Nitrogen and Phosphorus Reduction Associated with Harvest of Hatchery-Produced Oysters and Reef Restoration: Assimilation and Enhanced Denitrification

PANEL RECOMMENDATIONS

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Oyster BMP Expert Panel Second Incremental Report

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The novelty and complexity of oyster BMP development, as well as changes in Panel and Support personnel and COVID-related interruptions, at times have made the oyster BMP Panel process more difficult and lengthy than usual. The Panel is grateful for all the assistance we received and the contributions of data and data analysis by many individuals. In particular, the default denitrification rates were a product of both fieldwork and data analysis by Dr. Lisa Kellogg at the Virginia Institute of Marine Science. Her contributions of field and lab-derived data, data analysis, and report writing are infused throughout the report and the Panel is grateful for all her efforts.

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Contents

Acronyms in Document

BMP- Best Management Practice

CBF- Chesapeake Bay Foundation

CBP- Chesapeake Bay Program

DNF- Denitrification

DW- Dry Weight

EPA- Environmental Protection Agency

GIS- Geographic Information System

GIT- Goal Implementation Team

HPO- Hatchery Produced Oyster

LOH- Licensed Oyster Harvest

MD- Maryland

MD DNR – Maryland Department of Natural Resources

MDORIW- Maryland Oyster Restoration Interagency Workgroup

N- Nitrogen

NOAA- National Oceanographic and Atmospheric Administration

ORP- Oyster Recovery Partnership

ORR- Oyster Reef Restoration

P- Phosphorus

POA- Private Oyster Aquaculture

SH- Shell Height

SRP- Soluble Reactive Phosphorus

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

WTWG- Watershed Technical Workgroup

Key Definitions

Alternate substrates: All materials suitable for oyster settlement and survival not composed solely of oyster shells

Ancillary benefits: Potential positive effects of the oyster practice beyond its impacts on nitrogen and phosphorus.

Assimilation: Incorporation of nitrogen and phosphorus from digested food into oyster tissues and shells.

Batch incubation: Benthic time course incubation without continuous exchange of water

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

Biodeposition: The process through which biodeposits are deposited on the bottom.

BMP Site: The location in which enhancement activities occur and which is potentially eligible for nitrogen and phosphorus reduction credit if all qualifying conditions are met. The BMP site is an area.

BMP site area: Area (e.g., acres) of the actual enhancement activities at the BMP site. The BMP site area may be smaller than the BMP site.

Burial: The process in which nutrients are trapped in the bottom sediment for long timescales (i.e., below the active zone where active decomposition of organic and inorganic material and reworking of sediments occurs).

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 and is a form of nitrogen that is not readily available for phytoplankton growth. For the purposes of this document, we include all processes that produce nitrogen gas (N2) as denitrification.

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

Engineered structure: Suitable substrate for oyster larvae that has been manufactured (e.g., ReefBalls™, Oyster Castles®).

Flow-through incubation: An approach to measuring biogeochemical fluxes that assesses the difference in concentration of analytes of interest (e.g., oxygen, nitrate, nitrite, ammonium, di-nitrogen gas) between water flowing into and out of an incubation chamber and uses this information along with the flow rate to calculate a flux.

Flux: Change in concentration of analyte per unit time, generally expressed on a areal basis.

Hatchery-produced oyster: Diploid or triploid oysters that originated from oyster larvae propagated outside their natural environment.

Incubation: A method for measuring biogeochemical fluxes that involves sealing a sample of the bottom component of interest (e.g. sediments, oyster reef) in a chamber and collecting samples from the overlying water column either as a time series of measurements.

Incubation chamber: An enclosure containing a sample of the bottom component of interest (e.g. sediments, oyster reef) used for measuring biogeochemical fluxes.

Large substrate: Suitable substrate characterized by (a) <90% of the material by volume has a maximum diameter of ≤12 inches (304.8 mm) or (b) a uniform, regular structure when deployed.

Licensed oyster harvest: Oyster harvest from a State-managed fishery area by individuals holding the proper licenses.

Live oyster shell biomass: The total dry weight of shell from living oysters.

Live oyster tissue biomass: The total dry weight of soft tissue from living oysters.

No-harvest area: Designated areas where oysters are permanently protected from harvest (e.g., oyster sanctuaries or areas closed due to water quality concerns).

Oyster associated processes/ Oyster processes: Ecological, biological, chemical, or physical mechanisms that occur within individual oysters or on oyster reefs.

Oyster hatchery: Facility that produces diploid and/or triploid oyster larvae outside their natural environment for research, restoration, educational, and/or commercial uses.

Oyster practice: Oyster management approaches that can be implemented as best management practices to assess progress of water quality goals established by the Chesapeake Bay Total Maximum Daily Load.

Oyster protocol: Oyster-associated processes that reduce nitrogen, phosphorus, and/or suspended sediment as defined by this document

Oyster reef restoration: Activities aimed at increasing oyster populations/biomass in no-harvest areas.

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 affecting reproductive capabilities (e.g., infertile triploid oysters have three sets of chromosomes, while fertile diploid oysters have two complete sets).

Practice-protocol combination: Individual reduction effectiveness crediting protocols that can quantify the reduction of nitrogen, phosphorus, and/or suspended sediment for different oyster practices.

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

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.).

Seston: All organic and inorganic, living and non-living material suspended in the water column.

Small substrate: Suitable substrate that is characterized by (a) ≥90% of the material by volume has a maximum diameter of ≤12 inches (304.8 mm) and (b) a non-uniform or irregular structure when deployed.

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

Substrate addition: The act of placing suitable substrate (e.g., shell, stone, etc.) on the sediment surface to enhance the potential recruitment of wild oyster larvae or to serve as a base for planting spat on shell.

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.

Suitable substrate: Material on which oysters can settle and survive to adulthood. Can include, but are not limited to: non-oyster shell, fossilized shell, limestone, granite, crushed concrete, engineered structures, etc.

Suspended sediment: Very fine soil particles that remain in suspension in water for a considerable period of time.

Triploid oyster: Hatchery-produced oysters containing three sets of chromosomes and generally incapable of sexual reproduction.

Unintended Consequence: Potential negative effects resulting from the oyster practice.

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

In 2010, the U.S. Environmental Protection Agency (EPA) established the Chesapeake Bay Total Maximum Daily Load (TMDL), a set of accountability measures implemented towards improving water quality in Chesapeake Bay (EPA 2010). Since the TMDL was established, the Chesapeake Bay Program (CBP) has convened expert panels to assist in identifying best management practices (BMPs) and quantifying the degree to which those practices reduce inputs of nutrients (i.e., nitrogen and phosphorus) and suspended sediments to Chesapeake Bay. Once BMPs are established, their nutrient and suspended sediment reduction effectiveness is credited and progress towards achieving water quality goals is tracked using the CBP Partnership's model framework (CBP 2022).

The Oyster Best Management Practice Expert Panel (hereafter, "Panel") was convened in September 2015 because of interest in evaluating and implementing ***oyster practices*** as best management practices. Oysters can contribute to the reduction of nutrients (i.e., nitrogen and phosphorus) and suspended sediment by filtering organic and inorganic particulates, such as algae and suspended sediment, from the water column. The nitrogen and phosphorus from these particulates can be (1) assimilated in the oyster tissue or shell or (2) incorporated into oyster biodeposits (i.e., feces, pseudofeces) deposited on the seafloor along with ingested sediment where they can be denitrified or buried (Kellogg et al. 2013, 2014, Grizzle et al. 2018). Relative to other benthic environments, oyster reefs are hotspots for denitrification (Caffrey et al. 2016, Arfken et al. 2017, Jackson et al. 2018). Denitrification is the final step in a set of transformations that converts organic nitrogen to di-nitrogen gas (N_2), a form of nitrogen that cannot be used for growth by most phytoplankton and algae. Burial occurs when oyster waste is deposited onto the sediment surface and becomes trapped in the benthic sediment for long timescales (i.e., below the active zone where decomposition occurs) making the nitrogen, phosphorus, and sediment it contains unavailable to the water column (Newell et al. 2005).

The Panel was charged with developing (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) recommendations on the nitrogen, phosphorus, and suspended sediment reduction effectiveness of oyster practices based on existing science. As part of this process, the Panel worked with the EPA to verify that oyster practices could be applied as in-water BMPs under the Clean Water Act. The EPA agreed that CBP Partnership-approved oyster BMPs can qualify for nutrient and sediment pollutant reductions under the Clean Water Act (Appendix C).

The Panel's first set of recommendations were approved by the Chesapeake Bay Program (CBP) Partnership's Water Quality Goal Implementation Team (WQGIT), in coordination with the Habitat Goal Implementation Team (Habitat GIT) and Sustainable Fisheries Goal Implementation Team (Fisheries GIT), on December 19, 2016 and can be found in their first report (Reichert-Nguyen et al. 2016). This first report includes the Panel's decision framework and recommended estimates for nitrogen and phosphorus assimilated in tissue of oysters harvested from private oyster aquaculture practices. The approved decision framework allows for the incremental determination, approval, and implementation of individual reduction effectiveness crediting ***protocols*** that can quantify the reduction of nitrogen, phosphorus, and/or suspended sediment for different oyster practice categories (hereafter, ***practice-protocol combination***).

Overall, the Panel identified 96 potential practice-protocol combinations in which oysters could reduce nutrients and suspended sediments in Chesapeake Bay (Table 1.1). A total of six practice-protocol combinations were approved of the 10 reviewed in the first report (Reichert-Nguyen et al. 2016). In this report, the Panel reviewed 45 total practice-protocol combinations and is endorsing 12 combinations for approval by the CBP Partnership. Oyster biomass is an important parameter in developing the reduction effectiveness estimates. The Panel's decision concerning which oyster practices should undergo BMP consideration was based on whether the practices include an enhancement activity that could result in the overall production of new oysters, and consequently, oyster biomass.

The details and rationale for the practice-protocol combinations are described in the Panel's first report (Reichert-Nguyen et al. 2016). The practice-protocol combinations are based on twelve oyster practices and eight reduction effectiveness protocols. The oyster practices were determined after considering the oyster's fate (i.e., removed or remains in the waterbody), fisheries management approach (i.e., private oyster aquaculture, licensed oyster harvest [previously called public fishery], and oyster reef restoration), oyster type (i.e., diploid or triploid hatchery-produced oysters or wild diploid oysters), and activity/culture method (i.e., oysters grown off or on the bottom, transplanted oysters, substrate addition, or no activity). The Panel also added information on who has access to the oysters in connection with ownership (i.e., private oyster aquaculture leaseholders who grow and harvest oysters from leased State bottom, license-holders who fish on public harvest areas, state resource management agencies who plant and monitor oysters/substrate in no harvest areas) since it can influence the development of implementation and verification procedures (Table 1.2; further described in Chapter 5.0).

The Panel opted to change the overarching fisheries management approach title of "public fishery" to "licensed oyster harvest" to better reflect the Panel's intent to only put forward BMP recommendations for practices where activities occur that enhance oyster populations. ***Licensed oyster harvest*** specifically refers to oyster harvest from a State-managed fishery area by individuals holding the proper harvest licenses; BMP crediting occurs only in areas that are supplemented with hatchery produced oysters (e.g., spat on shell or single oysters). In addition to changes to the public fishery titles, the titles for the oyster reef restoration practices and descriptions have been slightly modified from the first report for clarity (Table 1.2).

The reduction effectiveness of the oyster practices endorsed for BMP use is based on biological processes that can reduce nitrogen, phosphorus, and suspended sediment (Figure 1.1). These were divided into the following eight reduction crediting protocols:

Protocol 1. Nitrogen assimilation in oyster tissue
Protocol 2. Nitrogen assimilation in oyster shell
Protocol 3. Enhanced denitrification associated with oysters
Protocol 4. Phosphorus assimilation in oyster tissue
Protocol 5. Phosphorus assimilation in oyster shell
Protocol 6. Suspended sediment reduction associated with oysters
Protocol 7. Enhanced nitrogen burial associated with oysters
Protocol 8. Enhanced phosphorus burial associated with oysters

Protocols 1, 2, 4, & 5 involve oysters consuming and assimilating nitrogen and phosphorus from filtered organic particles (e.g., algae, phytoplankton) into their tissue and shell. The filtration of particles out of the water column can also lead to enhanced burial of suspended sediments (**Protocol 6**) containing nitrogen and phosphorus (**Protocol 7 & 8**).

Protocol 3 involves the biogeochemical process of denitrification, which is dependent on the microbial communities living within the reef and surrounding sediment. While oysters do not perform denitrification directly, they can enhance the process by depositing excess organic matter to the sediment or by increasing the amount of habitat per-unit-area for nitrifying and denitrifying organisms.

Differences among the reviewed oyster practices (Table 1.2) affect the determination and verification of the nutrient reduction effectiveness. For assimilation (**Protocol 1, 2, 4, & 5**), harvest (via private oyster aquaculture or licensed oyster harvest) continually removes nitrogen and phosphorus assimilated into the tissue and shell of harvested oysters as long as new oysters are added and harvest occurs. In contrast, oysters that remain in the water (via oyster reef restoration in no-harvest areas) vary in the amount of nitrogen and phosphorus sequestered as the reef's standing stock biomass varies. Requirements could also differ between practices involving harvest or restoration for denitrification (**Protocol 3**), due to differences in the fate of oyster biodeposits and reef community structure on harvested vs. un-harvested reefs. Additional research is required to determine how oyster harvest, movement, and replacement impact denitrification in these different settings.

Differences in the context of oyster harvest can also affect the determination and verification of reduction effectiveness. Private oyster aquaculture occurs when the State permits water column or bottom leases to private entities who then grow oysters in those areas. In accordance with Virginia and Maryland State policies, private oyster aquaculture leases are typically permitted in areas with few to no pre-existing wild oysters (Code of Maryland Regulations COMAR 08.02.04.17; Code of Virginia §28.2-603). Licensed oyster harvest can occur on public, State-designated areas by any individual holding the proper licenses and harvesting in accordance with established rules and regulations. Licensed oyster harvest can occur in areas where there are existing or historically productive oyster bars. Compared to private oyster aquaculture practices, licensed oyster harvest practices require additional assessment of baseline conditions to verify whether nutrient reduction occurs.

Table 1.1. The Panel's review progress for the 96 oyster practice-protocol combinations. "Approved" indicates combinations that have been approved for BMP use by the CBP Partnership. "Complete" indicates combinations that are endorsed by the Panel in this report and ready for BMP use pending approval. "Research Gap" and "Policy Issue" identify combinations that have been endorsed by the Panel for BMP use but lack certain information to complete the recommendations. "Not Endorsed" are combinations that the Panel agreed should not undergo BMP consideration since they do not result in enhanced oyster populations. Practice-protocol combinations highlighted in dark gray were discussed in the Panel's first report (Reichert-Nguyen et al. 2016). Practice-protocol combinations highlighted in light gray are discussed in this report.

	Private Oyster Aquaculture					**Licensed Oyster Harvest**				**Oyster Reef Restoration**		
Oyster Practice Category x Crediting Protocol	A. Off-bottom private aquaculture using hatchery-produced oysters	B. On-bottom private aquaculture using hatchery-produced oysters	C. On-bottom private aquaculture using transplanted wild oysters	D. On-bottom private aquaculture using substrate addition	E. Private oyster aquaculture with no activity	F. Licensed harvest using hatchery-produced oysters	G. Licensed harvest using transplanted wild oysters	H. Licensed harvest using substrate addition	I. Licensed harvest with no activity	J. Reef restoration using hatchery-produced oysters	K. Reef restoration using substrate addition	L. Reef restoration using no harvest area designation only
1. Nitrogen assimilation in tissue	**1st Approved**	**1st Approved**	1st Not Endorsed	**1st Approved**	1st Not Endorsed	**2nd Complete**	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
2. Nitrogen assimilation in shell	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
3. Enhanced denitrification	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
4. Phosphorus assimilation in tissue	**1st Approved**	**1st Approved**	1st Not Endorsed	**1st Approved**	1st Not Endorsed	**2nd Complete**	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
5. Phosphorus assimilation in shell	2nd Research Gap	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	2nd Research Gap	2nd Not Endorsed	Later	2nd Not Endorsed	**2nd Complete**	**2nd Complete**	2nd Policy Issue
6. Suspended sediment reduction	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later
7. Enhanced nitrogen burial	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later
8. Enhanced phosphorus burial	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later	Later

Table 1.2. Chesapeake Bay oyster practice categories identified by the Panel. HPO = Hatchery-produced oysters, POA = Private oyster aquaculture, LOH = Licensed oyster harvest, ORR = Oyster reef restoration.

Oyster Fate	Oysters removed (harvested) from Bay									Oysters remain in Bay		
Fisheries Management Approach	Oyster cultivation									Conservation		
	Private oyster aquaculture (POA)					Licensed oyster harvest (LOH)				Oyster reef restoration (ORR)		
Description	Oyster harvest from State-issued water column and bottom leases					Oyster harvest from State-managed fishing areas				No harvest allowed		
Access to Oysters	Lease-holder					License-holder				State resource management agency		
Oyster Type	Hatchery-produced oysters (HPO)		Wild oysters			HPO	Wild oysters			HPO	Wild oysters	
Activity	HPO grown off the bottom using gear	HPO grown on the bottom using no gear	Moving wild oysters from one location to another	Addition of substrate to enhance recruitment of wild oyster larvae	None	Addition of HPO	Moving wild oysters from one location to another	Addition of substrate to enhance recruitment of wild oyster larvae	None	Designate no-harvest area followed by addition of HPO	Designate no-harvest area followed by addition of substrate	Designate no-harvest area with no additional activity
Oyster Practice	**A. Off-bottom POA using HPO**	**B. On-bottom POA using HPO**	C. On-bottom POA using transplanted wild oysters	**D. On-bottom POA using substrate addition**	E. POA with no activity	**F. LOH using HPO**	G. LOH using transplanted wild oysters	H. LOH using substrate addition	I. LOH with no activity	**J. ORR using HPO**	**K. ORR using substrate addition**	L. ORR using no-harvest area designation only
Recommended for BMP?	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	Later	No	**Yes**	**Yes**	Later

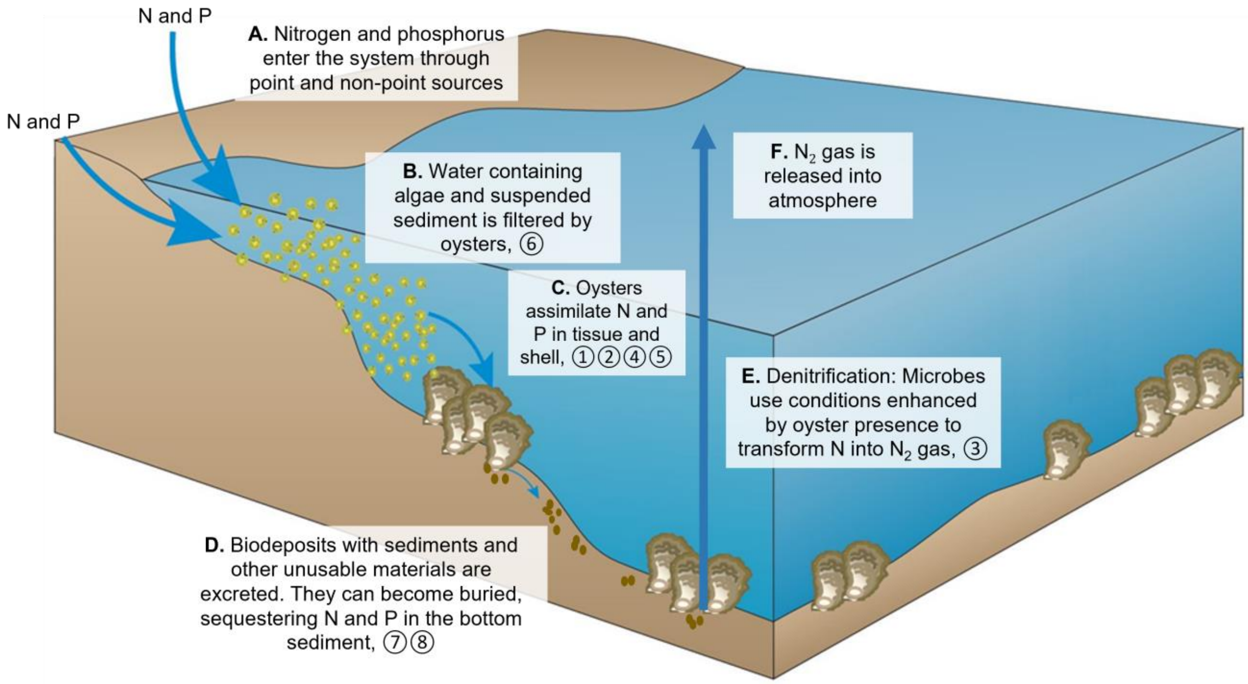


Figure 1.1. Oyster-associated processes that reduce nitrogen (N) and phosphorus (P) and suspended sediment. The numbers in circles correspond with the reduction effectiveness crediting protocols identified in Table 1.1.

This report includes recommendations for assessing and implementing nitrogen and phosphorus reduction effectiveness BMPs for twelve oyster practice-protocol combinations (Table 1.1). The recommended practice-protocol combinations are as follows:

- **Practice F**. Licensed oyster harvest using hatchery-produced oysters
  - **Protocol 1**. Nitrogen assimilation in oyster tissue
  - **Protocol 4**. Phosphorus assimilation in oyster tissue
- **Practice J**. Oyster reef restoration using hatchery-produced oysters
  - **Protocol 1**. Nitrogen assimilation in oyster tissue
  - **Protocol 2.** Nitrogen assimilation in oyster shell
  - **Protocol 3.** Enhanced denitrification associated with oysters
  - **Protocol 4.** Phosphorus assimilation in oyster tissue
  - **Protocol 5.** Phosphorus assimilation in oyster shell
- **Practice K.** Oyster reef restoration using substrate addition
  - **Protocol 1.** Nitrogen assimilation in oyster tissue
  - **Protocol 2.** Nitrogen assimilation in oyster shell
  - **Protocol 3.** Enhanced denitrification associated with oysters
  - **Protocol 4.** Phosphorus assimilation in oyster tissue
  - **Protocol 5.** Phosphorus assimilation in oyster shell

The Panel is asking the WQGIT, in coordination with the CBP Partnership and Fisheries and Habitat GITs, to review and approve the recommendations found in this second incremental report for BMP implementation.

This report covers two unique fishery management approaches and two distinct nutrient-reducing, oyster-associated processes. The Panel supports the approval of these separately, if needed, and is requesting that issues preventing approval of one set of recommendations not affect the approval of another. Once approved, the Panel expects that the practice-protocol combinations will be BMPs available to the implementing programs to help meet their TMDL goals. The incremental approach reviewed in this report is in line with the approved *Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework* from the Panel's first report (Reichert-Nguyen et al. 2016). This framework allows for a practical and adaptive strategy to implement oyster practices as BMPs that accounts for the variety of practices and processes in which oysters can reduce nutrients and suspended sediment.

The Panel provides informational recommendations for practice-protocol combinations where there was not enough information to develop complete recommendations in Appendix H & I. This information can be used later to formulate complete recommendations once research gaps are addressed.

1.1 Report Structure

The report structure is as follows:

Chapter 2.0 provides a summary of the Panel's recommendations for oyster practice-protocol combinations for BMP approval.
Chapter 3.0 provides a summary of the Panel's membership and charge.
Chapter 4.0 describes the Panel's *Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework* (Reichert-Nguyen et al. 2016). Once a reduction effectiveness crediting protocol is approved for a given oyster practice, it should be implemented in this framework.
Chapter 5.0 defines and provides examples of the oyster practices evaluated for BMP consideration in this report (Table 1.2).

The Panel's complete recommendations for oyster practice-protocol combinations involved extensive review of the scientific literature and addresses all requested items in the CBP Partnership's BMP Review Protocol (CBP 2015). The complete recommendations are described in the main body of this report and in the corresponding appendices for each chapter:

Chapter 6.0 describes the Panel's recommendations on the reduction effectiveness of nitrogen and phosphorus assimilated in tissue of hatchery-produced oysters removed by licensed oyster harvest.

- **Practice F.** Licensed oyster harvest using hatchery-produced oysters
    - Protocol 1. Nitrogen assimilation in oyster tissue
    - Protocol 4. Phosphorus assimilation in oyster tissue

Chapter 7.0 describes the Panel's recommendations on the reduction effectiveness of nitrogen and phosphorus assimilated in live oysters on restored oyster reefs.

- **Practices J & K.** Oyster reef restoration using hatchery-produced oysters and substrate addition
    - Protocol 1. Nitrogen assimilation in oyster tissue
    - Protocol 2. Nitrogen assimilation in oyster shell
    - Protocol 4. Phosphorus assimilation in oyster tissue
    - Protocol 5. Phosphorus assimilation in oyster shell

Chapter 8.0 describes the Panel's recommendations on the reduction effectiveness of nitrogen removed by enhanced denitrification associated with oysters on restored oyster reefs.

- **Practice J & K.** Oyster reef restoration using hatchery-produced oysters and substrate addition
    - Protocol 3. Enhanced denitrification associated with oysters

Chapter 9.0 describes the ancillary benefits of oyster reef restoration.

Chapter 10.0 provides a summary of the recommendations and progress described in detail in this report.

Chapter 11.0 provides a list of documents and sources referenced in this report.

Appendices associated with this report provide supplemental information on the Panel's approach to estimating reduction effectiveness, informational recommendations for future studies or adjusting the recommendations provided in this report, Panel activities, and technical reporting requirements for integrating the oyster BMPs into the CBP's TMDL model.

Appendix A provides a summary of the Panel's activities leading to the recommendations found in this report.

Appendix B describes this report's conformity with the CBP Partnership's BMP Review Protocol (CBP 2015).

Appendix C contains the legal opinion from the U.S. Environmental Protection Agency (EPA) concluding that the removal of pollutants from the water column by in-water BMPs is legal through the Clean Water Act.

Appendix D describes analyses used to develop the default reduction estimates for licensed oyster harvest (*Supplemental to Chapter 6*).

Appendix E contains supporting information and analyses used to develop the reduction estimates for oyster restoration practices (*Supplemental to Chapters 7 and 8*).

Appendix F provides the Panel's criteria while quantifying denitrification rates on restored oyster reefs (*Supplemental to Chapter 8*).

Appendix G provides the full denitrification lookup table created by the Panel to estimate annual denitrification enhancement in oyster tissue (*Supplemental to Chapter 8*).

Appendix H and I include informational recommendations for practice-protocol combinations and other considerations for which approval is not being sought at this time due to knowledge gaps.

- *Appendix H* discusses information relevant to future evaluations of nitrogen and phosphorus assimilated in oyster shell (**Protocols 2 and 5**) for harvested oysters (**Practice A, B, D, F**).
- *Appendix H* also includes a preliminary analysis that could inform updates to the estimates of nitrogen and phosphorus assimilated in tissue (**Protocols 1 and 4**) of harvested diploid oysters. These analyses are based on new data that became available after December 2016 for diploid oysters grown in gear.
- *Appendix I* discusses information relevant to future evaluations of enhanced denitrification (**Protocol 3**) for harvested oysters (**Practice A, B, D, F**) and for oyster restoration using large substrates.

Appendix J describes how oysters influence Chesapeake Bay water quality in the CBP Modeling framework.

Appendix K describes the Watershed Technical Workgroup's requirements for reporting and implementing the recommended oyster BMPs in the Phase 6 Watershed Model.

Appendix L explains why default denitrification reduction estimates cannot be generated for oyster restoration using large structures at this time. Note that the Panel provides guidelines for developing site-specific estimates in Chapter 8.

Appendix M contains the Panel's responses to the public and stakeholder comments received during the review period from January 30 to March 10, 2023.

Appendix N contains the minutes from all Panel meetings held throughout the second oyster BMP Expert Panel report development process.

1.2 Policy Issues

There were two policy issues identified by the Panel or CBP membership when reviewing oyster practices that could be recommended for BMP approval.

The Panel identified a policy issue for the CBP Management Board to review concerning the oyster reef restoration **Practice L** (oyster reef restoration using no-harvest area designation only). This practice designates an area where oysters are not allowed to be harvested but where there are no additional oyster plantings or addition of substrate to enhance oyster populations. Most of the Panel members agreed to endorse this practice for BMP consideration. One Panelist was not in support of endorsing this practice. The concern was that this practice was outside the scope of traditional land-based BMPs since no physical activity is occurring. Since the rationale for not endorsing this practice was based on a policy issue, the Panel recommends that the CBP Partnership Management Board review the issue and decide on whether this practice can be applied as a BMP. From a scientific perspective, the activity of removing harvest pressure on a natural oyster reef by designating it as a no-harvest area could result in increased oyster biomass, which would reduce nutrient concentrations via enhanced denitrification and sequestration in live oysters. The Panel agreed that the process for estimating nutrient reduction via enhanced denitrification and nitrogen and phosphorus assimilation recommended for other oyster restoration practices could also be applied for this practice if approved for BMP consideration.

A CBP representative on the Panel raised an additional policy concern related to the **Practice F** (licensed oyster harvest using hatchery-produced oysters). Since this practice applies to a public fishery, it is unclear if it would set a precedent that may have unintended management consequences for other fisheries. There were no issues concerning the technical merit of the Panel's recommendations for this practice. Therefore, further discussion within the CBP Partnership may be needed to evaluate policy implications.

The WQGIT determined that policy issues raised by the Panel and stakeholders were outside the purview of the Panel's charge and should be evaluated by the CBP Partnership Management Board. The CBP Partnership Management Board is working on resolving these policy issues as the Oyster BMP Expert Panel refines recommendations on the nutrient reduction effectiveness based on existing science. 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 nutrient reduction effectiveness of oyster practices.

2.0 Summary of Recommendations Covered in this Report

This report covers the Panel's recommendations for 45 of the 96 practice-protocol combinations identified as possible oyster BMPs (Table 1.1). Of the 45 combinations reviewed in this iteration, the Panel is putting forward complete recommendations for 12 combinations for BMP approval (labeled as "Complete" in Table 1.1). Two of these combinations fall under the "licensed oyster harvest" fishery management approach and involve nitrogen and phosphorus assimilation in tissue of harvested oysters (Chapter 6). Ten of these combinations fall under the "oyster reef restoration" fishery management approach and involve either nitrogen and phosphorus assimilation in tissue and shell (8 combinations; Chapter 7) or nitrogen removal from enhanced denitrification (2 combinations; Chapter 8).

Of the remaining 33 practice-protocol combinations not recommended for BMP approval at this time, 16 were not endorsed, 12 were identified as containing research gaps and therefore the reduction effectiveness cannot be estimated at this time, and 5 were not agreed upon by the Panel for possible policy issues (Table 1.1). Practices that involved transplanting wild oysters from one location to another (**Practice C & G**) or oyster harvest from areas receiving no enhancement activity (**Practice E & I**) were not endorsed (following Reichert-Nguyen et al. 2016).

Research gaps existed for the following practice-protocol combinations:

- **Practice F**. Licensed oyster harvest using hatchery-produced oysters
    - **Protocol 2 & 5**. Nitrogen and phosphorus assimilation in oyster shell
    - **Protocol 3**. Enhanced denitrification associated with oysters
- **Practice A, B, & D**. Private oyster aquaculture
    - **Protocol 2 & 5**. Nitrogen and phosphorus assimilation in oyster shell
    - **Protocol 3**. Enhanced denitrification associated with oysters

A policy issue was identified for **Practice L** (oyster reef restoration using no-harvest area designation) since no physical activity occurs to enhance oyster biomass (described in Subchapter 1.2). If the CBP Management Board decides that this practice can be considered a BMP, then the Panel's complete recommendations in Chapter 7 (restoration-assimilation) and 8 (restoration-denitrification) could also be applied to this practice.

To date, the Panel has reviewed a total of 55 practice-protocol combinations (10 from the first report; 45 in this report) of the 96 that were identified as possible oyster BMPs. Of the remaining 41 combinations, 36 involve the protocols on nitrogen and phosphorus reduction from enhanced burial (**Protocol 6 & 7**) and suspended sediment reduction associated with oysters (**Protocol 8**). The Panel felt it best to evaluate these in a future report since limited data are available to conduct a thorough review of these mechanisms. The Panel also decided to wait on evaluating the remaining 5 combinations because of conflicting information associated with Protocols 1-5 for **Practice H** (licensed oyster harvest using substrate addition; see Chapter 5.0). The Panel recommends waiting to evaluate these practice-protocol combinations until more relevant data become available.

2.1 Informational Recommendations to Support Future Evaluations

The Panel is not looking for approval on the informational recommendations included in this report (Appendix H & I). These Appendices outline the following considerations to update existing and/or to support future evaluation of additional oyster practices for BMP implementation.

- Appendix H – New data (after December 2016) can be used to update the estimates for percent nitrogen and phosphorus assimilated in oyster tissue (**Protocol 1 & 4**) for harvested diploid oysters grown in gear (**Practice A & B**).
- Appendix H – Recommendations for creating a decision framework to determine the reduction effectiveness estimates for nitrogen and phosphorus assimilated in shell (**Protocol 2 & 5**) of harvested oysters (**Practice A, B, D & F**).
- Appendix I – Existing data and knowledge gaps that need to be addressed to evaluate site-specific estimates of enhanced denitrification (**Protocol 3**) for practices where oysters are harvested (**Practice A, B, D, & F**) and for oysters growing on large substrates, such as engineered structures.

3.0 Expert Panel Membership, Charge, and Effort

3.1 Panel Membership

The Panel includes oyster scientists and practitioners from the US East Coast region. Panel members represent academia, non-profit organizations, and county, state, and federal agencies. Panel members are experts in oyster biology/ecology, water quality, biogeochemical processes, fishery management, and/or oyster practice implementation.

Panel membership changed slightly after November 2016. Matt Johnston assisted Jeff Sweeny as the Panel's Watershed Technical Workgroup (WTWG) representative from November 2016 to July 2018 and Ralph Spagnolo took over for Ed Ambrogio after his retirement from the EPA around March 2016. Ralph has since retired. Karen Hudson stepped down from the Panel after completion of the first report in December 2016. Frank Marenghi stepped in for Lynn Fegley around June 2018. Lisa Kellogg stepped down from the Panel in August 2022. Table 3.1 shows the current and past Panel membership.

Table 3.1. Current and past Oyster BMP Expert Panel membership.

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

Larry Sanford	Active	U. of Maryland Center for Environmental Science	Coastal physical oceanography; sediment transport; oceanographic instrumentation
Bill Wolinski	Active	Talbot County Department of Public Works (Retired July 2019)	Watershed Implementation Plans; BMP implementation; water quality
Advisors	**Status**	**Affiliation**	**Expertise**
Ed Ambrogio	Inactive	U.S. EPA Chesapeake Bay Program Office	EPA Region 3 Representative
Rich Batiuk	Inactive	U.S. EPA Chesapeake Bay Program Office	BMP Verification Representative
Matt Johnson	Inactive	U.S. EPA Chesapeake Bay Program Office	Watershed Technical Workgroup (WTWG) Representative
Lew Linker	Active	U.S. EPA Chesapeake Bay Program Office	Chesapeake Bay Modeling Team Representative
Lucinda Power	Active	U.S. EPA Chesapeake Bay Program Office	Water Quality Goal Implementation Team Representative
Jeremy Hanson	Active	U.S. EPA Chesapeake Bay Program Office (previously Virginia Tech)	Watershed Technical Workgroup (WTWG) Representative, Water Quality Goal Implementation Team (WQGIT) Coordinator
Jeff Sweeney	Active	U.S. EPA Chesapeake Bay Program Office	Watershed Technical Workgroup (WTWG) Representative
Ralph Spagnolo	Inactive	U.S. EPA Region III	EPA Region 3 Representative
Coordinators	**Status**	**Affiliation**	**Expertise**
Olivia Caretti	Active	Oyster Recovery Partnership	Oyster restoration and monitoring; coastal ecology
Emily French	Inactive	Oyster Recovery Partnership	Seagrass ecology; water quality monitoring; oyster restoration
Julie Reichert-Nguyen	Inactive	NOAA, Chesapeake Bay Office (previously Oyster Recovery Partnership)	Coordination and facilitation; Clean Water Act; TMDL program; water quality; fisheries science; eutrophication; climate change; ocean acidification
Ward Slacum	Active	Oyster Recovery Partnership	Program management; oyster restoration; environmental monitoring; fisheries ecology

3.2 Panel Charge

The Oyster BMP Expert Panel was charged with fulfilling three goals based on the Chesapeake Bay Program Partnership's Expert BMP Panel Review Protocol for nutrient (nitrogen and phosphorus) and sediment controls (CBP 2015):

> **Goal 1.** Reach a consensus on acceptable nutrient and suspended sediment reduction effectiveness estimates for oyster practices in Chesapeake Bay based on existing science.
>
> **Goal 2.** Determine a methodology to update these estimates when new science becomes available.
>
> **Goal 3.** Establish reduction effectiveness crediting and verification guidelines that can be incorporated in the CBP Partnership's model framework used to inform the Chesapeake Bay TMDL.

To meet these goals, the Oyster BMP Expert Panel focused on the following three charges:

Charge 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 2. Develop a decision framework that will allow for incremental approval of recommended oyster BMPs.

Charge 3. Propose recommendations for estimating nitrogen, phosphorus, and suspended sediment reduction effectiveness for various oyster practices and oyster-associated processes to help inform the Chesapeake Bay TMDL.

3.2.1 Key changes from the Oyster BMP Expert Panel Charge

- In the Panel Charge (ORP 2015) the decision framework was referred to as the *Pollutant Removal Crediting Decision Framework*. The Panel has decided to refer to it as the *Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Decision Framework*, (hereafter, "decision framework"). This change was executed 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 an incremental approval step in the timeline solely for the decision framework. This framework was instead presented and approved in the Panel's first report (Reichert-Nguyen et al. 2016).
- The oyster practices presented in this report have been refined from what was presented in the Panel Charge and the first report. Table 1.1 and 1.2 show the updated oyster practices.

3.3 Panel Effort

The Panel began developing the recommendations outlined in this report in December 2016. They have held 30 meetings to date and have had numerous e-mail and phone conversations to develop the recommendations found in this report. Panel meeting minutes are listed in Appendix L.

Public and stakeholder engagement and outreach was conducted while the Panel was convened. These efforts included open public stakeholder meetings, presentations at GIT meetings, and written updates to the GITs. Details of Panel engagement and communication with stakeholders are listed in Appendix A.

This report was open for a 40-day review period for the CBP Partnership and interested parties from January 30, 2023 to March 10, 2023.

4.0 Oyster BMP Nutrient and Suspended Sediment Reduction Effectiveness Determination Framework

The Panel created a decision framework to provide a consistent and science-based approach for designing oyster BMPs. The full decision framework was approved and is described in more detail in Reichert-Nguyen et al. (2016). This framework was implemented to (1) identify oyster practices that could lead to nutrient and suspended sediment reduction and (2) estimate reduction effectiveness of endorsed practices to inform the Chesapeake Bay TMDL. Figure 4.1 displays the main steps of the Panel's decision framework and Table 4.1 summarizes the main decision considerations for each step.

The Panel's decision framework allows for the incremental determination, approval, and implementation of nitrogen, phosphorus, and suspended sediment reduction effectiveness estimates based on available science for various oyster practices. The decision framework consists of individual reduction effectiveness crediting protocols based on oyster-associated processes that can reduce nitrogen, phosphorus, or suspended sediment. Developing protocols for individual practices allows these protocols to be applied in a step-wise manner when sufficient data becomes available to evaluate each practice-protocol combination for BMP use. Once approved, the practice-protocol combination is added as a BMP option along with any other previously approved oyster BMPs.

Multiple protocols can be paired with each practice as long as the qualifying conditions for each protocol are fulfilled. For multiple protocols that address the same nutrient (e.g., nitrogen), the reduction estimates can be added together to generate a total reduction estimate for a specific practice. The decision framework also allows for opportunities to identify knowledge gaps that should be addressed to determine nutrient reduction. This includes an option to re-evaluate estimates when new data become available.

Any policy questions that were raised by the Panel were shared with the CBP Partnership Management Board for resolution. 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.

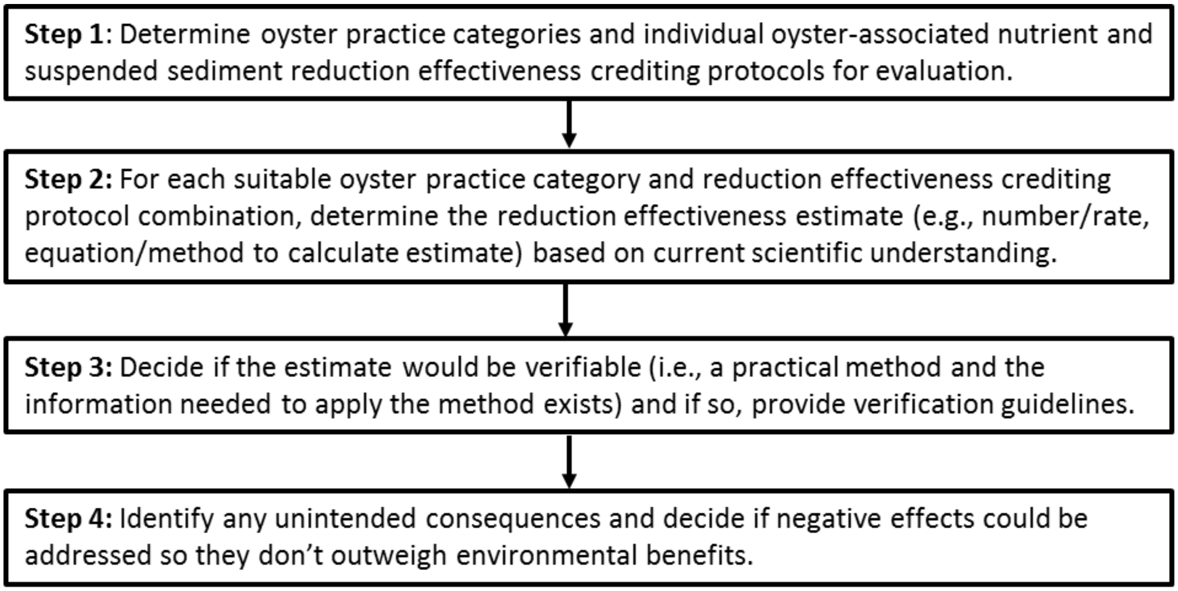


Figure 4.1. Main steps of the Panel's decision framework for providing nutrient reduction effectiveness estimates (Reichert-Nguyen et al. 2016).

Table 4.1. Key decision points for each step in the Panel's decision framework (Reichert-Nguyen et al. 2016). Decisions were made based on the Panel's best professional judgement.

Step	Decision Consideration	Description
1	Suitable for reduction consideration	The nutrient or suspended sediment reduction process should occur in association with a particular oyster practice. The reduction process involves an enhancement activity that could result in the production of new oysters.
2	Sufficient science	Data of sufficient quality and scope exist and can be used to generate a reasonable estimate of the reduction associated with a particular oyster practice.
3	Verifiable	A practical method exists, or could be created, to track reduction effectiveness if the BMP is implemented.
4	Unintended consequences	Identify potential negative effects on the environment resulting from the practice.

5.0 Oyster Practices Evaluated for BMP Consideration

Various oyster practices exist in the Chesapeake Bay that locally enhance oyster populations. The goals of these practices range from increasing oyster production for harvest to meeting oyster population and/or ecosystem-level restoration or conservation goals. Regardless of the goals or management approach of a particular practice, any practice that increases oyster biomass could potentially lead to water quality benefits.

The specific oyster practices identified and reviewed by the Panel encompass the following considerations (also provided in Table 1.2):

- Oyster type
  - Diploid vs. triploid
  - Hatchery-produced vs. wild
- Culture Method
  - Grown on- vs. off-bottom
  - Grown within vs. without gear
  - Planting hatchery-produced oysters vs. transplanting wild juvenile oysters
- Fisheries management approach
  - Private oyster aquaculture – oysters removed (harvested) from water
  - Licensed oyster harvest – oysters removed (harvested) from water
  - Oyster reef restoration – oysters remain in water

The oyster type varies based on the individual practice, fisheries management goal, and limitations of specific locations where enhancement is planned. 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, Dégremont et al. 2015). Hatchery-produced triploid oysters are created by manipulating chromosomes of reproductively viable adults to produce offspring incapable of sexual reproduction. Triploid oysters usually grow faster than diploid oysters (Allen & Downing 1986) and may exhibit greater disease resistance (Dégremont et al. 2015).

The remainder of this chapter discusses each oyster practice (summarized in Table 1.1 and 1.2), its definition, and relevant examples in detail. The Panel endorsed an oyster practice for BMP consideration if the practice includes an enhancement activity that could result in the production of new oysters and/or increases in oyster biomass. The reduction effectiveness must be attributed to the practice.

5.1. Private Oyster Aquaculture

Private oyster aquaculture practices occur in State-permitted areas where licensed oyster harvesting is not allowed and use either hatchery-produced diploid or triploid oysters, wild oysters, or a combination of these (Table 5.1). These practices involve growing oysters on or off the bottom 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 grown as single oysters where the initial shell substrate is indistinguishable from the rest of the shell ("cultchless"). Aquaculturists growing oysters on the bottom without gear typically enhance the bottom by reclaiming existing shell or adding hard substrate (e.g., shell, stone, etc.; hereafter, "substrate addition)" to facilitate recruitment of naturally-occurring oyster larvae. There are also on-bottom aquaculture operations that will plant hatchery-produced spat-on-shell (oyster larvae that have settled on a shell base) on their leased areas. Private oyster aquaculture operations may also move wild juvenile oysters (which occur naturally on pre-existing reefs) from one location to another to enhance areas that do not receive high densities of larvae. In some instances, lease holders do not carry out any enhancement activities and instead harvest wild oysters within their leased area. From the Panel's understanding, this is not the intended use of oyster aquaculture leases, since state policies typically issue leases in areas that are unlikely to have pre-existing oysters or viable reef habitat (Code of Maryland Regulations COMAR 08.02.04.17, Code of Virginia §28.2-603).

In it's first report, the Panel endorsed three out of five private oyster aquaculture practices for BMP consideration (Table 5.1):

- **Practice A**. Off-bottom private oyster aquaculture using hatchery-produced oysters
- **Practice B**. On-bottom private oyster aquaculture using hatchery-produced oysters
- **Practice D**. On-bottom private oyster aquaculture using substrate addition

The definitions and examples for these three practices are presented in Reichert-Nguyen et al. (2016). Currently, the Panel is not recommending any additional reduction effectiveness estimates for approval for these practices. The Panel has included additional considerations for these practices in Appendices E and F.

Table 5.1. Private oyster aquaculture practices and endorsement decisions approved in Reichert-Nguyen et al. 2016. HPO = Hatchery-produced oysters, POA = Private oyster aquaculture.

Oyster Fate	Oysters removed (harvested) from Bay				
Fisheries Management Approach	Private oyster aquaculture (POA)				
Description	Oyster harvest from State-issued water column and bottom leases				
Access to Oysters	Lease-holder				
Oyster Type	Hatchery-produced oysters (HPO: diploid or triploid)		Wild oysters (diploid)		
Activity	HPO grown off the bottom using gear	HPO grown on the bottom using no gear	Moving wild oysters from one bottom location to another	Addition of substrate to enhance recruitment of wild oyster larvae	None
Oyster Practice	**A. Off-bottom POA using HPO**	**B. On-bottom POA using HPO**	C. On-bottom POA using transplanted wild oysters	**D. On-bottom POA using substrate addition**	E. POA with no activity
Recommended for BMP?	**Yes**	**Yes**	No	**Yes**	No

5.2 Licensed Oyster Harvest

The Panel defined ***licensed oyster harvest*** as oyster harvest from a State-managed fishery area by individuals holding the proper licenses. The Panel reviewed four licensed oyster harvest practices (Table 5.2) but determined that crediting for licensed oyster harvest can only occur on areas that are supplemented with hatchery produced oysters (e.g., spat-on-shell or single oysters). The addition of hatchery-produced oysters is common in areas of the Chesapeake Bay where natural recruitment is low (e.g., Upper Bay). In other areas, natural larval supply is higher, and practices that increase the abundance of suitable substrate are common (i.e., substrate addition). In some cases, juvenile oysters are moved from areas of high density to areas of low oyster density to supplement local populations for harvest. All of these practices aim to enhance the number of harvestable oysters on public reefs. Licensed oyster harvest can also occur in areas where no additional enhancement activity takes place.

The Panel endorsed one out of four licensed oyster harvest practices for BMP consideration (Table 5.2):

- **Practice F**. Licensed oyster harvest using hatchery-produced oysters
  Definition: Planting oysters (e.g., spat-on-shell, single oysters) produced from hatchery techniques directly on the bottom to enhance the stock in State-designated fishing areas (e.g., public shellfish fishing grounds) for eventual removal (harvest) from the water by individuals holding the proper licenses.

This practice is similar to private oyster aquaculture **Practice B** (On-bottom private oyster aquaculture using hatchery-produced oysters), but there is a fundamental difference in where the oysters are planted and who has access to the oysters. Leases are typically issued in areas that are unlikely to have pre-existing oysters or viable reef habitat. For example, Virginia law currently does not allow leasing of “public oyster beds, rocks, or shoals, as defined by law and included in the Baylor survey” (Code of Virginia §28.2-603) and Maryland will only consider permitting a new lease “If the results of a biological survey conducted by the Department or a designated agent show that the average density of oysters per square meter is equal to or below the maximum threshold of one oyster that is 1 inch or greater per square meter” (Code of Maryland Regulations COMAR 08.02.04.17). **Practice F** explicitly applies only to areas where hatchery-produced oysters are planted on public harvest areas.

The location of enhancement and who has access to oysters could also affect verification procedures. Private oyster aquaculture offers a controlled setting as all oyster-related activities are generally implemented by a specific entity (single individual or small group of individuals). Planting oysters in a public harvest area results in oyster-related activities implemented by a much larger group of people. Oysters added to public harvest areas can also be harvested by any harvester that has the proper licenses. For this practice, accurate and timely harvest reporting and verification that the reported data are accurate will be crucial. Therefore, while the Panel is endorsing **Practice F** (Licensed oyster harvest using hatchery-produced oysters) for BMP consideration, they agreed that additional requirements are needed to ensure that these confounding factors are addressed. These recommendations are described in Chapter 6.0.

Similar to the private oyster aquaculture **Practice C & E**, the Panel agreed that licensed oyster harvest **Practice G & I** (transplant wild oysters & no enhancement activity) should not undergo BMP consideration. Transferring live animals from one location to another (**Practice G**) does not result in a net reduction of nitrogen or phosphorus because there is no increase in oyster production. Moreover, practices that do not include any enhancement activity (**Practice I**) are not endorsed by the Panel. These oysters are already present in the water and are better suited to be incorporated as an ecological component in the CBP Partnership’s TMDL model.

The Panel is not currently endorsing licensed oyster harvest using substrate addition alone (**Practice H**) because of the lack of information and confounding results on whether the addition of substrate alone increases oyster production in productive areas where harvesting occurs. This pending practice is discussed in Subchapter 5.4.

Table 5.2. Licensed oyster harvest practices and endorsement decisions seeking approval in this report. HPO = Hatchery-produced oysters, LOH = Licensed oyster harvest.

Oyster Fate	Oysters removed (harvested) from Bay			
Fisheries Management Approach	Licensed oyster harvest (LOH)			
Description	Oyster harvest from State-managed fishing areas			
Access to Oysters	License-holder			
Oyster Type	Hatchery-produced oysters (HPO: diploid or triploid)	Wild oysters (diploid)		
Activity	Addition of HPO	Moving wild oysters from one location to another	Addition of substrate to enhance recruitment of wild oyster larvae	None
Oyster Practice	**F. LOH using HPO**	G. LOH using transplanted wild oysters	H. LOH using substrate addition	I. LOH with no activity
Recommended for BMP?	**Yes**	No	Later	No

5.2.1 Example of **Practice F**: Licensed Oyster Harvest using Hatchery-Produced Oysters

Licensed oyster harvest using hatchery-produced oysters (**Practice F**) consists of planting hatchery-produced diploid or triploid oysters directly on the bottom. The goal is for these oysters to be removed once they reach market size (3 inches in MD and VA) and can be harvested for consumption. Oysters require approximately two to three years to reach minimum market size, but oysters may be left in the water beyond this size. In some cases, the fishery area may be temporarily closed to harvest to allow oysters to grow. These may be referred to as “reserves” or incorporated into a rotational harvest design.

To the best of the Panel’s knowledge, licensed oyster harvest using hatchery-produced oysters has only occurred in Maryland and spans less than 180 acres (F. Marenghi, MD DNR, pers. comm.). This practice is executed through a program where County Oyster Committees or local Waterman Associations work with the Maryland Department of Natural Resources (MD DNR) to (1) identify locations needing replenishment and (2) plant hatchery-produced oysters in public harvest areas (MD DNR 2016). MD DNR reviews the reefs selected for replenishment to ensure that policy guidance is being met. Plantings typically use diploid, hatchery-produced spat-on-shell and occur on portions of historically productive oyster bars where pre-existing oysters could be present. In rare cases, hatchery-produced, triploid oysters are used to reach minimum legal harvest size faster than would be possible if using diploid oysters (F. Marenghi, MD DNR, pers. comm.). The Oyster Recovery Partnership coordinates and assists with plantings and tracks the locations and amounts of oysters that are planted (ORP 2021). Although this practice is not currently used in Virginia, the Panel agreed it could be applied as a BMP in Virginia if occurs in the future.

5.3 Oyster Reef Restoration

In the Chesapeake Bay, oyster reef restoration in designated no-harvest areas aims to increase the number of oysters that will remain in the water. Oysters form 3-dimensional structures which provide additional surfaces available for oyster larvae to settle, grow, and reproduce. Adding diploid oysters to the water will also increase the number of oyster larvae that could settle, grow, and reproduce, thus contributing even more oyster larvae to the system through positive feedback mechanisms. The primary goal of enhancing oyster habitat is to create self-sustaining local oyster populations. Other goals include increasing disease resilience and providing additional ecosystem services, such as increasing habitat for other organisms, improving water quality, etc.

The oyster reef restoration practices evaluated by the Panel include two active approaches (**Practices J & K**) involving the addition of oysters and/or substrate and one passive approach (**Practice L**) in which neither oysters nor substrate are added as part of the restoration effort. In this case, the enhancement activity is the elimination of harvest pressure to allow the oyster population to naturally recover. The Panel is not endorsing **Practice L** at this time due to a policy issue but endorsement is pending (Subchapter 5.4).

The Panel endorsed two out of three oyster restoration practices for BMP consideration in this report (Table 5.3):

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

Enhancement activities associated with these restoration practices include planting hatchery-produced oysters as spat-on-shell and/or substrate (e.g., shell, stone, concrete, etc.) on the bottom to increase oyster density on a per-acre basis. There are instances where substrate is added to improve the bottom conditions for oyster survival before planting spat-on-shell. When only substrate is added, recruitment is based solely on wild oyster larvae settling on the added substrate.

Given that oyster shell is a limited resource in the Chesapeake Bay, there has been a need to use alternate substrate for restoration. The type of substrate used and how it is incorporated into restoration designs vary from project to project. The size and configuration of alternate substrates used for restoration should be considered if implementers seek to apply certain practice-protocol combinations for BMP use, as not all substrates are eligible for all restoration practice-protocol combinations endorsed by the Panel (see Subchapter 7.2.3, 8.2.3, and 8.5).

Table 5.3. Oyster reef restoration practices and endorsement decisions seeking approval in this report. HPO = Hatchery-produced oysters, ORR = Oyster reef restoration.

