Oyster BMP Expert Panel Update

October 3, 2019

Chris Moore
Representing Many Colleagues

Acknowledgements

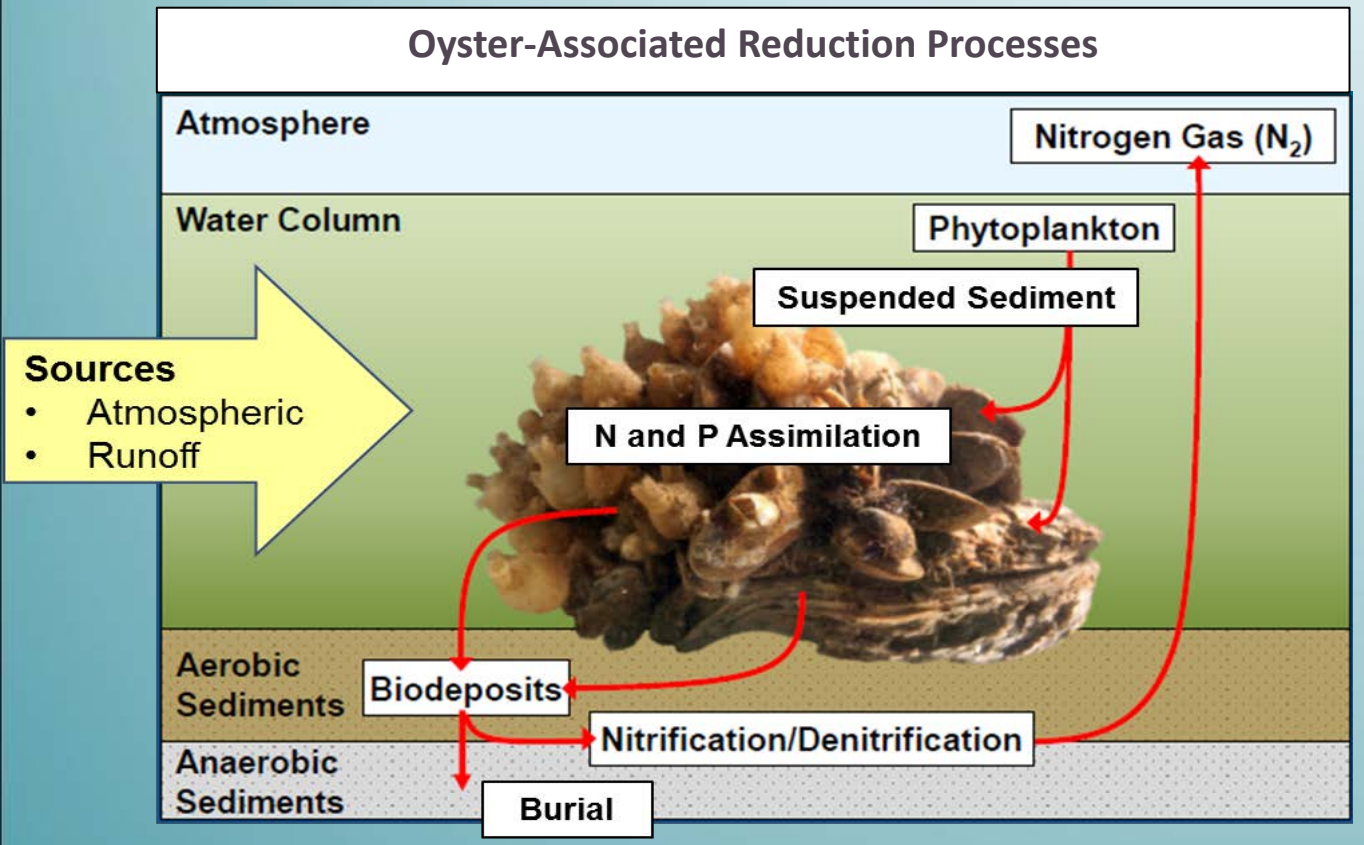
Role	Oyster BMP Expert Panel
Panelists	**Jeff Cornwell (Panel Chair)** and Larry Sanford (UMCES) Suzanne Bricker and Julie Rose (NOAA) Lynn Fegley, Frank Marenghi (MDNR) Karen Hudson, Lisa Kellogg, and Mark Luckenbach (VIMS) Andrew Lacatell (TNC) Chris Moore (CBF) Matt Parker (Sea Grant at U. of MD) and Ken Paynter (U. of MD) Bill Wolinski (Talbot County of Public Works)
Chesapeake Bay Program/US EPA Advisors	Lucinda Power, Rich Batiuk, Lew Linker, Matt Johnston, Ralph Spagnolo, and Ed Ambrogio, Jeff Sweeney, Jeremy Hanson
Panel Support	Julie Reichert-Nguyen, Ward Slacum and Emily French (ORP), Carl Cerco (US Army Corps of Engineers), Paige Hobaugh, Emilie Franke, and Kyle Runion (CBP)
Data	Colleen Higgins, Kurt Stephenson, Bonnie Brown, Peter Kingsley-Smith, Steve Allen, Paige Ross, Roger Mann, and Melissa Southworth
Stakeholder Review	Citizen Advisory Committee, Chesapeake Bay Foundation, Chesapeake Bay Commission, Lynnhaven River Now, Southern Environmental Law Center and partners, Oyster Company of Virginia, and Norfolk Public Works

