Panel Recommendations on the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework and Nitrogen and Phosphorus Assimilation in Oyster Tissue Reduction Effectiveness for Oyster Aquaculture Practices

Jeff Cornwell, Julie Rose, Lisa Kellogg, Mark Luckenbach, Suzanne Bricker, Ken Paynter, Chris Moore, Matt Parker, Larry Sanford, Bill Wolinski, Andy Lacatell, Lynn Fegley, Karen Hudson

Oyster BMP Expert Panel First Incremental Report

December 5, 2016

Prepared by:
Julie Reichert-Nguyen, Emily French, and Ward Slacum, Oyster Recovery Partnership

Chesapeake Bay Program (CBP) Partnership 30-Day Review: September 22 to October 22, 2016

Approved by Watershed Technical Work Group (WTWG): December 1, 2016

Approved by Water Quality Goal Implementation Team (WQGIT), in coordination with the Fisheries and Habitat GITs:

Acknowledgements

The Panel would like to thank Colleen Higgins, Kurt Stephenson, Bonnie Brown, Peter Kingsley-Smith, Steve Allen, and Paige Ross for sharing their data to support the development of the default nitrogen and phosphorus assimilation reduction effectiveness estimates. The Panel would also like to thank Lucinda Power, Rich Batiuk, Ed Ambrogio, and Tom Schuler for their support in guiding the Panel through the BMP review process and Lew Linker, Carl Cerco, and Matt Johnston for their assistance in understanding the models used to inform the TMDL and determining how the recommendations can be incorporated into the Phase 6 Watershed Model. The Panel would also like to express their gratitude to Delegate Anthony J. O'Donnell, Sue Kriebel, Steve McLaughlin, Russ Baxter, Tolar Nolley, Brad Rodgers, Johnny Shockley, and John Klein for their participation and input during the Panel's open stakeholder session and to the Citizen Advisory Committee, Chesapeake Bay Commission, Chesapeake Bay Foundation, Lynnhaven River Now, Southern Environmental Law Center and partners, and Norfolk Public Works for their review and feedback on the Panel's preliminary findings and recommendations presented during the February 8 and April 25, 2016 Water Quality Goal Implementation Team meetings.

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Acronyms in Document

AFDW- Ash Free Dry Weight

BMP- Best Management Practice

CBF- Chesapeake Bay Foundation

CBP- Chesapeake Bay Program

DW- Dry Weight

EPA- Environmental Protection Agency

FARM model- Farm Aquaculture Resource Management

GIT- Goal Implementation Team

N- Nitrogen

NOAA- National Oceanographic and Atmospheric Administration

P- Phosphorus

PVC- Polyvinyl chloride

SH- Shell Height

STAC- Scientific and Technical Advisory Committee

TMDL- Total Maximum Daily Load

TNC- The Nature Conservancy

UMCES- University of Maryland Center for Environmental Science

VIMS- Virginia Institute of Marine Science

WQGIT- Water Quality Goal Implementation Team

WW- Wet Weight

Key Definitions Related to their Use in this Report

Assimilation: The process where oysters convert the nitrogen and phosphorus within absorbed food into substance of the body (e.g., tissue, shell).

Biodeposition: Organic matter (e.g., feces and pseudofeces from oysters) deposited on the bottom (i.e., sediment surface).

Burial: The process in which nutrients are trapped in the bottom sediment for long timescales (i.e., below the active zone where decomposition occurs).

Cultch: Material suitable for settlement of oyster larvae (e.g., oyster shell). Also, referred to as substrate.

Cultchless oysters: Single oysters produced by settling oyster larvae on pieces of substrate small enough to be indistinguishable from the adult shell at the time of harvest.

Denitrification: The process that reduces nitrates or nitrites to nitrogen gas, commonly by bacteria in the bottom sediment. Nitrogen gas ultimately escapes into the atmosphere.

Diploid oyster: Wild or hatchery-produced oysters containing two complete sets of chromosomes, one from each parent and capable of sexual reproduction.

Hatchery-produced oyster: Diploid or triploid oysters propagated outside their natural environment in private or State-run hatcheries.

Oyster hatchery: Private or State-run operations that produce diploid and/or triploid oyster larvae outside their natural environment for research, restoration, educational, and/or commercial uses.

Oyster reef restoration: Activities aimed to restore and/or protect oysters to increase the wild oyster population.

Oyster sanctuary: An area of bottom closed to oyster harvest usually with the intention of allowing oyster populations to recover.

Oyster seed: Refers to oysters below legally harvestable size and typically used in connection to oysters that are being moved from one location to another (e.g. from a hatchery to aquaculture operation or from an area with high natural recruitment to an area with lower recruitment).

Oyster shell height: The longest distance (parallel to the long axis) between the hinge and lip of the oyster.

Oyster spat: Typically refers to oysters that have settled (attached) onto substrate and are less than one year old.

Ploidy: The number of sets of chromosomes in a cell.

Private oyster aquaculture: Growing and harvesting diploid or triploid oysters in areas designated for oyster aquaculture where public fishing is not allowed (e.g., State-permitted oyster aquaculture leases to private oyster aquaculturists).

Public fishery: Managed fishery that is open to harvest by individuals holding the appropriate licenses.

Quantile regression: Type of regression analysis that estimates the conditional median or other quantiles of the response variable.

Recruitment: The number of individuals surviving to a certain size, age, or life stage (e.g., spat, reproductive maturity, etc.).

Spat-on-shell planting: Oyster larvae that have settled (attached) onto shell and have been placed on the bottom.

Substrate: Materials (e.g., shell, granite, etc.) that oyster larvae can attach to. Shell substrate is also referred to as cultch.

Substrate addition: The act of placing substrate (e.g., shell, granite, etc.) on the sediment surface to harden the bottom to enhance the potential recruitment of wild oyster larvae.

Sufficient Science: In the Panel's best professional judgment, data of sufficient quality and scope exist and can be used to generate a reasonably constrained estimate of the reduction associated with a particular oyster practice category.

Suitable for Reduction Effectiveness Consideration: In the Panel's best professional judgment, the reduction process could occur in association with a particular oyster practice category and involves an enhancement activity that could result in the production of new oysters (i.e., the reduction effectiveness can be attributed to the practice).

Suspended sediment: Very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom.

Triploid oyster: Hatchery-produced oysters containing three sets of chromosomes, typically a result of hybridizing a diploid (2-set chromosome individual) with a tetraploid (4-set chromosome individual) via human manipulation. The resulting triploid oyster lacks reproduction capabilities.

Unintended Consequence: Potential unexpected negative or positive effects resulting from the practice. Positive unintended consequences are referred to as "ancillary benefits" in this report to match the terminology found in the BMP Review Protocol (CBP 2015).

Verifiable: In the Panel's best professional judgment, a practical method exists, or could be created, to track reduction effectiveness if the BMP is implemented.

Wild oyster: Diploid oysters produced in their natural environment without human involvement.

1.0 Introduction

Federal and State governments are actively rebuilding the Chesapeake Bay's Eastern oyster (*Crassostrea virginica*) population for ecological benefits while concurrently building a robust oyster aquaculture industry. With scientific research demonstrating that oysters can contribute to the reduction of nutrients (nitrogen and phosphorus) and suspended sediment from the water column (Kellogg et al. 2013 and 2014a, Grizzle et al. 2008), there is growing interest in recognizing oyster practices as best management practices (BMPs) and crediting their nutrient and suspended sediment reduction effectiveness in the Chesapeake Bay Program (CBP) Partnership's model framework,[1] a tool used to assess whether appropriate progress towards water quality goals, established by the Total Maximum Daily Load (TMDL), is being made for the Chesapeake Bay (U.S. EPA 2010). As a result, the CBP Partnership requested that an Oyster BMP Expert Panel be convened to develop recommendations for 1) a decision framework to determine the nutrient and suspended sediment reduction effectiveness of oyster practices as BMPs for application in the CBP Partnership's model framework and 2) the nitrogen, phosphorus, and suspended sediment reduction effectiveness of oyster practices based on existing science. The Oyster BMP Expert Panel (hereafter, "Panel") convened on September 30, 2015, has met monthly for a total of 17 meetings to date (see Appendix A for summary of the Panel's meetings and other activities and Appendix E for meeting minutes) and has had numerous e-mail and phone conversations to develop the recommendations found in this incremental report.

Oysters consume algae and other organic matter from the water column through filter feeding. A portion of the nutrients within that organic matter, including nitrogen (N) and phosphorus (P), are assimilated into the oyster's tissue and shell (Kellogg et al. 2013) and are thereby removed from the water column. Oysters further enhance nitrogen removal by creating conditions conducive to denitrification and burial of organic matter

[1] Details of the CBP partnership's model framework can be found at http://www.chesapeakebay.net/groups/group/modeling_team.

(Newell et al. 2005). Denitrification is the final step in a set of transformations that converts organic nitrogen to nitrogen gas, a form of nitrogen that cannot be used for growth by phytoplankton. When oyster waste is deposited onto the sediment surface, it can be buried, making the nitrogen and phosphorus it contains unavailable to the water column (Newell et al. 2005). In addition to filtering organic matter from the water column, oysters also remove inorganic matter in the form of suspended sediments and increase water clarity (Grizzle et al. 2008 and sources therein). These oyster-associated nutrient and suspended sediment reduction processes were used by the Panel to develop the individual reduction effectiveness crediting protocols for BMP application further described in Section 6.0.

Various oyster practices exist in the Chesapeake Bay involving different culture types (e.g., hatchery-produced diploid or triploid oysters, wild diploid oysters) and culture methods (e.g., oysters grown off-bottom in the water column in gear or on-bottom without gear, transplanting juvenile wild oysters from one location to another). Additionally, these practices operate under different fisheries management approaches, including private oyster aquaculture (i.e., oysters are grown and harvested by private oyster aquaculturists within State-permitted areas designated for oyster aquaculture), the public fishery (i.e., oysters are harvested by individuals with appropriate licenses within State-managed areas designated for public fishing), and oyster reef restoration (i.e., oysters are restored and/or protected in sanctuaries where harvesting is prohibited). Private oyster aquaculture and public fishery practices result in the eventual removal (harvest) of the oysters from the waterbody, while oyster reef restoration practices aim for the oysters to remain in the water with the intention of allowing oyster populations to recover. Oysters used in these practices are either hatchery-produced (i.e., oysters propagated outside their natural environment in private or State-run hatcheries) or wild (i.e., oysters that spawned within their natural environment with no human involvement). Additionally, the ploidy (i.e., the number of sets of chromosomes in a cell) of the oysters can be either diploid or triploid. Wild oysters are diploid and capable of sexual reproduction. Hatchery-produced diploid oysters are similar to wild oysters, but can also be selectively bred to exhibit faster growth and/or be resistant to common diseases (Rawson et al. 2010; Degremont et al. 2015). Hatchery-produced triploid oysters, created by manipulating chromosomes of broodstock to produce triploid offspring incapable of sexual reproduction, usually grow faster than diploid oysters (Allen and Downing 1986) and may exhibit greater disease resistance (Degremont et al. 2015). While triploid oysters may occur in the wild, it is rare; therefore, for the purposes of this report, wild oysters are assumed to be diploid oysters.

Private oyster aquaculture practices occurs in State-permitted areas where public fishing is not allowed and use either hatchery-produced diploid or triploid oysters, wild oysters, or a combination. These practices involve growing oysters off the bottom in the water column in protective gear (e.g., floating rafts near the surface or cages near the bottom) or directly on the bottom without gear. Oysters grown off-bottom are usually cultchless (i.e., individual oysters where the initial shell substrate is indistinguishable from the rest of the shell). Aquaculturists growing oysters on-bottom without gear typically enhance their leased bottom by reclaiming or adding hard substrate (e.g., shell, granite, etc.) suitable for recruitment of wild oyster larvae (hereafter, “substrate addition)” and/or adding hatchery-produced or wild oyster larvae set on oyster shell (hereafter, “spat-on-shell planting).” If using juvenile wild oysters, they are typically moved from one location and transplanted to a different location within the Chesapeake Bay or its tributaries. In some instances, lease holders do not enhance the bottom in any way and simply harvest wild oysters within the leased area.

Oyster practices that involve the public fishery include substrate addition, movement of wild seed oysters (refers to oysters below legally harvestable size) between locations, and/or the addition of hatchery-produced, diploid oyster spat-on-shell. These practices typically aim to enhance the oyster stock available for harvest. In the case of wild seed transplants, they are usually moved from an area where oyster growth and/or survival is poor to an area with better conditions for growth/survival.

While private oyster aquaculture and public fishery practices aim to increase the numbers or oysters available for harvest, oyster reef restoration practices aim to increase the number of oysters that will remain in the waterbody. Oyster reef restoration practices typically occur within State-designated sanctuaries where harvesting is currently prohibited to allow oyster populations to recover. These practices include passive and active oyster reef restoration techniques. Passive oyster reef restoration involves designating an area as a sanctuary with no additional activity. Active oyster reef restoration involves planting oysters (e.g., hatchery-produced, diploid oyster spat-on-shell, adult wild oysters), substrate addition, or a combination of these in the designated sanctuary. The ultimate goal of oyster reef restoration practices is to provide a starting point that will enhance natural recruitment success resulting in a self-sustaining, 3-dimensional reef and increases in the wild oyster population in the Chesapeake Bay and its tributaries.

The Panel identified a total of 12 oyster practice categories after considering the oyster's fate (i.e., removed or remains in the waterbody), fisheries management approach (i.e., private oyster aquaculture, public fishery, oyster reef restoration), culture type (i.e., diploid or triploid hatchery-produced oysters, wild oysters), and activity/culture method (i.e., oysters grown off or on the bottom, transplanted oysters, substrate addition, no activity) (Table 1a). This first report only includes recommendations for private oyster aquaculture practices. Of the five private oyster aquaculture practice categories identified, the Panel felt that only the following three categories should undergo BMP consideration (further described in Section 5.0):

- Off-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using substrate addition

The Panel's decision concerning which oyster practice categories they would recommend for BMP consideration was based on whether the practices include an enhancement activity that could result in the overall production of new oysters (i.e., the reduction effectiveness can be attributed to the practice). The Panelists agreed that "On-bottom private oyster aquaculture using transplanted wild oysters" and "Private oyster aquaculture with no activity" should not undergo BMP consideration because the former represents a transfer of production from one location to another (i.e., no net reduction), while the latter, by definition, does not include any enhancement activities.

Table 1a. Chesapeake Bay oyster practices identified by the Panel based on oyster fate, fisheries management approach, oyster culture type/ploidy, and activity/culture method.

Chesapeake Bay Oyster Practices												
Oyster Fate	Oysters removed (harvested) from waterbody									Oysters remain in waterbody		
Fisheries Management Approach	Private oyster aquaculture (water column and bottom leases)					Public fishery				Oyster reef restoration (sanctuaries)		
Oyster Culture Type/Ploidy	Hatchery-produced diploid or triploid oysters		Wild oysters (diploid)			Hatchery-produced diploid oysters	Wild oysters (diploid)			Hatchery-produced diploid oysters	Wild oysters (diploid)	
Activity/Culture Method	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)	Moving wild oyster from one location to another	Addition of substrate to enhance recruitment of wild 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	On-bottom public fishery oyster production using hatchery-produced oysters	On-bottom public fishery oyster production using transplanted wild oysters	On-bottom public fishery oyster production using substrate addition	Public fishery with no activity	Active oyster reef restoration using hatchery-produced oysters	Active oyster reef restoration using wild oysters	Passive oyster reef restoration
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	TBD	TBD	TBD	TBD	TBD	TBD	TBD

* The Panel's decision concerning which oyster practice categories they would recommend for BMP consideration was based on whether the practices include an enhancement activity that could result in the overall production of new oysters (i.e., the reduction effectiveness can be attributed to the practice). "Yes" indicates that the Panel supports the use of the recommended reduction effectiveness estimates for those practices because they could result in a reduction of the pollutants, while "No" indicates non-endorsement because there would be no reduction as a result of the practice. "TBD" indicates that these practices are still being evaluated by the Panel and their recommendation will be presented in a future report.

The Panel also identified eight oyster-associated nitrogen, phosphorus, and suspended sediment reduction processes (further described in Section 6.0):

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

When paired with the oyster practice categories, this created 96 unique oyster practice category-reduction effectiveness crediting protocol combinations (hereafter, "practice-protocol combination") in which oysters could reduce nutrients and suspended sediments in Chesapeake Bay. The Panel decided they could move forward with recommending reduction effectiveness estimates for some of these combinations, while others they felt needed more deliberation due to various outstanding scientific and policy issues. In light of this, and the interest the CBP has expressed in considering the Panel's recommendations in the Chesapeake Bay TMDL 2017 midpoint assessment, the Panel decided to submit its recommendations incrementally, allowing the reduction effectiveness protocols for some practices to be applied in a timelier manner. This approach is in line with the Panel's recommended decision framework to determine the reduction effectiveness of oyster practices for BMP application (further described in Section 4.0). The Panel is following the procedures outlined in the CBP Partnership's July 13, 2015 BMP Expert Review Protocol (CBP 2015). Appendix B describes this report's conformity with this protocol and additional information concerning BMP application.

The Panel's report schedule for these different combinations is presented in Table 1b, which highlights the combinations found in this report (1st), those tentatively scheduled for the next report (2nd), and those that are put on hold for Panel deliberation due to outstanding policy issues (i.e., legality of allowing nutrient sequestration and sediment deposition to be included in the reduction effectiveness estimate for a tidal in-water BMP). Oyster BMP policy issues are currently being discussed within the CBP Partnership Management Board.

Table 1b. The Panel's planned report schedule for the 96 oyster practice category-reduction effectiveness crediting protocol combinations. The recommendations found in this report are labeled "1st," the recommendations planned for the second incremental report are labeled "2nd," and recommendations that are labeled as "on hold" due to outstanding policy issues will likely be released in a third recommendation report.

	Private Oyster Aquaculture					Public Fishery				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. On-bottom public fishery oyster production using hatchery-produced oysters**	**G. On-bottom public fishery oyster production using transplanted wild oysters**	**H. On-bottom public fishery oyster production using substrate addition**	**I. Public fishery with no activity**	**J. Active oyster reef restoration using hatchery-produced oysters**	**K. Active oyster reef restoration using wild oysters**	**L. Passive oyster reef restoration**
1. Nitrogen Assimilation in Oyster Tissue	**1st**	**1st**	**1st**	**1st**	**1st**	2nd	2nd	2nd	2nd	On hold	On hold	On hold
2. Nitrogen Assimilation in Oyster Shell	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	On hold	On hold	On hold
3. Enhanced Denitrification Associated with Oysters	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd
4. Phosphorus Assimilation in Oyster Tissue	**1st**	**1st**	**1st**	**1st**	**1st**	2nd	2nd	2nd	2nd	On hold	On hold	On hold
5. Phosphorus Assimilation in Oyster Shell	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	On hold	On hold	On hold
6. Suspended Sediment Reduction Associated with Oysters	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold
7. Enhanced Nitrogen Burial Associated with Oysters	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold
8. Enhanced Phosphorus Burial Associated with Oysters	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold	On hold

In summary, the Panel's recommendations found in this first incremental report include:

- A decision framework to determine the nutrient and suspended sediment reduction effectiveness of oyster practices, referred to as the "Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework" or simply "Decision Framework" throughout this report.

- Default reduction effectiveness estimates for the "Nitrogen Assimilation in Oyster Tissue" and "Phosphorus Assimilation in Oyster Tissue" protocols and a methodology to establish site-specific estimates for the following private oyster aquaculture-related oyster practices: Off-bottom private oyster aquaculture using hatchery-produced oysters, on-bottom private oyster aquaculture using hatchery-produced oysters, and on-bottom private oyster aquaculture using substrate addition.

Public/stakeholder engagement and outreach included the Panel hosting an open public stakeholder meeting on November 2, 2015, offering two review opportunities for CBP Partnership and public feedback on preliminary recommendations (February and April 2016), six open briefings to the CBP Water Quality Goal Implementation Team (WQGIT) with notifications sent to interested parties, and several public presentations/webinars. Details of these engagement/outreach efforts are presented in Appendix A. The Panel also had a 30-day review period for the CBP Partnership and interested parties from September 22 to October 22, 2016. A response to comments document was provided as supplemental materials to the CBP Partnership and presented during the November 28, 2016 WQGIT meeting (see Appendix A for link to materials). The response to comments document highlights where the Panel made adjustments to this report based on feedback they received from the CBP Partnership and interested parties.

The WQGIT determined that policy issues raised by the Panel and stakeholders were outside the purview of the Panel's charge and would be evaluated by the CBP Partnership Management Board. The CBP Partnership Management Board is working on resolving these policy issues in parallel to the Oyster BMP Expert Panel developing reduction effectiveness recommendations. It is the Panel's understanding that unresolved policy issues will not prevent a decision on the Panel's report since the Panel's recommendations focus on the scientific and technical aspects concerning the reduction effectiveness of oyster practices. The Panel is using the policy decisions from the Management Board to help prioritize which practice-protocol combinations to focus on for each incremental report. The Panel has incorporated the relevant policy decisions from the June 15, 2016 Special Management Board Meeting[2] in this report. It is in the Panel's opinion that the recommendations found in this first incremental report are not influenced by any of the outstanding policy issues.

The Panel is asking the WQGIT, in coordination with the CBP Partnership and Fisheries and Habitat Goal Implementation Teams, to review and approve the recommendations found in this first incremental report.

[2] Policy decisions from the June 15, 2016 Special Management Board meeting can be found at http://www.chesapeakebay.net/calendar/event/24109/

The Panel recommends that, once a reduction effectiveness crediting protocol is approved for a given oyster practice category (Table 1a), it can be implemented for the practices within that category (see Section 5.0 for oyster practice definitions and Section 6.0 for descriptions of the oyster-associated reduction processes the protocols are based on). The Panel also recommends allowing incremental determination, approval, and implementation of nitrogen, phosphorus, and suspended sediment reduction effectiveness estimates where science exists for the various oyster practices as detailed in its Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework (described in Section 4.0). The Panel felt that this Decision Framework would allow the most practical and adaptive strategy in implementing oyster practices as BMPs given the variety of oyster practices and the wide range in the amount of science available to evaluate the reduction effectiveness of the various practice-protocol combinations.

2.0 Summary of Panel Recommendations in this Report

The Oyster BMP Expert Panel recommends that the CBP Partnership adopt a decision framework that allows the incremental determination, approval, and implementation of individual crediting protocols associated with oysters' reduction effectiveness of nitrogen, phosphorus, and suspended sediment, applied to different oyster practice categories (further described in Section 4.0). The Panel's recommended oyster practice categories are based on grouping individual oyster practices that would have similar reduction effectiveness considerations (further described in Section 5.0). The Panel's recommended reduction effectiveness protocols are based on oyster-associated processes that reduce nitrogen, phosphorus, and suspended sediment (further described in Section 6.0).

This first incremental report describes the Panel's recommendations concerning the reduction effectiveness estimates for the "Nitrogen Assimilation in Oyster Tissue" and the "Phosphorus Assimilation in Oyster Tissue" reduction effectiveness crediting protocols specific to *C. virginica* oysters when they are removed (harvested) from the water via private oyster aquaculture practices. The Panel is endorsing these recommendations only for practices in the following oyster practice categories (see description of practices in Section 5.0):

- Off-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using substrate addition

The Panel is still discussing these protocols for the oyster practice categories involving the public fishery and oyster reef restoration (Table 1a) and will present their recommendations in a future report. Table 2a summarizes the Panel's reduction effectiveness determination status for the identified private oyster aquaculture practice-protocol combinations.

Table 2a. The reduction effectiveness determination status for the Panel's recommended oyster practice category-reduction effectiveness crediting protocol combinations for private oyster aquaculture categories. "#" indicates that the Panel has recommended a reduction effectiveness estimate that is ready for implementation use once approved, "D" indicates that the Panel is still deliberating on this combination and will present recommendations in a future report, "X-Practice" indicates the Panel's decision to not endorse the practice-protocol combination for BMP consideration because it lacks an enhancement activity that could increase oyster production (i.e., there would be no net reduction in pollutants attributed to the practice), and "? - Policy" indicates that there is an outstanding policy issue still being deliberated on by the CBP Partnership Management Board and that Panel deliberations are currently on hold until the policy issues are resolved.

	Private Oyster Aquaculture				
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**
1. Nitrogen Assimilation in Oyster Tissue	#	#	X-Practice	#	X-Practice
2. Nitrogen Assimilation in Oyster Shell	D	D	X-Practice	D	X-Practice
3. Enhanced Denitrification Associated with Oysters	D	D	X-Practice	D	X-Practice
4. Phosphorus Assimilation in Oyster Tissue	#	#	X-Practice	#	X-Practice
5. Phosphorus Assimilation in Oyster Shell	D	D	X-Practice	D	X-Practice
6. Suspended Sediment Reduction Associated with Oysters	? - Policy	? - Policy	X-Practice	? - Policy	X-Practice
7. Enhanced Nitrogen Burial Associated with Oysters	? - Policy	? - Policy	X-Practice	? - Policy	X-Practice
8. Enhanced Phosphorus Burial Associated with Oysters	? - Policy	? - Policy	X-Practice	? - Policy	X-Practice

For protocols where sufficient science exists to establish the reduction effectiveness for an oyster practice category (e.g., practice-protocol combination indicated by the "#" symbol in Table 2a), the Panel recommends that once it is approved by the WQGIT, in coordination with the CBP Partnership and Habitat and Fisheries GITs, it becomes available as a BMP option that State and local governments can consider to select, fund, and implement within their jurisdictions to meet their water quality goals. The Panel recognizes that after approval of any recommended reduction effectiveness estimates, implementation and verification procedures would need to be established and outstanding policy issues resolved using approved procedures from the CBP Partnership. The Panel encourages the CBP Partnership to incorporate opportunities for stakeholder involvement and input during these procedure/policy-related determinations.

For practice-protocol combinations where the Panel determines there isn't sufficient science, the Panel recommends that once sufficient science is available, it be evaluated by an Expert Panel following the Panel's recommended Decision Framework and the CBP Partnership BMP Review Protocol (CBP 2015) to determine the reduction effectiveness and approval. According to the Panel's incremental approach, once approved, the practice-protocol combination would be added as a BMP option along with the other approved oyster BMPs. In order to use multiple protocols for a practice, the BMP implementer would need to fulfill the qualifying conditions for each protocol they would like to use. For protocols that address the same pollutant, the reduction effectiveness values would be added together for the total nitrogen, phosphorus, or suspended sediment reduction effectiveness.

The Panel is recommending the following reduction effectiveness estimates for the "Nitrogen Assimilation in Oyster Tissue" and "Phosphorus Assimilation in Oyster Tissue" protocols for endorsed private oyster aquaculture practices:

1. Default diploid and triploid estimates regardless of location (Section 7.1).

2. Site-specific estimates that can be pursued by the BMP implementer, in coordination with the Chesapeake Bay Partnership and reporting jurisdiction, using the Panel's recommended methodology (Section 7.2).

The recommended default diploid and triploid reduction effectiveness estimates use 50th quantile regression equations to convert oyster shell height to tissue dry weight, applying the regression equations using the midpoints from established oyster size classes to determine the tissue dry weight, and then multiplying the tissue dry weight by the percent nitrogen and phosphorus contents in oyster tissue. The Panel's default estimates for diploid and triploid oysters are presented in Table 2b. The method and rationale for the default estimates can be found in Section 7.1 and Appendix D.

Table 2b. The Panel's recommended default nitrogen and phosphorus reduction effectiveness estimates in oyster tissue for diploid and triploid oysters. These estimates were derived by using the midpoint of the recommended oyster size classes in millimeters in the diploid or triploid 50th quantile regression equations to determine the tissue dry weight in grams for each size class. The calculated tissue dry weight was then multiplied by the recommended 8.2% and 0.9% average nitrogen and phosphorus contents in oyster tissue by dry weight, respectively, to determine the grams of nitrogen and phosphorus in the oysters within that size class.

Default Estimates						
Oyster Size Class Range (inches)	Size Class Midpoint (inches)	Size Class Midpoint (mm)	Content in Oyster Tissue (g/oyster)			
			Diploid*		Triploid**	
			Nitrogen†	Phosphorus‡	Nitrogen†	Phosphorus‡
2.0 - 2.49	2.25	57	0.05	0.01	0.06	0.01
2.5 - 3.49	3	76	0.09	0.01	0.13	0.01
3.5 - 4.49	4	102	0.15	0.02	0.26	0.03
4.5 - 5.49	5	127	0.22	0.02	0.44	0.05
≥ 5.5	6	152	0.31	0.03	0.67	0.07

*Diploid 50th quantile regression equation: tissue dry weight (g) = 0.0004 * Shell Height (mm)$^{1.82}$
**Triploid 50th quantile regression equation: tissue dry weight (g) = 0.00005 * Shell Height (mm)$^{2.39}$
†8.2% average nitrogen content in oyster tissue dry weight (based on seven studies in waterbodies along the Atlantic Coast; used the average of the site means for studies outside of Chesapeake Bay; site-specific averages were used for studies within Chesapeake Bay)
‡0.9% average phosphorus content in oyster tissue dry weight (based on three studies in Chesapeake Bay; same averaging approach as nitrogen, but only studies in Chesapeake Bay were found).

The Panel also recommends that the CBP Partnership adopt an approach that allows the BMP implementers to establish site-specific nitrogen and phosphorus reduction effectiveness estimates for their oyster practice. The Panel used a conservative approach to develop the default estimates, therefore, they likely underestimate the overall nitrogen and phosphorus reduction effectiveness. Site-specific estimates would offer an opportunity to refine the estimates to better reflect the nitrogen and phosphorus reduction effectiveness of that practice in the specific location it occurs. The Panel's recommended methodology to determine site-specific estimates is described in Section 7.2. It involves the practice working with the CBP Partnership to determine their representative oyster size classes and average tissue biomass associated with their practice.

The Panel recommends the following qualifying conditions to be applied to both the default and site-specific estimates (Section 8.0):

- Only includes oysters that are removed moving forward from the time the BMP is approved/implemented for reduction effectiveness credit in the TMDL. This baseline condition was proposed by the CBP Partnership Management Board and the Panel concurs with their decision.

- Oysters had to have be grown from initial sizes < 2.0 inches shell height.

- Oysters have to be alive when removed to count toward the reduction effectiveness.

The Panel's recommended application and verification guidelines can be found in Section 9.0. The Panel is of the opinion that reporting oyster harvest in individuals is the preferred approach, since the total number of oysters is needed to calculate the reduction effectiveness. However, they also recognized that other units (e.g., bushels, boxes) are currently being used by States for reporting oyster harvest. Therefore, the Panel's recommended application and verification guidelines in Section 9.0 were developed to account for the use of different reporting units in a way that would offer flexibility to reporting jurisdictions (i.e., State agencies) in verifying the reduction effectiveness in a scientifically-defensible manner. Briefly, the Panel identified three types of data that would be needed to apply the reduction effectiveness estimates under different harvest reporting unit scenarios: type and total number of containers, average number of oysters in each container, and average size of oysters in each container type. The Panel also identified two ways in which oyster aquaculturists are packaging oysters, 1) variable sized oysters together in the same container and 2) uniform sized oysters in separate containers. The first approach is more relevant to on-bottom growers and the second approach is more relevant to off-bottom growers. The Panel's verification guidelines depend on the packaging approach. If packaging variable sized oysters in the same container, then the implementer can only report in one oyster size class determined by the average shell height of 50 random oysters per two time periods that are approximately 6 months apart. If packaging uniform sized oysters in separate containers then the implementer can report in multiple oyster size classes determined by the average shell height of 50 random oysters per two time periods that are approximately 6 months apart for each size class that they are reporting in. For both packaging approaches, the Panel recommends that the number of oysters per container is determined by counting the oysters from 10 containers and using the average. In instances where ploidy designation or verification measurements are missing, the Panel recommends using the diploid estimates with the minimum legal size of harvested oysters and State documented information specifying the average number of minimum legal sized oysters that can be packaged in a specific container. Examples of these approaches are presented in Section 9.4. Ultimately, it will be the reporting jurisdictions, in coordination with the CBP Partnership, that decide on which reporting unit to implement.

There are also instances where oysters are moved by a single oyster aquaculture entity from the initial grow-out location to another location in the Chesapeake Bay or its tributaries. The Panel identified two movement scenarios related to the application of the reduction effectiveness estimates: 1) oysters less than two inches are moved from their initial grow-out location to a final grow-out location where they are harvested and 2) oysters are grown predominantly in the initial grow-out location and are moved to the final grow-out location for a short amount of time (typically less than three months). If aquaculturists use the first strategy, then the Panel recommends that the entire reduction effectiveness credit is applied to the final grow-out location since the initial grow-out location would not qualify to receive any credit because the reduction effectiveness estimates only apply when oysters are greater than 2.0 inches. If the second strategy is used, then the Panel recommends that the entire reduction effectiveness credit is applied to the initial grow-out location because the oysters were predominantly growing and assimilating nutrients from that area. To determine which movement crediting scenario to apply, the Panel suggests measuring the shell height of 50 random oysters and calculating the average before they are placed in the final grow-out location. Both the default and site-specific estimates would be applicable for these movement scenarios. However, for the site-specific estimate, the aquaculture practice must have approved estimates for the location that is receiving the credit. In developing the above recommendations, the Panel's intent was that the aquaculture entity moving the oysters from the initial grow-out location would also be removing the oysters from the final grow-out location for reduction effectiveness credit.

The Panel recommends the following information to be reported if oysters are grown in one location or multiple locations:

<u>If oysters are grown at one location</u>

- Ploidy: Diploid or triploid oysters
- Type of aquaculture practice: Off-bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture using Hatchery-Produced Oysters, or On-Bottom Private Oyster Aquaculture Using Substrate Addition
- Reporting unit: Bushels, boxes, other container (indicate what type), or individuals
- Packaging type: Variable oyster sizes or uniform oyster sizes
- Central coordinates (latitude and longitude) of location (also referred to as initial grow-out location)
- Month/year removed from final grow-out location
- Number of containers of live oysters or individual oysters from final grow-out location
- Oyster count average for unit verification check (10 representative containers per two time periods from final grow-out location)
- Shell height average(s) for oyster size verification check (50 random oysters from 10 containers per two time periods from final grow-out location)

<u>Additional reporting if oysters are grown at multiple locations</u>

- Central coordinates (latitude and longitude) of the final grow-out location
- Month/year oysters were moved to the final grow-out location
- Average oyster shell height of 50 random oysters before being placed in the final grow-out location (verification check to know whether to apply the credit to the initial or final grow-out location)

The Panel's recommended estimates were developed to be reported annually based on removed (harvested) live oysters. As a result, any reduction effectiveness credits generated from these practices would only be applicable for the annual timeframe during which the live oysters are harvested. Therefore, the reporting jurisdiction will need to report the number of oysters harvested or pounds reduced annually. For oyster practices participating as a BMP, the Panel recommends that the reporting jurisdiction incorporates these components in existing monthly reports to track the BMP (e.g., State monthly harvest reports). The Panel recommends re-evaluation of estimates every 5 years, if new science becomes available, following the established re-evaluation procedures for existing estimates in the CBP Partnership BMP Expert Review Protocol (CBP 2015).

The technical requirements for reporting and simulating the private oyster aquaculture practices in the Phase 6 watershed model are described in Appendix F and were developed by the CBP Modeling Team based on reviewing the Panel's recommendations presented in this report.

3.0 Expert Panel Membership and Charge

3.1 Panel Membership

The Panel includes oyster scientists and practitioners from the East Coast region, including representatives from academia, non-profit organizations, and county, state, and federal agencies who have expertise in oyster biology/ecology, water quality, fishery management, and/or oyster practice implementation (Table 3a).

Table 3a. Experts participating in the Oyster BMP Expert Panel

Panelists	Affiliation	Expertise
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Oyster filter-feeding, nutrient cycling dynamics, modeling, sediment biogeochemistry, oyster ecology, population dynamics
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Nutrient-related water quality research, oyster and nutrient cycling modeling
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Fisheries management
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Shellfish Aquaculture
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Oyster reef ecology and restoration, oyster filter-feeding and nutrient cycling dynamics
Andy Lacatell	The Nature Conservancy (TNC)	Oyster restoration
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Oyster ecology and restoration; interactions between shellfish aquaculture and the environment; land-use practices and water quality in tidal water environments
Chris Moore	Chesapeake Bay Foundation (CBF)	Fisheries and oyster restoration, oyster aquaculture, water quality, implementation of Chesapeake Bay TMDL, BMP review
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Oyster aquaculture, business planning
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences/Chesapeake Bay Laboratory	Oyster restoration, oyster biology and population dynamics
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Nutrient bioextraction, marine spatial planning for shellfish activities, aquaculture-environment interactions
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Coastal physical oceanography, sediment transport, oceanographic instrumentation
Bill Wolinski	Talbot County Department of Public Works	Watershed Implementation Plans, BMP implementation, water quality

Advisors	**Affiliation**	**Expertise**
Lew Linker	U.S. EPA Chesapeake Bay Program Office	Chesapeake Bay Modeling Team Representative
Jeff Sweeney/Matt Johnston	U.S. EPA Chesapeake Bay Program Office	Watershed Technical Workgroup (WTWG) Representative
Ed Ambrogio	U.S. EPA Region III	EPA Region 3 Representative
Lucinda Power	U.S. EPA Chesapeake Bay Program Office	Water Quality Goal Implementation Team Representative
Rich Batiuk	U.S. EPA Chesapeake Bay Program Office	BMP Verification Representative
Coordinators	**Affiliation**	**Expertise**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Coordination and facilitation, Clean Water Act, TMDL program, water quality, fisheries science, climate change, ocean acidification
Ward Slacum	Oyster Recovery Partnership	Program management, oyster restoration, environmental monitoring, fisheries ecology
Emily French	Oyster Recovery Partnership	Seagrass ecology, water quality monitoring, oyster restoration
Guests	**Affiliation**	**Expertise**
Carl Cerco	US Army Corps of Engineers	Water Quality Modeling
Tom Schuler	Chesapeake Stormwater Network	Stormwater BMPs
Stephan Abel	Oyster Recovery Partnership	Implementation

3.2 Panel Charge

The Oyster BMP Expert Panel was charged with fulfilling three overall goals based on the Chesapeake Bay Program Partnership's Expert BMP Panel Review Protocol for nutrient (nitrogen and phosphorus) and sediment controls:

1. Reach a consensus on acceptable nutrient and suspended sediment reduction effectiveness estimates for oyster practices in Chesapeake Bay based on existing science.

2. Determine a methodology to update these estimates when new science becomes available.

3. Establish reduction effectiveness crediting and verification guidelines as it relates to their application in the CBP partnership's model framework used to inform the Chesapeake Bay TMDL.

To support the achievement of the above goals, the Oyster BMP Expert Panel is focusing on the following three charge items:

Charge Item 1: Identify and define oyster practices, including aquaculture and restoration activities, for nutrient reduction BMP consideration. Evaluate whether existing science supports the evaluation of sediment reduction effectiveness.

Charge Item 2: Develop a reduction effectiveness crediting decision framework that will allow the incremental approval of nutrient and suspended sediment reduction effectiveness estimates based on oyster-associated processes (e.g., nitrogen and phosphorus assimilation in tissue, nitrogen and phosphorus assimilation in shell, nitrogen removal via denitrification) for various oyster practices.

Charge Item 3: Use the established reduction effectiveness decision framework from charge item 2 to propose reduction effectiveness estimates that are determined to have sufficient science to help inform the Chesapeake Bay TMDL 2017 Midpoint Assessment.

3.2.1 Key changes from the Oyster BMP Expert Panel Charge

- In the Panel charge,[3] the decision framework was referred to as the "pollutant removal crediting decision framework;" however, the Panel decided it would be better to refer to it as the "Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework," (hereafter, "Decision Framework") in order to make it clear that the framework is for determining the nitrogen, phosphorus, and suspended sediment reduction effectiveness of oyster practices and not decisions concerning other pollutants or how to implement nutrient trading credits.

- Initially, the Panel charge included in the timeline an incremental approval step for just the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Decision Framework. Because the Panel found the need to modify the decision steps in the framework as they developed reduction effectiveness estimates, the Panel determined that approval of the Decision Framework with the Panel's 1st set of recommended estimates would be more efficient than a stand-alone report on the Decision Framework. Thus, reduction effectiveness estimates presented in this report can be viewed as a test case for the application of the proposed decision framework. While there isn't a stand-alone report on the Decision Framework, the Panel did provide two review/comment opportunities on Decision Framework drafts during the Panel's updates to the Water Quality GIT (February and April 2016; see Appendix A for more information). The Panel felt it was important to have the Partnership and interested parties review and provide input on the Decision Framework early in the development process. Comments that were received were reviewed by the Panel and they made changes accordingly resulting in the decision framework presented in Section 4.0.

- Oyster practice titles and definitions have been refined from what was presented in the charge (see Table 1a in Section 1.0 and Table 5b in Section 5.0)

[3] The Oyster BMP Expert Panel Charge can be found at http://www.chesapeakebay.net/channel_files/23104/oyster_bmp_expert_panel_charge_final_9-14-15.pdf

4.0 Recommended Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework

This section describes the Panel's recommended decision framework to determine the nitrogen, phosphorus, and suspended sediment reduction effectiveness of oyster practices as BMPs for application in the model framework used to inform the Chesapeake Bay TMDL. The Panel felt it was important to develop and apply an agreed upon decision framework because there are no existing BMPs involving filter-feeders within the tidal waters of Chesapeake Bay. Any policy questions that were raised by the Panel were shared with the CBP Partnership Management Board for resolution. The Decision Framework the Panel is proposing is specific to determining the reduction effectiveness and the proper application of the estimates in the CBP Partnership model framework used to inform the TMDL. Addressing policy issues (e.g. nutrient trading) is beyond the purview of the panel and not included in the Decision Framework. The Decision Framework is specific for oyster practices, but the Panel acknowledges that a similar framework could be developed for other filter-feeding organisms found in the Chesapeake Bay and its tributaries.

There were two CBP Partnership and stakeholder review opportunities on the Panel's Decision Framework during the February 8 and April 25, 2016 WQGIT meetings (see Appendix A for more details). The Panel considered all the comments they received on the draft documents. The recommended Decision Framework presented in this section captures these considerations.

Overall, the Panel's recommended Decision Framework allows for the incremental determination, approval, and implementation of nitrogen, phosphorus, and suspended sediment effectiveness estimates based on available science for various oyster practices. The Panel agreed that the Decision Framework should consist of individual reduction effectiveness crediting protocols based on oyster-associated nitrogen, phosphorus, and suspended sediment reduction processes so that these protocols could be incrementally determined and applied for oyster practices where there is sufficient science to do so. The panel also built into the Decision Framework opportunities to identify knowledge gaps and/or additional data needed to determine reduction effectiveness, including a decision pathway where unknown estimates could be revisited when new science becomes available. The Panel's recommended Decision Framework is further described below.

4.1 Main Steps of the Decision Framework

The Panel identified four main steps for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework (see Figure 4a). These steps are further described in their corresponding sections.

Figure 4a. Main steps for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework.

Step 1: Determine oyster practice categories and individual oyster-associated nutrient and suspended sediment reduction effectiveness crediting protocols for evaluation.

↓

Step 2: For each suitable oyster practice category and reduction effectiveness crediting protocol combination, determine the reduction effectiveness estimate (e.g., number/rate, equation/method to calculate estimate) based on current scientific understanding.

↓

Step 3: Decide if the estimate would be verifiable (i.e., a practical method and the information needed to apply the method exists) and if so, provide verification guidelines.

↓

Step 4: Identify any unintended consequences and decide if negative effects could be addressed so they don't outweigh environmental benefits.

The Panel's definitions of key criteria used in the Decision Framework are described below:

1. **Suitable for Reduction Effectiveness Consideration:** In the Panel's best professional judgment, the reduction process could occur in association with a particular oyster practice category and involves an enhancement activity that could result in the production of new oysters (i.e., the reduction effectiveness can be attributed to the practice).

2. **Sufficient Science:** In the Panel's best professional judgment, data of sufficient quality and scope exist and can be used to generate a reasonably constrained estimate of the reduction associated with a particular oyster practice category.

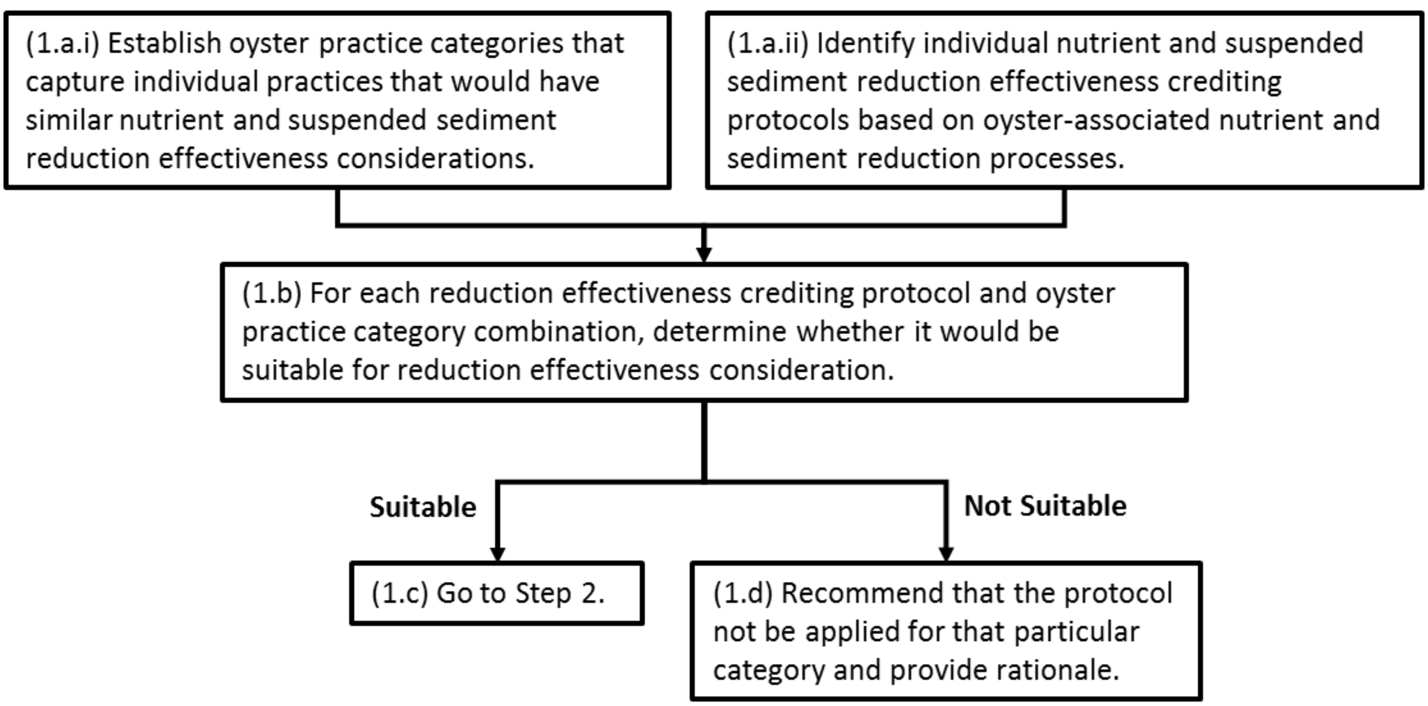
3. **Verifiable:** In the Panel's best professional judgment, a practical method exists, or could be created, to track reduction effectiveness if the BMP is implemented.