Oyster Fate	Oysters remain in Bay		
Fisheries Management Approach	Oyster Reef Restoration (ORR)		
Description	No harvest allowed		
Access to Oysters	State resource management agency		
Oyster Type	Hatchery-produced oysters (HPO: diploid)	Wild oysters (diploid)	
Activity	Designate no-harvest area followed by addition of HPO	Designate no-harvest area followed by addition of substrate	Designate no-harvest area with no additional activity
Oyster Practice	**J.** **ORR using HPO**	**K.** **ORR using substrate addition**	L. ORR using no harvest area designation only
Recommended for BMP?	**Yes**	**Yes**	Later

5.3.1 Example of **Practice J**: Oyster Reef Restoration using Hatchery-Produced Oysters

Oyster reef restoration using hatchery-produced oysters is most commonly used when natural oyster recruitment is a significant factor limiting local oyster populations. In the Chesapeake Bay, the addition of hatchery-produced oysters as part of a restoration effort is frequently achieved by planting spat-on-shell. Spat-on-shell consists of juvenile oysters, known as "spat", growing on adult oyster shell. Spat-on-shell is generally produced by placing hatchery-produced oyster larvae that are ready to settle in a tank with aged, clean oyster shell and allowing the larvae to settle on the shell and grow until they are deemed large enough for transport to the planting location. Spat-on-shell can either be planted directly on the bottom if it is suitable for oyster survival and growth, or the bottom may be amended prior to planting though the addition of substrate to improve conditions for oyster survival and growth. To date, spat-on-shell planting has been used in a wide variety of restoration efforts, including but not limited to:

- The "10 Tributaries by 2025" effort in Maryland and Virginia (ORIW 2022) established by the 2014 Chesapeake Bay Watershed Agreement in response to Executive Order 13508 (2009) entitled "Chesapeake Bay Protection and Restoration"
- MD DNR's Nanticoke (MD DNR 2022c) and Severn River (MD DNR 2022d) restoration projects.
- Chesapeake Bay community initiatives such as Marylanders Grow Oysters (MD DNR 2022a) and the Virginia Oyster Gardening (CBF 2022) programs.

5.3.2 Example of **Practice K**: Oyster Reef Restoration using Substrate Addition

Oyster reef restoration using substrate addition is most commonly used when a lack of hard substrate for oyster larvae to settle on is the primary factor limiting local oyster populations. Conventional oyster reef restoration methods using substrate addition involve (1) securing suitable substrate (e.g., shell, fossilized shell, granite, crushed concrete, concrete engineered structures, etc.) and (2) deploying this material to create habitat to support natural oyster recruitment. The substrate is deployed in areas where the bottom is suitable for oyster survival and typically in areas that have demonstrated relatively high natural oyster recruitment. This method has been practiced in both Maryland and Virginia but is more common in Virginia. Representative examples of this method can be found in several river systems in Virginia and Maryland that are part of the "10 Tributaries by 2025" restoration program (ORIW 2022). In many cases where suitable habitat is limited and larval supply is low, restoration practitioners employ both the addition of substrate followed by planting of spat-on-shell.

5.4 Oyster Practices with Pending Endorsement

The Panel is currently unable to fully endorse two of the 12 practices reviewed in this report due to lack of information or policy issues:

- **Practice H**. Licensed oyster harvest using substrate addition
  Definition: Planting oyster shells or alternative substrate directly on the bottom to attract recruitment of naturally occurring (wild) oyster larvae to enhance the stock in State-designated fishing areas (e.g., public shellfish fishing grounds) for eventual removal (harvest) from the water by individuals holding the proper licenses.

- **Practice L**. Oyster reef restoration using no-harvest area designation only
  Definition: Designating an area where the removal of oysters is not permitted to enhance the current oyster population with no additional activity (e.g., planting oysters and/or substrate).

The Panel is currently not endorsing licensed oyster harvest using substrate addition (**Practice H**) because of the lack of information and confounding results on whether the addition of shell alone consistently increases oyster production in productive areas where harvesting occurs (Judy 2017, Marenghi et al. 2012, R. Mann, VIMS, unpubl. data). This practice typically aims to restore a positive shell budget (i.e., replace shell removed by harvest) by adding shell to historically productive oyster reefs rather than enhancing oyster biomass directly through the addition of hatchery produced oysters. There is currently not enough information in the existing scientific literature to support the claim that this practice consistently enhances oyster production (leads to increases in oyster biomass) on already productive public harvest areas. Moreover, the Panel determined that it could be difficult to estimate nitrogen and phosphorus reduction effectiveness associated with adding substrate to areas where there is already abundant shell and/or oysters present. Future considerations should investigate whether this practice could be a useful BMP in areas that have relatively high natural recruitment but where substrate for oyster settlement is limited. An example of this pending practice is provided in Subchapter 5.4.1.

The majority of the Panel was in agreement to endorse **Practice L:** (oyster reef restoration using no harvest area designation only) for BMP consideration. This practice designates an area where oysters are not allowed to be harvested but this is not followed by any additional effort to enhance oyster populations (e.g., addition of substrate, addition of spat-on-shell). One panelist was not in support of endorsing this practice since no physical enhancement activity is occurring. Since the rationale for not endorsing this practice was based on a policy concern, the Panel recommends that the CBP Partnership Management Board review this issue and decide on whether this practice can be applied as a BMP (outlined in detail in Subchapter 1.2). From a scientific perspective, the activity of removing harvest pressure on a natural oyster reef by designating it as a no-harvest area could result in increased oyster biomass and consequently increased nitrogen and phosphorus removal via enhanced denitrification and assimilation. The Panel agreed that their recommendations to estimate the reduction effectiveness of nitrogen and phosphorus assimilated in live oysters (Chapter 7.0) and enhanced denitrification (Chapter 8.0) could be applied to this practice, if approved for BMP use. An example of this pending practice is provided in Subchapter 5.4.2.

5.4.1 Example of **Practice H**: Licensed Oyster Harvest using Substrate Addition

Licensed harvest using substrate addition involves (1) securing suitable substrate and (2) deploying this material to create habitat to support natural oyster recruitment. This practice typically occurs in areas where availability of hard substrate for settlement, rather than supply of naturally occurring oyster larvae, is the primary factor limiting local oyster populations. When oysters reach market size (3 inches) they are harvested for consumption. Oysters typically require two to three years to reach minimum market size, but oysters may be left in the water beyond this size. In some cases, the area may be temporarily closed to harvest to allow oysters to settle and grow. In other cases, the area is left open to harvest immediately after deploying the substrate.

Substrate addition to public harvest areas is a common practice in Virginia and Maryland. Locations where this practice occurs in Virginia are documented in the Virginia Oyster Stock Assessment and Replenishment Archive (VIMS 2022). In Maryland, this practice was used as part of the MD DNR Dredged Shell Program that ran from 1960-2006 (Judy 2017). This program dredged fossilized shell from other unproductive locations within the Chesapeake Bay and deployed it in areas where it was thought that the addition of shell substrate would improve oyster production.

5.4.2 Example of **Practice L**: Oyster Reef Restoration using No-Harvest Area Designation Only

No-harvest oyster areas are closed to harvest to protect or allow oyster populations to recover passively through naturally occurring processes (e.g., recruitment, growth, reproduction of wild oysters). This practice does not include any additional enhancement activity (e.g., planting oysters and/or substrate). No-harvest areas are assigned through policy, legislative, and/or regulatory actions. Both Virginia and Maryland have established several oyster sanctuaries where no additional enhancement activities occur (Code of Maryland Regulations COMAR 08.02.04.15, Virginia Administrative Code 4VAC20-650-10). In 2010, Maryland expanded oyster sanctuaries from 9% to 24% (~9,000 acres) of the remaining Maryland oyster reef habitat over a broad geographical range. Virginia has incorporated the preservation of brood-stock sanctuaries in their oyster restoration and rotational harvest into their oyster plan (VMRC 2021).

6.0 Recommendations on Reduction Effectiveness of Nitrogen and Phosphorus Assimilated in Tissue of Hatchery-Produced Oysters Removed by Licensed Oyster Harvest

In its first report (Reichert-Nguyen et al. 2016) the Panel identified two primary oyster harvest approaches used in the Chesapeake Bay: private oyster aquaculture and licensed oyster harvest. The harvest of nitrogen and phosphorus (hereafter "nutrients") assimilated in oyster tissue from private oyster aquaculture is now an approved best management practice. Licensed oyster harvest from public harvest areas also removes the nutrients contained in oyster tissue from the Chesapeake Bay. However, as noted in Chapter 5, the Panel is not endorsing harvest from areas where no enhancement activity has occurred (**Practice I**) or from areas where wild oysters have been transplanted to enhance oyster populations (**Practice G**). After considering whether to endorse licensed oyster harvest from areas where suitable substrate has been added (**Practice H**), the Panel concluded that data were insufficient at this time to support endorsement of this practice. Therefore, the Panel is only endorsing licensed harvest of hatchery-produced oysters (**Practice F**).

This chapter describes the Panel's recommendations for two practice-protocol combinations for licensed oyster harvest:

Practice F. Licensed harvest of hatchery-produced oysters

Protocol 1. Nitrogen assimilation in oyster tissue

Protocol 4. Phosphorus assimilation in oyster tissue

Hereafter, these practice-protocol combinations are referred to collectively as "harvest-assimilation" protocols.

As for private oyster aquaculture (Practices A, B, D), the Panel is recommending that reduction effectiveness be based on harvested oysters. Unlike a newly permitted private oyster aquaculture lease, public harvest areas can have robust oyster populations prior to and long after the enhancement activity occurs (i.e, the planting of hatchery-produced oysters). To account for this and to prevent over crediting for the enhancement activity, the Panel recommends:

- Designating the ***BMP site area*** before enhancement begins
- Using a ***default tissue nutrient content*** based on a diploid shell height to biomass quantile regression.
- Using ***site-specific tissue nutrient contents*** calculated from site-specific shell height to biomass regressions to estimate assimilation only using diploid, not triploid, hatchery-produced oysters.
- Setting a ***maximum harvest allowance*** based on the number of hatchery-produced oysters planted and either a default survival rate (3%) or a site-specific survival rate.
- Applying a ***crediting time lag*** based on either the default time it takes oysters to grow to harvest size (2 years) or a site-specific amount of time.
- Setting a ***maximum crediting timeframe*** of five years after the enhancement activity.
- Requiring calculation of credits based on the minimum legal harvestable oyster size for any harvest reported in units that include mixed sized classes of oysters.

A summary of the Panel's recommended reduction effectiveness determination and qualifying conditions for harvest-assimilation protocols is provided in Table 6.1. The literature and data reviewed by the Panel in developing their recommendations are documented in Subchapter 6.1. The Panel's rationale for its recommended approach to reduction effectiveness determination is described in Subchapter 6.2 followed by stepwise guidance for reduction effectiveness determination in Subchapter 6.3. TMDL baseline considerations and qualifying conditions are described in Subchapter 6.4 and Subchapter 6.5, respectively. Subchapter 6.6 provides guidelines for application and verification. Unintended consequences and ancillary benefits are described in Subchapter 6.7 and Subchapter 6.8, respectively. The Panel's recommendations for future research are provided in Subchapter 6.9.

Table 6.1. Summary of the nitrogen and phosphorus reduction effectiveness strategy for the harvest-assimilation protocols.

Fisheries management approach	Licensed oyster harvest
Oyster practice	**Practice F:** Licensed oyster harvest of hatchery-produced oysters
Practice definition	**Practice F:** Planting oysters (e.g., spat-on-shell, single oysters) produced from hatchery techniques directly on the bottom to enhance the stock in State-designated fishing areas (e.g., public shellfish fishing grounds) for eventual removal (harvest) from the water by individuals holding the proper licenses.
Protocols	**Protocols 1 & 4**: Nitrogen and phosphorus assimilation in oyster tissue
Abbreviated name for practice-protocols	Harvest-assimilation protocols
Reduction effectiveness determination (Subchapter 6.3)	Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 6.2.1) Step 2: Document the qualifying enhancement activity and date it occurred (Subchapter 6.2.2) Step 3: Determine the maximum harvest allowance using either the default (3%) or an approved site-specific survival rate (Subchapter 6.2.3) Step 4: Determine the harvest crediting timeframe (Subchapter 6.2.4) Step 5: Determine the total amount of nitrogen and phosphorus harvested from the BMP site during the harvest crediting timeframe based on the numbers and sizes of oysters harvested and either the default (Subchapter 6.2.5.1) or a site-specific (Subchapter 6.2.5.2) estimate of tissue nutrient content per oyster.
Qualifying Conditions (Subchapter 6.5)	• A qualifying enhancement activity using hatchery-produced oysters (Subchapter 6.2.2) must have occurred throughout the BMP site area (Subchapter 6.2.1). • The BMP site area must lie within an area open to licensed oyster harvest (Subchapter 6.2.2). • At the time of planting, the shell height of hatchery-produced oysters must be <2.0 inches (<50.8 mm; Subchapter 6.2.2). • At the time of harvest, all oysters must be live (Subchapter 6.2.2), of legal harvest size (Subchapter 6.2.5.1), and harvested from within the BMP site (Subchapter 6.2.1). • All oysters must be harvested within the harvest crediting timeframe (Subchapter 6.2.4).

6.1 Literature and Data Review

The Panel agreed that the ***default tissue nutrient contents*** for harvest-assimilation protocols could be based on those developed for private oyster aquaculture practices and approved in the Panel's first report. Detailed descriptions of the literature and data used to develop these estimates can be found in that report (Reichert-Nguyen et al. 2016).

After considering both the diploid and triploid default estimates for oyster tissue nutrient contents, the Panel decided to base default tissue nutrient contents solely on the diploid, not the triploid, nutrient contents from the first report. Diploid oysters are typically used for enhancement of public harvest areas with hatchery-produced oysters. The Panel identified only one case where hatchery-produced, triploid oysters were deployed. In this case, the goal was for oysters to reach market size (3 inches) as quickly as possible (F. Marenghi, MD DNR, pers. comm.). Moreover, the enhancement activity for the harvest-assimilation protocols occur in areas where licensed oyster harvest occurs. These areas are likely to have a pre-existing population of diploid oysters that it would make it difficult to distinguish planted triploids from naturally occurring diploids at the time of harvest. For this reason, if triploid oysters are used, only the default diploid estimates can be applied. Since the diploid tissue estimates are lower than the triploid tissue estimates, this leads to a conservative estimate of nitrogen and phosphorus reduction. If diploid oysters are used, either the default diploid estimates or the site-specific reduction effectiveness estimates can be applied.

There were initial concerns that, because the dataset used to develop the Chesapeake Bay-wide diploid shell height-to-tissue dry weight regression equation for oyster aquaculture practices included oysters grown in gear, it would not be representative of oysters from licensed harvest because the oysters are not grown in gear. However, re-evaluating the diploid data by culture method demonstrated that the majority of the tissue biomass estimates were unchanged from the diploid estimates from the first report (Appendix H). There was only one shell height size class (≥ 5.5 with midpoint of 6 inches) where the nitrogen estimate slightly decreased by 0.01 g per oyster, which equated to 22 lbs per one million oysters (Appendix H, Table H-2). The Panel felt this was an insignificant change, especially since this is a size class that is rarely found in areas open to harvest. Therefore, the Panel agreed that the use of the existing diploid estimates from the first report is sufficient for the harvest-assimilation protocols with some modification to how they are used in this context (see Subchapter 6.2.5.1).

6.2 Reduction Effectiveness: Panel Recommendations and Rationale

The following sections identify the information needed to determine reduction effectiveness, outline the Panel's recommendations, and explain the rationale underlying each of those recommendations.

6.2.1 BMP Site Location and Area

As noted in Chapter 1, for an oyster practice to be eligible for consideration as a BMP, the Panel required that the practice include an enhancement activity that could result in the overall production of new oysters, and consequently, an increase in oyster biomass. For the purposes of crediting, the Panel considers the ***BMP site*** to be the location in which enhancement activities occur and which is potentially eligible for nitrogen and phosphorus reduction credit if all qualifying conditions are met. Recognizing that that the planned location of enhancement activities may not always match the actual location of enhancement activities, the Panel specifically recommends that the ***BMP site*** be determined based upon the actual location of enhancement activities (Fig. 6.1). The BMP site should be described by a series of points (with latitudes and longitudes) which can be connected to form a polygon that encompasses only the area in which the enhancement activities occurred. The area of the polygon defined by these points is the ***BMP site area***. All oysters eligible for crediting must be harvested from within the BMP site.

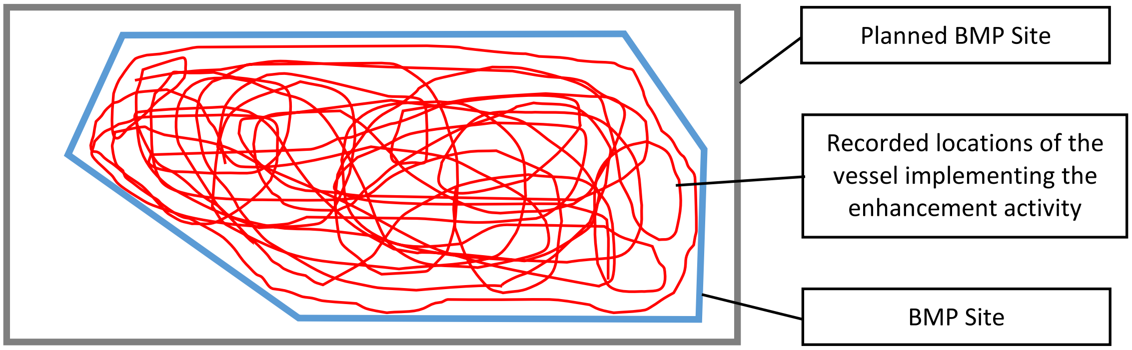


Figure 6.1. Hypothetical map of a BMP site. The area inside the rectangle outlined in gray represents the originally planned location of enhancement activity. The red line represents the recorded locations of the vessel implementing enhancement activity (e.g., the planting "tracklines"). Because the vessel did not implement the restoration activity throughout the entire planned BMP site, the actual BMP site area must be reduced from the original rectangle outlined in gray to the polygon outlined in blue.

6.2.2 Qualifying Enhancement Activities

The Panel considered the types of enhancement activities that could qualify as a BMP under this practice-protocol combination. The Panel found that planting hatchery-produced oysters set on oyster shell (i.e., "spat-on-shell") in areas open to licensed oyster harvest was the most common practice and that both diploid and triploid hatchery-produced oysters have been used. The Panel agreed that this practice and other similar practices that meet the following conditions could qualify for BMP crediting if:

- The enhancement activity includes the planting of hatchery-produced oysters (diploid or triploid) in an area open to licensed oyster harvest.
- The majority of nutrient assimilation into oyster tissue occurs at the BMP site (i.e., shell height of oysters at time of enhancement activity <2.0 inches shell height).

6.2.3 Maximum Oyster Harvest Allowance

Because enhancement activities for harvest-assimilation protocols occur in areas that likely have pre-existing oyster populations, the Panel deemed it important to try to prevent crediting of oysters unlikely to have resulted from the enhancement activity. As a first step, the Panel compiled reports that included data on the percent survival of oyster spat over time from sites within Chesapeake Bay (Table 6.2). The Panel found that reported survival rates were highly variable and that no studies assessed percent survival to harvest size/age.

Table 6.2. Studies reporting oyster spat survival rates that were reviewed by the Panel. All samples were collected from Chesapeake Bay. Time since planting refers to the amount of time that has elapsed between the time oysters were planted (i.e., deployed in the field) and the time samples were collected and assessed to estimate oyster survival. Lit. = Literature.

Source	Lit. Type	Sampling Locations		Year Sampled	Time since Planting	Survival (%)	
		State	***Sites***			***Mean***	***Range***
Congrove 2008	Thesis	VA	Yecomico, Coan, Great Wicomico, Rappahannock, and Piankatank Rivers	2006	1-2 weeks	63	1-100
Paynter et al. 2012	Report	MD	Chester, Choptank, Little Choptank, Nanticoke Rivers, Harris Creek, and Eastern Bay	2011	4-8 weeks	27	0.4-89.4
Paynter et al. 2013	Report	MD	Harris Creek, Upper Bay	2012	4-8 weeks	36.8	18-61
Paynter et al. 2014	Report	MD	Harris Creek, Severn River	2013	4-8 weeks	37	4-88
Congrove 2008	Thesis	VA	Yecomico, Coan, Great Wicomico, Rappahannock, and Piankatank Rivers	2007	2.5 years	21	8-33

The Panel considered other data that might be available to estimate survival from planting to harvest size and agreed that a subset of the oyster reef restoration monitoring data collected from Harris Creek, MD three years after planting would be most informative (NOAA 2016, 2017). These data were deemed suitable because:

- Monitoring data came from areas in Maryland relatively close to where licensed oyster harvest using hatchery produced oysters currently occurs
- The materials and methods used for restoration in the subset of data analyzed were extremely similar to the materials and methods commonly used for licensed oyster harvest using hatchery produced oysters
- Monitoring data were collected three years after planting. Harvest from areas supplemented with hatchery produced oysters typically occurs two to three years after planting. Use of a spat survivorship from three years after planting should lead to a relatively conservative survival estimate, thereby preventing over crediting.

Analyses found that oyster survival from planting of spat-on-shell to three years ranged from 0.07% to 4.49% with an average of 2.58% (Table 6.3). Weighting of data to account for the acreage of each reef resulted in a weighted average survivorship of 2.91%. Based on these data and rounding the value for the sake of simplicity, the Panel agreed that 3% is reasonable ***default survival rate*** for hatchery produced oysters from the time of planting to the time of harvest. Thus, the ***default maximum harvest allowance*** from a BMP site is 3% of the number of hatchery-produced oysters planted at that site.

Table 6.3. Results of Panel analysis of oyster survivorship from planting of spat-on-shell until three years after planting for select reefs in Harris Creek, MD. See Appendix D for details of analyses.

Reef name	Year planted	Year monitored	Area (acres)	% Survival
Reef #03	2012	2015	6.56	2.75%
Reef #04	2012	2015	11.24	3.48%
Reef #05	2012	2015	15.65	4.22%
Reef #07	2012	2015	10.95	2.52%
Reef #08	2012	2015	7.34	1.38%
Reef #09	2012	2015	12.29	3.02%
Reef #10	2012	2015	10.88	4.32%
Reef #11	2012	2015	6.53	1.80%
Reef #12	2012	2015	7.83	1.63%
Reef H42	2013	2016	5.63	1.81%
Reef H43	2013	2016	4.52	3.53%
Reef H44	2013	2016	2.58	1.95%
Reef H45	2013	2016	3.08	0.07%
Reef H46	2013	2016	7.95	1.69%
Reef H47	2013	2016	9.21	4.49%
			Average:	***2.58%***
		Average weighted by reef area:		***2.91%***

Because the rate of oyster survival to harvest size in some areas may consistently exceed 3%, the Panel agreed that a ***site-specific survival rate*** could be developed and used to create a ***site-specific maximum harvest allowance*** for reduction credit. At a minimum, developing a site-specific mortality estimate would require two surveys of the oyster population at the BMP site: one prior to the enhancement activity and another prior to oyster harvest. Because multiple survey and statistical approaches can be used to evaluate oyster populations and the best approach can depend on a variety of factors, the Panel did not feel it was appropriate to recommend a specific sampling approach. Instead, the Panel recommends that BMP implementers consult with expert(s) knowledgeable in oyster sampling and have their sampling designs endorsed by the state reporting agency and the CBP prior to implementation. The Panel also recommends that site-specific survival rates and the resulting site-specific maximum oyster harvest allowance be reviewed and approved using an approach similar to that described by CBP for re-evaluation of existing estimates (CBP 2015). If approved, revised values can be used only for the BMP site from which data were collected for use in developing site-specific values and cannot be used for other BMP sites.

Regardless of the approach used to set the maximum harvest allowance, the Panel agreed that crediting must be based on the actual numbers and sizes of oysters harvested. The Panel also agreed that all oysters must be alive at the time of harvest to be eligible for crediting.

6.2.4 Timing of Harvest Relative to Enhancement Activity

The Panel also considered the timing of harvest and crediting relative to the timing of the enhancement activity (i.e., planting of spat-on-shell). In Chesapeake Bay, hatchery-produced oysters are typically planted from May to September. Licensed oyster harvest is permitted from October to March. It is expected that most of the planted oysters that survive will reach the currently allowed harvest size of three inches (76 mm) within two years and will be eligible for harvest in the third harvest season after the enhancement activity. Specifically, to ensure that the majority of the harvested oysters eligible for nitrogen and phosphorus reduction credit are likely attributable to the enhancement activity, the Panel recommends a ***default credit time lag*** of two years after the date when hatchery-produced oysters were placed in the field (i.e., "planted").

Because oyster growth rates vary widely, the Panel agreed that a ***site-specific credit time lag*** can be developed if implementing programs collect sufficient oyster growth data from the BMP site to demonstrate that, on average, oysters reach harvest size in less than two years. If a site-specific credit time lag is sought, the Panel recommends that the plan for associated sampling and data analysis be developed in consultation with expert(s) knowledgeable in oyster sampling and endorsed by the state reporting agency and the CBP prior to implementation. Any adjustments to credit time lag should be reviewed and approved using an approach similar to that described by CBP for re-evaluation of existing estimates (CBP 2015). If approved, the revised time lag can be used only for the BMP site from which data were collected for use in developing site-specific values and cannot be used for other BMP sites.

Again, to ensure that the majority of the harvested oysters eligible for credit are likely attributable to the enhancement activity, the Panel considered the maximum amount of time after planting that harvest from a BMP site should be eligible. Based on their expert opinion, the Panel concluded that most of the hatchery produced oysters planted at the BMP site would be harvested within five years. Because planting activities generally occur in summer months, oysters will reach five years old between the fifth and six harvest season after planting. Thus, the Panel is recommending five years as the ***maximum harvest timeframe*** meaning that credits will expire after the fifth and before the sixth harvest season following the enhancement activity. The ***harvest crediting timeframe*** is the time window during which the nitrogen and phosphorus reduction from the oyster harvest allowance can be credited. If using the default reduction credit time lag, this window begins two years after the enhancement activity and ends three years later when the 5-year oyster harvest timeframe ends. If using the Panel's default timeframes, oysters harvested in the third, fourth and fifth harvest seasons after planting are eligible for crediting. For the BMP to remain continuously active, qualifying enhancement activities must occur at the BMP site at a minimum of once every three years.

The Panel agreed that, if the default oyster harvest allowance and default harvest crediting timeframe are used, pre-planting and pre-harvest oyster population assessments are not needed.

6.2.5 Amount of Tissue Harvested and Associated Nutrient Content

The Panel is recommending two options for determining the amount of nitrogen and phosphorus in the tissue of harvested oysters for this practice-protocol combination:

- Default approach
- Site-specific approach

The default estimates for nitrogen and phosphorus assimilation represent typical conditions across the entire Bay and the entire suite of environmental conditions that influence oyster growth. In contrast, site-specific estimates represent the nitrogen and phosphorus contained in the tissue of oysters at a single BMP site. Site-specific estimates can potentially be higher than the default estimate but require collection of considerably more data from the BMP site. Regardless of the approach used, the first step is determining the numbers and sizes of oysters harvested.

6.2.5.1 Numbers and Sizes of Harvested Oysters

The Panel agreed that to be eligible for credit the number and sizes of harvested oysters must be directly assessed. In considering methods that might be used to determine the number of oysters harvested, the Panel explored current oyster harvest reporting requirements. In the Chesapeake Bay, commercial fishermen are required to quantify and report monthly oyster harvest to their state management agency. Harvest is typically reported in the same units in which they are sold (e.g., bushels) and these units can vary across jurisdictions. The Panel agreed that a variety of reporting units should be allowed, but also agreed that there must be a clear and defensible method for converting these units into the number of individual oysters.

At present, a variety of approaches are used to convert the units in which oysters are reported to jurisdictions into numbers of individual oysters. For example, the Maryland Department of Natural Resources (MD DNR) defines a bushel by volume. In 2018, they used 228 oysters per bushel for their stock assessment based on data collected at an oyster dealer that year (F. Marenghi, MD DNR, pers. comm.). Another approach is to use independent third-party verifiers to randomly spot check oyster quantities in the container-type being used (Slacum et al. 2013). This approach is being implemented through the MD DNR’s pilot project that is testing daily electronic reporting by watermen for oyster harvest (MD DNR 2022b).

Because a variety of reporting units may be used and these units may change over time, the Panel did not think it was appropriate to recommend a specific method for converting harvest reporting units into the number of individual oysters. Instead, the Panel recommends that an implementer seeking credit work in conjunction with their local jurisdiction and the CBP to develop a scientifically defensible method for converting reporting units into numbers of individual oysters. This method should be reviewed and approved by the reporting jurisdiction and CBP to ensure that it can be applied to meet TMDL requirements. It should also be clearly documented in the implementation plan.

Another challenge in determining the appropriate nutrient credits for licensed oyster harvest is that the majority of harvest units reported include mixed oyster size classes. During harvest, oysters are typically culled to remove oysters smaller than the minimum legal size and then all oysters above that size limit are stored in the same container. The Panel agreed that when oysters of mixed size classes are combined within the reporting unit, the nitrogen and phosphorus content of the tissues of those oysters should be based on oysters of the minimum legal harvest size. For example, if three inches is the legal harvest size, then the 3-inch diploid estimate should be used to calculate the nitrogen and phosphorus reduction even though some larger oysters were likely harvested. This approach results in a conservative estimate of the amount of nitrogen and phosphorus assimilated in oyster tissue.

Although most commercially harvested oysters are not reported in terms of size class, the Panel agreed that, if procedures are in place that require the sorting of oysters by uniform BMP sizes along with statistically supported verification approaches, then crediting oysters by their respective size classes could be feasible. The Panel recommends that any approaches used to generate nutrient reduction credits above the minimum legal harvest size be incorporated into the BMP implementation plan and reviewed and approved by the reporting agency and CBP.

6.2.5.2 Default Tissue Nutrient Content

As noted in Subchapter 6.1, the Panel agreed that the default diploid oyster tissue nutrient contents developed for private oyster aquaculture could serve as the basis for default tissue nutrient content estimates for the harvest-assimilation protocols. The private oyster aquaculture default reduction effectiveness calculations allow crediting of oysters less than three inches in shell height (Fig. 6.2). However, current state regulations do not allow harvest of oysters less than three inches in shell height from public harvest areas (Code of Maryland Regulations COMAR 08.02.04.11, Virginia Administrative Code 4VAC20-260-30). The Panel agreed that only oysters of legal harvest size are eligible for crediting. For this reason, the Panel decided to remove the 2.00 – 2.49 inch size class. The Panel also decided to change the name of the 2.50 – 3.49 inch size class to a 3.00 – 3.49 inch size class but to retain the original estimated nutrient content for the 2.50 – 3.49 inch size class. This results in an intentionally conservative estimate of the nutrient content of oysters in this size class. The resulting ***default tissue nutrient contents*** for the harvest-assimilation protocols are given in Table 6.4 in terms of grams of nitrogen and phosphorus per oyster. In Table 6.5, these same values are given in terms of pounds of nitrogen and phosphorus per million oysters. Details of the approaches and data used to determine the default diploid tissue nutrient content can be found in the Panel's first report.

Figure 6.2. 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.

Table 6.4. Recommended default nitrogen and phosphorus content of diploid oyster tissue. Oyster size class based on shell height measurements. Mean percent nitrogen content = 8.2%; Mean percent phosphorus content = 0.9%; Regression equation: $y=0.0004x^{1.82}$ (Reichert-Nguyen et al. 2016).

Oyster size class (in)	Midpoint (in)	Midpoint (mm)	Tissue dry weight (g oyster^{-1})	Content in oyster tissue (g oyster^{-1})	
				Nitrogen	Phosphorus
3.00-3.49*	3	76	1.06	0.09	0.01
3.50-4.49	4	102	1.81	0.15	0.02
4.50-5.49	5	127	2.70	0.22	0.02
≥ 5.50	6	152	3.74	0.31	0.03

* Adjusted from 2.50-3.49. See text for details.

Table 6.5. Default nutrient reductions in pounds per one million harvested hatchery-produced oysters. Oyster size class based on shell height measurements.

BMP Name	Oyster size class (in)	Nitrogen (lbs./million oysters)	Phosphorus (lbs./million oysters)
Diploid Licensed Oyster Harvest, Hatchery Produced 3.0 Inches	3.00-3.49*	198	22
Diploid Licensed Oyster Harvest, Hatchery Produced 4.0 Inches	3.50-4.49	331	44
Diploid Licensed Oyster Harvest, Hatchery Produced 5.0 Inches	4.50-5.49	485	44
Diploid Licensed Oyster Harvest, Hatchery Produced >5.0 Inches	≥ 5.50**	683	66

* Adjusted from 2.50-3.49. See text for details.
** Based on midpoint of 6.0 inches

6.2.5.3 Site-specific Nitrogen and Phosphorus Reduction Estimates

The Panel also recommends allowing development of ***site-specific tissue nutrient contents*** for the harvest-assimilation protocols for harvested diploid oysters. The Panel is not recommending this option for areas where hatchery-produced triploid oysters are planted in public harvest areas (see Subchapter 6.1). The site-specific method recommended by the Panel relies on measured oyster tissue biomass and default values for the percentage of nitrogen and phosphorus in oyster tissue. The Panel decided this was a reasonable, scientifically defensible approach because variance in the relationships between oyster shell height and tissue dry weight is far greater than variance in the relationships between tissue dry weight and nutrient content.

To establish site-specific tissue nutrient contents, the Panel recommends the implementer work with the reporting jurisdiction, CBP Partnership, and expert(s) in oyster sampling and sample processing to:

- Define specific oyster size classes if they differ from the size classes used for default tissue nutrient contents
- Identify at least two evenly distributed sampling periods to ensure sampling reflects seasonal differences within the allowed harvesting timeframe set by state regulations.
- Assess the average tissue dry weight for each size class based on 50 randomly selected oysters per size class and sampling period. Oyster samples must be processed at 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; Mo & Neilson 1994, Carmichael et al. 2012).
- Multiply the average tissue dry weight for each size class by the default nitrogen percentage (8.2%) and phosphorus percentage (0.9%) in oyster tissue to determine the site-specific nitrogen and phosphorus content per oyster.

The Panel recommends that site-specific tissue nutrient content be reviewed and approved using an approach similar to that described by CBP for re-evaluation of existing estimates (CBP 2015). If approved, revised values can be used only for the BMP site from which data were collected for use in developing site-specific values and cannot be used for other BMP sites.

6.3 Reduction Effectiveness: Stepwise Determination

To calculate the reduction effectiveness for the harvest-assimilation protocols, the Panel recommends the following:

Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 6.2.1)

Step 2: Document the qualifying enhancement activity and the date it occurred (Subchapter 6.2.2)

Step 3: Determine the maximum harvest allowance using either the default (3%) or an approved site-specific survival rate (Subchapter 6.2.3)

Step 4: Determine the harvest crediting timeframe (Subchapter 6.2.4)

Step 5: Determine the total amount of nitrogen and phosphorus harvested from the BMP site during the harvest crediting timeframe based on the numbers and sizes of oysters harvested and either the default (Subchapter 6.2.5.1) or an approved site-specific (Subchapter 6.2.5.2) estimate of tissue nutrient content per oyster.

6.4 TMDL Baseline Considerations

The CBP Management Board defined the baseline for oyster practices that remove (harvest) oysters to only include oysters that are removed after the BMP is approved/implemented for reduction effectiveness credit in the TMDL. They also established that credit will be counted when oysters are removed (not planted) and that past harvest cannot be credited.

6.5 Qualifying Conditions

The Panel recommends the following qualifying conditions, which account for both the CBP Management Board's defined baseline and the Panel's criteria:

- A qualifying enhancement activity using hatchery-produced oysters (Subchapter 6.2.2) must have occurred throughout the BMP site area (Subchapter 6.2.1).
- The BMP site area must lie within an area open to licensed oyster harvest (Subchapter 6.2.2).
- At the time of planting, the shell height of hatchery-produced oysters must be <2.0 inches (<50.8 mm; Subchapter 6.2.2).
- At the time of harvest, all oysters must be live (Subchapter 6.2.2), of legal harvest size (Subchapter 6.2.5.1) and harvested from within the BMP site (Subchapter 6.2.1).
- All oysters must be harvested within the harvest crediting timeframe (Subchapter 6.2.4).

6.6 Recommended Application and Verification Guidelines

6.6.1 Reporting Guidelines

To assist with application of its recommendations, the Panel developed guidelines for the information to be reported by anyone seeking credit for this practice-protocol combination. The required information is listed below under the associated determination step.

Step 1: Document the BMP site location (Subchapter 6.2.1)

- Geospatial information documenting the vertices of a polygon representing the BMP site
- Name of the licensed oyster harvest area within which the BMP site lies or geospatial information documenting location of the licensed oyster harvest area

Step 2: Document the qualifying enhancement activity and date it occurred (Subchapter 6.2.2)

- Brief description of enhancement activity

- Date of enhancement activity
- Ploidy of hatchery-produced oysters
- Number and size of hatchery-produced oysters at the time of planting

Step 3: Determine the maximum harvest allowance using either the default (3%) or an approved site-specific survival rate (Subchapter 6.2.3)

- Method used to determine maximum harvest allowance (default or site-specific)
  - If site-specific survival rate is used, provide documentation of approval from CBP that site-specific approach has been reviewed and approved.
- Maximum harvest allowance
- Number of oysters previously credited from the same enhancement activity

Step 4: Determine the harvest crediting timeframe (Subchapter 6.2.4)

- Method used to determine the time lag (default or site-specific)
  - If site-specific time lag is used, provide documentation of approval from CBP that site-specific approach has been reviewed and approved.
- Length of time lag
- Start and end dates of harvest crediting timeframe

Step 5: Determine the total amount of nitrogen and phosphorus harvested from the BMP site during the harvest crediting timeframe based on the numbers and sizes of oysters harvested and either the default (Subchapter 6.2.5.1) or a site-specific (Subchapter 6.2.5.2) estimate of tissue nutrient content per oyster.

- Harvest month(s)
- Harvest season
- Units used for reporting oysters
  - If units are not individual oysters, provide documentation of the approved method used to convert units into numbers of individual oysters
- Oysters per reporting unit
- Total number of oysters harvested from the BMP site
  - If size classes are mixed or if all oysters harvested fall into same size class as the minimum legal harvest size class, report total number of individual oysters
  - If BMP size classes greater than the minimum legal harvest size class are used, report number of oysters harvested for each size class and provide documentation of approved size class sorting method and verification.
- Approach used to convert oysters to amounts of nitrogen and phosphorus (default or site-specific). If site-specific, then also include documentation on how the estimates were derived.
- Total amount of nitrogen and phosphorus eligible for credit

The Panel noted that optional information could be provided that could assist with verification of both the enhancement activity and the harvest. This information could include documentation of the purchase of oysters from a hatchery, documentation of costs associated with planting, and additional harvest information such as the name of the harvester and who the oysters were sold to (e.g., dealer, public, etc.).

6.6.2 Example

To give an example of the information needed for crediting, Table 6.6 provides a list of the information along with a hypothetical example of that information for the first year of harvest from a BMP site. Although this example assumes that credit is applied for at the end of the harvest season, credits can be applied for whenever oysters are harvested. Table 6.6 assumes that the values given in monthly reports have been added together and the resulting total number of oysters harvested was used in determining the annual reduction effectiveness credit.

Table 6.6. Information types required for the harvest-assimilation protocols along with an example of each. See text and Tables 6.7, 6.8, and 6.9 for details of calculations used to provide example information below. For this example, the report would also need to include documentation of the approved method used to convert the number of bushels to the number of individual oysters.

Step #	Information Type	Example
1	BMP site location	GIS layer with polygon for BMP site and latitude and longitude for all vertices provided as a separate file
	Name of licensed oyster harvest area	Cedar Point, Broad Creek, MD
2	Enhancement activity	Spat-on-shell planting
	Date(s) of activity (mm/dd/yy)	05/14/19, 06/02/19, 07/17/19
	Ploidy	Diploid
	Number of hatchery-produced oysters planted	50,000,000
	Size of hatchery-produced oysters at time of planting (mm)	10
3	Method used to determine maximum harvest allowance	Default
	Maximum oyster harvest allowance	1,500,000
	Number of oysters previously credited	0
4	Method used to determine time lag	Default
	Length of time lag	2 years
	Oyster harvest crediting timeframe start date	05/14/21
	Oyster harvest crediting timeframe end date	05/14/24
5	Months when harvest occurred	October - March
	Harvest season	2021/2022
	Oyster reporting units	Bushels
	Oysters per reporting unit	300
	Harvest reported	1,000 bushels
	Total number of oysters harvested	300,000
	Number of harvested oysters eligible for credit	300,000
	Method used to convert oyster tissue to nutrients	Default
	Nitrogen removed (lbs)	59.4
	Phosphorus removed (lbs)	6.6

Because oysters attributable to the enhancement activity can be harvested and credited from the start of the harvest crediting timeframe to up to five years after planting, implementers must track both planting and harvest at the BMP site across multiple years. Table 6.7 provides an example of tracking oyster plantings over a 10-year period using the information from Table 6.6 for the first planting. For a BMP to remain continuously active, enhancement activities must occur at least every three years. However, the number of oysters eligible for harvest during a particular harvest season will depend on when oysters are planted, how many are planted, and how many have already been harvested. Table 6.8 uses the planting information from Table 6.7 to provide an example of how all of these interact to determine how much of the harvest allowance is available for crediting at a particular point in time. Following Table 6.8 is a stepwise explanation of the calculations used to develop and fill the table.

Table 6.7. Example of tracking plantings starting with the scenario from Table 6.6.

Year:	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
Spat Planted (millions)	50.00	25.00	0		25.00	0	0	0	0	0	100.00
Maximum oyster harvest allowance[1] (millions)	1.50	0.75	0	0	0.75	0	0	0	0	0	3.00

[1] Based on 3% default value; could vary if site-specific assessment of spat survivorship is available.

Table 6.8. Example of tracking harvests for the plantings shown in Table 6.7.

Harvest Season:	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	Total
Harvest season after first planting	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	
Harvest of 2019 planting eligible for BMP credit?			Yes	Yes	Yes						
Harvest of 2020 planting eligible for BMP credit?				Yes	Yes	Yes					
Harvest of 2023 planting eligible for BMP credit?							Yes	Yes	Yes		
BMP active based on timeframe?	No[1]	No[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No[2]	
2019 planting harvest allowance remaining (millions)			1.50	1.20	0.75	0	0	0	0	0	
2020 planting harvest allowance remaining (millions)				0.75	0.75	0.75	0	0	0	0	
2023 planting harvest allowance remaining (millions)							0.75	0.15	0	0	
Oysters harvested (millions)			0.30	0.45	0	0.60	0.60	0.75	0.90	0.75	4.35
Oysters credited (millions)			0.30	0.45	0	0.60	0.60	0.15	0	0	2.1
Expiring harvest allowance[3] (millions)					0.75	0.15					0.9

[1] Less than 2 years have passed since 2019 planting
[2] Oysters from most recent planting are more than 5 years old
[3] Eligible harvest allowance not used in final year

Stepwise explanation of calculations in Table 6.8:

- The harvest allowance 1.5 million oysters for the 2019 planting (3% of the 50 million oysters planted) becomes eligible for crediting in the 2021/2022 harvest season and 0.3 million oysters are harvested and credited. This leaves a remaining harvest allowance of 1.2 million oysters at the start of the 2022/2023 harvest season.
- In the 2022/2023 harvest season, the 2020 planting becomes eligible for harvest, adding 0.75 million oysters to the total allowable harvest. To maximize crediting, the 2022/2023 harvest of 0.45 million oysters is subtracted from the harvest allowance for the 2019 planting resulting a remaining harvest allowance of 1.5 million oysters (0.75 million from 2019 planting and 0.75 million from 2020 planting) at the start of the 2023/2024 harvest season.
- In the 2023/2024 harvest season, no oysters are harvested or credited. Because the oysters from the 2019 planting have reached the end of their harvest crediting timeframe, the remaining harvest allowance of 0.75 million oysters expires, leaving 0.75 million oysters from the 2020 planting eligible for crediting at the start of the 2024/2025 harvest season.
- In the 2024/2025 harvest season, 0.6 million oysters are harvested and credited. Because the oysters from the 2020 planting have reached the end of their harvest crediting time frame, the remaining harvest allowance for the 2020 planting of 0.15 million oysters expires.
- In the 2025/2026 harvest season, the 2023 planting becomes eligible for harvest with a maximum harvest allowance of 0.75 million oysters. A total of 0.6 million oysters are harvested and credited leaving a harvest allowance of 0.15 million oysters at the start of the 2026/2027 harvest season.
- In the 2026/2027 harvest season, 0.75 million oysters are harvested. However, only 0.15 million can be credited before reaching the total harvest allowance for the 2023 planting. No credit is given for the remaining 0.60 million oysters.
- In the 2027/2028 harvest season, oysters are harvested but no credits are given because the harvest allowance for the 2023 planting has already been reached. Also, after the 2027/2028 harvest season, the 2023 planting reaches the end of its crediting timeframe.
- In the 2028/2029 harvest season, there is no harvest allowance because no qualifying enhancement activities have taken place since 2023, so the BMP is no longer active.

Out of the 4.35 million oysters harvested in the example given in Table 6.8, 2.1 million of the harvested oysters could be claimed for nitrogen and phosphorus reduction credit. As shown in Table 6.9, the credited harvest equates to a total of 415.8 lbs. of nitrogen and 46.3 lbs. of phosphorus removed.

Table 6.9. Example nitrogen and phosphorus reduction (lbs. removed) based on total harvest claimed for reduction credit (Table 6.7). Default nitrogen and phosphorus contents are for 3.0-inch oysters taken from Table 6.4.

Harvest Season	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023	2023/ 2024	2024/ 2025	2025/ 2026	2026/ 2027	2027/ 2028	2028/ 2029	*Total*
Nitrogen (lbs.)	0	0	59.4	89.1	0	118.8	118.8	29.7	0	0	***415.8***
Phosphorus (lbs.)	0	0	6.6	9.9	0	13.2	13.2	3.3	0	0	***46.3***

6.7 Unintended Consequences

The Panel identified no unintended consequences for the harvest-assimilation protocols.

6.8 Ancillary Benefits

The Panel identified several ancillary benefits for the harvest-assimilation protocols. Planting diploid oysters can potentially increase natural recruitment if the oysters spawn and produce viable larvae prior to harvest. In addition, plantings that use spat-on-shell can help maintain a positive shell budget. A positive shell budget increases the possibility of natural spat sets due to the increased availability of suitable substrate. Prior to harvest, oysters will also provide a variety of other ecosystem services including, but not limited to, improving water quality by filtering suspended organic matter and sediments from the water column and providing habitat for other organisms.

6.9 Future Research

The Panel identified the following research gap when developing the nitrogen and phosphorus reduction effectiveness recommendations for the harvest assimilation protocols:

- The default eligible harvest crediting cap was set at 3% of hatchery produced oysters planted based on analyses of data from oyster reef restoration sites in Harris Creek, MD. The Panel suggests that a more robust default harvest allowance and default crediting timeframe could be developed using long-term (>5 year) monitoring of the survival and growth of hatchery-produced oysters planted in areas open to harvest.

7.0 Recommendations on Reduction Effectiveness of Nitrogen and Phosphorus Assimilated in Live Oysters on Restored Oyster Reefs

Oyster reef restoration aims to enhance oyster populations and re-establish self-sustaining reefs. Numerous local, state, and federal partners have been restoring oyster reefs in the Chesapeake Bay since the mid-1990s. These efforts became more focused with the signing of Executive Order 13508 (2009). In 2014, the Chesapeake Bay Watershed Agreement established the goal to restore 10 Chesapeake Bay tributaries by 2025 to achieve increased habitat and water quality benefits (CBP 2014). The “10 Tributaries by 2025” program has been ongoing since 2014.

One of the many benefits of oyster reef restoration is the capacity of restored oyster reefs to sequester nitrogen and phosphorus in the tissues and shells of oysters. When oysters feed on phytoplankton and other organic matter, a portion of the nitrogen and phosphorus contained in that organic matter is assimilated into their tissues and shells. As long as this assimilated nitrogen and phosphorus is retained in the tissues and shells of oysters, water quality is improved because these nutrients cannot be used to fuel excess growth of phytoplankton.

In its first report (Reichert-Nguyen et al. 2016), the Panel identified 12 practice-protocol combinations that could remove nitrogen and phosphorus through assimilation into oysters on restored reefs (Table 1.1). This chapter describes the Panel’s recommendations on the following eight oyster practice-protocol combinations seeking BMP approval:

Practice J. Oyster reef restoration using hatchery-produced oysters

- **Protocol 1**. Nitrogen assimilation in oyster tissue
- **Protocol 2.** Nitrogen assimilation in oyster shell
- **Protocol 4.** Phosphorus assimilation in oyster tissue
- **Protocol 5**. Phosphorus assimilation in oyster shell

Practice K. Oyster reef restoration using substrate addition

- **Protocol 1**. Nitrogen assimilation in oyster tissue
- **Protocol 2.** Nitrogen assimilation in oyster shell
- **Protocol 4.** Phosphorus assimilation in oyster tissue
- **Protocol 5.** Phosphorus assimilation in oyster shell

Hereafter, these practice-protocol combinations are referred to collectively as “restoration-assimilation” protocols.

The Panel did not reach consensus on whether to endorse **Practice L** (oyster reef restoration using no harvest area designation only) because of one dissenting opinion due to a policy issue. However, they agreed that the recommendations presented in this chapter could be applied to this practice if endorsed for future BMP use.

To prevent over crediting, the Panel is recommending that the restoration-assimilation protocols be based on appreciated oyster biomass associated with restoration activities at the designated BMP site. Appreciated biomass is defined as the increase in oyster biomass over the maximum biomass previously determined for the site. For the first post-restoration biomass measurement, appreciated biomass will be equal to the post-restoration biomass minus the baseline (i.e., pre-restoration) biomass and is equivalent to biomass enhancement resulting from the restoration activity. For subsequent time periods, appreciated biomass is the amount by which biomass has increased beyond the maximum biomass previously measured at the site. As for other practice-protocol combinations, the Panel is recommending that only the nitrogen and phosphorus assimilated in live native oysters (*Crassostrea virginica)* be eligible for reduction credit.

In contrast to the harvest-assimilation and aquaculture-assimilation protocols, the Panel agreed that it was appropriate to credit nutrients assimilated into both tissue and shell because the shell is not removed from the water as part of reef restoration as it is for these other oyster practices. The Panel also agreed that the reduction effectiveness using restoration-assimilation protocols can be determined for oysters growing in all natural habitats (i.e., subtidal and intertidal) and on all suitable substrate types. For the purposes of this report, ***suitable substrate*** is defined as material on which oysters can settle and survive to adulthood and includes both oyster shell and alternate substrates. ***Alternate substrates*** are all materials not composed solely of oyster shells.

A summary of the Panel's recommended reduction effectiveness determination and qualifying conditions for the restoration-assimilation protocols is provided in Table 7.1. The literature and data reviewed by the Panel in developing their recommendations are documented in Subchapter 7.1. The Panel's rationale for its recommended approach to reduction effectiveness determination is described in Subchapter 7.2 followed by stepwise guidance for reduction effectiveness determination in Subchapter 7.3. TMDL baseline considerations and qualifying conditions are described in Subchapter 7.4 and Subchapter 7.5, respectively. Subchapter 7.6 provides guidelines for application and verification. Unintended consequences and ancillary benefits are described in Subchapter 7.7 and Subchapter 7.8, respectively. The Panel's recommendations for future research are provided in Subchapter 7.9.

The baseline and post-restoration biomass data needed for the restoration-assimilation protocols described in this chapter can also be used for the restoration-denitrification practice protocol combinations described in Chapter 8. The restoration-denitrification protocols include the qualifying condition that the post-restoration oyster tissue biomass from the BMP site has been assessed within the past three years. Therefore, if oyster biomass data are collected at least every three years, then the same data can be used to credit nitrogen reduction for both the restoration-assimilation and restoration-denitrification protocols, assuming all qualifying conditions are met.

Table 7.1. Summary of the nitrogen and phosphorus reduction effectiveness strategy for the restoration-assimilation protocols. Restoration-assimilation protocols can be applied to both subtidal and intertidal reefs, and reefs restored using all suitable substrates.

Fisheries Management Approach	Oyster Reef Restoration
Oyster Practice	**Practice J:** Oyster reef restoration using hatchery-produced oysters **Practice K**: Oyster reef restoration using substrate addition
Practice Definitions	**Practice J:** Planting oysters (e.g., spat-on-shell, single oysters) produced from hatchery techniques directly on the bottom or on suitable substrate to enhance oyster biomass in areas where removal is not permitted. **Practice K:** Planting oyster shells and/or alternate substrate directly on the bottom to attract recruitment of naturally occurring (wild) oyster larvae to enhance oyster biomass in areas where removal is not permitted.
Protocols	**Protocols 1 & 2**: Nitrogen assimilation in oyster tissue and shell **Protocols 4 & 5**: Phosphorus assimilation in oyster tissue and shell
Abbreviated name for practice-protocols	Restoration-assimilation protocols
Reduction Effectiveness Determination Strategy (Subchapter 7.3)	Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 7.2.1). Step 2: Document the qualifying enhancement activity and its date (Subchapter 7.2.2), the type(s) of substrate used for restoration (Subchapter 7.2.3), and the baseline approach (Subchapter 7.2.4). Step 3: Assess baseline and post-restoration tissue and shell biomass (Subchapters 7.2.5) and extrapolate it to determine total tissue and shell biomass estimates for the BMP site (Subchapter 7.2.6). Step 4: Determine the eligible appreciated tissue and shell biomass at the BMP site (Subchapter 7.2.7). Step 5: Convert eligible appreciated tissue and shell biomass to total nitrogen and phosphorus removed (Subchapter 7.2.8).
Qualifying Conditions (Subchapter 7.5)	• A qualifying enhancement activity (Subchapter 7.2.2) must have occurred throughout the BMP site area (Subchapter 7.2.1). • The BMP site area must lie within an area protected from harvest • Baseline oyster biomass must be determined using the appropriate approach and adhere to baseline conditions (Subchapter 7.2.4) • All biomass estimates (Subchapter 7.2.5) must be based on field data collected within 12 months of crediting using a survey design that ensures estimates are representative of the entire BMP site. • Only nutrients associated with eligible appreciated biomass (Subchapter 7.2.7) may be credited.

7.1 Literature Review

By definition, successful oyster reef restoration projects lead to an increase in the abundance and/or biomass of oysters. Numerous studies of oyster reef restoration success in areas where harvesting is not permitted have demonstrated that restoration activities, such as planting oyster shell, hatchery-produced oyster spat-on-shell, and/or alternate substrate, can lead to increases in oyster biomass (e.g., Powers et al. 2009). Within Chesapeake Bay, recent monitoring data from sites in Maryland demonstrate that restoration activities can lead to increases in oyster abundance and biomass (MORIW 2022). Because nitrogen and phosphorus are assimilated into the tissues and shells of oysters, an increase in the biomass per unit area on a reef represents a decrease in the nitrogen and phosphorus available to phytoplankton for growth.

As found for the aquaculture-assimilation protocols (Reichert-Nguyen et al. 2016) and harvest-assimilation protocols (Subchapter 6.1), the Panel's literature review revealed that the nitrogen and phosphorus contents measured in individual *C. virginica* tissue and shell were well constrained in estuaries along the Atlantic Coast of the United States (Appendix E). However, the Panel's review of shell height-to-oyster biomass regressions for sites along the Atlantic and Gulf coasts suggested that relationships were highly variable among sites. Therefore, the Panel decided it was most appropriate to develop default Chesapeake Bay-wide shell height-to-biomass equations based solely on data from the Chesapeake Bay region (Appendix E). Because establishing self-sustaining oyster populations via natural recruitment is almost always one of the goals of oyster reef restoration, the Panel agreed that only data from diploid oysters should be included in the dataset used to develop default tissue and shell nutrient contents for the restoration-assimilation protocols.

7.2 Reduction Effectiveness: Panel Recommendations and Rationale

The following sections identify the information needed to determine reduction effectiveness, outline the Panel's recommendations, and explain the rationale underlying each of those recommendations.

7.2.1 BMP Site Location and Area

As for the harvest-assimilation protocols, the ***BMP site*** is the location in which enhancement activities occur and which is potentially eligible for nitrogen and phosphorus reduction credit if all qualifying conditions are met. The ***BMP site area*** is equal to the area within which enhancement activities occur (i.e., the "footprint" of the restoration project). For additional information on how the BMP site and its area are determined, see Subchapter 6.2.1. Only oysters found within the BMP site are eligible for crediting.