Oyster BMP Expert Panel Charge

- **Panel convened on September 22, 2015; charged with:**
  - Establishing a nutrient and suspended sediment reduction effectiveness determination decision framework for oyster BMPs.
  - Determining the nutrient and suspended sediment reduction effectiveness of oyster practices using available science.

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

Identify individual nutrient and suspended sediment reduction effectiveness crediting protocols based on oyster-associated nutrient and 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

Best Management Practice Matrix

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 oyster harvest using hatchery-produced oysters	G. Licensed oyster harvest using transplanted wild oysters	H. Licensed oyster harvest using substrate addition	I. Licensed oyster harvest with no activity	J. Oyster reef restoration using hatchery-produced oysters	K. Oyster reef restoration using substrate addition	L. Oyster reef restoration using no harvest area designation only
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. Suspended Sediment Reduction Associated with Oysters												
7. Enhanced Nitrogen Burial Associated with Oysters												
8. Enhanced Phosphorus Burial Associated with Oysters												

Three Important Terms

- **Approved**
  - BMPs were approved by the CBP on December 19, 2016
- **Interim Planning**
  - Planning Estimates – Not to be used for actual crediting
- **Pending Approval**
  - Draft recommendations in the upcoming report

Incremental Recommendations

	Private Oyster Aquaculture					Licensed 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 oyster harvest using hatchery-produced oysters	G. Licensed oyster harvest using transplanted wild oysters	H. Licensed oyster harvest using substrate addition	I. Licensed oyster harvest with no activity	J. Oyster reef restoration using hatchery-produced oysters	K. Oyster reef restoration using substrate addition	L. Oyster reef restoration using no harvest area designation only
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 Not Endorsed	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

Approved Oyster BMPs

- **Several oyster aquaculture BMPs were <u>approved</u> 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 oysters for private oyster aquaculture practices.

Decision Points	Nitrogen Assimilation Oyster Tissue	Phosphorus Assimilation Oyster Tissue
Step 1 - Suitable for BMP Consideration	YES	YES
Step 2 - Sufficient Science	YES	YES
Step 3 – Verifiable	YES	YES
Step 4 – Identified Unintended Consequences Manageable	YES	YES

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.