4. **Unintended Consequence:** Potential unexpected negative or positive effects on the environment resulting from the practice. Positive unintended consequences are referred to as "ancillary benefits" in this report to match the terminology found in the BMP Review Protocol (CBP 2015).

4.2 Step 1 Decision Points

The Panel's recommended Step 1 decision points for the Decision Framework are described in Figure 4b. During Panel discussions, it became clear that a wide variety of oyster-related practices are implemented in Chesapeake Bay and certain practices would likely require different reduction effectiveness considerations than others. The Panel agreed that grouping oyster practices, including cultivation (i.e., private oyster aquaculture practices and public fishery practices) and restoration (i.e., oyster reef restoration practices), into broad categories with similar reduction effectiveness considerations would be more efficient than assessing practices individually. Essentially, categorization of practices would allow a more focused evaluation of the data to determine the reduction effectiveness estimates and also simplify the establishment of reduction effectiveness crediting and verification guidelines because the practices in each category would involve similar decisions. This decision point is incorporated in Step 1 (see Figure 4b, box 1.a.i). The Panel proposes that endorsed practice-protocol combinations for BMP consideration be thought of as separate BMPs so established estimates for one combination can move forward through the BMP approval process independent from the other combinations.

Figure 4b. The Panel's recommended Step 1 decision points for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework. The goal of this step is to determine the oyster practice categories and individual oyster-associated nutrient and suspended sediment reduction effectiveness crediting protocols for evaluation.



The Panel agreed that oysters can improve water quality because of their filter-feeding capabilities (described further in Section 6.0). The Panel decided that each oyster-associated process that reduces nitrogen, phosphorus, and suspended sediment should be developed as a separate reduction effectiveness crediting protocol (Figure 4b, 1.a.ii) that could be evaluated and applied individually. The Panel also agreed that the reduction effectiveness of protocols involving the same pollutant (e.g., nitrogen assimilation in oyster tissue, enhanced denitrification associated with oysters, and enhanced nitrogen burial associated with oysters) could be added together to determine the total reduction effectiveness of the practice in a manner similar to the approved approach used by the Urban Stream Restoration BMP Expert Panel (Schuler and Stack 2014). Step 2 of the Decision Framework describes the decision points concerning the determination of the reduction effectiveness estimates of the practice-protocol combinations (see Section 4.3).

During discussions, the Panel agreed that there may be instances where a reduction effectiveness protocol wouldn't be suitable to consider with a particular oyster practice category because the oyster-associated process would not occur. For instance, protocols associated with enhanced burial of nitrogen and phosphorus may not be suitable to group with harvest-related oyster practice categories because disturbance from harvesting may prevent burial processes from happening (i.e., the conditions would never be suitable to support enhanced burial). Also, the Panel agreed that not all practice-protocol combinations would result in a reduction of the pollutant. The Panel decided that the practice-protocol combination needs to include an enhancement activity that could result in the overall production of new oysters (i.e., the reduction effectiveness can be attributed to the practice) to be suitable for consideration. As a result, the Panel incorporated this decision point into Step 1 of the Decision Framework (see Figure 4b, Box 1.b). The Panel defined "suitable for reduction effectiveness consideration" as, "In the Panel's best professional judgment, the reduction process could occur in association with a particular oyster practice category and involves an enhancement activity that could result in the production of new oysters (i.e., the reduction effectiveness can be attributed to the practice)." The Panel felt this decision point was important to evaluate early on in the Decision Framework to avoid spending time evaluating combinations where the reduction would not occur or is not attributed to the practice. It is important to note that this step aims to identify which potential crediting protocols should be evaluated for a particular oyster practice category and does not involve the decision whether there is sufficient science to determine the reduction effectiveness, which is built into Step 2 of the Decision Framework (see Section 4.3). Suitable combinations would move forward to Step 2 of the Decision Framework to determine the reduction effectiveness estimate (Figure 4b, Box 1.c). The Panel decided that they would not evaluate any combinations that are determined to not be suitable for reduction effectiveness consideration (Figure 4b, Box 1.d).

4.3 Step 2 Decision Points

The Panel's recommended Step 2 decision points for the Decision Framework are described in Figure 4.3. These decision points focus on determining the reduction effectiveness estimate for each suitable oyster practice category and reduction effectiveness crediting protocol combination that was identified in Step 1 (see Section 4.2).

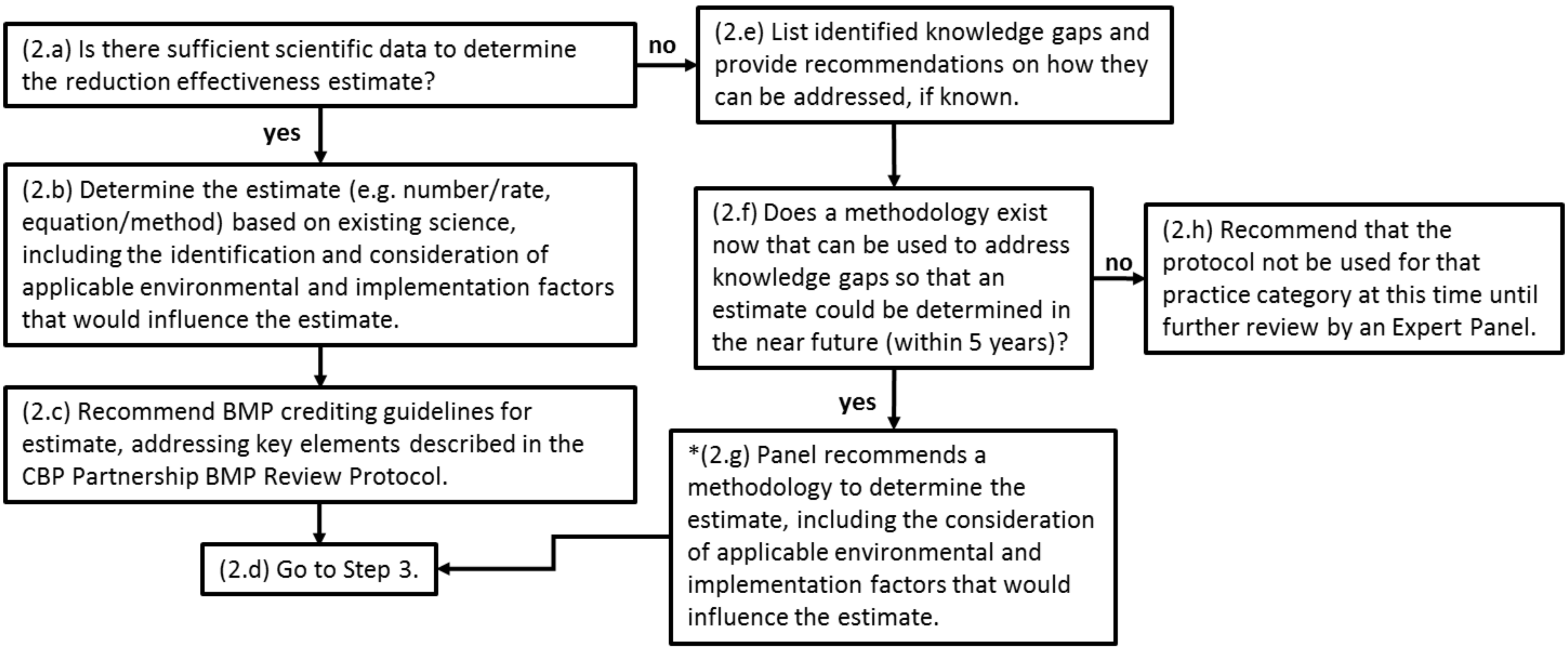
The Panel decided that it would be important to begin with a decision point that asks whether there is sufficient scientific data to determine the reduction effectiveness estimate (Figure 4c, Box 2.a). The Panel used their best professional judgment to answer this question. Specifically, they evaluated whether data of sufficient quality and scope existed to generate a reasonably constrained estimate of the reduction associated with a particular oyster practice category. If such data existed, then the Panel used it to determine the reduction effectiveness estimate (Figure 4c, Box 2.b). The Panel also built into this decision the identification and consideration of any applicable factors that could influence the estimate, particularly environmental and implementation-related factors (e.g., genetic ploidy, seasonal effects, culture method/type, type of gear used). These considerations may result in multiple estimates within a protocol to account for these influencing factors.

The Panel included both “number/rate” and “equation/method” as examples of how the estimate may appear because the Panel recognized that for some of the reduction effectiveness protocols it would be feasible to recommend an exact number or rate that could be applied regardless of location (i.e., low variability in the data), while other protocols would be more influenced by site-specific conditions requiring a method for jurisdictions to use to calculate the estimate (i.e., high variability in the data; Figure 4c, Box 2.b). In cases where the reduction effectiveness estimate for a protocol can be applied across multiple practice categories, the Panel recommends evaluating the crediting guidelines (Figure 4c, Box 2.c) separately for the different practice categories because they may not be the same depending on how the practices are implemented. The Panel’s recommended crediting guidelines are based on the key elements described in the CBP Partnership’s Expert BMP Panel Review Protocol (CBP 2015) and includes the following:

- Guidelines on the environmental conditions (e.g., water chemistry, bottom substrate) needed for the estimate to be valid.
- Guidelines on crediting timeframe; cumulative or annual, temporal performance (i.e., lag time between establishment and full functioning, effectiveness of the practice over time), when the estimate should be re-evaluated.
- Guidelines on determining baseline conditions.
- Guidelines on where and how estimates can be incorporated into the Chesapeake Bay Modeling Framework, including credit duration for applicable crediting protocols for a given oyster practice category.

The Panel agreed that crediting guidelines developed by the Panel should focus on ensuring that the recommended reduction effectiveness is correctly applied and helping the CBP Partnership and jurisdictions make an informed decision. The Panel acknowledges that the final decisions concerning which reduction effectiveness estimates to pursue and how they will be implemented and verified is the responsibility of the CBP Partnership and jurisdictions.

Figure 4c. The Panel's recommended Step 2 decision points for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework. The goal of this step is to determine the reduction effectiveness estimate for suitable oyster practice category-reduction effectiveness crediting protocol combinations identified in Step 1 (see Figure 4b).



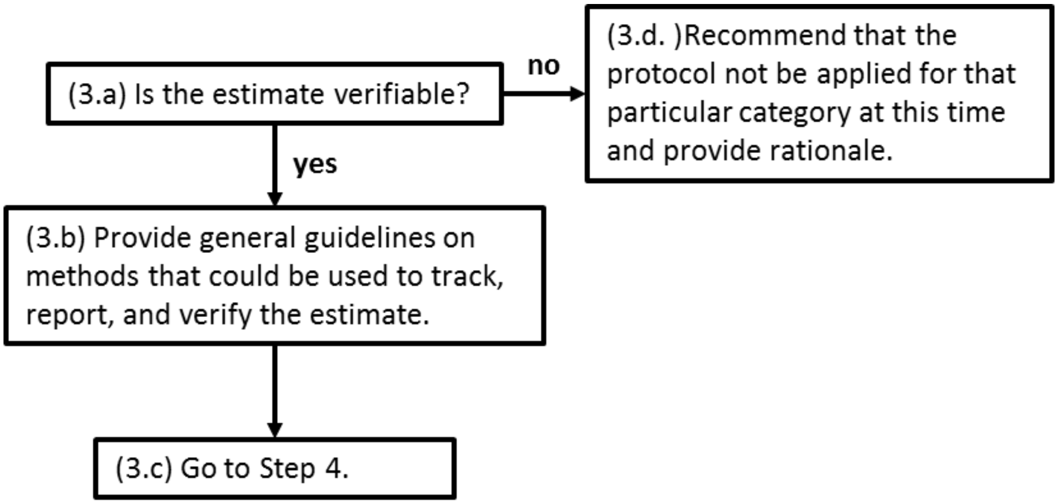
* If the recommended method is used to determine what the estimate would be within the 5 year timeframe, then the Panel recommends that the estimate is reviewed and approved using a similar approach as the re-evaluation procedures for existing estimates described in the CBP Partnership Expert Review Protocol (CBP 2015). The Panel encourages the CBP Partnership to incorporate opportunities for stakeholder involvement and input concerning these reduction effectiveness estimate determinations.

The Panel agreed that there should be a decision pathway for instances where sufficient data are not available to determine the reduction effectiveness for a practice-protocol combination. In such instances, the Panel recommends identifying knowledge gaps and including recommendations on how to address them, if known (Figure 4c, Box 2.e). From this knowledge gap evaluation, if the Panel identifies a method that could be used to establish the reduction effectiveness estimates in the near future (within 5 years) and sufficient data becomes available, then the Panel recommends that the recommended method be used to determine the estimates and that the review and approval of the estimates follows a similar approach as the re-evaluation procedures for existing estimates described in the CBP Partnership Expert Review Protocol (CBP 2015) (Figure 4c, Boxes 2.f and 2.g). For practice-protocol combinations where there isn't a clear method, the Panel recommends that the practice-protocol combination(s) be evaluated again by a newly convened Expert Panel following the CBP Partnership Expert Review Protocol (CBP 2015). The Panel felt this distinction was important to make because there are cases where methods exist, but sufficient data have not yet been collected but could with relative ease. The Panel felt it would not be necessary to convene a new Expert Panel to evaluate this information if an approved recommended methodology is in place.

4.4 Step 3 Decision Point

The Panel's recommended Step 3 decision point for the Decision Framework is described in Figure 4d. This decision point focuses on evaluating whether the reduction effectiveness estimate determined in Step 2 is verifiable (Figure 4d, Box 3.a). The Panel added this decision point based on CBP Partnership and stakeholder comments that were received on a previous draft. Verifiable is defined by the Panel as, "In the Panel's best professional judgment, a practical method exists, or could be created, to track reduction effectiveness if the BMP is implemented."

Figure 4d. The Panel's recommended Step 3 decision point for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework. The goal of this step is to evaluate whether the estimate would be verifiable (i.e., a practical method and the information needed to apply the method exists).

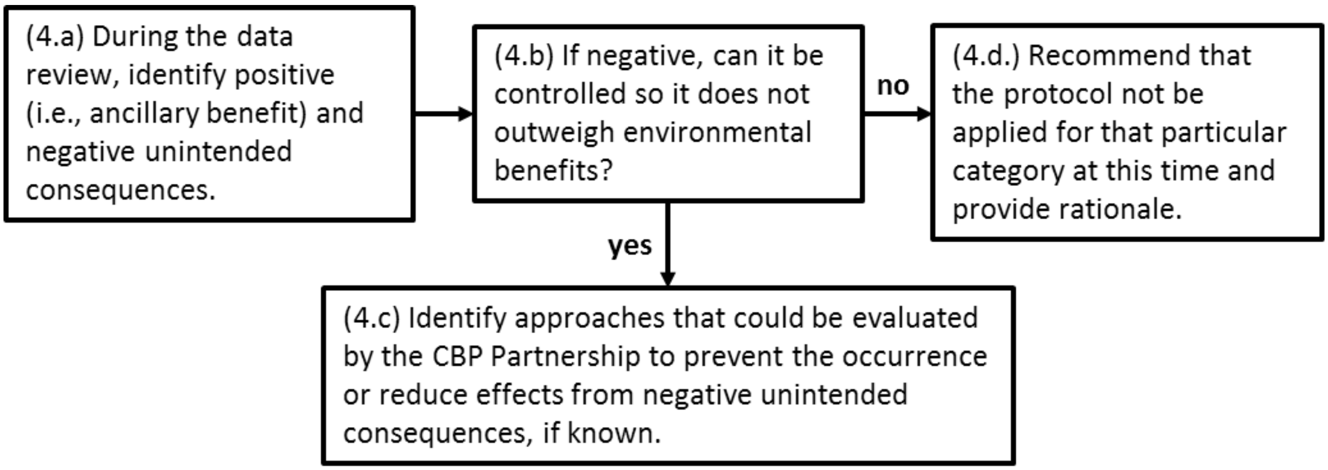


Per the CBP Partnership BMP Review Protocol (CBP 2015), the Panel also built into this step to provide general guidelines on methods that could be used to track, report, and verify the estimate (Figure 4d, 3.b). The Panel agreed that these guidelines should focus on key variables that need to be measured and reported to ensure that the recommended estimate is being used correctly. If the Panel decides that the estimate is not verifiable, then they will recommend that the protocol not be applied for that particular category at this time (Figure 4d, 3.d).

4.5 Step 4 Decision Point

The Panel's recommended Step 4 decision point for the Decision Framework is described in Figure 4e. This decision point focuses on identifying any unintended consequences associated with the practice-protocol combination (Figure 4e, Boxes 4.a-4.d) that the Panel encounters during their data review. The Panel defines unintended consequences as, "potential unexpected negative or positive effects on the environment resulting from the practice." For identified unintended consequences that are negative, the Panel will decide whether they can be controlled so they do not outweigh environmental benefits (Figure 4e, Box 4.b). If the Panel is in the opinion that they can be controlled, then they will also identify options they are aware of that could be evaluated by the CBP Partnership to assist in preventing or reducing the negative effect (Figure 4e, Box 4.c). Negative unintended consequences are discussed in Section 10.0. Positive unintended consequences are referred to as "ancillary benefits" in this report to match the terminology found in the BMP Review Protocol (CBP 2015) and are discussed in Section 11.0.

Figure 4e. The Panel's recommended Step 4 decision point for the Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework. The goal of this step is to identify unintended consequences from the data review and decide if any negative effects can be controlled so that they do not outweigh environmental benefits.



5.0 Private Oyster Aquaculture Practices Defined

5.1 Private Oyster Aquaculture Practice Categories

This section defines the private oyster aquaculture practice categories that the Panel recommends for BMP reduction effectiveness consideration. The Panel first categorized all oyster practices that occur in the Chesapeake Bay by oyster fate (i.e., removed or remains in the waterbody), fishery management approach (i.e., private oyster aquaculture, public fishery, oyster reef restoration), oyster culture type/ploidy (i.e., diploid or triploid, hatchery-produced or wild) and activity/culture method (i.e., off-bottom, on-bottom, transplanted, no activity) (Table 1a). The goal of the categories were to group individual practices that would have similar considerations concerning the determination of the reduction effectiveness. From there, the Panel determined which categories they would recommend for BMP consideration. Out of the five private oyster aquaculture practice categories that the Panel identified (Table 5a), they decided to recommend three of the categories for BMP consideration (Table 5b). The Panel's decision concerning which oyster practice categories they would recommend for BMP consideration was based on whether the practices include an enhancement activity that could result in the overall production of new oysters (i.e., the reduction effectiveness can be attributed to the practice). Definitions of the recommended oyster practice categories for BMP consideration can be found in Table 5b.

Table 5a. Identification and grouping structure of identified private oyster aquaculture practices in Chesapeake Bay. Definitions of categories recommended for BMP consideration are found in Table 5b.

Chesapeake Bay Oyster Practices					
Oyster Fate	Oysters removed (harvested) from waterbody				
Fisheries Management Approach	Private oyster aquaculture (water column and bottom leases)				
Oyster Culture Type/Ploidy	Hatchery-produced diploid or triploid oysters		Wild oysters (diploid)		
Activity/Culture Method	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
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
***Panel Recommends for BMP Consideration**	**Yes**	**Yes**	No	**Yes**	No
Oyster Practice Category	A	B	C	D	E

*The Panel's decision concerning which oyster practice categories they would recommend for BMP consideration was based on whether the practices include an enhancement activity that could result in the overall production of new oysters (i.e., the reduction effectiveness can be attributed to the practice). "Yes" indicates that the Panel supports the use of the recommended reduction effectiveness estimates for those practices because they could result in a reduction of the pollutants, while "No" indicates non-endorsement because there would be no reduction as a result of the practice.

Table 5b. Private oyster aquaculture practice categories recommended for BMP consideration and their definitions.

Category	Oyster Practice Title	Definition
A	Off-bottom private oyster aquaculture using hatchery-produced oysters	Hatchery-produced diploid or triploid oysters grown off the bottom in the water column using some sort of gear (e.g., floating rafts near the surface or cages near the bottom) in an area designated for oyster aquaculture where public fishing is not allowed (e.g., State-permitted oyster aquaculture leases to oyster aquaculturists) for eventual removal from the water.
B	On-bottom private oyster aquaculture using hatchery-produced oysters	Hatchery-produced diploid or triploid oysters (e.g., spat-on-shell) grown directly on bottom using no gear in an area designated for oyster aquaculture where public fishing is not allowed (e.g., State-permitted oyster aquaculture leases to oyster aquaculturists) for eventual removal from the water.
D	On-bottom private oyster aquaculture using substrate addition	Placing oyster shell or alternative hard substrate, such as granite, to the bottom sediment surface to attract recruitment of wild (diploid) oysters in an area designated for oyster aquaculture where public fishing is not allowed (e.g., State-permitted oyster aquaculture leases to private oyster aquaculturists) for eventual removal from the water.

5.2 Representative Oyster Practices for the Endorsed Private Oyster Aquaculture Categories

The representative oyster practices that occur in Chesapeake Bay that fall under each of the endorsed private oyster aquaculture practice categories defined in Table 5b are described below.

5.2.1 Category A: Off-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters

Representative off-bottom private oyster aquaculture methods using hatchery-produced diploid or triploid oysters involve rearing hatchery-produced cultchless oysters or spat-on-shell oysters in rafts, cages, bags, trays, nets or suspended on lines above the sediment surface. Oysters are typically reared in the gear for over a year until they reach market size (76 mm) and then harvested for consumption. Examples include:

- Raft culture—Rafts use floatation devices (e.g., buoys, PVC, foam) to suspend plastic mesh bags on the water surface or cages just below the surface of the water. Oysters are typically submerged at the surface using rafts. Rafts are frequently monitored and cleaned, and the oysters are sorted for size and transferred between containers as they get larger. Oysters are typically removed from the containers once they reach market size.

- Cage culture—Oyster cages are constructed with metal or plastic mesh surrounding a rigid metal frame that sits on the seafloor. Oysters remain suspended off the bottom because the frame of the cages are designed to touch the bottom and keep oysters several inches above the sediment surface. Like rafts, cages are frequently monitored and cleaned, and the oysters are sorted for size and transferred between cages as they grow. The oysters typically remain in the cages until they reach market size.

In some cases, oysters are moved from one water column lease to another. Reasons for moving oysters include poor water quality (e.g., moving oysters from polluted waters to approved waters for harvesting) or to change the taste profile (e.g., moving oysters to a more salty location).

5.2.2 Category B: On-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters

Representative on-bottom private oyster aquaculture methods include planting hatchery-produced diploid or triploid oysters as spat-on-shell directly on the bottom (no gear) for eventual removal from the water when oysters reach market size and can be harvested for consumption. Oysters typically require over two years to reach minimum market size, but oysters may be left in the water beyond this size. This practice may also involve moving the oysters from one bottom lease to another for eventual removal from the water. Reasons for moving oysters include poor water quality (e.g., moving oysters from polluted waters to approved waters for harvesting) or to change the taste profile (e.g., moving oysters to a more salty location).

5.2.3 Category D: On-Bottom Private Oyster Aquaculture Using Substrate Addition

Representative on-bottom private oyster aquaculture using substrate addition methods involve adding oyster shell or an alternative substrate, such as granite, directly on the bottom (no gear) to attract recruitment of natural (wild) oysters (assumed to be diploids) for eventual removal from the water. Oysters produced using this practice are treated and harvested similarly to on-bottom, hatchery-produced cultured oysters.

6.0 Oyster-Associated Processes for Reduction Effectiveness Crediting Protocols

The Panel discussed the various oyster-associated nitrogen, phosphorus and suspended sediment reduction processes and currently identified the following eight individual reduction effectiveness crediting protocols:

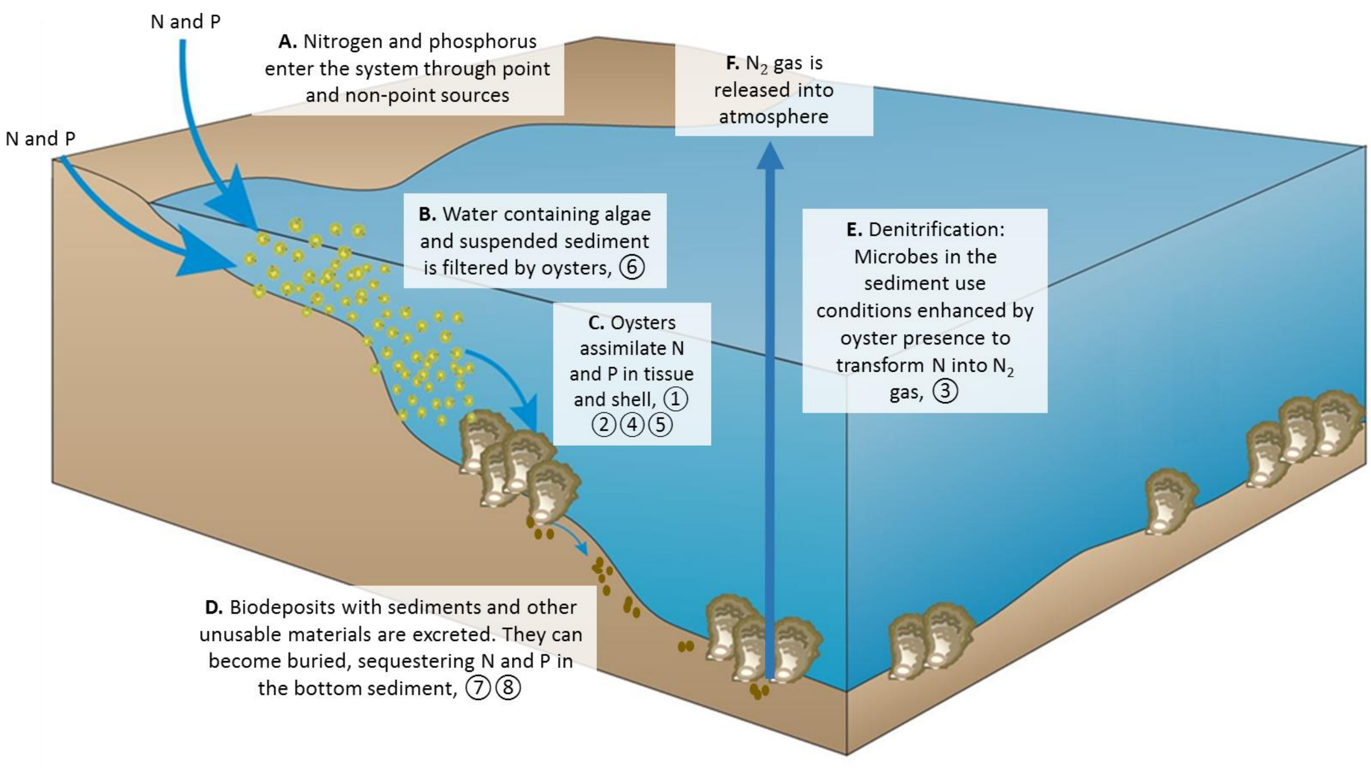
1. Nitrogen Assimilation in Oyster Tissue
2. Nitrogen Assimilation in Oyster Shell
3. Enhanced Denitrification Associated with Oysters
4. Phosphorus Assimilation in Oyster Tissue
5. Phosphorus Assimilation in Oyster Shell
6. Suspended Sediment Reduction Associated with Oysters
7. Enhanced Nitrogen Burial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

When algae or other organic matter are consumed by oysters through filter-feeding, the nitrogen and phosphorus within are assimilated in the oyster's tissue and shell. These nutrients are therefore unavailable to water column processes for a range of timescales dependent on whether oyster tissue or shell is considered (Kellogg et al. 2013). Oyster shells, whether buried in the bottom sediment or dissolved back into the water column, represent sequestration of nitrogen and phosphorus over long periods of time; while nutrients sequestered in tissue may be cycled back into the environment on a shorter timescale (Kellogg et al. 2013, Newell 2004 and sources therein). Oysters removed from the water for consumption or other purposes also remove the nutrients sequestered within the oyster.

Denitrification, which involves microbial transformation of biologically available nitrogen to N_2 gas, is an additional means by which nitrogen is removed from the system, and it is enhanced by the presence of oysters. Oysters enhance the formation of a heterogeneous sediment surface with oxic and anoxic sediments in close proximity and supply carbon in the form of biodeposits to the sediment surface, two characteristics that are necessary for denitrification to occur (Smyth et al. 2015 and sources therein, Gutierrez and Jones 2006, Kellogg et al. 2013). Once nitrogen is transformed to N_2 gas, it travels through the water column and escapes into the atmosphere.

The oyster filter feeding process removes inorganic particles, such as suspended sediments, and organic particles, such as algae containing nitrogen and phosphorus, from the water column, increasing water clarity (Grizzle et al. 2008). Like oyster shells, biodeposits may become buried (Newell 2004), which serves to remove nutrients from the water column for long time scales. Figure 6a depicts these N, P, and suspended reduction processes associated with oysters.

Figure 6a. Oyster-associated processes that reduce nitrogen (N), phosphorus (P), and suspended sediment. The numbers in circles correspond with the reduction effectiveness crediting protocols.



The Panel concurred that Protocols 1 and 4, involving nitrogen and phosphorus assimilation in oyster tissue, have sufficient data to recommend reduction effectiveness estimates for oyster aquaculture practices (see Section 7.0). The Panel also believes that there may be sufficient data to recommend estimates for nitrogen and phosphorus assimilation in shell (Protocols 2 and 5), but have decided to include these recommendations in the second incremental report because it is unclear at present how to address the issue of shells from harvested oysters being eventually returned to the Chesapeake Bay. Because oyster aquaculture and reef restoration practices rely heavily on oyster shell and with oyster shell being a limited resource, any decrease of shell being returned to the Chesapeake Bay could have unintended negative impacts on these practices.

The Panel agreed that Protocols 3, 7, and 8 would require more in depth discussion given the variability in denitrification data and the complexity of quantifying the enhanced burial of nutrients associated with an increase in oysters. The term "enhanced" and "associated with oysters" were added to Protocols 3, 7, and 8 because the Panel wanted to be clear that the oysters are not directly carrying out denitrification or burial, but instead enhance these processes by increasing the movement of organic particulate matter from the water column to the bottom through filtering and increasing the habitat area (via reef structures) for other contributing organisms to populate. The Panel is mindful that denitrification-related reduction effectiveness recommendations will have to adequately address variability. The Panel also recognizes that burial rates of nitrogen and phosphorus will depend on sedimentological and physical characteristics of sites and requires demonstrable long term sequestration for consideration of whether Protocols 7 and 8 should be applied to certain oyster practice categories. The Panel plans to include recommendations on the reduction effectiveness from enhanced denitrification associated with oysters in the second incremental report. Even though there is likely less information on enhanced burial of nutrients associated with oysters, the Panel still felt strongly that these protocols should be included because of their potential in reducing nutrients from the water column. However, the Panel agreed to put enhanced nitrogen and phosphorus burial protocols on hold until the CBP Management Board determines whether crediting burial from oyster practices would be legal since the pollutants are technically still in the Chesapeake Bay.

The Panel had an in depth conversation concerning how suspended sediment could be incorporated into a crediting protocol (protocol 6) since suspended sediment would only be removed from the water column and deposited on the bottom by the oysters and not removed from the Chesapeake Bay. The Panel decided that it would be important for the CBP Partnership Management Board to first evaluate the policy/legal issue of this (i.e., can removal from the water column followed by deposition on the bottom be incorporated in the reduction effectiveness credit). The Panel is putting the evaluation of this protocol on hold until the Management Board reviews pertinent policy issues.

7.0 Reduction Effectiveness Estimates for Nitrogen and Phosphorus Assimilated in Oyster Tissue

This section describes the Panel's recommendations concerning the reduction effectiveness estimates for the "Nitrogen Assimilation in Oyster Tissue" and the "Phosphorus Assimilation in Oyster Tissue" reduction effectiveness crediting protocols specific to *C. virginica* oysters when they are removed (harvested) from the water via private oyster aquaculture practices. The Panel is endorsing these recommendations only for practices in the following oyster practice categories (see description of practices in Section 5.0):

- Off-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using substrate addition

The Panel is still discussing these protocols for the oyster practice categories involving the public fishery and oyster reef restoration (Table 1a) and will present their recommendations in a future report.

The Panel is recommending two options for the "Nitrogen Assimilation in Oyster Tissue" and "Phosphorus Assimilation in Oyster Tissue" protocols' reduction effectiveness estimates:

1. Default estimates for recommended practices regardless of location (Section 7.1).

2. Site-specific estimates developed by the BMP implementer, in coordination with the CBP Partnership and reporting jurisdictions (i.e., State agencies), using the Panel's recommended methodology (Section 7.2).

The Panel reasoned that option 1 could be applied as long as the BMP implementer meets the qualifying conditions described in Section 8.0. Option 2 can be pursued if the BMP implementer decides they want to develop a site-specific estimate (see Section 7.2) for their practice. Because the Panel's default estimates are intentionally conservative (see Section 7.1), the Panel felt it was important to give BMP implementers the option to develop site-specific estimates that might have higher values than default estimates. The same qualifying conditions apply to all estimates.

The default reduction effectiveness estimates for assimilated nitrogen and phosphorus are described in detail in Section 7.1. While models exist that can be used to estimate growth and assimilation (e.g. FARM model, Appendix C), the Panel agreed that the reduction effectiveness estimates should be developed using an empirical approach. The default estimates are calculated using regressions based on existing data to convert oyster shell height to oyster biomass in terms of soft tissue dry weight of shell height midpoints and multiplying by the percent nitrogen and phosphorus content in dry tissue. Separate regressions were developed for diploid and triploid oysters due to clear differences in the shell height to tissue dry weight regression curves for these two types of oysters. The shell height midpoints are based on oyster size class ranges recommended by the Panel. The percent nitrogen and phosphorus content in oyster tissue were derived using averages from existing data from the Atlantic Coast of the U.S.

7.1 Option 1: Default Reduction Effectiveness Estimates for Nitrogen and Phosphorus Assimilated in Oyster Tissue

The Panel decided that there was sufficient empirical data to establish conservative default reduction effectiveness estimates for nitrogen and phosphorus assimilated in the soft tissue of diploid and triploid oysters using the following three-step process:

Step 1: Determine the oyster shell height to tissue dry weight regression equations for diploid and triploid oysters

This step involves the analysis of empirical data to establish regression equations to convert shell height to soft tissue dry weight (further described in Section 7.1.1). Refer to Figure 7.1 for the shell height measurement location on an oyster shell.

Step 2: Establish oyster size class ranges for the shell height midpoints that will be used to calculate the oyster soft tissue dry weight

This step involves establishing oyster size class ranges and using the midpoint of those ranges in the regression equations from Step 1 to calculate the soft tissue dry weight needed for Step 3 (further described in Section 7.1.2).

Step 3: Establish and apply the percent nitrogen and phosphorus content in oyster tissue to determine the reduction effectiveness estimates

This step involves multiplying the oyster soft tissue dry weights from Step 2 by the established percent nitrogen and phosphorus content in the oyster tissue (further described in Sections 7.1.3) to determine the reduction effectiveness estimates for the different oyster size class ranges (see Section 7.1.4).

Although similar to the approach recommended by STAC (STAC 2013 and 2014), the Panel's estimates explicitly consider variability resulting from ploidy (i.e., diploid and triploid), culture location (i.e., off-bottom in water column and on-bottom), season of harvest, and locations with different environmental conditions (e.g. salinity). In addition, the Panel also established estimates for different oyster shell height size class categories instead of one default estimate based on a 76 mm (3 inch) oyster.

7.1.1 Step 1: Oyster Shell Height to Tissue Dry Weight Regression Equations

The first step of the default nitrogen and phosphorus assimilated in oyster tissue reduction effectiveness estimates was to identify appropriate regression curves for the relationship between oyster shell height (Fig. 7a) and soft tissue biomass in terms of dry weight based upon actual shell height and tissue dry weight measurements from individual oysters.

Figure 7a. The measurement location for shell height. Shell height is the longest distance (parallel to the long axis) between the hinge and lip of the oyster. Note that shell height is also referred to as oyster shell length in some studies.

In reviewing the existing scientific literature from the Chesapeake Bay region, the Panel found shell height to biomass regressions highly variable (Table 7a), likely because the individual studies focused on different characteristics that could influence oyster growth (i.e., subtidal versus intertidal reefs, low versus high salinity environmental conditions) and/or used different biomass metrics (i.e., tissue dry weight versus tissue ash-free dry weight). Because incineration of samples is a required step in determining the ash-free dry weight and nitrogen content cannot be derived from an incinerated sample, it is not feasible to determine both ash-free dry weight and nitrogen content for the same individual. ***Therefore, the Panel concluded that only datasets from within the Chesapeake Bay watershed that included individual oyster shell heights and corresponding biomass in terms of tissue dry weight were suitable for inclusion in the compiled dataset used to determine default estimates for nitrogen and phosphorus contained in oysters.***

Table 7a. Summary of shell height to soft tissue dry weight biomass regression models for the Eastern Oyster grown in a variety of locations and conditions near or within the Chesapeake Bay. DW=dry tissue weight (g), AFDW=ash-free dry tissue weight (g), WW=wet weight (g), and SH=shell height (mm).

Ploidy	Location	Habitat/Culture Method	Equation	R^2	Reference
Diploid	Great Wicomico, Rappahannock and Piankatank Rivers, VA	Subtidal reefs - Spring	$AFDW=0.00004 \cdot SH^{2.4257}$	0.8	Ross & Luckenbach unpubl. data
		Subtidal reefs - Summer	$AFDW=0.00007 \cdot SH^{2.1704}$	0.7	
		Subtidal reefs - Fall	$AFDW=0.00001 \cdot SH^{2.6497}$	0.9	
		Subtidal reefs - All seasons	$AFDW=0.00002 \cdot SH^{2.5988}$	0.9	
	James River, VA	Subtidal reefs	$DW=0.000423 \cdot SH^{1.7475}$	-	Mann & Evans 1998
	Lynnhaven Inlet, VA	Intertidal Reefs	$AFDW=0.0003 \cdot SH^{1.9352}$	0.8	Ross & Luckenbach unpubl. data
		Subtidal Reefs	$AFDW=0.00003 \cdot SH^{2.3465}$	0.7	
		All Reefs	$AFDW=0.00006 \cdot SH^{2.2809}$	0.7	
	Spencer's Creek, VA	Floating Caged Aquaculture	TL (mm) = -35.5408 + (0.955 * shell DW (g))	0.8	Higgins et al. 2011
	St. Jerome Creek, MD				
	Upper Chesapeake Bay, MD	Subtidal reefs - Natural and Restored	$DW=0.00003 \cdot SH^{2.35}$	0.7	Liddel 2008
	West River, MD	Floating Tray	$WW=0.000068 \cdot SH^{2.49}$	0.9	Paynter & DiMichele 1990
Triploid	Chincoteague Bay	Floating Aquaculture	$AFDW=0.00003 \cdot SH^{2.3952}$	0.8	Ross & Luckenbach unpubl. data

The Panel sent out requests to various researchers for oyster data within Chesapeake Bay and its tributaries that included both oyster shell height and soft tissue dry weight measurements that captured different oyster sizes, ploidy (e.g., diploid, triploid), culture methods (e.g., off-bottom oyster aquaculture with gear, on-bottom aquaculture with no gear), diploid oyster culture type (e.g., wild, hatchery-produced), season (e.g., spring, summer, fall, winter), and locations (total of 22 general locations; Figure 7b) with different environmental conditions. For inclusion in the Panel's compiled dataset, the Panel required that data be of high to medium quality and suitability based upon study location, data collection methods, data quality, and data age. After closely examining data from unpublished studies and studies older than five years to data from recent, peer-reviewed datasets, the Panel concluded that the data warranted inclusion because there was no indication that these data were outliers. From their analysis, the Panel observed two very distinct shell height to tissue dry weight regression curves when comparing the diploid and triploid datasets and agreed that ploidy was likely driving differences in biomass and that these datasets would be sufficient to develop separate conservative oyster shell height to soft tissue dry weight regression equations for diploid and triploid oysters. The data used to establish the diploid and triploid regression equations are described in Section 7.1.1.1 and the method used, considerations, and recommended equations are described in Section 7.1.1.2.

7.1.1.1 Description of Data used to derive the Oyster Shell Height to Tissue Dry Weight Regression Equations for Diploid and Triploid Oysters

The Panel ultimately included data on a total of 5,750 diploid oysters collected between 1998 and 2015 from seven data sources (four published and three unpublished) and 1,066 triploid oysters collected between 2005 and 2007 from one published data source. Data were collected using standard methods, were from studies within the Chesapeake Bay and its tributaries, included a large range of shell heights (diploid shell heights: minimum = 13.5 mm, 0.53 inches, maximum = 184 mm, 7.24 inches; triploid shell heights: minimum = 10.2 mm, 0.40 inches, maximum = 139 mm, 5.47 inches), and included measurements from a variety of culture methods (caged and floating off-bottom aquaculture and on-bottom aquaculture with no gear from various reef sites), culture type (wild and hatchery-produced), seasons (spring, summer, fall, and winter), and habitat locations, with the exception that the triploid dataset had one representative culture method (off-bottom in cages near the bottom) and culture type (i.e., hatchery-produced) (Figure 7b, Table 7b, and Table 7c). Appendix D includes a summary of the studies used in the diploid and triploid regression analyses, description of data not used in the analyses, and description of other potential data sources that could be pursued to expand the compiled dataset.

Figure 7b. General locations where oysters in the compiled diploid and triploid datasets were grown grouped by their approximate location in the Chesapeake Bay based on the CBP Bay Regions (U.S. EPA 2004) and salinity characteristics based on the U.S. Army Corp. of Engineers salinity gradient maps (mesohaline =5-18 ppt, polyhaline = 19-30 ppt; http://www.nab.usace.army.mil/Missions/Environmental/Oyster-Restoration/Oyster-Master-Plan/).

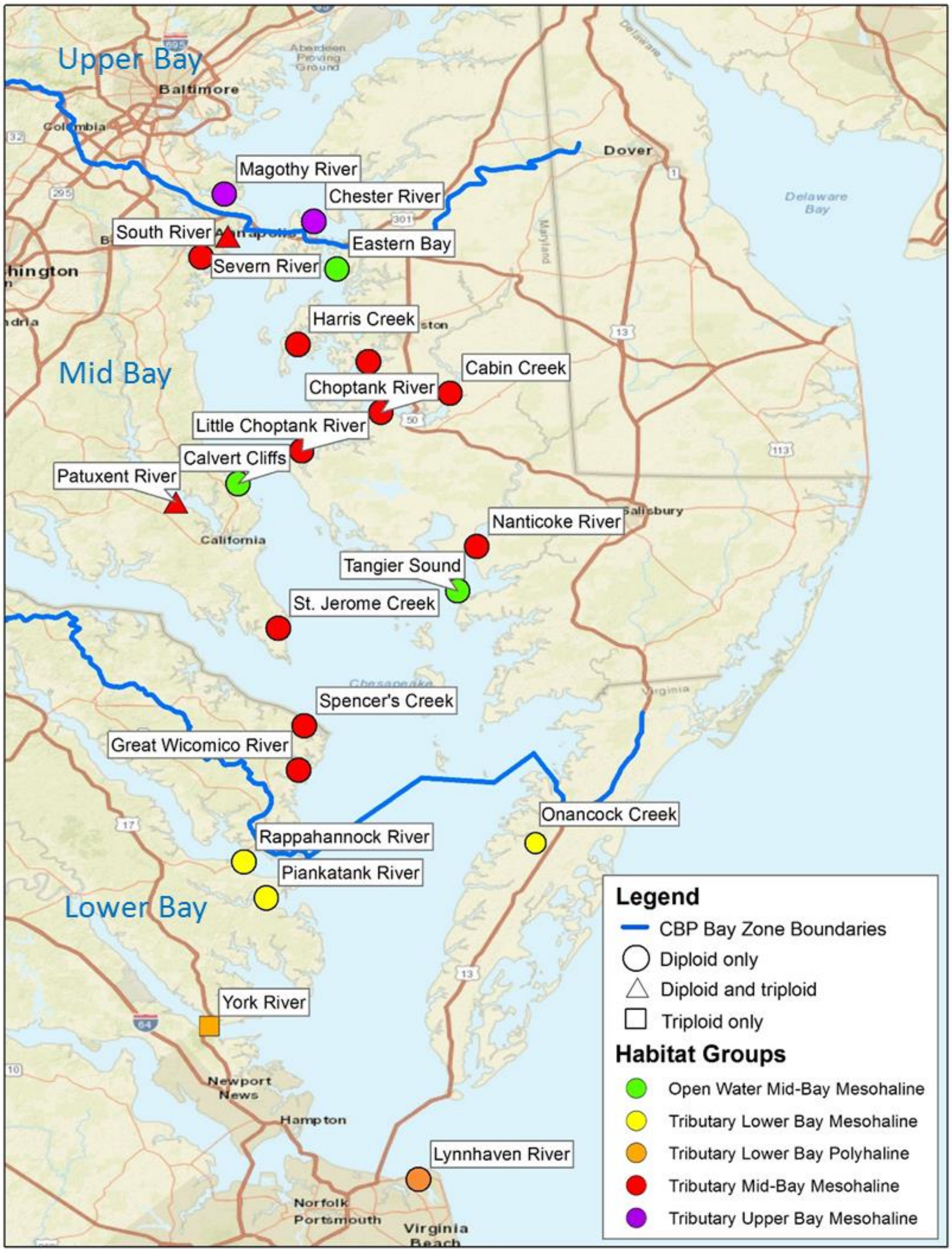


Table 7b. Summary of diploid oyster data (n = 5,750 individual oysters) and corresponding growth influencing factors (i.e., culture method, culture type, location oysters were grown, and year and season removed) from the different data sources used in the diploid regression analysis to determine the equation to convert shell height (mm) to soft tissue dry weight (g). Percent of total dataset represents the percent of the 5,750 oysters from that subset. Asterisks in the location column indicates oysters that were wild. All other oysters were hatchery-produced. Additional literature/data review information on these data sources can be found in Appendix D.

