
Endorsed Oyster Aquaculture Practices

- **Off-Bottom Culture:** with gear, such as near bottom cages or floating rafts, using hatchery-produced oysters.

- **Bottom Culture:** no gear using hatchery-produced oysters (oysters are planted directly on the bottom).
- **Bottom with Substrate Addition:** placing oyster shell or alternative substrate, such as granite, on the bottom to build habitat to support wild oysters.

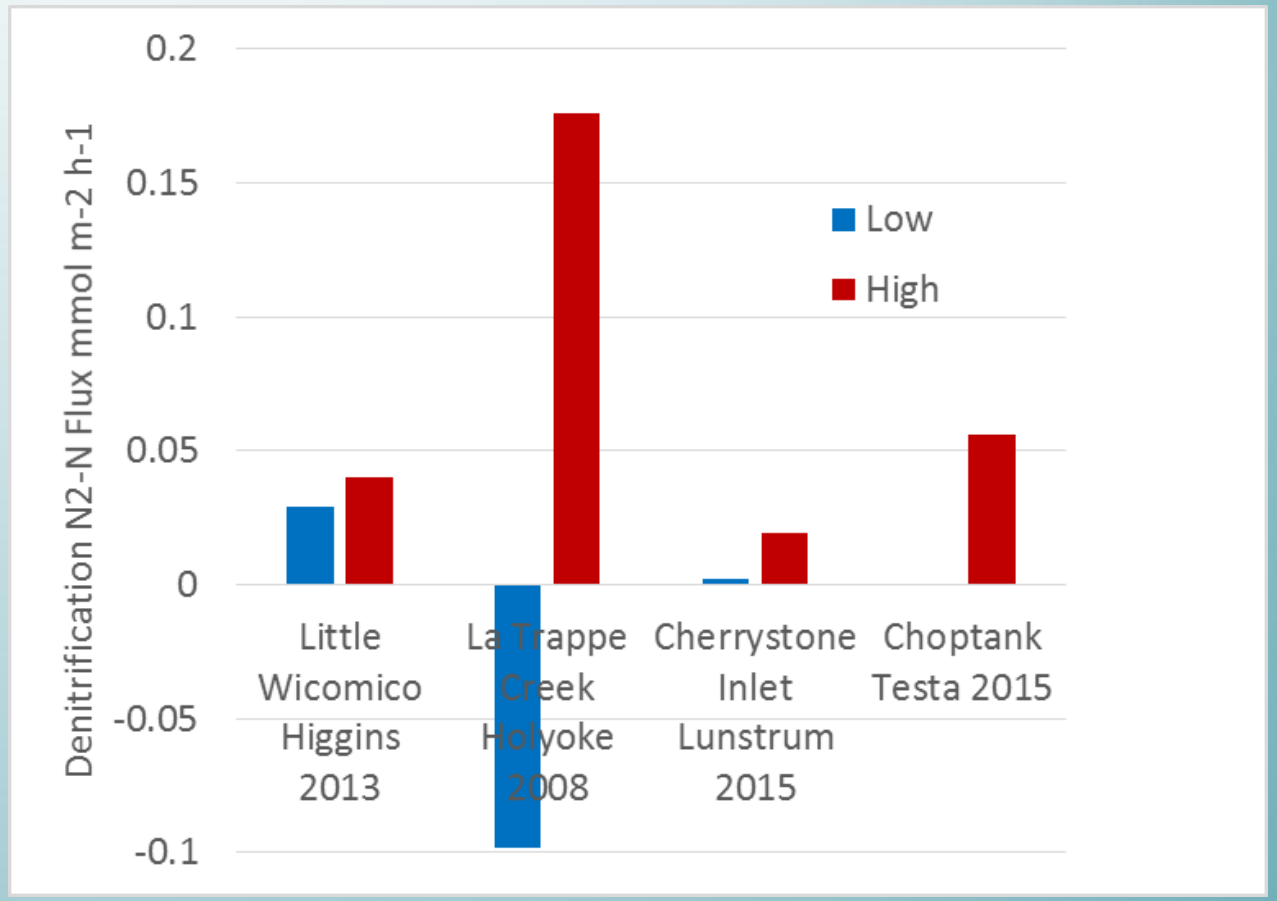
Enhanced Denitrification Protocol: Literature Review – High Variability