7.2.2 Qualifying Enhancement Activities

The Panel considered the types of enhancement activities that could qualify as a BMP under this practice-protocol combination. In reviewing practices in Chesapeake Bay and elsewhere, the Panel found that a wide variety of materials are used as part of oyster reef restoration efforts. Ultimately the Panel decided that any reef restoration activity that included the addition of hatchery-produced oysters and/or suitable settlement substrate could potentially qualify for crediting under the restoration-assimilation protocol. In this report, ***suitable substrate*** is defined as material on which oysters can settle and survive to adulthood and includes both oyster shell and alternate substrates. To ensure that the majority of the assimilation occurs within the BMP site, the Panel recommends that the shell height of oysters at the time of the restoration activity be <1.0 inch. For oysters larger than 1.0 inch, only incremental growth beyond the planting size can be credited.

7.2.3 Substrate Category

The data available for developing a default regression equation consisted almost entirely of data from projects using oyster shell, spat-on-shell and/or small alternate substrates. Therefore, the Panel decided to categorize substrates for which the default regression should and should not be used. For the purposes of this report, ***alternate substrates*** are all materials not composed solely of oyster shells. Two categories of substrate that are commonly used as part of oyster reef restoration efforts in Chesapeake Bay include:

1. Small, non-engineered substrate (hereafter "***small substrate***"):

- Suitable substrate characterized by:
    - ≥90% of the material by volume has a maximum diameter of ≤12 inches (304.8 mm) AND
    - a non-uniform or irregular structure when deployed
- Examples: Oyster shell, spat-on-shell, fossil oyster shell, clam and other types of shell, small concrete, small limestone, small granite or other non-calcium stone, and shell cemented into small irregular clumps.

2. Large or engineered alternate substrate (hereafter "***large substrate***"):
    - Suitable substrate characterized by:
        - <90% of the material by volume has a maximum diameter of ≤12 inches (304.8 mm) OR
        - a uniform, regular structure when deployed.
    - Examples: Large limestone, large granite or other non-calcium stone, and engineered structures including but not limited to ReefBalls™ and Oyster Castles©

The Panel chose to distinguish between large and small substrates because large substrates were not included in the dataset used to develop the default regression equations. The cutoff of 12 inches (304.8 mm) for distinguishing between small and large substrates was chosen to be representative of the maximum size of individual oyster clumps commonly found on reefs restored using oyster shell or spat-on-shell. As seen in Figure E-2 (Appendix E), oysters larger than 6 inches (152.4 mm) in shell height are relatively rare. Thus, two oysters growing in opposite directions outward from the same piece of suitable substrate will rarely result in a clump of oysters larger than 12 inches (304.8 mm) in diameter. The requirement that small structures create non-uniform, irregular structures when deployed was included to address the potential deployment of small uniform structures (e.g., individual Oyster Castles©) in an array that effectively builds a large structure from smaller subunits (e.g., a reef structure composed of many individual Oyster Castles©).

The Panel recommends that implementers restoring reefs with a mix of large and small substrates credit each substrate separately. If a substrate is not eligible for default rates or the default regression, then oysters growing on those substrates would not receive credit unless biomass was measured directly, or a site-specific estimate was generated (Subchapter 7.2.5). For example, an implementer restoring a reef with ReefBalls™ and spat-on-shell would sample each substrate separately to measure appreciated biomass. The biomass of oysters growing as spat-on-shell could be estimated using the Bay-wide default regression. The biomass of oysters growing on ReefBalls™ could be estimated using the direct measurement or site-specific approach.

7.2.4 Baseline Approach

The Panel identified two approaches for determining baseline oyster biomass depending on the oyster biomass data available for the BMP site prior to restoration and when the restoration activities occur relative to the approval of the restoration-assimilation protocols as BMPs. The two approaches are:

1. **Pre-restoration:** Using this approach, live oyster biomass is measured at the BMP site within two years prior to the start of restoration activities. This approach:
    - Must be used for all restoration projects with a start date after approval of the restoration-assimilation protocols as BMPs.
    - Should be used for restoration projects with a start date prior to approval of the restoration-assimilation protocols as BMPs if pre-restoration data are available and of sufficient quality.
2. **Representative site:** Using this approach, a non-restored representative site within the same basin as the BMP site and with conditions similar to those at the BMP site prior to restoration is identified and

oyster biomass at the site is surveyed. The selection of the non-restored representative site should include review by expert(s) knowledgeable in reef sampling. This approach:

- Can only be used for restoration projects with a start date prior to approval of the restoration-assimilation protocols as BMPs for which pre-restoration data either do not exist or are of insufficient quality.
- Requires that biomass data at the non-restored representative site be collected in the same year and season as the first post-restoration oyster biomass survey at the BMP site.

Regardless of the approach used to determine baseline biomass, all sampling plans should be reviewed and approved by the state reporting agency and the CBP prior to implementation.

7.2.5 Oyster Biomass Assessment

Because nutrient content is based on oyster tissue shell and biomass, accurate assessment of oyster biomass is crucial to accurate assessment of nutrient assimilation. The Panel agreed that all information used to determine baseline and post-restoration biomass must be based on field surveys of oysters per square meter or per large substrate unit, oyster shell heights, and/or direct measurements of oyster shell and tissue biomass per unit area. Because multiple survey and statistical approaches can be used to evaluate oyster populations and biomass on reefs and the best approach can depend on factors such as reef size, patchiness, and sampling gear (patent tongs, dredge, divers), the Panel did not feel it was appropriate to recommend a specific sampling approach. Instead, the Panel recommends that BMP implementers consult with expert(s) knowledgeable in oyster reef sampling and have their baseline and post-restoration sampling designs endorsed by the state reporting agency and the CBP prior to implementation.

Although the Panel did not think it was appropriate to recommend specific sampling designs, they did agree on a set of minimum requirements intended to ensure that biomass surveys collect sufficient data of sufficient quality to accurately assess oyster biomass. These requirements are:

- All biomass estimates must be based on data collected using a survey design that ensures estimates are representative of the entire BMP site.
- If subsampling is used, the methods used need to be documented and must be taken to ensure that each subsample is collected without bias and is extrapolated appropriately.
- A sufficient number of data points must be collected to allow calculation of both mean biomass and its variance. If multiple strata are included in the sampling design (e.g., a stratified random sampling design), data must be sufficient to calculate means and variances for all strata.
- All post-restoration survey data must be collected within 12 months prior to crediting.

After considering methods for determining oyster biomass per unit area based on survey data, the Panel identified three commonly used approaches to determining oyster biomass that are suitable for use for the assimilation-restoration protocols:

- Default regression (small substrate only)
- Direct measurement
- Site-specific regression

The ***default regression*** approach estimates oyster tissue and shell dry weight based on Chesapeake Bay-wide quantile regressions of oyster shell height to oyster tissue and shell dry weight (Appendix E). As such, this regression represents typical conditions across the entire Bay and the full suite of environmental conditions that influence oyster growth. Because all data for developing the default regression equations came from small substrates, the Panel does not recommend use of the default regression equations for large substrates.

The ***direct measurement*** approach does not rely on regressions of oyster shell height to oyster biomass. Instead, for each oyster collected as part of sampling, the tissue and shell are separated, and their dry weights are then measured separately.

The ***site-specific regression*** approach uses samples from the BMP site to develop a site-specific regression of oyster shell height to oyster biomass.

7.2.5.1 Default Regression

The Panel agreed that the approach used to develop default regressions for the aquaculture-assimilation (Reichert-Nguyen et al. 2016) and harvest-assimilation protocols (Chapter 6) could be used to develop default oyster shell height to oyster tissue and shell biomass for the restoration-assimilation protocols. The primary differences between the default regressions developed for the restoration-assimilation protocols and those developed for other protocols is that the data used were taken only from sites the Panel thought to be representative of oyster reef restoration in Chesapeake Bay (e.g., data from triploids and oysters grown in cages were removed) and regressions were developed for both oyster tissue and oyster shell (Appendix E). Because assessments of nutrient removal for the restoration-assimilation protocol are not based on oyster harvest records, the default regression is used with shell height measurements from samples collected during field surveys to determine oyster biomass rather than binning oysters by size class based on harvest records to estimate nutrient removal.

To develop default regressions for oyster shell height to oyster tissue dry weight (g tissue DW) and oyster shell dry weight (g shell DW), the Panel compiled a dataset of oyster shell heights and tissue and shell dry weights from multiple seasons, locations, and habitats across the Chesapeake Bay (Appendix E).

The Panel chose to apply 50th quantile regressions to the compiled datasets. Quantile regression uses the median of the data and is thus less influenced by extremes, making it an appropriate statistical approach to use with highly variable data (such as oyster height-weight relationships). All data and analyses to generate the quantile regression equations are outlined in Appendix E. The resulting default regression equations are presented in Table 7.2.

Table 7.2. Chesapeake Bay-wide quantile regression equations for oyster reef restoration practices, where x = oyster shell height (mm) and y = biomass (g DW).

Parameter	# of Oysters	50th Quantile Regression Equation	Error a	Error b
Tissue	6888	$y = 0.00037x^{1.83359}$	0.00005	0.02896
Shell	4296	$y = 0.00147x^{2.3964}$	0.00035	0.0557

To ensure that default regressions did not result in over crediting, the Panel also evaluated how sensitive the regression equations were to factors that could influence oyster growth and morphology (season, habitat, and salinity regime) (Appendix E). Sensitivity analyses indicated that any variance in the regression fit were within the standard error associated with the full dataset, and that the 50th quantile regression appropriately summarized the relationship between oyster shell height and tissue and shell biomass (Appendix E).

The Panel agreed that the regression equations could be used to estimate oyster biomass for oysters on both subtidal and intertidal reefs but could not be used for oysters growing on large substrates. Although intertidal oysters from only one study were included in the regression analyses, the range of oyster sizes present and the shell height-to-biomass relationships for this intertidal dataset were similar to those in the full dataset.

7.2.5.2 Direct Measurement

The Panel also agreed that direct measurement of oyster tissue and shell dry weights from reef samples can be used. The Panel recommends that implementers use standardized methods to measure the tissue and shell dry weight (Mo & Neilson 1994, Charmichael et al. 2012). The Panel recommends (but does not require) that implementers also measure individual shell heights of sampled oysters as these measurements could be used to develop site-specific shell height-to-dry weight regression equations for future use. The Panel agreed that this approach may be used for both subtidal and intertidal habitats and both large and small substrate categories.

7.2.5.3 Site-specific Regressions

Site-specific oyster shell height to tissue dry weight and oyster shell height to oyster shell dry weight regressions can be developed. If site-specific equations are developed, the Panel recommends that the review and approval of the new equations follow a similar approach as the re-evaluation procedure of existing estimates described in the CBP Partnership BMP Expert Review Protocol (CBP 2015). An expert panel does not need to be re-convened since it is expected that an expert in oyster reef restoration would be consulted during the development of the site-specific estimates. If approved, then the site-specific regression equations can be used to determine the mean live oyster tissue and shell biomass at that specific BMP site assuming conditions at the site remain similar to those present when data were collected for development of the regression equations. The Panel agreed that this approach may be used for both subtidal and intertidal habitats and both large and small substrate categories.

7.2.6 Extrapolating Oyster Biomass from Samples to BMP Site Area

In considering how assessment of oyster biomass differs between large and small substrates, the Panel identified differences in how biomass surveys should be designed and implemented and in how the resulting data should be extrapolated to the scale of the entire BMP site. Specifically, the Panel recommends that:

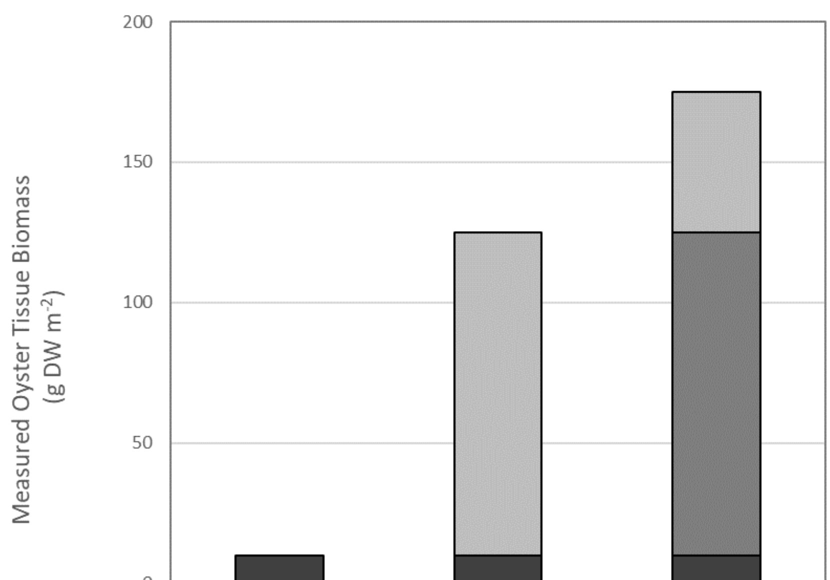
- For restoration using small substrate, oyster biomass should be assessed per unit area of substratum.
    - In general, this involves assessing all oysters within a standardized, defined area of substratum at each sampling point.
    - Examples of this type of sampling include diver quadrat surveys and patent tong surveys.
- For restoration using large substrate, oyster biomass should be assessed per structure.
    - In general, this involves either assessing all oysters on a structural unit or, for larger substrates, subsampling each structural unit and using those data to estimate the biomass of oysters per structural unit. If using subsamples, careful sampling design is needed to ensure that the subsamples are representative of the structural unit as a whole.
    - Examples of these types of surveys include assessing all oysters on an individual Oyster Castle© or divers using small quadrats to subsample the surface of a ReefBall™.

Again, because multiple survey and statistical approaches can be used to evaluate oyster populations and survey designs are often highly site-specific, the Panel did not feel it was appropriate to recommend a specific sampling or extrapolation approaches. Instead, the Panel recommends that BMP implementers consult with expert(s) knowledgeable in oyster reef sampling and have their baseline and post-restoration sampling designs and proposed means of extrapolation to the scale of the BMP site endorsed by the state reporting agency and the CBP prior to implementation. Examples of how extrapolation of measured oyster biomass to the BMP site area can differ between small substrates and large substrates and between different types of large substrates are provided in Subchapter 7.6.

7.2.7 Eligible Appreciated Biomass

A primary goal of most, if not all, oyster reef restoration efforts is to establish a self-sustaining population of oysters on the reef. Over time, individual oysters on the reef will die and new oysters will recruit. Although some nutrients are returned to the water column when an individual oysters dies, there is a net removal of nutrients at the scale of the reef as long as the live oyster biomass per unit area on the restored reef is greater than that prior to restoration, and as long as the amount of biomass per unit area is either stable or increasing. By crediting only increases in the amount of live oyster biomass and not crediting nutrients retained in the shell of dead oysters, the Panel chose an intentionally conservative approach to crediting nutrient assimilation associated with restored oyster reefs.

As shown in Figure 7.1, for the first post-restoration biomass measurement, ***eligible appreciated biomass*** is equal to the post-restoration biomass minus the baseline (i.e., pre-restoration) biomass and is equivalent to biomass enhancement resulting from the restoration activity. For subsequent time periods, eligible appreciated biomass is the amount by which biomass has increased beyond the maximum biomass previously measured at the site. If measured oyster biomass does not exceed previously credited biomass, no credit is given. Eligible appreciated biomass can be measured and credited over the lifetime of the BMP site.



	T0 (Baseline)	T1	T2
Eligible Appreciated		115	50
Non-eligible Appreciated		0	115
Baseline	10	10	10

Figure 7.1. Generalized example of tissue biomass crediting for the restoration-assimilation protocols. T0 represents the measured baseline biomass and T1 and T2 represent the measured biomass based on the first and second post-restoration biomass surveys, respectively. Note that biomass credited based on T1 surveys is no longer eligible for credit at T2.

Because different oyster reef restoration projects will have differing goals and resources available, the Panel is not recommending a specific timeline for measuring biomass. However, to ensure that measured biomass accurately reflects the condition of the BMP site at the time at crediting, the Panel is recommending that biomass surveys used for determining crediting be conducted within the 12 months prior to the time of crediting. Although not required, if the implementing program also plans to seek restoration-denitrification credits (Chapter 8.0), the Panel suggests that post-restoration biomass monitoring every three years would allow the same data to be used to support crediting under both the restoration-assimilation and the restoration-denitrification protocols.

7.2.8 Converting Eligible Appreciated Biomass to Assimilated Nutrients

As for the aquaculture-assimilation and the harvest-assimilation protocols, the Panel agreed that oyster tissue and oyster shell biomass can be converted to amounts of nutrients by multiplying by the appropriate percent content of nutrients. For oyster tissue, the Panel agreed that the diploid oyster tissue nutrient percentages developed previously and already approved by the CBP Partnership could be used for the restoration-assimilation protocols (see Reichert-Nguyen et al. 2016 for details and supporting data). The recommended percentages for use in converting oyster tissue biomass to nutrient content for the restoration-assimilation protocols are:

Mean Percent Nitrogen Content in Oyster Tissue Dry Weight = 8.2%

Mean Percent Phosphorus Content in Oyster Tissue Dry Weight= 0.9%

The percent nitrogen and phosphorus content in oyster shell for use in BMP crediting was not established in the first report (Reichert-Nguyen et al. 2016) but the Panel agreed that the same approach could be used for determining appropriate percentages for converting oyster shell biomass to oyster shell nutrient content. The Panel compiled and reviewed available relevant literature (Appendix E). Nitrogen data included two studies (three sites) from within Chesapeake Bay and three studies conducted outside Chesapeake Bay. Although studies from outside Chesapeake Bay were more variable than those from within the Bay, the mean for all studies and for Chesapeake Bay studies were the same (0.20%). Phosphorus data came from two studies (three sites) in Chesapeake Bay and all reported values were the same (0.04%). Thus, the recommended percentages for use in converting oyster shell biomass to nutrient content for the restoration-assimilation protocols are:

Mean Percent Nitrogen Content in Oyster Shell Dry Weight = 0.2%

Mean Percent Phosphorus Content in Oyster Shell Dry Weight = 0.04%

7.3 Reduction Effectiveness: Stepwise Determination

To calculate the reduction effectiveness for the restoration-assimilation protocols, the Panel recommends the following:

Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 7.2.1).

Step 2: Document the qualifying enhancement activity and its date (Subchapter 7.2.2), the type(s) of substrate used for restoration (Subchapter 7.2.3), and the baseline approach (Subchapter 7.2.4).

Step 3: Assess baseline and post-restoration tissue and shell biomass (Subchapters 7.2.5) and extrapolate it to determine total tissue and shell biomass estimates for the BMP site (Subchapter 7.2.6).

Step 4: Determine the eligible appreciated tissue and shell biomass at the BMP site (Subchapter 7.2.7).

Step 5: Convert eligible appreciated tissue and shell biomass to total nitrogen and phosphorus removed (Subchapter 7.2.8).

7.4 TMDL Baseline Considerations

The TMDL for Chesapeake Bay was created in 2009. Based on this, the CBP Management Board agreed that reduction crediting under the nitrogen and phosphorus restoration-assimilation protocols for oysters can only be given for oyster reef restoration projects that were initiated after the creation of the TMDL in 2009 (CBP 2016).

The Panel coordinated with the WTWG to devise a strategy to credit nitrogen and phosphorus reduction estimated from field data using the current TMDL modeling tools. The WTWG plans to credit appreciated nitrogen and phosphorus in live oyster tissue and shell when monitored oyster biomass demonstrates an increase that hasn't been credited previously. Given potential differences in the BMP and oyster monitoring schedules, application for the credit may or may not occur within the same calendar or fiscal year that the data were collected. To address this discrepancy in timeline, the Panel recommends that application for credit be accepted on a rolling basis, as long as data has been collected within the previous 12 months (Subchapter 7.2.2). No appreciation of live oyster biomass or a lapse in monitoring would result in no reduction credit.

7.5 Qualifying Conditions

The Panel recommends the following qualifying conditions, which account for both the CBP Management Board's defined baseline and the Panel's criteria:

- A qualifying enhancement activity (Subchapter 7.2.2) must have occurred throughout the BMP site area (Subchapter 7.2.1).
- BMP site must lie within an area protected from harvest
- At the time of planting, the shell height of any hatchery-produced oysters should be <1.0 inch (<25.4 mm; Subchapter 7.2.2). For oysters larger than 1.0 inch, only incremental growth beyond the planting size can be credited.
- Baseline oyster biomass must be determined using an appropriate approach and adhere to baseline conditions (Subchapter 7.2.4)
    - For projects using the representative site approach for determining baseline oyster biomass (Subchapter 7.2.4):
        - The representative site must be within the same basin as the BMP site and be representative of conditions at the BMP site before restoration occurred.
        - Data from a non-restored representative site must be collected within the same year and season as the first post-restoration biomass measurement at the BMP site.
    - For projects using the pre-restoration approach for determining baseline oyster biomass (Subchapter 7.2.4):
        - Pre-restoration biomass data must have been collected within two years prior to the start of restoration.

    - For baseline surveys using the pre-restoration approach and for all post-restoration surveys, all data used to estimate oyster biomass must be collected from within the BMP site.
- All biomass estimates (Subchapter 7.2.5) must:
  - Be based on field surveys of live *Crassostrea virginica*
  - Be based on data collected using a survey design that ensures estimates are representative of the entire BMP site.
  - Include enough data points to allow calculation of mean biomass and its variance. If multiple strata are included in the sampling design, data must be sufficient to calculate means and variances for all strata.
  - Be collected within 12 months prior to application for crediting.
- Biomass must be extrapolated appropriately to the scale of the BMP site (Subchapter 7.2.6)
- Only nutrients associated with eligible appreciated biomass (Subchapter 7.2.7) may be credited.

7.6 Recommended Application and Verification Guidelines

Prior to restoration activities, the Panel recommends that applicants submit a sampling plan that includes a detailed oyster biomass survey design for both baseline and post-restoration surveys. All survey designs should be developed in collaboration with experts knowledgeable in oyster reef sampling and should be endorsed by both the State reporting agency and the CBP. At a minimum, the sampling plan should include:

- A description of the type of survey design to be implemented (e.g., random, stratified random) and the rationale for the chosen survey design
- The number of samples to be collected per unit area and the rationale for that number.
- A map and GPS coordinates for proposed sampling points.

The reporting guidelines and examples below assume that a sampling plan has already been submitted and approved and that no significant deviations are made from the approved sampling plan. If significant changes are made after initial approval of the sampling plan, a revised plan should be submitted and approved prior to sampling.

7.6.1 Reporting Guidelines

To assist with application of its recommendations, the Panel developed guidelines for the information to be reported by anyone seeking credit for this practice-protocol combination. The required information is listed below under the associated determination step.

Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 7.2.1)
  - Geospatial information documenting the vertices of a polygon representing the BMP site
  - Area of the polygon representing the BMP site

Step 2: Document the qualifying enhancement activity and its date (Subchapter 7.2.2), the type(s) of substrate used for restoration (Subchapter 7.2.3), and the baseline approach (Subchapter 7.2.4).
  - Date of enhancement activity
  - Type(s) of substrate
  - Substrate category (small or large)

   - Amount of substrate used
   - If using hatchery-produced oysters:
     - Ploidy of oysters
     - Number of oysters planted
     - Size of oysters at time of planting
   - Baseline approach used (pre-restoration or representative site)

Step 3: Assess baseline and post-restoration biomass (Subchapters 7.2.5) and extrapolate it to determine total biomass estimates for the BMP site (Subchapter 7.2.6).

   - For first survey after reef restoration, provide a brief description of biomass survey sampling design for both the baseline and post-restoration biomass surveys. For subsequent surveys, only information on the post-restoration survey design is needed.
     - Sampling date(s)
     - Method used to collect samples (e.g., patent tongs, divers with quadrats, etc.)
     - Spatial scale of sample (e.g., 1.0 m^2, one Reef Ball™, etc.)
     - Number of samples collected
     - If subsampling is used, a description of the subsampling methods, number of subsamples per sample, and method of scaling
     - Methods used to assess oyster tissue and shell biomass per sample (default regression, direct measurement, or site-specific regression)
     - Method used to calculate mean sample biomass
     - Method used to extrapolate mean sample biomass to total biomass per unit area for the BMP site.
     - Mean tissue and shell biomass

Step 4: Determine the eligible appreciated biomass at the BMP site (Subchapter 7.2.7).

   - Appreciated tissue and shell biomass

Step 5: Convert eligible appreciated biomass to total nitrogen and phosphorus removed (Subchapter 7.2.8).

   - Total nitrogen in eligible appreciated biomass
   - Total phosphorus in eligible appreciated biomass

7.6.2 Application Examples

This subchapter provides three hypothetical examples to demonstrate the information and calculations needed to estimate nutrient removal using the restoration-assimilation protocols. The first example focuses on a restoration effort that uses small substrate, the second example focuses on a restoration effort that uses individual large substrate units distributed throughout the BMP site, and the final example focuses on a restoration effort in which individual structural units are used to construct larger substrate units that are distributed throughout the restoration site.

7.6.2.1 Example #1: Small substrate

The following example assumes a restoration project in Maryland which restores one acre of reef using spat-on-shell planted directly on the bottom. After initial planting, oyster biomass surveys were conducted every three years for 12 years using a random sampling design. Samples were collected using patent tongs that sampled a 1m^2 area of the substratum per sample. Table 7.3 provides a list of the information that needs to be reported for this scenario along with data submitted after the first post-restoration survey. For subsequent surveys, only the post-restoration biomass needs to be reported assuming previous biomass measurements are already on record.

Steps 1 and 2: These steps simply record information about the restoration project. The example presented here is a simple one. If more than one type of material is used, all types of materials, amounts and their categories should be recorded. If the BMP site is restored in sections and different methods and/or planting densities are used for different sections, this needs to be accounted for in the sampling design (e.g., use of a stratified random design).

Step 3: This step uses data from oyster biomass surveys to estimate oyster tissue and shell biomass for the entire BMP site for both the baseline and post-restoration surveys. In the example in Table 7.4, oyster biomass is estimated based on oyster shell height using the default regression equations given in Table 7.2.

Once the total sample biomass for each sampling point has been calculated, these data are used to calculate the mean biomass per unit area for the BMP site by taking their average to get the mean biomass for all samples collected (Table 7.5). Note that if the area sampled is not equal to 1 m^2 then this will need to be accounted for in converting biomass per sample to biomass per unit area. To calculate the total pounds of biomass at the BMP site, the mean biomass per unit area (g DW m^{-2}) is multiplied by the total area of the BMP site (m^2) and divided by 453.59 to convert from grams to pounds dry weight.

Step 4: This step calculates the post-restoration biomass that is eligible for crediting. As shown in Table 7.6 and Figure 7.2, this is accomplished by subtracting the baseline biomass and the previously credited biomass from the measured post-restoration biomass for the BMP site. Calculations are shown for all four post-restoration surveys at the site. In cases where calculations result in negative values, a zero is entered because there is no biomass eligible for credit for that sampling period.

Step 5: This step consists of taking the eligible appreciated biomass and converting to pounds of nitrogen and phosphorus. This is done by multiplying the tissue and shell dry weights by the appropriate percent nutrient content (tissue = 8.2% N and 0.9% P; shell = 0.2% N and 0.04% P). As shown in Table 7.7, the total removal for each nutrient is the sum of the amount in oyster tissue and in oyster shell.

Table 7.3. Information types required for the restoration-assimilation protocols along with an example of each. See text for details of calculations used to provide example information below.

Step #	Information Type	Example
1	BMP site location	See appended map and GIS file
	Area of the BMP site	1 acre
2	Date(s) of activity (mm/dd/yy)	09/21/21
	Type(s) of substrate	Diploid spat-on-shell
	Substrate category	Small
	Amount of substrate	1,000 Maryland bushels of spat-on-shell
	Number of hatchery-produced oysters planted	9,500,000
	Size of oysters at time of planting (mm)	10
	Baseline approach	Pre-restoration
3	Baseline biomass	
	Sampling points	See appended map and GIS file
	Sampling date(s)	07/15/20
	Sampling method	Patent tong
	Spatial scale of sample with units	1 m^2
	Number of samples collected	5
	Method used to assess biomass	Default regression
	Method used to calculate mean biomass	Average of all samples
	Mean biomass: Tissue	14 g DW m^{-2}
	Mean biomass: Shell	631 g DW m^{-2}
	Method for extrapolating to entire BMP site	Multiply by total m^2 and convert to lbs
	Total biomass for the BMP site: Tissue	125 lbs DW
	Total biomass for the BMP site: Shell	5,630 lbs DW
	Post-restoration biomass	
	Sampling date(s)	08/01/24
	Sampling method	Patent tong
	Spatial scale of sample with units	1 m^2
	Number of samples collected	5
	Method used to assess biomass	Default regression
	Method used to calculate mean biomass	Average of all samples
	Mean biomass: Tissue	119 g DW m^{-2}
	Mean biomass: Shell	5,960 g DW m^{-2}
	Extrapolation method	Multiply by total m^2 and convert to lbs
	Total biomass for the BMP site: Tissue	1,062 lbs DW
	Total biomass for the BMP site: Shell	53,178 lbs DW
4	Appreciated biomass: Tissue	937 lbs DW
	Appreciated biomass: Shell	47,548 lbs DW
	Non-eligible appreciated biomass: Tissue	0 lbs DW
	Non-eligible appreciated biomass: Shell	0 lbs DW
	Eligible appreciated biomass: Tissue	937 lbs DW
	Eligible appreciated biomass: Shell	47,548 lbs DW
5	Total nitrogen: Tissue	76.82 lbs N
	Total nitrogen: Shell	95.10 lbs N
	Total creditable nitrogen at BMP site	***171.91 lbs N***
	Total phosphorus: Tissue	8.43 lbs P
	Total phosphorus: Shell	19.02 lbs P
	Total creditable phosphorus at BMP site	***27.45 lbs P***

Table 7.4. Example of data collected for a single survey sample point. Oyster shell heights are converted to oyster tissue and shell biomass using the equations given in Table 7.2. Total sample biomass is the sum of the biomass of all individual oysters in the sample.

					Oyster Biomass		Total Sample Biomass	
Survey Type	Year	Sampling Point ID	Oyster ID	Shell Height (mm)	Tissue (g DW)	Shell (g DW)	Tissue (g DW)	Shell (g DW)
Baseline	2020	B1	1	97	1.63	84.80	17.66	933.08
Baseline	2020	B1	2	101	1.75	93.43		
Baseline	2020	B1	3	62	0.72	29.01		
Baseline	2020	B1	4	87	1.33	65.34		
Baseline	2020	B1	5	101	1.75	93.43		
Baseline	2020	B1	6	89	1.39	69.00		
Baseline	2020	B1	7	126	2.63	158.72		
Baseline	2020	B1	8	108	1.98	109.70		
Baseline	2020	B1	9	81	1.17	55.06		
Baseline	2020	B1	10	103	1.82	97.92		
Baseline	2020	B1	11	93	1.51	76.66		

Table 7.5. Example of baseline data collected for a BMP site and the resulting mean biomass per unit area and total BMP site biomass. Total BMP Site Biomass = Mean Biomass per Unit Area *x* total BMP site area (1 acre in this example). See text for details of calculations.

				Total Sample Biomass		Mean Biomass per Unit Area		Total BMP Site Biomass	
Survey type	Year	Sampling Point ID	# of Oysters	Tissue (g DW)	Shell (g DW)	Tissue (g DW m^{-2})	Shell (g DW m^{-2})	Tissue (lbs DW)	Shell (lbs DW)
Baseline	2020	B1	11	18	933	14	631	125	5,630
Baseline	2020	B2	13	15	695				
Baseline	2020	B3	8	3	102				
Baseline	2020	B4	25	19	783				
Baseline	2020	B5	16	15	642				

Table 7.6. Example of post-restoration survey data for oyster tissue biomass for a 12-year period. "Total Appreciated Biomass" is the portion of the total biomass that represents an increase over the baseline biomass level. See text for details of calculations. "Appreciated – Not Eligible" is the portion of the appreciated biomass that is not eligible for crediting because it has previously been credited. "Appreciated – Eligible" is the portion of the appreciated biomass that is eligible for crediting and represents an increase over the maximum previously recorded biomass for the BMP site.

Post-Restoration Survey	**1st**		**2nd**		**3rd**		**4th**	
Year	**2024**		**2027**		**2030**		**2033**	
Biomass Component	**Tissue (lbs)**	**Shell (lbs)**	**Tissue (lbs)**	**Shell (lbs)**	**Tissue (lbs)**	**Shell (lbs)**	**Tissue (lbs)**	**Shell (lbs)**
Measured Post-restoration Biomass	1,062	53,178	940	48,858	1,542	94,903	528	28,234
Baseline Biomass (2020)	125	5,630	125	5,630	125	5,630	125	5,630
Total Appreciated Biomass	937	47,548	815	43,228	1,417	89,273	403	22,604
Appreciated - Not Eligible	0	0	815	43,228	937	47,548	403	22,604
Appreciated - Eligible	***937***	***47,548***	***0***	***0***	***480***	***41,725***	***0***	***0***

Figure 7.2. Graph of oyster tissue biomass crediting for example given in Table 7.6

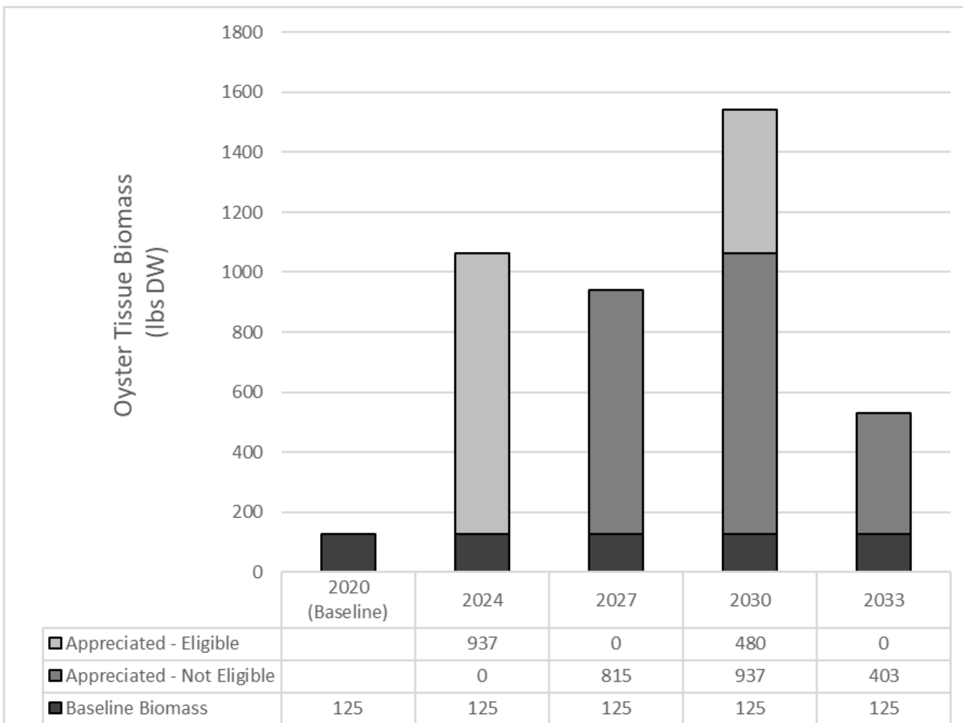


Table 7.7. Example of conversion of eligible biomass to nitrogen and phosphorus credits generated over a 12-year period.

Post-Restoration Survey	1st		2nd		3rd		4th		
Year	2024		2027		2030		2033		
Biomass Component	Tissue (lbs)	Shell (lbs)	Tissue (lbs)	Shell (lbs)	Tissue (lbs)	Shell (lbs)	Tissue (lbs)	Shell (lbs)	Total (lbs)
Appreciated - Eligible Biomass	937	47,548	0	0	480	41,725	0	0	
Creditable Nitrogen	77	95	0	0	39	83	0	0	295
Creditable Phosphorus	8	19	0	0	4	17	0	0	48

7.6.2.2 Example #2: Individual large substrate units

As noted in Section 7.2.5, restoration using large substrates requires a different approach to surveying and extrapolating oyster biomass to the scale of the BMP site. This example assumes that restoration practitioners deploy 25 Reef Balls™ (one Reef Ball™ = one large structural unit) evenly distributed across a 0.5-acre area. Because only the oysters growing on the Reef Balls™ will be considered for crediting and there are no oysters growing on the structures at the time of deployment, the baseline biomass for this restoration project is zero. After consulting with experts, the survey design implemented consists of randomly selecting five structural units, counting and measuring all oysters on the inside and outside of each, and collecting a subsample of oysters from each unit to be used in developing a site-specific shell height to biomass regression. When selecting oysters for sampling, care is taken to capture the full range of oyster sizes found on the units. Table 7.8 shows some of the required data that differ from those for the small substrate restoration project data provided in Table 7.3. Once total post-restoration biomass for the BMP site has been calculated, all other steps are the same as those for restoration projects using small substrates (Subchapter 7.6.2.1)

Table 7.8. Example of how some of data reported for large substrates differs from that for small substrates shown in Table 7.3.

Step #	Information Type	Example
2	Type(s) of substrate	Reef Balls™
	Substrate category	Large
	Amount of substrate	25 individual Reef Balls™
	Number of hatchery-produced oysters planted	0
	Baseline approach	Pre-restoration
3	Baseline biomass: Tissue	0 lbs DW
	Baseline biomass: Shell	0 lbs DW
	Post-restoration biomass	
	Sampling method	Retrieve randomly selected units for assessment
	Spatial scale of sample with units	1 Reef Ball™
	Number of samples collected	5
	Percent of each structural unit sampled	100%
	Method used to assess biomass	Site-specific regression
	Method used to calculate mean biomass	Average of all samples
	Mean biomass: Tissue	12 g DW structural unit^{-1}
	Mean biomass: Shell	52 g DW structural unit^{-1}
	Extrapolation method	Multiply by total # of structural units and convert to lbs
	Total biomass for the BMP site: Tissue	0.66 lbs DW
	Total biomass for the BMP site: Shell	2.87 lbs DW

7.6.2.3 Example #3: Individual structural units used to build larger structural units

This example assumes that restoration practitioners build four Oyster Castle® reefs on a BMP site. Each reef is constructed using 14 individual blocks and, by the time of post-restoration sampling, the blocks have become cemented together with oysters, requiring that each reef be sampled in place. As can be seen in Figure 7.3, some blocks are more accessible for oyster recruitment and biomass sampling than others. This needs to be accounted for in the sampling design and in the extrapolation of the data collected. One approach to sampling these reefs would be to use the interior and exterior of an exposed side (i.e., a side of the block that is on the outermost surface of the reef) as the sampling unit (equal to $1/4^{th}$ of one individual block). Once the biomass data are collected and biomass is calculated as a biomass per exposed side, this number needs to be scaled up to the biomass per reef and then multiplied by the four reefs included in the restoration effort. The simplest way to calculate biomass per reef would be to multiply the mean biomass per exposed side by the total number of exposed sides. In this case, there are four exposed sides on the top layer, eight exposed sides on the middle layer, and 12 exposed sides on the bottom layer for a total of 24 exposed sides. However, this is not the only approach that could be used. The potential complexity of the sampling design and extrapolation of data collected from these types of structures highlights the need to consult with experts in oyster reef sampling to develop a sampling plan and appropriately extrapolate the resulting data to the scale of the BMP site.

Figure 7.3. Example of a large structural unit composed of smaller units. Photo courtesy of P. Kingsley-Smith, South Carolina DNR.

Appreciated oyster biomass and the resulting BMP credits for restoration projects using other large substrates could be assessed using either, or a combination of, the approaches described in Subchapter 7.6.2.2 and 7.6.2.3. The most appropriate sampling approach will depend on the size and configuration of the reef materials. The Panel recommends that BMP implementers consult with expert(s) knowledgeable in oyster reef sampling and have their sampling designs endorsed by the state reporting agency and the CBP prior to implementation.

7.7 Unintended Consequences

There was one unintended consequence identified for the restoration-assimilation protocols. Since credits are given for permanent removal of nutrients, it is possible for over crediting to occur if biomass drops below the previous level of post-restoration biomass for which the BMP area was given nutrient reduction credit. For example, if a monitored reef accrues biomass between years 1 and 2 but then loses biomass between years 2 and 3, the permanent removal in year 3 is less than that which was credited during year 2. However, because both the shells of dead oysters on the reef and the tissues and shells of other reef organism (e.g. mussels, barnacles, etc.) contain significant amounts of nitrogen and phosphorus but are not eligible for credit, the Panel agreed that the risk of attributing more nitrogen and phosphorus to reef restoration than actually occurs was minimal.

7.8 Ancillary Benefits

The Panel identified several ancillary benefits for the restoration-assimilation protocols. Benefits of oyster restoration are described in Chapter 9.

7.9 Future Research

The Panel identified the following research gaps while reviewing the literature to develop the restoration-assimilation BMP recommendations:

- More research is needed on factors that influence spat survivorship and changes in oyster biomass over time. This could lead to the development of predictive relationships to estimate oyster biomass and reduce the need for field surveys.
- More data from intertidal reefs are needed to determine whether separate default shell height to dry weight regressions are warranted for intertidal reefs.
- Additional research is needed to investigate how best to estimate oyster biomass on large substrates and engineered structures. Specifically, measurements of the oyster dry weights and nutrient contents for oysters growing on engineered structures need to be taken to determine whether established relationships hold or whether new equations must be generated.

8.0 Recommendations on Reduction Effectiveness of Nitrogen Removed by Enhanced Denitrification Associated with Oysters on Restored Oyster Reefs

Live oysters and associated animal and bacterial communities on oyster reefs can enhance denitrification at the reef scale. Denitrification is an anaerobic process, usually facilitated by bacteria, that reduces oxidized forms of dissolved inorganic nitrogen, such as dissolved nitrate or nitrite, to nitrogen gas (N_2). This process converts bioavailable forms of nitrogen that can fuel phytoplankton growth in estuaries into N_2 that does not. High denitrification rates in aquatic habitats generally require a supply of organic material to aerobic benthic habitats that support communities of nitrifying bacteria adjacent to anoxic habitats that support communities of denitrifying bacteria. On oyster reefs, the filter-feeding activities of oysters and associated reef organisms supply reactive organic matter to the reef surface in the form of biodeposits (i.e., feces and pseudofeces). The complex three-dimensional structure of oyster reefs provides abundant surface area for the growth of nitrifying bacteria. Oyster reefs also provide an abundance of habitats for the growth of denitrifying bacteria both within anoxic areas found within the reef matrix and in reef sediments. Therefore, increased oyster tissue biomass from reef restoration activities can enhance the deposition of organic matter and the amount of suitable habitat for nitrifying and denitrifying bacteria and result in enhanced denitrification rates.

In its first report (Reichert-Nguyen et al. 2016), the Panel identified three practice-protocol combinations that could remove nitrogen through enhanced denitrification associated with oysters on restored reefs (Table 1.1). This chapter describes the Panel's recommendations on the following two restoration-denitrification protocols seeking BMP approval:

Practice J. Oyster reef restoration using hatchery-produced oysters

Protocol 3. Enhanced denitrification associated with oysters

Practice K. Oyster reef restoration using substrate addition

Protocol 3. Enhanced denitrification associated with oysters

Hereafter, these practice-protocol combinations are referred to collectively as "restoration-denitrification" protocols.

The Panel did not reach consensus on whether to endorse **Practice L** (oyster reef restoration using no-harvest area designation only); however, they agreed that the recommendations presented in this chapter could be applied to this practice if endorsed later for future BMP use. The Panel also decided that existing data were insufficient to determine the nitrogen reduction effectiveness of enhanced denitrification for oyster practices where harvesting occurs (Appendix I).

The Panel recommends that the nitrogen reduction effectiveness of the restoration-denitrification protocols be based on the oyster **tissue** biomass at the BMP site in combination with seasonal patterns in reef denitrification rates. Enhanced denitrification estimates are calculated by subtracting the baseline denitrification rate (determined based on baseline oyster tissue biomass) from the post-restoration denitrification rate (determined based on post-restoration oyster tissue biomass). For reef restoration projects using small substrate in subtidal habitats, the Panel developed a lookup table (Subchapter 8.2.5.1 and Appendix G) that provides annual enhanced denitrification estimates for expected ranges of baseline and post-restoration oyster tissue biomass. Because the data required to develop robust estimates for reef restoration projects in the intertidal and/or using large substrates are not currently available, the Panel recommends site-specific measurements be required for crediting of these projects.

A summary of the Panel's recommended reduction effectiveness determination and qualifying conditions for the restoration-denitrification protocols is outlined in Table 8.1. The literature and data reviewed by the Panel to inform development of their recommendations are documented in Subchapter 8.1. The Panel's approach and recommended steps for determining nitrogen reduction effectiveness by enhanced denitrification are outlined in Subchapter 8.2 and Subchapter 8.3. Enhanced denitrification is a form of permanent nitrogen removal when several qualifying conditions described in Subchapter 8.5 are met. Verification guidelines and recommended applications are described in Subchapter 8.6. Unintended consequences (Subchapter 8.7), ancillary benefits (Subchapter 8.8), and recommendations for future research (Subchapter 8.9) are also discussed for these practice-protocol combinations and reduction effectiveness approach.

Table 8.1. Summary of the nitrogen reduction effectiveness strategy for the restoration-denitrification protocols.

Fisheries Management Approach	Oyster Reef Restoration
Oyster Practice	**Practice J:** Oyster reef restoration using hatchery-produced oysters **Practice K**: Oyster reef restoration using substrate addition
Practice Definitions	**Practice J:** Planting oysters (e.g., spat-on-shell, single oysters) produced from hatchery techniques directly on the bottom or on suitable substrate to enhance oyster biomass in areas where removal is not permitted. **Practice K:** Planting oyster shells and/or alternative substrate directly on the bottom to attract recruitment of naturally occurring (wild) oyster larvae to enhance oyster biomass in areas where removal is not permitted.
Protocols	**Protocol 3.** Enhanced Denitrification Associated with Oysters
Abbreviated name for practice-protocols	Restoration-denitrification
Reduction Effectiveness Determination (Subchapter 8.3)	**Step 1.** Identify the BMP site location and determine the BMP site area (Subchapter 8.2.1) **Step 2.** Document the qualifying enhancement activity and the date it occurred (Subchapter 8.2.2) **Step 3**. Determine the appropriate baseline approach (Subchapter 8.2.4) **Step 4**. Assess baseline and post-restoration tissue biomass (Subchapter 8.2.5) **Step 5.** Determine denitrification enhancement per unit area (Subchapter 8.2.6) **Step 6.** Determine the total nitrogen removal attributable to enhanced denitrification using the estimated denitrification enhancement per unit area and the BMP site area (Subchapter 8.2.7)
Qualifying Conditions (Subchapter 8.5)	• A qualifying enhancement activity (Subchapter 8.2.2) must have occurred throughout the BMP site area (Subchapter 8.2.1). • The BMP site area must lie within an area protected from harvest. • If using the default approach to estimating enhanced denitrification, the reef must be in a subtidal habitat and restoration activities must have utilized only small substrates (Subchapter 8.2.2). • Only live oyster tissue biomass is eligible for credit. • The post-restoration oyster tissue biomass must be greater than the baseline oyster tissue biomass.

8.1 Literature and Data Review

For the purposes of BMP consideration, denitrification is best measured as the net flux of nitrogen gas from the benthos to the water column. Because nitrogen gas (N_2) is the most abundant component (78%) of air, accurate measurement of denitrification rates in aquatic environments is challenging. Methods for direct measurement of N_2 flux in oyster-associated environments are a relatively recent development, with the first laboratory study of the impacts of simulated oyster biodeposits on nitrogen cycling published in 2002 (Newell et al. 2002). Since then, methods for assessing N_2 fluxes from oyster-associated environments have continued to evolve.

In their review of the potential for using oysters to mitigate eutrophication in coastal waters, Kellogg et al. (2014c) found that, of the studies conducted to date, there was more evidence to support enhanced denitrification rates associated with oyster reefs than for oyster aquaculture. The Panel reached a similar conclusion through their independent literature review (Subchapter 8.1, Appendix I). Based on this, the Panel agreed that data were insufficient at present to develop reduction effectiveness estimates for enhanced denitrification associated with either oyster aquaculture or harvest of hatchery-produced oysters and focused their efforts on developing reduction effectiveness estimates for enhanced denitrification associated with restored oyster reefs.

The Panel conducted a thorough review of existing peer-reviewed literature to determine the most appropriate approach to (1) quantify the enhanced denitrification and to (2) estimate the nitrogen reduction effectiveness for the restoration-denitrification protocols. Enhanced denitrification was most commonly calculated as the denitrification rate at the reef site minus the denitrification rate at a reference site. Reference sites were nearby but outside the zone of influence of the restoration site (Figure 8.1) and were similar to the restored site in all respects except that the reference sites had very few or no oysters. The Panel chose to use this approach for the restoration-denitrification protocols with the amendment that the reference denitrification rate could also be calculated from the restoration site before restoration occurred.

Some published estimates for enhanced denitrification were based on methods that measure potential denitrification rates rather than actual denitrification rates (e.g., Seitzinger et al. 1993, Joye et al. 1996, Cornwell et al. 1999). The Panel agreed that actual denitrification rates were most appropriate to determine the nitrogen reduction effectiveness of oyster reef restoration practices.

Reported denitrification rates varied widely and the causes of variation were not easy to identify because of differences in the types of samples collected (e.g., some included oysters and others did not), the types of reefs sampled (e.g., subtidal versus intertidal), and the geographic locations of the studies (Table 8.2). After careful consideration of peer-reviewed published data, project reports, and unpublished data, the Panel decided that the most scientifically defensible nitrogen reduction effectiveness estimates for the restoration-denitrification protocols would come from a meta-analysis of data collected in the Chesapeake Bay. The results of the Panel's meta-analysis and the resulting recommendations are described in detail in Subchapter 8.2.6.1.

Figure 8.1. Diagram of restored reef BMP site and the surrounding area potentially affected by biodeposits from the reef. To accurately assess denitrification enhancement by direct measurement of denitrification rates, restored reef samples should be collected from within the BMP site and baseline measurements should be collected outside the area potentially affected by reef biodeposition.

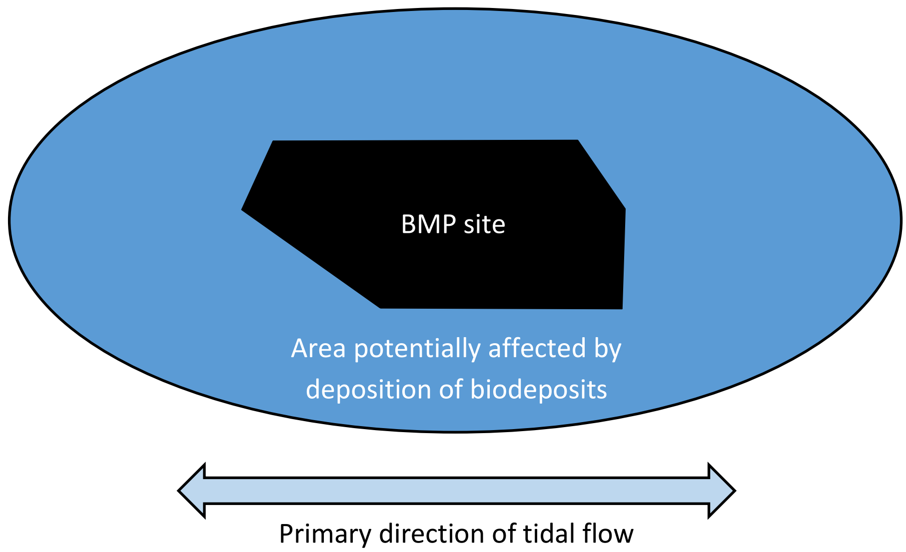


Table 8.2. Maximum denitrification enhancement (reef minus reference) observed in published oyster reef studies. Sediment-only samples contain sediments collected from within or adjacent to oyster reefs and may contain macrofauna but do not include oysters or sessile macrofauna commonly attached to oyster shells. Maximum enhancement is calculated as the greatest difference measured within a season between reef and reference samples. Mean values were used to calculate maximum enhancement unless noted otherwise. "NS" = no significant difference between mean fluxes at reef and reference sites (α = 0.05). DNF = denitrification.

Sample Type	Reef Type	Location	Max DNF Enhancement (µmol N_2-N m^{-2} h^{-1})	Source
Reef	Subtidal	Choptank River, MD	1,486	Kellogg et al. (2013)
		Ninigret Pond, RI	~1,100	Humphries et al. (2016)ⱡ
		Harris Creek, MD	~600	Jackson et al. (2018)
Sediment-only	Intertidal	Bogue Sound, NC	~160	Piehler & Smyth (2011)*
			~250	Smyth et al. (2013)
			102	Smyth et al. (2016)
			NS	Onorevole et al. (2018)
		Middle Marsh, NC	~160	Smyth et al. (2015)
		Smith Island Bay, VA	~14	Smyth et al. (2018)
	Subtidal	Lake Fortuna and Sister Lake, LA	NS	Westbrook et al. (2019)
		Great Bay Estuary, NH	~16	Hoellein et al. (2015)

ⱡ Based on median values

*Means not given; calculated by subtracting minimum reference rate from maximum reef rate

8.2 Reduction Effectiveness: Panel Recommendations and Rationale

The following sections identify the information needed to determine reduction effectiveness, outline the Panel's recommendations, and explain the rationale underlying each of those recommendations for the restoration-denitrification protocols.

8.2.1 BMP Site Location and Area

As for the harvest-assimilation and the restoration-assimilation protocols, the ***BMP site*** is the location in which enhancement activities occur and which is potentially eligible for nitrogen reduction credit if all qualifying conditions are met. The ***BMP site area*** is equal to the area within which enhancement activities occur (i.e., the "footprint" of the restoration project). For additional information on how the BMP site and its area are determined, see Subchapter 6.2.1. Only denitrification associated with oysters found within the BMP site are eligible for crediting.

The Panel considered restoration projects in both subtidal and intertidal habitats and found that far more data were available for subtidal habitats. Data from intertidal reefs came from only two areas in Virginia. Variance in these data was high and the sample size was low. The Panel agreed that it was not feasible to develop default relationships between oyster biomass per unit area and denitrification for intertidal reefs at this time.

8.2.2 Qualifying Enhancement Activities

The qualifying enhancement activities for the restoration-denitrification protocols are the same as those for the restoration-assimilation protocols (Subchapter 7.2.2). Specifically, any reef restoration activity that includes the addition of hatchery-produced oysters and/or suitable settlement substrate throughout the BMP site can potentially qualify for crediting. However, the type of substrate used for restoration (large or small) and its location (subtidal or intertidal) will determine the approaches that can be used to estimate denitrification enhancement. Oysters of any size can enhance denitrification, and therefore the Panel does not recommend a maximum size of hatchery-produced oysters at the time of planting.

8.2.3 Substrate Category

The Panel agreed that same substrate categories (large and small) used for the restoration-assimilation protocols should be used for the restoration-denitrification protocols (Subchapter 7.2.3). While reviewing the available data, the Panel found that denitrification rates have rarely been measured for restoration projects using large substrate. The few data that have been collected suggest that rates may be structure-specific (e.g., Reef Balls™ and Oyster Castles® with similar oyster biomass may not have similar denitrification rates; J. Cornwell, UMCES, pers. Comm.). Appendix I includes preliminary data on denitrification rates measured on large substrates. The Panel also noted that the size and distribution of large structures likely influences the extent to which oyster biodeposits are retained within the BMP site (e.g., increasing vertical height and decreasing density of structures per unit area likely decrease retention of biodeposits within the BMP site).

Because of the paucity of data for reef restoration using large structures, the Panel concluded that it was not feasible to develop default denitrification enhancement estimates for large structures at this time. However, the Panel noted that the recommendations presented in this chapter could be applied to reefs restored using large substrates if sufficient data become available to develop robust relationships between denitrification rates and oyster biomass on large substrates, recognizing that these relationships may need to be substrate-specific (e.g., one relationship for Reef Balls™ and a different relationship for Oyster Castles®).

8.2.4 Baseline Approach

The Panel agreed that both the ***pre-restoration*** and the ***representative site*** approaches used for the restoration-assimilation protocols can be used for the restoration-denitrification protocols and that the same conditions and restrictions apply. As for the restoration-assimilation protocols, all sampling plans should be reviewed and approved by the state reporting agency and the CBP prior to implementation regardless of the approach used to determine baseline values. See Subchapter 7.2.4 for a full description of these two baseline approaches.