Data Sources	Related Culture Method	Location	Year Oysters Removed	Season Oysters Removed	Percent of Total Dataset
Higgins unpubl. data	Bottom Oyster Planting (Reef)	Choptank River, MD*	2008	Spring	0.16
		Lynnhaven River, VA*			0.31
Higgins et al. 2011	Off Bottom in Water Column (Floating cages)	Spencer's Creek, VA	2008	Spring	0.80
		St. Jerome Creek, MD			0.66
Kellogg unpubl. data	Bottom Oyster Planting (Subtidal restored reef)	Harris Creek, MD	2015	Fall	2.80
				Winter	2.87
				Spring	2.92
				Summer	9.83
	Off Bottom in Water Column and Bottom Oyster Planting Combination (Subtidal restored reef - cages first and then transferred to bottom with no gear)	Onancock Creek, VA	2012	Spring	1.90
				Summer	0.02
Kellogg et al. 2013	Bottom Oyster Planting (Restored reef)	Choptank River, MD	2009	Fall	0.97
			2010	Spring	0.85
				Summer	1.91
Luckenbach and Ross 2009 (Part 1 of Report)	Bottom Oyster Planting (Subtidal patch reef)	Great Wicomico River, VA	2004, 2005	Fall	2.50
			2004	Spring	0.57
			2005	Summer	3.77
		Lynnhaven River, VA	2005	Fall	1.62
				Summer	2.07
		Piankatank River, VA	2004	Fall	0.71
			2004, 2005	Spring	0.87
				Summer	1.41
		Rappahannock River, VA	2004	Fall	0.35
			2004, 2005	Spring	1.72
				Summer	0.54

Luckenbach and Ross 2009 (Part 3 of Report)	Bottom Oyster Planting (Restored and existing oyster reefs on bulkheads, intertidal patch reefs, marsh, riprap, subtidal bottom (not discrete patches)	Lynnhaven River, VA*	2005, 2006	Spring	14.24
			2006	Winter	2.26
Paynter unpubl. data found in Liddel 2008	Bottom Oyster Planting (Restored reefs)	Cabin Creek, MD	1998	Fall	0.17
			2000	Spring	0.10
			1998	Summer	0.26
		Calvert cliffs, MD	1998	Fall	0.43
			1999	Spring	0.09
			1998, 1999	Summer	0.83
		Chester River, MD	2001, 2002, 2004	Fall	2.37
			2002	Spring	1.88
			2001, 2002, 2004	Summer	2.38
		Choptank River, MD	2000, 2002	Fall	3.20
			2001, 2002	Winter	1.67
			2001, 2002, 2004	Summer	5.77
		Eastern Bay, MD	2001	Fall	0.49
			2002	Winter	0.68
			2004	Spring	0.21
			2001, 2002	Summer	2.09
		Little Choptank River, MD	2004	Summer	0.43
		Magothy River, MD	2001, 2002	Fall	1.15
			2002	Spring	0.47
			2001, 2002	Summer	0.87
		Nanticoke River, MD	2001, 2002	Fall	0.21
			2002	Summer	0.26
		Patuxent River, MD	2001	Fall	0.31
				Spring	1.37
			2000, 2001, 2002	Summer	4.59
		Severn River, MD	2001, 2002	Fall	1.39
			2001	Winter	0.35
			2002	Spring	0.17
			2001, 2002	Summer	1.51
		South River, MD	2001, 2002	Fall	0.43
			2002	Spring	0.26
				Summer	0.24
		Tangier Sound, MD	2000, 2001, 2002	Fall	2.00
			2001, 2002	Summer	2.14
		Tred Avon River, MD	2000	Fall	0.26
			2001	Summer	0.30

* Wild oysters

Table 7c. Summary of triploid oyster data (n = 1,066 individual oysters) and corresponding growth influencing factors (i.e., location where oysters were grown and year and season removed) from the different data sources used in the triploid regression analysis to determine the equation to convert shell height (mm) to soft tissue dry weight (g). Percent of total dataset represents the percent of the 1,066 oysters from that subset. Triploid oysters were hatchery-produced. Additional literature/data review information on these data sources can be found in Appendix D.

Data Sources	Related Culture Method	Locations	Year Oysters Removed	Season Oysters Removed	Percent of Total Dataset
Kingsley-Smith et al. 2009	Off Bottom (cages near bottom; experiment was designed to be representative of oysters on the bottom)	Patuxent River, MD	2006, 2007	Fall	11.16
			2005	Winter	5.53
			2006, 2007	Spring	11.16
				Summer	11.26
		Severn River, MD	2006, 2007	Fall	14.07
			2005	Winter	5.63
			2006, 2007	Spring	11.26
				Summer	9.47
		York River, VA	2005, 2006	Fall	9.47
			2006	Spring	5.63
				Summer	5.35

7.1.1.2 Recommended Regression Equations to Convert Shell Height to Tissue Dry Weight for Diploid and Triploid Oysters

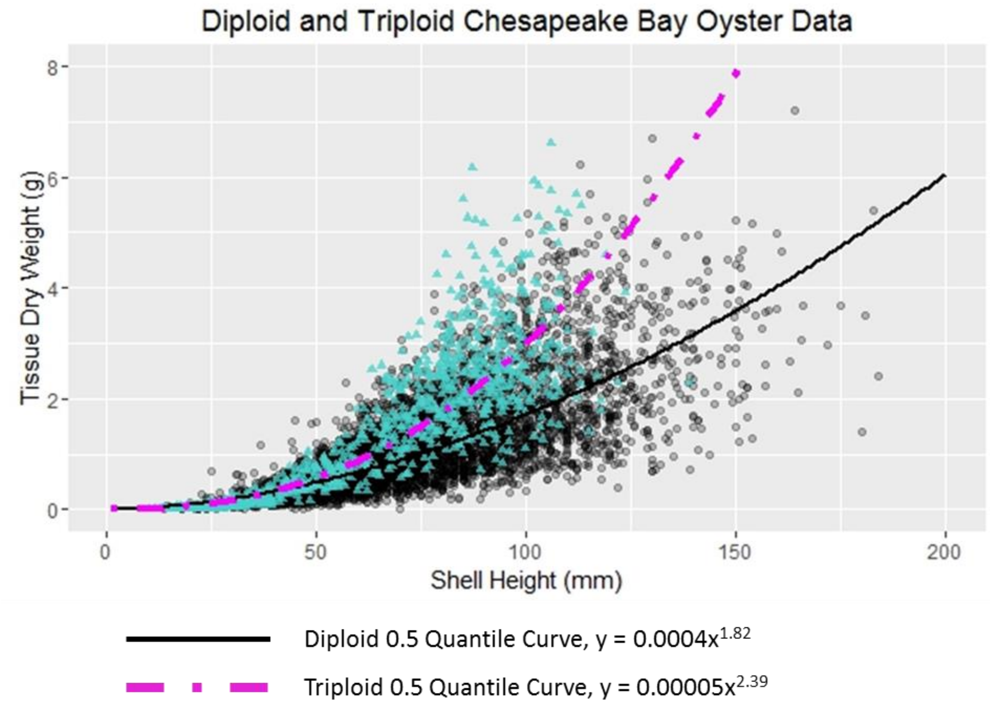
Given that there was a range of values for dry weight observed across the range of oyster shell heights (Figures 7c, 7d and 7e), the panel used the quantile regression statistical method (Koenker and Bassett, 1978) that was not sensitive to the presence of outliers, as the appropriate technique to derive and select conservative equations that could be used to convert shell height to soft tissue dry weight using the datasets from Table 7b (for diploid equation) and Table 7c (for triploid equation). Quantile regression is a commonly used statistical method that is employed across a variety of disciplines to explore relationships between two variables of interest (Yu et al. 2003). Regression quantiles represent a series of planes that contain an increasing proportion of sample observations (Cade and Noon, 2003). When the 0.5 quantile is calculated, this corresponds to the median of the dataset; i.e., 50% of the y values lie above and 50% of the y values lie below each specified x value. It is possible to calculate both linear (lrq) and nonlinear quantile regressions (nlrq) using the R statistical package quantreg (Koenker 2006; Koenker 2016), which was necessary since the relationship between oyster dry weight and shell length has been shown to be a power function. Overall, quantile regression was favored by the Panel because it better addresses datasets where high variability exists, which is the case for converting oyster shell height to soft tissue dry weight.

The Panel recommends using the 0.5 quantile oyster shell height (mm) to soft tissue dry weight (g) regression equations to derive default nitrogen and phosphorus reduction effectiveness estimates.

The 0.5 quantile was calculated for the entire dataset based on the equation $y = ax^b$, using the nlrq function and starting values for *a* and *b* based on mean estimates of the power function. Analyses indicated that differences in ploidy resulted in clear differences in the relationship between oyster shell height and oyster soft tissue dry weight, warranting the use of separate regression equations for diploid and triploid oysters (Figure 7c).

As a result, the Panel recommends that the corresponding 0.5 quantile regression equations be used to derive separate estimates from diploid and triploid oysters.

Figure 7c. Shell height to tissue dry weight 0.5 quantile regression curves for diploid and triploid oysters. Refer to Tables 7b and 7c for data that was used to develop the curves.



The following is the Panel's recommended 0.5 quantile regression equation for diploid oysters (Figure 7d):

$$y = 0.0004x^{1.82}$$

where x equals the oyster shell height in millimeters and y equals the soft tissue dry weight in grams.

The following is the recommended 0.5 quantile regression equation for triploid oysters (Figure 7e):

$$y = 0.00005x^{2.39}$$

where x equals the oyster shell height in millimeters and y equals the soft tissue dry weight in grams.

Figure 7d. The Panel's recommended equation to convert <u>diploid</u> oyster shell height in millimeters (x-variable) to tissue dry weight in grams (y-variable) based on the 0.5 quantile regression curve ($y = ax^b$; n = 5,750 oysters). Table 7b summarizes this data by data source, culture method, location, and date and season oysters were removed/harvested from Chesapeake Bay and its tributaries. The solid red line depicts the 50th quantile and the dashed red lines represents the error terms *a* and *b*.

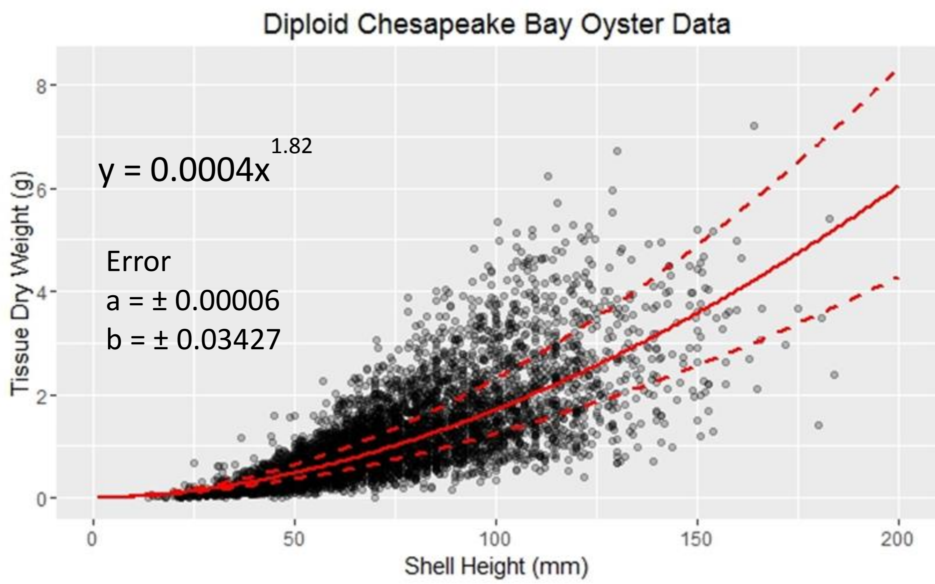
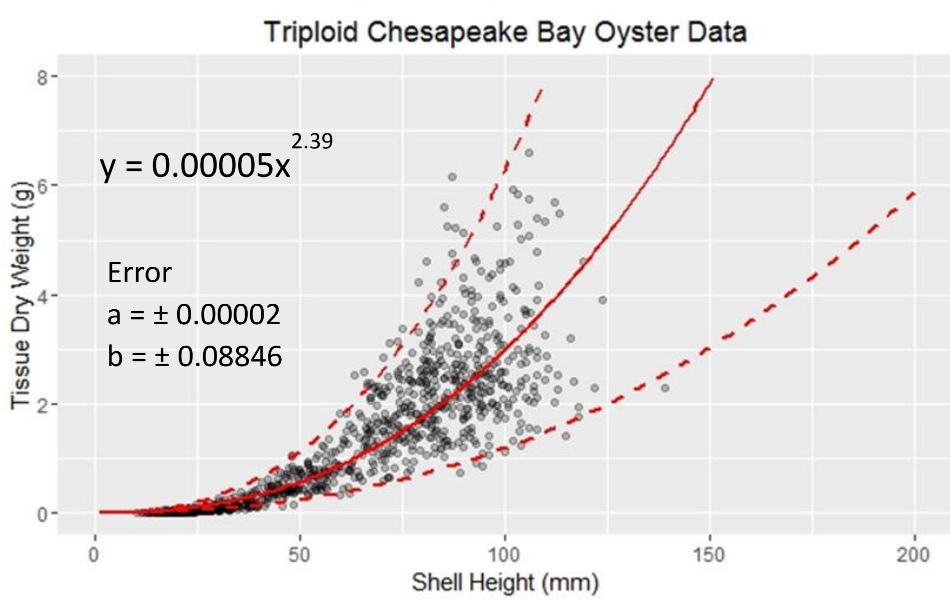


Figure 7e. The Panel's recommended equation to convert <u>triploid</u> oyster shell height in millimeters (x-variable) to tissue dry weight in grams (y-variable) based on the 0.5 quantile regression curve ($y = ax^b$; n = 1066 oysters). Table 7c summarizes this data by data source, culture method, location, and date and season oysters were removed/harvested from Chesapeake Bay and its tributaries. The solid red line depicts the 50th quantile and the dashed red lines represents the error terms *a* and *b*.



In addition to ploidy, the Panel also considered other factors that could influence growth, including differences in culture method (e.g., off-bottom, on-bottom) and type (e.g., hatchery-produced, wild), season of harvest (spring, summer, fall, and winter), and locations throughout the Chesapeake Bay (e.g., upper, mid, and lower) with different environmental conditions (e.g., mesohaline, polyhaline). In all cases, the Panel found that either there was not sufficient evidence that the factors significantly altered shell height to tissue dry weight relationships or that there were insufficient data to create robust regressions for all levels of a particular factor. Thus, at this time, the Panel does not recommend developing separate equations for these factors but recognizes that additional equations may be warranted if additional data are incorporated into the compiled dataset to address knowledge gaps. In the meantime, the Panel agreed that the 0.5 quantile regression equations of the current diploid and triploid complied datasets allow for conservative reduction effectiveness estimates because they capture the variability associated with the majority of these various influencing growth factors (i.e., diploid dataset included representative data from the different culture methods, culture types, seasons, and locations; triploid dataset included representative data from seasons and locations) in a manner that would likely underestimate the actual reduction effectiveness concerning nitrogen and phosphorus assimilated in oyster tissue. Table 7d briefly summarizes the Panel’s rationale for this. Details of these analyses and considerations are described in Appendix D, including the identification of data gaps.

Table 7d. Rationale for why the Panel concluded that the 0.5 quantile shell height to tissue dry weight regression equations would be conservative. For season and location factors, results were similar except the triploid data did not include all the habitat groups evaluated. For culture method, conclusions are based on the diploid dataset because only the off-bottom culture method was available for the triploid data. The Panel's evaluation leading to these conclusions is presented in Appendix D.

Factor	Conservative Estimate Rationale for 0.5 Quantile Regression Equation
Ploidy	Triploid oysters clearly exhibited higher biomass per mm shell height than diploid oysters and appeared to be driving the biomass differences observed when the two datasets were used together, warranting separate reduction effectiveness estimates for diploid and triploid oysters. The 50^{th} quantile regression equations were chosen by the Panel because it represents the median of the data, allowing for an even likelihood of underestimating or overestimating the biomass. The Panel felt this was the best quantile to develop the default reduction effectiveness estimates because it best captures the variability in the data.
Culture Method and Type	Oyster data for the culture methods that were evaluated (i.e., off-bottom, on-bottom, and combination of both) and type (i.e., hatchery-produced, wild) either skewed above or were similar to the 0.5 quantile curve of the entire dataset, suggesting that the recommended equations will more likely underestimate the tissue dry weight and hence, the reduction effectiveness.
Season	The fall, winter, and spring oyster data skewed above the 0.5 quantile curve of the entire dataset, while the summer data skewed slightly below. Given that 3 seasons skewed above the recommended 0.5 quantile curves and the reduction effectiveness is based on annual reporting with growers typically harvesting year round, the Panel felt that the reduction effectiveness would balance out (i.e., any potential overestimation would be negated by instances of underestimation).
Location/Environmental Condition	Sampling locations were grouped by location within the Chesapeake Bay (Upper, Mid, Lower; tributary or open-Bay) and by salinity (mesohaline and polyhaline). Oyster data for four of the five habitat groups skewed above or were similar to the 0.5 quantile curve of the entire dataset, suggesting a greater chance to underestimate the reduction effectiveness. The remaining habitat group was only slightly below the 0.5 quantile curve of the entire dataset.

7.1.2 Step 2: Oyster Size Class Range Midpoints to Determine the Oyster Soft Tissue Dry Weight

The second step of the default nitrogen and phosphorus assimilated in oyster tissue reduction effectiveness estimates involves the establishment of oyster shell height midpoints for different oyster size class ranges to calculate the oyster soft tissue biomass that will be used with the regression equations from Step 1. The Panel opted to use this midpoint size class approach because it is more realistic in regards to implementing the BMP because the oyster size class ranges are based on midpoints that reflect what is typically reported (e.g., harvested oysters are usually reported by whole numbers for the shell height in inches).

Table 7e outlines the Panel's recommended oyster size class categories and midpoints for determining the oyster soft tissue biomass using regression equations from Step 1 (see Section 7.1.1).

Table 7e. Recommended oyster size class ranges and midpoints in inches and millimeters (mm). Note that the shell height midpoints in millimeters would be the input into the diploid and triploid regression equations from Step 1 (see Section 7.1.1) to determine the oyster soft tissue dry weight biomass.

Oyster Size Class Range (Shell Height in inches)	Oyster Size Class Range (Shell Height in mm)	Approximate Shell Height Midpoint (in inches)	Shell Height Midpoint to Use with Regression Equation (Shell Height in mm)
a. 2.0 - 2.49	~50 - 63	2.25	57
b. 2.5 - 3.49	~64 - 88	3.0	76
c. 3.5 - 4.49	~89 - 114	4.0	102
d. 4.5 - 5.49	~115 - 139	5.0	127
e. ≥ 5.5*	≥ 140	6.0	152

*Midpoint based on 5.5-6.49 range

The data available allowed the Panel to recommend estimates for these five size class categories; however, it is not the Panel's intent that a practice must report in all five. Instead they would only report in the default size classes that is relevant to their practice.

The oyster soft tissue biomass associated with each oyster size class range is determined by using the shell height midpoints in millimeters of each oyster size class range with the diploid and triploid regression equations from Step 1 (see Section 7.1.1). Table 7.6 shows the results of these calculations. The resulting biomass is needed to determine the total nitrogen and phosphorus content in the oyster tissue.

Table 7f. The diploid and triploid oyster tissue dry weight values for the default reduction effectiveness estimates. The oyster size class range shell height midpoints in millimeters from Table 7e were used with the diploid and triploid oyster shell height (mm) to soft tissue dry weight (g) regression equations to calculate the soft tissue biomass.

Oyster Size Class Range (Shell Height in inches)	Diploid Tissue Dry Weight from Midpoint (g/oyster)*	Triploid Tissue Dry Weight from Midpoint (g/oyster)**
a. 2.0 - 2.49	0.63	0.79
b. 2.5 - 3.49	1.06	1.56
c. 3.5 - 4.49	1.81	3.16
d. 4.5 - 5.49	2.70	5.33
e. ≥ 5.5	3.74	8.20

*Diploid 0.5 quantile regression equation: oyster tissue dry weight (g) = 0.0004 * Shell Height (mm)$^{1.82}$

**Triploid 0.5 quantile regression equation: oyster tissue dry weight (g) = 0.00005 * Shell Height (mm)$^{2.39}$

The Panel decided that the above oyster size class ranges and associated midpoints would conservatively reflect the oyster soft tissue dry weight biomass of oysters being harvested. Oyster aquaculture harvest sizes vary according to the individual aquaculturists' marketing strategy. Often cultured oysters are marketed by specific size-classes. For example, "cocktail" or "petite"= 2 - 3 inches shell height, "standards" or "market" = 3.0 - 4.0 inches shell height, "extra large" = 4.0 - 5.0 inches shell height, jumbos > 5 inches shell height (see http://www.pangeashellfish.com/blog/the-culling-process-oyster-grades-and-sizes). However, the names and size ranges do vary between growers and even among different "brands" of oysters within a single aquaculture company (see http://www.ballardfish.com/products/oysters for sizes marketed by Ballard Fish & Oyster Co.). In contrast to oyster aquaculture, the wild fishery minimum size at harvest is set by regulation (3 inch, or 76 mm, shell height in VA and MD). While stock enhancement practices are not being considered yet due to ongoing Panel deliberation, these size class ranges would also be suitable for these practices.

7.1.3 Step 3: Percent Nitrogen and Phosphorus Content in Oyster Tissue

The third step of the reduction effectiveness estimates involve using percent nitrogen and phosphorus content in oyster tissue to determine how much nitrogen and phosphorus is contained in the oyster soft tissue dry weight (calculated by multiplying the tissue dry weight by the percent nitrogen and phosphorus content values). The panel conducted a literature review of studies that measured the percent nitrogen and phosphorus content in oyster tissue of C. *virginica* and concluded that the nitrogen and phosphorus content in oyster tissue was well constrained in estuaries along the Atlantic Coast of the United States. The Panel reasoned that the variation in total nitrogen and phosphorus content in tissue is driven more by biomass than the percent content (similar to conclusions found in Carmichael et al. 2012); therefore, they felt it would be appropriate to use the average percent content from the Atlantic coast studies. However, the Panel agreed that the average should be more weighted by Chesapeake Bay sites and therefore used the site-specific averages for studies within Chesapeake Bay and the overall average (sites combined) for studies outside of Chesapeake Bay.

The majority of studies found reported percent nitrogen dry weight tissue content for diploid oysters. Only 1 study (Reitsma et al. 2014) included measurements from triploid oysters from off bottom aquaculture in Cape Cod, MA. There were also a few studies that reported the percent phosphorus content in tissue for diploid oysters, but the Panel were not able to find any studies on triploid oysters. Given that the nitrogen and phosphorus content in oyster soft tissue is well constrained and large changes in the total nitrogen and phosphorus in oyster tissue appear to be driven by the oyster's biomass and not the percent nitrogen and phosphorus content in tissue (see Section 7.1.1; Carmichael et al. 2012), the Panel concluded that the average percent nitrogen and phosphorus content values from diploid oysters can be applied to triploid oysters.

The Panel recommends an average percent nitrogen content in oyster tissue of 8.2% and an average percent phosphorus content of 0.9%. Studies used to develop the recommended nitrogen content in oyster tissue of 8.2% and phosphorus content of 0.9% are further discussed in Sections 7.1.3.1 and 7.1.3.2, respectively. Appendix D includes a summary of the literature review.

7.1.3.1 Recommended Percent Nitrogen Content in Oyster Tissue

The Panel reviewed the literature and found eight published and three unpublished studies that measured and reported the percent nitrogen content in oyster tissue (summaries can be found in Appendix D). The average nitrogen percent content from these studies ranged from 5.64 in Fox Point, Great Bay, NH (Grizzle and Ward 2011) to 11.8 in Mobile Bay, AL (Dalrymple and Carmichael 2015). Even though the nitrogen content in oyster tissue, expressed as a percentage of dry weight, is relatively well constrained for estimate development purposes, the Panel agreed that it would be most conservative to use the average percent nitrogen content in oyster tissue from only the Atlantic Coast studies, resulting in the exclusion of one study in Mobile Bay, AL (Dalrymple and Carmichael 2015). The Panel also decided to omit Grizzle et al. 2016 and Newell and Mann 2012 because Grizzle et al. 2016 only reported size averages and not site averages (site averages would have to be estimated from a graph) and Newell and Mann 2012 didn't report the sample size or how the measurements were obtained; however, the Panel noted that the percent nitrogen content was comparable to the other studies (~7.8% and 7.0%, respectively). The Panel also left out unpublished Chesapeake data from Higgins from the Choptank River in MD and Lynnhaven River in Virginia because the data has not been fully analyzed yet. However, preliminary analyses show that the oysters in the Choptank River would have a percent nitrogen mean in tissue of 8.2% (n = 9 oysters) and in the Lynnhaven River, 8.8% (n = 18 oysters). These values are comparable to the values used to determine the average percent nitrogen content in tissue for the reduction effectiveness estimates.
The Panel recommends a percent nitrogen content in oyster tissue of 8.2% to be used to calculate the nitrogen assimilation in oyster tissue reduction effectiveness estimates. This number is based on 5 published studies

and 1 unpublished study on diploid oysters from Atlantic Coast estuaries found in Table 7g. These studies are further described in Appendix D. These studies capture varying culture methods (off bottom and on bottom), seasons, and environmental conditions, but did not include data on triploid oysters or during the winter season. Concerning triploid oysters, the Panel did find a Sea Grant funded study that measured the nitrogen content of triploid oysters grown off bottom in Cape Cod, MA (Reitsma et al. 2014). Their results showed that the average percent nitrogen in tissue was 8.5%, which is comparable and within the range of the diploid measurements.

Based on the six studies included in analyses (Table 7g; Appendix D), ***the Panel recommends a percent nitrogen content in oyster tissue of 8.2% to be used to calculate the nitrogen assimilation in oyster tissue reduction effectiveness estimates.*** These studies capture a variety of culture methods (off bottom and on bottom), seasons, and environmental conditions. They do not include any data on triploid oysters or on oysters collected during winter. Concerning triploid oysters, the Panel did find a Sea Grant funded study that measured the nitrogen content of triploid oysters grown off bottom in Cape Cod, MA (Reitsma et al. 2014). Their results showed that the average percent nitrogen in tissue was 8.5%, which is comparable and within the range of the diploid measurements.

The Panel also found in Grizzle et al. 2016 results indicating that there is a substantial decrease in soft tissue percent nitrogen content as an oyster ages in Great Bay, NH (from fitted model: ~65 mm oyster shell height = 8.3%, ~76 mm oyster shell height = 7.9%, and ~102 mm shell height = 5.6%). The Panel was not able to find any similar conclusions in any of the Chesapeake Bay studies. Since the estimates are based on conservative biomass determinations and average percent content, the Panel recommends that same average of 8.2% nitrogen content in tissue be used for the different size class ranges. However, it may be beneficial to explore potential differences in percent nitrogen content in oyster tissue of various oyster size classes in Chesapeake Bay in future studies.

Table 7g. Studies used to establish the recommended average percent nitrogen content in oyster tissue. SH = shell height, N = number of oysters analyzed, SE = standard error, and SD = standard deviation. Oysters evaluated in these studies were diploid. Studies are further summarized in Appendix D.

Source	Culture Method	Study Site and Environmental Conditions	N	% Nitrogen Mean	% Nitrogen Range
Carmichael et al. (2012)	Off Bottom Hatchery-Produced Oysters (cages 6 cm off bottom) SH = mean of 8.2 ± 0.2 mm at start of study to maximum of ~68 mm at end of study Growing Period: June-October 2003	Cape Cod, MA (5 sites total) Salinity Ranges = 25-28 N load Ranges =14×10^{-4}-601×10^{-4} kg N m-2 y-1	800	8.6 ± 0.2 SE	N/A
Grizzle and Ward (2011)[a]	Off Bottom (cages ~10-20 cm off bottom) SH = 7.8-55.6 mm Growing Period: April-November 2010	Great Bay, NH (6 sites total) Sites represent a range of ambient nutrient concentrations, water flow conditions, and locations with the estuary	108	7.28 ±0.49 SE	3.0-14.01
Higgins et al. (2011)	Off Bottom Hatchery-Produced Oysters (floating aquaculture cages) Mean SH = ~32-128 mm (from raw data) Growth Period: November 2006, August 2007 to October 2009	Spencer's Creek, VA Salinity = 5-15 Low flow, high sedimentation	47	8.1 ± 0.13 SE	5.80-9.97
	Off Bottom Hatchery-Produced Oysters (floating aquaculture cages) SH = ~57-150 mm (from raw data) Growth Period: May-July 2007 to October 2009	St. Jerome Creek, MD Salinity = 12-15 High flow, low sedimentation	37	7.37 ± 0.19 SE	5.43-10.36
Kellogg et al. (2013)	On Bottom Hatchery-Produced Oysters (restored subtidal oyster reef) Mean SH = 114 mm Growth Period: October 2009-August 2010	Choptank River, MD Salinity = 7.0-11.6	15[b]	9.27 ± 0.60 SD	8.58-9.71

Kellogg unpubl. data	On Bottom (intertidal reef) SH = 53-122 mm Time Period Removed: April, June, July, August, and October 2012; April and July, 2013	Hillcrest Oyster Sanctuary, Mockhorn Bay, VA	9[c]	8.13 ± 0.27 SE	7.8-7.92[e]
Sebastino et al. (2015)[d]	Off Bottom Hatchery-Produced Oysters (cages 1 m depth) Mean SH Range = 65-82 mm Growth Period: Spawned and settled in summer of 2009 and 2010; transplanted to sites June 2010 and 2011 and removed during July, August, and October 2010 and 2011	Jamaica Bay and Great South Bay, NY	N/A	8.94	N/A

[a]Values calculated using raw data provided in report appendix
[b]Three samples composed of five individuals per sample
[c]Three samples composed of 3 individuals
[d]Three sites were sampled within each bay, but results in Table 1 & 2 were aggregated data by bay.
[e]Range of aggregate averages

7.1.3.2 Recommended Percent Phosphorus Content in Oyster Tissue

The Panel reviewed the literature and found 3 published and 3 unpublished studies that reported the percent phosphorus content in oyster tissue (literature review summaries can be found in Appendix D). The average from these studies ranged from 0.62% (Hillcrest Oyster Sanctuary, Mockhorn Bay, VA; Kellogg unpubl. data) to 1.26% (Choptank River, MD; Kellogg et al. 2013). The Panel agreed to use the same data inclusion (i.e., Atlantic Coast studies) and averaging approach (i.e., site-specific averages for studies within Chesapeake Bay and the overall average of combined sites for studies outside of Chesapeake Bay) as for percent nitrogen content. Using the same rationale as that used for nitrogen, the Panel decided to omit the data from Newell and Mann 2012 and from Higgins from the Choptank River in MD and Lynnhaven River in Virginia. However, the reported percent phosphorus content in Newell and Mann 2012 of 0.8% and the preliminary analyses from Higgins of 1% for oysters (n = 9) in the Choptank River and 0.81% (n = 18 oysters) in the Lynnhaven River are comparable to the values used to determine the average percent phosphorus content in tissue for the reduction effectiveness estimates.

The Panel recommends a phosphorus content value of 0.9% of dry tissue weight be used to calculate the phosphorus assimilation in oyster tissue reduction effectiveness estimates. This number is based on two published studies and one unpublished study of diploid oysters from Atlantic Coast estuaries found in Table 7h. These studies are further described in Appendix D. These studies capture a variety of culture methods (off bottom and on bottom), seasons, and environmental conditions. They do not include any data on triploid oysters or on oysters collected during winter. However, since the percent phosphorus values are so well constrained and the percent nitrogen value of triploid oysters was comparable to the percent nitrogen content in triploid oysters, the Panel felt that the recommended percent phosphorus content based on diploid oysters could also be applied to triploid oysters.

Table 7h. Studies used to establish the recommended average percent phosphorus content in oyster tissue. SH = shell height, N = number of oysters analyzed, SE = standard error, and SD = standard deviation. Oysters evaluated in these studies were diploid. Studies are further summarized in Appendix D.

Source	Culture Method	Study Site and Environmental Conditions	N	% Phosphorus Mean	% Phosphorus Range
Higgins et al. (2011)	Off Bottom Hatchery-Produced Oysters (floating aquaculture cages) Mean SH = ~32-128 mm (from raw data) Growth Period: November 2006, August 2007 to October 2009	Spencer's Creek, VA Salinity = 5-15 Low flow, high sedimentation	47	0.83 ± 0.01 SE	0.60-1.05
	Off Bottom Hatchery-Produced Oysters (floating aquaculture cages) SH = ~57-150 mm (from raw data) Growth Period: May-July 2007 to October 2009	St. Jerome Creek, MD Salinity = 12-15 High flow, low sedimentation	37	0.82 ± 0.02 SE	0.53-1.07
Kellogg et al. (2013)	On Bottom Hatchery-Produced Oysters (restored subtidal oyster reef) Mean SH = 114 mm Growth Period: October 2009-August 2010	Choptank River, MD Salinity = 7.0-11.6	3[a]	1.26 ± 0.18 SD	N/A
Kellogg unpubl. data	On Bottom (intertidal reef) SH = 53-122 mm Time Period Removed: April, June, July, August, and October 2012; April and July, 2013	Hillcrest Oyster Sanctuary, Mockhorn Bay, VA	9[b]	0.62 ± 0.02 SE	0.59-0.67

[a]Three samples composed of five individuals per sample

[b]Three samples composed of 3 individuals

7.1.4 Default Reduction Effectiveness Estimates for Nitrogen and Phosphorus Content in Oyster Tissue for Diploid and Triploid Oysters

The Panel's recommended default diploid and triploid nitrogen and phosphorus reduction effectiveness estimates for endorsed practices when qualifying conditions are met are shown in Table 7i and 7j, respectively. These estimates were derived using the biomass from the oyster size class midpoints from Step 2 (Section 7.1.2; Table 7f) and multiplying by the recommended average percent nitrogen (8.2%) and phosphorus (0.9%) contents in oyster tissue from Step 3 (Section 7.1.3).

Table 7i. Nitrogen and phosphorus assimilated in oyster tissue reduction effectiveness estimates for diploid oysters.

Oyster Size Class Range (Shell Height in Inches)	Default Diploid N Content (g/oyster)	Default Diploid P Content (g/oyster)
a. 2.0 - 2.49	0.05	0.01
b. 2.5 - 3.49	0.09	0.01
c. 3.5 - 4.49	0.15	0.02
d. 4.5 - 5.49	0.22	0.02
e. ≥ 5.5	0.31	0.03

Table 7j. Nitrogen and phosphorus assimilated in oyster tissue reduction effectiveness estimates for triploid oysters.

Oyster Size Class Range (Shell Height in Inches)	Default Triploid N Content (g/oyster)	Default Triploid P Content (g/oyster)
a. 2.0 - 2.49	0.06	0.01
b. 2.5 - 3.49	0.13	0.01
c. 3.5 - 4.49	0.26	0.03
d. 4.5 - 5.49	0.44	0.05
e. ≥ 5.5	0.67	0.07

Based on the definitions of the practices (see Section 5.0), it is expected that the both the diploid and triploid estimates could be used for the off-bottom and on-bottom private oyster aquaculture using hatchery-produced oysters categories, while only the diploid estimates would be applicable for the on-bottom private oyster aquaculture using substrate addition category.

7.2 Option 2: Methodology for a Site-Specific Reduction Effectiveness Estimate for an Individual Practice

In addition to the default estimates, ***the Panel recommends that the CBP Partnership adopt an approach that allows the BMP implementers to pursue the development and implementation of site-specific nitrogen and phosphorus reduction effectiveness estimates***. The Panel acknowledges that, because the default reduction effectiveness estimates for nitrogen and phosphorus assimilation in oyster tissue are conservative, they will underestimate the total nitrogen and/or phosphorus removed in many cases and, much more rarely, overestimate it. Overall, the Panel felt that site-specific estimates would best represent the reduction effectiveness of an individual practice at a particular location. The Panel recommends the methodology described below to establish a site-specific estimate for their practice.

- The implementer of the oyster practice will first work with the reporting jurisdiction, in coordination with the CBP Partnership, to define their practice-specific oyster size classes if using different categories than the default estimate and two timeframes approximately 6 months apart set by the reporting jurisdiction to reflect seasonal differences.
- Once approved by the CBP Partnership, the implementer will have 50 random oysters per size class per season analyzed to determine the average tissue dry weight.
- The BMP implementer sends the samples to a lab that uses standardized methods to acquire the tissue dry weight in grams (e.g., tissue heated at 60°C until samples reach constant weight; Holme and McIntyre 1984; Mo and Neilson 1994).
- The average tissue dry weight for each size class will be multiplied by the default 8.2% nitrogen content and 0.9% phosphorus content in oyster tissue to determine the site-specific reduction effectiveness estimates.
- The site-specific reduction effectiveness estimates are reviewed and approved by the CBP Partnership. The Panel recommends the review and approval follows a similar approach as the re-evaluation procedure of existing estimates described in the CBP Partnership BMP Expert Review Protocol (CBP 2015). The Panel also encourages the CBP Partnership to incorporate opportunities for stakeholder involvement and input during these procedure-related determinations.
- Once approved by the CBP Partnership, the estimate would be applicable for that practice as long as they continue growing oysters under the same conditions when the reduction effectiveness evaluation was made.
- The Panel recommends using the existing procedures in the CBP Partnership BMP Expert Review Protocol (CBP 2015) for re-evaluation of the site-specific estimates. Given that the site-specific estimates will be derived using *in situ* data from the practice, the Panel does not anticipate that these estimates will have to be regularly re-evaluated, unless the recommended methodology used to derive the estimates is changed or the practice changes their grow-out approach (e.g., switching from on-bottom to off-bottom culture method, using triploid oysters instead of diploid oysters, selecting a different grow-out location, etc.).

The Panel conducted a sensitivity analysis to determine how many oysters should be measured per oyster size class. Diploid data from one habitat group (tributary mid-bay mesohaline) and from aquaculture practices representative of on-bottom oyster growth were selected based on yielding the largest data set (n = 3,016 oysters). Data were then divided into the default size classes in inches: 2.0-2.49; 2.5-3.49; 3.5-4.49; 4.5-5.49; 5.5-6.49. Using the R command "sample()," forty random subsamples were taken of each size class: 10 with n=25, 10 with n=50, 10 with n=75 and 10 with n=100. There was only enough data to do this for four of the five size classes, as the 5.5-6.49 class only had 42 total data points. The 0.5 quantile regressions for each subset were generated using the power function $y = ax^b$.

The average and distribution of each of the coefficients were examined, as well as the error terms, for each of the sample sizes. The error associated with *a* did not consistently change with increasing sample size and so was not used in this analysis. The error associated with *b* decreased the most when the sample size increased from 25 to 50 (see Table 7k). Further increased sample sizes did yield smaller error terms, as would be expected, but the largest gains were from increasing from 25 to 50 samples. Based on this analysis, the panel recommends n=50 per size class as a reasonable approach to minimizing both error and effort required to seek site-specific reduction effectiveness estimates. The panel also notes that, while the data used for these analyses encompass a range of locations, they are still likely much more variable than would be expected from a gear-intensive aquaculture operation with market pressures to produce a consistent product.

Table 7k. Error terms associated with coefficient *b* as the size of the subsample was increased.

Default Oyster Size Class	n = 25	n = 50	n = 75	n = 100
2.0 – 2.49	2.28	1.47	1.10	0.99
2.5 – 3.49	1.60	1.01	0.89	0.88
3.5 – 4.49	1.84	1.29	1.07	0.85
4.5 – 5.49	2.30	1.65	1.32	1.00

The Panel opted for the implementer to measure the biomass of their oysters and use the default percent nitrogen and phosphorus content instead of analyzing the percent nitrogen and phosphorus content in the tissue because, overall, the Panel saw that converting shell height to oyster biomass had much greater variability than the percent nitrogen and phosphorus content and felt that the more costly chemical analyses (approximately $30.00 per oyster) would not be reasonable for the BMP implementers. The Panel recommends that the refinement of the nitrogen and phosphorus percent contents in oyster tissue be done through research and not by the BMP implementers.

Since the method to determine oyster tissue dry weight is well established, the Panel felt there wouldn't be a need to convene a new expert panel to review the site-specific estimates. However, they did agree that the site-specific estimates should be reviewed and approved using a similar approach as the re-evaluation procedures of existing estimates described in the CBP Partnership BMP Expert Review Protocol (CBP 2015).

8.0 Qualifying Conditions

The Panel agreed that the qualifying conditions described below would apply to both the default and the site-specific estimates:

- Only includes oysters that are removed moving forward from the time the BMP is approved/implemented for reduction effectiveness credit in the TMDL. This baseline condition was proposed by the CBP Partnership Management Board and the Panel concurs with their decision.

- Oysters had to have been grown from initial sizes < 2.0 inches shell height.

- Oysters have to be alive when removed to count toward the reduction effectiveness.

9.0 Recommended Application and Verification Guidelines for the Nitrogen and Phosphorus Assimilation in Oyster Tissue Protocols for Private Oyster Aquaculture Practices

While the Panel is of the opinion that reporting oyster harvest in individuals is the preferred unit since the total number of oysters is needed to calculate the reduction effectiveness, they also recognized that other units are currently being used by States for reporting oyster harvest. In Chesapeake Bay, commercial fishermen and aquaculturists are required to quantify and report monthly oyster harvest to their State management agency. Harvest is reported according to how oysters are packaged and sold, which includes units of bushels, counts of oysters in boxes, or individual oysters (more information at http://dnr2.maryland.gov/fisheries/Pages/aquaculture/harvest-reporting.aspx; http://mrc.virginia.gov/regulations/FR610.shtm). The Panel' recommended application and verification guidelines in this section were developed to account for the use of different reporting units in a way that would offer flexibility to reporting jurisdictions (i.e., State agencies) in verifying the reduction effectiveness in a scientifically-defensible manner. Ultimately, it will be the reporting jurisdictions, in coordination with the CBP Partnership, that decide on which reporting unit to implement. These guidelines would be applicable for both the default and site-specific estimates.

For aquaculture, the unit of sale can vary depending on the method of harvest or how an individual business markets and sells its product. Oysters packaged in bushel baskets will typically have a range of shell heights and will most likely have been harvested directly from the bottom (on-bottom oyster aquaculture). Off-bottom aquaculture is done in cages and harvesters typically grade the product so that batches of oysters of similar size can be harvested together and marketed. Cage cultured oysters are generally packaged and sold in boxes or as individuals.

The common elements among these practices is that oysters are actively culled to a specific size by the processor to ensure they are legal or to group them uniformly for sale and they are placed in a standard type of container (e.g., bushel baskets, boxes or other standard container). Therefore, the most reasonable expectation for oyster aquaculture reduction effectiveness crediting is to report the number and sizes of oysters harvested using methods similar to existing State harvest reporting requirements.

The Panel identified three types of data that would be needed to apply the nutrient reduction effectiveness estimates:

1. *Types and total numbers of containers*- The total number and type of container used to package oysters needs to be documented annually.
2. *Average number of oysters in each container type*- The average number of oysters in a container is needed to apply the nutrient reduction effectiveness estimates to the number of oysters removed on an annual basis. The Panel recommends that the average number of oysters in a container is quantified by counting and documenting the total number of oysters in 10 containers. Oyster counts should be conducted during the two times a year when oysters are measured (see below).
3. *The average size of oysters in each container type*- The Panel recommends that the average size of oysters in containers be quantified by measuring and documenting the shell heights of 50 randomly selected oysters measured from representative containers (depends on packaging method described below). The Panel recommends that shell heights be measured two times a year to address any seasonal variability in biomass for similar shell heights. The Panel suggests that measurements are taken 6 months apart based on timeframes set by the reporting jurisdiction and CBP Partnership to reflect any changes in minimum harvest sizes.

The total number of containers is multiplied by the average number of oysters in a container to determine the total number of oysters eligible for reduction credit. Using these values, the nitrogen and phosphorus reduction effectiveness estimates will be applied to the oyster size category where the average shell height of all measured oysters falls.

There are two different ways in which aquaculturists currently package their oysters for reporting:

1. Oysters of variable shell heights are packaged together in the same container.
2. Oysters of uniform size are packaged in separate containers.

The representative containers in which oyster shell height measurements are made depends on which packaging method is used, further described below:

Oysters of variable shell heights are packaged together in the same container- Twice a year, 50 oysters are randomly selected from at least 10 containers for shell height measurements. The average shell height of all measurements is used to verify which oyster size class range estimate to use to determine the nutrient reduction effectiveness. This approach would most likely apply to on-bottom growers who typically report in bushels. Growers using this method will only be able to report in one size class category (unless oysters were moved; if so, then they will partition the credit to the appropriate locations based on recommendations under, "Movement of Oysters" below).

Oysters of uniform size are packaged together in separate containers- Twice a year, 50 oysters are randomly selected from at least 10 containers for each oyster size class range that the implementer is reporting in for shell height measurements. The average shell height of all measurements for that particular size class is used to verify which oyster size class range estimate to use to determine the nutrient reduction effectiveness. This approach would most likely be more relevant to off-bottom growers who package oysters in boxes at specific sizes. Growers using this method will be able to report in multiple oyster size class categories.