Reduction Effectiveness Estimates for N and P Assimilated in Harvested Oyster Tissue from Approved Oyster Aquaculture BMPs

BMP Name	Lbs N Reduced/1,000,000 Oysters Harvested	Lbs P Reduced/1,000,000 Oysters Harvested
Diploid Oyster Aquaculture 2.25 Inches	110	22
Diploid Oyster Aquaculture 3.0 Inches	**198**	**22**
Diploid Oyster Aquaculture 4.0 Inches	331	44
Diploid Oyster Aquaculture 5.0 Inches	485	44
Diploid Oyster Aquaculture ≥ 5.5 Inches	683	66
Triploid Oyster Aquaculture 2.25 Inches	132	22
Triploid Oyster Aquaculture 3.0 Inches	**287**	**22**
Triploid Oyster Aquaculture 4.0 Inches	573	66
Triploid Oyster Aquaculture 5.0 Inches	970	110
Triploid Oyster Aquaculture ≥ 5.5 Inches	1,477	154
Site-Specific Monitored Oyster Aquaculture	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).

Approved Interim BMPs

	Oyster Reef Restoration		
Oyster Practice Category x Crediting Protocol	J. Oyster reef restoration using hatchery-produced oysters	K. Oyster reef restoration using substrate addition	L. Oyster reef restoration using no harvest area designation only
1. Nitrogen Assimilation in Oyster Tissue	2nd Complete	2nd Complete	2nd Policy Issue
2. Nitrogen Assimilation in Oyster Shell	2nd Complete	2nd Complete	2nd Policy Issue
3. Enhanced Denitrification Associated with Oysters	2nd Complete	2nd Complete	2nd Policy Issue
4. Phosphorus Assimilation in Oyster Tissue	2nd Complete	2nd Complete	2nd Policy Issue
5. Phosphorus Assimilation in Oyster Shell	2nd Complete	2nd Complete	2nd Policy Issue

Approved Oyster Reef Restoration Practices for Interim BMP Use

Endorsed Oyster Practice Title	Practice Definition
J. Oyster reef restoration using hatchery-produced oysters	Planting oysters (e.g., spat-on-shell, single oysters) produced from hatchery techniques directly on the bottom or raised substrate to enhance oyster biomass in areas where removal is not permitted.
K. Oyster reef restoration using substrate addition	Planting oyster shells and/or alternative substrate directly on the bottom to attract recruitment of naturally occurring (wild) oyster larvae to enhance oyster biomass in areas where removal is not permitted.

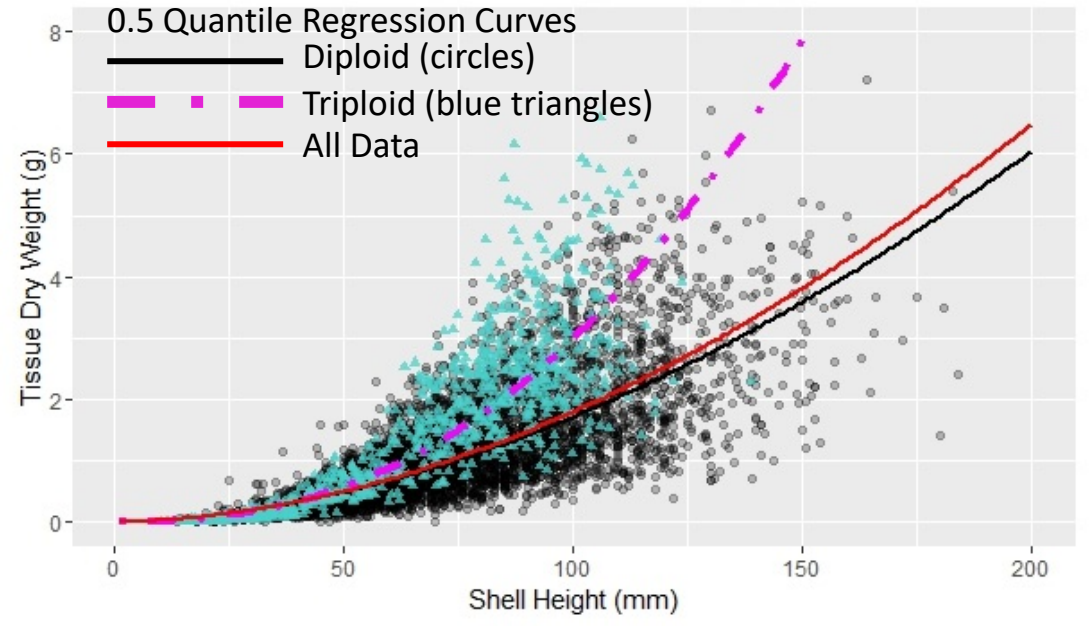
N & P Assimilation Interim BMPs—Combined Tissue & Shell