Chesapeake Bay, Restoration-Related



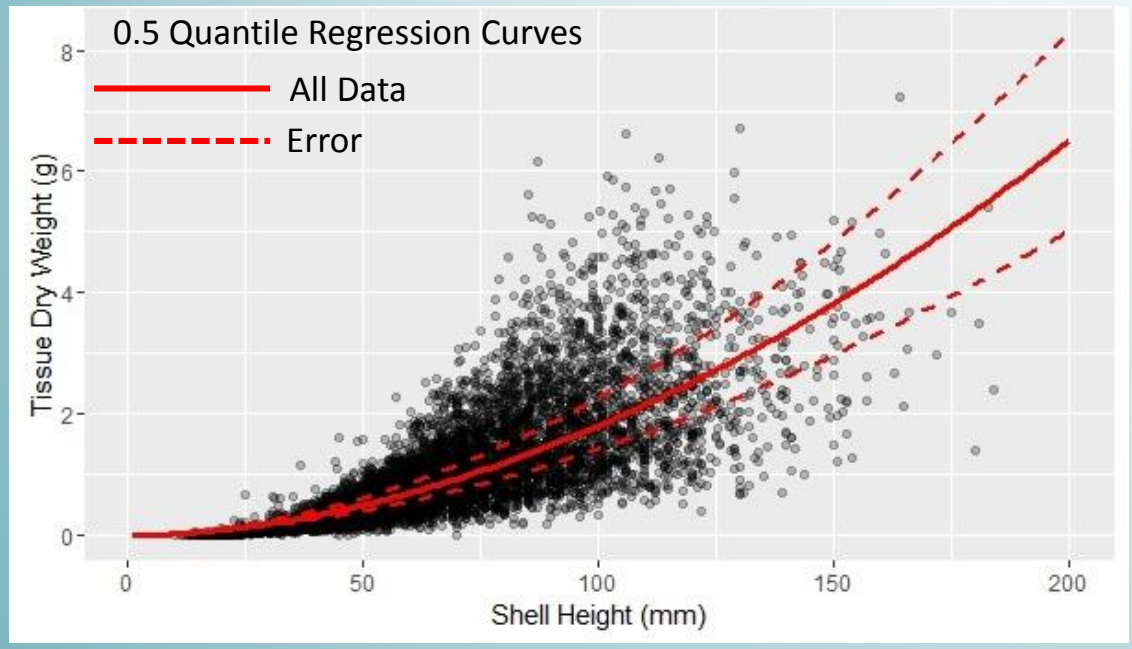
Low = minimum rate observed
High = maximum rate observed

Chesapeake Bay, Aquaculture-Related



Conclusion: Minimum data and high variability supports the need for site-specific estimates for restoration practices; more research needed to apply to aquaculture practices given negative values.

Protocols Related to N and P Assimilation: Strategy to Determine Default Reduction Effectiveness Estimates



Use quantile regression to determine shell height: tissue dry weight relationship (include data from multiple locations, practices, ploidy, and seasons)

Determine which growth influencing factors warrant separate quantile regression equations (e.g., ploidy)

Convert dry weight to N and P reduction using average N &P content of oyster tissue from East Coast estuaries

Identify typical industry size classes and generate N reduction per size class for diploid and/or triploid oysters