The Panel also discussed the issue of how much substrate should be added to be considered a "BMP" for the "on-bottom private oyster aquaculture using substrate addition" category brought up during the 30-day comment period on the draft report. The Panel agreed that a baseline guideline on the amount of substrate would not be appropriate because substrate requirements would vary greatly based on the site characteristics (e.g., type and existing condition of the bottom), type of substrate used (e.g., shell, granite, etc.), and requirements to maintain the site. The Panel is of the opinion that this issue is more related to implementation and should be sorted out when the jurisdiction, in coordination with the CBP Partnership, develops implementation and verification procedures for this practice. However, the Panel agreed that requirements related to substrate addition is integral to this practice operating as a BMP and should be determined before allowing application of the reduction effectiveness credit. It is of the Panel's understanding, that some jurisdictions may already have substrate addition-related requirements associated with this practice (e.g., Maryland's oyster aquaculture regulations includes requirements related to substrate). To assist with developing substrate requirements, the following guidance may be of use, in addition to reviewing existing regulations:

- USDA Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) guidance on oyster bed restoration and management (USDA NRCS Factsheet).
- Sea Grant, "Stabilizing Oyster Ground" (http://www.mdsg.umd.edu/topics/oysters/oyster-aquaculture-and-restoration)

The above should not be viewed as a comprehensive list, but as a starting point to assist with developing substrate addition requirements. The Panel also agreed that requirements will likely need to be evaluated on a case-by-case basis because of the factors described above.

9.1 Movement of Oysters

There are also instances where oysters are moved from their initial grow-out location to another location in the Chesapeake Bay or its tributaries by a single oyster aquaculture entity. Reasons for moving the oysters include, but are not limited to, changing the taste by moving oysters to an area with higher salinity (e.g., oysters that are moved from Chesapeake Bay to Chincoteague Bay) or having to move the oysters because of water quality problems in the initial grow-out location (e.g., the initial grow-out location is closed due to bacteria concentrations).

The Panel identified two movement scenarios related to the application of the reduction effectiveness estimates: 1) oysters less than two inches are moved from their initial grow-out location to a final grow-out location where they are harvested and 2) oysters are grown predominantly in the initial grow-out location and are moved to the final grow-out location for a short amount of time (typically less than three months). If aquaculturists use the first strategy, then the Panel recommends that the entire reduction effectiveness credit is applied to the final grow-out location since the initial grow-out location would not qualify to receive any credit because the reduction effectiveness estimates only apply when oysters are greater than 2.0 inches. If the second strategy is used, then the Panel recommends that the entire reduction effectiveness credit is applied to the initial grow-out location because the oysters were predominantly growing and assimilating nutrients from that area. To determine which movement crediting scenario to apply, the Panel suggests measuring the shell height of 50 random oysters and calculating the average before they are placed in the final grow-out location. Both the default and site-specific estimates would be applicable for these movement scenarios. However, for the site-specific estimate, the aquaculture practice must have approved estimates for the location that is receiving the credit. In developing the above recommendations, the Panel's intent was that the aquaculture entity moving the oysters from the initial grow-out location would also be removing the oysters from the final grow-out location for reduction effectiveness credit.

9.2 Reporting

Summarized below are the reporting components for the nitrogen and phosphorus assimilation in oyster tissue reduction effectiveness crediting protocols.

<u>If oysters are grown at one location</u>

- Ploidy: Diploid or triploid oysters
- Type of aquaculture practice: Off-bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture using Hatchery-Produced Oysters, or On-Bottom Private Oyster Aquaculture Using Substrate Addition
- Reporting unit: Bushels, boxes, other container (indicate what type), or individuals
- Packaging type: Variable oyster sizes or uniform oyster sizes
- Central coordinates (latitude and longitude) of location (also referred to as initial grow-out location)
- Month/year removed from final grow-out location

- Number of containers of live oysters or individual oysters from final grow-out location
- Oyster count average for unit verification check (10 representative containers per two time periods from final grow-out location)
- Shell height average(s) for oyster size verification check (50 random oysters from 10 containers per two time periods from final grow-out location)

Additional reporting if oysters are grown at multiple locations

- Central coordinates (latitude and longitude) of the final grow-out location
- Month/year oysters were moved to the final grow-out location
- Average oyster shell height of 50 random oysters before being placed in the final grow-out location (verification check to know whether to apply the credit to the initial or final grow-out location)

The Panel's recommended estimates were developed to be reported annually based on removed live oysters. As a result, any reduction effectiveness credits generated from these practices would only be applicable for the annual timeframe during which the live oysters are harvested. Therefore, reporting jurisdictions will need report the number of oysters harvested or pounds reduced annually. For oyster practices participating as a BMP, the Panel recommends that the reporting jurisdiction incorporates these components in existing monthly reports to track the BMP (e.g., State harvest reports). The Panel reasoned that the reporting jurisdiction could compile the monthly information and provide an annual report of the reduction effectiveness to the CBP. The Panel recommends that the estimates are re-evaluated every 5 years, if new science becomes available, following the established re-evaluation procedures for existing estimates in the CBP Partnership BMP Expert Panel Review Protocol (CBP 2015).

The Panel recommends that the reporting jurisdiction also incorporates procedures in their reporting design to verify that the oysters used for crediting purposes were at initial sizes less than 2.0 inches. For example, relevant to hatchery-produced oysters from off-bottom and on-bottom oyster practices, receipts could be used to demonstrate that larvae or spat were purchased by the practice (these life stages are < 2.0 inches). For wild oysters harvested under the substrate addition category, initial site assessments of current oyster populations during the bottom leasing process could be used to establish if there were oysters greater than two inches present. These oysters could then be estimated and subtracted from the total harvested oyster count of the first BMP reporting year.

9.3 Default Approach to Deal with Missing Ploidy and Verification Measurements

The Panel recommends that if ploidy is missing, then the diploid estimates would be applied. If the average oyster shell heights and average numbers of oysters in containers are not known (i.e., verification check measurements), then a default approach where the minimum legal size of oysters and State documented information specifying the average number of minimum legal sized oysters can be packaged in a specific container could be used. For example, in Maryland, the minimum legal oyster size is 2" (~50 mm) during parts of the year and 3" (~76 mm) during other parts. Maryland defines a bushel for 3-inch oysters as 300 individuals. Therefore, if there are missing measurements and the minimum is 3 inches and the grower is reporting in bushels for diploid oysters, all bushels would be multiplied by 300 and individual oysters would be assigned to the 2.5-3.49 oyster size class range and the corresponding diploid estimates for nitrogen and phosphorus assimilation in oyster tissue would be applied (Table 7i). If the reporting unit is indicated as individuals, then the BMP implementer must provide an oyster count. This approach would only allow the minimum reduction effectiveness to be applied even though the BMP implementer may have grown larger oysters.

The remaining reporting components presented in Section 9.2 would be required in order to calculate and apply the minimum reduction effectiveness. Ultimately, it will be the reporting jurisdiction and the CBP Partnership's decision on whether to allow missing ploidy and verification measurements. However, in the Panel's opinion, the absence of this information will not influence the minimum reduction effectiveness that would be applied.

9.4 Application and Verification Examples

Two examples are given below. One for an on-bottom grower who uses diploid oysters and packages variable sized oysters in bushel baskets and one for an off-bottom grower that uses triploid oysters and packages uniform sized oysters in boxes. These examples are specific to oysters being grown in one location.

9.4.1 On-Bottom Example (Oysters Grown in One Location)

Reported Information

Presented in Table 9a is an example of reported information a grower needs to submit in order to calculate the reduction effectiveness. In practice, there will likely be multiple reports since growers typically harvest and report their harvest monthly. The number of containers with live oysters reported from these monthly reports would be added together to determine the total number to use in the annual reduction effectiveness calculations. The reported verification information (Table 9b) is used to determine the amount of oysters per container and the oyster size class category the oysters belong in, both needed to calculate the reduction effectiveness credit.

Table 9a. Example of reported information for on-bottom private oyster aquaculture when variable sized oysters are packaged together.

On-Bottom Private Oyster Aquaculture-Variable Oyster Sizes per Packaged Container	
Reporting Component	**Information provided by grower**
Ploidy	Diploid
Practice Title	On-Bottom Private Oyster Aquaculture using Hatchery-Produced Oysters
Reporting unit	Bushels
Packaging type	Variable oyster sizes
Central coordinates of initial grow-out location	37° 36.444, -76° 25.411
Central coordinates of final grow-out location	37° 36.444, -76° 25.411
Month/Year removed from final grow-out location*	January-December 2016
Number of containers with live oysters	10,000

*In practice, monthly reports that are sent to the reporting jurisdiction (i.e., State agency) would have to be compiled to determine the total number of containers with live oysters harvested in the year.

Table 9b. Example of reported verification information for on-bottom private oyster aquaculture when variable sized oysters are packaged together.

Oyster Count for Unit Verification Check			
Time Period	**Date Measured**	**Container #**	**Oyster Count**
Time Period 1	**3/21/2016**	1	98
		2	112
		3	120
		4	156
		5	150
		6	149
		7	160
		8	98
		9	101
		10	105
Time Period 2	**9/22/2016**	1	100
		2	110
		3	120
		4	125
		5	180
		6	155
		7	150
		8	150
		9	170
		10	145
Average			**132**
Average Shell Height for Oyster Size Class Verification Check			
Time Period	**Date Measured**	**Container #**	**Average Shell Height (inches)***
Time Period 1	**3/21/2016**	1	3.25
		2	3.5
		3	3.5
		4	4.25
		5	3
		6	3.5
		7	2.5
		8	3.5
		9	3
		10	3.5
Time Period 2	**9/22/2016**	1	3
		2	3.5
		3	3.25
		4	3.5
		5	3
		6	3.5
		7	2.5
		8	3.5
		9	3.5
		10	3.75
Average (n = 100 oysters, 50 oysters per time period)			**3.33**

*Example shows the average of five random oysters per container. In practice, growers should report the measurements for all oysters.

Calculations

Number of individual oysters = 10,000 bushels multiplied by 132 oysters per bushel from unit verification check = 1.32 million oysters

Diploid estimates of 0.09 g N content and 0.01 g P content would be applied because the average from the shell height verification check was 3.3 inches falling into the 2.5-3.49 oyster size class. The total nitrogen and phosphorus removal would be calculated as follows using estimates from Table 7i:

Nitrogen (N)		g N Removed	
1,320,000 x 0.09 g N $oyster^{-1}$		118,800	
	Total	118,800	= 118.8 kg N removed

Phosphorus (P)		g P Removed	
1,320,000 x 0.01 g P $oyster^{-1}$		13,200	
	Total	13,200	= 13.2 kg P removed

9.4.2 Off-Bottom Example (Oysters Grown in One Location)

Reported Information:

Presented in Table 9c is an example of reported information a grower needs to submit in order to calculate the reduction effectiveness for an off-bottom private oyster aquaculture practice that packages uniform sized oysters per container. In practice, there will likely be multiple reports since growers typically harvest and report their harvest monthly. The number of containers with live oysters for each oyster size class reported from these monthly reports would be added together to determine the total number for each oyster size class to use in the annual reduction effectiveness calculations. The reported verification information (Table 9d) is used to determine the amount of oysters per container and the oyster size class categories the oysters belong in, both needed to calculate the reduction effectiveness credit.

Table 9c. Example of reported information for off-bottom private oyster aquaculture when uniform sized oysters are packaged together per container.

Off-Bottom Private Oyster Aquaculture-Uniform Oyster Sizes per Packaged Container	
Reporting Component	**Information provided by grower**
Ploidy	Triploid
Practice Title	Off-bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters
Reporting unit	Boxes
Packaging type	Uniform oyster sizes
Central coordinates of initial grow-out location	37° 36.444, -76° 25.411
Central coordinates of final grow-out location	37° 36.444, -76° 25.411
Month/Year removed from final grow-out location	January-December 2016
Containers with live oysters*	
Oyster Size Class (inches)	**Container Count**
2.0 - 2.49	0
2.5 - 3.49	5,000
3.5 - 4.49	5,000
4.5 - 5.49	0
≥ 5.5	0
Total	**10,000**

*In practice, monthly reports that are sent to the reporting jurisdiction (i.e., State agency) would have to be compiled to determine the total number of containers with live oysters harvested in the year.

Table 9d. Example of reported verification information for off-bottom private oyster aquaculture when uniform sized oysters are packaged together per container.

Oyster Count for Unit Verification Check				
Oyster Size Class (inches)			**2.5-3.49**	**3.5-4.49**
Time Period	**Date Measured**	**Container #**	**Oyster Count**	**Oyster Count**
Time Period 1	**3/21/2016**	1	99	95
		2	100	101
		3	101	100
		4	100	100
		5	105	105
		6	102	98
		7	100	99
		8	100	100
		9	100	100
		10	99	100
Time Period 2	**9/22/2016**	1	100	100
		2	98	100
		3	101	103
		4	100	101
		5	100	102
		6	98	98
		7	100	99
		8	102	95
		9	100	101
		10	103	105
Average			**100**	**100**
Average Shell Height for Oyster Size Class Verification Check				
Oyster Size Class (inches)			**2.5-3.49**	**3.5-4.49**
Time Period	**Date Measured**	**Container #**	***Average Shell Height (inches)**	***Average Shell Height (inches)**
Time Period 1	**3/21/2016**	1	3.25	4.25
		2	3.5	4.5
		3	3.5	4.5
		4	4.25	3.25
		5	3	4
		6	3.5	4.5
		7	2.5	3.5
		8	3.5	4.5
		9	3	4
		10	3.5	4.5

Time Period 2	**9/22/2016**	1	3	4
		2	3.5	4.5
		3	3.25	4.25
		4	3.5	4.5
		5	3	4
		6	3.5	4.5
		7	2.5	4.25
		8	3.5	4.25
		9	3.5	4.5
		10	3.75	4.75
Average (n = 100 oysters, 50 oysters per time period)			**3.33**	**4.25**

*Example shows the average of five random oysters per container. In practice, growers should report the measurements for all oysters for each size class they are seeking credit for.

Calculations

Number of individual oysters in the 2.5-3.49 size class = 5,000 boxes multiplied by 100 oysters per box from verification check = 500,000 oysters

Number of individual oysters in the 3.5-4.49 size class = 5,000 boxes multiplied by 100 oysters per box from verification check = 500,000 oysters

Triploid estimates of 0.13 N and 0.01 P tissue content would be applied for the 2.5-3.49 oyster size class and 0.26 N and 0.03 P tissue content for the 3.5-4.49 oyster size class. The total nitrogen and phosphorus removal would be calculated as follows:

Nitrogen (N)		g N Removed	
500,000 x 0.13 g N $oyster^{-1}$		65,000	
500,000 x 0.26 g N $oyster^{-1}$		130,000	
	Total	195,000	= 195 kg N removed

Phosphorus (P)		g P Removed	
500,000 x 0.01 g P $oyster^{-1}$		5,000	
500,000 x 0.03 g P $oyster^{-1}$		15,000	
	Total	20,000	= 20 kg P removed

10.0 Unintended Negative Consequences

The BMP Expert Panel Review Protocol (CBP Protocol) asks for the Panel to identify any negative unintended consequences that are found during the literature review. The Panel also built into their Decision Framework an additional step to identify options that they are aware of that could be used to prevent the occurrence or reduce effects from potential negative unintended consequences for the CBP Partnership to consider as they develop implementation and verification procedures. The Panel notes that these options are not a comprehensive list, but instead, should be viewed as a starting point for discussion.

There are consequences for each and every action made within the Chesapeake Bay watershed and aquatic ecosystem, including effects on economic activity, competition for utilization of estuarine resources, and water quality. The removal of nitrogen and phosphorus in oyster tissue from harvest by off-bottom and on-bottom private oyster aquaculture is the primary focus of this discussion. Any unintended consequences associated with reduction effectiveness protocols other than nitrogen and phosphorus assimilation in oyster tissue for private oyster aquaculture practices are not discussed here and will be evaluated in a future incremental report when those estimates are developed. This includes concerns that have been raised about permanent removal of oyster shell, a precious resource for oyster aquaculture and restoration practices. Moreover, any concerns about disease, aesthetic changes in waterfront views, competition with wild harvest, etc. are part of the broader issues with private oyster aquaculture, and this BMP would not change these concerns in any way.

The Panel identified two potential unintended negative consequences of bivalve aquaculture regarding Chesapeake Bay water and sediment quality. These are outlined in the Table 10a and discussed afterward.

Table 10a. Identified negative unintended consequences concerning nitrogen and phosphorus assimilation for aquaculture practices.

Issue	Select Relevant Studies
Biodeposition by bivalves leads to increased nutrient releases from sediment	Choptank River: (Testa et al. 2015) St. Jerome Cr., Spencer's Cr., Chesapeake Bay: (Higgins et al. 2013)
Loss or change of benthic biota through excessive organic matter loading	Puget Sound fish farm: (Weston 1990) New Zealand mussel farm: (Christensen et al. 2003)

The excessive loading of organic matter to sediments can have negative consequences to water quality, including the highly efficient return of nitrogen (mainly ammonium) and phosphorus (soluble reactive phosphorus) to the water column, rather than sequestration of phosphorus in solid phase deposits (Hartzell et al. 2010, Li et al. 2015) or removal of nitrogen through microbial denitrification (Jenkins and Kemp 1984, Cornwell et al. 1999). In the case of soluble reactive phosphorus, the loss of phosphorus-binding iron oxide minerals via conversion to iron sulfide minerals (O'Keefe 2007, Jordan et al. 2008) is enhanced by high rates of sediment metabolism and the consequent anaerobic conditions close to the sediment-water interface. For nitrogen, increased rates of sediment metabolism result in lower oxygen penetration depths in sediments, decreasing rates of nitrification – which needs oxygen, and minimizing denitrification because that process requires nitrate (Cornwell et al. 1999, Testa et al. 2013).

Biogeochemical unintended consequences generally arise because of the deposition of biodeposits to the sediment surface. The positive benefits of increased denitrification that are observed with oysters grown on the bottom (Kellogg et al. 2013) may result from the complex physical and biological structure within a reef, whereas the lower benthic complexity associated with off bottom aquaculture may result in biodeposits being overloaded onto sediments and a deleterious effect on beneficial sediment processes such as phosphorus burial and denitrification. Location may be a prime determinant in the fate of nutrients, with observations in the Choptank River that show physical redistribution of biodeposits leads to relatively good sediment quality (Testa et al. 2015). In contrast, the location of floating oyster farms in locations in the mesohaline Chesapeake Bay with lower physical forcing and initial poor sediment quality resulted in negative effects of aquaculture on sediment nutrient balances (Higgins et al. 2013). Holyoke observed modest changes in sediment nutrient fluxes in La Trappe Creek, but an increase in iron sulfide mineral formation (Holyoke 2008). For oysters planted on the bottom, enhanced denitrification is commonly observed and negative consequences appear minimal (Piehler and Smyth 2011, Kellogg et al. 2013, Smyth et al. 2013, Kellogg et al. 2014). The return of aquaculture nitrogen and phosphorus in forms that can grow algae is partially mitigated by the nature of oyster filtration, in which water column particulates, both algae and detritus, are brought to the bottom of the estuary. During such removal, the part of the decomposition and nutrient release that would have occurred in the water column in now transferred to the sediment; water column nutrient remineralization is completely efficient at growing algae.

Less is known about changes in the biomass and structure of benthic communities located underneath water column culture. There has been concern for such changes under finfish pens (Weston 1990) and some observation under mussel farms suggest community changes (Christensen et al. 2003). On bottom oyster communities tend to be diverse and abundant (Kellogg et al. 2013).

In conclusion, on-bottom culture appears to have few unintended negative consequences, with a general enhancement of nutrient removal likely. Off-bottom oyster culture in the water column may result in over-enrichment of sediments and elevated fluxes of fixed nitrogen and phosphorus relative to control sites. However, there is still a benefit to removing nitrogen and phosphorus from the water column where remineralization is more efficient in sustaining elevated algal biomass.

Overall, the Panel felt that these unintended consequences could be controlled. An example of an option that could assist jurisdictions, in coordination with the Chesapeake Bay Partnership, in developing procedures to control these potential negative consequences is to evaluate existing oyster aquaculture regulations and include metrics to detect the occurrence of these negative consequences (e.g., relevant sediment and water quality monitoring), if not present already.

During the 30-day comment period on the draft report, it was brought to the Panel's attention that oyster aquaculture may negatively affect hydrodynamics related to sediment accretion and reduced tidal flushing; however the commenter did not provide studies for the Panel to evaluate. The Panel discussed this potential effect and felt that this would likely be more of an issue with practices that use gear and within locations where tidal exchange is low (e.g., small creeks). Overall, the Panel felt that unintended consequences associated with hydrodynamics could also be controlled. Similar to the identified option for the biogeochemical-related consequences, metrics on flow could be built into oyster aquaculture implementation procedures.

The Panel also knew of instances where there were positive impacts associated with hydrodynamics related to shoreline protection due to created oyster reefs (Piazza et al. 2005, Scyphers et al. 2011). Piazza et al. (2005) found that in low wave energy areas, retreat of fringing marshes in Louisiana was reduced on shorelines treated with three-dimensional *Crassostrea virginica* reefs. Another study from Alabama found higher abundances of fishes around reefs created as shoreline buffers than compared to control areas (Scyphers et al. 2011).

11.0 Ancillary Benefits

Oysters provide valuable ecosystem services to the coastal water bodies where they reside. In addition to the nutrient reduction benefits detailed in this report, oyster reefs provide habitat for an abundance of marine species, and enhance water quality through filtration. The presence of oysters and shellfish may provide more light availability to seagrasses directly by filtering water, and indirectly by providing refuge for grazing animals which eat algae from seagrass leaves (Newell and Koch 2004, Orth and van Montfrans 1984). A Chesapeake Bay modeling study shows that when oysters filter seston out of the water column, light penetration in the bay has the potential to increase, which could contribute to increased seagrass growth and depth limit (Newell and Koch 2004). An additional study that assessed the influence of a 10% increase of oyster populations in the Chesapeake Bay determined that the greatest potential benefit would be an increase in SAV through water clarity (Cerco and Noel 2007). Because seagrasses are a refuge for marine animals and enhance water clarity (Orth et al. 2006 and sources therein), the relationship between oyster presence and seagrass establishment could be synergistic.

There is also a demonstrated connection between oyster reef presence and more abundant and rich marine life when compared to areas with no reef structure (Coen et al. 1999, Tolley and Volety 2005). Through ongoing research, details are emerging that suggest restored oyster reefs and oyster aquaculture systems may provide similar or a portion of the marine organismal habitat that natural oyster reefs provide. Dealteris et al. 2004 and O'Beirn et al. 2004 highlighted the diverse and abundant marine species associated with rack-and-bag and floating gear used for Eastern oyster aquaculture in a Rhode Island estuary and a coastal bay of Virginia, respectively. Tallman and Forrester (2007) showed that in Narragansett Bay, Rhode Island, near bottom Eastern oyster aquaculture cages provided valuable habitat for finfishes. Peer-reviewed literature on aquaculture and seagrass presence is still emerging; several North American studies highlight concerns about direct competition for space between oyster aquaculture gear and seagrass, or disturbances associated with harvest in the aquaculture areas (Dumbauld et al. 2009, Tallis et al. 2009).

12.0 Conclusions and Future Research

Using the decision framework described in Section 4.0 the Panel made the following conclusions:

- Nitrogen and phosphorus assimilation in oyster tissue protocols are suitable for consideration and sufficient science exists to provide reduction effectiveness estimates for private oyster aquaculture practices in Off-bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture using Hatchery-Produced Oysters, and On-Bottom Private Oyster Aquaculture Using Substrate Addition categories.

- The Panel agreed that the estimates are verifiable by conducting oyster shell height and oyster count verification checks using the guidelines described in Section 9.0.

- Potential unintended negative consequences were identified for Off-bottom Private Oyster Aquaculture Using Hatchery-Produced Oyster, but the Panel felt these are manageable by monitoring the condition of the sediment.

Future research suggestions to refine the estimates presented in this report are listed below:

- **Studies that work directly with aquaculturists to understand how aquaculture techniques influence oyster growth.**

  The default shell height to tissue dry weight regression equations were strongly influenced by data from oysters grown by researchers or as part of oyster reef restoration efforts. Since aquaculturists use techniques to enhance oyster growth, the default regression equations likely underestimate the reduction effectiveness.

- **Studies that evaluate seasonal differences for off-bottom aquaculture.**

  The regression equation for the diploid default estimates only included spring data for off-bottom aquaculture. While the Panel is not concerned about this for the application of the recommended reduction effectiveness estimates because oysters are usually at their smallest biomass at that time (i.e., using only spring data supports a conservative estimate), it would be beneficial to have a better understanding of any potential differences, if present, to refine the estimates to be more representative of all seasons.

- **Studies that evaluate potential differences in the percent nitrogen and phosphorus content between different oyster size classes.**

  The Panel found in Grizzle et al. 2016 results that suggest that the percent nitrogen content in tissue may decrease as the oyster ages. While this study was conducted in Great Bay, NH where environmental conditions may affect oyster growth differently than in Chesapeake Bay, the Panel felt it would be beneficial to examine potential differences in the percent nitrogen and phosphorus contents among different oyster size classes to better understand any variability that may exist.

- **Studies that evaluate the percent nitrogen and phosphorus contents in tissue for triploid oysters.**

  There was only one study found that measured the percent nitrogen in tissue for triploid oysters (Reitsma et al. 2014) and no studies for the percent phosphorus content. Such studies could help refine the estimates and provide confirmation that the average percent nitrogen and phosphorus contents in tissue are similar between diploid and triploid oysters. Depending on available funding, the Panel recommends the following priority setting in evaluating the different factors that may influence the percent nitrogen and phosphorus contents: ploidy, oyster age/sizes, locations with different environmental conditions (e.g., salinity, nutrient loading), season, and culture method. At a minimum, the study should examine the percent nitrogen and phosphorus contents of same age/sized triploid oysters using the same culture method at one location. This data could then be compared to existing diploid data. It would be beneficial to also examine diploid oysters during the same study for direct comparison. The study could also incorporate different oysters size classes, locations, and seasons to examine potential age, location, and seasonal effects. However, based on the literature review, the Panel anticipates that the seasonal impact is low for diploid oysters given the well constrained values from studies that analyzed oysters from the spring, summer, and fall. Also it is not expected that the percent nitrogen and phosphorus contents of triploid oysters will be affected since they do not undergo the same physiological changes as diploid oysters due to lacking reproduction capabilities. Different culture methods could also be evaluated, but since triploid oysters are typically grown off-bottom in gear, the Panel assigned this as the lowest priority to incorporate into the study.

Overall, the Panel is not concerned with applying the average percent nitrogen and phosphorus contents in tissue from diploid oysters for the default triploid oyster reduction effectiveness estimates because of evidence that triploid oysters likely have similar percent contents in tissue as diploids (i.e., percent nitrogen value reported by Reitsma et al. 2014 of 8.5% is comparable to the recommendation of 8.2%) and the fact that biomass appears to have a bigger role in influencing the total nitrogen and phosphorus assimilated in the tissue.

- **Studies that evaluate the amount of nitrogen and phosphorus removal resulting from removal of bio-fouling materials from aquaculture cages.**

The Panel found that the extent of the scale and management of bio-fouling in aquaculture operations has been reported in numerous publications (reviewed by Fitridge et al. 2012). Specific best management practices for shellfish aquaculture operations addressing bio-fouling are addressed in a State of Maryland publication, Maryland Aquaculture Coordinating Council (2007). Given that bio-fouling already has a need to be managed because of the negative impact it has on growing the oysters, the Panel discussed the potential of an added nitrogen and phosphorus removal benefit if the bio-fouling is managed in such a way where it is not being washed back into the water. The amount of nitrogen and phosphorus removal associated with bio- fouling control operations would be expectedly straightforward to determine by weighing and analyzing the nitrogen and phosphorus content in the organic matter.

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Appendix A: Summary of Oyster BMP Expert Panel Activities

Updates to the Water Quality Goal Implementation Team (WQGIT)

April 13, 2015—The Oyster Recovery Partnership (ORP) presented rationale for convening an Oyster BMP Expert Panel during the Chesapeake Bay Program (CBP) Partnership's Water Quality Goal Implementation Team (WQGIT) meeting. The WQGIT approved ORP to convene and coordinate the Oyster BMP Expert Panel. Meeting materials and minutes are located here.

August 5, 2015—Panel coordinators submitted a draft of the Panel's charge and membership recommendations to the CBP Partnership for review and comment.

September 14, 2015—Panel coordinators presented response to comments on the Panel's membership and charge that was sent for CBP Partnership review on August 5, 2015. The WQGIT approved the revised Panel's membership and charge. Meeting materials and minutes are located here.

February 8, 2016—The Panel chair and coordinators updated the CBP Partnership on the draft Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Decision Framework during their WQGIT meeting. The briefing paper and presentation can be found here. The CBP Partnership review and comment period on the framework paper was from February 1 to 15, 2016.

April 25, 2016—The Panel coordinator updated the CBP Partnership on their responses to CBP Partnership and stakeholder review comments concerning the draft Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Decision Framework and status of the Panel's data review. The responses to comments and presentation can be found here. The Panel also offered another 2 week review and comment period from April 25 to May 13, 2016 on the modified Decision Framework and the Panel's preliminary decisions from the data review.

August 22, 2016—The Panel coordinator and Chair updated the CBP Partnership on their first set of recommendations concerning nitrogen assimilation in oyster tissue for water column and designated bottom oyster planting aquaculture practices. Meeting materials and minutes are located here.

November 28, 2016—Panel update to the WQGIT to present their responses to comments from the CBP Partnership and interested parties on the draft first incremental report. Meeting materials, including the Panel's responses to comments supplemental document, are posted here.

Updates to the Watershed Technical Workgroup

September 1, 2016—The Panel presented their draft technical appendix on the technical requirements for reporting and simulating oyster aquaculture BMPs in the Phase 6 Watershed Model for initial input. Materials are posted here.

December 1, 2016—The Panel presented the revised technical appendix on model application of the Panel's recommendations found in the first incremental report for approval. Materials are posted here.

Panel Meetings

Panel meetings were 2 hours long unless indicated otherwise. Both in person and remote attendance options were made available to the panelists.

September 30, 2015—The Panel convened its first meeting. The agenda included panelist introductions and an overview of the CBP's Partnership BMP Expert Panel Review Protocol, panel charge, and panel member roles and expectations.

October 26, 2015—Agenda included a presentation on the STAC Review findings from their report, "Evaluation of the Use of Shellfish as a Method of Nutrient Reduction in the Chesapeake Bay" and discussions on oyster practice definitions and considerations for a decision framework for determining the nutrient (nitrogen and phosphorus) and suspended sediment reduction effectiveness of oyster practices.

November 2, 2015—Agenda included a presentation by Tom Schueler from the Chesapeake Stormwater Network on their stream restoration crediting decision framework and discussion on the oyster practice category descriptions and what steps should be included in the oyster BMP nutrient and suspended sediment reduction effectiveness decision framework.

November 19, 2015—Agenda included finalizing the oyster practice category descriptions.

December 14, 2015—Agenda included a more in depth discussion on the steps for the oyster BMP nutrient and suspended sediment reduction effectiveness decision framework.

January 7, 2016—Agenda included finalizing the decision points for the oyster BMP nutrient and suspended sediment reduction effectiveness decision framework.

February 24, 2016 (5-hour meeting)—The Panel's data review workshop. This workshop included data review sessions led by panelists on nitrogen and phosphorus assimilation in oyster tissue and shell, enhanced denitrification associated with oysters, enhanced nitrogen and phosphorus burial associated with oysters, and suspended sediment reduction associated with oysters. The Panel also reviewed the CBP Partnership and stakeholder comments on the draft oyster BMP nutrient and suspended sediment reduction effectiveness decision framework.

March 16, 2016 (3-hour meeting)—Agenda included presentation by Carl Cerco on the Oyster Sub-Model and the Panel discussed definitions to clarify terms used in the oyster BMP nutrient and suspended sediment reduction effectiveness decision framework.

April 14, 2016—Agenda included discussing which methods/papers should be considered in developing the reduction effectiveness estimates for the nitrogen assimilation-related protocols for water column and bottom oyster planting aquaculture practices.

May 19, 2016—Agenda included discussing the empirical approach (converting shell height to dry weight and applying a known percent nitrogen content) to determine the nitrogen assimilation in oysters.

June 16, 2016—Agenda included reviewing data analysis results for the oyster shell height to tissue dry weight quantile regression, deciding on a percent nitrogen content in oyster tissue from available studies, and discussing outstanding report items concerning qualifying conditions and timeline for re-evaluation of the Panel's recommended estimates.

July 14, 2016—Agenda included discussing acquired triploid oyster data and determining the oyster size classes that would be used when applying the shell height to tissue dry weight quantile regression.

July 25, 2016 (1.5 hour meeting)—Agenda included finalizing outstanding items for the first report.

August 18, 2016—Agenda included reviewing draft of the first report.

September 15, 2016—Agenda included reviewing Panel comments on the first recommendation report and reaching consensus.

October 27, 2016—Agenda included review and discussion of CBP Partnership and stakeholder comments on the first recommendation report and incorporating any necessary revisions.

November 17, 2016—Agenda included reviewing the responses to comments document and finalizing revision decisions for the first report.

Presentations/Webinars

November 2, 2015—The Panel hosted a public stakeholder meeting and webinar. Around 60 people participated, including 5 stakeholder groups who presented information related to how oyster practices could be implemented as BMPs to reduce nutrient pollution. More information on the public stakeholder meeting can be found on the CBP calendar webpage.

November 16, 2015—Panel coordinators briefed the Fisheries Goal Implementation Team on the Panel's objectives and status. The briefing presentation can be found here.

November 19, 2015—Panel coordinators briefed the Citizen Advisory Committee on the Panel's objectives and status.

January 16, 2016—Panel coordinators presented information about the Panel during the Maryland Watermen Association Trade Show in Ocean City, MD.

March 18, 2016—Panel coordinators presented information about the Panel during the "Conference on New Ideas to Accelerate Chesapeake Bay Restoration" hosted by the University of Maryland Center for Environmental Science. The presentation can be found here.

September 22, 2016—Webinar debuting the Panel's first incremental recommendation draft report followed by a 30-day review and comment period for the CBP Partnership and public. The webinar and report can be found here.

Other

June 15, 2016—Special CBP Partnership Management Board meeting to provide policy recommendations on issues raised by the Oyster BMP Expert Panel and stakeholders. Meeting materials and decisions can be found here.

Appendix B: Conformity with the CBP Partnership BMP Review Protocol

The CBP Partnership Expert Panel BMP review protocol established by the Water Quality Goal Implementation Team outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where the panel addressed the requested protocol criteria. These items are specific to nitrogen and phosphorus assimilation in oyster tissue of removed oysters for Off-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, and On-bottom Private Oyster Aquaculture Using Substrate Addition.

1. **Identity and expertise of panel members:** See Section 3.0.

2. **Practice name or title:** Off-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, and On-bottom Private Oyster Aquaculture Using Substrate Addition

3. **Detailed definition of the practice:** See Section 5.0. The recommendations apply to all practices in the Off-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, On-Bottom Private Oyster Aquaculture Using Hatchery-Produced Oysters, and On-bottom Private Oyster Aquaculture Using Substrate Addition categories.

4. **Recommended nitrogen reduction effectiveness estimate pertaining to nitrogen and phosphorus assimilation in oyster tissue of removed oysters:** See Section 7.0.

5. **Justification of selected effectiveness estimates:** See Section 7.0 and Appendix D.

6. **List of references used:** See Section 7.0.

7. **Detailed discussion on how each reference was considered:** See Section 7.0 and Appendix D.

8. **Land uses to which BMP is applied**: Not applicable. This is a tidal in-water BMP. The Phase 6 Model will have an estimated nutrient load in shoreline segments that can be reduced by shoreline and tidal water practices. The pounds of nutrients reduced by this practice will be credited as a reduction to the nutrient loads in the nearest shoreline segments to the practice location. If latitude and longitude are not submitted, then the practice benefits will be distributed amongst all shoreline segments in the geography submitted (Appendix F).

9. **Load sources that the BMP will address and potential interactions with other practices**: The CBP Partnership Management Board decided during the Oyster BMP policy issues special session on June 15, 2016 that oyster BMPs will not be credited to a specific source sector. Instead reduction credit will go toward total nonpoint source load allocation.

10. **Description of pre-BMP and post-BMP circumstances and individual practice baseline:** The CBP Partnership Management Board decided during the Oyster BMP policy issues special session on June 15, 2016 that when crediting the TMDL based on removal of oysters (aquaculture), only include oysters that are removed moving forward from the time the BMP is approved/implemented.

11. **Conditions under which the BMP works/not works:** See Section 8.0.

12. **Temporal performance of BMP including lag times between establishment and full functioning:** Removed (harvested) oysters that are equal to or greater than 2 inches can receive reduction effectiveness credit for the nitrogen and phosphorus assimilation in oyster tissue protocols.

13. **Unit of measure:** Grams of nitrogen and phosphorus in oyster tissue per oyster. Current harvest reporting allows growers to report in bushels, boxes, or individuals. See Section 9.0 for application and verification guidelines to determine how many individual oysters are in the reported unit. See Appendix F for appropriate reporting units to the Chesapeake Bay Program.

14. **Locations in Chesapeake Bay watershed where the practice applies:** Tidal segments in the Chesapeake Bay watershed where the qualifying conditions are met.

15. **Useful life of the BMP:** Remains useful until oysters die. As long as oysters are alive they are assimilating N and P in their tissue.

16. **Cumulative or annual practice:** Annual based on removed live oysters.

17. **Description of how BMP will be tracked and reported:** See Section 9.0 and Appendix F.

18. **Ancillary benefits, unintended consequences, double counting:** Potential unintended consequences are outlined in Section 10.0 and ancillary benefits in Section 11.0.

19. **Timeline for a re-evaluation of the panel recommendations.** 5 years, if new science becomes available, follow the established re-evaluation procedures for existing estimates in the CBP Partnership Expert Panel BMP Review Protocol.

20. **Outstanding issues:** None.

Appendix C: Review of Approaches to Determine the Reduction Effectiveness Estimate for Nitrogen and Phosphorus Assimilation in Oyster Tissue

The Panel reviewed two approaches in the scientific literature that could be used to determine the reduction effectiveness estimate for nitrogen (N) and phosphorus (P) assimilated in oyster tissue:

1. Empirical Approach (STAC 2013, Higgins et al. 2011)—This approach uses an established shell height (also referred to as shell length in some studies) to tissue dry weight regression equation and analyzed percent nitrogen and phosphorus content to calculate the total nitrogen and phosphorus assimilated in the oyster tissue.
    a. Converts shell height in millimeters to tissue dry weight in grams.
    b. Similar approach as recommendations presented by STAC during July 9 and August 7, 2014 Watershed Technical Workgroup meetings.

2. FARM Model Approach (Ferreira et al. 2007 and 2009, Bricker et al. 2014 and 2015, Rose et al. 2015)—Crediting N removal based on model estimates of potential farm-level oyster production via filtration/mass balance.
    a. The FARM Model framework combines physical and biogeochemical models, shellfish growth models, and screening models at the farm scale to determine shellfish production and assess water quality changes on account of shellfish cultivation.
    b. Applicable to suspended culture from rafts or longlines and bottom culture.

STAC Review Summary

The Chesapeake Bay Program's Management Board requested the Scientific and Technical Advisory Committee (STAC) to review the paper, "Shellfish Aquaculture: Ecosystem Effects, Benthic-Pelagic Coupling and Potential for Nutrient Trading" by Newell and Mann (2012) and other relevant studies related to the use of shellfish as a method of nutrient reduction and advise how it could be applied in the Chesapeake Bay TMDL watershed model. STAC leveraged the review conducted by the 2013 workshop, "Quantifying Nitrogen Removal by Oysters" and made the following conclusions:

- Nitrogen content of oyster soft tissue and shell can reasonably be estimated as 8.2% and 0.2% of dry weight, respectively.
- Phosphorus content of oyster soft tissue and shell can reasonably be estimated as 1.07% and 0.06% of dry weight, respectively.
- Due to variability in predicting oyster growth and survival, nutrient removal BMP efficiencies should be based on actual harvest data (oyster dry weight) multiplied by the nutrient percentages above.
- Nutrient removal rates for shell only apply to shell which is not returned to the Chesapeake Bay watershed.
- Burial rates for nutrients associated with biodeposits are not currently known.

- Measured denitrification rates associated with oyster aquaculture have not revealed any enhancement above background levels.
- Denitrification rates associated with oyster reefs typically exceed background levels, but are highly variable among locations and seasons.
- Lack of data on other grow-out methods (e.g., oyster grown in cages near the bottom and cage-less, spat-on-shell grown on the bottom) on denitrification rates.
- Oyster aquaculture has the potential to reduce nitrification (and hence coupled nitrification-denitrification) if rates of biodeposition by the oysters coupled with low flushing rates cause oxygen depletion. Modeling tools that provide site-specific guidance on oyster stocking densities should be developed to avoid this negative effect.

FARM Model Review Summary

The Panel reviewed the FARM model (Ferreira et al. 2007 and 2009, Bricker et al. 2014 and 2015, Rose et al. 2015), but agreed that there were existing limitations that wouldn't allow its use in determining the nitrogen reduction effectiveness at this time. The Panel planned to run a mock experiment to compare the nitrogen reduction in oyster tissue of harvested oysters determined by the FARM model versus the empirical approach recommended by STAC (2013 and 2014) but found that the present configuration of the model has limitations preventing such a comparison, including that it does not separate out the nitrogen assimilated in oyster tissue and shell or include oyster sizes related to the modeled biomass.

During their review of the model, the Panel also found that site-specific model calibration and nitrogen removal validation would be needed given that the FARM model was developed primarily as a tool to estimate harvestable biomass in certain areas outside of Chesapeake Bay and only provides an estimate of nitrogen removal that has not yet been validated with actual measurements.

Panel's Overall Conclusions

Empirical Approach:

1. Straightforward for tissue if harvest is reported (well established methods exist).
2. Sufficient shell height and tissue dry weight data exists to determine conservative nitrogen and phosphorus reduction effectiveness estimates related to oyster tissue.
3. The Panel is in the process of evaluating available empirical data to determine whether estimates can be determined for N and P assimilated in oyster shell (results will be presented in a different report).
4. If sufficient data exists, N and P reduction effectiveness in shell could be determined using this approach, but verification would be difficult due to not knowing where the shell ends up and what the degradation rate would be (i.e., release of N and P back in the water).

FARM Model Approach:

1. Not knowing the # of oysters per size class associated with the biomass and N removal numbers from the FARM model made it not possible to directly compare the amount of N assimilated between the STAC empirical (0.177 as the estimate of N content per market size, 76 mm, oyster) and FARM model approaches.
2. N content of particulate matter is considered as Redfield ratio with FARM model calculations done via carbon and then converted to nitrogen. The Panel is unsure if this would be representative of the location that is being simulated. The Panel felt N validation is needed.
3. Site-specific model calibration would be needed.
4. The Panel views this as a potential management tool; however, in the context of a method for BMP reduction effectiveness crediting, verification would likely be challenging; model limitations would need to be addressed and refined model re-evaluated by an expert panel.

Overall, panelists agreed that the empirical approach could be applied now for nitrogen and phosphorus assimilated in oyster tissue of removed (harvested) oysters. Due to current limitations of the FARM model, the Panel did not feel this method could be implemented for BMP reduction effectiveness determination at this time. In summary, the Panel concluded that the FARM model could be used as a management tool if calibrated to the location's growing conditions to assist with planning by allowing for a better understanding of the potential harvestable biomass, but for use in determining the reduction effectiveness for BMP application, the model's limitation concerning nitrogen validation would have to be addressed and the updated model re-evaluated by an expert panel. Panelists also expressed that the modeling approach, at best, would only estimate oyster growth, nitrogen and phosphorus assimilation, and harvestable biomass from an aquaculture practice and not actual removal; therefore, the number of oysters harvested would still have to be quantified to account for the actual biomass removed from the water. Given that growers already have to monitor oyster sizes and report numbers of oysters harvested, the empirical approach is a straight-forward method to calculate the amount of nitrogen and phosphorus in the tissue of removed oysters.

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Appendix D: Literature Review and Supplemental Analyses

Shell Height to Tissue Dry Weight Regression Analysis

This section provide additional details on the recommended 50th quantile regression equations to convert shell height to tissue dry weight, including literature/data reviewed, description of data removed from the analysis, the Panel's considerations concerning various oyster growth influencing factors, data limitations, and potential other sources that may have additional data that could be used to supplement the regression.

Literature/Data Review

The Panel considered the studies/data summarized below for the shell height to tissue dry weight regression analysis.

Ploidy	Data Source	Study/Data Purpose	Growing Conditions	How were measurements obtained?	Study Conclusions
Diploid	Higgins unpubl. data	Measurements included shell height and tissue dry weight of wild oysters.	Choptank River, MD and Lynnhaven River, VA - Reef	Similar to Higgins et al. 2011	None- unpublished
	Higgins et al. 2011	To evaluate the effectiveness of removal of excess nutrients from the Chesapeake Bay via bioassimilation of nutrients in hatchery-produced oyster tissue and shell using oyster aquaculture.	Spencer's Creek, VA and St. Jerome Creek, MD - Floating aquaculture cages Oysters per cage = 200 Cage area = 0.5 m^{-2} Mean SH = 44 – 118 mm	Oysters were opened, tissue and shell were separated and dried at 60°C for a period of time needed to dehydrate completely (greater than or equal to 7 days)	Model simulations showed greater nutrient reductions on basin rather than the bay-wide scale.
	Kellogg unpubl. data	Measurements included shell height and tissue dry weight of hatchery-produced oysters.	Harris Creek - Subtidal/restored reef Onancock Creek, VA – Subtidal/restored reef (cages first and then transferred to bottom with no gear)	Similar to Kellogg et al. 2013	None- unpublished
	Kellogg et al. 2013	To evaluate water column removal of nutrients via assimilation by hatchery-produced oysters in a restored oyster reef compared to an unrestored	Choptank River, MD - Restored reef	All organisms in the study were dried to a constant weight at 60°C and weighed to the nearest 0.1 mg.	The standing stock of nutrients was greater on the restored reef than the unrestored reef.