Based on 2017/2018 Harris Creek Data (Shell-Base Sites)

Oyster Reef Restoration-Assimilation Estimates for Planning		
Live Oyster Tissue + Shell Reduction Effectiveness	lbs acre^{-1} year^{-1} (max duration = 3 years)	
Treatment Category	Nitrogen	Phosphorus
Shell-Base + SOS n = 7 sites Mean Live Density = 42 oysters m^{-2}	24	4

- Planning estimates are one time credits expressed as annual rates. Can be applied for a total of three years on acres where substrate (shell or alternative substrate, such as granite or stone) and/or hatchery-produced SOS were planted.
- The total N and P reduction (tissue plus shell) ~ 72 lbs acre^{-1} and 12 lbs acre^{-1}, respectively.
- Represents a mean live oyster tissue and shell biomass of ~ 45 and 2300 g m^{-2}, respectively, three years post-restoration.

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

N & P Assimilation Conclusions

- The N and P reduction effectiveness for the oyster reef restoration-assimilation BMPs are driven by oyster tissue and shell biomass
  - Data from Harris Creek provided the largest dataset to determine conservative planning estimates
  - Reflects potential oyster tissue and shell biomass three years post restoration
- Planning estimates can be applied more broadly for other restoration projects in the Chesapeake Bay for planning purposes
- Should **NOT** be used to calculate the N and P reduction for crediting purposes
  - Oyster densities, and consequently, tissue and shell biomass, can vary quite significantly depending on the restoration activity and location
  - For crediting purposes, site-specific data should be acquired to determine the oyster tissue and shell biomass following the Oyster BMP Expert Panel's recommendations
- Planning estimates can apply for a max duration of three years
  - Unknown at this time whether there are additional increases in oyster tissue and shell biomass beyond three years post restoration.

A Planning Estimate for an Oyster Reef Restoration Enhanced Denitrification Rate Based on Harris Creek Data

Jeffrey Cornwell, UMCES

M. Lisa Kellogg, VIMS

Michael S. Owens, UMCES

Julie Reichert-Nguyen, Oyster Recovery Partnership

Denitrification Field Studies

	Enhanced Dark Denitrification Reef Rate ($\mu mol\ m^{-2}\ h^{-1}$)			Enhanced Light Denitrification Reef Rate ($\mu mol\ m^{-2}\ h^{-1}$)		
Oyster Tissue Biomass Category	***Spring***	***Summer***	***Fall***	***Spring***	***Summer***	***Fall***
Low	58	122	-13	140	210	0
Medium		248	41		259	51
High	370	296	67	674	367	99
Mean hours per day	9.7	9.7	12.2	14.3	14.3	11.8

	Daily Denitrification Reef Enhancement ($\mu mol\ m^{-2}\ d^{-1}$)			Denitrification Reef Enhancement during Measured Timeframe ($\mu mol\ m^{-2}\ 184\ d^{-1}$)
Oyster Tissue Biomass Category	***Spring***	***Summer***	***Fall***	***Sum of Season x Eligible Crediting Days***
Low	2,558	4,183	-160	454,425
Medium		6,112	1,096	629,202
High	13,218	8,115	1,980	1,277,154
Eligible Crediting Days	31	92	61	184

	Net Denitrification Reef Enhancement ($lbs\ acre^{-1}\ y^{-1}$)			
Oyster Tissue Biomass Category	***Spring***	***Summer***	***Fall***	***Annual Total Based on 184 Eligible Crediting Days***
Low	10	48	-1	**57**
Medium		70	8	79
High	51	93	15	160