8.2.5 Oyster Biomass Assessment

The Panel agreed that the same recommendations for assessment of oyster tissue biomass for the restoration-assimilation protocols can be used for the restoration-denitrification protocols and that all the same restrictions and conditions apply for biomass sampling and estimation of biomass per unit area. Because estimates of denitrification enhancement rely solely on oyster tissue dry weight per unit area, data on oyster shell dry weight per unit area are not needed. See Subchapter 7.2.5 for a full description of recommended approaches to oyster tissue biomass assessment.

8.2.6 Denitrification Enhancement per Unit Area

The Panel recommends two approaches for estimating nitrogen removal associated with the restoration-denitrification protocols: default and site-specific. As noted in Subchapters 8.2.1 and 8.2.3, the Panel's review of available data led them to conclude that data are currently insufficient for development of default denitrification estimates for either intertidal reefs or for reefs using large substrate. Therefore, the Panel agreed that the default approach to estimating denitrification enhancement can only be used for reefs restored in subtidal habitats using small substrate (which includes hatchery produced oysters). All other types of restoration must use site-specific estimates of denitrification enhancement. However, the Panel agreed that, if sufficient data become available, the same approach presented in this chapter for developing default relationships between oyster biomass and denitrification enhancement could be applied to restored intertidal oyster reefs and/or reefs using large substrate.

8.2.6.1 Default Approach

An initial review of the literature indicated that peer-reviewed published data from the Chesapeake Bay were sparse, and that denitrification enhancement varied by orders of magnitude among these studies (e.g., Kellogg et al. 2013, Smyth et al. 2018). The Panel noted that, while some studies focused on restored oyster reefs, others were from natural oyster reefs and/or the origin (i.e., natural vs. restored) was not clearly stated. Because there was no clear evidence for differences in denitrification for natural and restored oyster reefs with similar biomass per unit area, the Panel agreed that studies focusing on both natural and restored oyster reefs were suitable for inclusion in the meta-analyses. To increase the pool of data used to determine enhanced denitrification rates related to oyster tissue biomass, the Panel decided to include additional data from project reports and unpublished data that met criteria for inclusion and the Panel's standards for scientific rigor.

To identify data suitable for inclusion in the Panel's meta-analyses, the Panel decided that the studies needed to have:

- Measured denitrification using representative samples from the restored reef that included oysters, shell, sediments, and associated organisms

- Assessed the biomass of oysters within the sample used for denitrification measurements and included a sufficient description of reef characteristics
- Measured denitrification using either the N_2:Ar gas ratio or ^{15}N isotope pairing technique
- Used a batch approach to incubation
- If the study reef occurred in the euphotic zone (where light reaches the seafloor), included both light and dark incubations.

The Panel also preferred studies that reported fluxes of other nitrogen compounds and oxygen but did not exclude data if these measurements were not taken. The rationale for selecting these criteria is described in Appendix F. Many studies excluded from meta-analyses failed to include a representative sample of the oyster reef (e.g., sampling included only sediments collected from an oyster reef). In addition to these types of samples not being representative of the reef-level impacts on denitrification rates, many presented challenges in identifying relationships between oyster biomass per unit area and denitrification rates.

The full set of evaluated studies spanned from mid to lower Chesapeake Bay (Figure 8.2), occurred in all four seasons, and included a wide range of oyster biomass (Table 8.3).

Initial examination of the resulting set of denitrification data for subtidal reefs suggested that, as expected, denitrification rates varied with season, leading the Panel to focus their meta-analyses on identifying seasonal relationships between oyster biomass and denitrification. In examining the distribution of available data across seasons, the Panel found only one study at a single location that sampled denitrification rates during the winter. Based on this, the Panel decided that data were insufficient to estimate winter denitrification rates and that, until more data become available, annual estimates of enhanced denitrification should assume that no denitrification occurs in winter. In total, seven studies from the Chesapeake Bay were used in the meta-analyses to develop season-specific relationships between oyster biomass per unit area and denitrification rates (Table 8.3).

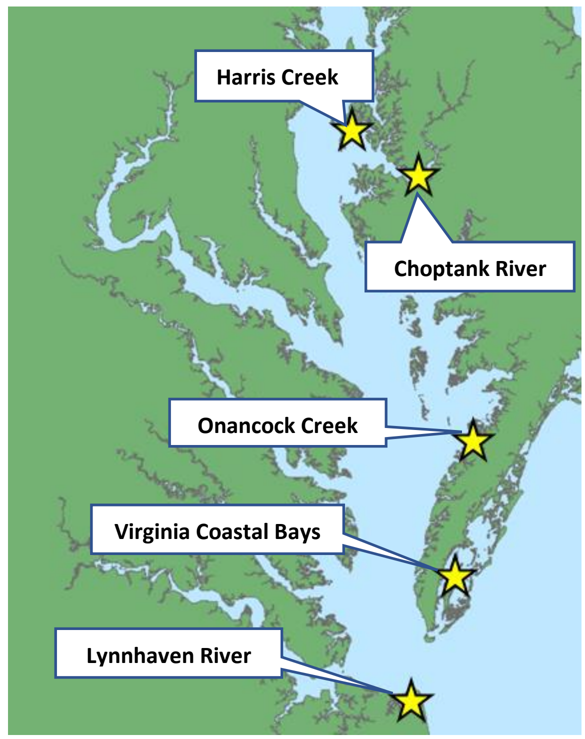


Figure 8.2. Map of Chesapeake Bay showing locations (yellow stars) where oyster reef denitrification rates included in the Panel's meta-analysis were measured. Some of the stars represent multiple sites in close proximity.

Table 8.3 Summary of the data included in analyses to determine if a default rate for enhanced denitrification associated with oyster reef restoration could be generated. Data from intertidal reefs were not included and some data from subtidal reefs were excluded from analyses (see text for details). NA = not applicable.

Reef Setting	Season	State	Water Body	Source	# of Samples Collected	# of Samples Included in Meta-Analyses
Subtidal	Spring	MD	Choptank River	Kellogg et al. (2013)	8	8
			Harris Creek	Cornwell et al. (2016 and 2019)	8	6
		VA	Lynnhaven River	Kellogg et al. (unpublished)	4	3
			Onancock Creek	Kellogg et al. (2014a,b)	6	5
	Summer	MD	Choptank River	Kellogg et al. (2013)	15	12
			Harris Creek	Cornwell et al. (2016 and 2019)	93	84
		VA	Lynnhaven River	Kellogg et al. (unpublished)	8	5
			Onancock Creek	Kellogg et al. (2014a,b)	7	7
	Fall	MD	Choptank River	Kellogg et al. (2013)	8	8
			Harris Creek	Cornwell et al. (2016 and 2019)	26	23
		VA	Lynnhaven River	Kellogg et al. (unpublished)	4	3
				Sisson et al. (2011)	2	2
	Winter	MD	Harris Creek	Cornwell et al. (2016 and 2019)	8	NA
Intertidal	Spring	VA	Virginia Coastal Bays	Kellogg et al. (2014a,b)	7	NA
	Summer	VA	Virginia Coastal Bays	Kellogg et al. (2014a,b)	22	NA
	Fall	VA	Lynnhaven River	Sisson et al. (2011)	6	NA
			Virginia Coastal Bays	Kellogg et al. (2014a,b)	7	NA

The first steps the Panel took in conducting meta-analyses was to normalize all data and screen it for outliers. All studies included in the meta-analyses reported denitrification rates in terms of nitrogen flux per unit area (µmol N m^{-2} h^{-1}). However, some of the studies included in the dataset were conducted in the euphotic zone (i.e., sufficient light reached the substratum to stimulate photosynthesis) while others were conducted below the euphotic zone. Because denitrification rates can be influenced by the presence of light, studies conducted in the euphotic zone measured denitrification rates for the same samples incubated in both the presence and absence of light. Because the number of daylight hours varies between seasons, the data from each study were used to calculate a mean hourly denitrification rate that accounted for the number of daylight hours in each season. For samples from euphotic reefs, there were some instances in which data were successfully collected only under light or only under dark conditions. Because a mean hourly rate could not be calculated for these samples, they were removed from the meta-analyses. This reduced the total number of data points from 26 to 24 for spring, 123 to 111 for summer, and 40 to 36 for fall.

Using the resulting dataset, the Panel then calculated mean hourly denitrification rates for 171 samples. To do this, the Panel first determined the number of daytime and nighttime hours in each season (Table 8.4) using NOAA's Solar Calculator (https://gml.noaa.gov/grad/solcalc/index.html). After considering differences in day length throughout Chesapeake Bay, the Panel decided its impact was minimal and decided to use the day and night hours from the geographic midpoint of the Chesapeake Bay for all locations.

Table 8.4. Number of months, days, hours, daytime hours, and nighttime hours for each season at the midpoint of the Chesapeake Bay.

Season	Months in Season	# Days	# Hours	# Daytime Hours	# Nighttime Hours
Spring	March, April, May	92	2208	1209.8	998.2
Summer	June, July, August	92	2208	1311.3	896.7
Fall	Sept., Oct., Nov.	91	2184	1022.1	1161.9
Winter	Dec., Jan., Feb.	90	2166	909.2	1256.8

The Panel used the resulting daytime and nighttime hours for each season to calculate the mean hourly denitrification (DNF) rate (µmol N_2-N m^{-2} h^{-1}) for each sample included in the meta-analysis:

$$Mean\ Hourly\ DNF\ Rate = \frac{(DNF_L\ x\ h_L) + (DNF_D\ x\ h_D)}{h_T}$$

where: DNF_L = denitrification rate measured in the presence of light
DNF_D = denitrification rate measured in the absence of light
h_L = total number of daytime hours in season
h_D = total number of nighttime hours in season
h_T = total number of hours in season

For samples from sites where light reaching the bottom was insufficient to stimulate photosynthesis, the formula was simplified to:

$$Mean\ Hourly\ DNF\ Rate = DNF_D\ x\ h_T$$

The mean hourly denitrification rates were plotted as a function of oyster tissue biomass density (g DW oyster tissue m^{-2}) for each sample and assessed for outliers. To ensure that denitrification rate estimates based on oyster tissue biomass were conservative, the Panel removed three data points from the spring dataset and three data points from the fall dataset that had unusually high denitrification rates relative to the remainder of these data. After outliers were removed, regression lines were plotted, and the significance of each regression was tested (Figure 8.3).

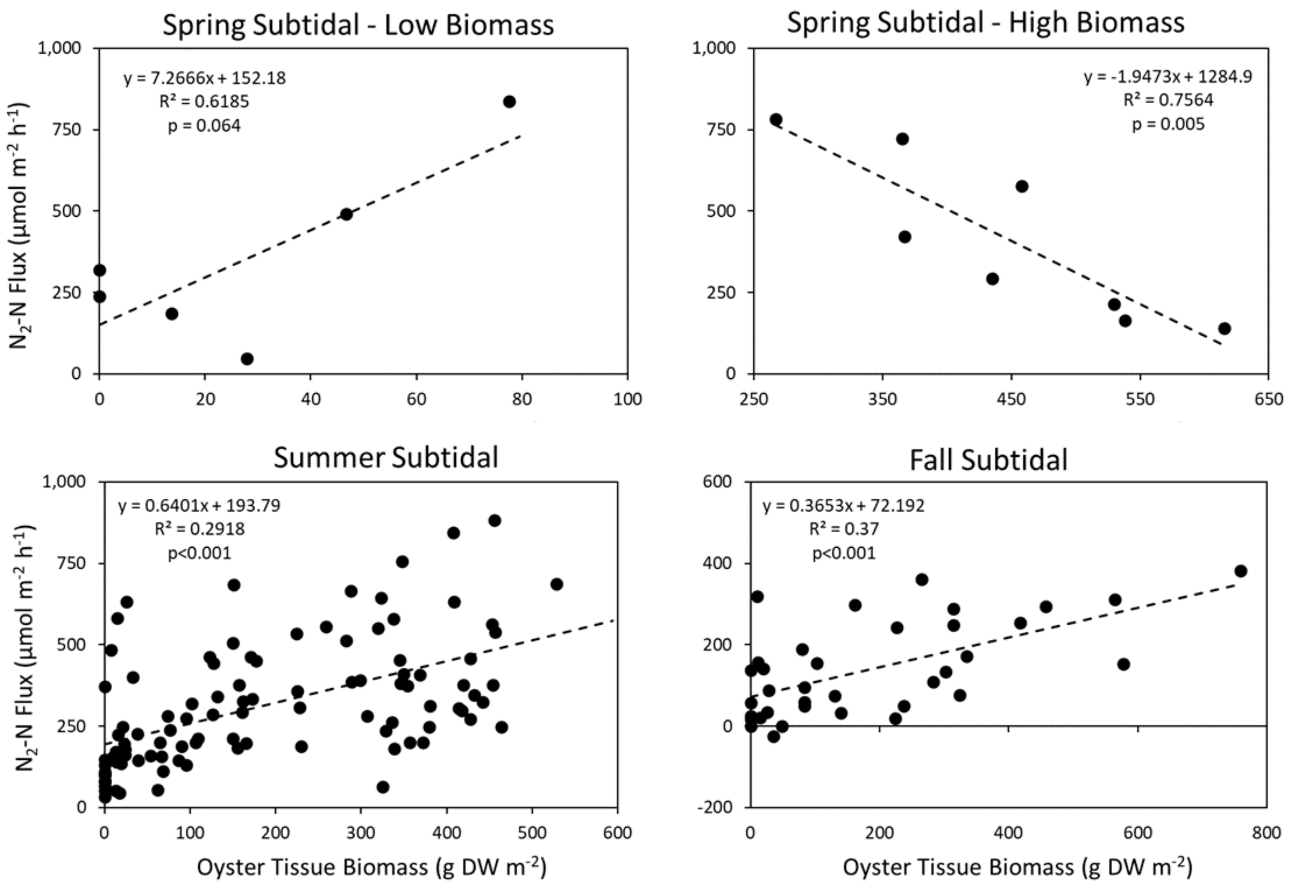


Figure 8.3. Final linear regressions of spring, summer and fall data oyster reef denitrification rates plotted as a function of oyster tissue biomass.

Mean hourly denitrification rates were related to oyster tissue biomass in spring, summer, and fall but that the relationship differed among seasons. In summer and fall, there was a significant ($p < 0.001$) linear increase in denitrification rate with oyster tissue biomass. The pattern for spring was more complicated. For samples with relatively low oyster tissue biomass (≤78 g DW oyster tissue m^{-2}), there was a marginally significant ($p = 0.064$) increase in denitrification rates with oyster tissue biomass. However, for samples with high oyster tissue biomass (≥267 g DW m^{-2}), denitrification decreased significantly ($p = 0.005$) with oyster tissue biomass. The spring dataset included no data for oyster tissue biomass between 78 and 267 g DW m^{-2}. Based on these results, the Panel agreed that default denitrification enhancement estimates based on oyster biomass per unit area could be developed for subtidal oyster reefs in Chesapeake Bay restored using small substrate. Specifically, the Panel agreed that:

- Season-specific linear regressions could be used to estimate denitrification rates based on oyster tissue biomass.
- Summer and fall linear regressions could be used without modification to estimate denitrification rates based on oyster tissue biomass.
- Spring estimates of denitrification rates would be based on two separate linear regressions for reefs with low and high oyster tissue biomass and that values for the region between these two regressions would be derived by connecting the ends of the two regressions with a straight line (a more conservative approach than fitting a polynomial or other type of regression to the gap in data).

- The marginal significance ($p = 0.064$) of the spring low oyster biomass regression was acceptable to estimate denitrification rates for the purposes of this BMP.

The resulting equations are provided in Table 8.5.

Table 8.5. Equations used to estimate seasonal denitrification rates for oyster reef habitats, where x = oyster tissue biomass (g DW m^{-2}) and y = denitrification rate (µmol N_2-N m^{-2} h^{-1}).

Season	Biomass Density	Equation	R^2	p-value
Spring	Low	y=7.2666x + 152.18	0.6185	0.064
	Moderate	y=0.2602x + 695.46	NA	NA
	High	y=-1.9473x + 1284.9	0.7564	0.005
Summer	All	y=0.6401x + 193.79	0.2918	<0.001
Fall	All	y=0.3653x + 72.192	0.3700	<0.001

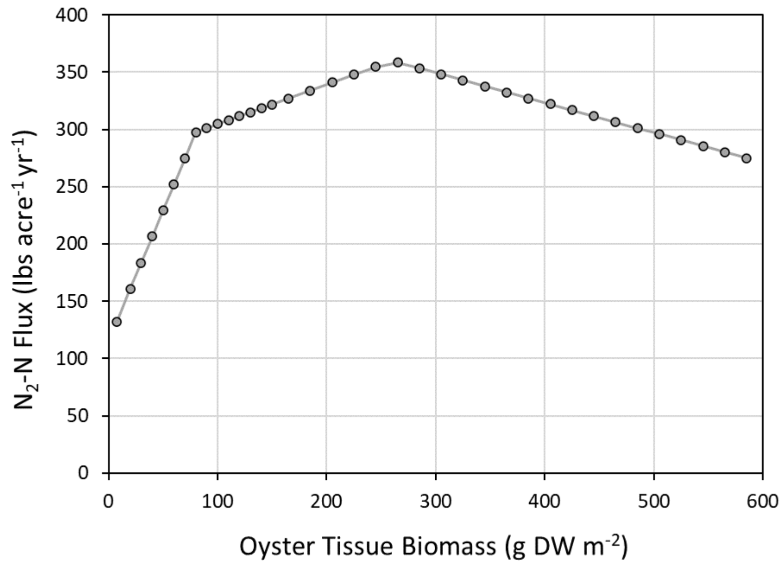
Recognizing the complexities of calculating annual denitrification rates from these regressions, the Panel developed a lookup table that allows implementers to estimate annual enhanced denitrification rates based on baseline and post-restoration oyster tissue biomass. The first step in developing the lookup table was to determine appropriate bins for the levels of oyster biomass per unit area. The Panel decided that the first oyster tissue biomass bin should range from 0-14.9 g DW m^2 because an oyster tissue biomass of 15 g DW m^{-2} is the minimum threshold value for restored oyster reefs to be considered "marginally successful" in Chesapeake Bay (Oyster Metrics Workgroup 2011). For reefs with biomass per unit area ranging from 15-154.9 g DW m^{-2}, the Panel decided to divide oyster tissue biomass into 10 g DW m^{-2} bins based on the following considerations:

- Slope of the curve for each oyster tissue biomass range (denitrification increased more quickly at lower oyster tissue biomass ranges)
- Frequency with which each oyster tissue biomass range was observed in the field (most restoration projects to date have seen oyster tissue biomass range from 15-154.9 g DW m^{-2})
- Number of bins that would be practical for implementation

For sites with oyster tissue biomass ≥155 g DW m^{-2}, the Panel agreed that 20-g bins were the best tradeoff between accurate estimation of denitrification rates and complexity of implementation. Oyster tissue biomass ranges and midpoints were not identified for sites with greater than 594.9 g DW m^{-2} because the regressions did not extend beyond this value for all three seasons and the Panel did not want to extrapolate beyond the range of the data included in analyses. Few, if any, restoration efforts achieve this level of mean oyster tissue biomass.

Once biomass bins were established, the annual denitrification rate for each biomass bin was determined. To do this, the total nitrogen removal per season for each oyster tissue biomass range was calculated by entering the midpoint biomass for each bin into each of the seasonal regression equations (Table 8.5) to get the corresponding denitrification rate per unit area (µmol m^{-2} h^{-1}). This was then multiplied by the total number of hours per season (Table 8.4) to get the total nitrogen removal per season (µmol N_2-N m^{-2}) and the units converted to pounds per acre. The annual denitrification rate (lbs. N $acre^{-1}$ yr^{-1}) was then calculated as the sum of the individual seasonal nitrogen removals.

Figure 8.4. Plot of estimated annual denitrification rates in relation to oyster tissue biomass per unit area for reefs restored using small substrate in subtidal habitats.



The annual nitrogen removal rates were then used to construct a lookup table with baseline oyster tissue biomass (g DW m^{-2}) ranges listed in the rows and post-restoration oyster tissue biomass (g DW m^{-2}) ranges listed in the columns. The cells in the lookup table contain estimates of the enhanced denitrification (lbs $acre^{-1}$ yr^{-1}), which was calculated by subtracting the annual denitrification rate for the baseline oyster tissue biomass range in each row from the annual denitrification rate for the post-restoration oyster tissue biomass range in each column. A partial lookup table is shown in Table 8.6 and the full lookup table is provided in Appendix G. In cases where post-restoration oyster tissue biomass was equal to or less than the baseline oyster tissue biomass, or where enhanced denitrification did not occur (e.g., in cases where biomass >275 g DW m^{-1}; Figure 8.4, Appendix G), the cell was left blank.

Table 8.6. Partial lookup table for use in determining the annual enhanced denitrification rates. For full lookup table, see Appendix G.

Enhanced Nitrogen Removal (lbs $acre^{-1}$ yr^{-1})		*Post-restoration Oyster Biomass Range (g DW m^{-2})*												
		15 - 24.9	***25 - 34.9***	***35 - 44.9***	***45 - 54.9***	***55 - 64.9***	***65 - 74.9***	***75 - 84.9***	***85 - 94.9***	***95 - 104.9***	***105 - 114.9***	***115 - 124.9***	***125 - 134.9***	***135 - 144.9***
Baseline Oyster Biomass Range (g DW m^{-2})	***0 - 14.9***	29	51	74	97	120	143	165	169	172	176	179	183	186
	15 - 24.9		23	46	68	91	114	137	140	144	147	151	154	158
	25 - 34.9			23	46	68	91	114	118	121	124	128	131	135
	35 - 44.9				23	46	68	91	95	98	102	105	109	112
	45 - 54.9					23	46	68	72	75	79	82	86	89
	55 - 64.9						23	46	49	53	56	59	63	66
	65 - 74.9							23	26	30	33	37	40	44
	75 - 84.9								3	7	10	14	17	21
	85 - 94.9									3	7	10	14	17
	95 - 104.9										3	7	10	14
	105 - 114.9											3	7	10
	115 - 124.9												3	7
	125 - 134.9													3

8.2.6.2 Site-specific Approach

For restoration efforts that utilize large substrate and/or reefs in intertidal habitats, denitrification rates must be based on site-specific measurements of denitrification. The Panel recommends that implementers develop season-specific regression equations in consultation with expert(s) knowledgeable in oyster reef sampling and the measurement of oyster-associated denitrification rates. Considerations for measuring denitrification rates on restored reefs are outlined in Appendix F.

8.2.7 Total Annual Denitrification Enhancement

The total amount of nitrogen removed annually from the BMP site through enhanced denitrification is determined by multiplying the enhanced denitrification estimate (lbs $acre^{-1}$) by the total BMP site area.

8.2.8 Crediting Timeframe

Since monitoring timeframes differ between oyster reef restoration projects and because oyster tissue biomass on a restored reef can fluctuate from year to year, the Panel considered how frequently oyster biomass needs to be measured to verify the persistence of oyster biomass levels at the restoration site and prevent over crediting. The Panel decided that nitrogen reduction effectiveness should be valid for a maximum of three years after a post-restoration biomass survey. After three years, no credit is given until the post-restoration oyster tissue biomass has been determined again from field measurements at the BMP site and the enhanced denitrification estimate is re-evaluated using the baseline oyster tissue biomass and the newly determined post-restoration oyster tissue biomass. If crediting is warranted after a gap in monitoring, crediting can begin again for the year the reef was surveyed but cannot be given retroactively. If biomass is assessed more frequently than once every three years, the most recent post-restoration biomass should be used for determining the appropriate level of credit. Post-restoration oyster tissue biomass can be measured and enhanced denitrification can be credited over the lifetime of the BMP site.

8.3 Reduction Effectiveness: Stepwise Determination

To calculate the reduction effectiveness for the restoration-denitrification protocols, the Panel recommends the following:

Step 1. Identify the BMP site location and determine the BMP site area (Subchapter 8.2.1)

Step 2. Document the qualifying enhancement activity and the date it occurred (Subchapter 8.2.2)

Step 3. Determine the appropriate baseline approach (Subchapter 8.2.4)

Step 4. Assess baseline and post-restoration tissue biomass (Subchapter 8.2.5)

Step 5. Determine denitrification enhancement per unit area using either the biomass-based default denitrification rates per unit area (Subchapter 8.2.6.1) or site-specific measured denitrification rates (Subchapter 8.2.6.2)

Step 6. Determine the total nitrogen removal attributable to enhanced denitrification using the estimated denitrification enhancement per unit area and the BMP site area (Subchapter 8.2.7)

8.4 TMDL Baseline Considerations

The TMDL for Chesapeake Bay was created in 2009. Based on this, the CBP Management Board agreed that reduction crediting under the restoration-denitrification protocols for oysters can only be given for oyster reef restoration projects that were initiated after the creation of the TMDL in 2009.

8.5 Qualifying Conditions

The Panel recommends that the following qualifying conditions be met for applying the restoration-denitrification protocols to receive nitrogen reduction credit. These account for both the CBP Management Board's defined baseline and the Panel's criteria. Most of the qualifying conditions for the restoration-denitrification protocols are identical to those for the restoration-assimilation protocols (highlighted in gray).

- A qualifying enhancement activity (Subchapter 8.2.2) must have occurred throughout the BMP site area (Subchapter 8.2.1).
- BMP site must lie within an area protected from harvest
- Baseline oyster biomass must be determined using an appropriate approach and adhere to baseline conditions (Subchapter 8.2.4)
- All biomass estimates (Subchapter 7.2.5) must:
    - Be based on field surveys of live *Crassostrea virginica*
    - Be based on data collected using a survey design that ensures estimates are representative of the entire BMP site.
    - Include enough data points to allow calculation of mean biomass and its variance. If multiple strata are included in the sampling design, data must be sufficient to calculate means and variances for all strata.
- If using the default approach to estimating enhanced denitrification, the reef must be in a subtidal habitat and restoration activities must have utilized only small substrates (Subchapter 8.2.2).
- Only live oyster tissue biomass is eligible for credit.
- The post-restoration oyster tissue biomass must be greater than the baseline oyster tissue biomass

8.6 Recommended Application and Verification Guidelines

8.6.1 Reporting Guidelines

To assist with application of its recommendations, the Panel developed guidelines for the information to be reported by anyone seeking credit for this practice-protocol combination. The required information is listed below under the associated determination step. The majority of this information is identical to the information that needs to be reported for the restoration-assimilation protocols (highlighted in gray).

Step 1: Identify the BMP site location and determine the BMP site area (Subchapter 7.2.1)

- Geospatial information documenting the vertices of a polygon representing the BMP site
- Area of the polygon representing the BMP site

Step 2: Document the qualifying enhancement activity and its date (Subchapter 7.2.2), the type(s) of substrate used for restoration (Subchapter 7.2.3), and the baseline approach (Subchapter 7.2.4).

- Date of enhancement activity
- Type(s) of substrate

- Substrate category (small or large)
- Amount of substrate used
- If using hatchery-produced oysters:
  - Ploidy of oysters
  - Number of oysters planted
  - Size of oysters at time of planting
- Baseline approach used (pre-restoration or representative site)

Step 3: Assess baseline and post-restoration tissue biomass (Subchapters 7.2.5) and determine the mean tissue biomass per meter square for each.

- For first survey after reef restoration, provide a brief description of biomass survey sampling design for both the baseline and post-restoration biomass surveys. For subsequent surveys, only information on the post-restoration survey design is needed.
  - Sampling date(s)
  - Method used to collect samples (e.g., patent tongs, divers with quadrats, etc.)
  - Spatial scale of sample (e.g., 1.0 m^2, one Reef Ball^{TM}, etc.)
  - Number of samples collected
  - If subsampling is used, a description of the subsampling methods, number of subsamples per sample, and method of scaling
  - Methods used to assess oyster tissue biomass per sample (default regression, direct measurement, or site-specific regression)
  - Method used to calculate mean sample biomass
  - Mean tissue biomass in grams dry weight per square meter

Step 4: Determine annual denitrification enhancement per acre (Subchapter 8.2.5).

- Document approach used to estimate denitrification enhancement (default or site-specific)
- Denitrification enhancement per acre
  - If using the default approach, determine denitrification enhancement using the lookup table. No additional documentation is required.
  - If using the site-specific approach, a full report of the methods used to measure denitrification, estimate enhancement, and extrapolate enhancement per unit area is required.

Step 5: Determine total annual denitrification enhancement (Subchapter 8.2.6).

- Total nitrogen removed annually by restoration at the BMP site.

8.6.2 Example

To give an example of the information needed for crediting, Table 8.7 provides a list of the information along with a hypothetical example of that information for the first year of harvest from a BMP site. To emphasize the similarity between the information required for the restoration-assimilation and restoration-denitrification protocols, the example below uses the same scenario as that given for small substrate for the restoration-assimilation protocol (Subchapter 7.6.2.1) and the items below that are identical for both examples are highlighted in gray. The primary difference between the restoration-denitrification and restoration-assimilation calculations is that for restoration-denitrification protocols, the most recently measured oyster biomass per square meter is always compared to the baseline data to determine denitrification enhancement.

In contrast, for the restoration-assimilation protocol, the data from the most recent post-restoration biomass survey is compared the highest previously measured biomass per unit area.

Table 8.7. Information types required for the restoration-denitrification protocols along with an example of each. See text for details of calculations used to provide example information below. Items that are identical for both the restoration-assimilation and restoration-denitrification protocols are highlighted in gray.

Step #	Information Type	Example
1	BMP site location	See appended map and GIS file
	Area of the BMP site	1 acre
2	Date(s) of activity (mm/dd/yy)	09/21/21
	Type(s) of substrate	Diploid spat-on-shell
	Substrate category	Small
	Amount of substrate	1,000 Maryland bushels of spat-on-shell
	Number of hatchery-produced oysters planted	9,500,000
	Size of oysters at time of planting (mm)	10
	Baseline approach	Pre-restoration
3	Baseline biomass	
	Sampling points	See appended map and GIS file
	Sampling date(s)	07/15/20
	Sampling method	Patent tong
	Spatial scale of sample with units	1 m^2
	Number of samples collected	5
	Method used to assess biomass	Default regression
	Method used to calculate mean biomass	Average of all samples
	Mean biomass: Tissue	14 g DW m^{-2}
	Post-restoration biomass	
	Sampling date(s)	08/01/24
	Sampling method	Patent tong
	Spatial scale of sample with units	1 m^2
	Number of samples collected	5
	Method used to assess biomass	Default regression
	Method used to calculate mean biomass	Average of all samples
	Mean biomass: Tissue	119 g DW m^{-2}
4	Approach used to estimate denitrification enhancement	Default
	Annual enhanced denitrification per acre	179 lbs $acre^{-1}$ $year^{-1}$
5	Total annual denitrification enhancement	179 lbs $year^{-1}$

If the default approach to estimating denitrification is used, the annual nitrogen removal per acre can be determined by simply finding the cell that corresponds to the appropriate baseline and post-restoration biomass levels and using the value from the lookup table. In this example, the pre-restoration biomass was 14 g DW oyster tissue m^{-2} and the post-restoration biomass was 119 g DW oyster tissue m^{-2}, corresponding to an annual removal of 179 pounds of nitrogen per acre per year. Because the BMP site area is one acre, the annual nitrogen removal for this restoration effort is 179 lbs of nitrogen per year. In this example, biomass is not measured again until 2027, so the value of 179 lbs of nitrogen removal is credited for the years 2024, 2025, and 2026 (Table 8.8). In 2027, the biomass level dropped to 105 g DW m^{-2}. As a result, the estimated denitrification enhancement is reduced to 176 lbs $acre^{-1}$ yr^{-1}. In 2030, a biomass survey finds that biomass has increased to 173 g DW m^{-2} resulting in an increase in annual nitrogen removal to 195 lbs $acre^{-1}$ yr^{-1}. The final reef survey conducted in 2033 finds that biomass had declined to 59 g DW m^{-2} resulting in a decrease in annual crediting to 120 lbs $acre^{-1}$ yr^{-1}. Over the 12-year period during which crediting occurs, the one-acre reef results in a total enhanced nitrogen removal via denitrification of 2,010 lbs (Table 8.8).

Table 8.8. Example of crediting for the restoration-denitrification protocol based on biomass surveys conducted at three year intervals.

Year	Survey Type	Measured Biomass (g DW m^{-2})	Annual Enhanced Nitrogen Removal (lbs $acre^{-1}$)
2020	Baseline	14	NA
2021			NA
2022			NA
2023			NA
2024	Post-restoration	119	179
2025			179
2026			179
2027	Post-restoration	105	176
2028			176
2029			176
2030	Post-restoration	173	195
2031			195
2032			195
2033	Post-restoration	59	120
2034			120
2035			120
		Total	***2,010***

8.7 Unintended Consequences

The Panel's review of published data found no instances where the restoration of subtidal oyster reefs using small substrates resulted in a decrease in net denitrification at the restoration site. However, the approach taken by the Panel to estimate denitrification enhancement focuses on local effects on biogeochemical cycling and does not consider effects at the landscape scale. Post-restoration denitrification rates can be orders of magnitude higher than baseline denitrification rates, but denitrification efficiency may be lower after restoration than before. Denitrification efficiency is a measure of the amount of total nitrogen that is denitrified. It is calculated by dividing the flux of N_2-N by the sum of all nitrogen fluxes and is reported as a percentage. When considered at a landscape scale, it is feasible that the total amount of nitrogen removed from the system could be lower after reef restoration if the restored reef had a low denitrification rate and if phytoplankton would have been remineralized in an environment with higher denitrification efficiency had it not been filtered from the water column by oysters.

However, these conditions are unlikely in Chesapeake Bay. The filtering actions of oysters greatly increase deposition of organic matter to the benthos. In the absence of oyster filtration, much of that phytoplankton would have been remineralized in the water column where denitrification does not occur. The portion of the phytoplankton that did fall to the benthos in the absence of oysters would have to be deposited on oxic sediments for denitrification to occur. Given the eutrophic condition of Chesapeake Bay and that large portions of the Bay are subject to anoxic conditions each year, only a portion of that phytoplankton is likely to fall onto habitats that support high-efficiency denitrification. Because reef restoration also supports assimilation of nitrogen in the tissues and shells of oysters (Chapter 7), the Panel concluded that situations in which reef restoration led to a net decrease in nitrogen removal at the landscape scale would be rare if they occur at all.

Oyster filtration of phytoplankton leads to increased deposition of organic matter to the benthos. Although increasing the supply of organic matter to the seafloor is part of why restored reefs can enhance denitrification rates, too much organic matter can have negative impacts on water quality. The microbial processes that break down organic matter consume oxygen. If bottom waters become anoxic, nitrification (a microbial process that requires oxygen and a precursor to denitrification) can no longer supply the substrates needed for denitrification to occur. The Panel found no reports of situations where reef restoration drove local anoxia or led to a decrease in denitrification rates. However, because these studies focused on restoration efforts using small substrates and few studies have examined the biogeochemical changes associated with the use of large substrates, it is unclear whether this could occur in association with the use of large (e.g., engineered structures) for reef restoration. However, since the Panel is recommending that separate measurements are made to evaluate denitrification on large substrates for crediting purposes, any excessive loading of organic matter would be observed and allow for adaptive management of the practice. Consideration of the potential for negative consequences should be explicitly considered as part of any effort to develop reduction effectiveness estimates for reefs restored using large substrates.

In addition to altering nitrogen dynamics, reef restoration can also alter the phosphorus dynamics on the seafloor. Some of the studies used in the Panel's meta-analysis included data on soluble reactive phosphorus (SRP) fluxes. Results showed both increasing and decreasing SRP flux with increasing oyster biomass. Factors driving differences between studies were unclear. High variance in SRP flux data is not unexpected because phosphorus dynamics can be altered by local sediment composition, specifically whether they contain significant amounts of iron oxides. Under anoxic conditions, iron oxides that bind phosphorus can be converted to iron sulfides leading to the release of phosphorus (O'Keefe 2007, Jordan et al. 2008). Reefs may be on a trajectory of increasing phosphorus flux as the sulfide in sediments increases as the reef matures. Given the limited amount of data available and its high degree of variability, the Panel suggested that the effects of reef restoration on local phosphorus dynamics should be a topic of future study.

8.8 Ancillary Benefits

The Panel identified several ancillary benefits for the restoration-denitrification protocols. Benefits of oyster restoration are described in Chapter 9.

8.9 Future Research

Although the Panel found sufficient data to develop reduction effectiveness estimates for nitrogen removed by enhanced denitrification on subtidal oyster reefs using small substrates, additional research is needed to refine these estimates, to develop default estimates for intertidal reefs and reefs restored using large substrates, and to develop estimates for practices not covered in the current set of recommendations. The Panel suggests that the following future research:

- Determine whether relationships between denitrification rates and oyster tissue biomass are influenced by salinity and/or nutrient gradients. Measurement in more sites would be beneficial.
- Prioritize denitrification measurements for oysters within the 75-270 g DW m^{-2} tissue biomass range. These data will refine the relationship between denitrification rates and oyster tissue biomass and refine the estimates for nitrogen removal.

- Determine whether significant relationships exist between denitrification and oyster tissue biomass on intertidal reefs and on reefs built using large substrates. If these relationships exist, explore whether they are sufficiently robust to develop default nitrogen reduction effectiveness estimates for these practices.
- Develop new methods for measuring denitrification associated with oyster reef restoration that are more cost-effective, allowing efficient development of better seasonal and spatial denitrification measurements.
- Develop denitrification techniques to assess the nutrient removal values for oysters attached to large substrates such as ReefBalls™ and Oyster Castles©.
- Determine whether significant relationships between denitrification rates and oyster tissue biomass for restored oyster reefs exist in winter. If these relationships exist, explore whether they should be incorporated into current nitrogen reduction effectiveness estimates.
- Improve understanding of how restored oyster reefs alter nitrogen dynamics at spatial scales greater than the footprint of the restoration project.
    - A significant portion of reef biodeposits may not be retained within the reef footprint. If these biodeposits are remineralized in oxic sediments outside the footprint of the reef and subsequently denitrified, restored reefs may remove more nitrogen than accounted for in the current reduction effectiveness estimates.
    - The current reduction effectiveness estimates focus on local impacts on denitrification rates. However, reef restoration takes place within a broader landscape. A true accounting of the net effect of oyster reef restoration would evaluate reef impacts at the landscape scale and would account for the fate of phytoplankton had the reefs not been constructed.
- Explore effects of reef restoration on phosphorus dynamics.
- Examine whether on-bottom aquaculture has similar value as restored reefs for enhancing denitrification.

9.0 Ancillary Benefits of Oyster Reef Restoration

The ancillary benefits of oyster reef restoration are numerous (e.g., Coen et al. 1999, 2007). Perhaps the most well-documented benefit of oyster reef restoration is the provision of habitat for other organisms. Oyster reefs provide habitat for an abundance of marine species. Numerous studies have recorded a greater abundance and diversity of marine fauna on natural and restored oyster reefs relative to areas with no reef structure (e.g., Tolley & Volety 2005, Rodney & Paynter 2006, Kellog et al. 2013). Many reef-associated species serve as prey for commercially and recreationally important species. Thus, reef restoration has the potential to enhance the production of recreational and commercially significant species in the Chesapeake Bay, which would have additional economic benefits in the region (e.g., Grabowski et al. 2012, Knoche et al. 2020, Bruce et al. 2021).

Because many reef-associated organisms are also filter feeders and also assimilate nitrogen and phosphorus, enhancing their populations through reef restoration may increase water quality benefits beyond those provided by oysters. For example, hooked mussels are filter feeders commonly found on oyster reefs in Chesapeake Bay. A study by Gedan et al. (2014) found that hooked mussel biomass can sometimes exceed that of oysters on restored reefs and that they can more than double the filtration capacity of the reef. In their assessment of reef nutrient assimilation, Kellogg et al. (2013) found that 34% of the total assimilated nitrogen and 33% of the total assimilated phosphorus in oyster reef samples was in organisms other than oysters. This suggests that increases in biomass of other reef organisms can assimilate greater portions of nutrients than oysters alone and therefore the estimates generated in this report are likely conservative.

The filtration capacity of oysters and reef communities has the potential to increase light penetration through the water column which may benefit seagrasses. A modeling study by Newell & Koch (2004) suggested that increasing oyster populations in Chesapeake Bay would reduce turbidity and facilitate seagrass growth and the expansion of seagrass beds to deeper water. Another modeling study by Cerco & Noel (2007) suggested that a 10% increase in oyster populations in Chesapeake Bay should increase the biomass of submerged aquatic vegetation (SAV). Because seagrasses are a refuge for marine animals and provide other water quality benefits (Orth et al. 2006), the relationship between oyster restoration and seagrass establishment could be synergistic. However, more recent field studies on the effects of increased oyster density and/or oyster reef restoration on SAV habitats suggest that these effects may not be observed under field conditions, that their spatial scale may be very limited, and that interactions may be positive or negative (Booth & Heck 2009, Plutchak et al. 2010, Grizzle et al. 2018).

Restored oyster reefs can also provide protection for shorelines vulnerable to wave energy and sea level rise. Some such breakwater reefs have increased sedimentation to adjacent marsh edges and reduce erosion and marsh loss (Stricklin et al. 2010) while creating habitat for commercially important species like blue crab and red drum (Scyphers et al. 2011). The potential economic impact of combined benefits from shoreline protection and increased fish production can be significant (e.g., Kroeger & Guannel 2014).

10.0 Conclusion

In this report, the Panel provides complete recommendations for implementing twelve oyster practice-protocol combinations for BMP use (Table 1.1) in addition to the six combinations approved in the Panel's first oyster BMP report (Reichert-Nguyen et al. 2016). For these twelve combinations, the Panel verified that sufficient data and information were available to address all items outlined in the CBP Partnership's BMP Review Protocol. The Panel concluded that certain licensed oyster harvest (**Practice F**) and oyster restoration (**Practices J & K**) practices could permanently remove nitrogen and phosphorus through assimilation in oyster tissue (**Protocols 1 & 4**) and shell (**Protocols 2 & 5**), and/or through the biogeochemical process of denitrification (**Protocol 3**).

For all practice-protocol combinations, the Panel concluded that oyster biomass data are required to estimate reduction effectiveness and to verify that the enhancement activity led to an increase in oyster production. The Panel used common statistical approaches (e.g., 50^{th} quantile regression) to determine relationships between oyster tissue and/or shell biomass and the amount of nitrogen and/or phosphorus removed from the water column. The Panel developed tools (e.g., default equations and/or lookup tables) for implementers to use to estimate reduction effectiveness and developed a comprehensive set of verification guidelines and qualifying conditions to minimize nutrient over crediting for each oyster practice.

The Panel identified a few potential unintended consequences associated with crediting oyster restoration practices; however, the Panel agreed that significant over crediting is unlikely because the recommended crediting approaches are intentionally conservative and significant nitrogen and phosphorus are removed by processes that are not captured by the recommended practice-protocol combinations (e.g. nutrients retained in dead oyster shells, nutrients assimilated in reef-associated organisms, enhanced denitrification associated with oysters prior to harvest).

The Panel also identified several next steps and research needs required to more accurately quantify nutrient reduction through oyster-related processes in the Chesapeake Bay. In general, these include gaining a better understanding of:

- Nitrogen and phosphorus assimilation in shell on harvested oyster reefs
- Spat survivorship estimates on both harvested and restored reefs
- Oyster biomass estimates and denitrification rates for intertidal reefs
- Oyster biomass estimates and denitrification rates for large structures and other suitable substrates
- How abiotic factors impact denitrification rates at the reef scale
- Seasonal and spatial variability in denitrification measurements (e.g., in winter)
- How restored reefs alter nitrogen dynamics at the landscape scale
- Denitrification rates associated with other oyster practices (harvest and/or aquaculture)
- Phosphorus cycling processes associated with oysters

The Panel was unable to provide recommendations for suspended sediment reduction (**Protocol 6**) or enhanced nitrogen and phosphorus burial associated with oysters (**Protocols 7 & 8**). Quantifying permanent removal through these processes is challenging because sediment can be resuspended and deposited several times within a basin. Sediment transport patterns also vary within and among basins as a function of several abiotic factors. The Panel agreed that more research is needed to minimize uncertainty in sediment deposition rates and recommends that STAC convene a workshop to re-evaluate whether data are available or can be collected. The CBP Management Board will need to work closely with a future oyster BMP Panel to reach consensus on which metrics can most accurately quantify sediment and nutrient removal through deposition and burial.

If approved by the CBP Partnership, the BMP process and recommendations described here can contribute measurable positive progress towards the water quality goals established by the Chesapeake Bay Total Maximum Daily Load framework.

11.0 References

Allen SK Jr, Downing SL (1986) Performance of triploid Pacific oysters, *Crassostrea gigas* (Thunberg): I. Survival, growth, glycogen content, and sexual maturation in yearlings. J Exp Mar Biol Ecol 102:197–208

Arfken A, Song B, Bowman JS, Piehler M (2017) Denitrification potential of the eastern oyster microbiome using a 16S rRNA gene based metabolic inference approach. PLOS ONE 12:e0185071

Booth DM, Heck KL Jr (2009) Effects of the American oyster *Crassostrea virginica* on growth rates of the seagrass *Halodule wrightii.* Mar Ecol Prog Ser 389:117-126

Bruce DG, Cornwell JC, Harris L, Ihde TF, Kellogg ML, Knoche S, Lipcius RN, McCulloch-Prosser DN, McIninch SP, Ogburn MB, Seitz RD, Testa J, Westby SR, Vogt B (2021) A synopsis of research on the ecosystem services provided by large-scale oyster restoration in the Chesapeake Bay. NOAA Tech. Memo. NMFS-OHC-8

Caffrey JM, Hollibaugh JT, Mortazavi B (2016) Living oysters and their shells as sites of nitrification and denitrification. Mar Pollut Bull 112:86-90

Carmichael RH, Walton W, Clark H, (2012) Bivalve-enhanced nitrogen removal from coastal estuaries. Can J Fish Aquat Sci 69:1131–1149

CBF (Chesapeake Bay Foundation) (2022) Virginia oyster gardening. https://www.cbf.org/how-we-save-the-bay/programs-initiatives/virginia/oyster-restoration/oyster-gardening (accessed 29 July 2022)

CBP (Chesapeake Bay Program) (2014, as amended 2020) Chesapeake Bay watershed agreement. https://www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement.withsignatures-HIres.pdf (accessed 29 July 2022)

CBP (2015) Protocol for the development, review, and approval of loading and effectiveness estimates for nutrient and sediment controls in the Chesapeake Bay Watershed Model. http://www.chesapeakebay.net/publications/title/bmp_review_protocol (accessed 29 July 2022)

CBP (2016) Oyster BMP policy issues: special management board session https://www.chesapeakebay.net/channel_files/24109/oyster_bmp_policy_session_6-15_summary_final_6-23.pdf (accessed 29 July 2022)

CBP (2017) Discussion and feedback summary: May 22, 2017 Oyster BMP Expert Panel open meeting, https://www.chesapeakebay.net/channel_files/25062/summary_22may17_oyster_bmp_open_meeting_final_7-18-17.pdf (accessed 29 July 2022)

CBP (2022) Modeling workgroup: overall CBP model framework. https://www.chesapeakebay.net/who/group/modeling_team (accessed 29 July 2022)

Cerco CF, Noel MR (2007) Can oyster restoration reverse cultural eutrophication in Chesapeake Bay? Estuar Coasts 30:331-343

Code of Maryland Regulations. Department of Natural Resources. Fisheries Science. Oysters. General Provisions. COMAR 08.02.04.11. http://www.dsd.state.md.us/comar/comarhtml/08/08.02.04.11.htm (accessed 29 July 2022)

Code of Maryland Regulations. Department of Natural Resources. Fisheries Science. Oysters. Oyster Sanctuaries. COMAR 08.02.04.15. http://www.dsd.state.md.us/comar/comarhtml/08/08.02.04.15.htm (accessed 29 July 2022)

Code of Maryland Regulations. Department of Natural Resources. Fisheries Science. Oysters. Public Shellfish Fishery Area. COMAR 08.02.04.17. http://www.dsd.state.md.us/comar/comarhtml/08/08.02.04.17.htm (accessed 29 July 2022)

Code of Virginia. Fisheries and Habitat of the Tidal Waters. Tidal Fisheries. Planting Grounds. General Oyster-Planting Grounds. Va. Code §28.2-603. https://law.lis.virginia.gov/vacode/title28.2/chapter6/section28.2-603 (accessed 29 July 2022)

Coen LD, Luckenbach MW, Breitburg DL (1999) The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. Am Fish Soc Symp 22:438–454

Coen LD, Brumbaugh RD, Bushek D, Grizzle R, Luckenbach MW, Posey MH, Powers SP, Tolley G (2007) Ecosystem services related to oyster restoration. Mar Ecol Prog Ser 341:303-307

Congrove MS (2008) A bio-economic feasibility model for remote setting: potential for oyster aquaculture in Virginia. MS Thesis, College of William & Mary, Williamsburg, VA

Cornwell JC, Kemp WM, Kana TM (1999) Denitrification in coastal ecosystems: environmental controls and aspects of spatial and temporal scale. Aquatic Ecology 33:41-54.

Cornwell JC, Owens MS, Kellogg ML (2016) Integrated assessment of oyster reef ecosystem services: quantifying denitrification rates and nutrient fluxes. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/JDFV-GD71 (accessed 1 Aug 2022)

Cornwell JC, Owens MS, Jackson M, Kellogg ML (2019) Integrated assessment of oyster reef ecosystem services: quantifying denitrification rates and nutrient fluxes. https://doi.org/10.25773/F30H-3G51 (accessed 1 Aug 2022)

Dégremont L, Garcia C, Allen SK Jr (2015) Genetic improvement for disease resistance in oysters: a review. J Invertebr Pathol 131:226-241

EPA (U.S. Environmental Protection Agency) (2010) Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=9101KBW7.PDF (accessed 30 July 2022)

Executive Order 13508 (2009) Chesapeake Bay Protection and Restoration. 3 CFR 13508. https://www.govinfo.gov/content/pkg/CFR-2010-title3-vol1/pdf/CFR-2010-title3-vol1-eo13508.pdf (accessed 30 July 2022)

Gedan KB, Kellogg L, Breitburg DL (2014) Accounting for multiple foundation species in oyster reef restoration benefits. Restor Ecol 22:517-524

Grabowski JH, Brumbaugh RD, Conrad RF, Keeler AG, Opaluch JJ, Peterson CH, Piehler MF, Powers SP, Smyth AR (2012) Economic valuation of ecosystem services provided by oyster reefs. Bioscience 62:900-909

Grizzle RE, Rasmussen A, Martignette AJ, Ward K, Coen LD (2018) Mapping seston depletion over an intertidal eastern oyster (*Crassostrea virginica*) reef: implications for restoration of multiple habitats. Estuar Coast Shelf Sci 212:265-272

Hoellein TJ, Zarnoch CB, Grizzle RE (2015) Eastern oyster (*Crassostrea virginica*) filtration, biodeposition, and sediment nitrogen cycling at two oyster reefs with contrasting water quality in Great Bay Estuary (New Hampshire, USA). Biogeochemistry 122:113–129

Humphries AT, Ayvazian SG, Carey JC, Hancock BT, Grabbert S, Cobb D, Strobel CJ, Fulweiler RW (2016) Directly measured denitrification reveals oyster aquaculture and restored oyster reefs remove nitrogen at comparable high rates. Front Mar Sci 3:74

Jackson M, Owens MS, Cornwell JC, Kellogg ML (2018) Comparison of methods for determining biogeochemical fluxes from a restored oyster reef. PLOS ONE 13:e0209799

Jordan TE, Cornwell JC, Boynton WR, Anderson JT (2008) Changes in phosphorus biogeochemistry along an estuarine salinity gradient: the iron conveyer belt. Limnol Oceanogr 53:172-184

Joye SB, Smith SV, Hollibaugh JT, Paerl HW (1996) Estimating denitrification rates in estuarine sediments: a comparison of stoichiometric and aceylene based methods. Biogeochemistry 33: 197-215.

Judy C (2017) DNR repletion program: 1960-2006. https://calendarmedia.blob.core.windows.net/assets/e61edb86-33d6-41b8-819b-d06124f5e77c.pdf (accessed 30 July 2022)

Kellogg ML, Cornwell JC, Owens MS, Paynter KT (2013) Denitrification and nutrient assimilation on a restored oyster reef. Mar Ecol Prog Ser 480:1-19

Kellogg ML, Cornwell JC, Owens MS, Luckenbach M, Ross PG, Leggett TA, Dreyer JC, Lusk B, Birch A, Smith E (2014a) Scaling ecosystem services to reef development: effects of oyster density on nitrogen removal and reef community structure. Virginia Institute of Marine Science, William & Mary. http://doi.org/10.21220/V5G013

Kellogg ML, Luckenbach M, Cornwell JC, Ross PG, Lusk B (2014b) Linking structural and functional characteristics of restored oyster reefs: a restoration project in the Virginia Coast Reserve. Virginia Institute of Marine Science, William & Mary. http://doi.org/10.21220/V5KS3Q

Kellogg ML, Smyth AR, Luckenbach MW, Carmichael RH, Brown BL, Cornwell JC, Piehler MF, Owens MS, Dalrymple DJ, Higgins CB (2014c) Use of oysters to mitigate eutrophication in coastal waters. Estuar Coast Shelf Sci 151:156-168

Knoche S, Ihde TF, Samonte G, Townsend HM, Lipton D, Lewis KA, Steinback S (2020) Estimating ecological benefits and socio-economic impacts from oyster reef restoration in the Choptank River Complex, Chesapeake Bay. NOAA Tech. Memo. NMFS-OHC-6, 68 p.