Diploid		reef, as well as to measure oxygen and nitrogen fluxes on both types of reefs.			
	Luckenbach and Ross 2009 (Part 1 of Report)	To monitor larval settlement on clean substrate placed in four tributaries, and to evaluate substrate quality on restoration reefs. Dry tissue weight of hatchery-produced oysters collected from the sites were also evaluated.	Great Wicomico, Lynnhaven, Piankatank, and Rappahannock Rivers, VA - Subtidal patch reefs	Oysters were frozen, removed from the freezer, shell height measured to the nearest 0.1 mm, thawed, shucked, placed into aluminum pans and placed in a 90°C drying oven for a 48 hour minimum or until a constant weight was achieved.	Settlement onset and rate varied between tributaries and years measured.
	Luckenbach and Ross 2009 (Part 3 of Report)	To assess the stock of both restored and natural populations of wild oysters in the Lynnhaven River prior to an Army Corps of Engineers oyster restoration project.	Lynnhaven River, VA - Restored and existing oyster reefs on bulkheads, in intertidal patch reefs, marsh, riprap, subtidal bottom (not discrete patches)	Oysters were frozen, removed from the freezer, shell height measured to the nearest 0.1 mm, thawed, shucked, placed into aluminum pans and placed in a 90°C drying oven for a 48 hour minimum or until a constant weight was achieved.	Restoration reefs were mapped. Patterns of oyster cover were analyzed according to dominant shoreline types.
	Paynter unpubl. data found in Liddel 2008	These data were originally collected as monitoring data of hatchery-produced oysters on restored reefs, then used in Liddel (2008) for modeling purposes.	Locations listed in Table 7b of report - Restored oyster reefs	Oyster tissue was dried in a drying oven at 60°C for 72 h and weighed. Clump height was measured.	None- unpublished
Triploid	Kingsley-Smith et al. 2009	To evaluate the growth and survival of hatchery-produced triploid Eastern Oysters and Asian oysters at four sites with different salinities, tidal regimes, depths, predation intensities and disease pressures.	Patuxent and Severn Rivers, MD and York River, VA - On-bottom cages	Tissue dry weight was determined by drying all soft tissue at 40°C to a constant weight for 1-7 days depending upon oyster size.	Oyster growth and survival varied significantly with site and species.

Data Removed from Analysis

The Panel decided to not use shell height and tissue dry weight data from sites that were outside of the Chesapeake Bay and its tributaries because of the variability that exists concerning oyster biomass between oysters with the same shell heights. This resulted in the exclusion of 2,429 oysters from four different data sources and four different locations:

Date Source	Location	Number of Oysters
Kellogg unpubl. data	Hillcrest Sanctuary in Mockhorn Bay	1232
Kingsley-Smith et al. 2009	Machipongo River	393
Paynter unpubl. data found in Liddel 2008	Chincoteague Bay	448
O'Beirn et al. 2004	Waters near Chincoteague Bay	356
Total		**2,429**

The Panel also removed the data below due to missing shell height or tissue dry weight measurements or because of quality concerns (e.g., dry weight greater than wet weight, zero or negative weights, note from researcher indicating the sample was compromised, obvious data entry error):

Data Source	**Location**	**Number of Oysters**
Higgins et al. 2011	n/a	1
	St. Jerome Creek	1
	Spencer's Creek	1
Kellogg et al. 2013	Choptank River	4
Kellogg unpubl. data	Harris Creek	2
Kellogg-Hillcrest	Mockhorn Bay	1
Kingsley-Smith et al. 2009	Machipongo River	10
	Patuxent River	1
	Severn River	2
	York River	7
Paynter unpubl. data found in Liddel 2008	Choptank River	2
	Eastern Bay	1
	Patuxent River	5
	South River	2
	Tangier Sound	2
Luckenbach and Ross 2009 (Part 3 of Report)	Lynnhaven River	2
Luckenbach and Ross 2009 (Part 1 of Report)	Great Wicomico River	1
	Lynnhaven River	5
	Rappahannock River	1
Ross unpubl. data	Rappahannock River	133
Total		**184**

The Ross unpubl. data from Rappahannock was removed in its entirety because there appeared to be a data entry error that resulted in the data being an order of magnitude greater than all the other Rappahannock River data points.

Evaluation of Influencing Factors on Oyster Growth

The Panel evaluated individual aspects of the data in order to confirm that the 50th quantile would conservatively address factors that could influence oyster growth and resulting tissue biomass, including ploidy (i.e., diploid and triploid), culture method (i.e., off-bottom, referred to as "water column," on-bottom, and combination of both) and type (e.g., hatchery-produced, wild), season (fall, winter, spring, summer), and environmental condition scenarios based on different habitat groups (i.e., location in the Chesapeake Bay: upper, mid, lower, tributary or open bay; salinity characteristics: mesohaline and polyhaline). Differences in ploidy appeared to have the largest impact on oyster growth resulting in the Panel recommending the use of separate regression equations for triploid and diploid oysters. The diploid data is graphically presented for the culture method, seasonal, and environmental condition considerations. The triploid data is not graphically presented here, but it had similar trends as the diploid data for available scenarios (four seasons—fall, winter, spring, summer, and two habitat groups—Chesapeake Bay Tributary Mid-Bay Mesohaline and Chesapeake Bay Tributary Lower-Bay Polyhaline). For culture method considerations, only the diploid data could be evaluated because the triploid data were from one study that used the same culture method at each site. However, since the trends were similar for the two available habitat groups and also for the four different seasons, the Panel felt confident that the missing triploid scenarios would also be similar. Both wild and hatchery-produced culture types were included in the diploid dataset. Culture type was not relevant for the triploid analysis since triploid oysters used in these practices are hatchery-produced (the occurrence is rare in the wild). Overall, the Panel felt that the driving factor influencing tissue biomass is the difference in ploidy, likely due to triploid oysters not having to expend energy on reproduction.

The 0.5 quantiles for subsets of the data corresponding to different ploidy, geographic location, season, and culture method were calculated.

The table below shows the equation terms and associated error for the different curves.

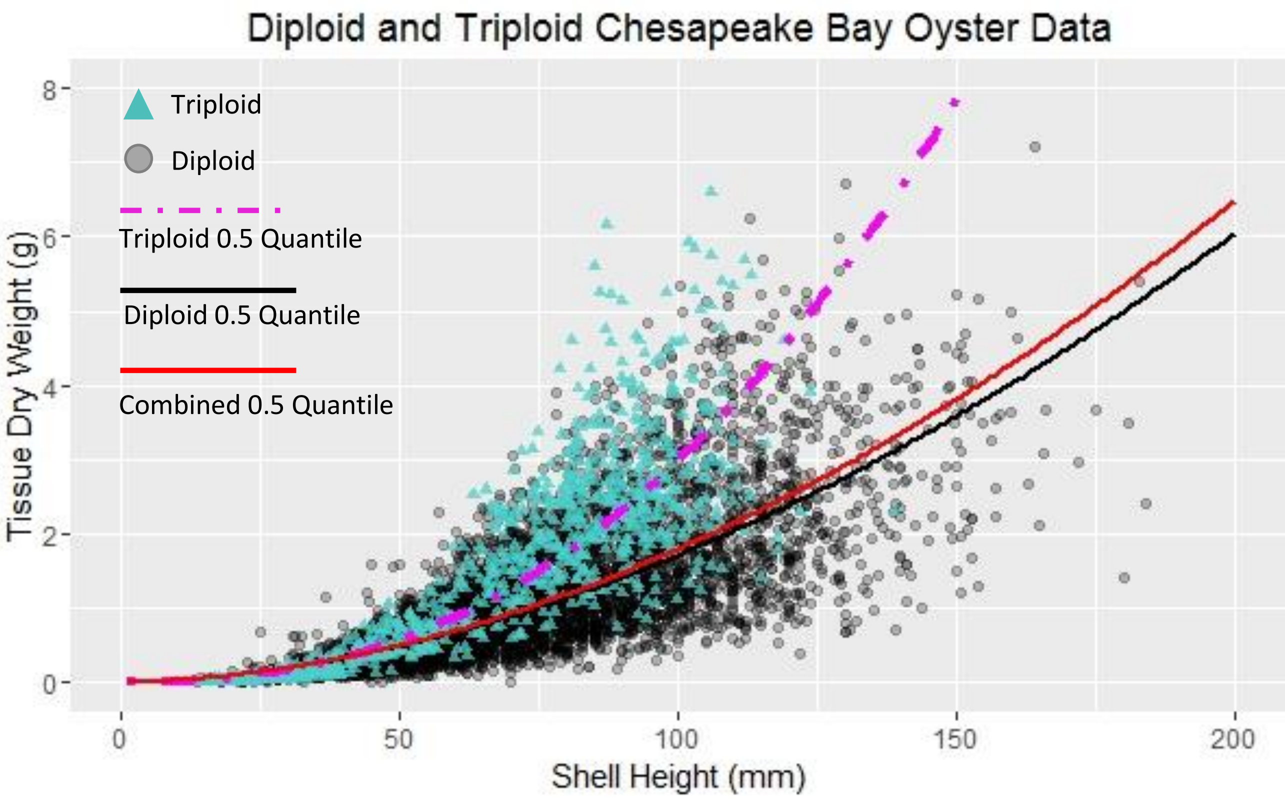
Equation: $y = ax^b$ **y = tissue dry weight (g), x = shell height (mm)**						
Oyster Data	**Number of Oysters**	**Quantile**	**a**	**b**	**Error a**	**Error b**
All data	6816	50	0.00036	1.84958	0.00004	0.02616
Diploid only	5750	50	0.00040	1.81627	0.00006	0.03427
Triploid only	1066	50	0.00005	2.38812	0.00002	0.08846
Tributary Mid-Bay Mesohaline	3948	50	0.00027	1.89815	0.00004	0.03869
Open Water Mid-Bay Mesohaline	515	50	0.00003	2.40561	0.00001	0.12084
Tributary Lower Bay Mesohaline	432	50	0.00026	2.00597	0.00016	0.15426
Tributary Lower Bay Polyhaline	1397	50	0.00008	2.2407	0.00003	0.07461
Tributary Upper Bay Mesohaline	524	50	0.00043	1.80438	0.00017	0.08703
Winter	569	50	0.00005	2.25556	0.00003	0.11467
Spring	1999	50	0.00031	1.94123	0.00007	0.05564
Summer	2649	50	0.00036	1.80421	0.00004	0.02776
Fall	1599	50	0.00037	1.86002	0.00009	0.05919
Water Column	1150	50	0.00005	2.36601	0.00003	0.11302
Bottom Oyster Planting	5556	50	0.0004	1.8112	0.00005	0.02909
Water Column and Bottom Oyster Planting	110	50	0.0001	2.29765	0.00009	0.22416

The Panel's evaluation on each of the growth-influencing factors are further described below.

Ploidy Considerations

Research suggests that triploid oysters grow faster and have more biomass than diploid oysters (Degremont et al. 2012). Therefore, the Panel evaluated and compared the 50^{th} quantile regression curves using the combined triploid and diploid data (n = 6816 oysters), diploid only data (n = 5750 oysters), and triploid only data (n = 1066 oysters).

The figure below depicts the different ploidy curves in relation to one another.



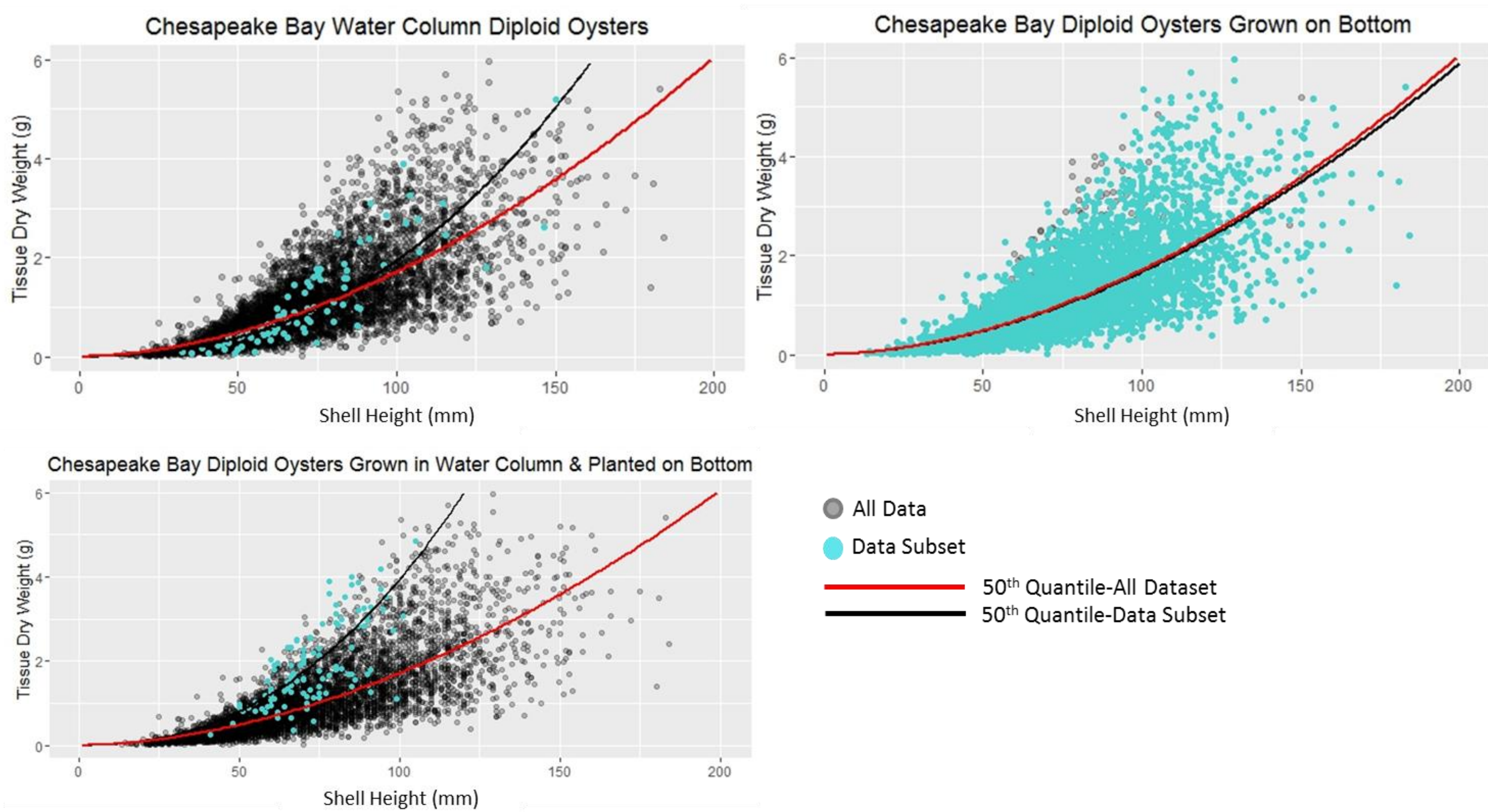
The Panel chose the 50th quantile curve because it captures the median of the dataset where 50% of the data falls above the curve and 50% of the data falls below the curve. The Panel felt this would be most appropriate for a default estimate because it evenly distributes the likelihood of underestimating or overestimating the biomass associated with a certain shell height.

The triploid only 50th quantile curve was clearly distinct and much steeper than the combined diploid and triploid curve and the diploid only curve. The diploid only curve matches the combined diploid and triploid curve to around 75 mm shell height, and slightly deviates below the combined curve around shell heights greater than 75 mm. The Panel felt that the much steeper triploid curve warranted separate reduction effectiveness estimates for triploid oysters because the data shows that triploid oysters have greater tissue biomass than diploid oysters. Therefore, the triploid only and the diploid only regression equations were used to develop separate reduction effectiveness estimates for triploid and diploid oysters.

Culture Method and Type Considerations

Research has shown that oysters grown off-bottom in the water column tend to have more tissue biomass at smaller shell heights than oysters grown directly on the bottom (Kinsley-Smith et al. 2009). Therefore, the Panel evaluated the data based on the culture method used to grow the oysters. The diploid dataset included 3 main oyster culture methods—off-bottom in the water column (oysters grown in cages near the bottom or floating rafts near the surface), on-bottom (planting hatchery-produced oysters or sampling wild oysters from existing or restored reefs), and a combination of off-bottom water column and on-bottom oyster practices (oysters were grown to 50 mm in cages and then planted on the bottom). The Panel plotted these different categories as an overlay over the entire dataset and considered their location in relation to the 50th quantile curve of the entire dataset. These plots are shown below.

Oyster Culture Method Considerations



The water column (i.e., off-bottom) and the combination of water column and on-bottom culture methods skewed above the 50th quantile curve of the entire dataset (i.e., smaller shell sizes have greater biomass), with the latter having a much steeper curve than the 50th quantile of the entire dataset. Since this culture method and the water column culture method produced steeper curves, the Panel decided that the 50th quantile regression equation will more likely underestimate the tissue dry weight, and hence, the nitrogen content, supporting that it will result in a conservative reduction effectiveness estimate.

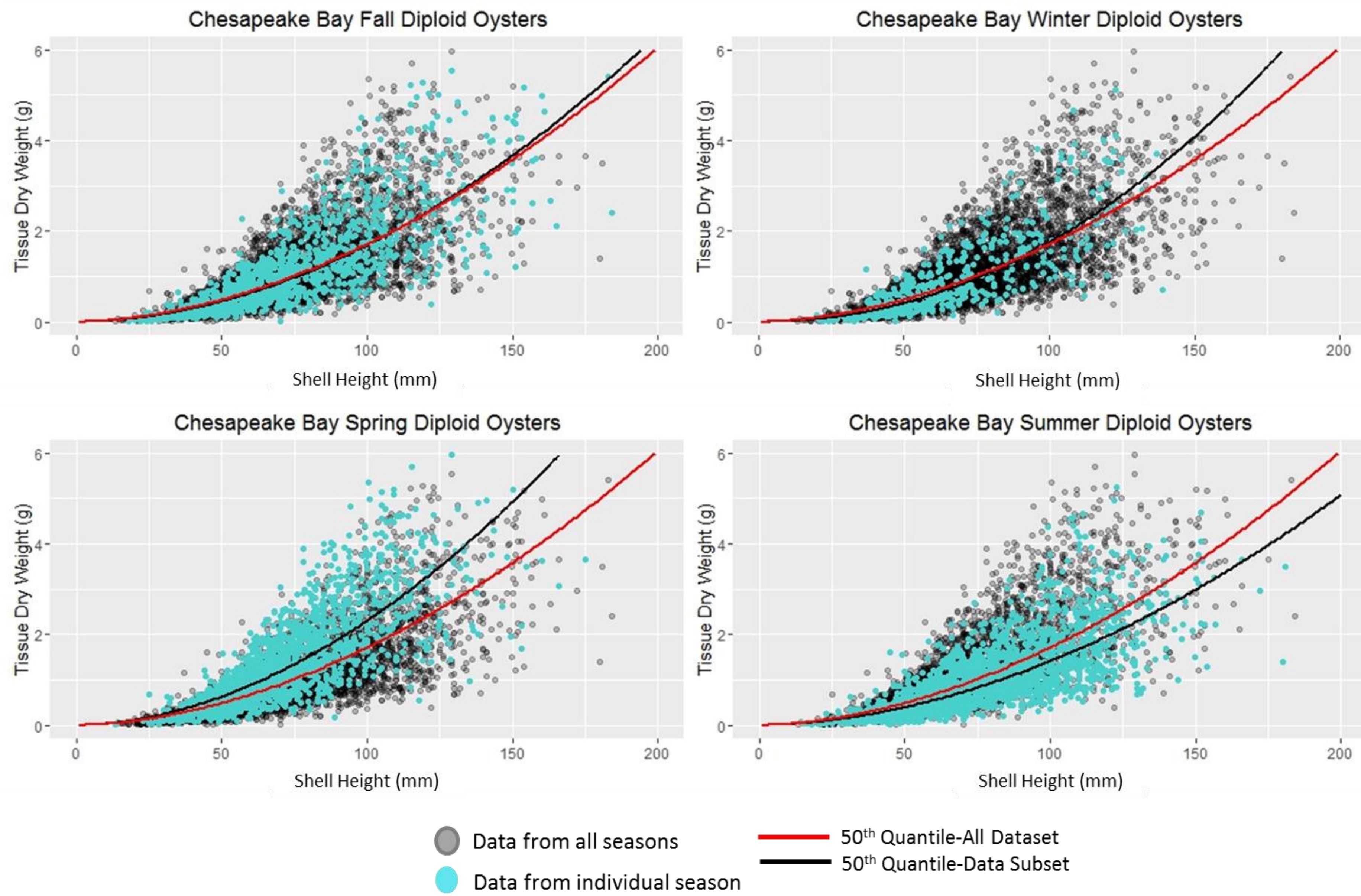
The on-bottom data skewed slightly below the 50th quantile curve; however, since the majority of the data is from this category, the regression curve itself is influenced by it, meaning that greater shell sizes have less biomass (i.e., the curve is more shallow than steep), supporting a conservative estimate. Additionally, aquaculturists use techniques for optimal oyster growth, unlike the data in this category which includes wild oysters and research grown oysters, suggesting that in real-world application as a BMP, the data will likely fall more so above the 50th quantile curve of the entire dataset.

The compiled dataset also included both wild and hatchery-produced diploid oysters, but the wild oysters were only from two locations: predominantly, the Lynnhaven River in Virginia (n = 967 oysters) and a small sample size from the Choptank River in Maryland (n = 9 oysters). Interestingly, when plotted, the on-bottom wild oyster data produced a similar curve as the water column (off-bottom) subset and the hatchery-produced oyster data had a similar result as the grown on bottom curve depicted above. Given that hatchery-produced diploid oysters are typically bred selectively to exhibit faster growth, it would seem that the hatchery-produced oysters would have produced a steeper curve when compared to the wild oysters. However, since the majority of the wild oyster data were from one location, it may be location-driven effects causing this result. Even so, with the subset curves being steeper or similar to the 50th quantile curve, it supports that the estimates are conservative because the diploid shell height to tissue dry weight equation likely underestimates or has equal potential to underestimate or overestimate the reduction effectiveness.

Seasonal Considerations:

Research has shown that there could be seasonal differences in oyster soft tissue biomass due to differences in food availability (Lenihan et al. 1996) and reproductive cycle (e.g., tissue lost during spawning) (Kennedy et al. 1996). The Panel evaluated potential seasonal differences by plotting the four different seasons (fall, winter, spring, and summer) as an overlay over the entire dataset and considering their location in relation to the 50th quantile curve of the entire dataset. These plots are shown below.

Seasonal Considerations



The spring oyster data skewed above the 50th quantile curve of the entire dataset and the summer oyster data skewed below. The spread of the fall and winter oyster data is evenly distributed above and below the 50th quantile curve to the approximate shell height of 125 mm and 100 mm, respectively, producing similar curves as the 50th quantile curve of the entire dataset. Above these shell heights, the data subset curves are slightly above the entire dataset curves. If only removing oysters during the spring, there may be a greater chance in underestimating the biomass and if removing only during the summer, a greater chance in overestimating the biomass. Given that 3 seasons skewed above the recommended 0.5 quantile curves and the reduction effectiveness is based on annual reporting with growers typically harvesting year round, the Panel felt that the reduction effectiveness would balance out (i.e., any potential overestimation would be negated by instances of underestimation).

Environmental Condition Considerations:

The Panel considered potential environmental condition differences on oyster growth by grouping the data by location within the Chesapeake Bay (Upper, Mid, Lower), including whether the oysters were grown in tributaries or in open-Bay waters, and by their salinity characteristics (i.e., mesohaline, polyhaline). The Chesapeake Bay locations and the salinity regimes were defined using the Chesapeake Bay Program bay-wide segmentation scheme (U.S. EPA 2004) and spatially-explicit salinity gradient maps from the U.S. Army Corp. of Engineers (http://www.nab.usace.army.mil/Missions/Environmental/Oyster-Restoration/Oyster-Master-Plan/), respectively. These raster salinity maps were generated in support of the U.S. Army Corp. of Engineers Oyster Restoration Master Plan and derived from interpolated spring and summer water quality samples collected between 2001 and 2006.

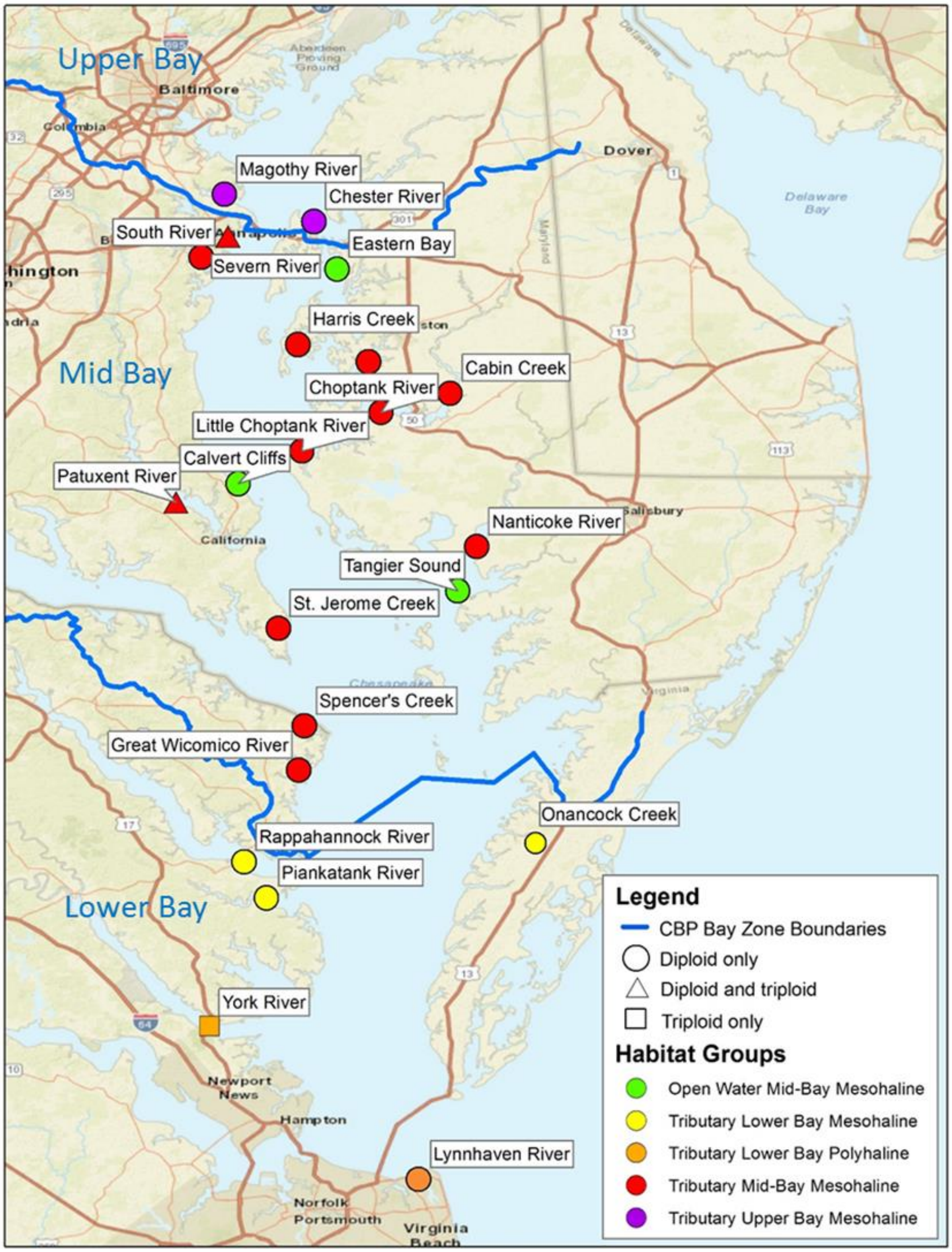
This strategy resulted in five main habitat groups:

- Tributary Upper Bay Mesohaline
- Tributary Mid-Bay Mesohaline
- Tributary Lower Bay Mesohaline
- Tributary Lower Bay Polyhaline
- Open Water Mid Bay Mesohaline

The dataset used to develop the regression equations included oysters collected at 22 general sampling locations distributed throughout the Chesapeake Bay and its tributaries. Raster maps and the geographic coordinates of each sampling location were plotted in a geographic information system (GIS) and the spring and summer salinity for each location were documented. Dominant salinity regimes were assigned based on the range of spring and summer salinities.

The map below depicts the sampling locations and assigned habitat groups for the diploid and triploid oysters used in the shell height to tissue dry weight regression analysis.

Sampling locations and habitat groups of oyster data used in shell height to tissue dry weight regression analysis

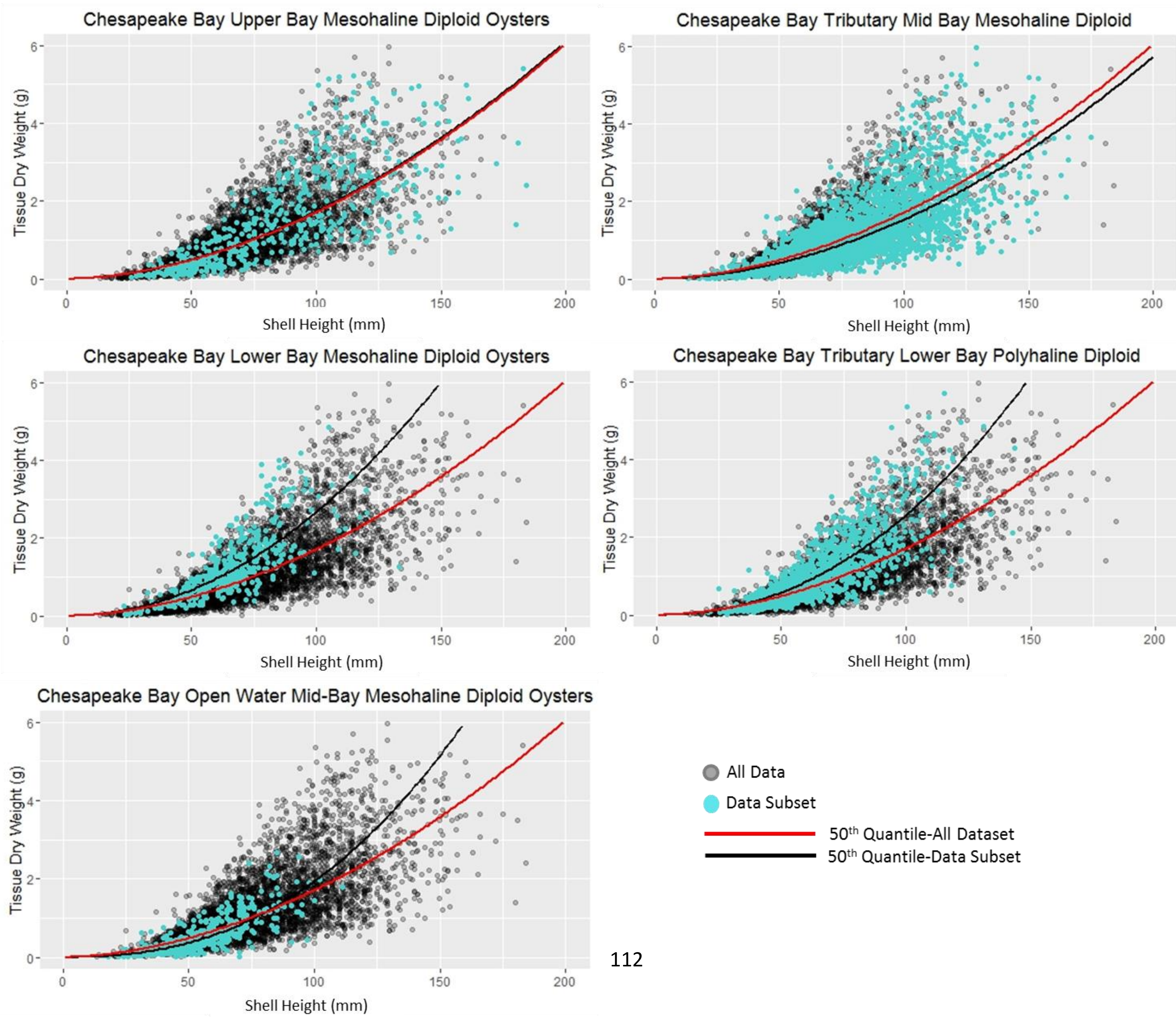


Most of the oysters were collected from riverine mesohaline habitats in Maryland, but 8% and 20% were from open-Bay mesohaline and tributary polyhaline portions of the Chesapeake Bay, respectively. The number of individual oysters associated with each habitat group ranged between 25 and 1179. The table below further summarizes the number of sites and oysters within each habitat group. References refer to the studies the oyster data came from.

Habitat Group	General Sampling Location	Sites (#)	Oysters (#)	References
Diploid				
Open Water Mid-Bay Mesohaline	Calvert Cliffs	1	78	Paynter unpubl. data found in Liddel 2008
	Eastern Bay	9	199	Paynter unpubl. data found in Liddel 2008
	Tangier Sound	5	238	Paynter unpubl. data found in Liddel 2008
Tributary Upper Bay Mesohaline	Chester River	23	381	Paynter unpubl. data found in Liddel 2008
	Magothy River	4	143	Paynter unpubl. data found in Liddel 2008
Tributary Mid-Bay Mesohaline	Cabin Creek	1	31	Paynter unpubl. data found in Liddel 2008
	Choptank River	22	836	Higgins unpubl. data, Kellogg et al. 2013, Paynter unpubl. data found in Liddel 2008
	Great Wicomico River	2	394	Luckenbach and Ross 2009
	Harris Creek	8	1059	Kellogg unpubl. data
	Little Choptank River	2	25	Paynter unpubl. data found in Liddel 2008
	Nanticoke River	1	27	Paynter unpubl. data found in Liddel 2008
	Patuxent River	14+	361	Paynter unpubl. data found in Liddel 2008
	Severn River	6+	197	Paynter unpubl. data found in Liddel 2008
	South River	1	54	Paynter unpubl. data found in Liddel 2008
	Spencer's Creek	1	46	Higgins et al. 2011
	St. Jerome Creek	1	38	Higgins et al. 2011
	Tred Avon River	2	32	Paynter unpubl. data found in Liddel 2008
Tributary Lower Bay Mesohaline	Onancock Creek	1	110	Kellogg unpubl. data
	Piankatank River	2	172	Luckenbach and Ross 2009
	Rappahannock River	2	150	Luckenbach and Ross 2009
Tributary Lower Bay Polyhaline	Lynnhaven River	24	1179	Higgins unpubl. data, Luckenbach and Ross 2009
Triploid				
Tributary Mid-Bay Mesohaline	Patuxent River	1	417	Kingsley-Smith et al. 2009
	Severn River	1	431	Kingsley-Smith et al. 2009
Tributary Lower Bay Polyhaline	York River	1	218	Kingsley-Smith et al. 2009

Overlays of oyster shell heights and corresponding tissue biomass associated with the habitat groups were added to the quantile regression plots to evaluate whether distinct differences were noticeable. The diploid plots are shown below.

Environmental Condition Considerations



Oyster data from the polyhaline tributary and mesohaline tributary and open-Bay locations in the Lower Bay skewed above the 50th quantile curve of the entire dataset (i.e., smaller oyster sizes exhibited greater biomass), suggesting a greater chance to underestimate the reduction effectiveness. Oyster data from the mesohaline tributary locations in the mid-Bay zone skewed slightly below, while the mesohaline upper-Bay tributary curve overlapped the curve of the entire dataset. Given that four of the five habitat group curves either matched or were steeper than the 50th quantile curve of the entire dataset and the tributary mesohaline curve was only slightly below, the Panel felt that the 50th quantile equation of the entire dataset would produce conservative default reduction effectiveness estimates.

Data Limitations

The tables below summarizes the number of oysters available for the shell height to tissue dry weight regression analysis based on the different factor scenarios:

Diploid	**Season Removed (# of Oysters)**				
Representative Culture Method	**Fall**	**Winter**	**Spring**	**Summer**	**Total**
Off-Bottom Water Column	0	0	84	0	**84**
On-Bottom Oyster Planting	1229	450	1507	2370	**5556**
Water Column and Bottom Oyster Planting Combination	0	0	109	1	**110**
Total	**1229**	**450**	**1700**	**2371**	**5750**

Triploid	**Season Removed (# of Oysters)**				
Representative Culture Method	**Fall**	**Winter**	**Spring**	**Summer**	**Total**
Off-bottom Water Column	370	119	299	278	**1066**
On- Bottom Oyster Planting	0	0	0	0	**0**
Water Column and Bottom Oyster Planting Combination	0	0	0	0	**0**
Total	**370**	**119**	**299**	**278**	**1066**

Diploid oyster data were limited for the off-bottom culture method within all seasons, with data only being available in the spring, when compared to the on-bottom culture method. On the other, triploid oyster data were limited for the on-bottom culture method, with no data being available in any season, when compared to the off-bottom culture method. These scenarios would benefit from additional research.

The combined water column and bottom oyster planting culture method was unique to the research project and does not typically occur as an aquaculture technique. However, given that the data produced a much steeper curve than the recommended 50th quantile curve (see culture method considerations above), it may be worthwhile to investigate if this difference is being driven by the culture method or by the season the oysters are removed. The current dataset is not sufficient to explore this because it only has limited spring diploid oyster data.

Wild oyster data was limited to predominantly one location (Lynnhaven River) in the diploid dataset used for the regression analysis. It is difficult to discern whether the steeper regression curve for the wild oysters compared to the hatchery-produced diploid oysters is driven by site or culture type.

Other Potential Data Sources

The 2010-2012 Chesapeake data from the Virginia portion of the Chesapeake Bay used in Powell et al. 2015 is another large dataset that includes shell height and dry tissue weight measurements from 19 oyster grounds. This dataset could be mined to address data gaps; however, since the data was representative of diploid on-bottom culture (collections were from subtidal reefs) from the spring (oysters were removed during April and May), the Panel did not feel it would greatly change the results of the regression analysis. Supporting this conclusion is the scaling exponent range (*b*) presented in Powell et al. 2015 of 1.61-2.75. The scaling exponent of the recommended diploid regression equation is 1.82, which fall within this range.

A specific knowledge gap that the Powell et al. 2015 dataset could potentially help address is whether a culture type or site effect is occurring concerning the wild oyster data from the Lynnhaven having a steeper curve (higher biomass at smaller shell heights) than the hatchery-produced diploid oysters given that this dataset has wild oyster data from other locations. Since hatcheries selectively breed oysters to exhibit faster growth, it was expected that an opposite result should occur (i.e., hatchery-produced diploid oysters would produce a steeper curve than wild oysters). A preliminary analysis of the Powell et al. 2015 dataset suggests that the observed steeper curve from the quantile regression analysis is likely a location effect, but a more thorough analysis would help confirm this.

Percent Nitrogen and Phosphorus Content in Oyster Tissue Literature Review

Nitrogen Content Literature Review

Summary of studies that were reviewed by the Panel that included information on the nitrogen content of oyster tissue as a percentage of dry weight are presented in the tables below. N = number of oysters sampled, SH = Shell Height. All oysters were *Crassostrea virginica*. All studies were on diploid oysters, except for Reistma et al. 2014, which included measurements for both diploid and triploid oysters (only triploid values are reported in table below).

Studies used for the estimate								
Source	**Growing Conditions**	**Study Site**	**% Nitrogen Mean**	**% Nitrogen Range**	**N**	**Study Purpose**	**How were N content measurements obtained?**	**Study Conclusions**
Carmichael et al. (2012)	Cages 6 cm off bottom Oysters per cage = 67 Cage area = 0.15 m^{-2} SH = 8.2 ± 0.2 mm at start of study Maximum SH ~68 mm at end of study Growing season: June-October 2003	Sage Lot Pond, Cape Cod, MA Salinity = 28 N load =14 x 10-4 kg N m-2 y-1	8.47 ± 0.09 SE		160	To evaluate N removal by oyster tissue assimilation by examining removal from land-derived N sources in five different Cape Cod estuaries. The sampling design aimed to capture spatial and temporal variation in growth, survival, and N content during the growing season.	Obtained empirical, estuary-specific N content of oyster tissue only. Dried samples were ground to a powder, and combusted during stable isotope analysis. Researchers estimated time they would reach harvestable size (76.2 mm shell height), and used regression analysis to extrapolate the soft tissue N content when oysters did not reach harvestable size within the study season (page 1137).	The data on N content and time to reach harvest size from this study was consistent with previous studies measuring the same variables in N-enriched estuaries. This suggests food resources are not limited, and that N removal in a given estuary to be relative to N load. N content did not differ among estuaries; however, the significant difference in relative dry mass at harvest size resulted in different N content per oyster and therefore, different N removal capacities via tissue assimilation.
		Wild Harbor, Cape Cod, MA Salinity = 26 N load = 65 x 10-4 kg N m-2 y-1	8.95 ± 0.16 SE		160			
		Green Pond, Cape Cod, MA Salinity = 28 N load = 178 x 10-4kg N m-2y-1	8.04 ± 0.24 SE		160			
		Snug Harbor, Cape Cod, MA Salinity = 25 N load = 236 x 10-4kg N m-2y-1	9.19 ± 0.15 SE		160			
		Childs River, Cape Cod, MA Salinity = 26-27 N load = 601 x 10-4kg N m-2y-1	8.37 ± 0.27 SE		160			

Grizzle and Ward (2011)[a]	Cages ~10-20 cm off bottom Oyster density per cage: "Seed" = 1,000 indiv. 1-yr olds= 200 indiv.	Adams Point, Great Bay, NH	7.20 ± 1.61 SD	5.20 - 9.56	10	Carbon and nitrogen removal was evaluated at six sites in the Great Bay estuarine system in NH in order to determine the bioextraction potential by oysters.	Obtained empirical, site-specific N content of oyster tissue only, as well as growth data. Tissue was dried, homogenized (using a blender) and N content was determined by using an elemental analyzer. Shell height and soft tissue dry weight were used as a proxy for growth. N removal variations were assessed by comparing final %N content. To obtain a whole-oyster N content for the two larger size classes evaluated in this study, Higgins et al. 2011 shell N content data were used (pages 8 and 11).	Significance testing yielded lower C and N assimilation values at one site compared to the others, as well as higher C and N assimilation at one site compared to the others.
		Bellamy River, Great Bay, NH	6.63 ± 2.13 SD	3.00 - 9.87	10			
		Oyster River, Great Bay, NH	7.55 ± 2.14 SD	3.23 - 9.55	9			
		Fox Point, Great Bay, NH	5.64 ± 1.70 SD	3.85 - 9.07	10			
		Nannie Island, Great Bay, NH	7.39 ± 2.07 SD	3.70 - 10.66	10			
		Squamscott R., Great Bay, NH	9.27 ± 2.38 SD	5.13 - 14.01	10			
Higgins et al. (2011)	Floating aquaculture cages Oysters per cage = 200 Cage area = 0.5 m^{-2} Mean SH = 44 – 118 mm	Spencer's Creek, VA Salinity = 5 – 15 Low flow, high sedimentation Growth Period: November 2006, August 2007 to October 2009	8.10 ± 0.13 SE	5.80 – 9.97	47	To evaluate the effectiveness of removal of excess nutrients from the Chesapeake Bay via bioassimilation of nutrients into oyster tissue and shell using oyster aquaculture.	Obtained empirical N content of oyster tissue by grinding up dehydrated tissue into a fine powder, combusting and use of an elemental analyzer (page 273). Nutrient contents of tissue were recorded as percent of dry weight.	Model simulations showed greater nutrient reductions on basin rather than the bay-wide scale.
		St. Jerome Creek, MD Salinity = 12 – 15 High flow, low sedimentation Growth Period: May-July 2007 to October 2009	7.37 ± 0.19 SE	5.43 – 10.36	37			
Kellogg et al. (2013)	Restored oyster reef Oyster density = 131 m^{-2} Mean SH = 114 mm	Choptank River, MD Salinity = 7.0-11.6 Subtidal reef	9.27 ± 0.60 SD	8.58 – 9.71	15[b]	To evaluate water column removal of nutrients via assimilation by a restored oyster reef compared to an unrestored reef, as well as to measure oxygen and nitrogen fluxes on both types of reefs.	Obtained empirical N content of oyster tissue data. Dried samples were ground to a fine power and N was analyzed with an automated CHN analyzer. The total amount of nitrogen assimilated was determined by multiplying the total dry weight of oysters by its percentage of N (Page 7). Shell and tissue were analyzed separately when the oyster was greater than 10 mm in shell height.	The standing stock of nutrients was greater on the restored reef than the unrestored reef.
Kellogg unpubl. data	Wild oysters from intertidal reef Oyster sizes ranged from 53 to 122 mm	Hillcrest Oyster Sanctuary, Mockhorn Bay, VA	8.13	7.8 - 8.67	9[c]	Included %N content measurements in oyster tissue.	Similar to Kellogg et al. 2013	None-unpublished

Sebastino et al. (2015)[d]	Cages 1 m depth Cage area: 0.4 m^2 Oysters per cage: 600	Jamaica Bay, NY	8.93 ± 0.03 SE			The potential sequestration of nutrients by oysters was evaluated in a high-nitrogen input estuary and a medium-nitrogen input estuary in New York state.	Obtained empirical N content of oyster tissue (page 575). Tissue N content was determined by grinding and homogenizing the dry sample and combustng it using an elemental analyzer, and standardizing to aspartic acid samples. Regression analysis was used to determine an equation from which tissue %N could be predicted from a given dry tissue mass after one season of growth.	Oysters in the high-N input estuary (Jamaica Bay) provided less removal of the total N input in that area than the oysters at the medium-N input estuary removed of the total N input to that estuary (Great South Bay). Oysters from Jamaica Bay would not be able to be sold as food.
		Great South Bay, NY	8.94 ± 0.03 SE					

[a]Values calculated using raw data provided in report appendix

[b]Three samples composed of five individuals per sample

[c]Three samples composed of 3 individuals

[d]Three sites were sampled within each bay, but results in Table 1 & 2 were aggregated data by bay.

Summary of studies/data that were not used to determine the nitrogen content because they were outside the Atlantic Coast region, were estimated values, or lacked source information.