Enhanced Denitrification Conclusions

- The most conservative estimate for nitrogen removal via denitrification comes from the low oyster tissue biomass estimate of 57 lbs N $acre^{-1}$ y^{-1}
  - Based on 184-day timeframe of measured values
  - Appropriate for extrapolation to the whole Harris Creek restoration area and for other restoration sites in Chesapeake Bay for planning purposes

- Should **NOT** be used to calculate the N reduction for crediting purposes
  - Site-specific estimates are needed to address variability in denitrification values

- Note: N reduction from assimilation and enhanced denitrification protocols are additive

Important Timeframes

- Interim Oyster Reef Restoration-N and P Assimilation (Approved for Planning): 24 lbs N/acre/year and 4 lbs P/acre/year for a max of 3 years

- Oyster Reef Restoration-N and P Assimilation BMP (DRAFT): Since crediting is based on monitoring data as long as there is an appreciation of live oyster biomass and you haven't received credit for it yet, you can claim it. We do recommend monitoring at a minimum every 3 years, but you can monitor more frequently if you want to.

- Interim Oyster Reef Restoration-Enhanced Denitrification (Approved for Planning): 57 lbs N/acre/year

- Based on the timeframe from May 1 to October 31 (184 days total) which represents the warmer months. When converting to the daily rate, hourly DNF rates were averaged and multiplied by the corresponding days using the seasonal timeframes of Spring (May = 31 days), Summer (June-August = 92 days), and Fall (Sep to Oct = 61 days).

- Oyster Reef Restoration-Enhanced Denitrification BMP (DRAFT): The established site-specific seasonal rates can be used as long as oyster tissue biomass is maintained or increases when compared to the oyster tissue biomass the denitrification rates were established at. Note that we are still sorting this out and draft recommendations will be included in upcoming report.

Oyster BMPs (Pending Approval)

- Several additional oyster BMPs will be recommended by the Panel in 2nd report:
  - N and P **assimilation in tissue of harvested oysters** from **licensed oyster harvest** that use hatchery-produced oysters.
  - N and P **assimilation in whole live oysters** (tissue and shell) for **oyster reef restoration practices** (sequestration).
  - N reduction via **enhanced denitrification** associated with oysters for **oyster reef restoration practices**.

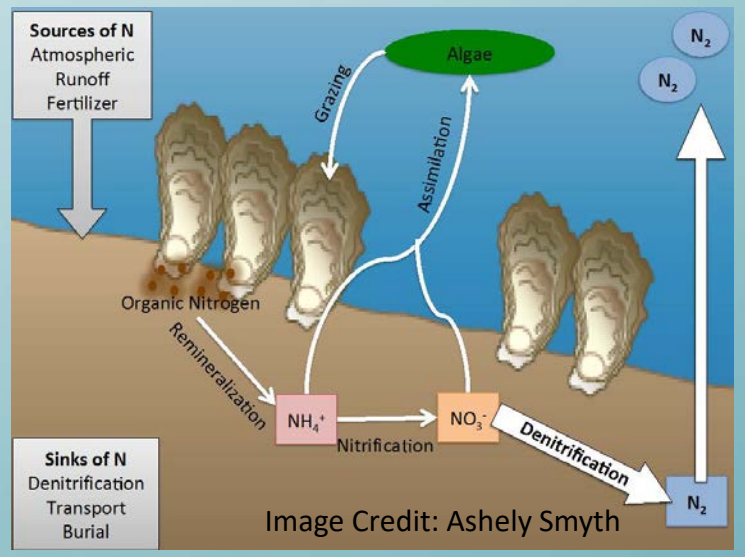


Image Credit: Ashely Smyth

2nd Report Schedule

Julie Reichert-Nguyen
Panel Coordinator
Oyster Recovery Partnership

1805 A Virginia Street
Annapolis, MD 21401
Direct Tel: (443) 808-2869
Main Tel: (410) 990-4970
jreichert@oysterrecovery.org

Chris Moore
Senior Scientist
Chesapeake Bay Foundation
3663 Marlin Bay Drive
Virginia Beach, VA 23455
(757) 644-4109
cmoore@cbf.org