Kroeger T, Guannel G (2014) Fishery enhancement and coastal protection services provided by two restored Gulf of Mexico oyster reefs. In: K. Ninan (ed.), Valuing ecosystem services: methodological issues and case studies. Edward Elgar, Cheltenham, p. 334-357

Marenghi FP, Livings ME, Dew-Baxter J, Greenhawk K (2012) Five decades of oyster fishery enhancement strategies in upper Chesapeake Bay: effects on landings and relative abundance. J Shellfish Res 31:318

MD DNR (2016) Oyster management review: 2010-2015. https://dnr.maryland.gov/fisheries/Documents/FiveYearOysterReport.pdf (accessed 30 July 2022)

MD DNR (2022a) Citizens Working to Enhance Maryland's Oyster Reefs. https://dnr.maryland.gov/fisheries/pages/MGO/index.aspx (accessed 23 July 2022)

MD DNR (2022b) FACTS Shellfish Reporting. https://dnr.maryland.gov/fisheries/Pages/e-reporting/shellfish.aspx (accessed 23 July 2022)

MD DNR (2022c) Nanticoke River Restoration. https://dnr.maryland.gov/fisheries/Pages/oysters/nanticoke.aspx (accessed 23 July 2022)

MD DNR (2022d) Severn River Restoration Project. https://dnr.maryland.gov/fisheries/Pages/oysters/severn-river.aspx (accessed 23 July 2022)

Mo C, Neilson B (1994). Standardization of oyster soft tissue dry weight measurements. Water Resources 28: 243-246

MORIW (Maryland Oyster Restoration Interagency Workgroup) under the Chesapeake Bay Program's Sustainable Fisheries Goal Implementation Team (2022) 2021 Oyster Reef Monitoring Report: Analysis of Data from the 'Ten Tributaries' Sanctuary Oyster Restoration Initiative in Maryland

Newell RIE, Cornwell JC, Owens MS (2002) Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics. Limnol Oceanogr 47:1367–1379

Newell RIE, Koch EW (2004) Modeling seagrass density and distribution in response to changes in turbidity stemming from bivalve filtration and seagrass sediment stabilization. Estuaries 27:793-806

Newell RIE, Fisher TR, Holyoke RR, Cornwell JC (2005) Influence of eastern oysters on nitrogen and phosphorus regeneration in Chesapeake Bay, USA. In: Dame RF, Olenin S (eds) The comparative roles of suspension-feeders in ecosystems. Springer, Dordrecht, p 93-120

NOAA (National Oceanic and Atmospheric Administration) (2016) Analysis of monitoring data from Harris Creek Sanctuary oyster reefs: data on the first 102 acres/12 reefs restored. https://dnr.maryland.gov/fisheries/documents/2015_oyster_monitoring_report.pdf (accessed 22 Nov 2022)

NOAA (2017) 2016 Oyster reef monitoring report: analysis of data from large-scale sanctuary oyster restoration projects in Maryland. https://www.chesapeakebay.net/what/publications/2016-oyster-reef-monitoring-report (accessed 22 Nov 2022)

O'Keefe JA (2007) Sediment biogeochemistry across the Patuxent River estuarine gradient: geochronology and Fe-S-P interactions. MS Thesis, University of Maryland, College Park, MD

Onorevole KM, Thompson SP, Piehler MF (2018) Living shorelines enhance nitrogen removal capacity over time. Ecol Eng 120:238-248

ORIW (Maryland and Virginia Oyster Restoration Interagency Workgroups) (2022) 2021 Chesapeake Bay oyster restoration update: progress toward the Chesapeake Bay Watershed Agreement's 'Ten Tributaries by 2025' oyster outcome. https://www.chesapeakebay.net/documents/2021_Chesapeake_Bay_Oyster_Restoration_Update_FINAL.pdf (accessed 30 July 2022)

ORP (Oyster Recovery Partnership) (2015) The Oyster BMP Expert Panel scope of work and panel membership recommendations. https://www.chesapeakebay.net/channel_files/23104/oyster_bmp_expert_panel_charge_final_9-14-15.pdf (accessed 30 July 2022)

ORP (2021) Public fishery plantings: supporting the public oyster fishery. https://oysterrecovery.org/public-fishery-plantings (accessed 23 July 2022)

Orth RJ, Carruthers TJ, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes GA, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, and Williams SL (2006) A global crisis for seagrass ecosystems. Bioscience 56: 987-996

Oyster Metrics Workgroup (2011) Restoration goals, quantitative metrics and assessment protocols for evaluating success on restored oyster reef sanctuaries. http://www.chesapeakebay.net/channel_files/17932/oyster_restoration_success_metrics_final.pdf (accessed 30 July 2022)

Paynter K, Lane H, Michaelis A (2012) Paynter Lab annual summary 2011. https://www.oyster.umd.edu/s/Paynter-Lab-ORP-Annual-Report-2011_Revised3-12-13.pdf (accessed 30 July 2022)

Paynter K, Lane H, Michaelis A (2013) Paynter Lab annual monitoring and research summary 2012. https://www.oyster.umd.edu/s/2012-Paynter-Lab-Annual-Report-to-the-ORP.pdf (accessed 30 July 2022)

Paynter K, Michaelis A, Handschy A (2014) Paynter Lab annual monitoring and research summary 2013. https://www.oyster.umd.edu/s/2012-Paynter-Lab-Annual-Report-to-the-ORP.pdf (accessed 30 July 2022)

Piehler MF, Smyth AR (2011) Habitat-specific distinctions in estuarine denitrification affect both ecosystem function and services. Ecosphere 2:1-17

Plutchak R, Major K, Cebrian J, Foster CD, Miller MC, Anton A, Sheehan KL, Heck KL Jr, Powers SP (2010) Impacts of oyster reef restoration on primary productivity and nutrient dynamics in tidal creeks of the North Central Gulf of Mexico. Estuar Coasts 33:1355-1364

Powers SP, Peterson CH, Grabowski JH, Lenihan HS (2009) Success of constructed oyster reefs in no-harvest sanctuaries: implications for restoration. Mar Ecol Prog Ser 389:159-170

Rawson PD, Lindell S, Guo X, Sunila I (2010) Cross-breeding for improved growth and disease resistance in the eastern oyster. NRAC Publication No. 206-2010

Reichert-Nguyen J, Cornwell J, Rose J, Kellogg L, Luckenbach M, Bricker S, Paynter K, Moore C, Parker M, Sanford L, Wolinski B, Lacatell A, Fegley L, Hudson K, French E, Slacum W (2016) 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. https://www.oysterrecovery.org/wp-content/uploads/2017/01/Oyster-BMP-1st-Report_Final_Approved_2016-12-19.pdf (accessed 30 July 2022)

Rodney WS, Paynter KT (2006) Comparisons of macrofaunal assemblages on restored and non-restored oyster reefs in mesohaline regions of Chesapeake Bay in Maryland. J Exp Mar Biol Ecol 335:39-51

Scyphers SB, Powers SP, Heck KL Jr, Byron D (2011) Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. PLOS ONE 6:e22396

Seitzinger SP, Nielsen LP, Caffrey J, Christensen PB (1993) Denitrification measurements in aquatic sediments: A comparison of three methods. Biogeochemistry 23:147-167

Sisson M, Kellogg ML, Luckenbach M, Lipcius RN, Colden A, Cornwell J, Owens MS (2011) Assessment of oyster reefs in Lynnhaven River as a Chesapeake Bay TMDL best management practice. Special Reports in Applied Marine Science and Ocean Engineering (SRAMSOE) No. 429. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.21220/V52R0K

Slacum, HW Jr., Dew-Baxter J, Corbin R, Richkus B (2013) Pilot Project to Test and Evaluate Rapid and Accountable Commercial Blue Crab Reporting in Maryland. Prepared for the Blue Crab Industry Design Team and MD DNR. Versar, Inc. 9200 Rumsey Rd., Columbia, MD. 20145

Smyth AR, Thompson SP, Siporin KN, Gardner WS, McCarthy MJ, Piehler MF (2013) Assessing nitrogen dynamics throughout the estuarine landscape. Estuar Coasts 36:44-55

Smyth AR, Piehler MF, Grabowski JH (2015) Habitat context influences nitrogen removal by restored oyster reefs. J Appl Ecol 52:716-725

Smyth AR, Geraldi NR, Thompson SP, Piehler MF (2016) Biological activity exceeds biogenic structure in influencing sediment nitrogen cycling in experimental oyster reefs. Mar Ecol Prog Ser 560:173-183

Smyth AR, Murphy AE, Anderson IC, Song B (2018) Differential effects of bivalves on sediment nitrogen cycling in a shallow coastal bay. Estuar Coasts 41: 1147-1163

Stricklin AG, Peterson MS, Lopez JD, May CA, Mohrman CF, Woodrey MS (2010) Do small, patchy constructed intertidal oyster reefs reduce salt marsh erosion as well as natural reefs? Gulf Caribb Res 22:21−27

Tolley SG, Volety AK (2005) The role of oysters in habitat use of oyster reefs by resident fishes and decapod crustaceans. J Shellfish Res 24:1007−1012

VIMS (Virginia Institute of Marine Science) (2022) Virginia oyster stock assessment and replenishment archive (VOSARA). http://cmap2.vims.edu/VOSARA/viewer/VOSARA.html (accessed 23 July 2022)

Virginia Administrative Code. Conservation and Natural Resources. Marine Resources Commission. Establishment of Oyster Sanctuary Areas. Purpose. 4VAC20-650-10. https://law.lis.virginia.gov/admincode/title4/agency20/chapter650/section10 (accessed 29 July 2022)

Virginia Administrative Code. Conservation and Natural Resources. Marine Resources Commission. Pertaining to Designation of Seed Areas and Clean Cull Areas. Purpose. 4VAC20-260-10. https://law.lis.virginia.gov/admincode/title4/agency20/chapter260/section10 (accessed 29 July 2022)

Virginia Administrative Code. Conservation and Natural Resources. Marine Resources Commission. Pertaining to Designation of Seed Areas and Clean Cull Areas. Minimum cull size. 4VAC20-260-30. https://law.lis.virginia.gov/pdf/admincode/4/20/260/30 (accessed 29 July 2022)

VMRC (Virginia Marine Resources Commission) (2021) Conservation and replenishment department. https://mrc.virginia.gov/replenishment.shtm (accessed 30 July 2022)

Westbrook P, Heffner L, La Peyre MK (2019) Measuring carbon and nitrogen bioassimilation, burial, and denitrification contributions of oyster reefs in Gulf coast estuaries. Mar Biol 166:1–14

Appendix A. Summary of Oyster BMP Expert Panel Activities

A.1 External Updates and Activities

A summary of external BMP Panel activities with relevant stakeholders is listed below. All updates to the CBP Goal Implementation Teams (GITs) were also made available to stakeholders and other interested parties.

April 4, 2017 – Oyster BMP Presentation, Interstate Seafood Seminar, Harrisburg, PA

May 8, 2017 – Water Quality GIT (WQGIT): The Panel provided an update on BMP report progress and sought feedback on draft recommendations. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/water-quality-goal-team-conference-call-may-8th-2017

May 22, 2017 – The Panel hosted an open meeting to solicit feedback on draft recommendations. *Meeting materials and summary of discussion:* https://www.chesapeakebay.net/what/event/oyster-bmp-expert-panel-open-feedback-meeting

November 5-9, 2017 – Oyster BMP presentation(s), Coastal and Estuarine Research Federation biennial meeting, Providence, RI

November 27, 2017 – WQGIT: The Panel provided an update on draft recommendations in this report. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/water-quality-goal-implementation-team-november-27-conference-call

December 18, 2017 – Fisheries GIT: The Panel provided an update on draft recommendations in this report. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/december-2017-full-sustainable-fisheries-git-meeting

December 20, 2017 – CBP Trading and Offsets Workgroup: The Panel provided an update on the BMP report status and recommendations. *Meeting materials:* https://www.chesapeakebay.net/what/event/trading-and-offsets-workgroup-conference-call-december-2017

February 1, 2018 – CBP Partnership: The Panel provided a written update summarizing the oyster practice-protocol combinations that are covered in this report. *Update:* https://oysterrecovery.org/wp-content/uploads/2015/10/Update-on-Oyster-BMP-Expert-Panel-2nd-Report_2-1-18_Final.pdf

February 23, 2018 – Citizen Advisory Committee: The Panel provided an overview of report structure and an update on draft recommendations in this report. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/citizens-advisory-committee-quarterly-meeting-february-2018

March 29, 2018 – Oyster BMP presentation, Interstate Seafood Seminar, Rehoboth Beach, DE

June 27, 2018 – Panel members met with EPA to discuss how the licensed oyster harvest using hatchery produced oysters practice would qualify as a BMP.

July 24, 2018 – Oyster BMP presentation, Mussel Restoration Discussion and Luncheon hosted by Chesapeake Bay Foundation & VCU Rice Rivers Center, Charles City, VA

December 18, 2018 – Fisheries GIT: The Panel presented an update on draft recommendations in this report. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/sustainable-fisheries-december-2018-biannual-full-git-meeting

July 8, 2019 – WQGIT: The Panel presented an update on draft recommendations in this report. The Panel also discussed draft recommendations to be used for watershed management planning scenarios while the Panel's recommendations are still being developed.
Meeting materials and presentation: https://www.chesapeakebay.net/what/event/water-quality-goal-implementation-team-conference-call-july-8-2019

January 8, 2020 – Fisheries GIT: The Panel provided an update on BMP report status. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/winter-2019-2020-sustainable-fisheries-git-biannual-meeting

March 5-6, 2020 –CBP Scientific and Technical Advisory Committee, Incorporating Freshwater Mussels in the Chesapeake Bay Partnership Workshop, Annapolis, MD: The Panel discussed components of the oyster BMP that could be considered for freshwater mussels. *Meeting materials:* https://www.chesapeake.org/stac/events/incorporating-freshwater-mussels-in-the-chesapeake-bay-partnership/

May 1, 2020 – Oyster BMP denitrification data presentation, Choose Clean Water Coalition webinar, virtual

April 25, 2022 – WQGIT: The Panel gave a brief verbal update on the BMP report status. *Meeting materials:* https://www.chesapeakebay.net/what/event/water-quality-goal-implementation-team-conference-call-april-25-2022

July 21, 2022 – Fisheries GIT: The Panel presented an updated on report status and an overview of the draft oyster BMP recommendations. *Meeting materials and presentation:* https://www.chesapeakebay.net/what/event/fisheries-git-summer-meeting-july-2022

October 26, 2022 – Oyster BMP presentation, CBF Oyster Alliance Steering Committee meeting, virtual.

February 7 & 14, 2023 – Public webinars to describe the Panel's recommendations in this report during the open comment and feedback period. Webinars will include Q&A.

Report and Webinar 1: https://www.chesapeakebay.net/what/event/oyster-bmp-expert-panel-recommendation-roll-out-webinar-part-1-oyster-reef-enhanced-denitrification-protocols
Webinar 2: https://www.chesapeakebay.net/what/event/oyster-bmp-expert-panel-recommendation-roll-out-webinar-part-2-oyster-assimilation-protocol

A.2 Panel Meetings

The Panel met on the following dates to discuss items described in this report. Both in-person and remote attendance options were available. Meetings were 2 hours unless stated otherwise. Panel meeting minutes are listed in Appendix L. During the COVID-19 pandemic, most Panel discussion was conducted via email. Periods of significant email discussion are also listed below.

December 8, 2016 – The Panel discussed how to calculate reduction estimates for the shell assimilation protocols

January 19, 2017 – The Panel discussed how to calculate reduction estimates for the denitrification protocol

February 16, 2017 – The Panel discussed how to calculate reduction estimates for the denitrification protocol

March 16, 2017 – The Panel reviewed the denitrification literature and discussed shell dissolution considerations for the shell assimilation protocols

April 20, 2017 – The Panel outlined materials on denitrification and shell assimilation protocols for the May 8, 2017 WQGIT update

May 18, 2017 – The Panel finalized the logistics and content for the May 22, 2017 open feedback meeting

May 22, 2017 (*closed session, 1.5 hrs*) – The Panel reviewed feedback from the open May 22, 20217 meeting

June 15, 2017 – The Panel discussed and defined the oyster practices included in this report

August 17, 2017 – The Panel discussed and defined oyster practices in this report, reviewed new data relevant to the denitrification and shell assimilation protocols

September 19, 2017 – The Panel discussed how to calculate reduction estimates for multiple oyster practice-protocol combinations in this report

October 19, 2017 – The Panel reviewed draft denitrification text and discussed which oyster practices should be recommended for BMP consideration

November 16, 2017 – The Panel discussed how to calculate reduction estimates for multiple oyster practice-protocol combinations in this report

January 4, 2018 – The Panel discussed how to calculate reduction estimates for the denitrification protocol, and which oyster practices to recommend for BMP consideration

January 18, 2018 – The Panel reached consensus on practice-protocol practices to be included in this report, and discussed how to calculate reduction estimates for the denitrification and assimilation protocols

February 15, 2018 – The Panel discussed how to verify nutrient reduction associated with restoration-assimilation and restoration-denitrification protocols

March 15, 2018 – The Panel discussed how to verify nutrient reduction associated with restoration-assimilation and restoration-denitrification protocols

May 17, 2018 – The Panel continued to develop recommendations for practice-protocol combinations in this report

June 8, 2018 – The Panel continued to develop recommendations for practice-protocol combinations in this report

June 28, 2018 – The Panel continued to develop recommendations for practice-protocol combinations in this report

August 16, 2018 – The Panel continued to develop recommendations for practice-protocol combinations in this report

October 18, 2018 – The Panel continued to develop recommendations for practice-protocol combinations in this report

November 7, 2018 (*1 hr*) – The Panel reviewed definitions and recommendations for the harvest-assimilation protocols

April 18, 2019 (*3 hrs*) – The Panel reviewed technical applications for the proposed recommendations and discussed revisions to the report

May 10, 2019 (*3 hrs*) – The Panel discussed revisions to the report related to the harvest- and restoration-assimilation protocols

June 21, 2019 (*2.5 hrs*) – The Panel continued to develop recommendations for practice-protocol combinations in this report

July 24, 2019 (*2.5 hrs*) – The Panel continued to develop recommendations for practice-protocol combinations in this report

September 5, 2019 (*2.5 hrs*) – The Panel discussed revisions to the denitrification protocol recommendations

July 29, 2020 (*2.5 hrs*) – The Panel reviewed recommendations for the denitrification protocol

October 2020 (*email*) – The Panel refined recommendations for the denitrification protocol (created lookup tables, Appendix G)

June-July 2021 (*email*) – The Panel reviewed recommendations and draft chapters for the restoration-denitrification and restoration-assimilation protocols

December 15, 2021 (*3 hrs*) – The Panel discussed revisions to the draft recommendations and reviewed new data relevant to the denitrification protocol

January 2022 (*email*) – The Panel revised the restoration-denitrification and restoration-assimilation protocols (focus: baseline approaches)

May 2021 (*email*) – The Panel refined terms and definitions in this report and refined the restoration-assimilation and restoration-denitrification qualifying conditions (focus: substrate categories)

July 2022 (*email*) – The Panel refined recommendations for the harvest-assimilation protocols (focus: default spat survival rate)

October 6, 2022 – The Panel reviewed final major report revisions and approved the report

April 2023 (*email*) – The Panel discussed major comments from the stakeholder review period and reached consensus on how to address these in the final report.

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 chapters within the report where the Panel addressed the requested protocol criteria.

1. **Identity and expertise of panel members:** Subchapter 3.1

2. **Practice name or title:** Chapter 1.0

The Panel is recommending three oyster practices and 5 oyster protocols (12 total practice-protocol combinations) for BMP consideration. These fall into three BMP categories:

- <u>Harvest-Assimilation:</u> Nitrogen and phosphorus assimilation in tissue of live oysters (**Protocols 1 & 4**) from endorsed licensed harvest using hatchery-produced oysters (**Practice F**).
- <u>Restoration-Assimilation:</u> Nitrogen and phosphorus assimilation in tissue (**Protocols 1 & 4**) and shell (**Protocols 2 & 5**) of live oysters from oyster reefs restored using hatchery produced oysters (**Practice J**) and substrate addition (**Practice K**).
- <u>Restoration-Denitrification:</u> Enhanced denitrification associated with oysters (**Protocol 3**) from oyster reefs restored using hatchery produced oysters (**Practice J**) and substrate addition (**Practice K**).

3. **Detailed definition of the practices:**

   Practice F. Licensed oyster harvest using hatchery produced oysters: Subchapter 5.2

   Practice J. Oyster reef restoration using hatchery produced oysters: Subchapter 5.3

   Practice K. Oyster reef restoration using substrate addition: Subchapter 5.3

4. **Recommended reduction effectiveness estimates for each practice:**

   Harvest-Assimilation: Subchapter 6.3

   Restoration-Assimilation: Subchapter 7.3

   Restoration-Denitrification: Subchapter 8.3, Appendix G

5. **Justification of selected effectiveness estimates:**

   Harvest-Assimilation: Subchapter 6.2, Appendix D

   Restoration-Assimilation: Subchapter 7.2, Appendix E

   Restoration-Denitrification: Subchapter 8.2, Appendix E, Appendix F

6. **List of references used:** Chapter 11.0

7. **Detailed discussion on how each reference was considered:**

   Harvest-Assimilation: First report, Subchapter 6.1, Appendix H

   Restoration-Assimilation: Subchapter 7.1, Appendix E

   Restoration-Denitrification: Subchapter 8.1, Appendix E, Appendix F, Appendix I

8. **Land uses to which BMP is applied**: Not applicable. This is a tidal in-water BMP. The Phase 6 Model estimates nutrient loads in shoreline segments that can be reduced by shoreline and tidal water practices. Credit for the pounds of nutrients reduced by the oyster practices will go to the shoreline segments closest to the practice location. If geographic coordinates are not submitted, then the credit will be distributed amongst all shoreline segments in the reported geographic area (Appendix K).

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. Instead, reduction credit will go toward total nonpoint source load allocation.

10. **Description of pre-BMP and post-BMP circumstances and individual practice baseline:**
    Harvest-Assimilation: Subchapter 6.4
    Restoration-Assimilation: Subchapter 7.4
    Restoration-Denitrification: Subchapter 8.4

11. **Conditions under which the BMP works/does not work:**
    Harvest-assimilation: Subchapter 6.2.2, Subchapter 6.5
    Restoration-assimilation: Subchapter 7.2.2, Subchapter 7.5
    Restoration-denitrification: Subchapter 8.2.2, Subchapter 8.5

12. **Temporal performance of BMP including lag times between establishment and full functioning:**
    Harvest-assimilation: Subchapter 6.2.4, Subchapter 6.4
    Restoration-assimilation: Subchapter 7.2.7, Subchapter 7.4
    Restoration-denitrification: Subchapter 8.2.8, Subchapter 8.4

13. **Unit of measure:** Pounds of nitrogen and/or phosphorus removed

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

15. **Useful life of the BMP:**
    Harvest-assimilation: 5 years after enhancement (Subchapter 6.2.4)
    Restoration-assimilation: lifetime of BMP site, as long as biomass is accumulating (Subchapter 7.2.7)
    Restoration-denitrification: lifetime of BMP site (Subchapter 8.2.8)

16. **Cumulative or annual practice:**
    Harvest-assimilation: Annual (Subchapter 6.2.4)
    Restoration-assimilation: Annual (Subchapter 7.2.7)
    Restoration-denitrification: Annual (Subchapter 8.2.8)

17. **Description of how BMP will be tracked and reported:**
    Harvest-assimilation: Subchapter 6.6
    Restoration-assimilation: Subchapter 7.6
    Restoration-denitrification: Subchapter 8.6

18. **Ancillary benefits, unintended consequences, double counting:**
    Harvest-assimilation: Subchapter 6.7, Subchapter 6.8
    Restoration-assimilation: Subchapter 7.7, Subchapter 7.8, Chapter 9.0
    Restoration-denitrification: Subchapter 8.7, Subchapter 8.8, Chapter 9.0

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. EPA Legal Opinion

Recognizing Pollutant Reductions via In-situ Oyster Filtration Under the Clean Water Act

The Chesapeake Bay Program Partnership's (Partnership) Oyster BMP Expert Panel posed the question "Can in-situ, permanent removal of sediment, nitrogen, and phosphorus pollutants from the estuarine water column via oyster filtration be recognized and credited as pollutant removal under the Clean Water Act?". The U.S. Environmental Protection Agency[1] (EPA) prepared the following response to this specific question.

The use of term "credited" in this context is assumed by EPA to mean the acceptance of a certain best management practice (BMP), treatment or technology to count toward achievement of a Chesapeake Bay watershed jurisdiction's pollutant reduction goals based on application through the Chesapeake Bay Program Partnership's suite of modeling tools. The use of term "credited" was not assumed by EPA to refer to water quality offsets or trading.

EPA recognizes that the Oyster BMP Expert Panel has concluded in its first report, approved by the Partnership in December 2016, and will possibly further conclude in forthcoming panel reports, that there is scientific and technical support for in-situ oyster filtration, in the form of aquaculture or oyster reef restoration, as a Partnership-approved BMP that results in the permanent removal of pollutants—nitrogen, phosphorus, and sediment—from the water column. EPA further assumed that this involves native oyster species only and does not contemplate introduction of non-native oyster species.

Having established those assumptions, EPA sees nothing in the Clean Water Act or its implementing regulations that would prevent a Partnership-approved BMP from qualifying for nitrogen, phosphorus or sediment pollutant reductions simply because it is physically located within the water column instead of outside the water column. EPA notes that there are at least a few existing examples of in-situ BMPs that have been documented as achieving water quality improvements through pollutant reductions and are recognized as accepted BMPs. These BMPs include the floating wetland BMP already approved by the Partnership[2], as well as the Anacostia River Trash Trap Program and Baltimore Water Wheel Trash Interceptor, both of which are described in EPA's December 2016 Aquatic Trash Prevention National Great Practices Compendium[3]. All of these BMPs are physically located within the water body and are recognized as achieving pollutant reductions.

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[1] Prepared by the U.S. Environmental Protection Agency Region 3's Office of Regional Counsel and Chesapeake Bay Program Office, in consultation with the Agency's Office of General Counsel, and provided to the Chesapeake Bay Program Partnership's Oyster BMP Expert Panel on January 4, 2018.

[2] https://www.chesapeakebay.net/who/group/bmp_expert_panels

[3] https://www.epa.gov/sites/production/files/2017-02/documents/aquatic_trash_prevention_national_great_practices_compendium_december_2016.pdf

Appendix D. Calculation of a Default Spat Survival Rate for Harvest-Assimilation Protocols (Ch 6)

Oyster enhancement activities for harvest-assimilation protocols occur in areas that likely have pre-existing oyster populations. Therefore, the Panel concluded it was necessary to try to prevent crediting oysters that are unlikely to have resulted from the enhancement activity. The Panel's first step was to determine a maximum harvest allowance based on the number of hatchery-produced oysters planted and a survival rate from time of planting to time of harvest (see Subchapter 6.2.3). The Panel generated a default survival rate using a subset of oyster reef restoration monitoring data collected from Harris Creek, MD three years after planting (NOAA 2016, 2017). These data were deemed suitable because:

- Monitoring data came from areas in Maryland relatively close to where licensed oyster harvest using hatchery produced oysters currently occurs
- The materials and methods used for restoration in the subset of data analyzed were similar to the materials and methods commonly used for licensed oyster harvest using hatchery produced oysters
- Monitoring data were collected three years after planting. Harvest from areas supplemented with hatchery produced oysters typically occurs two to three years after planting. Use of a spat survivorship from three years after planting should lead to a relatively conservative survival estimate, thereby preventing over-crediting.

The subset of data used to calculate spat survivorship were selected following these criteria:

- Reefs must have been treated with spat on shell only (hatchery produced oysters)
- Data were only eligible for analysis if they were from 3 years after planting

Using these criteria, the Panel selected a total of 15 reefs for analysis that were planted in 2012 and monitored in 2015 and planted in 2013 and monitored in 2016 (Table D-1).

Since it can take two to three years for oysters to grow to harvest size, it is unlikely that monitored oysters in the 'spat' size class had originated from the planted hatchery-produced oysters. To account for this, the Panel used the percent spat reported at monitoring to estimate an adult oyster density (Table D-1). The percent spat was multiplied by oyster density, and then the resulting value was subtracted from oyster density for each reef.

The spat survival rate from planting to harvest size was calculated by dividing the density of adult oysters by the density of planted oysters (which was first converted to spat m^{-2} by multiplying by 4046.86 m^2 per acre) (Table D-1). Spat survival was then weighted to account for the acreage of each reef. Survival was multiplied by reef area to estimate the resulting area over which oysters had survived from planting to 3 years (Table D-1, % Survival x Area). The resulting areas were summed and divided by the 122.25 total acres that were planted with spat on shell.

Oyster survival from planting of spat on shell to three years ranged from 0.07% to 4.49% with an average of 2.58% (Table D-1). Weighting of data to account for the acreage of each reef resulted in a weighted average survivorship of 2.91%.

Table D-1 Planting and 3-year post-planting data from a subset of restored oyster reefs in Harris Creek, MD that were used to calculate a default spat survival rate. Text highlighted in gray was calculated by the Panel. Unhighlighted text was reported in NOAA (2016, 2017). Proportion spat (%) is the percent of the sampled oysters that were < 40 mm shell height. Adult oyster density is the density of oysters minus the density of spat. % Survival x area was used to calculate a weighted average survival rate based on reef area.

Reported Reef ID	Restoration Type	Year Planted	Year Monitored	Area (acres)	Reported spat planted (mil.)	Planted spat density (mil. acre^{-1})	Planted spat density (m^{-2})	Reported oyster density (m^{-2})	Proportion spat (%)	Adult oyster density (m^{-2})	Survival rate (%)	% Survival x Area (acres)
Reef 03	Spat on shell only	2012	2015	6.56	29.50	4.49	1,111	32.86	7	30.56	2.75	0.18
Reef 04	Spat on shell only	2012	2015	11.24	44.30	3.94	974	38.96	13	33.90	3.48	0.39
Reef 05	Spat on shell only	2012	2015	15.65	62.24	3.98	983	47.15	12	41.49	4.22	0.66
Reef 07	Spat on shell only	2012	2015	10.95	50.06	4.57	1,130	29.95	5	28.45	2.52	0.28
Reef 08	Spat on shell only	2012	2015	7.34	48.65	6.63	1,639	24.11	6	22.66	1.38	0.10
Reef 09	Spat on shell only	2012	2015	12.29	47.23	3.84	950	32.18	11	28.64	3.02	0.37
Reef 10	Spat on shell only	2012	2015	10.88	52.09	4.79	1,183	58.10	12	51.13	4.32	0.47
Reef 11	Spat on shell only	2012	2015	6.53	28.19	4.32	1,067	20.39	6	19.17	1.80	0.12
Reef 12	Spat on shell only	2012	2015	7.83	31.10	3.97	981	16.53	3	16.03	1.63	0.13
Reef H42	Spat on shell only	2013	2016	5.63	49.58	8.80	2,175	41.84	6	39.33	1.81	0.10
Reef H43	Spat on shell only	2013	2016	4.52	19.10	4.22	1,044	43.34	15	36.84	3.53	0.16
Reef H44	Spat on shell only	2013	2016	2.58	16.42	6.35	1,570	43.09	29	30.59	1.95	0.05
Reef H45	Spat on shell only	2013	2016	3.08	52.51	17.03	4,207	3.04	4	3.00	0.07	0.002
Reef H46	Spat on shell only	2013	2016	7.95	46.00	5.79	1,431	25.06	19	24.23	1.69	0.13
Reef H47	Spat on shell only	2013	2016	9.21	40.85	4.44	1,097	50.88	14	49.23	4.49	0.41

Average survival rate	***2.58%***
Average survival rate weighted by reef area	***2.91%***

D.1 References

NOAA (National Oceanic and Atmospheric Administration) (2016) Analysis of monitoring data from Harris Creek Sanctuary oyster reefs: data on the first 102 acres/12 reefs restored. https://dnr.maryland.gov/fisheries/documents/2015_oyster_monitoring_report.pdf (accessed 30 July 2022)

NOAA (2017) 2016 Oyster reef monitoring report: analysis of data from large-scale sanctuary oyster restoration projects in Maryland. https://www.chesapeakebay.net/what/publications/2016-oyster-reef-monitoring-report (accessed 22 Nov 2022)

Appendix E. Supporting Literature Review and Data Analyses for the Restoration-Assimilation (Ch 7) and Restoration-Denitrification (Ch 8) Protocols

This appendix provides details on (1) the percent nitrogen and phosphorus content in oyster biomass and (2) the Panel's default 50th quantile regression equations for estimating oyster biomass. The default equations convert oyster shell height to tissue and shell dry weight, and should be used for cases specified in Chapters 7 and 8 to determine the reduction effectiveness of the restoration-assimilation and restoration-denitrification protocols (Table E-1).

Table E-1. Percent N and P content and the Panel's recommended default quantile regression equations for the restoration-assimilation and restoration-denitrification protocols.

Parameter	Percent N	Percent P	0.50 Quantile Regression Equation
Tissue	8.2	0.9	$y = 0.00037x^{1.83359}$
Shell	0.2	0.04	$y = 0.00147x^{2.3964}$

E.1 Percent Nitrogen and Phosphorus Content

The Panel reviewed the existing scientific literature to estimate the content of nitrogen and phosphorus in oyster tissue and shell as a percentage of dry weight. A review of the data for oyster tissue is described in the Panel's first report (Reichert-Nguyen et al. 2016).

The data reviewed for oyster shell were for *Crassostrea virginica* in the Chesapeake Bay, Mid-Atlantic, and Northeast US (Table E-2, E-3). All data were for diploid oysters, except for Reitsma et al. (2017), which included measurements for both diploid and triploid oysters. When not specified, data were assumed to be for diploid oysters.

Based on the data reviewed from the sources in Table E-2, the Panel recommends a mean nitrogen content in oyster shell of 0.2%. Based on the data reviewed from the sources in Table E-3, the Panel recommends a mean phosphorus content in oyster shell of 0.04%.

Table E-2. Nitrogen content of shell as a percentage of dry weight. SH = Shell Height, N = number of oysters sampled.

Source	Oyster Information	Location(s)	% Nitrogen mean	% Nitrogen Range	N	% Nitrogen Mean for BMP Use
Grizzle et al. 2016	Cages 10 cm off bottom using hatchery-produced oysters Initial SH of "small" oysters = 19-42 mm (0.3 years old) 1-yr olds = 200 individuals Sampling Period: August 2010-November 2012	Adams Point, Great Bay, NH (AP)	0.10	0.03 - 0.24	10	0.11
		Bellamy River, Great Bay, NH (BMY)	0.11	0.05-0.16	4	
		Oyster River, Great Bay, NHG (GSS)	0.09	0.06-0.14	10	
		Little Bay, Great Bay, NH (LBO)	0.08	0.02-0.18	10	
		Nannie Island, Great Bay, NH (NI)	0.14[a]	0.04-0.14	10	
		Squamscott River, Great Bay, NH (SQR)	0.14[a]	0.09-0.23	10	
Higgins et al. 2011	Off bottom floating aquaculture cages using hatchery-produced diploid oysters Mean SH=~32-128mm (from raw data) Sampling Period: November 2006, August 2007 to October 2009	Spencer's Creek, VA Salinity=5-15 Low flow, high sedimentation	0.20 ± 0.01SE	0.11-0.39	47	0.20
Higgins et al. 2011	Off bottom floating aquaculture cages using hatchery-produced diploid oysters SH=~57-158mm (from raw data) Sampling Period: May-July 2007 to October 2009	St. Jerome Creek, MD Salinity=12-15 High flow, low sedimentation	0.20 ± 0.02SE	0.11-0.48	37	0.20
Kellogg et al. 2013	On bottom hatchery-produced diploid oysters (restored subtidal oyster reef) Mean SH=144mm Sampling Period: October 2009-August 2010	Choptank River, MD Salinity=7.0-11.6	0.21 ± 0.08SD	0.16-0.30	16[b]	0.21
Reitsma et al. 2017	Wild on bottom diploid oysters; Mean SH=82.7mm; represents 4 sites Sampling Period: June 2012, October 2012	Cape Cod, MA (12 sites; see Table 1 in study)[c]	0.26	Spring: 0.23-0.40 Fall: 0.15-0.29	32	0.26
Reitsma et al. 2017	Cultured on bottom using hatchery-produced diploid oysters Mean SH=84.9mm; represents 6 sites Sampling Period: June 2012, October 2012	Cape Cod, MA (12 sites; see Table 1 in study)[c]	0.26	Spring: 0.15-0.45 Fall: 0.15-0.33	48	
Reitsma et al. 2017	Cultured off bottom using hatchery-produced diploid oysters Mean SH=83.1mm; represents 9 sites Sampling Period: June 2012, October 2012	Cape Cod, MA (12 sites; see Table 1 in study)[c]	0.21	Spring: 0.12-0.33 Fall: 0.14-0.37	64	

Table E-2 (continued). Nitrogen content of shell as a percentage of dry weight. SH = Shell Height, N = number of oysters sampled.

Reitsma et al. 2017 (continued)	Cultured off bottom using hatchery-produced triploid oysters Mean SH=86.5 mm; represents one site and age of oysters likely much younger: fall triploid samples were ~6 months versus rest of oysters that were 1+ years in age)	Cape Cod, MA (12 sites; see Table 1 in study)[c]	0.32	N/A	8	0.26
Sebastiano et al. 2015[d]	Off bottom cages using hatchery-produced oysters (1 m depth) Mean SH Range=65-82mm Sampling Period: July, August, and October 2010 and 2011	Jamaica Bay, NY	0.20 ± 0.07SE	N/A	10	0.2
		Great South Bay, NY	0.19 ± 0.07SE	N/A	10	
					Average for BMP	**0.2**

[a]Grizzle et al. 2016 Fig. 10 refers to data from November 2012 and sample sizes in Table 1. To match sample size, the Panel also included Jan 2013 data sent by Grizzle used to derive graph (n = 29 small, 25 large); numbers look slightly off (NI and SQR both equal 0.14% instead of SQR having a higher percent).
[b]Three samples composed of 4-6 individuals
[c]Reitsma et al. 2017 included several sites within and near Cape Cod: Cape Cod Bay (n=3 sites), Atlantic Ocean (n=2 sites), Nantucket Sound (n=4 sites), and Buzzards Bay (n=3 sites); % N content data was aggregated based on culture method.
[d]Three sites were sampled within each bay, but results in Table 1 & 2 aggregated data by bay.

Table E-3. Phosphorus content of shell as a percentage of dry weight. SH = Shell Height, N = number of oysters sampled.

Source	Oyster Information	Location(s)	% Phosphorus Mean (Study)	% Phosphorus Range	N	% Phosphorus Mean for BMP Use
Higgins et al. (2011)	Off bottom floating aquaculture cages using hatchery-produced diploid oysters Mean SH=~32-128 mm (from raw data) Sampling Period: November 2006, August 2007 to October 2009	Spencer's Creek, VA Salinity = 5-15 Low flow, high sedimentation	0.04 ± 0.00	0.03-0.05	47	0.04
	Off bottom floating aquaculture cages using hatchery-produced diploid oysters SH=~57-150 mm (from raw data) Sampling Period: May - July 2007 to October 2009	St. Jerome Creek, MD Salinity = 12-15 High flow, low sedimentation	0.04 ± 0.00	0.03-0.05	37	0.04
Kellogg et al. (2013)	On bottom hatchery-produced diploid oysters (restored subtidal oyster reef) Mean SH=114mm Sampling Period: October 2009-August 2010	Choptank River, MD Salinity = 7.0 - 11.6	0.04 ± 0.01	N/A	16[a]	0.04
					Average for BMP	**0.04**

[a]Three samples composed of 4-6 individuals

E.2 Quantile Regression Analyses

The quantile regression approach was used to establish regression equations to convert measured oyster shell heights to oyster tissue and shell dry weights for BMP use. The Panel established a positive relationship between oyster shell height and tissue dry weight in their first report (Reichert-Nguyen et al. 2016) and Higgins et al. (2011) established a positive relationship between oyster shell height and shell dry weight. The regressions varied greatly between these two studies; therefore, the Panel decided to generate new equations using a dataset of oysters from across the Chesapeake Bay to establish regression equations that could be applied Chesapeake Bay-wide for BMP use.

Quantile regression is a statistical approach that estimates the conditional median (50^{th} or 0.50) or other quantiles (e.g., 25^{th}, 75^{th}) of the response variable (Yu et al. 2003). This approach is not as sensitive to outliers as regression approaches that use the data mean. In a BMP context, this could help account for potential differences in factors that influence oyster growth (e.g., ploidy, culture method, season, habitat type), and minimize overestimation of nutrient reduction. The Panel decided this approach would best represent the data given the variability in oyster shell heights and growth forms across the Chesapeake Bay.

The Panel specifically applied the 50^{th} quantile (median) regression framework to a Chesapeake Bay-wide dataset. Most of the data included in the 50^{th} quantile regression analysis were from subtidal reefs. The Panel included data from one study conducted in intertidal reefs in northern Virginia. The oyster shell height and biomass relationships fit the power function:

$$y = ax^b$$

where y is tissue or shell dry weight in grams and x is the shell height in millimeters. The Panel used the R statistical package quantreg (Koenker 2006; Koenker 2016) to generate nonlinear quantile regressions (nlrq). The starting values for coefficients *a* and *b* were based on mean estimates of the power function.

The resulting 50^{th} quantile of the Chesapeake Bay-wide dataset was compared with 50^{th} quantiles generated from a series of sub-datasets to determine whether the season (i.e., Spring, Summer, Fall, and Winter) and habitat (i.e., mesohaline and polyhaline environments located in the upper, mid, and lower regions of Chesapeake Bay) from which oysters were collected influenced the resulting regression equations. Analyses involving ploidy and culture method were not needed since oyster reef restoration practices only involve diploid oysters.

In cases where the 50^{th} quantile regression generated from a sub-dataset was lower than the 50^{th} quantile regression generated from the Chesapeake Bay-wide dataset, the Panel conducted a sensitivity analysis to evaluate whether a lower quantile (< 0.50) should be applied to the Chesapeake Bay-wide dataset. Applying a lower quantile would prevent overestimating oyster biomass, which would prevent overestimating the total nitrogen and phosphorus reduction. If the 50^{th} quantile regression generated from a sub-dataset was near or above the 50^{th} quantile regression generated from the entire dataset, the Bay-wide regression would result in no change or an underestimate of biomass and nutrient reduction. In these cases, the Panel concluded that the 50th quantile of the Chesapeake Bay-wide dataset was appropriate to use with data collected anywhere in the Bay.

E.2.1 Oyster Tissue Biomass

The Chesapeake Bay-wide dataset used to establish the default shell height to tissue dry weight regression equation included a total of 6,888 oysters from eight studies (three from peer-reviewed publications, two studies presented in a report, and one unpublished source) from 22 locations (Figure E-1, Table E-4).

Figure E-1. Sampling locations and assigned habitat groups for diploid oysters used in the shell height to tissue dry weight regression analyses.

Table E-4. Data used to generate shell height to tissue dry weight regression.

Data Source	Habitat/Oyster Information	Location	Data Age (Year Oysters Removed)	Season Oysters Removed	Percent of Total Oysters used in Regression Analysis
Higgins unpubl. data	Subtidal reefs; wild oysters	Choptank River, MD	2008	Spring	0.13
	Reefs; wild oysters	Lynnhaven River, VA			0.26
Kellogg unpubl. data	Subtidal reefs; mix of wild and hatchery-produced oysters	Harris Creek, MD	2015	Fall	2.34
				Winter	2.40
				Spring	2.44
				Summer	8.2
Kellogg et al. 2013	Subtidal reefs; hatchery-produced oysters	Choptank River, MD	2009	Fall	0.81
			2010	Spring	0.71
				Summer	1.6
Luckenbach and Ross 2009 (Part 1 of Report)	Subtidal patch reefs; mix of wild and hatchery-produced oysters	Great Wicomico River, VA	2004, 2005	Fall	2.09
			2004	Spring	0.48
			2005	Summer	3.15
		Lynnhaven River, VA	2005	Fall	1.35
				Summer	1.73
		Piankatank River, VA	2004	Fall	0.6
			2004, 2005	Spring	0.73
				Summer	1.18
		Rappahannock River, VA	2004	Fall	0.29
			2004, 2005	Spring	1.44
				Summer	0.45
Luckenbach and Ross 2009 (Part 3 of Report)	Restored and existing oyster reefs on intertidal structures, intertidal patch reefs, and subtidal reefs; wild oysters	Lynnhaven River, VA	2005, 2006	Spring	11.89
			2006	Winter	1.89
Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015	Subtidal reefs (public grounds); wild oysters	Great Wicomico River, VA	2010, 2011, 2012	Fall	2.13
		James River, VA	2010, 2011, 2012	Fall	5.73
		Mobjack Bay, VA	2010, 2012	Fall	0.73
		Piankatank River, VA	2010, 2011, 2012	Fall	1.8
		Pocomoke Sound, VA	2010, 2011, 2012	Fall	0.71
			2010, 2011, 2012	Winter	0.36
		Rappahannock River, VA	2010, 2011, 2012	Fall*	4.99
		Tangier Sound, VA	2011, 2012	Fall	0.73
		York River, VA	2010, 2011	Fall	2.15

Table E-4 (continued). Data used to generate shell height to tissue dry weight regression.

Paynter unpubl. data found in Liddel 2008	Subtidal reefs; hatchery-produced oysters	Cabin Creek, MD	1998	Fall	0.15
			2000	Spring	0.09
			1998	Summer	0.22
		Calvert Cliffs, MD	1998	Fall	0.36
			1999	Spring	0.07
			1998, 1999	Summer	0.7
		Chester River, MD	2001, 2002, 2004	Fall	1.97
			2002	Spring	1.57
			2001, 2002, 2004	Summer	1.99
		Choptank River, MD	2000, 2002	Fall	2.67
			2001, 2002	Winter	1.39
			2001, 2002, 2004	Summer	4.82
		Eastern Bay, MD	2001	Fall	0.41
			2002	Winter	0.57
			2004	Spring	0.17
			2001, 2002	Summer	1.74
		Little Choptank River, MD	2004	Summer	0.36
		Magothy River, MD	2001, 2002	Fall	0.96
			2002	Spring	0.39
			2001, 2002	Summer	0.73
		Nanticoke River, MD	2001, 2002	Fall	0.17
			2002	Summer	0.22
		Patuxent River, MD	2001	Fall	0.26
				Spring	1.15
			2000, 2001, 2002	Summer	3.83
		Severn River, MD	2001, 2002	Fall	1.16
			2001	Winter	0.29
			2002	Spring	0.15
			2001, 2002	Summer	1.26
		South River, MD	2001, 2002	Fall	0.36
			2002	Spring	0.22
				Summer	0.2
		Tangier Sound, MD	2000, 2001, 2002	Fall	1.67
			2001, 2002	Summer	1.79
		Tred Avon River, MD	2000	Fall	0.22
			2001	Summer	0.25

*25 oysters not labeled with a season. Assumed oysters were removed in the fall

The 50th quantile regression for oyster tissue dry weight using the Chesapeake Bay-wide dataset (n=6,888 oysters) is: **$y = 0.00037\ x^{1.83359}$** (Figure D-2).

The sections below describe the results of the comparisons between the Bay-wide regression and regressions generated from sub-datasets designated by season and oyster habitat (Table E-5). The goal was for the Bay-wide regression to minimize overestimating oyster tissue biomass and therefore minimize over crediting nitrogen and phosphorus reduction.

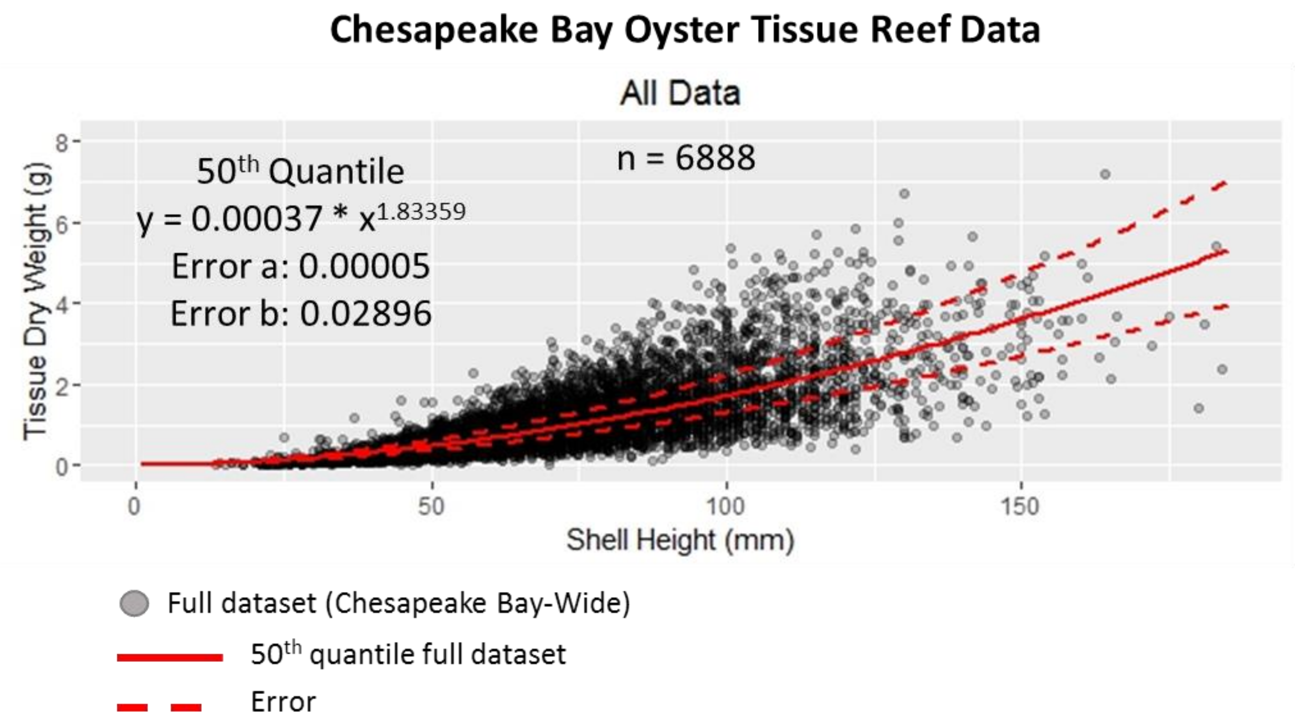


Figure E-2. Oyster shell height to tissue dry weight 50th quantile regression using oysters included in the full Chesapeake Bay-wide dataset.

Table E-5. Regression and error terms associated with each of the 50th quantile regression analyses for tissue biomass. Open Water Lower Bay Polyhaline habitat did not have enough tissue data to generate a quantile regression.

Oyster Data	# of Oysters	a	b	Error a	Error b
Full Dataset					
Chesapeake Bay-wide	6888	0.00037	1.83359	0.00005	0.02896
Sub-Datasets					
Fall	2511	0.00029	1.89203	0.00006	0.04508
Winter	475	0.00014	2.04735	0.00007	0.10898
Spring	1507	0.00041	1.86954	0.00008	0.04522
Summer	2370	0.00029	1.84454	0.00004	0.03217
Tributary Upper Bay Mesohaline	524	0.00043	1.80483	0.00019	0.09888
Tributary Mid-Bay Mesohaline	3163	0.00024	1.90115	0.00005	0.04556
Tributary Lower Bay Mesohaline	790	0.00016	2.08482	0.00006	0.08291
Tributary Lower Bay Polyhaline	1722	0.00028	1.92701	0.0001	0.08752

Open Water Mid-Bay Mesohaline	639	0.00003	2.44470	0.00002	0.14148
Intertidal	130	0.00043	1.91395	0.00028	0.15908

E.2.1.1 Tissue Seasonal Considerations

The Panel evaluated whether the Bay-wide tissue regression was sensitive to the season in which oysters were collected. The 50th quantile tissue regression of the fall, winter, and spring sub-datasets were in line or slightly above the 50th quantile tissue regression of the Bay-wide dataset (Figure E-3). This suggests that the Chesapeake Bay-wide 50th quantile tissue regression equation does not overestimate tissue biomass or over credit nitrogen and phosphorus reduction, and is appropriate for estimating the reduction across these seasons. For the spring sub-dataset, tissue biomass and the nitrogen and phosphorus reduction are likely underestimated for oysters larger than ~60 mm shell height (SH).

The summer sub-dataset fell below the 50th quantile tissue regression curve of the Bay-wide dataset for oysters > 75 mm SH (Figure E-3). There may be a greater chance that tissue biomass, and therefore nitrogen and phosphorus reduction, may be overestimated relative to other seasons if oysters are monitored in the summer.

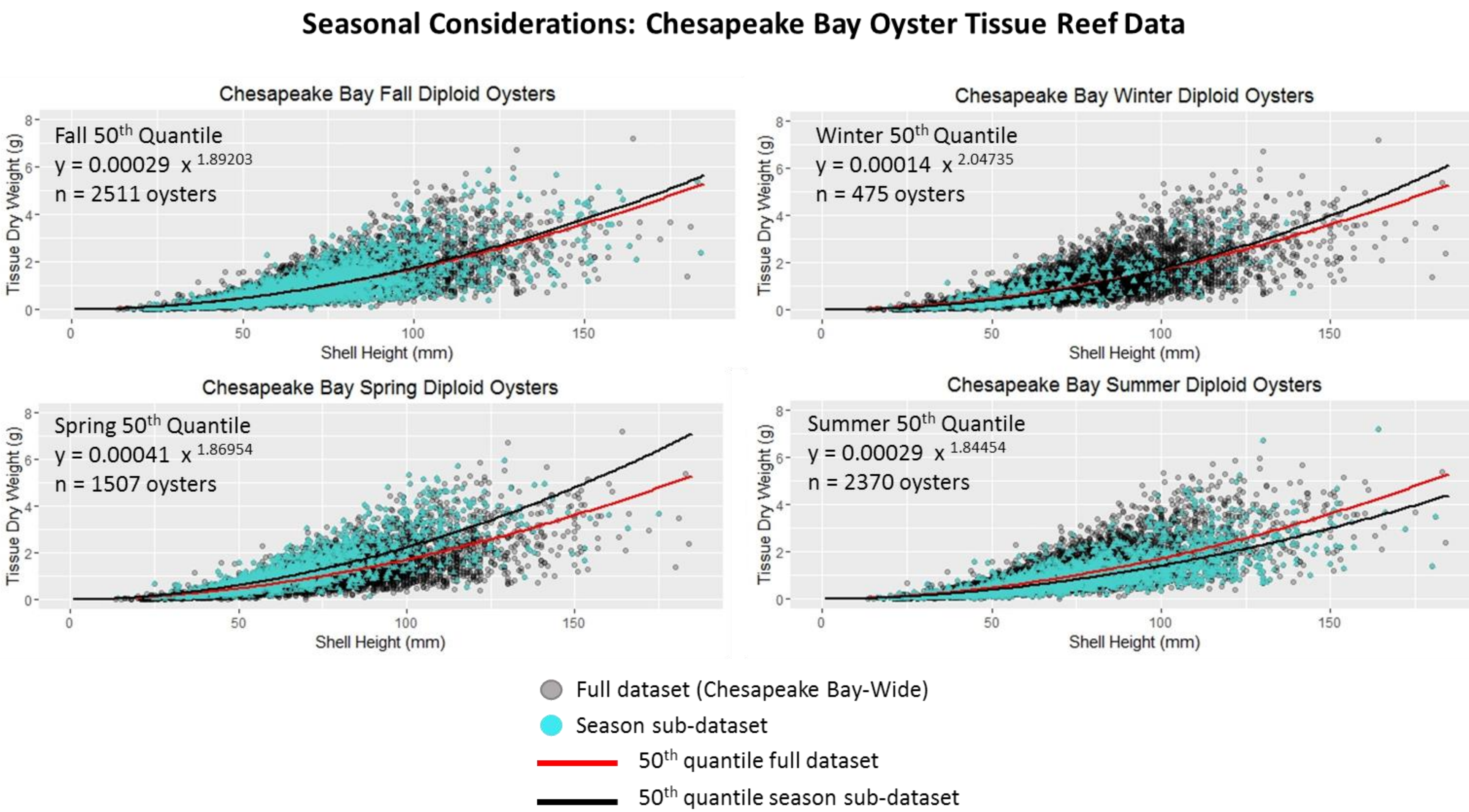


Figure E-3. Oyster tissue 50th quantile regression by season (turquoise dots, solid black line) evaluating potential seasonal differences in tissue dry weight compared to the full, Chesapeake Bay-wide dataset (gray dots, solid red line).

The Panel conducted a sensitivity analysis comparing the nitrogen reduction estimates from using the Bay-wide tissue regression versus the tissue regression for a subset of data from oysters sampled in the summer to evaluate whether the potential overestimation warranted generating a tissue regression equation for the Bay-wide dataset using a lower (< 0.50) quantile. The Panel calculated oyster tissue biomass across a range of size classes using both the Bay-wide and sub-dataset tissue regressions. Oyster tissue biomass was then multiplied by the mean percent nitrogen content in oyster tissue (8.2%) to estimate the total nitrogen reduced (Table E-6). The Panel only performed this sensitivity analysis for nitrogen since it has the greater percent content in oyster tissue compared to phosphorus. The proportion of the data (6,888 oysters) in each size class was used to estimate the potential nitrogen reduction overestimates for a site with one million oysters.

The Bay-wide 50th quantile tissue equation overestimated nitrogen reduction by 33 lbs per one million oysters compared to the tissue sub-dataset for summer alone. This estimate is within the margin of error associated with the 50th quantile of the Baywide default tissue equation (Table E-5). Therefore, the Panel agreed that the potential nutrient reduction overestimation in the summer season could be negligible, and these data should be included with the full dataset.

Table E-6. Sensitivity analysis performed on the summer dataset to consider potential overstimulation.

Oyster Size Class Category	Average Difference (lbs N)	Proportion of Dataset (n=6888)	Proportion of 1 million (# of oysters)	Difference in lbs N per 1 million oysters
< 2.0	0.00001	0.2	200000	2
2.0 - 2.49	0.00002	0.2	200000	4
2.5 - 3.49	0.00003	0.35	350000	12
3.5 - 4.49	0.00006	0.2	200000	11
4.5 - 5.49	0.00008	0.04	40000	3
5.5 - 7.49	0.00013	0.01	10000	1
			Total difference (lbs)	**33**

E.2.1.2 Tissue Habitat Considerations

The Panel evaluated whether the Bay-wide tissue regression was sensitive to the habitat in which oysters were collected. Habitat was characterized by geographic location within the Bay (upper, mid, lower), reef context (within a tributary vs. in open water), and salinity regime (mesohaline, polyhaline). The Chesapeake Bay locations and the salinity regimes were defined using the Chesapeake Bay Program bay-wide segmentation scheme (https://www.chesapeakebay.net/what/maps/20chesapeake-bay-2003-segmentation-scheme-codes) and spatially-explicit salinity gradient maps from the U.S. Army Corps of Engineers (http://www.nab.usace.army.mil/Missions/Environmental/Oyster-Restoration/Oyster-Master-Plan/). These raster salinity maps were generated in support of the U.S. Army Corps 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 six main habitat groups:

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

The dataset used to develop the shell height to tissue regression equation included oysters collected at 22 general sampling locations distributed throughout the Chesapeake Bay and its tributaries (Figure E-1). Raster maps and the geographic coordinates of each sampled reef 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 (Figure E-1).