Studies not used for the estimate								
Source	**Growing Conditions**	**Study Site and Environmental Conditions**	**% Nitrogen Mean**	**% Nitrogen Range**	**N**	**Study Purpose**	**How were N content measurements obtained?**	**Study Conclusions**
Dalrymple and Carmichael (2015)[a]	Cages 10-20 cm off bottom Cage area: 0.65 m^{-2} Oysters per cage Juvenile: 600 Adult: 200 Mean juvenile SH = 42 mm Mean adult SH = 98 mm	Mobile Bay, AL	11.8 ± 0.01 SE	9.10-13.54	108	To understand how nitrogen removal by oysters is affected by ontogeny	Obtained empirical N content of oyster tissue via combustion during stable isotope analysis. For some oyster samples, only the adductor muscle N content was measured, and a correction factor was applied from the relationship between adductor muscle and whole tissue N (page 208).	Juvenile oyster assimilated N while adult oysters lost mass and returned N to the estuary. However, the percentage of N in soft tissues did not differ between age classes.
Grizzle et al. (2016)[b]	Cages 10 cm off bottom Oyster density per cage: “Seed” = 1000 individuals 1-yr olds = 200 individuals	Oyster River, Great Bay, NH	~8.3			To quantify the relationships among various factors (oyster size, seasonality, nutrient content in ambient water) on the growth, morphometrics, and percent N and C content of farmed Eastern oysters.	Obtained empirical, site-specific N content of oyster tissue (page 2). Tissue was dried, homogenized, and analyzed using a CHN/O elemental analyzer.	A quadratic polynomial fit showed a 63 mm oyster would be reached after 2 years and a 76 mm oyster would be reached after 3 years. Significant differences in growth rates and nutrient content existed between the sites.
		Little Bay, Great Bay, NH	~6.9					
		Adams Point, Great Bay, NH	~7.8					
		Bellamy River, Great Bay, NH	~7.6					
		Squamscott River, Great Bay, NH	~8.7					
		Nannie Island, Great Bay, NH	~7.4					
Higgins unpubl. data	Reef	Choptank River, MD	8.2	5.48-10.6	9	%N, %P, and %C content in oyster tissue were measured.	Similar to Higgins et al. 2011	None-unpublished
		Lynnhaven River, VA	8.8	6.99-10.52	18			
Newell, R. I. E. and Mann, R. 2012	See Note[c]	See Note[c]	7	See Note[c]	See Note[c]	See Note[c]	See Note[c]	See Note[c]

Reitsma et al. 2014	On bottom and off bottom Mean SH = 83.8 mm	Cape Cod, MA (10 sites; aggregated data presented)	8.5[d]			To test the % N and %C content of C. virginica and M. mercenaria from coastal waters in Cape Cod, MA	%N and %C analysis was done on dried ground soft tissue with gut intact using standard laboratory methods.	Local oysters had an average of 0.69% N by total dry weight (~0.22N/animal). Values did vary by season and to a lesser extent by location or grow-out method. Biggest driver of N content differences among similar size cohorts was the tissue mass as opposed to the %N content in tissue.

[a]Figure 10 reports additional unpublished data from Mobile Bay, AL, and Grand Bay, MS. The mean nitrogen tissue content for all Gulf of Mexico sites was 10.62 ± 0.17 SE

[b]Average %N estimated from Figure 9 in study

[c]The table provided in this review did not have a range or number of samples, and did not explicitly state that the %N was a mean. This publication references: Newell, R.I.E. 2004. Ecosystem Influences of Natural and Cultivated Populations of Suspension feeding Bivalve Molluscs: a Review. Journal of Shellfish Research. 23:51-61, but this paper only had a sentence about the data, and does not contain any of the information above, and also has no information about location, growing conditions, or how N measurements were made.

Phosphorus Content Literature Review

Summary of studies that were reviewed by the Panel that included information on the phosphorus content of oyster tissue as a percentage of dry weight are presented in the tables below. N = number of oysters sampled, SH = Shell Height. All oysters were *Crassostrea virginica*. All studies were assumed to be on diploid oysters.

Studies used for estimate								
Source	**Growing Conditions**	**Study Site**	**% Phosphorus Mean**	**% Phosphorus Range**	**N**	**Study Purpose**	**How were P content measurements obtained?**	**Study Conclusions**
Higgins et al. (2011)	Cultivated oysters; grown in floating cages, 200 oysters per bag Bag size = 100 cm L x 50 cm W x 8 cm D	Spencer's Creek, VA Salinity = 5 – 15 Low flow, high sedimentation	0.83 ± 0.01	0.60–1.05	47	To evaluate the effectiveness of removal of excess nutrients from the Chesapeake Bay via bioassimilation of nutrients into oyster tissue and shell using oyster aquaculture.	Tissue was dehydrated and ground into a fine powder. Phosphorus was then measured by using USEPA method SW 846-3051/6010B, which involves acid digestion followed by inductively coupled plasma–atomic emission spectrometry.	Assuming no mortality, at a density of 286 oysters m^{-2} harvest size (76 mm shell height) phosphorus removal rate can be as high as 54 kg TP ha^{-1}
		St. Jerome Creek, MD Salinity = 12 – 15 High flow, low sedimentation	0.82 ± 0.02	0.53–1.07	37			
Kellogg et al. (2013)	1 restored oyster reef and one adjacent unrestored control reef were used as sites for the experiments. 4 X4 m experimental plots were on each one. Presumably oysters were both hatchery and wild oysters (see next column). At restored site, oyster density was increased to ~100 oysters/ m2 by taking oysters from the surrounding areas and placing them in the plots.	One restored site and one control site in Choptank River, MD.	1.26±0.18	NA	3	To evaluate water column removal of nutrients via assimilation by a restored oyster reef compared to an unrestored reef, as well as to measure oxygen and nitrogen fluxes on both types of reefs.	Samples were ground into a fine powder using a mortar and pestle prior to nutrient analyses. Phosphorus was analyzed by extraction of P from combusted sampled using 1 N HCl followed by colorimetric analyses (Aspila et al. 1976). For oysters >10mm in shell height, shells and soft tissue were analyzed separately.	The standing stock of nutrients was greater on the restored reef than the unrestored reef.
Kellogg unpubl. data	Wild oysters from intertidal reef Oyster sizes ranged from 53 to 122 mm	Hillcrest Oyster Sanctuary, Mockhorn Bay, VA	8.13	7.8 - 8.67	9[a]	Included %P content measurements in oyster tissue.	Similar to Kellogg et al. 2013	None-unpublished

[a]Three samples composed of 3 individuals

Summary of studies/data that were not used to determine the phosphorus content because they were outside the Atlantic Coast region, were estimated values, or lacked source information.

Studies not used for the estimate								
Source	**Growing Conditions**	**Study Site**	**% Phosphorus Mean**	**% Phosphorus Range**	**N**	**Study Purpose**	**How were P content measurements obtained?**	**Study Conclusions**
Higgins unpubl. data	Reef	Choptank River, MD	1	0.79-1.25	9	%N, %P, and %C content in oyster tissue were measured.	Similar to Higgins et al. 2011	None-unpublished
		Lynnhaven River, VA	0.81	0.67-1.03	18			
Newell, R. I. E. and Mann, R. 2012	See Note[a]	See Note[a]	0.80	See Note[a]	See Note[a]	See Note[a]	See Note[a]	See Note[a]

[a]The table provided in this review did not have a range or number of samples, and did not explicitly state that the %P was a mean. This publication references: Newell, R.I.E. 2004. Ecosystem Influences of Natural and Cultivated Populations of Suspension feeding Bivalve Molluscs: a Review. Journal of Shellfish Research. 23:51-61, but this paper only had a sentence about the data, and does not contain any of the information above, and also has no information about location, growing conditions, or how N measurements were made.

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Appendix E: Panel Meeting Minutes

Oyster BMP Expert Panel Meeting, 9/30/15, 1:00-2:30 PM

Location

Oyster Recovery Partnership, 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Attendance

Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Phone
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	In person
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In Person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Phone
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action Items before Next Meeting

1. **Panel Members**
    a. Review bios/expertise in the Who's Who document. Provide a picture or other information, if missing.
    b. Respond to Doodle Poll for October panel meeting.

   c. Review and provide any initial comments on preliminary list/definitions of oyster practices and BMP policy/science considerations.
   d. Optional: Let coordinators know if there are any people/groups they would like ORP to notify them of the public stakeholder meeting.

2. Coordinators

   a. Send Stream Restoration BMP Report to panelists before next meeting—example of crediting decision framework.
   b. Send Doodle Poll to schedule October panel meeting.
   c. Send preliminary list of oyster practices/definitions and BMP policy/science considerations for panelists to review.
   d. Send request to panel members for any recommendations of people/groups they would like ORP to send an e-mail to notify them of the public stakeholder meeting.
   e. Follow-up with Lucinda regarding the role of panel advisors and whether she knows of any panel reports that included negative benefits.

Meeting Minutes

1. **Introductions**
   a. Panel members briefly introduced themselves (~2 minutes per panel member). Coordinators asked panelists to also let them know if their expertise focused more on oyster aquaculture or restoration or both in order to help plan future meetings to maximize the availability of panel members.

Panelist Introductions—aquaculture and/or restoration expertise/specialty in **bold**

- Jeff Cornwell- Nutrient and metal cycling, Conowingo dam, sediment chemistry. Working on denitrification and nutrient removal project with Lisa Kellogg in Harris Creek.
- Lynn Fegley- Focused in stock assessment, would classify her work as **restoration**-based, but interested in **aquaculture**.
- Bill Wolinski- **Aquaculture and restoration**
- Matt Parker- **Aquaculture** business specialist, also PhD in process from UMD
- Suzanne Bricker- Has studied eutrophication nationally in Long Island sound, in China, Europe, comparing local models to ecosystem models, primarily **aquaculture**
- Karen Hudson- Commercial **aquaculture** specialist
- Lisa Kellogg- Studies ecosystem services provided by restored reefs, **restoration**
- Andy Lacatell- Worked for TNC for 15 years, interested in alternate substrate's role in restoration, **restoration**
- Mark Luckenbach- **Aquaculture and restoration**
- Chris Moore- Senior scientist for CBF, coordinated oyster gardening program at CBF, **restoration**
- Julie Rose- Academic background- studied plankton ecology, has personal interest in **restoration**, but professional career in **aquaculture**
- Larry Sanford- Shallow water oceanographer, studies flow and sediment transport on dispersal of biodeposits, doesn't fit into **aquaculture or restoration**

Advisor Introductions

- Lew Linker- Chesapeake Bay modeling coordinator
- Jeff Sweeney- Chesapeake Bay watershed model

- Ed Ambrogio- Works with the National Estuaries Program- region 3 in particular are involved with shellfish programs

2. **Overview of BMP Expert Panel Review Protocol**
    a. Lucinda Power from the Chesapeake Bay Program Office went over the Partnership's BMP Review Protocol.
    b. Lynn Fegley asked- During the 30 day open comment period, what is the responsibility of the panelists to respond to public comments?
        i. Lucinda responded that it depends on the involvement panel members would like to have; typically the panel chair and coordinators take the lead in responding and reach out to the appropriate panel members to help with the response. Public comments are usually from CBP's partners.

3. **Overview of Panel Charge and Panel Member Roles and Expectations**
    a. Julie Reichert (panel coordinator) gave a presentation on the panel goals outlined in the charge and expectations of the panel members.
    b. Ed Ambrogio asked- What will the advisor's role be?
        i. Julie Reichert answered that Lucinda would be the best person to answer that question, but from her understanding, advisors will provide guidance on an as needed basis regarding implementation of the panel's recommendations. Julie Reichert will follow up with Lucinda to verify the role of panel advisors.

4. **Panel Next Steps**
    a. Julie Reichert went over the panel next steps, including October meeting and the November public stakeholder meeting action items.
    b. Bill Wolinski asked- When presentations are scheduled, could you send us any pertinent reading material beforehand so we can be prepared?
        i. Julie Reichert answered that the panel coordinators will send out relevant reading material before upcoming meetings to help with discussions on the agenda.
    c. Julie Rose asked- Could you send out the Stream Restoration BMP report for the panel to review how they developed their framework? Would be helpful as we navigate through this process.
        i. Julie Reichert will send out the report before the next meeting.
5. **Misc.**
    a. Larry Sanford- Certain oyster practices if practiced wrongly could actually do harm- as opposed to other BMPs which are 'starting from zero'—have nothing to lose and everything to gain. Are there any other BMPs that also could do harm if practiced improperly?
        i. Julie Reichert will follow-up with Lucinda to see if any existing panel reports identified negative effects.

Oyster BMP Expert Panel Meeting, 10/26/15, 10:00 AM-12:00 PM

Location

UMCES Annapolis Office, 1 Park Place, Suite 325, Annapolis, MD 21401 and remote conference

Attendance

Panelists	Affiliation	Present?
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	In person
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In Person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	In person
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In Person

Action Items

1. **Panel members**
   a) Google Drive issue- panelists and advisors will let Julie know if it is not accessible to them.

2. **Coordinators**

a) Make Doodle poll for standing meeting time

b) Adjust definitions of oyster practices to reflect suggestions from panel members

c) Send reference list of studies from STAC and new papers since STAC to panel members

Minutes

1. **Presentation on the STAC review findings by Mark Luckenbach**

a) Mark's presentation can be found in the Oyster BMP Expert Panel Google drive folder (Panel Meetings, 2015-10-26, Presentations).

b) Questions for Mark and ensuing discussion:

- Matt Parker: Have there been any on bottom denitrification aquaculture studies? Mark Luckenbach: There has been one in the Lynnhaven. Study looks into denitrification relationship between oyster biomass in that system.
- Ken Paynter followed up: Even though there may be no denitrification studies on the bottom pertaining to aquaculture, denitrification could be quantified on bottom for these operations.
- Jeff Cornwell followed up: Would have to discern what stays and what gets washed away.

The conversation turned to conditions that affect denitrification

- Lynn Fegley: Are there any differences in denitrification with diploid vs. triploid oysters? Mark said triploid oysters may be growing more quickly and perhaps excreting more, and surface for microbes is another factor to consider, but probably no significant difference.
- Lynn also brought up the types of gear used in the way oysters are harvested could affect denitrification- tonging vs. dredging. This could also affect pollutant reduction crediting guidelines for denitrification because of resuspension.
- Jeff C. commented that in a highly reducing environment, denitrification is probably inhibited because of low flow. Reefs on bottom typically associated with enhanced denitrification.
- Bill Wolinski asked if there are any additional P studies that have come out since the STAC review. Mark responded with yes. Jeff mentioned studies in which a shallow site had almost complete retention of P while a deeper site had almost complete loss.
- A panel member asked if surface area or benthic community is more important regarding denitrification. Jeff C. responded that we aren't sure. Commented that he and Larry Sanford are working on a publication together in understanding how material in the Choptank is transported; mentioned that the system needs to be modeled in order to see where it ends up.
- Mark mentioned that there was one sentence in the STAC review that causes a lot of stir; the sentence basically amounted to whether in-situ BMPs should be on the same plane as BMPS that prevent pollutants from entering the water to determine reduced loads.
- A panel member asked if denitrification reduction from an oyster BMP could be included in the model used to inform the TMDL. Lew Linker followed up and said that the water quality and sediment transport model is capable to include benthic denitrification, but it is going to be a policy question where and how to account for it. If there is increased organic matter on the bottom, hopefully there will be discernable differences. Jeff C. mentioned that there would be site-specific considerations and model would need to control processes at the reef scale. Lew suggests a smaller group could meet and discuss how oyster practices as BMPs could fit into the model.
- Larry mentioned that denitrification could be hindered at some threshold of excess organic matter (heavily loaded bottom would interfere with nitrification—negative effect) and we should conceptually figure out how this could be included in the model.
- Bill mentioned we need to inventory new papers, Julie explained ORP is doing that and will get the reference list to the panel before December's meeting.

2. Panel logistics presentation- Julie Reichert and Ken Paynter introduction

a) Ken Paynter introduction- Studies physiological and ecological processes related to the eastern oyster.
b) Google Drive Issue- Panelists and advisors will let Julie know if it is not accessible for them.
c) Standing meeting- Mark suggested a Doodle poll be created to see when the best time for a standing meeting would be.

3. Discussion on the definitions of oyster practices

a) Several suggested adding 'alternate substrate' to the definitions, e.g., reef balls, granite, mixed shell, limestone
b) Matt Parker asked: how can you say oysters are removing nutrients on a sanctuary reef when they just die and re-release those nutrients?
    - Suzanne Bricker followed up and asked, as long as they're removing phytoplankton from the water column, why shouldn't it count?
    - Bill mentioned that counties (e.g., Talbot) are involved in small scale sanctuary and aquaculture (Maryland Grow Oysters) projects.
    - Jeff C. followed up: If reefs keep accumulating, the additional biomass could make a difference, but we don't have all the information we need yet.
    - Ken Paynter contributed that in some tributaries, reefs are sustainable, biomass is increasing, while at other tributaries, biomass is stable or declining, and these reefs need to be supplemented by additional plantings.
    - Lynn mentioned that in Harris Creek it was a management decision to repopulate reefs to maintain restored area. Population is monitored year to year to determine natural set versus planted.
    - Matt asked, so is there a threshold at which the reef is successful at removing nutrients?
    - Panel members cautioned that we don't want to send the wrong message when developing metrics for pollutant reduction; seems like it would be great to harvest all the oysters and therefore get a lot of nutrients out of the bay, yet this would reduce filtering capacity, so there has to be a happy medium between harvesting and not harvesting. For example, leaving them in the water past market size could increase their pollutant reduction potential. Need to consider net benefit when considering harvesting and leaving oysters in the water. Water quality credit for incremental increase in biomass?
    - Mark mentioned a Kellogg and Owens paper that says a similar amount of N can be removed through denitrification as the same amount of oysters that would have assimilated it and been harvested.
    - Larry Sanford: Soft tissue would decompose and rapidly release nutrients, but burial of shell could sequester; asked, if the animal dies but the shell is buried, isn't that nutrient removal?
    - Suzanne followed up and mentioned a dissertation (Beth Darrow) from Dauphin Island that concludes shells can retain nutrients long-term that are buried.

4. Suggestions to change oyster practices table

a) Matt suggests getting rid of 'cultchless' since some spat in aquaculture are spat on shell
b) Matt also suggests getting rid of 'bags and cages' and replacing it with 'container' so as not to rule out future possibilities

c) Jeff C. suggests definitions 1 and 2 be combined because they are similar from a biogeochemical perspective.

Oyster BMP Expert Panel Open Stakeholder Meeting, 11/2/15, 9:30 AM-12:00 PM

Location

Joe Macknis memorial conference room, 410 Severn Avenue, Suite 117, Annapolis MD and remote conference

Attendance

Panelists	Affiliation	Present?
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not Present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	In person
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	In person
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	In person
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	In person
Bill Wolinski	Talbot County Department of Public Works	In Person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	In person
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	In person
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In Person
Stakeholder Presenters	**Affiliation**	**Present?**
Delegate Anthony J. O'Donnell	District 29C, Calvert and St. Mary's Counties, MD	In person
Sue Kriebel	City of Virginia Beach	Phone
Steve McLaughlin	City of Virginia Beach	Phone
Russ Baxter	Deputy Secretary of Natural Resources for the Chesapeake Bay, Office of Governor McAuliffe, Virginia	Phone
Tolar Nolley	Oyster Company of Virginia	In person
Brad Rodgers	Moreland Advisors	In person
Johnny Shockley	Hooper Island Oyster Aquaculture Co.	In person
John Klein	Hooper Island Oyster Aquaculture Co.	In person

Meeting Minutes

1. **Attendance**

a. Around 60 people attended, including 5 stakeholder groups.

2. **Welcome and introduction**
   a. Jeff Cornwell introduced himself as the Panel Chair, and described how oysters fit into the management of the Chesapeake Bay (CB).
   b. Julie Reichert presented information on CBP's Partnership BMP Review Protocol, Panel membership, and the overview of the Oyster BMP Expert Panel's charge.
      - Described the Chesapeake Bay Total Maximum Daily Load (TMDL) allocation and how Best Management Practices are accounted for.
      - Emphasized the difference between the terminology 'credited' as it relates to the CB TMDL and nutrient trading credits; the Oyster BMP Panel are evaluating potential reduction effectiveness crediting of oyster practices for application in the CB TMDL modeling tools and not nutrient trading policy or use.
      - Explained why the Oyster BMP Panel was convened, how the panel process works, panel charge, panelist tasks, and timeline of panel.
   c. Panel members introduced themselves.

3. **Stakeholder presentations**
   a. Delegate Tony O'Donnell- Maryland's Story in Oyster Aquaculture- a Good Start and a Promising Future
      - Described the Maryland Aquaculture Coordinating Council (MACC).
      - Emphasized that it could be a bigger challenge to quantify nutrient removal from restoration efforts than aquaculture.
      - Recommended that the recommendations from the Panel be incorporated into the statutory framework of the MACC and support legislation in 2016 to add one representative from the Maryland Farm Bureau and one representative from the Oyster Recovery Partnership to the statutory membership of the MACC.
   b. Sue Kriebel and Steve McLaughlin- Sanctuary Oyster Reefs
      - Described Virginia Institute of Marine Science's report on the assessment of oyster reefs in the Lynnhaven River as a Chesapeake Bay TMDL BMP to the Army Corps of engineers.
      - Proposed creating sanctuary reefs in the Lynnhaven River in conjunction with local non-profit Lynnhaven River NOW.
        - They wanted to do a larger study to evaluate the seasonal nitrogen removal via denitrification from the reef, but didn't want to spend any more public money until decisions were made concerning oyster reefs use as a BMP.
      - Discussed potential issues impeding sanctuary reefs such as cownose rays
      - Question was asked on why larger oysters that can filter 350 gallons/ day were not included in analysis; Steve said it was because they had took a conservative approach.
      - Larry Sanford asked how successful Lynnhaven restoration has been, Steve answered that it has been successful
      - Jeff Cornwell asked if Lisa Kellogg is doing any work in Virginia Beach; Lisa said yes, 4x a year.
   c. Russ Baxter- No PowerPoint
      - Asks that the Panel considers aquaculture before restoration in terms of a BMP, since he says it is highly managed whereas there are more unknowns in restoration.

- Russ mentioned that VA DEQ approved a nutrient trading pilot proposal submitted by the Oyster Company of Virginia; however, the permit is on hold by EPA until the recommendations from this Panel are completed.
- Rich commented that there are hundreds of BMPs, and EPA has an agreement where BMPs must be established before nutrient trading, Russ acknowledged this.

d. Tolar Nolley and Brad Rogers- No PowerPoint
   - Talked about the monetary, social/ environmental benefits of oyster aquaculture.
   - Described first pilot program to assess oyster caged aquaculture nutrient trading through MS4 permit approved by VA DEQ and how they used the conservative numbers determined by the STAC 2013 report.
   - Discussed oyster aquaculture cage technology that provides time/date stamp where the cage is pulled out allowing for real-time data that can be shared with the community.
   - Brad Rogers- Talked about caged aquaculture business models and investing in environmental opportunities- providing another tool in the toolbox that is easily measured and verified.
     - Larry Sanford asked, how much of a value would a nutrient credit make? What would be the cost savings/ marginal capital? One of the two presenters answered there would be an upfront capital cost but it is all part of the business model.
     - Larry asked, what if the reduction effectiveness is small; will it be appropriate for a business model? Someone answered, leave that up to the private sector to see; not up to the panel to decide.

e. Johnny Shockley (no PowerPoint) and John Klein (PowerPoint)
   - Talked about wanting to open a hatchery on Hooper’s island that would generate 5 billion oysters/year.
   - Said they are in the process of developing partnerships to move sustainability programs forward.
   - John Klein expanded on the idea of opening up a hatchery, said it would give waterman their historical trade back, generate environmental and economic capital.
   - Talked about favorable oyster aquaculture conditions and expressed desire to have real-time water quality monitoring stations.

f. A few comments were made before meeting adjourned
   - Bill Wolinski asked if microchipping technology could be used for poaching; Ken Paynter remarked it would be tough.

g. Jeff Cornwell made closing remarks and thanked the presenters; meeting adjourned.

Oyster BMP Expert Panel Meeting, 11/2/15, 12:30-2:30 PM

Location

Chesapeake Bay Program Office, Annapolis, MD and remote conference

Attendance

Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not Present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	In Person
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	In Person
Chris Moore	Chesapeake Bay Foundation (CBF)	In Person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not Present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	In Person
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	In Person
Bill Wolinski	Talbot County Department of Public Works	In Person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	In Person
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	In person
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	Not Present
Emily French	Oyster Recovery Partnership	In Person

Action Items

1. **Panel members**
    a. Review Oct 26th meeting minutes
    b. Respond to Doodle Poll for standing meeting
    c. Review revised draft of oyster practice definitions

2. **Coordinators**
    a. Create a flow chart diagram that explains crediting decision framework
    b. Consider having meeting at Colonial Beach, MD- Potomac River Fisheries Society
    c. Consider FTP website to share literature for literature review
    d. Ask CBP reps about water clarity protocol

<u>Meeting Minutes</u>

1. **Finalize Oyster Practice Descriptions for BMP Consideration, All, 12:30-1:00 PM**
    c) Discussion:
        - Jeff- Everyone was fine with combining definitions 1 and 2 from original description (intensive off-bottom suspended aquaculture, intensive near bottom cage or rack-and-bag aquaculture, and also, just changed the term to 'container'), correct?
            - Larry- Not sure, for denitrification, container could make a difference on hydrodynamics
                - Mark- Community-wise, we don't know the difference different containers would make.
                - Jeff- Adding cages could have negative unintended consequence (anaerobic condition resulting in loss of phosphorus-binding oxide via conversion to iron sulfide).
                - Mark- Not only does the container make a difference, but the environment it's in. Aquaculture may require environmental monitoring, if nothing else, bottom O_2.
            - Mark- Aquaculture will probably tend to naturally not be in low-flow areas; permitting-related.
        - Larry- On revised oyster practice document, 1 is basically the same importance-wise as 2-6
        - Mark- Suggested combining definitions 2 and 3 and 5 and 6 from revised oyster practice document (handed out 11/2), for a result of four main practice categories: 1) water column aquaculture, 2) on bottom aquaculture, 3) on bottom shell plantings, and 4) on bottom shell restoration
        - Julie reminded everyone that we can build specifics into crediting protocols.
        - Bill asked if MGO counts toward oyster definition 4, another asked if it did, what tributary would it count toward- where they are grown or placed. Panel leaned towards where they are placed.
        - Lew- the 2010 TMDL did not include oysters because, at that time, the biomass in sanctuaries was too small to make a difference in final loadings, but now the question being asked is what about now? It will be important to understand how the credit will be applied in the model- What is the credit and who would get the credit? These are questions that would be related to policy decisions.
        - Julie- The charge includes some policy-related decisions, but more in the context of the reduction effectiveness and not implementation—i.e., provide recommendations on 1) how oyster practices would be classified as BMPs (e.g., bioextraction BMP, *in situ* BMP) and 2) use in CBP model framework.
        - Lew- All recommendations would need to be approved by all Chesapeake Bay partners.

2. **Stream Restoration Crediting Decision Framework for the Chesapeake Bay TMDL, Tom Schueler, 1:00-1:30 PM**

a. Presentation Notes
    i. Went over Chesapeake Bay Program approved BMPs, including expert panels in the works, one was floating treatment wetlands, where DNR could retrofit ponds with floating wetlands.
    ii. Comprehensive approach- in stream restoration BMP, the panel looked for functional improvement of streams in addition to nutrient reduction.
    iii. Lumping vs. splitting practices- difficult to come up with universal numbers, but don't want to split too much, because then it is difficult to report data.
    iv. Reporting and verification- where is it located, how long does credit last, which protocol was used.
    v. Panel should decide on thresholds for when the practices should be credited or not, which may depend on scale of the operation.
    vi. The panel should establish conditions where credit is not received, i.e., improper application of the practice.

b. Presentation Questions
    i. Bill asked- do you monitor baseline conditions? Tom answered yes.
    ii. Enhanced denitrification from oyster reefs likely have more variability than denitrification in streams; Panel should evaluate stream restoration report to see method that reached consensus.
    iii. Julie asked- what's your recommendation for breaking down the oyster practices definitions into detailed vs. less detailed categories? Tom- fewer, like 3 or 4, would be better.
        - Julie- we can build details into crediting protocols, like gear used to harvest and container used for aquaculture.

3. **Public stakeholder meeting and oyster BMP TMDL crediting decision framework discussion, All, 1:30-2:30 PM**
    a. Presentations mostly had to do with nutrient trading.
    b. Mark- people are doing extensive aquaculture in the Lynnhaven River.
    c. Larry would like to see a flow diagram as a map for where we're going with crediting protocols; Mark agrees; Larry suggested harvest versus not harvested (harvest→intensive/ extensive, not harvested→ sanctuary, etc.).
    d. Bill asked, when will we talk about sediment? He said this was discussed during the first shoreline erosion BMP meeting because of erosion prevention capability.
        i. Larry- oysters concentrate sediment, increase settling velocity of sediment, although it can still get swept away.
        ii. Lew- thinks sediment concentration by oysters would have a local effect- clearing up water and also nutrient removal benefits.
        iii. Larry- biodeposits are packaged, clear the water by taking it from the water column and putting them on the bottom; should have the same effect for farms and reefs.
        iv. Suzanne- could we tackle sediment from a different perspective, like from a turbidity/ SAV regrowth standpoint?
        v. Julie- not sure, the TMDL is specifically written for sediment loading, not turbidity, but will ask the CBP representatives.
    e. Chris- Do we have to determine baselines? Julie answered, yes, that this is included in the BMP Review Protocol as an item for the recommendation report.

- **f.** Mark- What has biomass accumulation been on sanctuary reefs- not a lot of linear processes? Need to establish how Panel will approach quantifying enhanced denitrification. Relate to biomass accumulation over a period of time?
- **g.** Matt- suggested that this particular credit may have to be re-assessed (maybe every 3 years).
    - **i.** Jeff- What about a provisional credit until assessment can be applied (15-18 months; assessment would confirm oyster biomass and corresponding denitrification).
- **h.** Should discuss conditions where you wouldn't get credit (bad application of the practice).
    - **i.** Panelist mentioned that we should keep in mind that real people have to report data up the chain- data requirements need to be reasonable, but scientifically-defensible.
- **i.** Panelist mentioned that there is a practice where oyster seed is moved from location to another in Maryland.
- **j.** Panelist stressed that the reduction effectiveness credit has to be intentional (based on an activity with the goal to enhance reduction; not status quo).

Oyster BMP Expert Panel Meeting, 11/19/15, 1:00-3:00 PM

Location

Remote conference; no in-person option

Attendance

Panelists	Affiliation	Present?
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Phone
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Not present
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Not present
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	Phone
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Phone
Ward Slacum	Oyster Recovery Partnership	Not present
Emily French	Oyster Recovery Partnership	Phone

Note: Some panel members are absent due to a Citizen Advisory Committee meeting (Mark, Ward, and Lynn)

Meeting Minutes

Action items

1. Panel review revised oyster practice category descriptions and reach a consensus decision on 11/25/15.
2. Julie will send out the revised Oyster BMP Crediting Decision Framework flowchart before the next meeting.
3. Julie will send Jeff literature review list to distribute to panel; papers will be uploaded to Google Drive folder and papers will be sent to Lucinda to distribute to EPA panel members.
4. Next meeting Dec 17th, 1-3 PM; in person option will be available at ORP.

Notes

1. Oyster Practice Category Discussion
    a. Jeff and Julie- This meeting is specifically for finalizing the category definitions of oyster practices; Jeff- last meeting, we boiled the definitions down to four categories; for reference, the version of the table that was being evaluated during this meeting is below.

Category	Oyster Practice	Description
1	Water Column Oyster Aquaculture	Hatchery-produced oysters reared in containers either near the bottom or near the surface for eventual harvest.
2	Bottom Oyster Culture	Hatchery-produced, spat-on-shell planted directly on the bottom or small wild oysters moved from one bottom location to another for eventual harvest.
3	Bottom Oyster Substrate Planting	Planting oyster shells or alternative substrate directly on the bottom to attract recruitment of natural (wild) oysters for eventual harvest.
4	Bottom Oyster Reef Restoration	Hatchery-produced spat-on-shell planted alone or on alternative substrate, such as granite, to promote natural reproduction in areas where harvesting is not permitted (e.g., sanctuaries).

    b. Lisa- not sure how some of the things on her list (sent on 11/19; see supplemental material below) would fit into current categories. For example, CBF oyster gardening program. Her list is broken down into two categories that each have two subcategories: (1) water column oyster culture, which includes (a) oyster removed and (b) oysters that remain in the Bay, and (2) bottom oyster culture, which also includes (a) oyster removed and (b) oysters that remain in the Bay. Lisa commented that the category, "bottom oyster culture" has major implications for denitrification in the Bay.
    c. Jeff asks- is CBF oyster gardening a big enough project to get BMP credit for?
        i. Lisa- Not sure
        ii. Chris- They produce about 300,000 oysters per year of variable size that are moved to aid oyster reef restoration projects; most likely, it is a smaller operation than the scale we will be dealing with for BMPs;
        iii. Jeff- Movement of oysters will need to be further discussed. For instance, how to quantify any denitrification benefit; would be difficult if they are moved.
        iv. Bill- Feels like their efforts should be recognized, contribution from the public should be acknowledged.
        v. Chris- Oyster gardening is more difficult to credit than aquaculture. Oyster size and survivorship is varied, so while it's a great program for the public, it doesn't lend itself to being reliable as a means of nutrient reduction.
        vi. Bill- Says he worked with Chris Judy on Marylanders Grow Oysters, analyzed those oysters' survivorship, that program was valuable.
    d. Julie- do we need to change wording of #4 to reflect oyster gardening programs?
        i. Jeff- If they're part of any definition, it should be #4 because the oysters end up at the oyster reef being restored.
        ii. Panel agreed to include oysters being moved in category 4 description.
        iii. Lisa- #4 should also reflect shell planted in VA to recruit wild strike, and other substrate types like reef balls.

e. Lisa- the way the practices are written now, they also do not include closing an area/ making it a sanctuary so populations can rebound naturally
    i. Rich reminded everyone- You can stay with the 4 broad categories and include in the report a section that describes individual practices that fit into each category and the rationale.
    ii. Jeff suggested creating a diagram for what fits into the categories; including the rationale for inclusion/ exclusion.
f. Jeff asks, what does everyone think of practice 1?
    i. Lisa suggests just saying 'above sediment surface' instead of 'near bottom/ near surface' as it is written currently, makes statement more inclusive
    ii. Julie agrees, and says that this takes care of Matt Parker's comment concerning not all oyster water column aquaculture may be done in a "container" (i.e., ropes).
g. Jeff asks, what does everyone think of practice 2?
    i. Panelist asked- why call it 'culture' when #1 says 'aquaculture'?
        - Julie- Culture was used because public fishery areas were included in this category.
        - Suzanne- So as not to confuse people, let's use aquaculture for both. Panelists agreed.
    ii. Lisa- In Virginia Beach, there was a proposal for spat-on-shell on the bottom for harvesting and land-based dumping (not for human consumption), would that be considered aquaculture?
        - Jeff- There was a presentation at CERF where mussels were used to remove nutrients and then fed to swine.
        - Suzanne- In Sweden, there is a market for nutrient removal with mussels, not for human consumption.
        - Jeff- So is any commercial/ economic benefit/ growth to be considered aquaculture?
        - Lisa added, would Virginia Beach example be aquaculture if they're growing oysters to meet the TMDL?
        - Rich added, what happens on land will also have to be part of the mass-balance calculation.
        - Jeff- Since the word 'harvest' has food implications, can we change it to 'eventual removal'?
        - Panel members agreed. Aquaculture will include practices where oysters are grown for eventual removal.
h. Jeff asks, what does everyone think of #3?
    i. Julie asked- besides shell planting, is there anything else that gets planted for natural recruitment?
    ii. Panelist- Yes, alternative substrate should be left in the description.
i. Jeff asked, what does everyone think of #4?
    i. The word 'harvest' will be changed to 'removal' for consistency.
    ii. Jeff- There are low salinity oysters that get moved to Chincoteague. If they get credited, when does that happen?
    iii. Rich- It will be the responsibility of other people in the Partnership to figure out those details. Could be wherever they spend the majority of the time.
    iv. Jeff- Agreed

2. Oyster BMP Crediting Decision Framework Flowchart Introduction
   a. Main objective of finalizing the oyster practices completed, so moving on to introducing the flowchart Julie created based on Larry's recommendation from previous meeting. This flowchart will be discussed in more detail during the next meeting.
   b. Suzanne and Lisa both mentioned that nitrogen and phosphorus burial should be incorporated as crediting protocols, even if little is known.
      i. Jeff suggests adding below, although burial would need to be highly efficient to be effective, and we don't know if that's the case
   c. Larry- For #6- suggests wording be changed to 'water column turbidity reduction' rather than 'sediment removal from water column'
      i. Julie asks- Since the TMDL is written for sediment, can we use turbidity?
      ii. Rich- Yes, turbidity can be used.
   d. Panel will continue discussion during next meeting.

Supplemental Material

<u>List of Oyster Practices sent by Lisa Kellogg on 11/19/15:</u>

After reading through the latest revisions of the categories, it looks like the practices fall into two primary categories: oysters grown on the sediment surface and those grown above the sediment surface. Within those categories, it looks like the next division is whether or not the oysters remain in the Bay or are removed from the Bay. With this in mind, I made a list of all the practices I could think of that were either currently in use, have been in use in the recent past, or might come into use as oyster shell becomes more and more scarce.

1) Water column oyster culture (i.e. oysters reared above sediment surface)
   a) Oysters removed from Bay (e.g. aquaculture harvest)
   b) Oysters remain in Bay (e.g. CBF oyster gardener program that transplants oysters from floats to broodstock sanctuaries)
2) Bottom oyster culture (i.e. oysters reared on surface of sediments)
   a) Oysters removed from Bay
      i) Harvest of wild strike from naturally occurring substrate (e.g. public fishery)
      ii) Harvest of wild strike from planted shell or alternate substrate (e.g. oyster leases in VA)
         (1) No maintenance of site
         (2) Periodic maintenance of site
      iii) Harvest of transplanted wild oysters
         (1) No maintenance of site (e.g. repletion program)
         (2) Periodic maintenance of site (e.g. on-bottom aquaculture)
      iv) Harvest of hatchery-produced oysters
         (1) No maintenance of site (e.g. managed reserve program)
         (2) Periodic maintenance of site (e.g. on-bottom aquaculture)
   b) Oysters remain in Bay
      i) Restoration via transplant of wild oysters
      ii) Restoration via wild strike on
         (1) Naturally occurring substrates (e.g. creation of oyster sanctuary that increases oyster population)
         (2) Oyster shell (e.g. VA restoration programs)
         (3) Other types of shell
         (4) Alternate substrates
         (5) Oyster castles, reef balls, etc.
      iii) Restoration via hatchery spat set on

(1) Oyster shell (e.g. Harris Creek)
    (a) Direct planting on bottom
    (b) Planting on base of oyster shell
    (c) Planting on base of other shell (e.g. mixed shell)
    (d) Planting on alternate substrate (e.g. granite)
(2) Other types of shell
(3) Alternate substrates
(4) Oyster castles, reef balls, or other 3D structures (e.g. CBF setting oysters on Reef Balls)

Oyster BMP Expert Panel Meeting, 12/14/15, 10:00 AM-12:00 PM

Location

ORP office, 1805 A Virginia Street, Annapolis, MD and remote conference.

Attendance

Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Phone
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Not present; follow-up call on 12/15/15
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Phone
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	Phone
Emily French	Oyster Recovery Partnership	In Person

Note: Some panelists and EPA representatives were not present due to the Water Quality and Fisheries GIT meetings taking place at the same time as this meeting.

Meeting minutes

Action items

1. Flow chart will be revised to reflect panelist input.
2. Julie Reichert will send out WQGIT meeting info for those interested.

Notes

1. **Panel communications guidelines**
   a. Julie explained the communications guidelines document sent out 11/25/15. Jeff noted that some Panel members receive requests from managers for updates at their meetings and asked that Panel members check with the Panel if disclosing information that is not publicly available yet.
      i. Mark asked- I get asked frequently about my research results, and recently the Citizen Advisory Committee asked me to brief them on the BMP process. I ended up talking about the STAC findings instead, is that alright? Jeff responded, yes, it's ok to talk about your own research, but if it's related to Panel decisions that haven't been disclosed yet, then it needs to get Panel approval first.
      ii. Matt asked, is it ok to give general updates, (e.g., we've come up with definitions, we're working on developing the framework, etc.). Julie responded that this was fine; as our process was in our charge and is public, it's more decisions that haven't been made publicly available yet that shouldn't be disclosed unless there is Panel approval.

2. **Oyster BMP crediting decision framework steps**
   a. Jeff opened this topic for discussion by mentioning that the definitions of oyster practices went through several iterations, but this framework would be the biggest challenge. He emphasized that it would be important to have the framework mostly worked out before the data review.
   b. Julie mentioned that during the January 11th or February 8th Water Quality GIT meeting, we want to present how we came up with the steps in the decision framework and how we decided on the definitions of the oyster practice categories. Julie asked if anyone had concern about providing input on the decision framework flowcharts by January 1st:
      i. Larry mentioned that Horn Point is closed from December 24th – Jan. 4th. Julie said as long as everyone gets their comments in before the January 7th, then that's fine.
   c. Jeff led discussion on step 1 of framework involving the identification of individual pollution reduction crediting protocols.
      ii. Jeff mentioned water column turbidity reduction, one of the processes, and wondered if double-counting could occur because organic particles can also be deposited to the bottom, which contain N and P. Larry felt that double counting would probably not occur, because you could quantify what's being assimilated; however, we may not know enough to assign a N or P credit for what's being deposited (this area needs further research).
      iii. Bill- What about nitrogen/ phosphorus burial? Jeff said concerning N and P, if burial is valuable, it would have to be enhanced in a given area due to oysters. Larry said material like biodeposits do get down to the surface of the sediment, but then is easily re-suspended just like anything else on the bottom. He said we do not currently know what the efficiency of net burial is.
      iv. Jeff prompted the panel members to discuss denitrification. Ed asked if denitrification is a function of the reef structure, or actually having live oysters present. Jeff responded that it is possible that just the reef structure contributes; Lisa Kellogg's work shows that denitrification in Harris Creek isn't as efficient as other locations, even though it has a lot of oysters/oyster restoration work going on. Bill contributed, but those restored areas will eventually form reefs. Ed asked, could a community on a pile of rocks denitrify just as well as an oyster reef? Jeff said perhaps, but it's still being researched. Matt then suggested to

change the name of the denitrification protocol to "enhanced denitrification;" Mark and Larry agreed.

v. Mark also suggested to add "enhanced" to the name of protocols 7 and 8, to make them "enhanced N burial" and "enhanced P burial."
vi. Matt also suggested adding "enhanced" to protocol 6, water column turbidity reduction, but Larry did not agree because oysters are directly related to reducing suspended sediment (oysters are efficient filter-feeders).
vii. Bill had a question about how turbidity is modeled in the Chesapeake Bay model. Julie stated that the Panel will be working with Lew Linker and the Chesapeake Bay Modeling workgroup on how the oyster-involved pollution reduction estimates will be incorporated into the model. She will look into Lew giving a presentation to help the Panel understand the components of the Chesapeake Bay Model.

d. Jeff led discussion on step 2 of framework (determination of reduction effectiveness estimates).
   i. Matt suggested moving the box "is there enough scientific information to account for influencing environmental factors" up.
   ii. Mark suggested eliminating bottom type/water flow box, Larry and Jeff agreed.
   iii. Matt suggested combining the "is there scientific information…" and "is there high variability in results?" into "evaluate scientific quality of the data."
   iv. Larry- change terminology to "confidence" in estimates.
   v. Mark suggested using "sufficient confidence"'- if not sufficient to determine an estimate, then could possibly allow a provisional estimate and guidelines to refine it (seasonal adjustment, etc.).
e. Jeff led discussion on step 3 of framework (evaluating whether any implementation factors require step 2's estimates to be adjusted).
   i. Julie provided an overview of step 3, highlighting that this step was formed because it was mentioned at prior meetings about how protocols could be influenced by moving oysters from one location to another, the use of different gear to harvest oysters, triploid vs. diploid for nutrient assimilation purposes, etc.
   ii. Julie Rose- is time built into the framework at all? Jeff agrees that the time component is important, in terms of things like denitrification and the microbial community. Larry says, for this reason, perhaps there will need to be a phase-in period, where credit is given after two years, for example. Lisa agreed- this is important since some reefs thrive and some fail.
   iii. Matt- should we take the oyster practice definitions and use them instead of the pollutant reduction crediting protocols to lead us through the framework/ flow chart?
   iv. Mark- disagrees that we should only use the definitions, but likes the idea of using them in conjunction with the pollutant reduction crediting protocols. He also says many of these combinations will probably converge in their estimates.
   v. Jeff agreed that compressing steps 2 and 3 works.
   vi. Matt asked if we should run through an example in the Water Quality GIT meeting, Julie and Jeff said yes, but one without numbers.

3. Next steps

a. Julie- In order to present at the Jan. 11th WQGIT meeting, we would have to make the changes on the flow chart and reach consensus by Jan 7th. If not completed in this timeframe, then we are also have time on the Feb 8th meeting as a back-up.
b. Julie- will send out WQGIT meeting info; can call in and listen, open to all.
c. Jeff- Planning to have the data workshop on Feb 18th from 10 AM-3 PM. Will try to have discussion leaders, and have 20 minute discussions on data for each protocol.

Oyster BMP Expert Panel Meeting, 1/7/16, 1:00-3:00 PM

Location

ORP office, 1805 A Virginia Street, Annapolis, MD and remote conference

Attendance

Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Phone
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Phone
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In Person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Not present
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In Person

Meeting minutes

Action items

1. Julie will add ancillary benefits to step 3.
2. Julie will follow-up with Lucinda to see if nutrient removal through macroalgal growth (fouling) on cages (and subsequent removal by putting on land) could go under ancillary benefits.
3. Jeff and Julie will send revised flowcharts and briefing paper for the panel members to review before Feb. 8th WQGIT Meeting.