Nitrogen and Phosphorus Assimilation-Licensed Public Oyster Harvest Example

Time Code (Annual Timeframe)	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Total
Year and Seasonal Timeframe of Activity	2019 Planting (May-Sep) 2019/2020 Harvest (Oct-Mar)	2020 Planting (May-Sep) 2020/2021 Harvest (Oct-Mar)	2021/2022 Harvest (Oct-Mar)	2022/2023 Harvest (Oct-Mar)	2023 Planting (May-Sep) 2023/2024 Harvest (Oct-Mar)	2024/2025 Harvest (Oct-Mar)	2025/2026 Harvest (Oct-Mar)	2026/2027 Harvest (Oct-Mar)	2027/2028 Harvest (Oct-Mar)	2028/2029 Harvest (Oct-Mar)	2029/2030 Harvest (Oct-Mar)	
When BMP Plantings Occurred	P	P			P							
Total Spat Planted in BMP Area (Individuals)	10,000,000	5,000,000	0	0	5,000,000	0	0	0	0	0	0	20,000,000
Potential Harvest Allowance for Reduction Credit after 2-Yr Time Lag (Max 15% of Planted Total) (Individuals)	1,500,000	750,000	0	0	750,000	0	0	0	0	0	0	**3,000,000**
Bushel Equivalent of Harvest Allowance (300 oysters/bushel)	5,000	2,500	0	0	2,500	0	0	0	0	0	0	10,000

Nitrogen and Phosphorus Assimilation-Licensed Public Oyster Harvest Example

Time Code (Annual Timeframe)	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Total
Year and Seasonal Timeframe of Activity	2019 Planting (May-Sep) 2019/2020 Harvest (Oct-Mar)	2020 Planting (May-Sep) 2020/2021 Harvest (Oct-Mar)	2021/2022 Harvest (Oct-Mar)	2022/2023 Harvest (Oct-Mar)	2023 Planting (May-Sep) 2023/2024 Harvest (Oct-Mar)	2024/2025 Harvest (Oct-Mar)	2025/2026 Harvest (Oct-Mar)	2026/2027 Harvest (Oct-Mar)	2027/2028 Harvest (Oct-Mar)	2028/2029 Harvest (Oct-Mar)	2029/2030 Harvest (Oct-Mar)	
When BMP Plantings Occurred	P	P			P							
BMP Lifespan			Active	Active	Active	Active	Active	Active	Active	Active	**Expired**	
Total Oysters Harvested from BMP Area (Bushels)	0	0	1,000	1,500	0	2,000	2,000	2,500	3,000	2,500	1,500	16,000
Individual Equivalent Harvested from BMP Area (300 oysters/bushel)	0	0	300,000	450,000	0	600,000	600,000	750,000	900,000	750,000	450,000	**4,800,000**
First Eligible Harvest for Credit after Reduction Credit Time Lag of 2 Years (By Time Code of Planting)			T0	T1			T4					
Last Eligible Harvest for Credit based on Max of 5 Years Harvest Allowance Lifespan (By Time Code of Planting)						T0	T1			T4		
Available Harvest Allowance after 2-Yr Time Lag and 5-Yr Expiration (Individuals)	0	0	1,500,000	1,950,000	1,500,000	1,500,000	1,500,000	750,000	0	0	0	
Total Harvest Claimed for Reduction Credit (Individuals)	0	0	**300,000**	**450,000**	**0**	**600,000**	**600,000**	**750,000**	0	0	0	**2,700,000**
Expired Harvest Allowance (Individuals)	0	0	0	0	0	0	150,000	150,000	0	0	0	**300,000**

Nitrogen and Phosphorus Assimilation-Licensed Public Oyster Harvest Example

	Lbs Removed											
Time Code (Annual Timeframe)	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**	**Total**
Nitrogen Credit (3-Inch Oyster)	0	0	60	89	0	119	119	149	0	0	0	**536**
Phosphorus Credit (3-Inch Oyster)	0	0	7	10	0	13	13	17	0	0	0	**60**

N and P Assimilation in Oyster Shell: Strategy to Determine the Reduction Effectiveness for Private Oyster Aquaculture Practices (DRAFT)

1. Can shell weight be reliably determined from shell length measurements?

Yes ✓ Can use same approach as tissue for default values

2. Can N and P content in shell be quantified?

Yes ✓

3. Can credit be given in a way that does not disincentivize shell recycling?

Yes ✓ Assume 100% of shell removed is returned to the Bay

4. Dissolution Approach: Can a reasonable estimate of dissolution losses be obtained from the literature?

No, not feasible at this time due to research gap

5. Is the loss rate feasible for a BMP?

?

6. Recommend appropriate sequestration estimate that includes deduction for dissolution

Sequestration for in water BMPs is valid (EPA legal opinion 2018)