Most (65%) of the oysters were collected from Tributary Mesohaline habitats in Maryland, followed by Tributary Polyhaline habitats (25%). A small portion of the data were from Open Water Mesohaline (9.28%) and Polyhaline (0.73%) environments (Table E-7). Intertidal oysters made up 2% (n=130) of the sample size used to calculate the Bay-wide tissue regression.

Table E-7. Summary of the percent of the oyster tissue data within each habitat group and data sources (references). All oysters are diploid. Data from Table E-4.

Habitat Group	General Sampling Location	Percent of Oyster Data (n=6888)	References
Tributary Upper Bay Mesohaline	Chester River	5.53	Paynter unpubl. data found in Liddel 2008
	Magothy River	2.08	Paynter unpubl. data found in Liddel 2008
Tributary Mid-Bay Mesohaline	Cabin Creek	0.45	Paynter unpubl. data found in Liddel 2008
	Choptank River	12.14	Higgins unpubl. data Kellogg et al. 2013 Paynter unpubl. data found in Liddel 2008
	Great Wicomico River	7.85	Luckenbach and Ross 2009
	Harris Creek	15.37	Kellogg unpubl. data
	Little Choptank River	0.36	Paynter unpubl. data found in Liddel 2008
	Nanticoke River	0.39	Paynter unpubl. data found in Liddel 2008
	Patuxent River	5.24	Paynter unpubl. data found in Liddel 2008
	Severn River	2.86	Paynter unpubl. data found in Liddel 2008
	South River	0.78	Paynter unpubl. data found in Liddel 2008
	Tred Avon River	0.46	Paynter unpubl. data found in Liddel 2008
Tributary Lower Bay Mesohaline	Piankatank River	4.3	Luckenbach and Ross 2009, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Rappahannock River	7.17	Luckenbach and Ross 2009, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Tributary Lower Bay Polyhaline	Lynnhaven River	17.12	Higgins unpubl. data Luckenbach & Ross 2009
	James River	5.73	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	York River	2.15	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Open Water Mid-Bay Mesohaline	Calvert Cliffs	1.13	Paynter unpubl. data found in Liddel 2008
	Eastern Bay	2.89	Paynter unpubl. data found in Liddel 2008
	Pocomoke Sound	1.07	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Tangier Sound	4.18	Paynter unpubl. data found in Liddel 2008, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Open Water Lower Bay Polyhaline	Mobjack Bay	0.73	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015

For most of the reviewed habitats, the 50th quantile tissue regression of each sub-dataset was above the 50th quantile tissue regression of the Bay-wide dataset, which suggests that the 50th quantile tissue regression equation from the Bay-wide dataset does not overestimate the nitrogen and phosphorus reduction (Figure E-4). The 50th quantile tissue regression of the Tributary Mid-Bay Mesohaline dataset was slightly below the 50th quantile tissue regression of the Bay-wide dataset for oysters > 75 mm SH (Figure E-4). However, this is within the margin of error of the tissue regression for the Bay-wide dataset (Table E-5) and does not significantly overestimate the nitrogen reduction.

Data from only one intertidal location were included in the Panel's Chesapeake Bay-wide tissue dataset (Luckenbach and Ross 2009 [Part 3]; 2% of oyster tissue data). The 50th quantile tissue regression of the sub-dataset was above the 50th quantile tissue regression of the Bay-wide dataset (Figure E-5). If this relatively small dataset is representative of intertidal oysters across the Chesapeake Bay, then the Bay-wide tissue regression likely underestimates oyster tissue biomass and under credits nutrient removal. Given the large error and small sample size for the intertidal data (Table E-5), the Panel agreed that the Bay-wide tissue regression equation could be used to estimate oyster tissue biomass for oysters on both subtidal and intertidal reefs. Because of the sparsity of data, the Panel recommends re-evaluating this relationship as more data become available from intertidal reefs in other locations and seasons.

The Panel concluded that the 50th quantile tissue regression equation of the full, Bay-wide dataset can be used for all habitats and seasons.

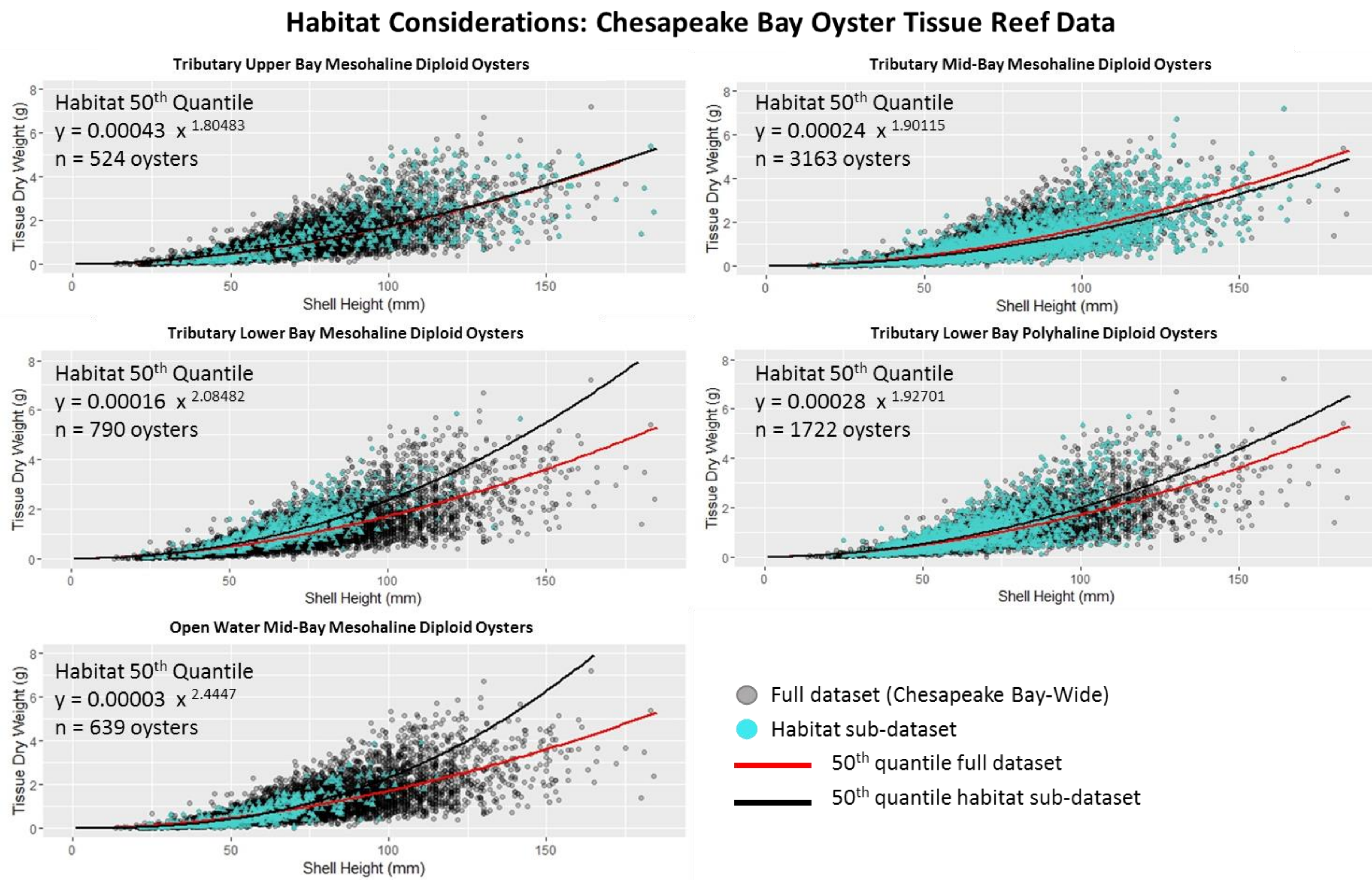


Figure E-4. Oyster tissue 50th quantile regression by habitat (turquoise dots, solid black line) evaluating potential habitat differences in tissue dry weight compared to the full, Chesapeake Bay-wide dataset (gray dots, solid red line).

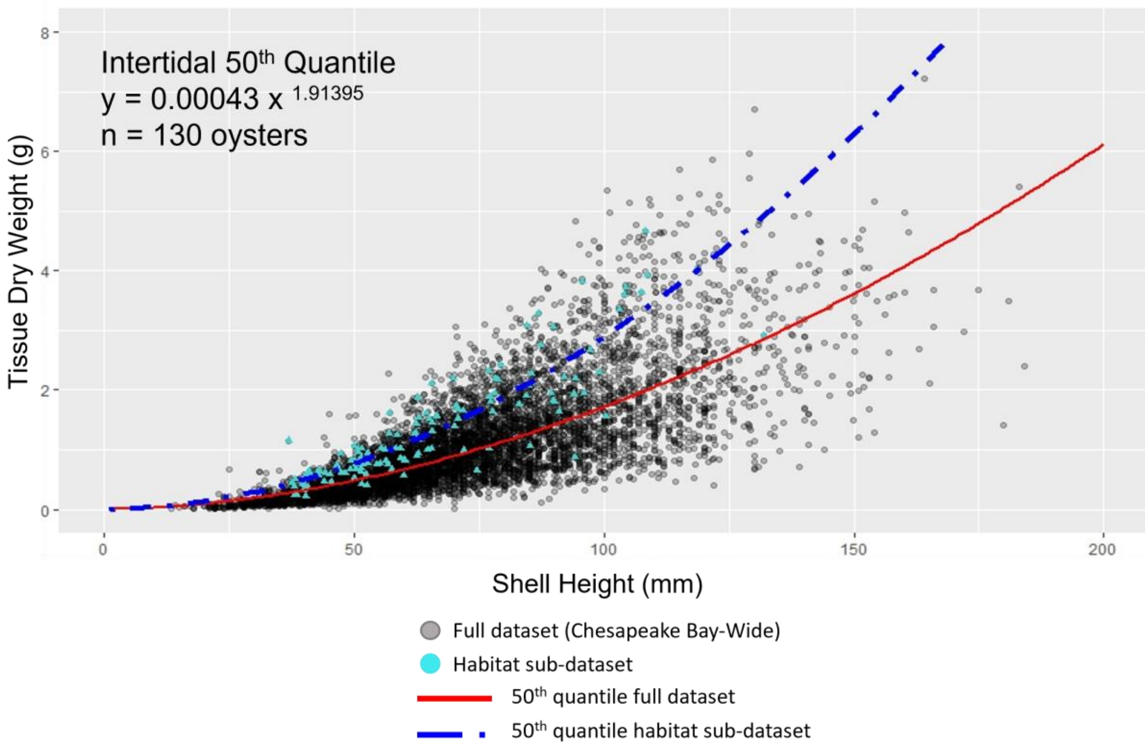


Figure E-5. Oyster tissue 50th quantile regression for oysters growing on intertidal reefs (turquoise triangles, blue dashed line) compared to the full Chesapeake Bay-wide dataset (gray dots, red line).

E.2.2 Oyster Shell Biomass

The Chesapeake Bay-wide dataset used to establish the shell height to shell dry weight regression equation included a total of 4,296 oysters from five studies (one peer-reviewed publication, two studies presented in a report, and two unpublished data sources) from 11 locations (Figure E-6, Table E-8). Some data used to generate the shell height to tissue dry weight equation were not included in this analysis since a number of those studies reported only tissue dry weight and not shell dry weight. Oyster samples from aquaculture sites were also removed.

Figure E-6. Sampling locations and assigned habitat groups for diploid oysters used in the shell height to shell dry weight regression analyses.

Table E-8. Data for the shell height to shell dry weight regression analyses.

Data Sources	Habitat/Oyster Information	Locations	Data Age (Year Oysters Removed)	Season Oysters Removed	Percent of Total Oysters used in Regression Analysis
Higgins unpubl. data	Subtidal reefs; wild oysters	Choptank River, MD	2008	Spring	0.21
	Reefs; wild oysters	Lynnhaven River, VA			0.42
Kellogg unpubl. data	Subtidal reefs; mix of wild and hatchery-produced oysters	Harris Creek, MD	2015	Fall	3.75
				Winter	3.84
				Spring	3.91
				Summer	13.20
Luckenbach and Ross 2009 (Part 1 of Report)	Subtidal patch reefs; mix of wild and hatchery-produced oysters	Great Wicomico River, VA	2004, 2005	Fall	3.35
			2004	Spring	0.77
			2005	Summer	5.05
		Lynnhaven River, VA	2005	Fall	2.16
				Summer	2.77
		Piankatank River, VA	2004	Fall	0.95
			2004, 2005	Spring	1.16
				Summer	1.89
		Rappahannock River, VA	2004	Fall	0.47
			2004, 2005	Spring	2.30
				Summer	0.72
Luckenbach and Ross 2009 (Part 3 of Report)	Restored and existing oyster reefs on bulkheads, intertidal patch reefs, marsh, riprap, subtidal bottom (not discrete patches); wild oysters	Lynnhaven River, VA	2005, 2006	Spring	19.04
			2006	Winter	3.03
Mann, Southworth and Wesson unpubl. data found in Powell et al. 2015	Subtidal reefs (public grounds); wild oysters	Great Wicomico River, VA	2010,2011, 2012	Fall	3.42
		James River, VA	2010,2011, 2012	Fall	9.19
		Mobjack Bay, VA	2010, 2012	Fall	1.16
		Piankatank River, VA	2010, 2011, 2012	Fall	2.89
		Pocomoke Sound, VA	2010, 2011, 2012	Fall	1.14
			2010, 2011, 2012	Winter	0.58
		Rappahannock River, VA	2010, 2011, 2012	Fall*	8.01
		Tangier Sound, VA	2011, 2012	Fall	1.16
		York River, VA	2010, 2011	Fall	3.45

*25 oysters not labeled with a season (assumed oysters were removed in the fall)

The 50th quantile regression for oyster shell dry weight using the Chesapeake Bay-wide dataset (n=4,296 oysters) is: $\mathbf{y = 0.00147\ x^{2.3964}}$ (Figure E-7).

The sections below describe the results of the comparisons between the Bay-wide shell regression and regressions generated from sub-datasets designated by season and oyster habitat (Table E-9). The goal was for the Bay-wide shell regression to minimize overestimating oyster shell biomass and therefore minimize over crediting nitrogen and phosphorus reduction.

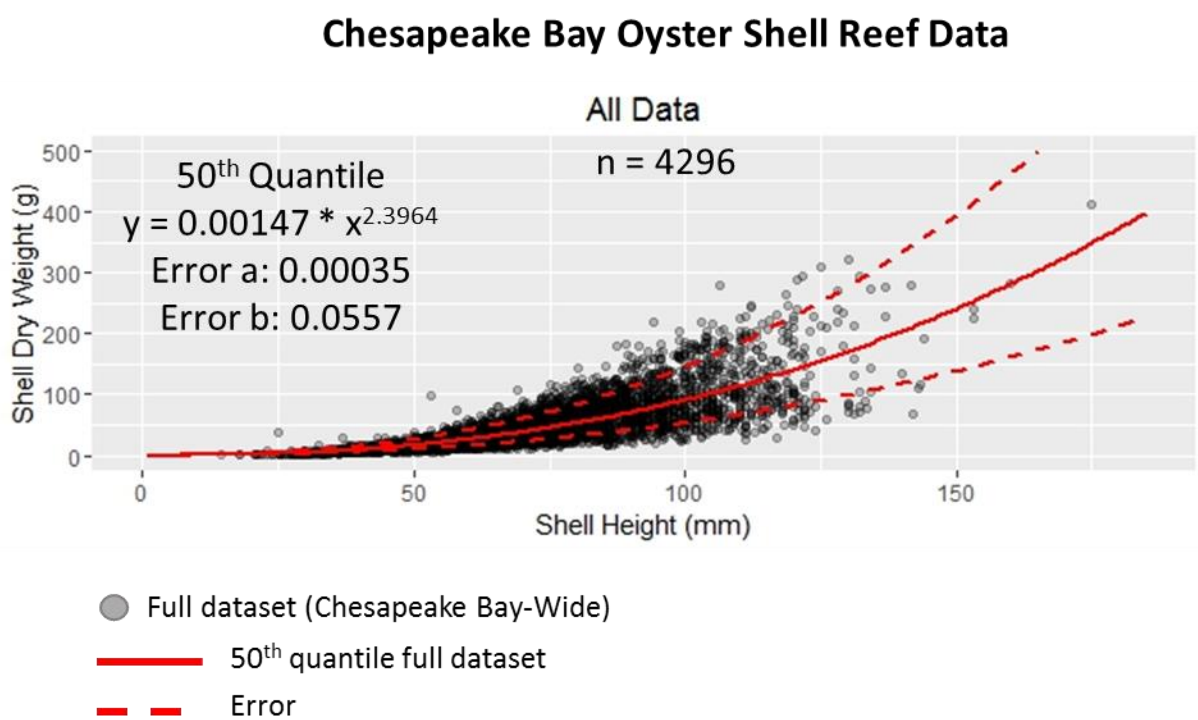


Figure E-7. Oyster shell height to shell dry weight 50th quantile regression using the full Chesapeake Bay-wide dataset (n=4,296 oysters).

Table E-9. Regression and error terms associated with each of the 50th quantile regression analyses for shell biomass. Open Water Lower Bay Polyhaline habitat did not have enough shell data to generate a quantile regression.

Oyster Data	# of Oysters	a	b	Error a	Error b
Full Dataset					
Chesapeake Bay-wide	4296	0.00147	2.3964	0.00035	0.0557
Sub-Datasets					
Fall	1741	0.00176	2.40328	0.00045	0.05928
Winter	320	0.00756	2.00003	0.00395	0.12503
Spring	1195	0.00026	2.73590	0.00007	0.06134
Summer	1015	0.00413	2.15238	0.0015	0.08283
Tributary Mid-Bay Mesohaline	1611	0.00251	2.27161	0.00083	0.0765
Tributary Lower Bay Mesohaline	790	0.00084	2.59788	0.00029	0.08208
Tributary Lower Bay Polyhaline	1721	0.00084	2.46481	0.00034	0.09904
Open Water Mid-Bay Mesohaline	124	0.00033	2.82404	0.0002	0.14097

Intertidal	130	0.00105	2.50074	0.00087	0.20242

E.2.2.1 Shell Seasonal Considerations

The Panel evaluated whether the Bay-wide shell regression was sensitive to the season in which oysters were collected. The summer and winter 50th quantile shell regression were below the 50th quantile shell regression of the Bay-wide dataset for oysters > 100 mm SH (Figure E-8). The Panel agreed the resulting overestimate of nitrogen and phosphorus reduction was negligible and within the margin of error of the full Bay-wide dataset (Table E-9). The fall 50th quantile shell regression was slightly above the 50th quantile shell regression of the Bay-wide dataset (Figure E-8). The Panel agreed this was also within the margin of error of the full dataset and would not significantly underestimate the nitrogen and phosphorus reduction. **The Panel concluded that the 50th quantile regression equation of the full shell dataset can be used to estimate shell biomass across seasons.**

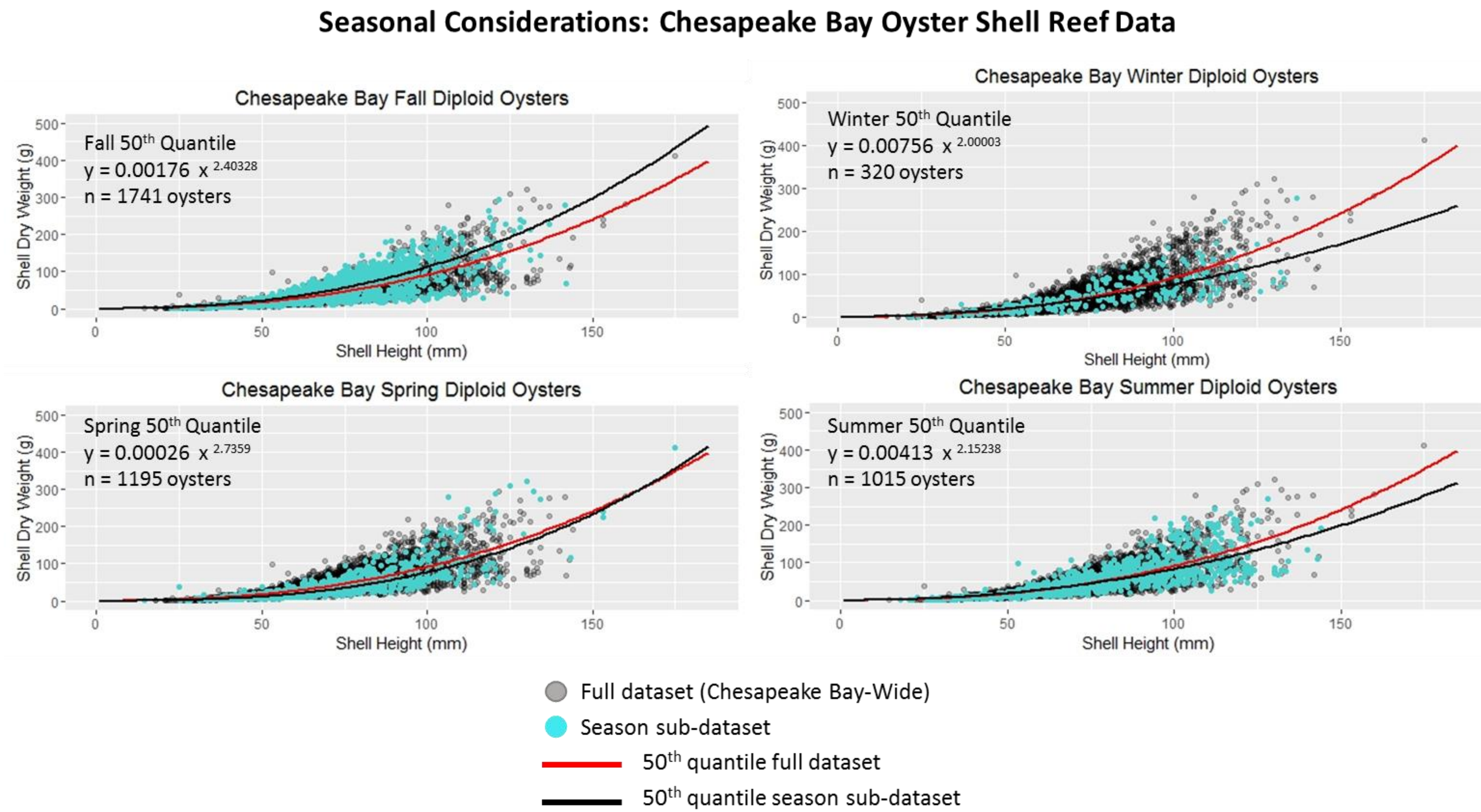


Figure E-8. Oyster tissue 50th quantile regression analyses by season (turquoise dots, solid black line) evaluating potential seasonal differences in shell dry weight compared to the full dataset (gray dots, solid red line).

E.2.2.2 Shell Habitat Considerations

The Panel used the same approach as for oyster tissue to determine whether the Bay-wide shell regression was sensitive to oyster habitat. The shell dataset included the following five habitat groups:

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

Table E-10. Percentage of oyster shell data within each habitat group and data sources (references). Data from Table E-8.

Oyster Restoration-Tissue Assimilation Habitat Analysis			
Habitat Group	**General Sampling Location**	**Percent of Oyster Data (n=4296)**	**References**
Tributary Mid-Bay Mesohaline	Choptank River	0.21	Higgins unpubl. data, Kellogg et al. 2013, Paynter unpubl. data found in Liddel 2008
	Great Wicomico River	12.59	Luckenbach and Ross 2009, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Harris Creek	24.70	Kellogg unpubl. data
Tributary Lower Bay Mesohaline	Piankatank River	6.89	Luckenbach and Ross 2009, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Rappahannock River	11.5	Luckenbach and Ross 2009, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Tributary Lower Bay Polyhaline	James River	9.19	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Lynnhaven River	27.42	Higgins unpubl. data, Luckenbach and Ross 2009
	York River	3.45	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Open Water Mid-Bay Mesohaline	Pocomoke Sound	1.72	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
	Tangier Sound	1.16	Paynter unpubl. data found in Liddel 2008, Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015
Open Water Lower Bay Polyhaline	Mobjack Bay	1.16	Mann, Southworth, and Wesson unpubl. data found in Powell et al. 2015

The dataset used to develop the shell height to shell dry weight regression equation included oysters collected at 11 general sampling locations distributed throughout the Chesapeake Bay and its tributaries (Figure E-6). Raster maps and the geographic coordinates of each sampled reef 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 (Figure E-6).

Most of the oysters were collected from Tributary Mesohaline (56%) habitats in Maryland, followed by Tributary Polyhaline habitats (40%). A small portion of the data are from Open Water Mesohaline (3%) and Polyhaline (1%) environments (Table E-10). Intertidal oysters made up 3% (n=130) of the sample size used to calculate the Bay-wide regression for shell.

The Open Water Mid-Bay Mesohaline and Tributary Lower Bay Mesohaline 50th quantile shell regression was greater than the 50th quantile shell regression of the full Bay-wide dataset (Figure E-9). This suggests that the 50th quantile regression equation from the Bay-wide dataset does not overestimate oyster shell biomass and therefore the nitrogen and phosphorus reduction. Instead, the reduction is likely underestimated at these habitat types for oysters > 75mm SH.

The Tributary Lower Bay Polyhaline shell regression was slightly below the 50th quantile shell regression of the Bay-wide dataset for oysters > 75mm SH (Figure E-9). The Panel conducted a sensitivity analysis following the same process as for oyster tissue in summer (Section E.2.1.1, Table E-6). The sensitivity analysis estimated that the Tributary Lower Bay Polyhaline regression overestimated nitrogen reduction by ~50 lbs of nitrogen per one million oysters. The Panel considered this difference to be negligible from a reduction effectiveness standpoint. The Panel agreed that this overestimation was within the margin of error associated with the 50th quantile of the Bay-wide default shell equation and that these data should be included with the full dataset.

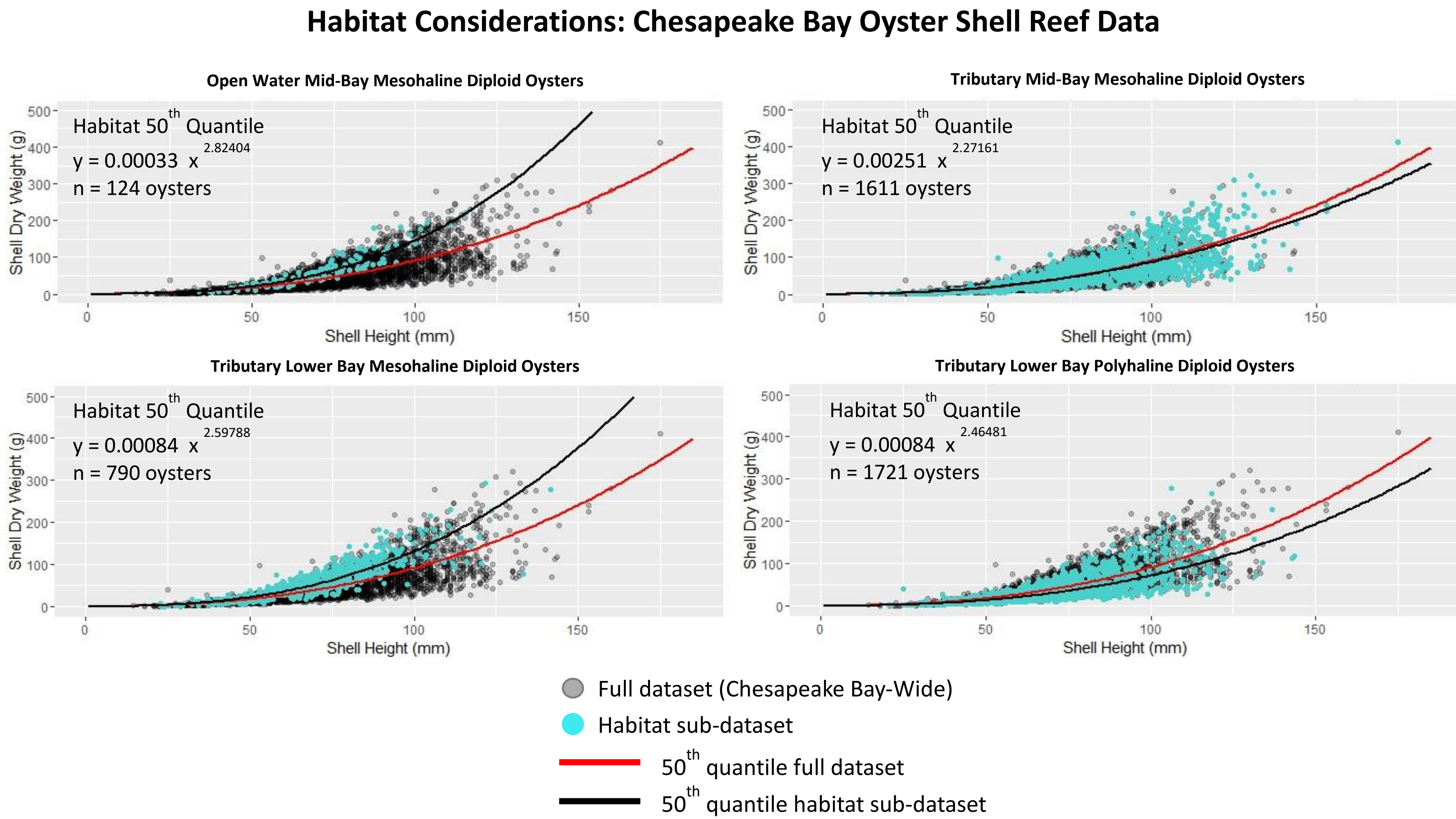


Figure E-9. Overlays of oyster shell heights and corresponding shell dry weight associated with four habitat groups (differentiated by location and salinity (turquoise dots, solid black line) added to 50th quantile regression plots using the full dataset (gray dots, solid red line).

Data from only one intertidal location were included in the Panel's Chesapeake Bay-wide dataset (Luckenbach and Ross 2009 [Part 3]; 3% of oyster shell data). The intertidal shell regression was slightly above the 50th quantile shell regression and within the margin of error of the Bay-wide dataset, suggesting that the 50th quantile shell regression equation for the full dataset does not overestimate the nitrogen and phosphorus reduction for oysters growing on intertidal reefs (Figure E-10). The Panel agreed that the shell regression equations could be used to estimate oyster biomass for oysters on both subtidal and intertidal reefs. Because of the sparsity of data, the Panel recommends re-evaluating this relationship as more data become available from intertidal reefs in other locations and seasons.

The Panel concluded that the 50th quantile shell regression equation of the full dataset can be used for all habitats.

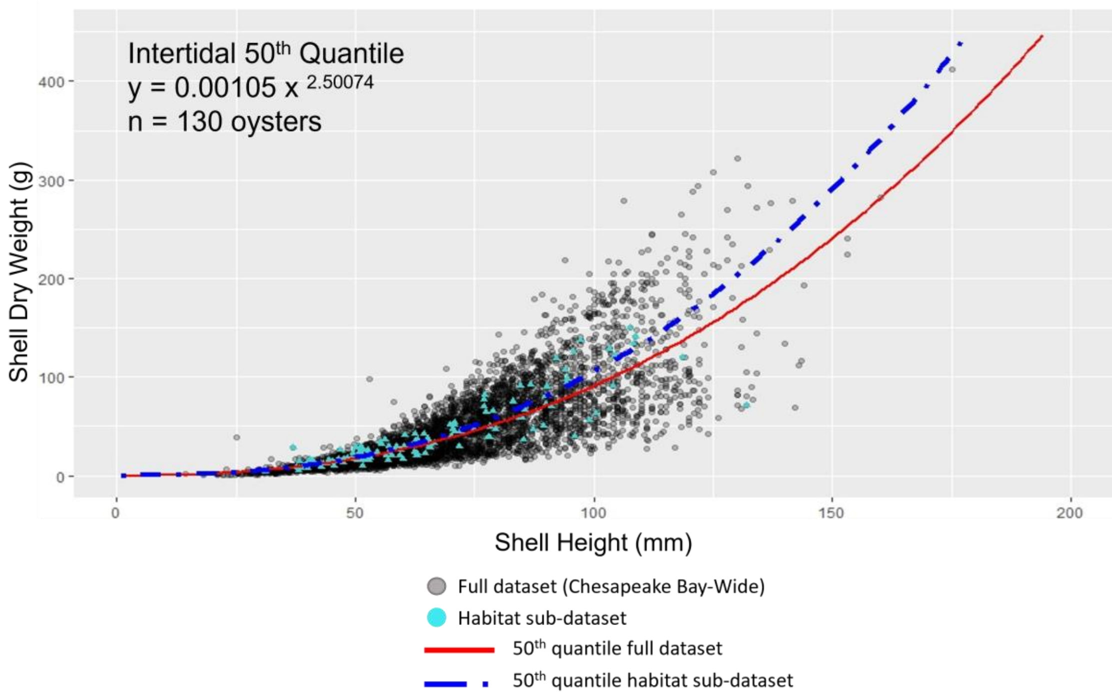


Figure E-10. Oyster shell 50th quantile regression for oysters growing on intertidal reefs (turquoise triangles, blue dashed line) compared to the full Chesapeake Bay-wide dataset (gray dots, red line).

E.3 References

Grizzle RE, Ward KM, Peter CR, Cantwell M, Katz D, Sullivan J (2016) Growth, morphometrics and nutrient content of farmed eastern oysters, Crassostrea virginica (Gmelin), in New Hampshire, USA. *Aquaculture Research* 1–13

Higgins CB, Stephenson K, Brown BL (2011) Nutrient Bioassimilation Capacity of Aquacultured Oysters: Quantification of an Ecosystem Service. *Journal of Environment Quality* 40 (1): 271

Kellogg ML, Cornwell JC, Owens MS, Paynter, KT (2013) Denitrification and nutrient assimilation on a restored oyster reef. *Mar Ecol Prog Ser* 480: 1-19

Koenker R (2016) Package 'quantreg': Quantile Regression. Available online from the R Development Core Team: https://cran.r-project.org/web/packages/quantreg/quantreg.pdf

Koenker R (2006) Quantile regression in R: a vignette. Available online: http://www.econ.uiuc.edu/~roger/research/rq/vig.pdf

Liddel MK (2008) A von Bertalanffy Based Model for the Estimation of Oyster (Crassostrea virginica) Growth on Restored Oyster Reefs in Chesapeake Bay. Master's Thesis, University of Maryland at College Park

Luckenbach MW, Ross, PG (2009) Recruitment, Substrate Quality and Standing Stock Monitoring in Support of NOAA-ACOA Oyster Restoration Projects in the Great Wicomico, Rappahannock, Piankatank and Lynnhaven River Basins, 2004-2006: Supplementary Materials. Eastern Shore Laboratory, Virginia Institute of Marine Science

Powell EN, Mann R, Ashton-Alcox KA, Kim Y, Bushek, D (2015) The allometry of oysters: spatial and temporal variation in the length–biomass relationships for Crassostrea virginica. *Journal of the Marine Biological Association of the United Kingdom* 96(5): 1127–1144

Reichert-Nguyen J, Cornwell J, Rose J, Kellogg L, Luckenbach MW, Bricker S, Paynter K, Moore C, Parker M, Sanford L, Wolinski B, Lacatell A, Fegley L, Hudson K, French E, Slacum H.W. JR (2016) 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. Report submitted to the Chesapeake Bay Program Partnership Water Quality Goal Implementation Team, December 19, 2016. Available at https://www.chesapeakebay.net/channel_files/24555/oyster_bmp_1st_report_draft_for_wtwg_and_wqgit_review_2016-12-05_pgs197_1.pdf

Reitsma, J., Murphy , D.C., Archer , A.F., and York, R.H. (2017). Nitrogen extraction potential of wild and cultured bivalves harvested from nearshore waters of Cape Cod, USA. *Marine Pollution Bulletin* 116:**,** 175-181.

Sebastiano D, Levinton JS, Doall M, Kamath S (2015) Using a shellfish harvest strategy to extract high nitrogen inputs in urban and suburban coastal bays: practical and economic implications. *J Shellfish Res* 34(2): 573-583

Yu K, Lu Z, Stander J (2003) Quantile regression: applications and current research areas. Journal of the Royal Statistical Society 52 (3): 331-350

Appendix F. Panel Criteria for Data Used to Estimate Enhanced Denitrification and Future Study Considerations for Restoration-Denitrification Protocols (Ch 8)

The Panel recognized that the inherent variability in denitrification rates and the range of methods used to assess them could introduce significant errors into the evaluation of denitrification enhancement associated with oyster reef restoration. As a result, the Panel established a set of criteria that must be met for data to be included in the dataset used to determine enhanced denitrification estimates for BMP use. The Panel based these criteria on a combination of the best available scientific information and the applicability of measurements in the context of BMP crediting. The questions the Panel considered to develop the criteria are described below. Each question is followed by the criteria (and supporting rationale) for inclusion or exclusion of data based on that question.

The Panel believes that it is feasible to develop denitrification reduction estimates for restored reef types and settings for which data are currently insufficient (e.g., restoration using large substrates or restoration of intertidal reefs). Developing crediting for these situations or refining the current crediting recommendations for subtidal reefs will require collecting additional denitrification data from restored reefs. Considering this and the extensive discussions the Panel held to determine whether data was suitable for inclusion in current recommendations, each of the criteria below is also followed by guidance for future efforts to measure restored reef denitrification rates for BMP use. Some guidance (e.g., data needed for QA/QC) also applies to denitrification data needed for developing BMPs for other oyster practices (e.g., aquaculture). Some guidance (e.g., sampling design considerations) will apply in concept, but the details will need to be revised to fit the oyster practice of interest. For example, gear type, gear location in the water column, and farm practices (such as oyster maintenance and harvest) will have to be considered when developing denitrification sampling designs for oyster aquaculture practices. The Panel recommends that all denitrification sampling designs be developed in consultation with expert(s) knowledgeable in the oyster practice of interest, denitrification experiments, and local habitat characteristics.

F.1 Are the samples used to determine denitrification rates representative of the site?

F.1.1 Panel Criteria

To date, most studies assessing denitrification rates on restored oyster reefs sample the reef using cores or trays. Core samples are taken using a relatively small diameter tube to collect sediments from within or adjacent to an oyster reef. The core diameter is small enough to exclude intact oyster clumps and associated fauna from the sample. Tray samples are taken from trays that are large enough to hold multiple clumps of oysters and embedded within the reef matrix. The tray is filled with reef material including oysters, shell, sediment and associated fauna.

Several studies to date have demonstrated significant nitrogen cycling associated with oysters, oyster clumps and associated fauna (Caffrey et al. 2016, Arfken et al. 2017, Jackson et al. 2018). In a study directly comparing denitrification rates measured using core samples versus tray samples from the same reef, Kellogg et al. (in revision) found that core samples significantly underestimated reef denitrification rates. Based on these studies, the Panel concluded that oyster reef sampling approaches that include the entire reef matrix (i.e., sediment, oysters, shell, associated fauna), such as the tray approach, provide a better estimate of total enhanced denitrification associated with oyster restoration. The Panel also concluded that cores containing only sediments can be used to assess baseline denitrification values on unrestored areas, or areas with no pre-existing oysters.

F.1.2 Panel Guidance for Future Studies

Future studies that measure denitrification rates on restored oyster reefs should collect samples that are representative of the entire habitat of interest (e.g., using trays). Specifically, the Panel recommends that the entire reef matrix (reef materials, underlying sediment, and associated organisms) be collected to estimate denitrification rates at the reef scale. To date, studies that have taken samples representative of the entire reef habitat used divers to collect samples from the field and incubated them in the lab (e.g., Kellogg et al. 2013) or incubated samples in situ (e.g., Humphries et al. 2016). These are currently the only published methods using sampling trays to capture denitrification within the reef matrix.

These approaches have been applied on subtidal reefs and intertidal reefs. Presently, data are too sparse to develop enhanced denitrification estimates for intertidal reefs, but, once more data are available, the Panel agreed that this can be done. For intertidal reefs, care should be taken when scaling measured hourly denitrification rates to annual rates because enhanced denitrification can only be credited for the times that the restored intertidal reef is submerged.

The ex-situ approach for measuring denitrification was developed to minimize concerns that chambers or domes used for in situ, on-bottom incubations would not seal due to the irregularity of reef topography. If not properly sealed, water in the incubation chamber will be diluted by exchanging with water outside the chamber, which will result in an inaccurate denitrification measurement. Installation of semi-permanent “rings” into the substrate have been used to attach chambers with promising results (Humphries et al. 2016). However, using semi-permanent rings for in situ denitrification measurements limit studies to fixed sites.

An ongoing study funded by the Chesapeake Bay Trust is examining the efficacy of using of chambers that can be lowered to the bottom on restored oyster reefs to measure denitrification. A tracer can be used to determine the rate of chamber dilution in combination with time course measurements of oxygen and N_2. Denitrification rates can then be determined through a flux/dilution model. Potential advantages of this approach include being able to conduct rapid measurement with lower effort and measuring more accurate denitrification rates by minimizing bottom disturbance. However, remotely measuring denitrification from the surface does not allow for determining oyster biomass, which is necessary for calibrating the relationship between biomass and enhanced denitrification. Therefore, the Panel recommends that denitrification measurements be made at sites with known oyster biomass.

Measuring denitrification rates associated with most large substrates will likely require developing new methods for incubating samples as well as careful thought about how measured values will be scaled up to the entire restoration site. For large substrates that are deployed as individual units (i.e., spaced far enough apart that the biogeochemical processes of adjacent units are unlikely to interact with one another), the appropriate sampling unit is likely the individual structure (see Subchapter 7.6.2.2). Measuring denitrification rates associated with these units (in or ex-situ) could likely be achieved by building incubation chambers large enough to handle these units. Using this approach and measuring the biomass of oysters on each unit would contribute to developing regressions of denitrification rates against oyster biomass per unit that could be implemented similar to the approach for subtidal oyster reefs described in this report. In this case, verification would require assessing mean oyster biomass per structural unit rather than per unit area of substratum (Subchapter 7.6.2.2). Scaling up to entire restoration site would then require multiplying by the total number of structures rather that the area of the site (Subchapter 7.6.2.2). Because the designs of large substrates vary widely, it is unlikely that measurements from one type of structure will be applicable to another.

Measuring denitrification associated with arrays of structures (e.g., many Oyster Castles® adjacent to and stacked on top of each other) will be more challenging because the position of the element within the array may determine its influence on local fluxes. Measuring denitrification rates associated with arrays of large substrates may require developing new techniques that allow measurement of denitrification rates in the field. For both arrays and individual large substrates, separate regressions for subtidal and intertidal settings will likely be needed.

Regardless of the type of restored reef for which denitrification data are collected, the design of denitrification sampling regimes should consider that both denitrification rates and oyster biomass can change significantly over time. Seasonal changes in denitrification rates are well documented, emphasizing that data collected in one season cannot reasonably be extrapolated to a different season. The meta-analysis conducted by the Panel also underscores that denitrification rates for reefs at one level of oyster tissue biomass cannot accurately be extrapolated to other oyster biomass levels unless sufficient data are available to conduct regression analyses. Without denitrification data for a range of oyster biomass levels, it may not be feasible to determine an appropriate nitrogen reduction credit if oyster biomass declines or increases significantly at a specific reef/ BMP site. The Panel recommends that sampling regimes should be developed in consultation with expert(s) knowledgeable in oyster reef restoration, denitrification experiments, and local habitat characteristics.

F.2 Are the characteristics of the reef site described in sufficient detail (e.g., oyster biomass, habitat characteristics, etc.) to determine the types of reefs to which the data can reasonably be extrapolated in a BMP context?

F.2.1 Panel Criteria

Oyster reef denitrification is supported by the feeding activity of oysters followed by microbial processing of the resulting biodeposits. Biodeposit production is generally expected to increase with increasing oyster abundance and/or biomass until food becomes limiting. Therefore, reef samples collected for measuring denitrification should also include a description of the oysters and/or an oyster tissue biomass per unit area. This will also be important to assess whether rates measured at one site can reasonably be extrapolated to another. Studies in Chesapeake Bay have demonstrated that increases in oyster biomass per unit area can lead to increases in denitrification rates (Sisson et al. 2011, Kellogg et al. 2014a, Kellogg et al. 2014b, Cornwell et al. 2016).

The environmental setting of the oyster reef is also important. Intertidal oyster reefs are exposed to air during low tides for a portion of the day; therefore, denitrification rates collected from subtidal reefs should not be extrapolated to intertidal reefs, and vice-versa. The Panel agreed that only those studies that assessed the biomass of oysters within the sample used for denitrification measurements and that included a sufficient description of reef characteristics should be included in data analyses.

F.2.2 Panel Guidance for Future Studies

Studies seeking to assess denitrification enhancement on restored oyster reefs should include sufficient data to allow for the direct comparison of denitrification rates from one site to rates measured at other sites. At a minimum, data should include information on the types and amounts of materials used for restoration, the location of the restoration site, the position of the restoration site relative to local tidal regimes (i.e., is the site subtidal or intertidal), and mean oyster tissue biomass before and after restoration. Oyster tissue biomass information should be collected and reported using the units most meaningful for the type of materials used for restoration. For small substrates, the most appropriate unit for reporting will likely be oyster tissue biomass per unit substratum area (i.e., g oyster tissue dry weight m^{-2}). For large substrates, the most appropriate unit will likely be oyster tissue biomass per structural unit (i.e., g oyster tissue dry weight $unit^{-1}$). Oyster biomass should be calculated from oysters in each sample used for denitrification measurements. Additional data, such as sediment characteristics (e.g., organic content), ambient conditions of dissolved nitrogen, and fouling community structure, among others, may also be used to compare denitrification rates between sites.

F.3 Of the many analytical approaches used to measure denitrification, which are most appropriate for use in a BMP context?

F.3.1 Panel Criteria

Existing literature included both indirect and direct denitrification assessment techniques. Indirect techniques that have been used to measure microbial denitrification include N_2 depuration/flux (Seitzinger et al. 1993), acetylene block (Joye et al. 1996), and overall mass balances to determine rates (Cornwell et al. 1999). These techniques have limitations since they generally produce *potential* rates. The Panel agreed that studies using these methods should not be applied to determine denitrification rates for BMP use. Instead, the Panel agreed to only use studies that employ one of the two methods that adequately capture *areal* denitrification rates: N_2:Ar gas ratios (e.g., Kana et al. 1994, Kellogg et al. 2013) and ^{15}N isotope pairing (e.g., Nielsen 1992). Overall, the field of biogeochemistry has coalesced around these two techniques for measuring benthic denitrification in estuarine environments.

F.3.2 Panel Guidance for Future Studies

To date, only the N_2:Ar gas ratio approach has been used to measure areal denitrification rates for restored oyster reefs. Although use of ^{15}N isotope pairing techniques is theoretically feasible, use of this method requires complete mixing of the labeled nitrogen throughout the incubated sample. Given the difficulties of achieving complete mixing in samples that contain impervious structures (e.g., oyster shells, large substrates), studies using this approach will need to demonstrate that complete mixing has been achieved for associated measurements to be considered valid. The Panel recognized that new methods for accurately measuring N_2 fluxes are likely to be developed, especially for large substrates, and noted that these should be considered on a case by case basis to determine if they are suitable for use in the context of BMP crediting.

F.4 Are “batch” and “flow-through” incubation techniques equally appropriate for measuring denitrification rates on restored oyster reefs?

F.4.1 Panel Criteria

Two time-course incubation methods are generally used for obtaining denitrification measurements: “batch” and “flow-through.” In batch incubations, the sample is sealed in a water-tight and gas-tight chamber and multiple water samples are collected over the time course of the incubation via sampling ports. The concentrations of N_2 in the water samples are then regressed against time to determine the change in concentration per unit time. In contrast, flow-through incubations involve continual flow of water through the incubation chamber and assess denitrification rates based on the flow rate and the difference in concentration of di-nitrogen gas in the water flowing into the chamber and the water flowing out of the chamber. This technique requires the concentrations of gases and nutrients to be at steady state prior to the start of the incubation which, for sediment cores, takes 17-24 hours. Although flow-through chamber incubations of oyster reef samples are theoretically possible, none have been successfully conducted to date. Flow through incubations of oyster reef samples will require overcoming challenges associated with providing a flow of temperature-equilibrated water sufficient to maintain necessary oxygen concentrations without disturbing the sediment-water interface of the sample. A pilot study by Kellogg et al. (2013) that repeatedly incubated reef samples over a two-day period observed changes in nitrogen dynamics over time. These results suggest that denitrification rates are more likely to deviate from field conditions the longer samples are held in the laboratory. The long equilibration time surpasses the time frame for dark or light time periods, and the flow-through approach is generally limited to dark-only incubations. For these reasons, the Panel only considered measurements made using batch incubation techniques.

F.4.2 Panel Guidance for Future Studies

To date, only batch incubations have been used to assess denitrification rates for oyster reef samples that include representative samples of the habitat. However, this does not mean that other approaches could not be used or developed. Any measurements using new techniques will need to demonstrate that the assumptions of the technique have been met. For samples brought into the laboratory, care needs to be taken to ensure that laboratory methods do not lead to significant changes in nitrogen dynamics that would not be observed under field conditions. The most recent studies of denitrification on restored oyster reefs (e.g., Cornwell et al. 2019) aerate samples during transport and begin incubation at field salinity and temperatures within an hour of reaching the laboratory to ensure minimal deviations from field conditions. Regardless of the method used, data should be collected to demonstrate that oxygen concentrations were sufficient (i.e., dissolved oxygen concentrations ≥4 mg L^{-1} during incubations) and temperature was constant (±1 °C) throughout the incubation. Because it is difficult to accurately measure denitrification rates for complex substrates, such as an oyster reef, sampling methods should be selected and/or developed in consultation with expert(s) knowledgeable in measuring denitrification in these environments.

F.5 Are incubations under both light and dark conditions necessary for accurate determination of denitrification rates?

F.5.1 Panel Criteria

Oyster reefs in Chesapeake Bay occur across depths ranging from intertidal to deep subtidal reefs below the euphotic zone (the portion of the water column with sufficient light to support photosynthesis). For soft sediments, it is well-known that denitrification can be reduced by the presence of photosynthetic organisms (e.g., macroalgae and benthic microalgae) that compete with microbes for the substrates needed to support denitrification. In this context, the Panel considered whether studies of oyster reef denitrification that did not include incubations under both light and dark conditions were appropriate for inclusion in the dataset used to develop default denitrification rates. The Panel concluded that studies of reefs in the euphotic zone should include both light and dark incubations but that studies of reefs below the euphotic zone did not need to include an incubation under light conditions.

F.5.2 Panel Guidance for Future Studies

Where sufficient light reaches the bottom to support photosynthesis (i.e., where ≥ 2% of incident sunlight reaches the bottom or benthic algae are present), both dark and light incubations are necessary for extrapolating measured hourly denitrification rates to a daily rate. If sufficient light does not reach the bottom, then only dark incubations are required, and data can be extrapolated to the entire day. In some cases, accurate measurement of denitrification rates is not feasible in the presence of light because photosynthesis that occurs during the incubation leads to the formation of bubbles in the incubation chamber. The presence of bubbles in the incubation chamber alters gas fluxes in ways that would not normally be observed under field conditions. If significant bubble formation occurs during light incubations or if light incubations are not conducted for sites where light is sufficient to allow benthic photosynthesis, then only data from dark incubations can be used. In this situation, denitrification during daytime hours should be assumed to be zero and denitrification measurements from dark incubations should be multiplied by the number of dark hours in the day to determine daily denitrification rates.

F.6 Are additional data reported that can be used to assess the quality of the denitrification data?

F.6.1 Panel Criteria

Studies that include data on other nitrogen fluxes (e.g., ammonium fluxes, nitrate or combined nitrate/nitrite fluxes) and oxygen fluxes are preferred because these data can be helpful in verifying the quality of the data collected. The ratio of oxygen (or dissolved inorganic carbon [DIC]) to the sum of all nitrogen fluxes should be reasonable based on oxygen and total nitrogen (O_2:N) stoichiometry and the amount of ammonium that is nitrified (Froelich et al. 1979). Because denitrification rates are difficult to measure, the Panel decided that reporting these fluxes is valuable for verifying the quality of the data incorporated into a BMP.

F.6.2 Panel Guidance for Future Studies

Accurately measuring denitrification is difficult and mistakes can easily be made. Thus, the Panel suggests that additional data be collected that can be used to verify the quality of the denitrification measurements. At a minimum, sufficient data should be collected to confirm that temperature remained constant (±1 °C) throughout incubations, that oxygen concentrations did not fall below 4 mg L^{-1}, and that total nitrogen concentration (sum NO_3^-, NH_4^+, and N_2-N gas) increased linearly as oxygen concentration decreased. Ideally, sufficient data should be collected to allow for the calculation of stoichiometric ratios for C:N:P based on fluxes to determine if the ratios are similar to those expected based on the Redfield ratio of 106C:16N:1P for marine algae (see Kellogg et al. 2013 for an example). If O_2 is measured but CO_2 is not, a flux ratio of 1:1 for O_2:CO_2 can be assumed, which will allow oxygen fluxes to be used for these calculations. If the calculated stoichiometric ratio is similar to the Redfield ratio, it is likely that the majority of carbon (or oxygen), nitrogen, and phosphorus fluxes have been accounted for in flux measurements. Significant deviation from the Redfield ratio would suggest that significant fluxes may not have been captured and/or that mistakes were made during sample collection or incubation. If this is the case, the resulting data should be examined carefully and used with caution or rejected as possibly erroneous.

F.7 References

Arfken A, Song B, Bowman JS, Piehler M (2017) Denitrification potential of the eastern oyster microbiome using a 16S rRNA gene based metabolic inference approach. PLOS ONE 12:e0185071

Caffrey JM, Hollibaugh JT, Mortazavi B (2016) Living oysters and their shells as sites of nitrification and denitrification. Mar Pollut Bull 112:86-90

Cornwell JC, Kemp WM, Kana TM (1999) Denitrification in coastal ecosystems: environmental controls and aspects of spatial and temporal scale. Aquatic Ecology 33:41-54.

Cornwell JC, Owens MS, Kellogg ML (2016) Integrated assessment of oyster reef ecosystem services: quantifying denitrification rates and nutrient fluxes. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/JDFV-GD71 (accessed 1 Aug 2022)

Cornwell JC, Owens MS, Jackson M, Kellogg ML (2019) Integrated assessment of oyster reef ecosystem services: quantifying denitrification rates and nutrient fluxes. https://doi.org/10.25773/F30H-3G51 (accessed 1 Aug 2022)

Froelich PN, Klinkhammer GP, Bender ML, Luedtke NA, Heath GR, Cullen C, Dauphin P, Hammond D (1979) Early oxidation of organic matter in pelagic sediments of the eastern equatorial Atlantic: suboxic diagenesis. Geochim Cosmochim Acta 43: 1075-1090.

Humphries AT, Ayvazian SG, Carey JC, Hancock BT, Grabbert S, Cobb D, Strovel CJ, Fulweiler RW (2016) Directly measured denitrification reveals oyster aquaculture and restored oyster reefs remove nitrogen at comparable high rates. Front Mar Sci 4: https://doi.org/10.3389/fmars.2016.00074

Jackson M, Owens MS, Cornwell JC, Kellogg ML (2018) Comparison of methods for determining biogeochemical fluxes from a restored oyster reef. PLOS ONE 13:e0209799

Joye SB, Smith SV, Hollibaugh JT, Paerl HW (1996) Estimating denitrification rates in estuarine sediments: a comparison of stoichiometric and aceylene based methods. Biogeochemistry 33: 197-215.

Kana TM, Darkangelo C, Hunt MD, Oldham JB, Bennett GE, Cornwell JC (1994) Membrane inlet mass spectrometer for rapid high-precision determination of N_2, O_2, and Ar in environmental water samples. Anal Chem 66: 4166–4170.