Notes

1. **Coordination updates**
    a. Publicly-available oyster BMP info is up on the Chesapeake Bay Program website now, but it is in several different places; will have an ORP website soon that will include links to direct people to the different CBP webpages where the Panel has given updates.
    b. Suzanne mentioned getting a call requesting info about the panel's progress, Julie mentioned that if needed, those kind of calls can be directed to panel coordinators.
    c. Julie reiterated not to give out the Google Drive link when sending info to people that are not panel members/advisors/coordinators, because then they will be able to access all the contents of the drive.
    d. WQGIT meeting has been rescheduled to Feb 8th.
    e. Data workshop is scheduled from 10 AM-3 PM at Potomac River Fisheries Commission on Feb 24th
        i. Note: Ken Paynter will not be able to make it, Matt Parker may not be able to make it either; National Shellfisheries Association meeting is that week as well.

2. **Oyster BMP crediting decision framework steps**
    a. General comments on framework
        i. Comment from Larry (provided to Julie before the call)- suggested a language correction to step 2, "each suitable combination of…"
        ii. Lew commented, "when talking about pollution reduction crediting protocols, crediting mean to credit a process, not an entity or organization, right?" Jeff and Julie answered yes this is right.
        iii. Suzanne suggested terminology should be changed to "nutrients and sediments" rather than pollutants for more specificity, Lynn and Lew agreed, the more specific, the better. Also, this change would emphasize that the Panel is not addressing pollutants such as toxins and other contaminants.
        iv. Ken also suggested saying "suspended sediment" rather than "sediment" since oysters are taking it out of the water column and depositing on the bottom.
        v. Julie mentioned she had a hard time with this in the past- is moving sediment to the bottom "removing" it?
        vi. Lew said the water quality standard for which the TMDL is written for has to do with water clarity and feels a protocol that addresses this would be beneficial.
        vii. Bill- asked whether improvement of water clarity would involve both organic and inorganic matter; the Panel agreed that it would; Lew stated that the TMDL uses total suspended solids, which would include both organic and inorganic particulates.
        viii. Jeff- mentioned that there would also be nutrient content of labile material.
        ix. Panel felt the protocol should be changed to "Water Column Clarity Associated with Oysters," which would include suspended sediments.

x. This change would address Larry's comment concerning whether the protocol is stated in such a way that matches what's in the TMDL.

xi. Ken asked whether the oyster practice "bottom oyster substrate planting" has any combinations with the reduction crediting protocols. It was explained that practices that fall under this category aims to establish oyster populations in that area. Ken suggested that "bottom oyster substrate planting" should be replaced with "planting substrate for oyster reef benefits." Julie explained that consensus had already been reached and asked the Panel if they want to make this change; Jeff said that we could elaborate what this category entails in the recommendation report and a change to the name wasn't necessary; the Panel agreed.

b. Comments on Step 1

i. Suzanne asked why 1B and 1C are on the same level- are they being done at the same time?; Julie explained that they are on the same level because they could be figured out independently from one another.

ii. Chris had asked about including a step that evaluates whether it makes sense to determine an estimate for an oyster practice/crediting protocol combination. Julie informed the Panel of conversation with Lucinda and Rich- they recommended that the Panel only eliminate combinations based on scientific rationale and not for a policy or implementation-related reason.

iii. Bill brought up that in aquaculture, in the cage-washing process, algae gets washed off and that it is a substantial amount of biomass that could potentially be removed. Matt said it could end up on land, but Chris thought it probably would end up in the water. Ken commented that biomass on tray cultures can be similar to the oysters that grow on them themselves. Jeff mentioned that in southern Delmarva clam aquaculture, there is sometimes more macroalgae than clam biomass. Jeff commented he would like to know how much of that stays on land compared to how much goes back into the water. Bill mentioned that maybe adding nutrient removal through macroalgae rinsed from cages could be a crediting protocol, and it could be an impetus to improve practices to prevent rinse water from returning the Bay, especially since aquaculture is such a developing field in VA and MD. Chris believes there is not much information out there for a separate protocol. Suzanne said we could make a note of it being a possible benefit, and Julie Rose commented that it could be an ancillary benefit. Lisa brought up that might not fit into ancillary benefits because it has to do with nutrient removal. Julie will ask Lucinda about this and to help the Panel understand what is meant by "ancillary benefits." Mark felt this is an appropriate topic to discuss in future meetings- he provided an example of caged aquaculture in New England that calls for washing cages on land or bringing back the rinse water to land. Mark is not sure if it is tourism and aesthetics-related or environmentally-related. Lisa also brought up long-lining mussels in Canada, and how the fouling is dumped on land. Julie asked: does this warrant its own protocol? Responses were mixed as to whether it should be an ancillary benefit or protocol. Julie will follow-up with EPA advisors.

c. Comments on Step 2

- Lynn- asked whether there is a time component associated with the decision concerning whether knowledge gaps can be reasonable addressed. Chris mentioned that we may need guidance by the WQGIT. Lew- BMPs are adaptive, and the GIT would be happy to answer that question. Julie will follow-up with WQGIT.

- Chris- baseline is important, we need guidance from the WQGIT on that part too. Julie said that ORP is compiling data sources for oyster biomass in hopes to assist with the baseline discussion. ORP is aiming to have this information available for the data review workshop.
- Bill asked if models have to be calibrated with actual data. Lew briefly explained. Panel coordinators will work with Lew to have the CB Modeling workgroup to give a presentation about the model.
- Lisa asked whether it would be possible to model estimates based on a particular area (local effects) versus a system-wide estimate (CB-wide effects); Lew said that they could run the different scenarios.

d. Comments on Step 3
- Suzanne had questions about G, "Guidelines on the conditions needed for the estimate to be valid"- asked if Julie/Jeff could elaborate. Julie stated that these would be environmental-related conditions (e.g., salinity). Chris mentioned that it should also include bottom substrate. Suzanne mentioned a DNR report written by Nicole Carlozo that has data concerning the suitable bottom for oysters, including variables like depth, salinity and substrate.
- Lisa commented on 3G (guidelines on the conditions needed for the estimate to be valid) and said guidelines that apply to some areas may not to others.
- Panelist provided an example for an unintended consequence- excessive deposition of organic matter from too many aquaculture cages could hinder nitrification/denitrification process.
- Julie will add ancillary benefits box to Step 3.

e. Briefing document
- The purpose of the briefing document would be to focus on the 7 points, so if anyone has concerns with our approach, it can be brought to our attention before the data review workshop.
- Chris- agreed that it would be helpful to ask WQGIT to comment on the combinations between oyster practices and protocols to help the Panel with future deliberations.
- Ed asked what to expect from a WQGIT meeting- others responded that they are usually on topic.
- Suzanne asked if we should add fouling (as mentioned earlier in the minutes) to the 7 questions. Panelist thought this would be too in the weeds for this briefing; Julie will instead ask Lucinda about whether it would fit as an ancillary benefit.

f. Data review workshop
- NSF type protocol, discussion groups will be led by assigned panelists and will be based on expertise pertaining to oyster practice category/crediting protocol combinations.

Oyster BMP Expert Panel- Data Review Workshop, Feb. 24, 2016, 10:00 AM-3:00 PM

Location: Potomac Fisheries Commission Bldg., 222 Taylor Street, Colonial Beach, VA and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	In person
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	In person
Andy Lacatell	The Nature Conservancy (TNC)	In person
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	In person
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Not present
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Remotely
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	In person
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Meeting Minutes:

1. **Overview of workshop goals**
    a. Review and discuss existing science and figure out priority order of practice-protocol combinations to evaluate based on existing science.

2. **Summary of public comments on decision framework**
    a. Mark asked- are there other BMP panels that consider variance to mean ratios? Rich answered there isn't anything out there like that now, but it's hard to compare between panels.

3. **Data Review Session 1: Nitrogen and phosphorus assimilation in oyster tissue and shell Mark Presented**

a. Panelist mentioned- variances from the STAC studies were relatively low for tissue (dry weight) and shell, and those measurements are easily relatable to weight and shell height.
    i. A panelist asked if these numbers would change over different seasons; possible for diploids.
    ii. A panelist mentioned that STAC did not talk about bottom planting (extensive aquaculture); only focused on intensive caged aquaculture.
    iii. A panelist mentioned that it would be interesting if aquaculturists took their own measurements (length/ weight) to get a range of data from different operations.
    iv. Lisa agreed that it would be good to have mean size at harvest or size distribution data coming from aquaculturists.
    v. Suzanne mentioned that she worked on a bioextraction study with oysters from different locations, and that oysters from Long Island Sound weighed 91 g, while oysters from another location weighed 30 g, so oysters farmed in different places can be different weights, and also shell thinness may play into it.
    vi. A panelist mentioned the temporal loss of N from oyster shell, and said we should be aware of that variability.
    vii. Mark said very few people are growing hatchery SOS on the bottom
    viii. A panelist mentioned the study two panelists had participated in (Matt and Suzanne) in Rock Hall and Crisfield.
    ix. Julie Rose brought up- are STAC numbers still current or do they need to be refined? Refinement needed since only covered intensive caged aquaculture.
b. Julie Rose brought up- could we consider where the oysters are located in the watershed, so that different equations could be applied to different regions of the Bay? Someone answered yes, this is happening in other BMPs.
    i. Rich contributed that some BMPs have default values that can be changed if data are available.
    ii. Julie Rose suggested that growers could be worked with to refine these numbers; also group should highlight data gaps that would be easy to fill in versus more complicated ones.

Julie Rose Presented

c. A panelist mentioned that if there was a way to document N in shells on the bottom, maybe that would not discourage shell recycling programs.
    i. Lisa said that this would be dependent upon where the shells are, some areas have boring sponges which may contribute to shell erosion.
    ii. Mark said that there is a difference between biodegraded and buried shell; only credit N that is buried.
    iii. Julie Reichert- asked whether a correction factor of sorts could be applied based on dissolution rate; group could consider, but there may not be enough information yet.
    iv. Matt contributed that it is not unreasonable to ask aquaculturists to count shells in a bushel; aquaculturists should keep records; they will be harvesting much more shell than they put in.
    v. Lynn said there are 4,000 acres of leased bottom in MD; “harvest accountability measures” would have to be in place to properly document shell movement.

Suzanne presented (FARM model)

d. Suzanne mentioned that she couldn't' get harvest numbers from Long Island Sound folks in the study she presented
    i. Lisa remarked that for the purposes of this BMP, it would be a non-starter to not report harvest.
    ii. Mark mentioned a study by Annie Murphy that showed at Cherrystone aquafarms, almost all N is going back into the system, although it is different oyster environment in that the sediment is sulfidic.
    iii. Chris asked, what would happen if restoration numbers were in this model? Suzanne responded that the model shows how much that is harvestable, mortality in the FARM model is based on reports of typical mortality from growers and is inclusive or total mortality for all reasons.
    iv. Mark said that it seems like a slippery slope to credit something population-based in the water and not harvest-based.
    v. Matt asked how restoration relates to the Bay model, Lew said menhaden and oysters are separate parts of secondary production. Matt said that we don't want to double-count in the model.
    vi. Lynn said to Mark's point about population based organisms in the water- if a disease wiped them out, where would we be? Lew responded that consideration is in the model, there are huge swings associated with recruitment; also modeling can be used to understand performance of BMP.
    vii. Bill brought up the point that the investment in oyster reefs in Maryland has expectations from the public, therefore, important to quantify the water quality benefit.

4. **Data Review Session 2: Suspended sediment reduction associated with oysters**
   Emily French presented
   a. Jeff Cornwell commented- materials don't necessarily stick around once they are deposited; one small patch in a tidal system won't give a signal; important to know fate of filtered material.
      i. Lisa said near bed flow will be a lot slower; also mentioned tracking a parcel of water (modeling would be needed).
      ii. Julie Reichert- Does the filtration help with progress toward water quality standards? Panel- water clarity improvement is occurring in Harris Creek due to oyster restoration.
      iii. Julie Reichert asked- can we use secchi depth as a measurement? Panel- may be too basic; wouldn't be able to understand re-suspension.
   b. Lisa mentioned that when diving she has seen localized water quality benefits right over a reef, but this would be hard to measure.
      i. Mark said a bass balance with sediment could be done, but at its max value it would only be representative of a miniscule amount of sediment.
      ii. Rick remarked that it's fine if it's minuscule; the Partnership is interested in what the number would be.
   c. Julie Reichert- asked if oyster castles could fit into this category since they reduce erosion.
      i. Bill said no- that falls under the shoreline BMP.
      ii. Chris said shoreline BMPs are in effect in VA, some including oysters.
      iii. Lew said the water quality standards are to protect shallow water habitats; standards for depths below 2 m are unseen.
5. **Data Review Session 3: Enhanced denitrification associated with oysters**
   Jeff presented
   a. Jeff- there are different denitrification scenarios to consider: shallow water with good light and deeper water with little light (i.e., depth is relevant in understanding denitrification benefit); also need to establish how oysters enhance denitrification (denitrification does occur without the

presence of oysters); oysters do move biologically available N from water column to bottom where it can be converted to nitrogen gas more rapidly than without the presence of oysters (i.e., oysters increase vertical setting rate); movement of material also occurs; more so with floating aquaculture; knowing the fate of organic material deposited by oysters would lead to better understanding of denitrification benefit.

   b. Panel member commented that there may be a denitrification benefit associated with aquaculture; Rich asked is there not enough science? Jeff responded yes and no, it will likely be difficult to establish a default estimate with existing information.
      i. Matt said how about working with oyster farms? DNR could be helpful.
      ii. Lynn said the numbers would be highly location-based, could get complicated. Mark responded yes, but this is true of many BMPs.
      iii. Matt commented that bottom oyster aquaculture can't be placed on sites where there are oysters.
      iv. Mark commented that harvesting would re-suspend material; Matt asked if damage to sediments could be minimized by hand harvesting, or considering other harvesting besides dredging; Mark said good idea, but doesn't think anyone would pay more for oysters because they're harvested in a more expensive way.
      v. Chris asked if there are any VA denitrification study reefs that are for aquaculture
      vi. Lisa answered yes, extensive aquaculture in the Lynnhaven, in their study they put down shell.
      vii. Rich- recommended the Panel identify knowledge gaps; once gaps are filled, the Panel's recommendations can always be amended.
   c. Panel- felt that denitrification benefit would be more straight-forward to calculate for oyster restoration and more complicated for aquaculture.

6. **Data Review Session 4: Enhanced nitrogen and phosphorus burial associated with oysters Lisa Kellogg presented**
   a. Lisa said estimates of burial have been published, but they are from Newell et al. 2005. She said there is one other Piehler et al. paper where they tested N in the sediments, but it's not yet published; to understand burial, need to know filtration, deposition, and retention (for this credit, long-term burial understanding is needed, e.g., constant concentration in sediment core for x depth); it appears that constant concentration may occur at 10-15 feet; overall she felt it would be reasonable to fill knowledge gaps to calculate a N burial rate.
   b. Panel member mentioned we would have to determine how the presence of oysters enhanced burial (like denitrification, burial is occurring when there are no oysters).
   c. Jeff said a dating method may be needed.
   d. Lynn brought up that this BMP would take years to be credited.
      i. Jeff commented about a range of N concentrations being constant across a reef
      ii. Julie Reichert remarked that BMPs can be annual rates or cumulative; a burial protocol sounds like it would be cumulative.
      iii. Panel member mentioned that the estimate could be based on assumed portion of organic deposits from the oysters will be buried; could be difficult to determine given that this is highly dependent on the site characteristics.
   e. Rich remarked that this is like no-till farmland, to keep carbon in the soil.
   f. Jeff mentioned that in a sediment/ water exchange experiment, 100% of P from oyster deposits were re-released.

7. **Prioritization Exercise**
   a. Panelists prioritized which practice-protocol combinations they felt there was the most science available

i. Conclusion: Panel will first focus on off and on bottom aquaculture and N and P assimilated in oyster tissue and shell.

Oyster BMP Expert Panel Meeting, 3/16/16, 9:00 AM-12:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street, Annapolis, MD and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	In person
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	In person
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Not Present
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person
Guests	**Affiliation**	**Present?**
Carl Cerco	U.S. Army Corps of Engineers	Phone

Action items

1. Lisa suggested that the same table that exists for N assimilation should be made for existing P assimilation studies.

2. Jeff suggested creating a table for information about oyster and shell movement in and out of water bodies.

Meeting Minutes

1. Chesapeake Bay model framework and oyster sub-model

Chesapeake Bay model framework presentation

a. Bill asked during the presentation if clams have been evaluated:
    i. Mark and Lynn commented that these would be *mercinaria* and razor clams for VA and MD, respectively.
b. Suzanne asked about a diagram of the CB model- are there still 3000 cells in the model?
    i. Carl answered no, now there are 11,000 cells and their dimensions have changed.

Oyster sub-model presentation

c. Lynn asked- is oyster mortality constant over time in the model?
    i. Carl answered that mortality is spatially uniform and proportional to biomass for grid cells with oyster bars.
d. Lynn asked- does the model account for disease and salinity?
    i. Carl answered, no, it does not.
e. Lew commented that work is currently underway to update natural oyster bar biomass in the Bay and also to gather information on the spatial extent and amount of aquaculture oyster biomass throughout Chesapeake Bay.
f. Larry asked about light attenuation and oyster influence- is it considered?
    i. Larry asked- is it a one-way removal or are biodeposits resuspended?
    ii. Carl responded- organic particles are not resuspended from any source in the model:
        1. Via follow-up e-mail to Carl from Julie requesting more details: Carl explained that effects of resuspension are captured through deposition. For example, particles which settle through the water column with a velocity of V are settled into the sediments with a much lower velocity, maybe 10% of V.
        2. Carl- Overall, difficult to model resuspension of oyster deposits due to not knowing how local conditions affect resuspension (e.g., bottom type, wave action, tides, reef geometry, etc.); would be difficult to model in a meaningful fashion bay-wide; however, could assign a portion of oyster feces to the water column and a portion to bottom sediments, if desirable.
g. Suzanne- How does the model compute tons of carbon to area related to submerged aquatic vegetation (SAV)?
    i. Carl- SAV is fixed based on observed distribution; SAV gets denser with increasing oyster biomass, but can't speak to area.
    ii. Bill mentioned that there could be low cost methods to determine how much SAV expansion- Talbot County uses drones to conduct aerial surveys to get SAV data;
h. Carl mentioned that model results obey what scientists have observed- greater water clarity results in more benthic production than pelagic phytoplankton; allows for increased confidence that the model is capturing what would be expected in this regard.
i. Carl noted that the model accounted for 8400 individual oyster bars:
    i. GIS data of bars was provided by Katie Hopkins (University of MD, CBP); not sure where oyster bar information in GIS data came from
    ii. Carl- looking to update this data in the model; where are the active reefs (sanctuaries versus harvested reefs)?
    iii. Bill asked whether there has been a recent side scan sonar survey of oyster distribution in Chesapeake Bay?; Lynn and Mark mentioned 1983 data (provided by Gary Smith).

j. Carl mentioned that the oyster sub-model is in the 2005 CBP model code, but it was left dormant in the 2010 model runs:
    i. Lew elaborated that the sense at that time was that oyster biomass was too low to support sufficient water quality improvement and uncertainty concerning disease and future aquaculture was too high.
k. Carl mentioned that oysters likely have a bigger impact on the local environment than system-wide (i.e., increases in oyster biomass would result in a greater benefits in smaller embayments/shallow tributaries when compared to the entire Bay), which studies have demonstrated (Gerritsen et al. 1994).
l. Larry mentioned that if water clarity is one of the major effects that oysters have, it should be better integrated in the Chesapeake Bay model, which should also include resuspension:
    i. Carl agreed that there is a need for water clarity improvement from oysters to be better incorporated into the Chesapeake Bay model.
    ii. Lew mentioned to be careful of double-counting- shouldn't count in model and also count in N and P removal via measurements from aquaculture; Carl mentioned that the model could be used to project aquaculture growth.
m. Larry said if there is a positive local effect on water clarity, then it could provide support for oyster restoration.
    i. Lew asked whether there is any observed data; Larry responded- working on collecting the data now.
    ii. Lynn asked if any publications exist now on localized effects of oysters on water clarity; Mark responded that Richard Dame and Ray Grizzle had made these types of localized measurements.
    iii. Mark asked- if Harris Creek data could provide filter feeder abundance, could it be extrapolated from local to regional effects? Carl answered yes, local measurements could be used to do this.
    iv. Carl- suggested that they could run scenarios for Harris Creek, Little Choptank, and Tred Avon to show oyster effects on local scales where there is good data.
    v. Jeff- there are a lot of ongoing process-based modeling efforts looking to improve or create new model components (Oyster Futures, NOAA-funded Harris Creek project, Mark Brush from VIMS, Jeremy Testa from UMCES); none of these efforts can be done in a timeline of 1 year, but could be used to help improve the model later on.
    vi. Lew- expressed interest in the approach in corroborating the large-scale model with small scale processes.
    vii. Bill- shoreline restoration panel had recommendations that used mathematical models with field verification.

2. Definitions for "scientifically suitable," "sufficient data," and "verifiable"- N and P assimilation protocols for water column oyster aquaculture and bottom oyster planting aquaculture as starting point for conversation:
    a. Lisa said "scientifically" before "suitable" should be omitted since suitable is based on a fundamental part of the biological-related process; more to do with biological feasibility for that particular process to occur in the context of a particular practice.
        i. Chris suggested "suitable for consideration."
        ii. Mark was unsure if this step should include whether processes for a particular practice would be suitable as a BMP versus just whether the process can occur with that practice; for some

combinations it may make more sense for it to be incorporated into the Chesapeake Bay model and not as a BMP.

b. Suzanne asked for clarification about the context of "verifiable"—are we talking about scientifically?
   i. Mark and Chris said that verifiable is an accounting sense when the BMP is implemented; Jeff and Ward agreed and elaborated that step 2, "sufficient science," involves the scientific evaluation.
c. Jeff brought up his thoughts about shell- we could say this should be evaluated in step 2 concerning whether there is enough science to determine the rate at which the N and P would return to the water.
   i. Mark elaborated- we could say yes, that the shell protocols are suitable for consideration based on the process occurring; we could also say yes, that there is sufficient science to determine N and P removal if the shell is not returned to the bay; however, if shell is returned to the bay, then we would need science to say what the dissolution rate would be; in regards to verification, it is feasible to verify the percent of shell returned to the Bay versus what is shipped away by operations.
   ii. Chris felt "verifiable" for shell would be difficult from a regional perspective- shell is taken out of the James River and used for restoration in Lynnhaven could potentially result in an increased load in the Lynnhaven.
      1. Note from Julie Reichert (post-meeting): Appears that movement of shell or even oysters for that matter from one location to another could result in transferring the pollutants and not a reduction- how should this be handled in the reduction effectiveness estimate?
   iii. Jeff said he heard during the Oyster Futures meeting that watermen are concerned that MD shucking houses are sending shell to VA and MD can't get shell- this is another example how shell movement could influence regional differences adding another level of complexity to the crediting of shell.
d. Jeff said that overall it sounds like there is consensus that removal of N and P from oysters related to assimilation is worth investigating (i.e., "suitable for consideration").
e. Lisa mentioned that one study seems low regarding the example definition for "sufficient science," and asked whether there is any guidance about the number of studies from other panels?
   i. Jeff explained that there isn't any standard guidance and it's up to the Panel to reach consensus based on their expert opinion.
   ii. Suzanne and Mark suggested "sufficient science" could include "sufficiently constrained" meaning that the Panel will determine what degree of variance would be acceptable.
   iii. Lisa asked whether sufficiently constrained would also involve the geographic location or the species?
   iv. Mark suggested that we don't limit ourselves to geographic location because there could be an effort to help understand environmental conditions using research from different geographic locations to constrain the denitrification numbers (e.g., C:N biodeposit ratios in the sediment from locations with different environmental conditions could potentially be used to develop denitrification relationships).
   v. Suzanne reminded folks that the numbers recommended from STAC were based on findings from different geographic locations.
   vi. Julie Rose suggested that information be reviewed from other estuaries as long as the review is strictly about oysters

1. Mark said, species-wise, that it would depend on the protocol- when talking about denitrification it's the microbes that do the work, so studies that help understand the rate of denitrification wouldn't necessarily be oyster-specific; however, for bivalves, we would need to know what's deposited and at what rate; for the assimilation protocols it would make sense that it's specific to *Crassostrea virginica*.

vii. Jeff- agreed that assimilation would be specific to *virginica*; other protocols would be more specific to site-specific characteristics (e.g., salinity, temperature), not species; an enhanced denitrification estimate could be a rate or proportional removal of nitrogen.

f. Jeff- Concerning N assimilation in oyster tissue for Water Column Oyster Aquaculture and Bottom Oyster Planting Aquaculture, it would seem that the 2 would have similar considerations; these combinations would be suitable (does occur), there appears to be sufficient science (range of values from studies with agreeable methods), and could be measured for verification purposes (removal via harvesting); panelists agreed.

g. Jeff- Phosphorus assimilation in oyster tissue appear to be similar to nitrogen; however, there appears to be a greater range in values.

   i. Lisa asked, "How many estimates do we have of P in tissue? Isn't it only about two papers (Kellogg and Higgins)?" If remembering correctly, the numbers for either tissue or shell were quite different (varied by 30-50%).

      1. Panelists couldn't think of any papers with additional P measurements; Lisa feels an estimate could be derived similar to N, but we would likely need more measurements if the measurement were in fact that different.
      2. Matt said it still could be verifiable; you could collect oysters and have them tested for P content to determine a number; Julie Rose agrees and said that the framework included identifying data that would be easily obtained to figure out the number.

   ii. Lisa suggested that the same table of existing studies for N assimilation should be made for P assimilation

   iii. Jeff said- sounds like P assimilation in tissue is "suitable" (does occur), need more data to determine the number, but easy to acquire, and would be verifiable (easily measured).

h. Jeff- N and P assimilation in shell can be measured, but the fate of the shell (if it stays removed or returned to the Bay and where) is less known (provided James River to Lynnhaven River example again, see above).

   i. Matt mentioned that it is easy to keep track and keep records of aquaculture shell (how much put in and how much taken out).

   ii. Jeff- do we have to account for different uses of the shell (e.g., commercial source of shell for restoration)? Matt- as long as you can record how much is put in and taken out the source of shell shouldn't matter; mass balance approach could be used in TMDL model.

      1. Chris- It would become really complicated to track across different states in the TMDL.
      2. Lynn- it would be difficult to track from a record-keeping stand point to meet the mass balance approach when shell is being used for public bottom.
      3. Matt- it would easy for water column aquaculture (they already track how much shell they buy and how much they use and take out).

   iii. Lisa brought up that we don't know the decay rate of shell, so how would this be handled from a mass balance approach in the model.

1. Lew said we are data constrained in that we don't know the decay rate of shell, but if we had the data, it could be applied in the model in a highly generalized approach.

iv. Mark- mass balance accounting may be difficult (won't add up) because a lot of shell is bought elsewhere (didn't originate in Chesapeake Bay); therefore you could have a greater load than what is removed (i.e., VA buy 1/3 of shell from out of state from Chesapeake Bay region). Shell is in high demand (identified as a limiting resource) and the amount of book-keeping to track the shell fate would make verification difficult. It may be better to not give any credit.

v. Jeff- giving additional credit for a limited resource could result in the resource being less available in Chesapeake Bay; Mark- agreed and stated that we need to be mindful of the larger objectives of the Bay Program, which includes restoration goals; could say that it's not suitable for consideration because impacts overall goal in the Bay to return shell; Lynn- can we rule it out because it's not practical (we shouldn't incentivize people to throw away shell)?

1. Ward- suitable is more to do with if the process occurs with that practice—N and P is assimilated in shell does occur, so a reduction effectiveness number is possible if there is enough data, but it may not be verifiable due to the complications of tracking where the shell ends up.
2. Jeff- shell has potential net removal of N and P or it's sequestered for a long time, but the accounting of it may be too complicated to do at this time.

vi. Suzanne brought up that there is research that supports long-term N sequestration in shell; Mark commented how removal of N and P in shell might fit better under the burial protocol (would better represent long term removal than uncertainty in tracking where shell ends up concerning its use to implement practices).

vii. Matt- agree with what's being said, but brought up the point that even with tissue, the N and P will likely make its way back via human waste from those who consume oysters, so how far do we want or should take the mass balance approach?

1. Lew- that load will be considered through point sources (waste water treatment plants), so the Panel doesn't have to concern themselves with that; Jeff agreed that the Panel doesn't have to address N and P from oyster tissue returning to the Bay via waste; however, shell is different given it is a source of N and P not being addressed elsewhere.

viii. Chris mentioned that part of the panel charge was to identify "unintended consequences" and that would be where the panel could address the uncertainty of verifying the shell budget and the potential disincentive to return shell back to the Bay if shell was approved as a BMP for N and P removal (in reference to permanent N and P removal)

ix. Suzanne commented that she liked the idea of reviewing information about N and P in shell and determining if sufficient data exist to assign an estimate and then discussing the consequences in the "unintended consequences" section.

x. Jeff suggested making a table capturing information about oyster shell movement in and out of water bodies.

Oyster BMP Expert Panel Meeting, 4/14/16, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Not Present
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Phone
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action items:

1. Julie Reichert and Rich will send panel members materials used during policy subcommittee meeting.

2. Subcommittee that is developing example estimate table will get it to Julie Reichert by 4/22/16.

Meeting Minutes:

1. Coordination updates

a) Chris asked- Does it work to give incremental recommendations, so we can roll out the first set of recommendations in June?
   - Julie answered yes, and a second round of recommendations is possible later.
   - Rich commented that it is important to get some recommendations ready to go.

b) Julie explained the concept of the policy sub-group
    - Rich explained that as the panel is moving forward with technical recommendations, we will be working with the Chesapeake Bay Partnership in the realm of policy.
    - Julie said she would send the panel materials on policy subgroup.

c) Julie explained that she will be giving an update to the WQGIT on 4/25/16, which will include how public comments were addressed.
    - Julie reiterated that public comment are up on the Google Drive
    - Julie explained a few of the public comments. Several were about the unintended consequences of anoxia after deposition of organic matter from aquaculture.
    - Several public comments were also about raft culture vs. cage culture.
        i. Chris commented that surface rafts vs. cage culture look so different- maybe that's why folks have issues
            - Julie asked- N and P filtration between the two would be similar, right?
            - Jeff answered yes, although deposited waste going through the water column may exhibit a small difference given limited circulation when cages are near the bottom. Also depends on the benthic community in the sediment.
            - Ken said that assimilation would likely only be marginally different.

d) Julie asked panel to send her any edits to the definitions by Tuesday 4/19/16.

2. Nitrogen Assimilation Protocols for Water Column Oyster Aquaculture and Bottom Oyster Planting Aquaculture

a) Panel discussed N assimilation figures from STAC report.
    - Ken asked if equations from STAC report (refers to Higgins et al. 2011 data) were missing a power function; Panelist indicated that they used linear regression; Ken said he uses Liddel (2007) as a reference to shell height to tissue dry weight regression equation, which is power function; Panelists agreed that power function would provide a better fit.
    - Mark commented that using wet weights instead of dry weights give values greater variability.
    - A panel member remarked that shell height vs. dry weight correlations are different between different locations; regression analysis should account for this.
    - Ken said oysters grown on bottom may have thicker shells than oysters grown in cages.
    - A panel member said they are not sure if any of the numbers come from triploid oysters.
        i. Ken suggested getting the *C. ariakensis* study data from when it was being debated whether they would be introduced into the Bay; triploid *C. virginica* samples were included in this study and could be used to evaluate triploid growth.
    - Mark suggested that it wouldn't be a huge project to get more shell height to N removal values.
    - Panel members said that the formula for N assimilation needs to be refined according to diploid/ triploid, on bottom/ off bottom, and location.
    - Panel member commented that N and P could differ as a function of dry weight and salinity.
    - Mark mentioned a study by Ruth Carmichael about ontogenetic variation in the N/C ratio, so regression would have to be built for different size ranges.
        i. Mark said Higgins paper should be checked to see if their size ranges are comparable to current aquaculture sizes; panelist checked and confirmed that the Higgins paper covered a range of sizes.

ii. A panel member remarked that if function between dry weight and N is linear, what's driving the equation if how dry weight is related to size.
iii. Mark said he will check to see if there is dry weight to variation between oyster lengths.
iv. Suzanne mentioned she looked at the Darymple and Carmichael paper, and it represents 30-120 mm oysters. Mark remarks that covers the range.
v. Mark asked if that regression equation would be good to use if refined?
    - Jeff answered yes, under the condition that aquaculture farmers have to submit oysters to establish practice/site-specific estimates.

- Mark suggested making a table of estimates reflecting the different ploidy, size ranges, practices, and locations; Jeff agreed.
- Ken brought up the fact that he didn't think the Higgins paper was a reasonable starting point, since the fit would be better as a power function.
- Julie Reichert asked- does the panel think we can develop equations by June?
  i. Jeff mentioned making an example table first described by Mark; several panel members agreed.
  ii. Jeff said he thinks there is sufficient science for a limited size range for diploids.
  iii. Mark said- getting regressions for shell height/length to tissue dry weight would be more samples, but cheaper, while getting dry weight to N regression would be lower variability, and fewer samples, but more expensive.
  iv. Mark said this needs to happen a priori, in advance of people getting credit.
  v. A panel member suggests getting a subcommittee together to build these conversions. Jeff, Lisa, Mark and Ken are on this subcommittee. They will develop an example table.
  vi. Mark commented that this work could be funded, could be a grad student project.
  vii. Julie Reichert asked for an initial draft of the table by Friday 4/22/16.
  viii. Panel members agreed it is important to get this together for the WQGIT meeting 4/25/16.

b) Suzanne and Julie Reichert presented their findings on whether the FARM model output can be directly compared to STAC N measurements; overall conclusion, no.
    - Found that the FARM model does not separate out N assimilated in tissue and shell or size of oysters biomass is associated with; also needs to be calibrated to the specific region and N content needs to validated since it's based on Redfield ratio and not *in situ* measurements.
    - Ended up making large assumptions to compare total N removed from harvestable biomass of total oyster (shell and tissue combined); Julie Reichert/ Suzanne explained that there was a large discrepancy between the STAC and FARM model methods (most likely a result of the model's limitations and large assumptions).
    - Mark commented that modeling approaches may not be a way in which BMP credit will be given, but could be a good planning tool.
    - Lisa brought up that models could be used in crediting sequestration for restoration.
    - A panel member brought up a webinar by Abby Lindstrom.

Oyster BMP Expert Panel Meeting, May 19, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street, Annapolis, MD and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Not present
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Phone
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	Not present

Action items:

1. Conservative N in oyster tissue reduction effectiveness analysis for aquaculture-removed oysters—use quantile regression to examine shell height, dry weight, and N content relationships with available data pooled by certain decision criteria (i.e., grow-out method, ploidy, size class) to determine a conservative estimate.
    a. The goal is to submit an example of this approach by the July 11th deadline for CBP approval and to refine the analysis with all data later on.
    b. ORP will assist in compiling the data next week (aim to send data to Julie Reichert, jreichert@oysterrecovery.org, by Wednesday, May 25th)
    c. Lisa will send her data (Kellogg et al. 2013) and look into getting the Ross & Luckenbach unpubl. data.

d. Ward will reach out to Ken to see about getting the Liddell, 2008 and Paynter & DiMichele 1990 data.
e. Julie Rose will contact Kurt Stephenson about getting the Higgins et al. 2011 data.
f. Data of interest includes shell height, dry weight of tissue, and N content. Include metadata and units.
g. Data that is acquired will be compiled and sent out to Panelists to do mock analyses to demonstrate the analysis approach. Julie Rose, Lisa, Jeff, and Larry have volunteered to develop analysis example with the data. Suzanne and Chris offered to tentatively look at the data.

2. Jeff will write up the unintended consequence section concerning heavy biodeposits from floating water column aquaculture.

3. Julie Reichert will write up revised decision framework section.

4. ORP will reach out to Panelists who weren't present during this meeting to go over strategy in action item 1.

Meeting Minutes:

1. **Coordination Updates**
    a. Document being drafted to respond to public comments on the April 25th WQGIT update.
    b. Step 2 of decision framework was modified to clarify that this is the Panel's process to determine the reduction effectiveness recommendations.
    c. Panel Report Timeline:
        i. Decision: 1st set of recommendations will include N assimilation in oyster tissue for water column and bottom oyster planting aquaculture to be presented to the WQGIT on July 11th. P assimilation in tissue and shell assimilation protocols will be moved to the 2nd set of recommendations.

2. **Nitrogen Assimilation in Oyster Tissue for Water Column Oyster Aquaculture and Bottom Oyster Planting Aquaculture**
    a. Lisa presented evaluation by Mark, Ken and her on an approach to address knowledge gaps to determine the Shell Height to Dry Weight conversion and N content. Findings included:
        i. Triploid data is lacking.
        ii. High variation in the shell height to biomass regression equations.
        iii. Shell height to biomass equations mostly based on ash-free dry weight; dry weight is better to relate with N content in tissue.
        iv. Studies to fill shell height to biomass to N content knowledge gaps focused on commercial sites because researchers may not grow oysters the same way.
        v. Approach focused on addressing the shell height to biomass uncertainty because it is cheaper to measure shell height and dry weight than it is to measure N content (~$35 for one oyster and would need probably more than 100 oysters to establish the shell height to dry weight to N content regression with $r^2 \geq 0.80$)
        vi. Intent of knowledge gap studies would be for practice scenarios where data doesn't exist (e.g., triploids).

b. Julie Rose- emphasized after meeting that existing N content data is more tightly constrained than the shell height to dry weight relationship, so there is much less uncertainty in assigning a value based on existing data.
c. Lew and Larry suggested an approach that would determine a conservative equation/reduction effectiveness number (see action item # 1).
    i. The Panel agreed on this approach and decided to use it to determine the reduction effectiveness. They also agreed to describe different pathways to refine the conservative number, if so desired:
        1. Pathway A: BMP implementer conducts their own analysis to determine the reduction effectiveness of their practice following the methodology guidelines provided by the Panel to be submitted to CBP for approval.
        2. Pathway B: A comprehensive study is done to fill the knowledge gaps needed to refine the reduction effectiveness for the oyster practice category so that practices within the category could use these refined numbers without having to conduct their own analysis. Guidelines for the study will be provided in the Panel report.
d. Suzanne- how often are triploids used in aquaculture practices
    i. Matt- in MD, diploids makes up the majority of acres for spat-on-shell on bottom aquaculture
    ii. Chris- in VA, water column aquaculture uses mostly triploids; a few on bottom spat-on-shell operations use triploid oysters, but given that they are more expensive, diploids are typically used; all in all, it comes down to cost concerning what is used.
e. Chris- it would appear there may be enough data to establish a conservative reduction effectiveness number for diploids, but not triploids.
f. Larry- A low end conservative number wouldn’t necessarily be the best number, but it would give people a way forward; may help incentivize folks to support efforts to determine a better number.
g. Matt- Informed group of a study being done at Horn Point in testing oyster growth in different containers. Not for this Panel effort, but it could be worthwhile to collaborate with such groups to see if the N content could be analyzed for some of the oysters.
h. Julie Rose and Bill- Need to provide guidance on how long numbers would be good for (when should they be re-evaluated).
    i. Usually BMP inspections happen every 5 years.
i. Jeff- Given limited time, can we provide the recommended approach to be approved with an example of how it would be calculated and then refine the equation/#s once the data analysis is complete.
    i. Lew- Felt that this would be ok. The Panel could leave place-holders for where the final recommendations would be inserted based on the approach.
j. Lisa- Recommended that the 10^{th} percentile be evaluated for the conservative equation/number.

3. Unintended consequences-heavy biodeposit discussion

a. Jeff- presented results from various studies; some studies should an increase in ammonium while other showed no negative effect; Jeff mentioned that studies that showed an increase in ammonium didn’t take into account where the material came from and what would the ammonium concentrations be without the oysters filtering.
b. Panelists agreed that this unintended consequence could occur with floating aquaculture, but unlikely with near bottom cages or bottom spat-on-shell practices.

c. Julie Rose- in New England, bottom type/quality is taken into account during the aquaculture lease permitting process; could this potential unintended consequence be managed through the permitting process?
    i. Matt and Chris- Currently, both MD and VA do not require bottom type or flow to be measured for the permit.
d. Jeff- verification that the sediment/water quality is fine could be done using photos of sediment cores under floats in comparison with a nearby control (no floats); black sediment would indicate that the practice may be causing poor water quality.
e. Mitigation approach would include rotating the floats so that the bottom is not overloaded with biodeposits.

4. Panel did not have time to discuss shell-related protocols; it was decided to move these protocols to the 2nd set of recommendations and to focus on finalizing decision framework and the N assimilation in oyster tissue/water column and bottom aquaculture combinations for the 1st set of recommendations.

Oyster BMP Expert Panel Meeting, June 16th, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Follow-up call on 6/21/16
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Follow-up call on 6/21/16
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Follow-up call on 6/21/16
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	In person
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Follow-up call on 6/21/16
Bill Wolinski	Talbot County Department of Public Works	Follow-up call on 6/20/16
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action items:

1. Lisa: Send request for triploid data from Kingsley-Smith.
2. Coordinators (Julie Reichert, Ward, and Emily):
    a. Incorporate new information into the analysis spreadsheet and send to data sub-group (Julie).
    b. Draft report for 1st set of recommendations (Julie, Ward, and Emily).
    c. Schedule meeting to update panelists that weren't at the meeting (Julie).

3. Data subgroup (Julie Rose, Lisa, Ken, and Mark): Finalize data analysis for shell height to dry weight regression.
4. Jeff: E-mail Julie Reichert webinar dates that would work for him.

Meeting Minutes:

1. **Coordination updates**
    a. Mark asked if only the 1st set of recommendations are going to be discussed in the webinar (N assimilation in oyster tissue for removed oysters for water column and bottom oyster planting aquaculture); Julie confirmed yes.
    b. Julie explained that in the recent policy meeting with the management board, the group was not sure if it is legal in the current Clean Water Act water quality standards from to consider sequestration or sediment deposition in the reduction effectiveness for an in-water BMP.
        i. Suzanne asked- is that because it's technically not being removed from the water? Julie answered yes.
        ii. Panelists agreed to put on hold any protocols to do with nutrient sequestration and sediment disposition until legal questions are answered.
        iii. Since shell may not be returned to the Bay (not sequestered), the panelists agreed to continue determining the assimilated nutrient reduction effectiveness in oyster shell for their 2nd set of recommendations.

2. **Nitrogen assimilation in oyster tissue protocol for removed oysters via aquaculture- shell height to tissue dry weight relationship discussion**
    a. Julie Reichert began the discussion with a PowerPoint that showed that there are over 7,700 data points obtained for the shell height to tissue dry weight regression across various grow-out approaches, locations (environmental condition), and seasons. The only big gap was no definitive triploid data.
    b. Lisa Kellogg presented analyses on data source and season. She looked at regressions where there were 100 or more data points.
        i. Conclusion: Given that most of the regression data were from the summer and the highest biomass per size class was in the winter, the 50th percentile is expected to be a conservative estimate even though there is less winter data.
        ii. Suzanne asked for clarification- when Lisa says 'expect' she means that's based on data, correct? Lisa and Ken said this is an observational conclusion from the data (not statistical conclusion).
        i. Mark commented that the seasonal category fits the data, but ploidy could confound other factors (e.g., practice type- water column aquaculture in VA is predominantly triploid oysters)
    c. Matt asked if the data had been broken out to look at just aquaculture versus restoration reefs for tissue dry weight to shell height relationships.
        i. Ken said the variability was small enough to be ignored.
        ii. Lisa added that only two studies included just aquaculture that had more than 100 data points, so there wasn't a good distribution to separate it out.
    d. Matt asked if he could get the shell height to dry weight measurements for an aquaculture study he is starting for triploids whether that would be helpful.

i. Ken responded yes; Matt responded that he will start collecting the data in a month or so. Given the lag time, it won't be ready for the 1st set of recommendations, but he would be happy to supply it to the panel to help with any updates to the recommendations.
ii. Julie Reichert added that the BMP Review protocol asks for a timeframe to be given in which estimates will be reevaluated.

e. Lew commented on the analysis and rationale table, and suggested that the Panel includes the table and explanations for how recommendations are conservative in the report. He also commented that we may not fall into the category of a BMP with rapidly changing technology, so a timeframe of 10 years may be appropriate.
   i. Mark disagreed on the timeframe for certain aspects of the recommendations- with almost all data being from diploids, there would be a need to re-evaluate sooner when triploid data is acquired.
   ii. A panel member also noted that only ~14% of the data came from aquaculture.
   iii. Julie Rose informed the group that they could analyze N content for triploid oysters over the summer; they would just need to know how many oysters from which locations.
   iv. Panel agreed that 5 years would be a good timeframe for reevaluation; would allow time for new data to be collected.
f. Lisa turned over the presentation to Julie Rose, who talked about quantile regression. She explained how the regression worked, noting 50% of the data are above and below the line for the 50% quantile, while 10% of the data falls below the 10th quantile, etc.
   i. Julie Reichert informed the panelists that they will be working with the Watershed Technical Workgroup on a technical appendix to incorporate the recommendations in their modeling framework for the TMDL; she said this approach would likely be straight-forward to incorporate into the scenario builder portion of the model.
g. The panel members evaluating the data for the quantile regression reported to the other panel members that in a prior meeting, that they agreed that the 50% quantile would be conservative based on the analysis that Lisa did.
h. Julie asked how would the standard error be incorporated? Ken said they're comfortable with the error; Mark agreed the regression was tight.
i. Suzanne asked, why does 50% make sense? Mark and Ken answered, and Julie Rose also added that when looking across all datasets and categories, there was good spread in the data, no bias of winter, and that over-crediting and under-crediting are balanced.
j. The panelists reached consensus and agreed to use the 50% quantile for the shell height to dry weight regression.