Kellogg ML, Cornwell JC, Owens MS, Paynter KT (2013) Denitrification and nutrient assimilation on a restored oyster reef. Mar Ecol Prog Ser 480: 1-19

Kellogg ML, Cornwell JC, Owens MS, Luckenbach M, Ross PG, Leggett TA, Dreyer JC, Lusk B, Birch A, Smith E (2014a) Scaling ecosystem services to reef development: effects of oyster density on nitrogen removal and reef community structure. Virginia Institute of Marine Science, William & Mary. http://doi.org/10.21220/V5G013

Kellogg ML, Luckenbach M, Cornwell JC, Ross PG, Lusk B (2014b) Linking structural and functional characteristics of restored oyster reefs: a restoration project in the Virginia Coast Reserve. Virginia Institute of Marine Science, William & Mary. http://doi.org/10.21220/V5KS3Q

Nielsen LP (1992) Denitrification in sediment determined from nitrogen isotope pairing. Fems Microbiology Ecology 86: 357-362

Seitzinger SP, Nielsen LP, Caffrey J, Christensen PB (1993) Denitrification measurements in aquatic sediments: A comparison of three methods. Biogeochemistry 23:147-167

Sisson M, Kellogg ML, Luckenbach M, Lipcius RN, Colden A, Cornwell J, Owens MS (2011) Assessment of oyster reefs in Lynnhaven River as a Chesapeake Bay TMDL best management practice. Special Reports in Applied Marine Science and Ocean Engineering (SRAMSOE) No. 429. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.21220/V52R0K

Testa JM, Brady DC, Cornwell JC, Owens MS, Sanford LP, Newell CR, Suttles SE, Newell RIE (2015) Modeling the impact of floating oyster (Crassostrea virginica) aquaculture on sediment-water nutrient and oxygen fluxes. Aquaculture Environment Interactions 7: 205-222

Appendix G: Lookup Table for Annual Denitrification Enhancement (Ch 8)

Table G.1. Lookup table developed by Panel to determine annual nitrogen removal attributed to enhanced denitrification on subtidal restored oyster reefs. Refer to text for definitions and survey methods for determining baseline and post-restoration biomass. See Subchapter 8.6.2 for examples illustrating how to use the lookup table.

Enhanced Nitrogen Removal (lbs acre^{-1} yr^{-1})		***Post-restoration Oyster Tissue Biomass Range (g DW m-2)***																				
		0 - 14.9	***15 - 24.9***	***25 - 34.9***	***35 - 44.9***	***45 - 54.9***	***55 - 64.9***	***65 - 74.9***	***75 - 84.9***	***85 - 94.9***	***95 - 104.9***	***105 - 114.9***	***115 - 124.9***	***125 - 134.9***	***135 - 144.9***	***145 - 154.9***	***155 - 174.9***	***175 - 194.9***	***195 - 214.9***	***215 - 234.9***	***235 - 254.9***	***255 - 274.9***
		Annual DNF Rate for Midpoint of Biomass Rage (lbs. acre^{-1} yr^{-1})																				
Baseline Oyster Tissue Biomass Range (g DW m^{-2})	*Annual DNF Rate for Midpoint of Biomass Range (lbs. acre^{-1} yr^{-1})*	*132*	*161*	*184*	*206*	*229*	*252*	*275*	*298*	*301*	*305*	*308*	*311*	*315*	*318*	*322*	*327*	*334*	*341*	*348*	*355*	*359*
0 - 14.9	*132*		29	51	74	97	120	143	165	169	172	176	179	183	186	190	195	202	209	215	222	226
15 - 24.9	*161*			23	46	68	91	114	137	140	144	147	151	154	158	161	166	173	180	187	194	198
25 - 34.9	*184*				23	46	68	91	114	118	121	124	128	131	135	138	143	150	157	164	171	175
35 - 44.9	*206*					23	46	68	91	95	98	102	105	109	112	115	121	128	134	141	148	152
45 - 54.9	*229*						23	46	68	72	75	79	82	86	89	93	98	105	112	119	125	129
55 - 64.9	*252*							23	46	49	53	56	59	63	66	70	75	82	89	96	103	107
65 - 74.9	*275*								23	26	30	33	37	40	44	47	52	59	66	73	80	84
75 - 84.9	*298*									3	7	10	14	17	21	24	29	36	43	50	57	61
85 - 94.9	*301*										3	7	10	14	17	21	26	33	40	47	54	57
95 - 104.9	*305*											3	7	10	14	17	22	29	36	43	50	54
105 - 114.9	*308*												3	7	10	14	19	26	33	40	47	51
115 - 124.9	*311*													3	7	10	16	22	29	36	43	47
125 - 134.9	*315*														3	7	12	19	26	33	40	44
135 - 144.9	*318*															3	9	16	22	29	36	40
145 - 154.9	*322*																5	12	19	26	33	37
155 - 174.9	*327*																	7	14	21	28	32
175 - 194.9	*334*																		7	14	21	25
195 - 214.9	*341*																			7	14	18
215 - 234.9	*348*																				7	11
235 - 254.9	*355*																					4
255 - 274.9	*359*																					

Table G.1. (continued)

Enhanced Nitrogen Removal (lbs acre^{-1} yr^{-1})		***Post-restoration Oyster Tissue Biomass Range (g DW m^{-2})***															
		275 - 294.9	***295 - 314.9***	***315 - 334.9***	***335 - 354.9***	***355 - 374.9***	***375 - 394.9***	***395 - 414.9***	***415 - 434.9***	***435 - 454.9***	***455 - 474.9***	***475 - 494.9***	***495 - 514.9***	***515 - 534.9***	***535 - 554.9***	***555 - 574.9***	***575 - 594.9***
		Annual DNF Rate for Midpoint of Biomass Rage (lbs. acre^{-1} yr^{-1})															
		353	*348*	*343*	*338*	*332*	*327*	*322*	*317*	*312*	*306*	*301*	*296*	*291*	*285*	*280*	*275*
Baseline Oyster Tissue Biomass Range (g DW m^{-2})	*Annual DNF Rate for Midpoint of Biomass Range (lbs. acre^{-1} yr^{-1})*																
0 - 14.9	*132*	221	216	211	205	200	195	190	185	179	174	169	164	158	153	148	143
15 - 24.9	*161*	193	187	182	177	172	166	161	156	151	146	140	135	130	125	119	114
25 - 34.9	*184*	170	165	159	154	149	144	138	133	128	123	118	112	107	102	97	91
35 - 44.9	*206*	147	142	136	131	126	121	116	110	105	100	95	89	84	79	74	69
45 - 54.9	*229*	124	119	114	108	103	98	93	88	82	77	72	67	61	56	51	46
55 - 64.9	*252*	101	96	91	86	80	75	70	65	60	54	49	44	39	33	28	23
65 - 74.9	*275*	78	73	68	63	58	52	47	42	37	31	26	21	16	11	5	
75 - 84.9	*298*	56	50	45	40	35	30	24	19	14	9	3					
85 - 94.9	*301*	52	47	42	37	31	26	21	16	10	5						
95 - 104.9	*305*	49	44	38	33	28	23	17	12	7	2						
105 - 114.9	*308*	45	40	35	30	24	19	14	9	4							
115 - 124.9	*311*	42	37	31	26	21	16	11	5								
125 - 134.9	*315*	38	33	28	23	18	12	7	2								
135 - 144.9	*318*	35	30	24	19	14	9	4									
145 - 154.9	*322*	31	26	21	16	11	5										
155 - 174.9	*327*	26	21	16	11	5											
175 - 194.9	*334*	19	14	9	4												
195 - 214.9	*341*	12	7	2													
215 - 234.9	*348*	6															
235 - 254.9	*355*																
255 - 274.9	*359*																

Appendix H: Informational Recommendations on the Harvest-Assimilation Protocols

H.1 Preliminary Re-evaluation of Default Estimates for Nitrogen and Phosphorus Content in Tissue of Oysters Removed via Licensed Oyster Harvest

The licensed oyster harvest Practice F (licensed oyster harvest using hatchery-produced oysters) being submitted for approval in this report only credits diploid oysters that are grown directly on the bottom in harvest areas without gear. Some members of the Panel had concerns that the diploid shell height to tissue dry weight quantile regression equation from the first report (Reichert-Nguyen et al. 2016) would not be appropriate to estimate nitrogen and phosphorus reduction resulting from this practice since it included data from oysters that were grown off the bottom in gear (e.g., cages, floating bags). The Panel did a preliminary re-evaluation of these data by ploidy and culture method using the same quantile regression approach described in Reichert-Nguyen et al. (2016) to examine whether culture method significantly altered the reduction estimates. This preliminary re-evaluation included additional data from Cubillo et al. (2018) and Mann, Southworth, and Wesson (unpubl.) that were provided after the approval of the first report. Data from Cubillo et al. (2018) provided additional shell height and tissue dry weight measurements for both diploid (n = 420) and triploid (n = 2,328) oysters grown in gear from oyster aquaculture farms located in Chesapeake Bay, Chester River, Honga River, and Potomac River in Maryland (Table H-1). Data from Mann, Southworth, and Wesson (unpubl.) provided additional shell height and tissue dry weight measurements for diploid oysters (n = 1,332) grown directly on reefs from eight locations in Virginia (Table H-1, summarized in Appendix E). These data were added to the dataset used to determine the diploid and triploid shell height to tissue dry weight regression equations from the Panel's first report (Reichert-Nguyen et al. 2016).

Table H-1. Comparison of sample sizes from datasets used in the Panel's first report and this report by ploidy and culture method.

Category Based on Ploidy and Culture Method	First Report Sample Size	Updated Sample Size
Triploid, With Gear	1066	3394
Diploid, With Gear	84	504
Diploid, Without Gear	5556	6888

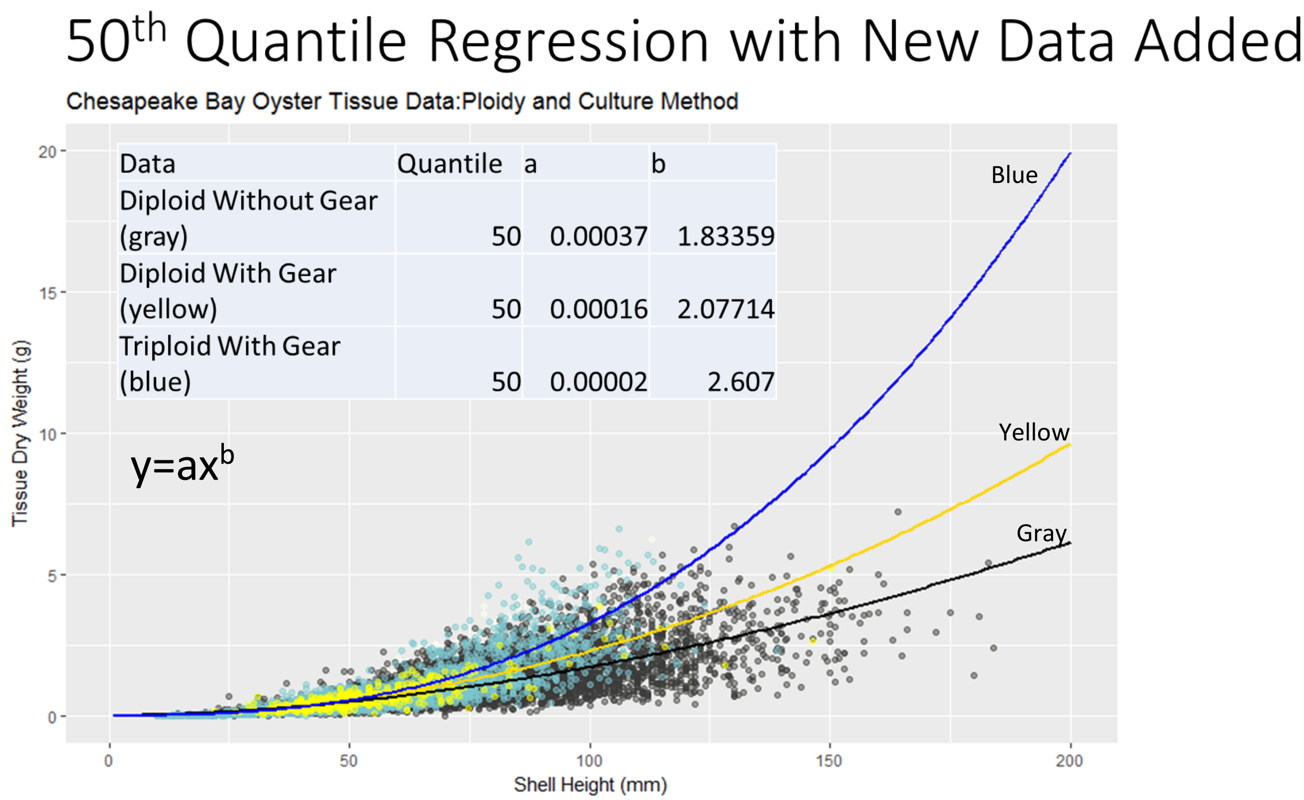


Figure H-1. Oyster shell height to tissue dry weight 50th quantile regression with additional data on ploidy and culture method: diploid without gear (gray), diploid with gear (yellow), triploid with gear (blue).

The quantile regression analysis using the additional data described in Table H-1 generated three distinct curves for oysters greater than 50 mm (~ 2 inches) shell height. Triploid oysters had greater tissue biomass than diploid oysters grown with or without gear (Figure H-1). Diploid oysters grown in gear had greater tissue biomass than diploid oysters grown without gear (Figure H-1). Estimates of nitrogen and phosphorus removed from harvested tissue were generated from these three equations and compared with estimates from the first report (Table H-2).

The tissue contents for diploid oysters grown without gear were unchanged relative to the contents generated using oysters grown with and without gear in the first report (Table H-2). The Panel agreed that the decrease in nitrogen by 22 lbs per million oysters in the largest size class (6-inch midpoint) was not a substantial change. Moreover, oysters this large are not typically harvested, which reduces the likelihood that total nitrogen reduction from harvest would be overestimated by using the approved equation. As a result, the Panel concluded that the reduction estimates for diploid oysters grown with and without gear from Reichert-Nguyen et al. (2016) would be appropriate to use for licensed oyster harvest practices.

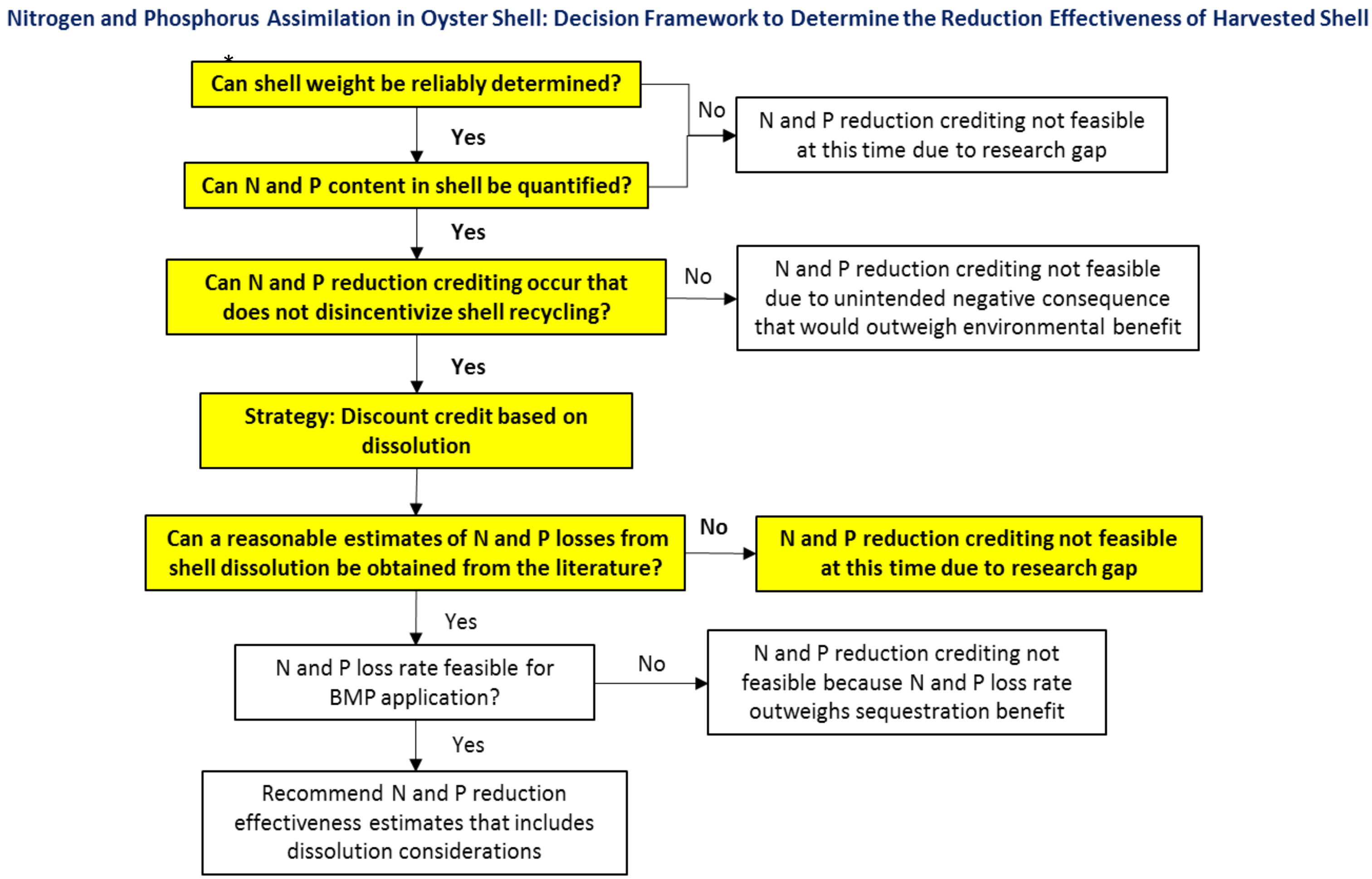
The reduction estimates for diploid and triploid oysters grown in gear increased substantially relative to the approved estimates in the first report (Table H-2). While not relevant for the licensed oyster harvest practices, the Panel recommends that the approved estimates are re-evaluated for the private oyster aquaculture practices that use gear and oysters with different ploidy.

Table H-2. Change in oyster tissue N & P reduction estimates (lb per million oysters) relative to approved reductions from Reichert-Ngyuen et al. (2016) for different combinations of ploidy and culture type when adding new data.

Size Class Midpoint (in)	Size Class Midpoint (mm)	Diploid				Triploid	
		Without Gear		With Gear		With Gear	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus
2.25	57	0	0	+22	0	0	0
3	76	0	0	+45	0	0	0
4	102	0	0	+110	0	+44	0
5	127	0	0	+198	+22	+132	0
6	152	-22	0	+309	+44	+287	+44

H.2 Literature Review and Recommended Reduction Effectiveness Determination Framework for Nitrogen and Phosphorus Assimilated in Shell of Harvested Oysters

This section describes the Panel's recommended decision framework and strategies to determine the reduction estimates for nitrogen (Protocol 2) and phosphorus (Protocol 5) assimilated into shell of harvested oysters. This framework would be applied for private oyster aquaculture or licensed oyster harvest practices. Oyster shell is a limited resource and the successful implementation of oyster practices to enhance oyster recruitment, survival, and growth is dependent on the availability of shell. Therefore, the Panel agreed that recommendations for implementing these practice-protocol combinations should not negatively impact oyster practices that rely on the return of harvested shell to the Bay by unintentionally incentivizing the collection of shell to receive credit. Such an unintended consequence would outweigh any water quality benefit. The Panel proposes implementing the decision framework in Figure H-2 to allow for nutrient reduction credit from assimilation in the shell of harvested oysters while not disincentivizing shell recycling.



*Bolded yellow decision boxes indicate the current decision pathway. Overall, research is lacking to assign a dissolution rate regarding shell returned to the Chesapeake Bay.

N = Nitrogen, P = Phosphorus

Figure H-2. The Panel's recommended decision framework to determine the reduction effectiveness of harvested shell.

The Panel agreed that shell dry weight and the amount of nitrogen and phosphorus assimilated in shell can be reliably quantified with existing data. Since percent nitrogen and phosphorus content in oyster shell is well constrained (Appendix E; Table E-2 & E-3), the Panel agreed that the values applied for the restoration-shell assimilation protocols could be applied to aquaculture-shell assimilation protocols.

To convert shell height to shell dry weight, a similar strategy applied in Appendix E could be implemented to develop Bay-wide shell quantile regression equations for harvested oysters. Separate quantile regression equations may be needed for diploid and triploid oysters (following tissue regression equations in Reichert-Nguyen et al. 2016). Data currently exist for oysters harvested from private oyster aquaculture (Higgins et al. 2011, Cubillo et al. 2018) and licensed oyster harvest practices (Powell et al. 2015) that could contribute to generating these regressions.

The Panel agreed that including a step that discounts the reduction credit based on shell dissolution (1) accounts for returning shell to the Bay and (2) reduces risk to shell recycling programs. The dissolution value will be based on relevant research (Table H-3). This approach assumes that 100% of harvested shell will be returned to the Chesapeake Bay to create no incentive to keep shell on land. This assumption can be adjusted once more is known about the fate of shell (e.g., dissolution rates, burial).

The Panel reviewed the literature to assess whether there was enough information to estimate nitrogen and phosphorus loss from shell dissolution. The Panel found several studies that examined shell loss rates and decay (Table H-3), but only one study directly measured shell dissolution. These studies measured carbonate loss only; nitrogen and phosphorus loss were assumed to be proportional to carbonate loss. The Panel concluded that there is not currently enough information to determine the fate of harvested shell once it is returned to the Bay. Spatial variability in environmental conditions and geochemical processes could alter the mechanisms of shell loss, burial, and dissolution in different locations; therefore, additional research is required to understand the long-term storage of nitrogen and phosphorus in harvested shell before the reduction effectiveness for private oyster aquaculture and licensed oyster harvest practices can be determined.

Table H-3. Summary of shell dissolution results and conclusions from literature review.

Study Group	Summary of Findings	Conclusions
Annual shell loss rates from field studies in Delaware Bay and James River	Powell et al. 2006 Delaware Bay: Half-life of shell added in a given year ranges from 2-10 years. Intermediate salinities have shortest half-lives. Avg shell loss rate per year ranged from 5-37%. Mann et al. 2009 James River: Most shell loss rates are >20% per year for high and medium relief reefs, with many between 30-50% per year; suggests shell half lives of less than or equal to 3 yrs for high and medium relief reefs	In these two well-managed study areas, sedimentation rates are very low, so these rates were assumed to be a result of dissolution. In other areas, sedimentation could be significant such that it limits shell production and changes dissolution rates.
Instantaneous shell decay rates based on field studies	Jordan-Cooley et al. 2011; DePiper et al. 2016: instantaneous rate of shell decay 0.5-0.9 per year based on Smith et al. 2005: determined how long it took shell to reach various degraded conditions. Wilberg et al. 2011: instantaneous decay rates of 0.45 per year for market size and 0.52 per year for small size oysters based on Christmas et al. 1997: determined time-since-death required for oyster disarticulation.	
Shell dissolution rates lab study	Waldbusser et al. 2011: Weathered shell degraded from 0.06-0.15% per day depending on pH. Fresh shell degraded faster than weathered or dredged shell. Shell dissolution generally increased with increasing pH.	Only study directly measuring dissolution. Concern that lab conditions do not adequately account for ecosystem processes.

H.3 References

Christmas JF, McGinty MR, Randle DA, Smith GF, Jordan SJ (1997) Oyster shell disarticulation in three Chesapeake Bay tributaries. J Shellfish Res 16:115-123

Cubillo AM, Bricker SB, Parker M, Ferreira JG (2018) NCCOS Ecological Assessment to support NOAA's Choptank Complex Habitat Focus Area: Eutrophication and shellfish aquaculture/restoration ecosystem services modeling. Final report submitted to NOAA NCCOS, Cooperative Oxford

Laboratory by Longline Environmental, Ltd., National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Silver Spring, MD.

DePiper GS, Lipton DW, Lipcius RN (2016) Valuing Ecosystem Servies: Oysters, Denitrificaiton, and Nutrient Trading Programs. Marine Resource Economics 32. http://dx.doi.org/10.1086/688976

Higgins CB, Stephenson K, Brown BL (2011) Nutrient Bioassimilation Capacity of Aquacultured Oysters: Quantification of an Ecosystem Service. *Journal of Environment Quality* 40: 271

Jordan-Cooley WC, Lipcius RN, Shaw LB, Shen J, Shi J (2011) Bistability in a Differential Equation Model of Oyster Reef Height and Sediment Accumulation. Journal of Theoretical Biology 289: 1-11

Mann R, Southworth M, Harding JM, Wesson JA (2009) Population Studies of the Native Eastern Oyster, Crassostrea virginica, (Gemlin, 1791) in the James River, Virginia, USA. J Shellfish Res 28: 193-220

Powell EN, Kraeuter JN, Ashton-Alcox KA (2006) How long does oyster shell last on an oyster reef? Estuarine Coastal Shelf Sci 69: 531-542

Powell EN, Mann R, Ashton-Alcox KA, Kim Y, Bushek D (2015) The allometry of oysters: spatial and temporal variation in the length-biomass relationships for *Crassostrea virginica*. *Journal of the Marine Biological Association of the United Kingdom* 96: 1127-1144

Reichert-Nguyen J, Cornwell J, Rose J, Kellogg L, Luckenbach M, Bricker S, Paynter K, Moore C, Parker M, Sanford L, Wolinski B, Lacatell A, Fegley L, Hudson K, French E, Slacum W (2016) 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. https://www.oysterrecovery.org/wp-content/uploads/2017/01/Oyster-BMP-1st-Report_Final_Approved_2016-12-19.pdf (accessed 30 July 2022)

Smith GF, Bruce DG, Roach EB, Hanson A, Newell RIE, McManus AM (2005) Assessment of Recent Habitat Conditions of Eastern Oyster Crassostrea virginica Bars in Mesohaline Chesapeake Bay. North American Journal of Fisheries Management 25: 1569-1590

Waldbusser GG, Steenson RA, Green MA (2011) Oyster Shell Dissolution Rates in Estuarine Waters: Effects of pH and Shell Legacy. J Shellfish Res 30: 659-669

Wilberg MJ, Livings ME, Barkman JS, Morris BT, Robinson JM (2011) Overfishing, disease, habitat loss, and potential extirpation of oysters in upper Chesapeake Bay. Mar Ecol Prog Ser 436: 131-141

Appendix I: Research Gaps for Applying Denitrification Protocols to Oyster Harvest and Restoration Practices Using Large Substrates

This appendix provides a synopsis of information currently available for developing BMP recommendations for harvest- and aquaculture-denitrification protocols. The Panel agreed that private oyster aquaculture and licensed oyster harvest practices may have the potential to remove nitrogen via microbial denitrification; however, the Panel agreed that data were too sparse at this time to develop BMP recommendations for these practices in this report. This appendix also provides considerations to apply restoration-denitrification protocols to reefs restored using large substrates (e.g., ReefBalls™, Oyster Castles®).

I.1 Literature Review of Enhanced Denitrification for Oyster Aquaculture and Licensed Oyster Harvest Practices

A review of the current peer-reviewed literature indicates that few denitrification studies have been conducted in areas where oysters are harvested. Three studies evaluated denitrification associated with off-bottom private oyster aquaculture practices. Two studies estimated denitrification rates associated with on-bottom aquaculture practices.

I.1.1 Off-Bottom Aquaculture Studies

Currently in the Chesapeake region, there are only three water column aquaculture studies that are useful for consideration of an oyster harvest denitrification BMP:

- **Higgins et al. (2013)** assessed denitrification rates in floating rafts within St. Jerome Creek, MD and Spencer's Creek. VA. St. Jerome Creek was open with a sandy bottom, while Spencer Creek was a very shallow, low-energy site in a cove. Sampling took place four times in St. Jerome Creek and three times in Spencer Creek. Denitrification was measured from homogenized sediment with ^{15}N amendments, and therefore should be regarded as "potential rates" that have a tenuous connection to areal rates. Denitrification rates were also estimated using the N_2:Ar approach with intact cores, with rates generally similar to the ^{15}N potential rates. Most oyster N_2 flux rates (cores at site) were 25-65 µmol N m^{-2} h^{-1}. The rates in the aquaculture area were lower than those observed at control sites and the effects of benthic microalgae were not evaluated. Considerable effort was devoted to determining the oyster biodeposition rates, with variable total nitrogen (sum of all forms) flux rates below the floats (70-590 µmol N m^{-2} h^{-1}). Intact core releases of ammonium were considerably higher under floats than in control areas.
- **Testa et al. (2015)** assessed denitrification rates and benthic fluxes of nitrogen in floating aquaculture cages at Marinetics Inc. oyster farm (now the Choptank Oyster Company) on

LeCompte Bay on the Choptank River, MD. The specific study site is located at Castle Haven Point in a relatively high energy environment. Denitrification and nutrient fluxes were measured in sediments under the floats (farm site) and at two control sites (near farm and reference sites). Fluxes were measured using the N_2:Ar approach under both dark and light conditions four times throughout the growing season. In addition, sedimentation rates were measured directly under floats, at the sediment surface, and at control sites. Average denitrification rates at the farm, near-farm, and reference sites were 55.8 ± 20.8, 72.8 ± 21.4, and 56.6 ± 16.1 µmol N m^{-2} h^{-1}, respectively. Average ammonium flux rates at the farm, near-farm, and reference sites were 394, 127, and 21.8 µmol N m^{-2} h^{-1}, respectively. Thus, in the footprint of the floats, decreased denitrification and increased ammonium effluxes suggest the sediments are overloaded with biodeposits. However, if the whole system is examined, the sediment nitrogen cycling rates at the site are inconsistent with the N biodeposition rates. A mass balance indicates that the downward flux of nitrogen biodeposits (3,714 µmol N m^{-2} h^{-1}) is much larger than the net deposition to footprint sediments, suggesting a net export of almost 90% of biodeposits. If the exported biodeposits are denitrified at rates similar to those measured in nearby sediments, the net denitrification associated with aquaculture may be positive instead of negative (Figure I-1).

- **Lunstrum et al. (2018)** examined denitrification and benthic fluxes of nitrogen and oxygen in a “rack and bag” oyster farm in Cherrystone Inlet of the Virginia Eastern Shore. Nutrient incubations were carried out similar to those in Testa et al. (2015), with measurement sequentially made using 1) the N_2:Ar approach for denitrification and 2) the ^{15}N isotope pairing approach, using $^{15}NO_3^-$ additions. In addition, the $^{15}NH_4^+$ generated was used as a measure of DNRA (dissimilatory nitrate reduction to ammonium), a process that competes with denitrification. Maximum aquaculture denitrification rates were very low (19.2 µmol N m^{-2} h^{-1}) and were dwarfed by the high efflux of ammonium (maximium 900 µmol N m^{-2} h^{-1}). Thus, at this site denitrification was a minor process in the footprint of the aquaculture farm.

Combined, these three studies suggest that the increase in ammonium efflux associated with oyster aquaculture is proportionately much larger than any increases in denitrification. This suggests that the sediment conditions beneath off-bottom aquaculture leases may not always be conducive to enhancing denitrification (Burkholder & Shumway 2011), and that the potential consequences of enhanced ammonium may negate any enhancements in denitrification within the aquaculture lease footprint.

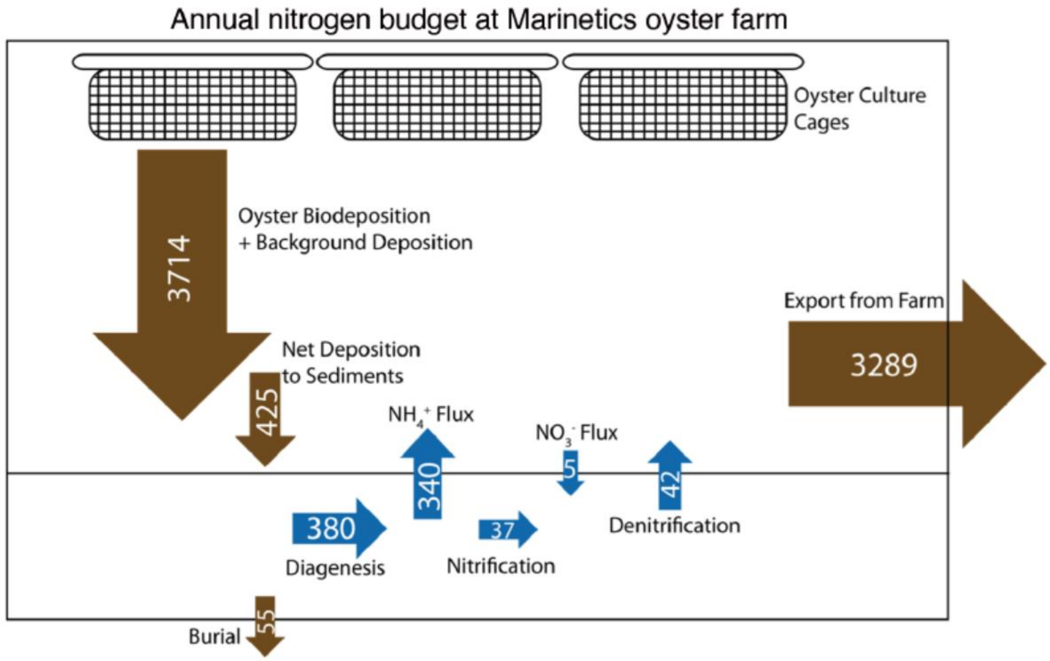


Figure I-1. Annual nitrogen balance at Marinetics oyster farm from Testa et al. (2015). All rates are µmol $m^{-2}h^{-1}$. These are modeled rates with a strong correspondence to measured rates.

I.1.2 On-Bottom Aquaculture and Licensed Oyster Harvest Studies

The Panel identified two studies that assessed denitrification rates on on-bottom aquaculture:

- **Humphries et al. (2016)** assessed denitrification rates on restored oyster reefs and on-bottom aquaculture areas in a shallow estuary in Rhode Island. The measurements were made with bottom chambers fixed to a ring inserted into the substrate and used the N_2:Ar approach. Restored oyster reefs and on-bottom oyster aquaculture both greatly increased the rates of denitrification relative to bare sediments and sediments only containing cultch. The aquaculture denitrification rates (mean ± S.E. 346 ± 169 µmol m^{-2} h^{-1}) were 14 times higher than rates on bare sediment.
- **Jackson et al. (2018, 2019)** assessed denitrification rates in sediment cores from an on-bottom oyster aquaculture lease that was planted with spat on shell in the Nanticoke River, MD. The N_2:Ar approach was used to measure denitrification. Rates were elevated in spring and fall relative to sediment that was not planted, with rates in the spring occurring at 4 times the rate on bare sediment (Jackson 2019). Since denitrification was measured in sediment cores rather than within the reef itself, rates may be conservative (Jackson et al. 2018).

Collectively, these studies suggest that on-bottom aquaculture enhances denitrification rates relative to un-treated sediments. The timing of sampling will be especially important as denitrification rates may vary based on when and how often oyster harvest and replenishment (planting shell or spat on shell) occur.

No studies were identified that assess denitrification rates on reefs in harvest areas.

I.2 Research Gaps and Considerations Associated with Enhanced Denitrification for Oyster Aquaculture and Licensed Oyster Harvest Practices

Through their literature review, the Panel concluded that estimates of enhanced denitrification cannot be made for practices where oysters are harvested (private oyster aquaculture, licensed oyster harvest) at this time because data is lacking that demonstrates an enhancement in denitrification and nitrogen reduction. The Panel also found that there is no research on the influence of harvest on denitrification rates.

Broadly, the Panel recommends additional studies that (1) better define temporal changes (over 1-2 years) in the biogeochemistry in areas that received spat on shell or shell additions and (2) examine post-harvest denitrification and nutrient balances. Control sites should be carefully selected to contain similar sediment characteristics as those beneath or around an aquaculture site or harvest area. Collecting baseline data on denitrification rates prior to the addition of shell or spat on shell would also be useful for estimating denitrification enhancement.

The following sections describe specific research needs and considerations for different culture types.

I.2.1 Off-Bottom Aquaculture Considerations

There is limited understanding on how denitrification associated with off-bottom oyster aquaculture results in a reduction of nutrients from the water column. Since oysters are near the surface, less disturbance of benthic sediments and biodeposits may occur which may reduce the likelihood that sequestered nitrogen is resuspended. However, the Panel agreed that oyster biodeposits are more likely to be swept away by water currents before reaching the seafloor than retained. It is possible that the export of biodeposits may result in off-site denitrification enhancements. The advection of biodeposits may also occur in oyster reef restoration settings but has not yet been assessed.

Specific questions for future research include:

- Can the proportion of off-site deposition and remineralization of oyster biodeposits be estimated?
- Can an estimate of oyster biodeposit export, denitrification rates, and denitrification efficiency in surrounding areas be used to estimate enhanced denitrification associated with oyster practices?

- What is the fate of the remineralized nitrogen within oyster floats and cages and does denitrification occur in close association with the oysters?

To assess the complete effects of off-bottom aquaculture on denitrification rates, study designs should consider areas beyond the lease site (Figure I-2). It is possible that net denitrification occurs if biodeposits are dispersed to the surrounding ecosystem. An understanding of all fates of seston is required to quantify the export of biodeposits. Specifically, studies should:

- Determine sediment denitrification and other N cycling processes in the aquaculture footprint, areas potentially subject to biodeposit deposition, and control areas (Process 3A, 3B in Figure I-2).
- Measurement of water column respiration and/or water column nitrogen remineralization (Process 4, Figure I-2).
- Biodeposit downward flux as a measure of biodeposit input to the ecosystem (Process 1A).
- Estimation of biodeposit export (Process 4A). This can be accomplished by direct measurement of biodeposit export using current meters and seston filtration; there are no studies published on this approach. Alternatively, modeling remineralization of N in the footprint to back-calculate net deposition/retention can result in an export calculation by difference (Process 1A minus the net deposition predicted by process 2A).
- An understanding of direct nutrient processing and release to the water column from the floats/bags may be valuable for determining the net water quality value.

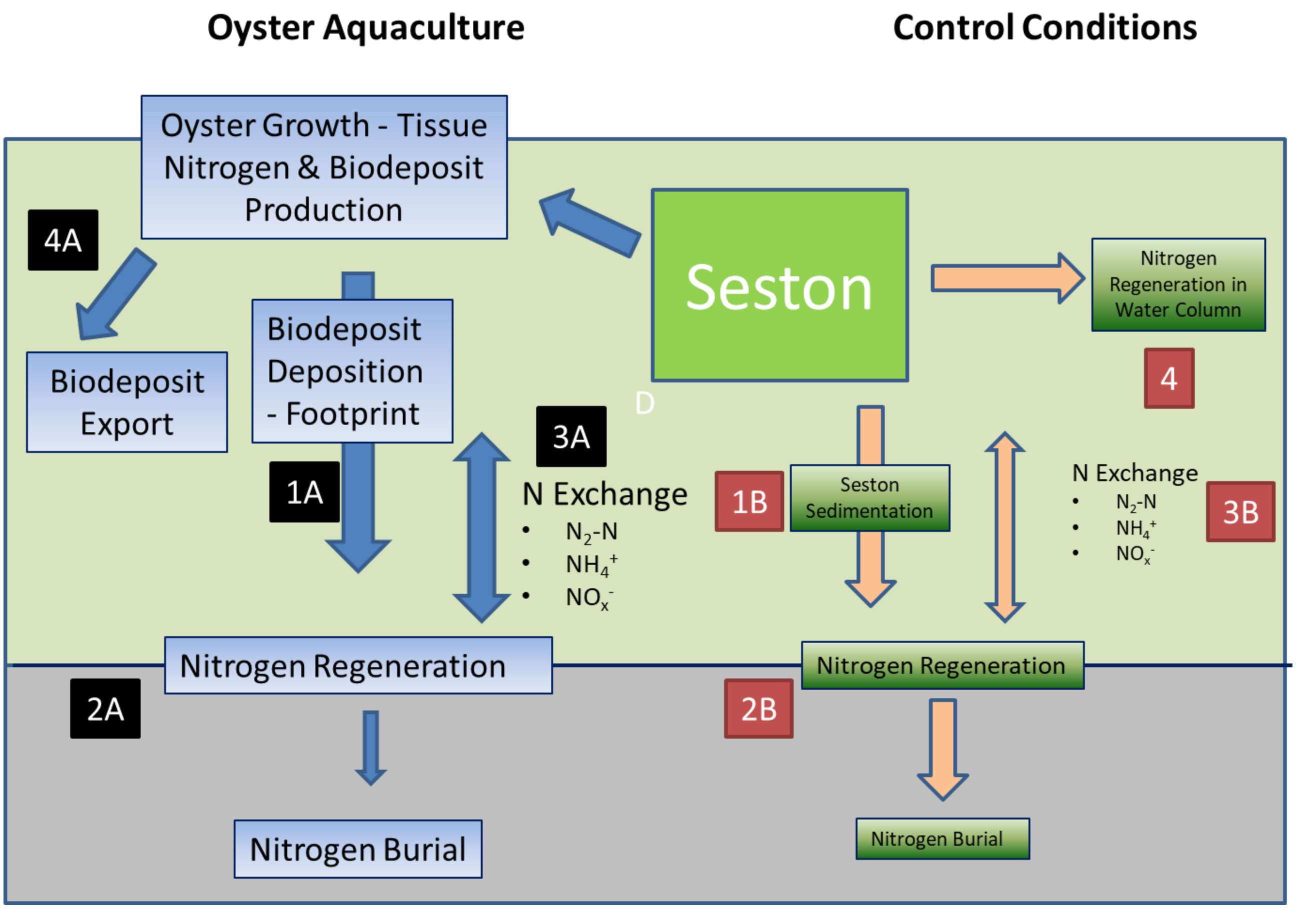


Figure I-2. Elements of measurement needed for estimating net biogeochemical nitrogen removal from the ecosystem. Prior to the addition of oysters, N is regenerated in the water column (4) and sediments (2B) after deposition (1B), leading to the exchange of dissolved N, leading to denitrification (N_2-N) and N burial. The addition of oysters increases the downward flux of N as biodeposits (1A, 4A), leading to N regeneration and production of N_2-N and other N species. The net value of denitrification from adding oysters is the denitrification that is observed in the footprint of the oyster float plus the denitrification of biodeposits exported elsewhere, minus the denitrification that would have occurred without oyster additions.

I.2.2 On-Bottom Aquaculture and Licensed Oyster Harvest Considerations

No information exists on the denitrification rates associated with on-bottom oyster aquaculture or in harvest areas. The act of harvesting oysters may disrupt biogeochemical processes with negative or positive consequences for microbial denitrification. For future studies, the timing of sampling will be important as denitrification rates may vary based on when and how often oysters are harvested or planted. For licensed oyster harvest, a time series of denitrification rates from the planting of spat on shell or shell through harvest, and for a period (1-2 years) after harvest would be useful for assessing the impact of harvest on denitrification. Since on-bottom aquaculture and licensed oyster harvest practices typically occur on reefs rather than in gear, approaches (e.g., Humphries et al. 2016) that sample the entire benthic community (sediments, oysters, other fouling organisms) may be useful for estimating realistic denitrification rates.

For on-bottom aquaculture practices, assessments of oyster biomass will be key for estimating enhanced denitrification. The Panel recommends that nitrogen reduction credit associated with denitrification for aquaculture practices only be allowed prior to harvest (Reichert-Nguyen et al. 2016).

Specific research questions include:

- How soon after oyster deployment does enhanced denitrification start and what is the short-term trajectory of denitrification as oysters mature?
- What is the effect of harvest on the denitrification process? Are initial benefits minimized by harvest-related disturbance? Are there negative consequences associated with increased biodeposition or changes to phosphorus dynamics?
- Are there minimum rates of enhanced denitrification that can be broadly applied to on-bottom aquaculture?
- Are biodeposits exported beyond oyster communities, resulting in off-site denitrification?

I.3 Denitrification Associated with Oyster Restoration Practices Using Large Substrates

Large structures for the creation of fish habitat and for shoreline protection can also enhance oysters in certain areas and under certain conditions. For example, concrete structures such as ReefBalls™ have been deployed by the Coastal Conservation Association (https://www.ccamd.org/living-reef-action-campaign/) and the Chesapeake Bay Foundation (https://www.baltimoresun.com/news/environment/bs-md-reef-balls-20170621-story.html) to enhance fish habitat. In several cases, post-deployment monitoring identified that oysters had settled on these structures. In some cases, concrete structures such as Oyster Castles®(inter-locking concrete blocks) have been inoculated with oyster spat prior to deployment (https://blog.nwf.org/2020/11/greening-the-grey-to-grow-more-oysters-in-the-bay/).

There are no published data on nutrient removal associated with oyster ReefBalls™ or Oyster Castles® but efforts are being made to determine their value in oyster-related denitrification. Preliminary results from unpublished research (Cornwell, Owens, Colden, Gray unpubl.) show elevated rates of denitrification on these large substrates relative to reefs restored with small substrates (Figure I-3). Additional measurements of denitrification rates in different settings would be needed to 1) suggest a standard methodology for measuring denitrification rates on these substrates and 2) identify whether rates are related to oyster biomass. In addition, a comparison of the ex-situ approach used by Cornwell, Owen, Colden, Gray (unpubl.) to in-situ methodology would provide added information about scaling up incubation of individual units to deployments on larger structures.

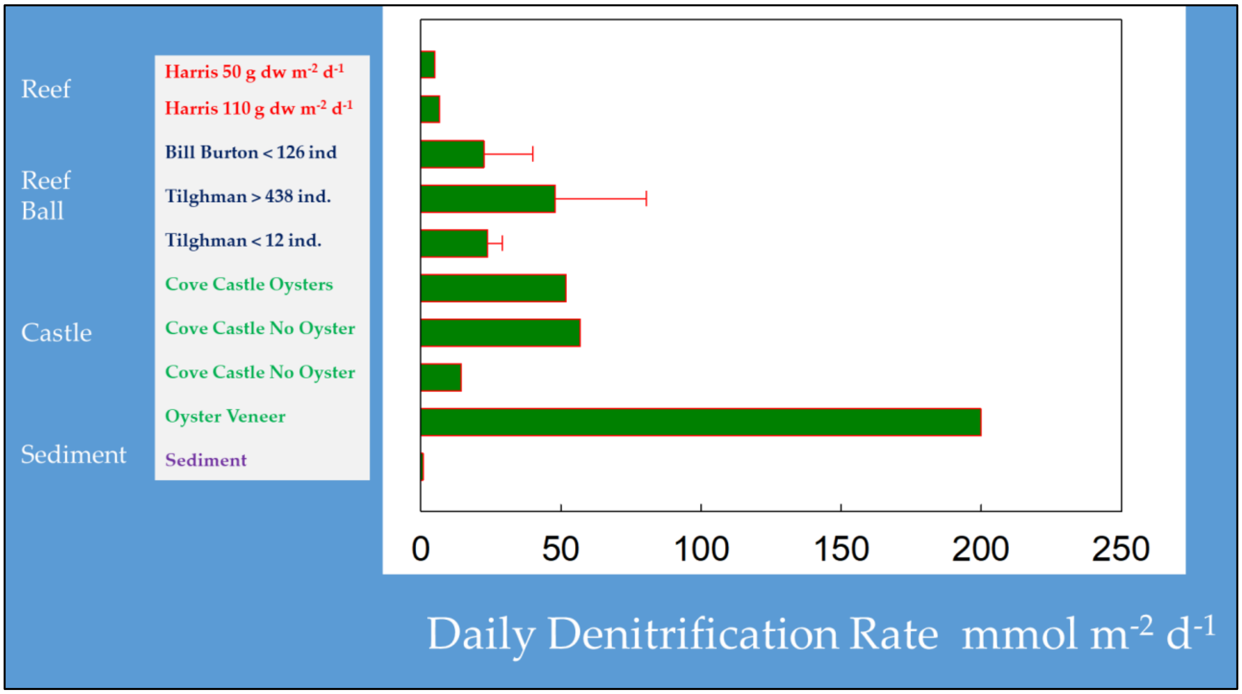


Figure I-3. Daily denitrification rate per unit area on different restoration substrates and in different locations in Chesapeake Bay. Harris = oyster reef restoration using hatchery produced oysters in Harris Creek, MD; Bill Burton and Tilghman = restoration using ReefBalls™ in Choptank River and Tilghman Island, MD; Cove = restoration using Oyster Castles© in Choptank River, MD; Oyster Veneer = restoration using Oyster Castles© and rock in Choptank River, MD; Sediment = no restoration, muddy bottom in Choptank River, MD. Data from Cornwell, Owens, Colden, Gray unpubl. data.

I.4 References

Burkholder JM, Shumway SE (2011) Bivalve shellfish aquaculture and eutrophication. In: SE Shumway (ed.), Shellfish Aquaculture and the Environment, First Edition. John Wiley & Sons, Inc, p. 155-215

Higgins CB, Tobias C, Piehler MF, Smyth AR, Dame RF, Stephenson K, Brown BL (2013) Effect of aquacultured oyster biodeposition on sediment N_2 production in Chesapeake Bay. Mar Ecol Prog Ser 473: 7-27

Humphries AT, Ayvazian SG, Carey JC, Hancock BT, Grabbert S, Cobb D, Strovel CJ, Fulweiler RW (2016) Directly measured denitrification reveals oyster aquaculture and restored oyster reefs remove nitrogen at comparable high rates. Front Mar Sci 4: https://doi.org/10.3389/fmars.2016.00074

Jackson ML, Owens MS, Cornwell JC, Kellogg ML (2018) Comparison of methods for determining biogeochemical fluxes from a restored oyster reef. PLoS One 13: e0209799

Jackson ML (2019) Characterization of oyster-associated biogeochemical processes in oyster restoration and aquaculture. Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, and the University of Maryland Center for Environmental Science, in partial fullfillment of the requirements for the degree of Doctor of Philosophy.

Lunstrum A, McGlathery K, Smyth A (2018) Oyster (*Crassostrea virginica*) Aquaculture Shifts Sediment Nitrogen Processes toward Mineralization over Denitrification. Estuaries Coasts 41:1130-1146

Reichert-Nguyen J, Cornwell J, Rose J, Kellogg L, Luckenbach M, Bricker S, Paynter K, Moore C, Parker M, Sanford L, Wolinski B, Lacatell A, Fegley L, Hudson K, French E, Slacum W (2016) 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. https://www.oysterrecovery.org/wp-content/uploads/2017/01/Oyster-BMP-1st-Report_Final_Approved_2016-12-19.pdf (accessed 30 July 2022)

Testa JM, Brady DC, Cornwell JC, Owens MS, Sanford LP, Newell CR, Suttles SE, Newell RIE (2015) Modeling the impact of floating oyster (Crassostrea virginica) aquaculture on sediment-water nutrient and oxygen fluxes. Aquaculture Environment Interactions 7: 205-222

Appendix J. Chesapeake Bay Program Modeling Integration on Assessment of Oyster Influence on Chesapeake Water Quality

Carl Cerco, Lew Linker, and Richard Tian, CBP Modeling Team

Suggested Citation:
Cerco, C., Linker, L., Tian, R. 2021. Chesapeake Bay Program Modeling Integration on Assessment of Oyster Influence on Chesapeake Water Quality. In, Nitrogen and phosphorus reduction associated with harvest of hatchery-produced oysters and reef restoration: Assimilation and enhanced denitrification: Panel recommendations. Report submitted to the Chesapeake Bay Program Partnership Water Quality Goal Implementation Team January 30, 2023.

J.1 Introduction

Bivalve filter feeders were introduced in the Chesapeake Bay Model as part of the Tributary Refinements phase (Cerco et al. 2002). The initial representation included two freshwater species, *Corbicula flumenea* and *Rangia cuneata*, and one saltwater species, *Macoma balthica*. Subsequently, native oysters, *Crassostrea virginica*, were substituted for *Macoma* to investigate the potential impact of a tenfold increase in native oyster population (Cerco & Noel 2007). Oysters were included in the 2010 model version but received limited attention. Their activity was not explicitly incorporated into the 2010 TMDL. Oysters are the subject of renewed attention because of increases in the natural population in sanctuaries and the tremendous growth of the aquaculture industry. Nutrient removal credits associated with oyster restoration and with aquaculture will be included in future nutrient management plans. Renewed management attention demands a corresponding renewal of the oyster module in the 2017 Chesapeake Bay Water Quality and Sediment Transport Model (WQSTM). Representation of the freshwater bivalves is unchanged from the previous model version (Cerco & Noel 2010).

J.2 Oyster Model Basics

The revised oyster module considers four populations. The influence of the four populations on Chesapeake water quality are made by an integrated approach by the Oyster BMP Expert Panel and the WQSTM so that double counting of the influence is avoided. The populations are:

- Natural populations on public reefs and subject to harvest – simulated by the WQSTM.
- Natural populations in sanctuaries and not subject to harvest – simulated by the WQSTM with oyster harvest mortality set to zero.
- Natural populations in sanctuaries, not subject to harvest, and with rebuilt/enhanced oyster habitat– estimated by Oyster BMP Expert Panel procedures and approaches.
- Aquaculture operations - estimated by Oyster BMP Expert Panel procedures and approaches for nutrients in soft tissue harvested and by the WQSTM for biogeochemical processes resulting from oyster aquaculture biomass.

Application of the WQSTM to each population requires resolution of the following issues:

- Location
- Biomass
- Model parameterization

J.2.1 Mass-Balance Equation

The fundamental mass-balance equation for the filter feeders is shown in equation 1:

$$\frac{dO}{dt} = \alpha \cdot Fr \cdot POC \cdot IF \cdot (1 - RF) \cdot O - BM \cdot O - \beta \cdot O - H \cdot O \qquad (1)$$

where:

O = oyster density (g C m^{-2})
α = assimilation efficiency ($0 < \alpha < 1$)
Fr = filtration rate (m^3 g^{-1} C d^{-1})
POC = particulate organic carbon (g m^{-3})
IF = ingestion fraction ($0 < IF < 1$)
RF = respiration fraction ($0 < RF < 1$)
BM = basal metabolism (d^{-1})
β = mortality (d^{-1})
H = harvest rate (d^{-1})

Parameter values in the governing equation are largely as described by Cerco & Noel (2007).

Oyster reefs occupy small fractions of model computational cells, which average 1 km by 1 km in extent. The "foraging arena" concept was introduced in the model to represent the limited encounters between predators and prey induced by the small fraction of each computational cell occupied by reefs (Cerco & Noel 2010). We found, however, that the computed biomass of oysters, in g C, was excessive when the computed density, in g C m^{-2}, was multiplied by the cell area. We also found that the potential impact of oysters on prey was exaggerated despite the foraging arena. Consequently, the concept of "coverage" is introduced in the WQSTM. Coverage is the fraction of cell area occupied by oyster reefs. Biomass is computed as the product of density, cell area, and fraction of cell covered by reefs. Corrections for coverage are also introduced into the mass-balance equations for mass transfers between oysters and their surroundings.

J.2.2 Modifications for Aquaculture

Oyster density in each cell, as computed by equation 1, varies spatially and temporally depending on local conditions. Aquaculture operations, including year-round planting and harvesting, tend to reduce the intraannual and interannual oscillations that occur in natural oyster beds. The spatial distribution of oyster biomass depends on the location of aquaculture operations. Water quality managers wish to explore the impacts of varying levels of aquaculture activity, which has led to a model representation in which oyster density in each cell is a specified constant value. Setting dO/dt = 0 in equation 1 leads to the representation in equation 2:

$$IF = \frac{BM+\beta+H}{\alpha \cdot Fr \cdot POC \cdot (1-RF)} \qquad (2)$$

The ingestion fraction becomes a variable rather than a parameter, as in equation 1. Employment of the variable ingestion fraction in the balance of the model formulations results in a constant oyster density, which is specified at model initiation.

In the event the rate of biomass loss (represented in the numerator on the right-hand side of equation 1) exceeds food intake (represented in the denominator), the computed ingestion fraction will exceed unity. That situation is physically impossible, although the model will operate under those conditions. Consistent computation of an ingestion fraction greater than unity indicates that oysters cannot persist at the specified density under modelled conditions. Either sufficient food resources are unavailable or losses from respiration, mortality, and harvest exceed sustainable levels.

J.3 Location

J.3.1 Natural Population

More than 8,000 oyster bars were located as part of a 2008 study of oyster restoration alternatives (MD DNR 2008). Bar locations were mapped to the model grid and consolidated by cell (Figure J-1). The total bar area in each cell was employed to compute coverage (see section J.2, *Oyster Model Basics*). Oyster bars occurred in 2,068 of the 11,064 model surface cells. Coverage for those 2,068 cells ranged from less than 0.01 percent to 100 percent. The median coverage was 5 percent and was less than 10 percent for the vast majority of cells with oyster bars.