3. Nitrogen assimilation in oyster tissue protocol for removed oysters via aquaculture- % N content discussion

a. The discussion opened with talking about the 8.5 ±0.6% average from Lisa Kellogg's synthesis for the Atlantic coast.
   i. Panelists agreed that this number would be conservative given that the data is tightly constrained.
b. Julie Reichert asked- since there is no N content measurements specifically for triploids, what numbers should we go with?
   i. Matt said- isn't it conservative to use the diploid N content to apply to triploids, since there is likely more N in triploids year round?

    ii. Mark answered- there are seasonal biochemical changes happening in triploids, but he's not sure how that affects N content.
    iii. Panelists commented that since triploids are not putting anything in reproduction, their growth is likely more than diploids, therefore, using the 50th quantile offers a conservative approach since triploid oysters would likely be above the 50th quantile.
    iv. Lisa mentioned a Roger's report that she thought stated that triploids contained more N? Mark remarked that the panel should make recommendations on the conservative side even though triploids could potentially have more N.
  c. Mark brought up- why isn't phosphorus being included in the 1st set of recommendations? Seems like a low hanging fruit.
    i. Julie Reichert said because there were fewer data sources for it than N, thought that it would require more discussion. Lew said seems like we should consider it, Matt agreed.
    ii. Julie and the panel decided that they should make sure that the N recommendations get out the door, so if including phosphorus will hold them up, they should postpone it, but if possible, they will include P recommendations in the 1st set of recommendations. If there's not enough time, then it will be included in the 2nd set of recommendations.
  d. The panelists reached consensus to use the 8.5% for both diploid and triploid oysters.

4. Discussion on Outstanding Items for Report
  a. During policy meeting, it was decided by management board that crediting would only be for new oysters that are removed after the BMP is approved.
    i. No back calculation on what aquaculture has already removed.
    ii. Panelists felt that oysters that are in the water now should also be allowed to be credited if they are removed after the BMP approval date.
    iii. Julie reminded the panel that the policy subgroup provides the Panel guidance, but if they don't agree then the Panel can include a different recommendation.
  b. The panel discussed using grow out sites and how they would be handled.
    i. Credit should be based on grow-out location and not relay location. Oysters should have spent the majority of their lives in the location where credit is given.
    ii. For Bottom Oyster Planting Aquaculture, only include practices on bottom leases in 1st set of recommendations. For public fishing grounds, evaluate in second set of recommendations given the issue on differentiating between wild strike and what was planted.
      1. Lisa brought up if this model is used in an area with a lot of wild strike, how easy would it be to differentiate? Don't want to be crediting a wild fishery for naturally occurring oysters.
    iii. Matt suggested that a public fishery/ private enterprises section be added to the BMP report.
  c. Panelists discussed verification reporting
    i. Include year planted, date removed, number of oysters removed per size class, grow-out location, and relay location.
  d. When should recommendations be reassessed?
    i. Panel suggests 5 years. Matt says that gives us time to collect new data.
  e. Ancillary benefits- Bill was interested in seeing if fouling on cages qualified.
    i. Mark brought up that in NH, cages are washed off on land.

ii. Several panel members agreed that fouling is bad and generally growers are attempting to keep it off their cages; however, they can mention that there may be additional nutrients removed if not washed back in the water.

6/21/16- Follow-up call with panelists that missed the meeting

1. Use of 50th Quantile Regression Equation
    a. Panelists were in agreement.
2. Use of 8.5% N content in oyster tissue
    a. Panelists were in agreement.
3. Reporting
    a. Lynn- MD aquaculture operations are required to report where they grew oysters and if moved to different location to relay. Also they are required to submit a business plan.
        i. Karen- VA does not have this level of oversight/reporting.
    b. Panelists expressed concern of including when oysters are planted
        i. Karen- this will be very difficult to track
4. Qualifying Conditions
    a. Lynn- agreed that for now the public fishery areas should not be included given the lack of accountability measures/requirements to track what's harvested from the public fishery.
        i. Every year MD provides counties with spat-on-shell from hatchery to put on public fishery areas for grow-out and eventual harvest.
5. Verification
    a. There is a paper trail for the # of seed/spat that is sold from the hatcheries. Could use as a form of verification that the oysters were in fact planted at a size less than

Oyster BMP Expert Panel Meeting, July 14, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Not Present
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Phone
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	In person
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Phone
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	phone
Emily French	Oyster Recovery Partnership	In person

Action items:

1. Julie Reichert- set up Panel meetings past August 2016; set up Panel follow-up meeting to finish discussing items from this meeting.
2. Julie Rose- Run growth factor quantile regression analyses for the triploid dataset where data is available to see if there are similar trends as the diploid data.
3. Mark will re-evaluate and suggest a size class table to use.
4. Julie Rose, Mark, and Lisa- Run analysis to determine how many oysters should be sampled to determine the site-specific average biomass.
5. Ken and Suzanne will look up documentation to define the standardized method for measuring oyster tissue dry weight for the site-specific methodology.

Meeting Minutes:

1. **Coordination updates**
   a) Julie talked about the new schedule
      i. Suzanne asked if Julie would be setting up future meetings past August; Julie said yes.

2. **Julie presented outstanding items panelists need to reach consensus on for discussion**
   a) Julie Reichert asked about whether the triploid data should be separately analyzed from the diploid data or should it be combined concerning the application of the 50th quantile regression.
      ii. Ken said triploid data has advantages to being considered separately, and said if data show that triploids have greater biomass at smaller sizes then it should be credited that way.
      iii. Suzanne and Ken commented that the error differences is driven by sample size.
      iv. Mark added that the experiment the triploid oyster data came from featured large cages, high, medium and low salinities, Asian oysters as well as Eastern oysters, took place in VA and MD, and involved a large number of oysters; so the data captures the variability from a wide salinity range and wide geographic range.
      v. Mark noted that even slow growing oyster data points are above the diploid oysters; Mark said people who work with triploids know there is more biomass in them.
      vi. Ken agreed that the experiment from which the triploid oyster data came from was well organized and encompassed a wide geographic range.
      vii. A panelist suggested the recommendation could possibly be made to exclude data outside the range industry would be harvesting.
         a. Julie Reichert noted that since this is a BMP, it's not necessarily just when oysters are harvested for human consumption, but could also include oysters that are grown/removed for water quality benefits.
      viii. Julie Reichert asked whether there was consensus on having two different equations, one for triploid and one for diploid oysters.
         a. Ed asked- is there any way to run an analysis to get a bottom line to see how much of a difference it'll make? Mark felt that it wouldn't make much of a difference when looking at the big picture.
         b. Bill said since we're looking at different practices, this gives us better sensitivity for those practices.
         c. When looking at the regression, Ken asked whether the 2.36 or 2.37 exponent for diploids is correct given that their data has shown greater exponents than that.
         d. Julie Rose responded and explained that quantile regression uses the median and not the mean, so it would be less influenced by extremes, hence the different number. Mark agreed that the median is better to use.
         e. Consensus was given to separate diploid and triploid data.
      ix. Ken said he would suggest a difference be calculated in N assimilation/ dry weight and apply that to different salinities.
      x. Larry reminded everyone that breaking this down into several equations will ultimately not be helpful.
      xi. Ken stated that he thinks there are too many categories in the habitat groups for the location analysis.

a. Ward stated that the habitat analysis was to do our due diligence in considering different environmental conditions that could influence oyster growth, which gave rise to the different habitat groups.

xii. Julie asked, are these estimates conservative?

a. Julie Rose made a comment that the people who would be most concerned would be the ones worried about over-crediting. She suggested putting in the appendix where deviations occur in the negative direction (i.e., summer data); however, any over-crediting would likely be canceled out by the under-crediting.

b. Julie Reichert mentioned that taking a conservative approach would likely ease public concerns. Ken stressed that we just have to make sure the recommendations are defensible.

c. Matt asked, could the data analysis be rerun with the triploid distinction?

i. Julie Rose said she could rerun the analysis, but due to the smaller sample sizes it may be difficult to do the quantile regression on all the separate factors.

ii. Mark said it's likely not needed because the Kinsley-Smith study itself addressed many of these factors and to instead reference that; we can show examples with the diploid dataset.

xiii. Mark asked if the report has appendices so we can include the consideration details on the factors that influence oyster growth; Julie Reichert answered yes, and that is how the current draft is structured.

b) Size classes

i. Mark said that midpoints commonly measured by aquaculturists should be used to define the size class ranges.

ii. Julie asked- for site-specific method, which size classes should be analyzed? A panelist mentioned that an agreement with the jurisdiction is needed if default size classes are not used.

iii. Lew commented that the Bay Program wears two hats, encourages useful trade programs and tracks pollutant reduction regardless is someone gets involved with trading.

iv. Mark agreed to have flexibility for different size categories.

v. Ken mentioned that if the market goes down, ecological benefit goes up (oysters are left in longer).

vi. Bill said whether or not it's aquaculture, there is an incremental benefit.

vii. Mark said- to avoid any confusion, take words like 'petite, jumbo' out of the table.

viii. Matt mentioned that he heard from multiple growers that 4" is too big to buy.

ix. Ken would like a mean in the size class table; Mark pointed out that the midpoint of the size range is being used; Ken was ok with that.

x. Mark says he suggests dropping the oyster size class words, and calling them size class 1, 2, 3, and 4, for example. They can ID which size class they want to market in. Also to have more smaller size classes available.

xi. Ken said he suggests making over 100 mm a category; would allow growers to grow this size range for ecological benefit for credit.

xii. Mark said he will think about a table and splitting it into different size ranges.

c) Julie Reichert asked about consensus on the methodology to determine site-specific N reduction estimates

a. Ken said we have incorporated data that captures variability, people can show their own averages if they want, but this is our best estimate.

b. Mark, Lisa, and Julie Rose offered to run a statistical test to see how many oysters should be measured to establish the site-specific average biomass per size class category.
c. Panelists discussed having a certified lab to measure oyster shell height and tissue dry weight; measure using standardized method (Ken and Suzanne will send info on this).

3. Meeting Wrap-up

i. Julie asked is folks were available for a call the following week to wrap up items that still need consensus, since a draft of the report is needed for review in August; panelists agreed.

Oyster BMP Expert Panel Meeting, July 25, 2016, 10:00-11:30 AM

Location: Remote conference; no in person option

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Phone
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Not Present
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not Present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Not Present
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Phone
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Not Present
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	Phone
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Phone
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Phone
Ward Slacum	Oyster Recovery Partnership	Phone
Emily French	Oyster Recovery Partnership	Not Present

Action items:

1. Julie Reichert- Re-send phosphorus content in oyster tissue literature.
2. Panelists- Review literature and decide whether there is sufficient science to include assimilated phosphorus recommendation in oyster tissue.

Meeting Minutes:

1. **Nitrogen Assimilation in Oyster Tissue Protocol—Removed Oysters via Water Column and Bottom Lease Oyster Planting Aquaculture practices**
    a. Consensus discussion on separate diploid and triploid regressions (shell height to tissue dry weight).
        i. Julie Rose- Presented diploid and triploid regressions.
            1. Clear difference with triploids having a much steeper curve.

2. Mark- Error larger than diploid, but this is a function of s smaller sample size and more spread at bigger shell heights; shell height 100 mm and below there isn't as much spread (these sizes are more representative of aquaculture); Panel agreed to use separate diploid and triploid equations for the estimates.

b. Consensus discussion on oyster size class categories.
   i. Mark- Discussed his and Karen's evaluation of oyster size categories and how categories should encompass aquaculture oyster sizes; Mark- changed his mind that there should be more detailed categories since industry will not be able to measure at smaller categories; broad categories makes more sense based on midpoints that are typically measured
      1. Slight adjustments so midpoints are whole numbers (3, 4, 5, and 6 inches), except first smallest category of 2.0-2.49 (midpoint of 2.25 inches)
      2. Panelists agreed that credit should not be given to oysters that are less than 2 inches.
      3. Ed- asked for confirmation that the 6 inch midpoint would be used for any oysters larger than 5.5 inches; panelists answered, yes, this is correct.
   ii. Consensus discussion on site-specific estimate method
      1. Mark and Julie Rose- discussed their evaluation of the variance and how many oysters may be required to establish a reasonable relationship between shell height and dry tissue weight; 50 oysters was what was recommended.
      2. Ward- Asked if this approach was to define the number of oysters to build a separate regression or an average dry weight to shell height, and would they still apply the 8.5% N in the tissue that the panel recommended.
         a. Mark explained that it would be used to establish the average dry weight of that particular size class and the default % N and P contents would be applied.
      3. Group- There was some discussion about the practicality of implementing option 2. Most agreed that it would be unlikely that it was used.
      4. Julie Reichert summarized the second option- Operation will establish size class categories with reporting jurisdiction and CBP, use a sample size of 50 oysters as the standardized approach to obtain the average tissue dry weight of size class category; average tissue dry weight will be measured using standardized procedures from certified lab and submit results to the Chesapeake Bay program (who may send out to third party for review). This would provide site specific estimates for that practice; Panelists agreed.
      5. Lew- Pointed out that the State's would be the parties to evaluate the site specific data.
      6. Group- Agreed that the differences in seasonality likely negligible, so site-specific estimates can be derived from one season.
   iii. Qualifying condition- Time lag for credit? What is the cutoff for majority of time in location?
      1. Lew- don't have to worry about time lag since credit is applied at harvest; time lags more in reference to decadal timescales; not appropriate for oysters.
      2. Matt- Can't we estimate within an oyster size class, how many are removed from the location?
      3. Ken- Relaying can be substantial. Need to be cautious of how long oysters are in a location.

4. Chris- Relaying typically refers to moving oysters from closed condemned waters to open waters; instead, how about using the terminology "transferred" to a different location; Panel agreed.
5. Group decided to partition credit between initial grow-out location and removal location if different based on final number of oysters harvested.
6. Ken- Would there be no credit for oysters moved outside of the Chesapeake Bay and grown in another estuary (Chincoteague)?
   a. Group agreed that portion of time in Chesapeake Bay would receive credit by determining the size class oysters were at when removed and using that estimate.
   b. Ed mentioned it would still be good to know the amount for Chincoteague since there is a TMDL there as well.

iv. Reporting recommendations
1. Chris- Is aquaculture reporting monthly in MD as it is in VA; Ward, yes.
2. Parameters- year planted, date removed, size class.

2. Percent Phosphorus Content in tissue

a. Ran out of time during this call to discuss; Panel agreed to review literature and discuss via e-mail; need to decide if there is sufficient science to include phosphorus recommendations.

Oyster BMP Expert Panel Meeting, 8/18/16, 1:00-3:00 PM

Location

Oyster Recovery Partnership, 1805A Virginia St, Annapolis, MD 21401 and remote conference

Attendance

Panelists	Affiliation	Present?
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Phone
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Not present
Andy Lacatell	The Nature Conservancy (TNC)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	In person
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Not present
Bill Wolinski	Talbot County Department of Public Works	In Person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In Person

Action Items:

1. **Panelists-** Review new oyster practice categories; consensus via e-mail.

Meeting Minutes:

1. Coordination items

a) Matt asked- is the webinar on Sept 22nd public? Julie Reichert answered yes.

2. Oyster Practice Categories- Concern over grouping public shellfish fishing areas under aquaculture

a) Julie Reichert suggested two options on how to modify the oyster practice categories; to remove aquaculture from bottom oyster planting and have subcategories, or to have 6 categories.
   i. Matt contributed that having six categories would be simpler to comprehend, no one could miss a main category, but could miss a subcategory; he liked the idea of having aquaculture and stock enhancement separated into their own categories.
   ii. Lynn said there are nuances, like MGO, and when MDE closes an area because of water quality issues, etc. She said when talking aquaculture, refer to it as "leased bottom." People may be confused because the practice says aquaculture, but then talks about an area closed to fishing.
   iii. Mark added he would also add "from leases" (bottom or water column) and agrees with the 6 categories suggestion. Mark had ideas for reordering the categories also, which he sent to the group during the meeting. Mark said moving wild seed around is still part of the public fishery.
      a. Matt asked- from one leased bottom to another leased bottom?
      b. Mark commented- there are people with leased bottom in the Great Wicomico that put shells out for wild strike, and then move to the Rappahannock for grow out. He said we should have clear separation for management purposes for moving wild fishery oysters to grow out.
      c. Lynn said one clear difference on the management side is accountability. A panel member commented that that's more management than science, and perhaps not necessary to make distinction,
      d. Mark said a row should be inserted between C and D for wild seed oysters planted on and removed from leased bottom.
      e. Matt commented that in a previous version of the categories there was a column for wild set and it was removed. Matt said we should include oyster practice of grabbing oysters from closed areas and taking them to private lease for harvest.
      f. Mark said that's not the only time it happens; historically shucking house leaseholders would move wild strike ("seed bed"); "bottom planting of wild seed oysters for harvest."
      g. Bill said it looks like category B includes what the group is talking about. Mark said since the initial discussion, management could take that category and interpret it how they want.
      h. Chris- agreed with Mark; there are big differences between these two categories, and we are charged with giving managers the best information available. Matt agrees.
      i. Julie Reichert summarized that the con of adding more categories is a more complicated matrix, while a pro of having it separated out is that it may make it easier to implement for managers.
      j. In the end, the Panel agreed to have more categories, with transferring of wild oysters as its own category.
      k. Julie asked everyone to review the categories and adjust to see where the new wild seed category will go. Matt said the new practice fits in with categories A and B.
   iv. Julie said the final consensus will be done via email on the new categories.

3. Nitrogen and Phosphorus Percent Content

a) Panelists agreed there was sufficient data to recommend a default % P content in oyster tissue.
b) Julie Rose's approach to deal with data outside of Chesapeake Bay- Average sites from studies outside of Chesapeake Bay, leave site specific data from Chesapeake Bay. This makes for a value of 8.24%.
   i. Panelists liked this approach so that non-Chesapeake values would not dominate the outcome.
   ii. Julie Rose commented- the variability in the data is quite low across the Atlantic coast.

iii. Julie Reichert asked, two decimal places or one? Group decided one. So, 8.2% for N, 0.9% for P using same averaging method.

4. Application and verification of estimates

a) Julie explained details related to movement of oysters (partitioning of credit).
   i. Matt said seems logical, but what about survivorship; what if some of the oysters die after being moved?
   ii. A panel member remarked that we're not counting number of oysters from location 1, just the ones from location 2.
   iii. Mark-oysters would have to be alive when removed.
   iv. Matt asked- is there a permit required to move oysters?; Lynn said yes.
   v. Matt asked what about from a lease to another lease? Lynn said yes.
   vi. Panelists agreed to use the proposed partitioning method based on alive oysters removed from final grow-out location as long as oyster size class is known from initial grow-out location (based on measuring 50 oysters)

b) Ward talked about unit of measurement. He said for aquaculturists using bushels or boxes as the primary way of reporting, subset of oysters (50 oysters per size class) should be measured when they are harvested to determine appropriate size classes to apply.
   i. Matt had a question for Lynn, does MD DNR count by individual, bushels, containers, etc.? Lynn said that it depends, but usually by bushels. A panel member commented that the standard is 275/ bushel, if aquaculturists wanted to do more work to show there are more or less, that's fine; if size classes aren't determined (lacking measurements) the they would get a minimum number (based on unit definition set by the reporting jurisdiction).
   ii. Chris brought up MD vs. VA bushels; there is a difference.
   iii. Ed asked- what's the variability in sizes in a bushel? Matt said for Asian oyster study, 275/bushel were market size (76 mm).
   iv. Julie Rose- Does length to tissue dry weight vary seasonally? Is there any difference between summer and winter? Yes, there could be a difference. Julie Reichert- suggested twice a year, 50 oysters per size class being reported in per 2 seasons as a verification check; Panelists agreed as long as the seasons are ~6 months apart.
      i. Lynn had commented that sizes could be different depending on season; Maryland allows smaller oysters to be harvested in the Spring/Summer/part of fall compared to other times in the year.
   v. Matt said not a lot of aquaculturists are selling 2.5 inch oysters.
   vi. Mark said VA has no minimum size for aquaculture oysters.
   vii. A panel member asked if aquaculturists are micromanaging size classes; is 50 oysters reasonable to measure for a verification check? All agreed yes.

c) Reporting
   i. A panel member said without certain information, default numbers cannot be used; Panelists agreed if verification checks are missing then minimum legal size could be used and unit definition of the reporting jurisdiction.

Oyster BMP Expert Panel Meeting, September 15, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	In person
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Phone
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Not present
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Not present
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not Present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action Items:

1. Jeff- provide new language for what is meant by "highly efficient" for burial.
2. Lynn- provide how many oysters in bushel for MD example.
3. Bill- write text for biofouling research section.
4. Emily- draft ancillary benefit section based on studies sent by Panel.

5. All- review revised report and send comments to Julie by 9/20/16.

Meeting Minutes:

1. Coordination updates

a) Julie talked about the webinar (date: September 22nd from 1:30-3 PM) to debut the first set of recommendations, mentioned that the report will be posted on the Chesapeake Bay Program calendar page.

2. Oyster practice categories

a) Julie Reichert asked the panel about the addition of a column in Lisa's table for another oyster practice category, and asked if they felt that captured all the oyster practices that could occur.
    i. Mark asked if Julie Reichert could summarize any additional info received.
        a. Julie- Lisa is suggesting we separate out use of propagated oysters and use of wild oysters into their own practice categories within harvest from private leases, harvest from public grounds, and sanctuary creation. Also add 1 additional oyster restoration category to capture passive oyster restoration (sanctuary creation without adding substrate or spat-on-shell
        b. Panelists agreed to add the additional practice categories.
    ii. Lisa also expressed that certain practices shouldn't be considered a BMP when there is no enhancement activity; Lynn agreed enhancement must be taking place for the reduction to be credited; a panel member brought up moving oysters; would one area be enhanced at another's expense?
        a. Jeff wondered whether there would be a hole in ecosystem services left by moving the oysters.
        b. Mark gave the example of 'seed beds' areas where high concentrations of seed are moved to lower salinities, and said in this example oyster production could actually be increasing.
        c. Larry advocated to include all categories as possibilities, let implementers decide if they want to use them
        d. A panel member expressed that in order to know the difference concerning ecosystem services, one would have to know their growth and survival in the original place, which is difficult to do. Therefore they said this practice should not be recommended
        e. In the end, the Panelists agreed to not endorse movement of wild oysters from one location to another because it would be taking away from one area (i.e., transfer where N and P are assimilated; does not enhance reduction).
    iii. Julie Reichert- with changes, there are now 96 oyster practice-reduction effectiveness protocol combinations; Jeff said we will only focus on the categories that are endorsed; Suzanne agreed.
b) Suzanne asked- Are there differences between propagated/ hatchery-produced oysters?
    i. Julie Reichert- the term propagated was used because wasn't sure if the word hatchery meant State-run; didn't want to exclude oysters from private producers.
    ii. Mark- Virginia private hatcheries fuel aquaculture. Maryland has a State hatchery and has been slowly growing private hatcheries; VA has private hatcheries and private leases; Mark- asked if we can change "propagated" to "hatchery-produced."

iii. Lynn suggested adding hatchery-produced in definition section and including that it refers to oysters from private and State hatcheries; Panel agreed to change "propagated" to "hatchery-produced" and add to definition section.

c) Bill asked whether there are remote setting operations with wild oysters as there are on the west coast of the US? Yes, but oysters are moved to restoration site.

d) Panel discussion on which practices to endorse
   i. Mark said it would be difficult to find bars that haven't had shell added via state enhancement programs. A panel member asked, if the state is enhancing the bar, is everything that comes off of it credible for BMP?
   ii. Chris said column 6 (public fishery, substrate addition) shouldn't be endorsed; there is no way of telling how much additional substrate added to oyster harvest; Lisa- if we say that, do we say the same for spat-on-shell since we don't know what's hatchery produced and what's wild?; Chris- we'd have to talk about it more to figure out whether to endorse as a BMP.
   iii. Chris- there is a gray area as to what's enhancement and what's not.
   iv. Julie Reichert- suggest we move this discussion to a future meeting, since public fishery practices will be in a different report.
   v. Panel agreed to endorse off-bottom and on-bottom using hatchery-produced oysters and on-bottom substrate addition because there being an enhancement activity that could result in the production of additional oysters.

Review of items that outstanding from report. Numbers below correspond to document Julie Reichert supplied to panel coordinators.

1. Panel agreed with new restoration text.
2. Panel agreed with summary section.
3. Ken will be emailed to figure out what affiliation he wants in a table in the report.
4. Suzanne- mentioned that there are also positive unintended consequences; Panel agreed to define that unintended consequences refer to negative ones and the term "ancillary benefits" refers to positive ones (matches terminology in BMP Review Protocol).
5. Decision- Panel not further evaluating oyster practice combinations that are not endorsed.
6. Panel members agreed to the addition of "State" in step 2 of framework
7. Panel reached consensus on which oyster practice categories estimates apply to: A, B, and D or revised table (off and on-bottom using hatchery-produced oysters and substrate addition for private oyster aquaculture).
8. Panel members talked about no gear on the bottom, resolved the question of whether to include on-bottom wild seed oyster stock enhancement (not endorsing).
9. Panel confirmed text written in category C, on bottom wild seed oyster aquaculture. Mark commented that he knows of people who have leased ground, get a lot of strike and then move to lower Rappahannock; non-issue now since Panel is not endorsing this practice for application of reduction effectiveness.
10. Which state practices occur in was resolved- panel decided to remove text, describe practice itself, and remove "more in VA than MD."
11. Broodstock addition text- will resolve in future report.

12. Figure- panel agreed the figure is fine, but fish should be removed, and first stage of figure should read “point and non-point sources.”
13. Panel agreed on revising language associated with “highly efficient for burial” so it’s more clear what is meant; Jeff will provide new language.
14. Panel members decided more discussion is needed on public fishery categories and will evaluate in future report.
15. Panel decided shell height figure already in the report was simpler, so keep.
16. Ward and Emily will look into the link to CBP zones.
17. Ward will provide citations for sources of different salinity ranges/ polyhaline/ mesohaline.
18. Panel- will review factor rationale table and provide input.
19. Citations for relatively-well constrained- no citation, based on data; add “estimate.”
20. Data footnotes for P table were discussed and resolved.
21. Citations for standard tissue dry weight method- Matt and Suzanne will provide.
22. Methods for sensitivity analysis resolved.
23. How many oysters in MD bushels- Lynn will resolve.
24. Emily will write draft of ancillary benefits section.
25. Julie Reichert- Is there any additional recommended research? Bill brought up the soft shell clam and possible reduction of its habitat; not related to N and P reduction effectiveness so Panel agreed not to include in this report.
26. Text on N removal from fouling of cages- Bill will provide text and references.
27. FARM model conclusion from Appendix D- panel members discussed and resolved.
28. Panel members are alright with text in Appendix E under “Evaluation of influencing factors on oyster growth” section.

Oyster BMP Expert Panel Meeting, October 27, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Phone
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Not present
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Not present
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Phone
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Phone
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Phone
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In person
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action Items:

1. Jeff- draft hydrodynamic and sediment text for unintended consequences section.
2. Chris- assist with substrate addition response.
3. Julie Reichert- reach out to CBP reps concerning procedure-related comments.
4. Julie Reichert- revise responses and report based on Panel's input.
5. All- review revised report draft and response to comments.

Meeting Minutes:

1. Coordination Updates, Julie Reichert, 1:00 – 1:10 PM

a) Julie asked the panelists what they would like to tackle on the next report.

i. Jeff said he would like to lay the groundwork for denitrification, even if a default estimate can't be reached right away (for the on-bottom aquaculture and restoration oyster practice categories).
ii. Suzanne mentioned tackling assimilation in shell now, since most of the groundwork has been done even though there are some outstanding policy issues; Jeff and Panelists agreed to tackle shell next.
iii. Ed asked- is there a way to measure how much shell is coming and going?
iv. Ken- it's eroding all the time; Chris asked- even when they're alive? Panel member answered, yes; need to address shell dissolution rate.
v. Bill asked if there are denitrification studies in the Panel's literature database.
    a. Julie Reichert said yes, but we will organize those sources for review after the shell discussions.
vi. Ken said- Eric Powell and Roger Mann have a paper about shell that could be helpful.

2. Review and Discussion of Public Comments, 1:10 – 2:30 PM

a) Public Comment: Commenters wanted the panel to provide a threshold of how much shell needs to be added to enhance new oyster production.
    i. Matt- amount of shell is highly dependent on the site; the MD USDA EQIP program requires at least 2 inches be dredged up or be purchased and put down; could use as a guideline instead.
    ii. Ward asked- has private leases on public bars been an issue in Virginia?
        a. Mark said yes, there are not a lot of rules in place to prevent this.
    iii. Mark said there are definitely people who put shell out to get a spat set in VA. Also made a comment about VA having "use it or lose it [lease]" program.
    iv. Julie commented that we have choices, the panel could provide general guidelines or not endorse it as a BMP because it's uncertain that it would produce oysters.
    v. Panel felt it should still be endorsed since putting substrate down does enhance oyster production; Matt will send Julie Reichert MD USDA EQIP info; Chris will help draft the response.
b) Public Comment: Diploid oysters should be encouraged to be left in the Bay; support triploid only model.
    i. Julie Reichert- the Panel charge is to evaluate the reduction effectiveness of oyster practices; CPB reps have advised that when it comes to which practices to implement, it is up to the jurisdiction, in coordination with CBP Partnership to make that decision based on the recommended reduction effectiveness; panelists agreed we should include reduction evaluation for both diploid and triploid.
    ii. Lisa said diploid oysters are providing larvae to the system regardless if they are harvested; she feels this is a big plus for use of diploid over triploid.
    iii. Mark said diploids can get to market before diseases set in.
    iv. Mark said that triploids are typically more expensive than diploids to purchase.
c) Public Comment: More details concerning method to use sediment cores to monitor over-enrichment
    i. A panelist asked- who makes the call? Who would take away their BMP credit if sediments are over-enriched? Julie Reichert- likely the jurisdiction, buy would have to check with CBP reps.
    ii. Mark said floats could be in a place with sediment that is questionable from the start. Should they have controls? DO we need to provide a method to address these unintended consequences?
    iii. Lisa asked- do we need to include that level of detail? From her understanding, the Panel is just providing general guidelines that can be pursued by the implementers, who would then work out the details; Julie Reichert- correct, we are just asked to provide general guidance,

which could include the identification of methods the jurisdiction and CBP Partnership can evaluate; the CBP does not expect the Panel to develop detailed steps on how to do this.

iv. Larry- bottom sediment assessment during hot summer months could be incorporated in aquaculture siting plan to make sure the sediment can handle the extra nutrient load ahead of choosing that site for a farm or expanding an existing farm; need more scrutiny of sites before private leases are awarded; would like to include a sentence in the report describing this.

v. Bill mentioned that side-scan sonars have been used to help distinguish if the bottoms are good for oysters.

vi. Ken recommends water quality testing instead of sediment cores; eutrophication/low DO is the main problem.

vii. Mark says this is a self-regulating problem; if water quality is bad, then the oysters won't survive and there won't be any credit.

viii. Panelists agreed to provide general guidelines and not detailed procedures; implementation and verification procedures should be sorted out by implementers.

d) Public Comment: Aquaculture impact on hydrodynamics

ix. Larry mentioned the higher tidal flow in VA.

x. A panelist mentioned aquaculture impact on hydrodynamics that would build up sediment in tidal environment is unlikely; Larry said hydrodynamics could be influenced if there were cages across a creek that would impede sediment transport.

xi. Bill- mentioned that consequence could be positive by preventing erosion based on studies elsewhere; Bill will send citations to Julie Reichert.

xii. Ken mentioned an aquaculture study in Wye Creek that lowered DO, Julie Reichert commented this could be an unintended consequence.

xiii. Jeff mentioned a Merenitics study in which biodeposits were swept away.

xiv. Jeff offered to revise unintended consequence section to describe these other consequences; overall, Panel felt hydrodynamics could be managed.

e) Public Comment: Estimate review by experts

i. More related to procedure to be decided by CBP; Panel recommends that these estimates should go through a public review process.

f) Public Comment: too many size class categories

i. Science supports this many size class categories; the Panel decided to include language that these are options and not all size classes need to be reported in to qualify as a BMP if the operation doesn't grow oysters within particular size ranges.

g) Public Comment: Movement of oysters should not be outside of watershed.

i. Matt suggests "within the same farming entity;" another panelists mentioned that this would avoid double counting.

h) Public Comment: Reporting recommendations; don't allow incomplete reporting and include hatchery name

i. Panel felt hatchery name is not needed; however could include in verification suggestions that purchase receipts could be used to verify that oysters were likely an initial size < 2.0 inches.

ii. Panel felt that the recommendations concerning missing measurements is justified because they would be receiving the lowest available credit based on jurisdiction's laws; they did decide they will indicate which reporting parameters are required, which is unclear in the current draft of report (e.g., location info, if oysters were moved, etc.)

i) Public Comment: Verification guidelines- don't allow reporting in boxes and bushels

i. Panel felt this should be included given that reporting does occur in this way; recommended guidelines would support calculating the number of oysters in the bushels and boxes in a scientifically defensible manner to apply the estimates; the Panel did support adding language that reporting in individuals is the preferred unit.

j) Public Comment: Seasonal N and P content of triploid oysters and biofouling research

   i. Panel felt that triploid oysters would be less affected by season because they don't undergo reproductive changes because they do not spawn.
   ii. Bill mentioned there is a lot of literature on aquaculture and biofouling; Panelists agreed that there is a potential additional N and P reduction if biofouling is disposed of properly; agreed to keep in future research section.

k) Julie Reichert will draft responses based on conversations today for Panel review.

Oyster BMP Expert Panel Meeting, November 17, 2016, 1:00-3:00 PM

Location: Oyster Recovery Partnership, 1805A Virginia Street, Annapolis, MD and remote conference

Attendance:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Phone
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	In person
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Phone
Karen Hudson	Virginia Institute of Marine Science (VIMS)	Phone
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	Not present
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	In person
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Not present
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	In person
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Phone
Bill Wolinski	Talbot County Department of Public Works	In person
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Phone
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	Not present
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In person
Ward Slacum	Oyster Recovery Partnership	In person
Emily French	Oyster Recovery Partnership	In person

Action items:

1. Julie will revise substrate addition, unintended consequence, movement guideline, and intro text based on what was discussed and send to the Panel to review before WQGIT November 28th update.

Meeting Minutes:

5. **Coordination Updates**
    a. 1st report approval schedule:
        i. Update to the WQGIT on November 28th to go over revisions to the report based on the public comments.
        ii. Approval decision by the Watershed Technical Workgroup (WTWG) on December 1st.

iii. Approval decision by the WQGIT on December 19th.

6. 1st Report Consensus Check

a. Shell substrate addition response
   i. Concerning USDA EQIP factsheet, Matt says web link no longer works, only has the pdf he sent via email.
   ii. Chris said this BMP is a grey area. If there is an acre lease, but substrate on half of it, do you only give BMP credit to half? Chris agreed that recommending a baseline substrate amount is not appropriate, but given that substrate requirements are integral to this BMP and is dependent on site characteristics, he said additional language should be added to make sure substrate requirements are sorted out by the implementation program before the reduction effectiveness is applied.
   iii. Lynn asked- is substrate addition annual/periodic?
      1. A panel member said leaseholders are bringing up shell; would reclaimed shell count? Panel agreed yes.
      2. Chris asked- would they be planting spat on shell too; Lynn said yes; Chris responded that this scenario would fall under the category where oysters are planted.
      3. Lynn asked if substrate addition would have to be in the same year as BMP credit is given; Chris said maybe every 3 years, but would again be dependent on site characteristics.
   iv. Julie Reichert said- we will tweak this response based on this input and send out for Panel review.

b. Non-agenda issue: Matt Johnston commented- The panel didn't say whether the default, site-specific, or both estimates apply when partitioning of credit. Is this recommendation specific to the site-specific estimates?
   i. Julie Reichert- the intent was that this would apply to both default and site-specific estimates; will add clarification text.
   ii. Chris asked- how big of a movement constitutes a movement? Out of a condemned area into another tributary; Panel were in the opinion if they are moved at all then it constitutes as movement.
   iii. After further discussion, the Panel realized that there are only two main movement scenarios: 1) Oysters are move when they are less than 2 inches and when they are larger than 2 inches (usually in 2nd location no more than 3 months); these scenarios wouldn't require partitioning the credit because for the 1st scenario, the final location would get the entire credit (credit is not granted for oysters less than 2 inches) and for the second scenario they predominantly grew in the initial location (entire credit should go to the initial location).
   iv. Matt Johnston recommended- drop partitioning and assign to either the initial location or final location based on these scenarios; Panel agreed.

v. Julie Reichert- Do we keep the verification check when moved; Panel agreed yes.

c. Culture type analysis
    i. Julie: culture type (hatchery-produced versus wild) analysis was added to the report; wild oysters produced steeper curve than hatchery-produced, but wild oysters were predominantly from one location (Lynnhaven River).
    ii. Lisa commented- preliminary analysis from VA data from Powell et al. 2015 suggest that this is likely a site-driven effect and not a culture-type effect.

d. Unintended consequences section revision
    i. A panel member commented low oxygen results in ammonium release.
    ii. Julie Reichert added new section with WQ monitoring, sediment cores, aquaculture siting requirements, asked if panel is ok with putting in these options.
        1. Jeff said a photo is subjective. We don't want to get too technical.
        2. Lynn said low dissolved oxygen areas can be patchy. What would be the criteria?; Julie Reichert believed it would be the water quality standards.
        3. Bill said low dissolved oxygen could be from other factors; Bill also mentioned that one study from VA showed improving water quality conditions on the bottom.
        4. Larry said that low oxygen has denitrification implications.
        5. Mark said- we've identified the right unintended consequence, but I don't think we need to go into the details of how to address them. This is more related to implementation; e.g., VMRC addresses too much benthic enrichment when they permit. VMRC has VIMS do an analysis to determine the number of cages to combat enrichment.
        6. Lisa said- I think that all of these issues are related to siting and should be under local jurisdiction.
        7. Jeff- we may be going down implementation route too far by leaving in these details; it should be up to the implementation programs/policy-makers; Panel agreed to only present options; revise framework to make it clear that the intent wasn't to provide detailed protocols.
    iii. Julie- should hydrodynamics be added to unintended consequences section?
        1. Bill said several studies show favorable effects of oyster reefs related to hydrodynamics; will send studies to Julie Reichert.
        2. Mark said he is fine with being in unintended consequences; VMRC is taking care of this in VA.
        3. Matt Parker said- take out specific examples, but leave basic info; similar to enrichment effects, suggest option that this can be addressed via aquaculture regulations through the implementation programs.

Appendix F: Technical Requirements for Reporting and Simulating Oyster Aquaculture BMPs in the Phase 6 Watershed Model

Background: In June, 2013 the Water Quality Goal Implementation Team (WQGIT) agreed that each BMP expert panel would work with CBPO staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert report. The purpose of the technical appendix is to describe how the expert panel's recommendations will be integrated into the modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Q1: What types of oyster aquaculture practices will be available for credit for nutrient reductions in the Phase 6 Model?

A1: The expert panel recommended pound reduction credits for nutrients assimilated in harvested oyster tissue for the following types of aquaculture operations:

- Off-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using hatchery-produced oysters
- On-bottom private oyster aquaculture using substrate addition

The reduction credits may be applied for any of these types of operations based upon the size and type of oyster harvested. However, the reporting requirements vary depending upon the type of aquaculture operation.

Q2: What are the reduction credits for these oyster aquaculture practices?

A2: The expert panel recommended that all three types of oyster aquaculture practices will receive the same pound reduction credits, which will vary based upon the average size and type of oyster harvested at an operation. The table below provides the new BMP names and lbs of nutrient reduction related to maximum size and type of oysters harvested.

Table 1. Nutrient Reductions per 1,000,000 Oysters Harvested by BMP

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

Q3: What credit may be given if an operation or state does not know the type or average size of oysters harvested?

A3: If the type or average size is not known, then the diploid estimate will be used based on the State's minimum legal harvest size. For example, if the minimum legal harvest size is 3 inches then the State should submit this for credit under the "Diploid Oyster Aquaculture 3.0 Inches" BMP. States are expected to describe the minimum legal harvest requirements in their Quality Assurance Project Plan (QAPP).

Q4: How would an operation or state receive credit for the "Site-specific Monitored Oyster Aquaculture" practice?

A4: An operator will need to provide the state with the average tissue dry weight of subsample of 50 oysters per oyster size class category within two seasons that are at least six months apart. These dry tissue estimates can then be multiplied by a default nitrogen content of 8.2% and a default phosphorus content of 0.9%, and aggregated to determine the total nutrients reduced by the harvested oysters.

Q5: What should a state report to NEIEN to receive credit for the diploid or triploid oyster practices?

A5: Please reference Figure 1 to determine exactly how to report each practice. States should report the following parameters to NEIEN:

- *BMP Name:* Select from list in Table 1 above.
- *Measurement Name:* Oysters Harvested
- *Land Use:* NA
- *Geographic Location:* Approved NEIEN geographies: Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)
- *Date of Implementation:* Year oysters were harvested.

Q6: What should a state report to NEIEN to receive credit for the site-specific monitored practice?

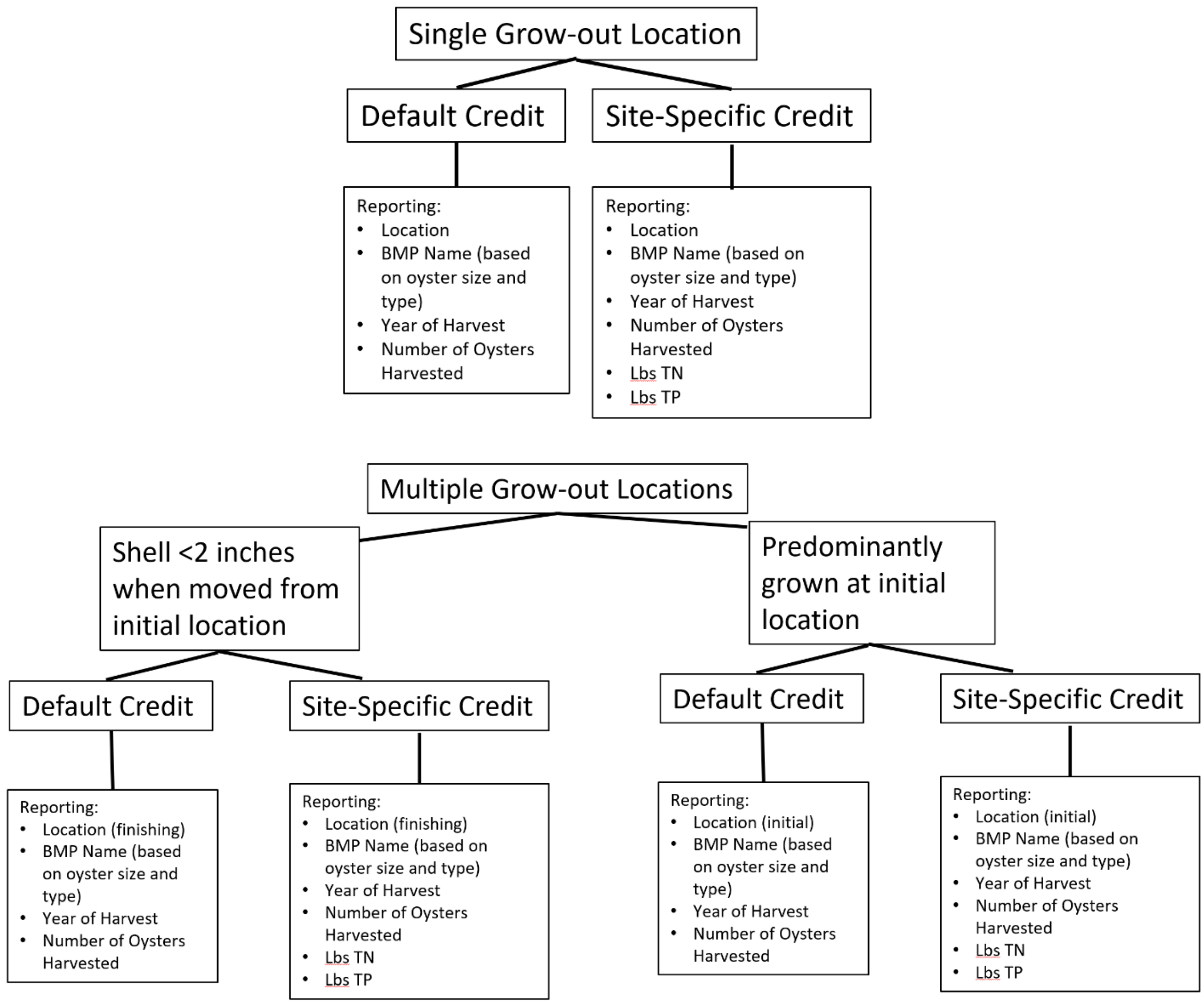
A6: Please reference Figure 1 to determine exactly how to report each practice. States should report the following parameters to NEIEN:

- *BMP Name:* Site-Specific Monitored Oyster Aquaculture
- *Measurement Name(s):* Oysters Harvested; Lbs TN; Lbs TP
- *Land Use:* NA
- *Geographic Location:* Approved NEIEN geographies: Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)
- *Date of Implementation:* Year oysters were harvested.

Q7: Is there an easy way to determine the reporting requirements based upon the type of oyster aquaculture operation and the amount of data available from the operation?

A7: Please use the figure below to help determine exact reporting requirements.

Figure 1. How to Determine Reporting Requirements



Q8: How will the practice be credited in the Phase 6 Watershed Model?

A8: The Phase 6 Model will have an estimated nutrient load in shoreline segments that can be reduced by shoreline and tidal water practices. The pounds of nutrients reduced by this practice will be credited as a reduction to the nutrient loads in the nearest shoreline segments to the practice location. If latitude and longitude are not submitted, then the practice benefits will be distributed amongst all shoreline segments in the geography submitted.

The WTWG will work with the Chesapeake Bay Program Office to investigate potential changes to NEIEN that would allow states to report tidal geographies, rather than land-based geographies.

The WTWG will work with the Modeling Workgroup to determine if a cap on load reductions is appropriate for this and other site-specific pound reduction BMPs including stream restoration, shoreline management, and algal flow-ways.

Q9: How will credit be simulated for oysters grown at multiple locations?

A9: The Panel recommended that oysters moved from their initial location when shells are less than 2 inches in size should be credited as removing nutrients from the final, or finishing location. However, many operators move oysters for a short time period at the end of grow-out (typically less than three months) to a second, finishing location. The Panel recommended in this situation that the entire credit be given at the initial location. Thus, it is important that states submit the correct location (finishing or initial) for these types of operations. Please see Figure 1 for more reporting details.

Q10: Can this practice be submitted in non-tidal waters?

A10: No. This practice is only eligible in tidal waters.

Q11: Is this an annual practice?

A11: Yes. States must report the number of oysters harvested or pounds reduced annually.