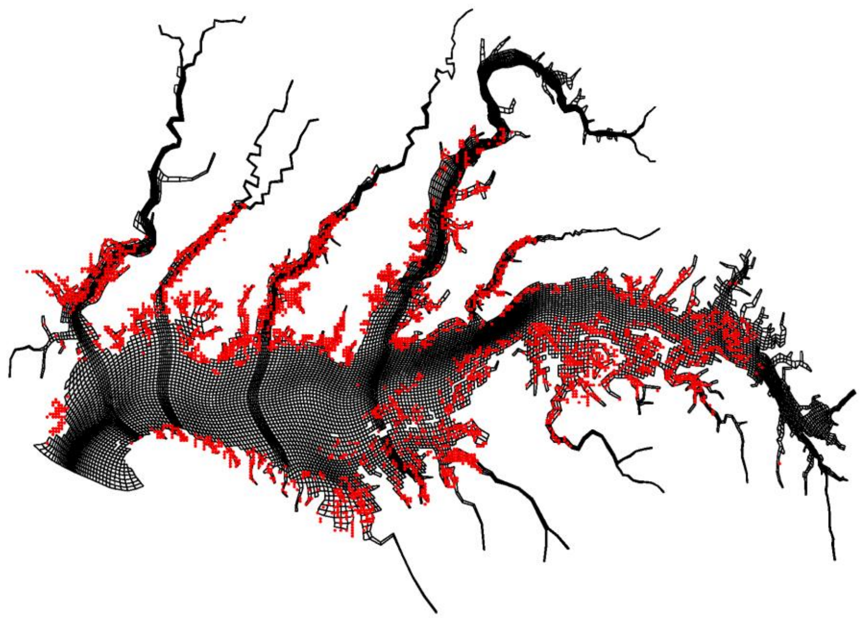


Figure J-1. Location of natural oyster bars mapped to model grid.

J.3.2 Sanctuaries

Locations of oyster sanctuaries in Maryland were obtained by the project sponsor and mapped to the model grid. Considerable overlap occurred between the location of reefs determined in 2008 and the present location of sanctuaries. In the event a natural bar and a sanctuary were coincident, we assumed the bar is presently a sanctuary.

J.3.3 Aquaculture

Locating aquaculture operations presented a considerable challenge. Although various state agencies have that information, they cannot release anything considered proprietary. For the state of Maryland, we were provided with the aquaculture harvest totals by county for the years 2014–2016 collected by Maryland Department of Natural Resources (J. Reichert-Nguyen, Oyster Recovery Partnership, pers. comm., December 21, 2016). We created a map of potential model aquaculture cells within those counties by assuming aquaculture is restricted to water less than 12 feet deep and with salinity greater than 7 parts per thousand (ppt) (Figure J-2). The depth constraint was based on assumptions regarding accessibility. The salinity constraint was determined by Cerco & Noel (2007) as the minimum required for a healthy natural population.

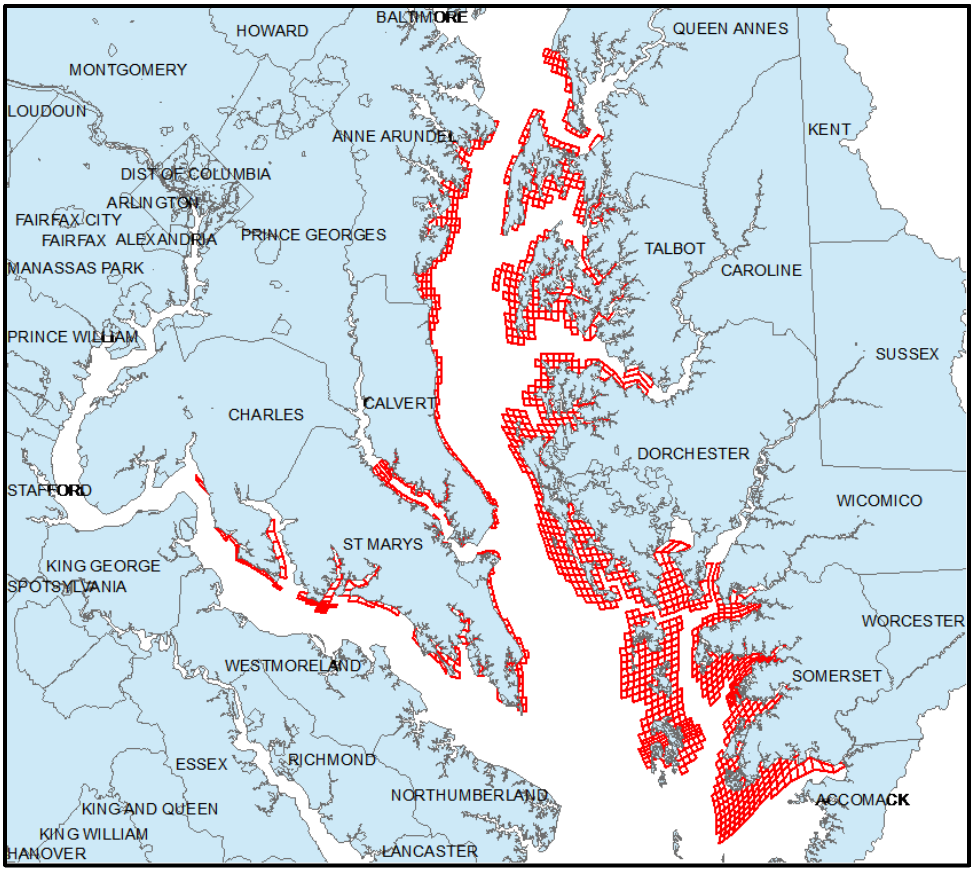


Figure J-2. Potential aquaculture cells in Maryland. Criteria are depth ≤ 12 feet and salinity > 7 ppt.

A geographic information system file was available that mapped private lease areas in Virginia. That map was superimposed on the model grid to indicate cells that contain leases (Figure J-3). Potential aquaculture cells were then limited to lease areas less than 12 feet deep and with greater than 7 ppt salinity.

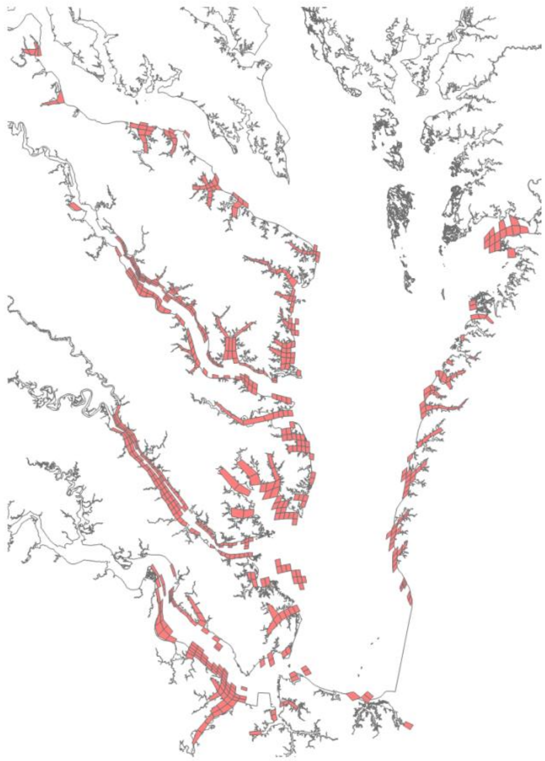


Figure J-3. Potential aquaculture cells in Virginia. Cells shown include private lease areas and meet the criteria depth ≤ 12 feet and salinity > 7 ppt.

As noted in Section J.2 *Oyster Model Basics*, it is possible to assign aquaculture to a cell that cannot support the specified level of activity. We minimized this possibility through a “self-locating” process. An exploratory model run was conducted in which oysters were assigned to all potential aquaculture cells. They were modelled as a natural population that was allowed to thrive or perish according to ambient conditions. We restricted aquaculture cells to those that supported a density of 10 mg C m^{-2} (Figure J-4).

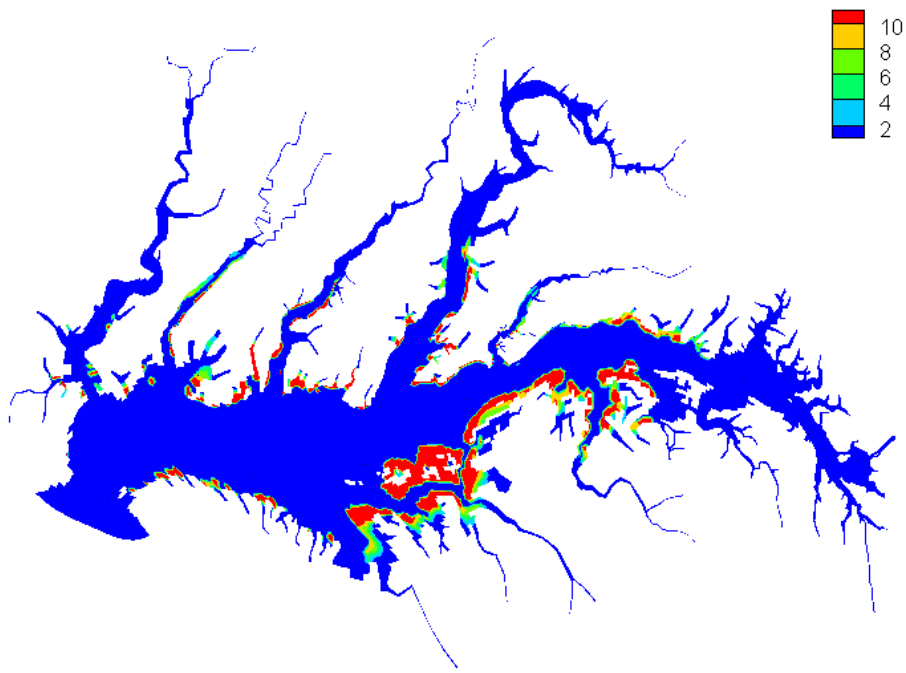


Figure J-4. Self-location of aquaculture cells. Aquaculture is restricted to areas capable of supporting a density of 10 mg C m^{-2}.

J.4 Biomass

J.4.1 Natural Population and Sanctuaries

The primary data source for the population on oyster bars is the website for the Chesapeake Bay Oyster Population Estimate (CBOPE) project, which is maintained by the Virginia Institute of Marine Science (VIMS) (VIMS 2017). The CBOPE project was conducted to monitor progress towards a tenfold increase in Chesapeake Bay oyster population called for in the Chesapeake 2000 Agreement. The site reports various categories of standing stock and harvest for Virginia (1994–2008) and Maryland (1994–2002). The state totals are reported for various basins within each state in various years. Major population categories include the following:

- Fishery-Independent Data—Collected during annual patent tong surveys in Virginia and annual dredge surveys in Maryland.

- Fishery-Dependent Data–Public/Commercial—Based on annual oyster landings reported to the Virginia Marine Resources Commission (VMRC) and the Maryland Department of Natural Resources (MDNR).
- Fishery-Dependent Data–Private Fishery—Based on reports by private leaseholders to VMRC and MDNR.

The total population in each state was considered to be the sum of the fishery-independent data plus the amount removed in public and private landings (Table J-1). For Virginia, the private landings were adjusted to remove aquaculture activities from 2005 onward. The landings, adjusted for aquaculture, were tracked separately to assist in parameter assignment of the harvest rate in equation 1.

Table J-1. Reef biomass and harvest

Year	VA Biomass (kg DW)	VA Harvest (kg DW)	VA Harvested Fraction	MD Biomass (kg DW)	MD Harvest (kg DW)	MD Harvested Fraction
1994	512560	23548	0.046	411614	21614	0.053
1995	511522	7519	0.015	512930	51930	0.101
1996	681933	9923	0.015	561680	70680	0.126
1997	471609	8606	0.018	631470	68470	0.108
1998	581486	20475	0.035	721221	122221	0.169
1999	582623	9615	0.017	736000	147000	0.200
2000	657979	9753	0.015	720555	129555	0.180
2001	698260	13246	0.019	698568	138568	0.198
2002	561166	18215	0.032	184000	40000	0.217
2003	575272	9997	0.017			
2004	734962	33864	0.046			
2005	993351	71780	0.072			
2006	819680	37747	0.046			
2007	651726	29950	0.046			
2008	1039207	28039	0.027			

J.4.1.1 Assignment to Basins

CBOPE reporting by basins was sporadic and the state data could not be reliably split by basin over the reporting period. Based on alternative data sources, 13 basins were defined (Table J-2). The Virginia basins were defined to coincide with harvest data provided by the VMRC (J. Wesson, department head, Conservation and Replenishment, pers. comm., December 30, 2016). The Virginia population was split into basins in proportion to the total public harvest taken in each basin. The Maryland basins were defined to coincide with a 1994–2006 population estimate (Greenhawk & O'Connell 2007). The Maryland population was split into basins according to the proportions in the estimate.

Table J-2. Basin fractions of total reef biomass

VA Basin	Fraction	MD Basin	Fraction
Chesapeake	0.294	Chester	0.151
James	0.354	Eastern Bay	0.076
York	0.082	Choptank	0.118
Rappahannock	0.262	Little Choptank	0.026
Potomac	0.007	Tangier Sound	0.136
		Potomac	0.074
		Patuxent	0.037
		Chesapeake	0.371

J.4.2 Aquaculture

The aquaculture biomass was difficult to estimate because of the proprietary nature of the data on operations. In addition, necessary information was obtained through personal communication and sources were not always in agreement. The original source for Virginia aquaculture biomass was a summary of surveys conducted by VIMS (Hudson & Murray 2016). The surveys reflect the number of oysters sold through Virginia aquaculture operations for the years 2005–2015. The surveys risk underreporting the sales because of a lack of response from some operators. Alternatively, the surveys risk overestimating the sales since operations on the Atlantic side of the Delmarva Peninsula are included. Nevertheless, the survey report is the primary citable source for Virginia aquaculture data.

The number of oysters sold was converted to dry tissue weight using the factor for market-size oysters of 2.1 g DW per oyster (Cerco & Noel 2007). Converting the harvest to standing stock required consideration of aquaculture practices and grow-out period from seed to harvest. Aquaculture practices can be broadly divided into "cage culture" and "bottom culture." We were advised that roughly 80 percent of aquaculture in Virginia is conducted in cages and 20 percent is conducted on bottom. We were further advised that the grow-out period for cage culture is 2 years while the grow-out period for bottom culture is 3 years (M. Parker, University of Maryland Extension, pers. comm., February 16, 2017). Assuming linear growth and continuous planting and harvest, the standing stock of oysters in cages is 1.5 times the annual harvest. The standing stock of oysters on bottom is twice the annual harvest. Combining these factors indicates the biomass of aquaculture oysters in Virginia is 1.6 times the annual harvest (Table J-3).

Table J-3. Aquaculture biomass and harvest

Year	VA Biomass (kg DW)	VA Harvest (kg DW)	MD Biomass (kg DW)	MD Harvest (kg DW)
2005	3398	2124		
2006	11892	7433		
2007	16989	10618		
2008	25483	15927		
2009	32279	20174		
2010	56063	35039		
2011	79847	49904		
2012	93438	58399		
2013	103631	64770		
2014	134211	83882	40905	21529
2015	118921	74326	60612	31901
2016			64550	33974
2025	508032	317520	241315	127008

Note: Data for the year 2025 are projections employed in management scenarios as detailed in subsection J.6.1.1 *Estimate of Aquaculture Activity through 2025*.

Data for Maryland aquaculture originated with the MDNR and was provided through the Oyster Recovery Partnership (J. Reichert-Nguyen, Oyster Recovery Partnership, pers. comm., December 21, 2016). The original data consisted of the number of bushels harvested for the years 2014–2016. Statewide totals as well as data for some counties were provided. Bushels were converted to number of oysters using the factor of 300 oysters per bushel provided along with the data. The number of oysters was subsequently converted to dry tissue weight using the factor of 2.1 g DW per oyster for market-size oysters (Cerco & Noel 2007). We were advised that, in Maryland, roughly 80 percent of aquaculture is conducted on the bottom while 20 percent is conducted in cages. Those proportions are the inverse of operations in Virginia. Using the grow-out periods quoted previously, the Maryland aquaculture standing stock is 1.9 times the annual harvest (Table J-3).

J.4.2.1 Assignment to Basins

Data on private landings for major basins in Virginia were provided by the VMRC (J. Wesson, department head, Conservation and Replenishment, pers. comm., December 30, 2016). The Virginia aquaculture biomass was assigned to basins according to the fraction of the total private landings in each basin (Table J-4).

Maryland aquaculture biomass was assigned to counties in proportion to the fraction of the total harvest represented by each county (Table J-4). Data were not available for all individual counties, however, so fractions were assigned to those counties according to surface area.

Table J-4. Basin fractions of aquaculture biomass

VA Basin	Fraction	MD Basin	Fraction
Chesapeake	0.293	Anne Arundel	0.022
James	0.360	Calvert	0.030
York	0.128	Dorchester	0.475
Rappahannock	0.050	St. Mary’s	0.215
Potomac	0.170	Somerset	0.025
		Talbot	0.072
		Wicomico	0.162

J.5 Model Parameterization

J.5.1 Model Calibration to Reef Population

The fundamental parameter values for the oyster module are adapted from the 2005 study of the impact of a tenfold increase in natural oyster population (Cerco & Noel 2007). Values of two parameters, mortality and harvest (equation 1), are newly assigned in the 2017 model to match current biomass data. First the harvest is assigned to calculate values representative of data, then the mortality is assigned to obtain representative biomasses. Harvest values range from 1.23 x 10^{-4} to 6.75 x 10^{-4} d^{-1} in the months from October through April. Harvest is zero otherwise. The seasonal assignment reflects that harvest from natural reefs is minimal during spawning season. Mortality ranges from 0.025 to 0.05 d^{-1} in the months from June to October. Mortality is zero otherwise. The seasonal assignment reflects the influence of temperature on predators and disease organisms.

The reef biomass data reflect annual surveys (fishery-independent data) combined with annual summaries of oyster landings (fishery-dependent data). They are compared to annual-average biomass computed by the model. Comparison of computations and observations (e.g., Figures J-5 and J-6) indicates the model largely reflects the regional biomasses, although interannual variations in the observations are not reproduced.

The correlation (R^2) between computed annual-average biomass in Maryland basins and observed biomass is 0.62 and is highly significant ($p < 0.01$) (Figure J-7). The correlation between computed and observed biomass in Virginia is lower ($R^2 = 0.47$) but remains significant nonetheless (Figure J-8).

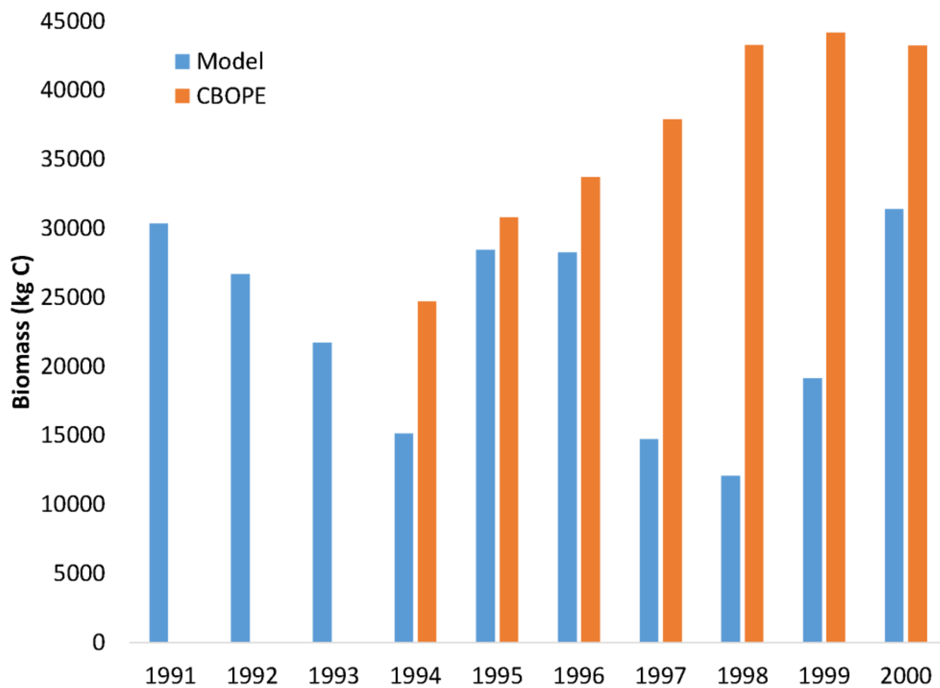


Figure J-5. Computed (annual average) and observed oyster biomass in the Choptank River, MD.

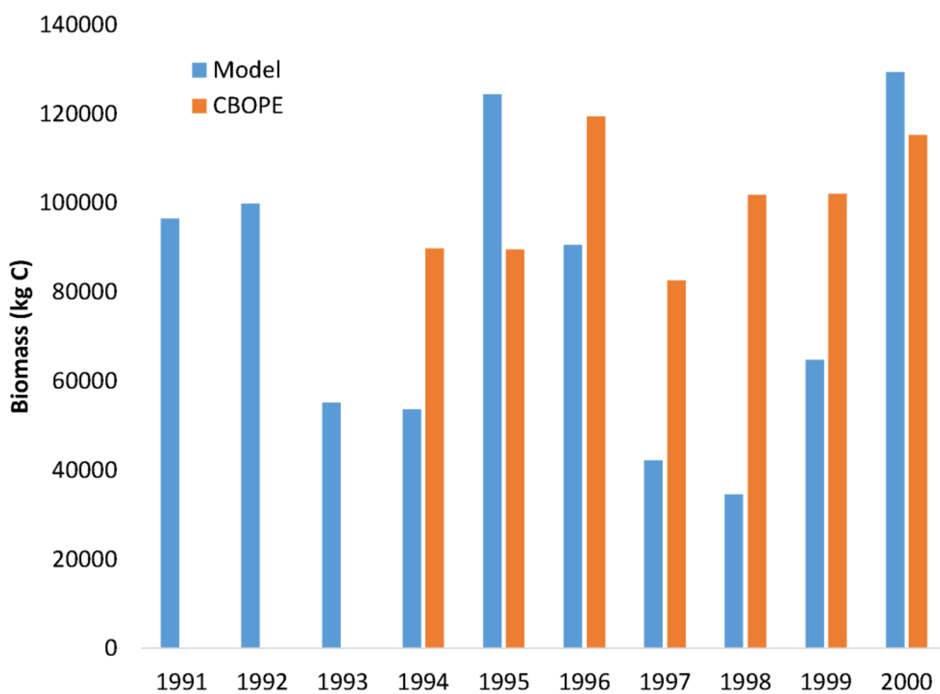


Figure J-6. Computed (annual average) and observed oyster biomass in the James River, VA.

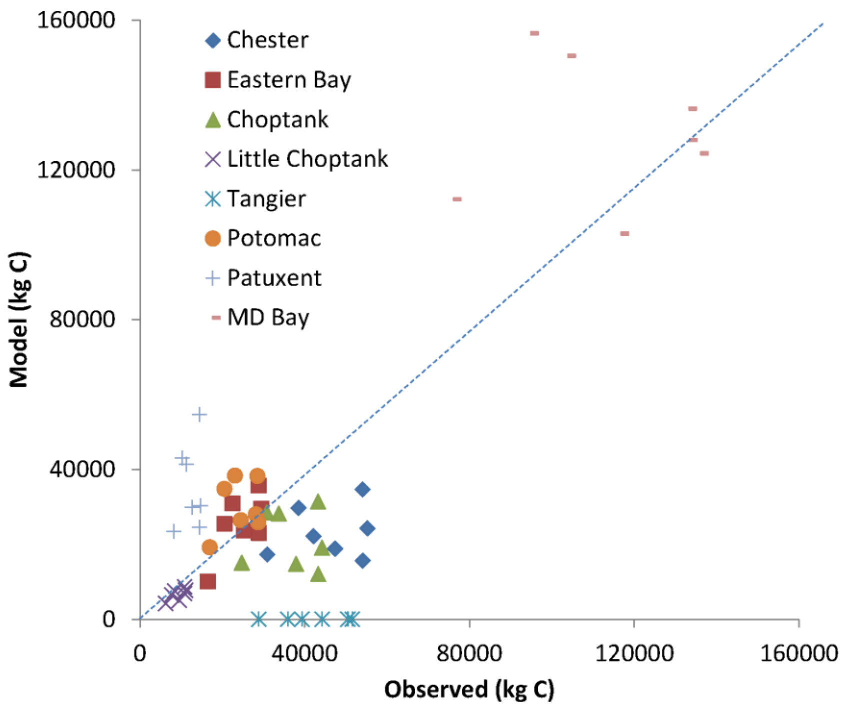


Figure J-7. Computed vs. observed biomass for Maryland basins designated in Table J-2. Computed values are annual averages for 1994–2000. Observations are derived from CBOPE.

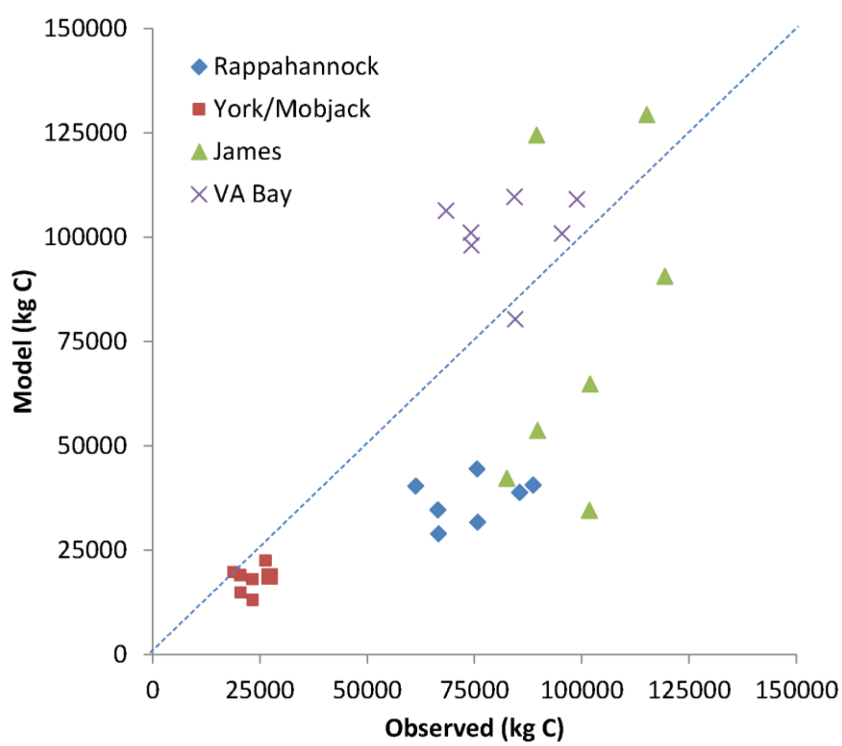


Figure J-8. Computed vs. observed biomass for Virginia basins designated in Table J-2. Computed values are annual averages for 1994–2000. Observations are derived from CBOPE.

J.6 Management Considerations

J.6.1 Oyster Aquaculture

The Virginia aquaculture biomass was negligible, compared to the reef biomass, through the WQSTM calibration and verification years, 1991–2000 and 2002–2011 (Figure J-9). Aquaculture in Maryland was nonexistent during those periods. Consequently, the aquaculture feature of the oyster module was not implemented in the calibration or verification periods spanning 1991 to 2011. Aquaculture activities are growing rapidly, however, in both Virginia (Figure J-9) and Maryland (Figure J-10) and nutrient removal through aquaculture is now considered a best management practice (Reichert-Nguyen et al. 2016). Consequently, aquaculture is implemented in various Chesapeake Bay Model scenarios for 2025 conditions.

J.6.1.1 Estimate of Aquaculture Activity through 2025

We were provided with 2025 projections of aquaculture activity by state (O. Devereux, Devereux Consulting, pers. comm., December 8, 2017). Data included the number of oysters harvested and the nitrogen and phosphorus content of individual oyster soft tissue. Since the WQSTM quantifies oysters as carbon, the total nitrogen removed was multiplied by the WQSTM oyster carbon-to-nitrogen ratio of 6 g C g^{-1} N to convert the projected harvest to model carbon units. Harvest was converted to standing-stock biomass as described in subsection, *Aquaculture*, under section, *Biomass*.

The aquaculture biomass obtained from the harvest was distributed to model cells capable of supporting aquaculture in each state. The projected harvest and biomass were subsequently converted to dry weight for comparison with previously computed values for the years 2005–2016 (Table J-3). The 2025 projections are much higher than the most recent data but are consistent with extrapolations from present trends.

The 2025 “full buildout” oyster aquaculture estimates are the approximate maximum biomass of Maryland aquaculture oysters because of constraints in available shallow waters of suitable salinities and water quality. For scenario years of 2025 and beyond, the 2025 full buildout biomass estimates are used. For Progress Scenario years before 2025, Virginia and Maryland provide the annual estimates of aquaculture oyster harvest through the Chesapeake Assessment and Scenario Tool (CAST) (CBPO 2017), which is then used to represent the influence of aquaculture on water quality.

J.6.1.2 Implementing Aquaculture in the WQSTM

CAST operates by reducing the watershed loads to appropriate cells of the WQSTM to account for nutrient removal by harvest and consumption of oyster soft tissue (Reichert-Nguyen et al. 2016). (Nitrogen and phosphorus content of harvested shells are uncounted and assumed to be net zero because shells from oyster aquaculture are commonly collected and replanted on aquaculture grounds with new oyster spat.) Therefore, in the WQSTM, the harvest of aquaculture oysters is specified as zero (equations 1 and 2) to prevent "double counting" of nutrient removal in both watershed loads and through algorithms in the oyster module. However, oyster functions of particle filtration and nutrient recycling to the water and sediments remain in operation for simulation of oyster aquaculture. Consequently, aquaculture in scenarios provides potential benefits in water clarity and enhanced nutrient burial and denitrification as well as the reductions of oyster soft tissue nitrogen and phosphorus represented in CAST as per the guidance of the Oyster BMP Expert Panel.

J.6.1.3 Sensitivity Scenario

The overall influence of oyster aquaculture at 2025 full buildout biomass is estimated to increase spring and summer bottom dissolved oxygen (DO) by more than 0.05 mg/l in CB4MH and CB5MH segments (Figure J-11) (Modeling Workgroup 2018). Improvement in bottom DO from the WQSTM oyster simulated processes of particle filtration and nutrient cycling is more than twice that of nutrient removal by oyster aquaculture harvest alone.

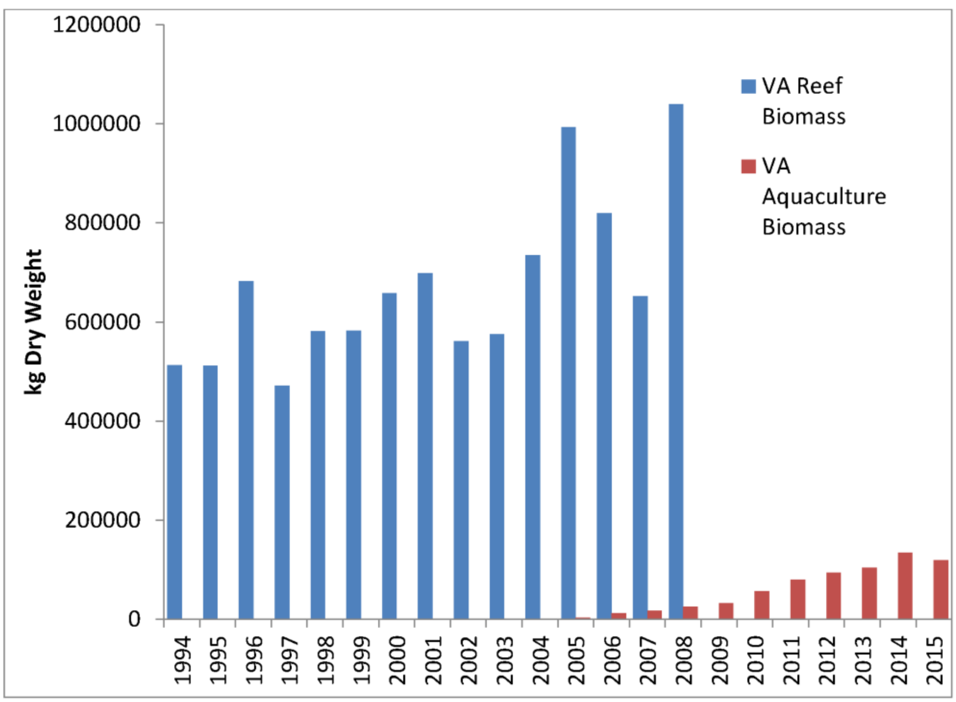


Figure J-9. Virginia natural reef and aquaculture biomass 1994–2015.

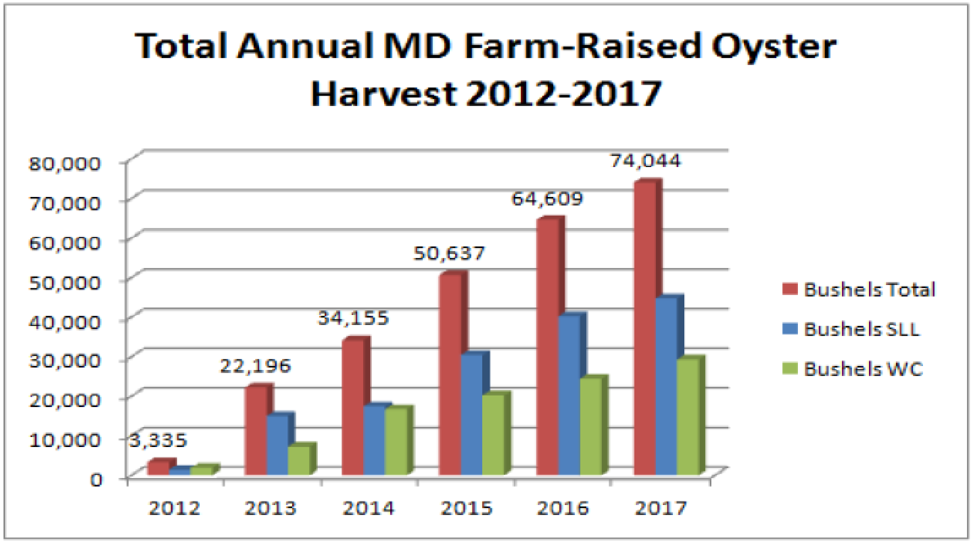


Figure J-10. Annual harvest of aquaculture (farm-raised) oysters in Maryland 2012–2017. SLL = submerged land lease; WC = water column lease (*Source*: Roscher 2019)

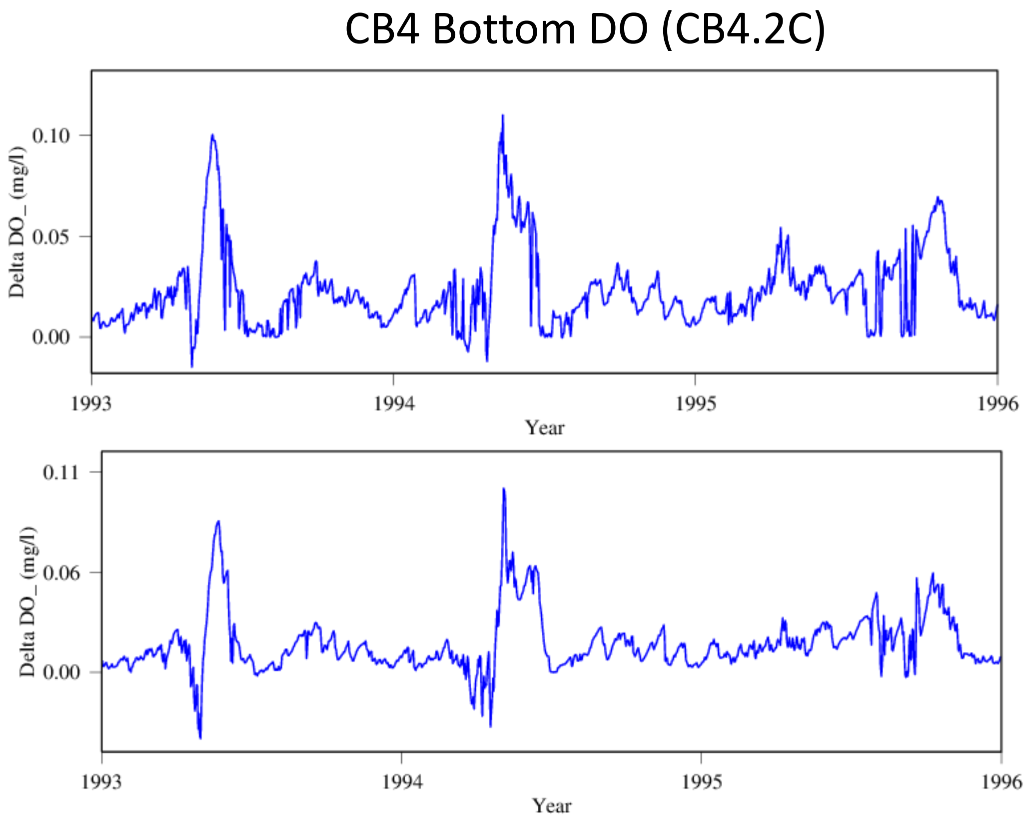


Figure J-11. Influence of oyster aquaculture at 2025 full buildout biomass on bottom cell DO in CB4MH and CB5MH. Delta DO > 0 indicates an increase in DO (*Source*: Modeling Workgroup 2018).

J.7 Nutrient Credits for Oyster Habitat Restoration

By 2025, 10 areas of the Chesapeake Bay will have an extensively restored bottom along with oyster spat planting. The 10 areas of existing or planned specific, large, and intensive restoration of oyster habitat are shown in Figure J-12. Nutrient removal associated with restoration in those areas is equated to load reductions in CAST (CBPO 2019). The credits for restoration are 81 pounds of nitrogen and 4 pounds of phosphorus per acre of restored oyster sanctuary habitat (CBPO 2019). The credits account for nutrient assimilation into oyster tissue and enhanced sediment denitrification. To avoid double counting of nutrient removal in the oyster module and in CAST, the oyster module is disabled in the areas for which specific information on restoration site size and location is available.

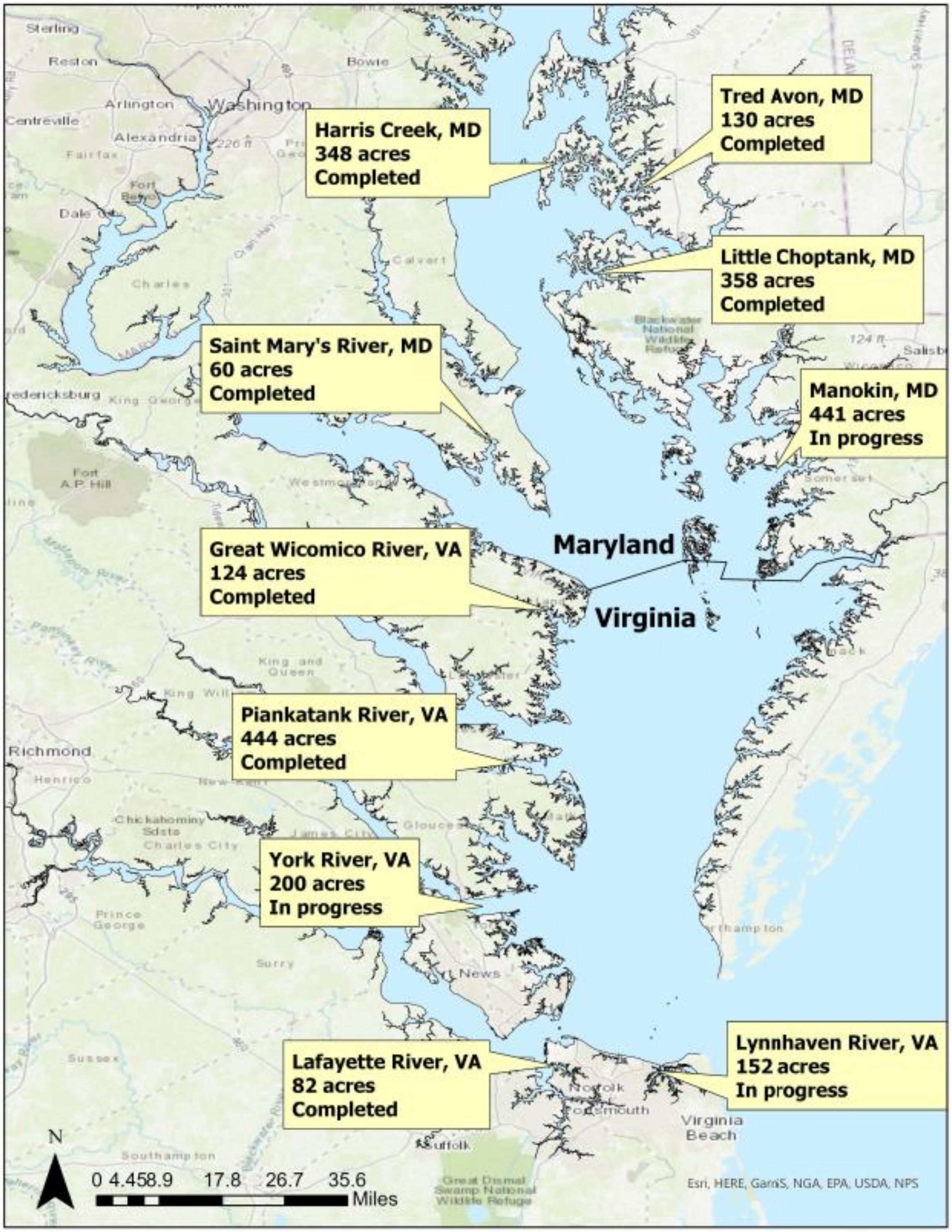


Figure J-12. Location of 10 areas of large-scale oyster habitat restoration to be completed by 2025. Restoration status as of September 2022.

J.8 References

Bruce, D., and Westby, S. 2018. *Restoring Oyster Habitats Requires Geodesign.* ArcNews Fall 2018. Accessed October 10, 2019. https://www.esri.com/content/dam/esrisites/en-us/newsroom/arcnews/G195835_AN_Fal2018_165035_final.pdf

CBPO (Chesapeake Bay Program Office). 2017. Chesapeake Assessment and Scenario Tool (CAST) Version 2017d. Chesapeake Bay Program Office, Annapolis, MD. Accessed August 6, 2019. https://cast.chesapeakebay.net/Documentation/ModelDocumentation.

CBPO (Chesapeake Bay Program Office). 2019. Chesapeake Assessment and Scenario Tool: Technical Appendix for Oyster Reef Restoration Planning BMPs in the Phase 6 Watershed Model and CAST. Chesapeake Bay Program Office, Annapolis, MD. Accessed August 6, 2019. https://cast.chesapeakebay.net.

Cerco, C., B. Johnson, and H. Wang. 2002. *Tributary Refinements to the Chesapeake Bay Model*. ERDC TR-02-4. US Army Engineer Research and Development Center, Vicksburg, MS.

Cerco, C., and M. Noel. 2007. Can oyster restoration reverse cultural eutrophication in Chesapeake Bay? *Estuaries and Coasts* 30(2):331-343.

Cerco, C., and M. Noel. 2010. Monitoring, modeling, and management impacts of bivalve filter feeders in the oligohaline and tidal fresh regions of the Chesapeake Bay system. *Ecological Modeling* 221:1054-1064.

Greenhawk, K., and T. O'Connell. 2007. *Oyster Population Estimates for the Maryland Portion of Chesapeake Bay 1994–2006*. Maryland Department of Natural Resources, Fisheries Service, Annapolis, MD.

Hudson, K., and T. Murray. 2016. *Virginia Shellfish Aquaculture Situation and Outlook Report*. VIMS Marine Resource Report 2016-4. Virginia Institute of Marine Science, Gloucester Point, VA.

MDNR (Maryland Department of Natural Resources). 2008. *Draft Programmatic Environmental Impact Statement for Oyster Restoration in Chesapeake Bay including the Use of a Native and/or Nonnative Oyster*. Maryland Department of Natural Resources, Annapolis, MD. http://dnr.maryland.gov/fisheries/Pages/EIS.aspx.

Modeling Workgroup. 2018. Estimated Oyster Aquaculture Influence on Chesapeake Water Quality. Chesapeake Bay Program, Annapolis, MD. Accessed August 8, 2019. https://www.chesapeakebay.net/channel_files/25850/attachment_e_oyster_aquaculture_influence_on_water_quality_2.pdf.

Reichert-Nguyen, J., J. Cornwell, J. Rose, M.L. Kellogg, M. Luckenbach, S. Bricker, K. Paynter, C. Moore, M. Parker, L. Sanford, B. Wolinski, A. Lacatell, L. Fegley, K. Hudson, E. French, H.W. Slacum Jr. 2016. 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. https://www.oysterrecovery.org/wp-content/uploads/2017/01/Oyster-BMP-1st-Report_Final_Approved_2016-12-19.pdf (accessed 30 July 2022)

Roscher, K. 2019. Maryland Shellfish Aquaculture Conference Policy and Regulatory Developments. February 2019 Annapolis, MD. Accessed August 6, 2019. https://www.cbf.org/events/maryland/maryland-shellfish-aquaculture-conference.html.

VIMS (Virginia Institute of Marine Science). 2017. *Chesapeake Bay Oyster Population Estimate*. Virginia Institute of Marine Science, Gloucester Point, VA. http://web.vims.edu/mollusc/cbope/overview.htm.

Appendix K. Technical Requirements for Reporting and Simulating Oyster BMPs in the Phase 6 Watershed Model

Approved by Watershed Technical Workgroup May 4, 2023

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, CAST and the Watershed Model.

This appendix covers the technical requirements for the following oyster BMPs:

- Harvest-Assimilation: Nitrogen and phosphorus assimilation in tissue of live oysters from endorsed licensed harvest using hatchery-produced oysters
- Restoration-Assimilation: Nitrogen and phosphorous assimilation in tissue and shell of live oysters from oyster reefs restored using hatchery produced oysters and substrate addition
- Restoration-Denitrification: Enhanced denitrification associated with oysters from oyster reefs restored using hatchery produced oysters and substrate addition

Technical requirements for each oyster BMP are outlined below.

K.1 Harvest-Assimilation

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

A1: The Panel recommends applying reduction credits in pounds (lbs) for nutrients assimilated in harvested oyster tissue for one licensed oyster harvest practice:

Practice F: Licensed oyster harvest using hatchery-produced oysters.

The enhancement activity is the planting of hatchery produced oysters in harvest areas. The form of nutrient removal is by removing oysters from the water via harvest. The reduction credits may only be applied to this practice based on the size, number, and type of oysters harvested.

Q2: What are the reduction credits for this licensed oyster harvest practice?

A2: The Panel recommends applying reduction credits in pounds (lbs) of nitrogen and phosphorous assimilated per million oysters (Table K.1). These reduction estimates were adapted from the Panel's first report (Reichert-Nguyen et al. 2016). For this practice, the reduction estimates only apply to the harvest of diploid hatchery produced oysters. The total amount of nutrients assimilated depends on the size (shell height) of harvested oysters, whereby larger oysters assimilate more nutrients.

Table K.1 (*Table 6.3 in report*)**.** Default nutrient reductions in pounds per one million harvested hatchery-produced oysters. Oyster size class based on shell height measurements.

BMP Name	Oyster size class (in)	Nitrogen (lbs./million oysters)	Phosphorus (lbs./million oysters)
Diploid Licensed Oyster Harvest, Hatchery Produced 3.0 Inches	3.00-3.49*	198	22
Diploid Licensed Oyster Harvest, Hatchery Produced 4.0 Inches	3.50-4.49	331	44
Diploid Licensed Oyster Harvest, Hatchery Produced 5.0 Inches	4.50-5.49	485	44
Diploid Licensed Oyster Harvest, Hatchery Produced >5.0 Inches	≥ 5.50**	683	66
Diploid Licensed Oyster Harvest, Site-Specific Monitored	N/A	N/A	N/A

* Adjusted from 2.5-3.49. See text for details.
** Based on midpoint of 6.0 inches

The following conditions should be applied to estimate when and how many oysters are eligible for credit:

- **Maximum harvest allowance** – No more than 3% of hatchery produced oysters planted per planting.
- **Crediting time lag** – Oyster harvest becomes eligible for credit two years after enhancement unless an assessment is done demonstrating a timeframe less than two years is appropriate.
- **Maximum crediting timeframe** – Oyster harvest is eligible for credit for a maximum of five years after enhancement.

Q3: What credit may be given if the size of oysters harvested is not known?
A3: If the size of harvested oysters is not known, then the BMP matching the State's minimum legal harvest size (3 inches in Maryland and Virginia – row 1 in Table 1) can be applied. States are expected to describe the minimum legal harvest requirements in their Quality Assurance Project Plan (QAPP).

Q4: How would an implementer receive credit for using site-specific reduction estimates?
A4: Site-specific reduction estimates can be estimated by establishing site-specific oyster tissue nutrient contents. The Panel recommends the process outlined in Section 6.2.5.3. Briefly, the implementer should:

- Define specific oyster size classes
- Sample oysters from the site across multiple seasons.
- Assess the average tissue dry weight for each size class based on 50 randomly selected oysters per size class and sampling period (following Mo & Neilson 1994, Carmichael et al. 2012).
- Multiply the average tissue dry weight for each size class by the default nitrogen percentage (8.2%) and phosphorus percentage (0.9%) in oyster tissue to determine the site-specific nitrogen and phosphorus content per oyster.

The implementer can also develop site-specific estimates of when and how many oysters are eligible for credit by establishing a site-specific credit time lag (Section 6.2.4) and site-specific spat survival rate (Section 6.2.3), respectively.

Q5: What should a state report to NEIEN to receive credit for the harvest-assimilation BMPs?
A5: States should report these parameters to NEIEN. Additional reporting details for the implementer are in Table 6.5 in the report.

- BMP Name: Select from list in Table K.1 above.
- Measurement Name:
    - Required (parent) - Oysters Harvested or Millions of Oysters Harvested, Unit = count, both measurements will be available in NEIEN
    - If site specific monitored
        - Required (child) – lbs TN, Unit = lbs
        - Required (child) – lbs TP, Unit = lbs
- NEIEN geographic BMP site location: [Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)]
- Year eligible oysters are harvested

Q6: How will the practice be credited in the Phase 6 Watershed Model?
A6: The Phase 6 Model estimates nutrient loads in shoreline segments that can be reduced by shoreline and tidal water practices. Credit for the pounds of nutrients reduced by licensed oyster harvest will go to the shoreline segments closest to the harvest location. If geographic coordinates are not submitted, then the credit will be distributed amongst all shoreline segments in the reported geographic area.

Q7: How will credit be simulated for oysters grown at multiple locations?
A7: Hatchery produced oysters must be < 2 inches in shell height when planted on a harvest area to be eligible for credit.

Q8: Can this practice be submitted in non-tidal waters?

A8: No. This practice is only eligible in tidal waters.

Q9: Is this an annual practice?
A9: Yes. Credit can be received annually for oysters harvested 2-5 years after the enhancement activity. Only up to 3% of planted hatchery produced oysters are eligible for credit when harvested.

K.2 Restoration-Assimilation

Q1: What types of oyster reef restoration practices will be available for credit for nutrient reductions in the Phase 6 Model?
A1: The Panel recommends applying reduction credit in pounds (lbs) for nutrients assimilated in oyster tissue and shell for two oyster restoration practices:

Practice J: Oyster reef restoration using hatchery produced oysters.
Practice K: Oyster reef restoration using substrate addition.

The enhancement activity is the addition of substrate suitable for natural oyster recruitment and/or the addition of hatchery produced oysters to areas protected from harvest. The reduction credits may only be applied to this practice based upon increases in live oyster tissue and shell biomass following restoration.

Q2: What are the reduction credits for the oyster reef restoration-assimilation practices?
A2: The Panel recommends applying reduction credits in pounds (lbs) of nitrogen and phosphorous assimilated per acre, based on an increase in live oyster tissue and shell biomass per unit area.

Q3: What is needed to calculate the reductions?
A3: Calculating the nutrient reductions requires the following:

- Baseline oyster tissue and shell biomass per unit area
- Post-restoration oyster tissue and shell biomass per unit area
- BMP site area

Q4. How are the reductions calculated?
A4. To calculate the nutrient reductions, the Panel recommends the following:

Step 1: Identify the BMP site location and determine the BMP site area

Step 2: Document the qualifying enhancement activity and its date, the type(s) of substrate used for restoration, and the baseline approach

Step 3: Assess baseline and post-restoration tissue and shell biomass and extrapolate it to determine total tissue and shell biomass estimates for the BMP site

Step 4: Determine the eligible appreciated tissue and shell biomass at the BMP site

Step 5: Convert eligible appreciated tissue and shell biomass to total nitrogen and phosphorus removed

Q5: What credit may be given if the baseline is not known for (a) progress scenarios, or (b) in hypothetical planning scenarios in the Watershed Model or CAST?
A5. (a) None. The Panel concluded that the empirical data available were too variable and sparse to recommend wide-ranging regional or Bay-wide default estimates. However, for small substrates the

panel does provide a regression-based approach to simplify calculation of estimates for applicable projects.
(b) The existing planning-only BMP *oyster reef restoration – nutrient assimilation* can be used in a planning scenario within CAST based on planned acres of restoration activity. The planning-only version of oyster reef restoration – enhanced denitrification could be applied in addition to this, using planned acres of applicable projects.

Q6: How would an implementer receive credit for the restoration-assimilation practices?
A6: An implementer would receive reduction credit for nutrient assimilation if oyster tissue and/or shell biomass increased above the previously credited oyster tissue and/or shell biomass.

Q7: What should a state report to NEIEN to receive credit for the oyster reef restoration-assimilation BMP?
A7: States should report these parameters to NEIEN. Additional reporting details for the implementer are in Table 7.3 in the report.

- BMP type/name: Oyster reef restoration – assimilation
- Measurements
  - Required (parent) - site area or restoration area, Unit = acres, both measurements will be available in NEIEN
  - Required (child) – lbs TN, Unit = lbs
  - Required (child) – lbs TP, Unit = lbs
  - Optional(child) - appreciated oyster tissue and shell biomass, Unit = lbs
  - Optional(child) – no. of structures, Unit = count
- NEIEN geographic BMP site location: [Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)]
- Year of post-restoration biomass assessment in which oyster tissue and shell biomass appreciated above previously credited biomass

Q8: How will the practice be credited in the Phase 6 Watershed Model?
A8: The Phase 6 Model estimates nutrient loads in shoreline segments that can be reduced by shoreline and tidal water practices. Credit for the pounds of nutrients reduced by oyster restoration practices will go to the shoreline segments closest to the restoration location. If geographic coordinates are not submitted, then the credit will be distributed amongst all shoreline segments in the reported geographic area.

Q9: Can this practice be submitted in non-tidal waters?
A9: No. This practice is only eligible in tidal waters.

Q10: Is this an annual practice?

A10: Yes. Credit for appreciated oyster tissue and shell biomass must be applied within 12 months of the most recent post-restoration biomass assessment. Credit for newly appreciated biomass can only be applied one time.

Q11: Are there any qualifying conditions or other key criteria for this practice to be eligible for nutrient reductions in the Watershed Model?
A11: The Panel recommends the following qualifying conditions (Subchapter 7.5):

- An enhancement activity using hatchery produced oysters and/or substrate addition must occur throughout the BMP site area
- Default oyster biomass regressions can only be used for reefs restored using small substrate(s)
- The BMP site area must lie within an area protected from harvest
- At the time of planting, shell height of hatchery produced oysters must be < 1 inch. For oysters > 1 inch, only incremental growth beyond the planting size can be credited
- Baseline oyster biomass must be determined using the appropriate approach and adhere to baseline conditions
- All biomass estimates must be based on field data collected within 12 months of crediting using a survey design that ensures estimates are representative of the entire BMP site
- Biomass must be extrapolated appropriate to the scale of the BMP site
- Only nutrients associated with eligible appreciated biomass may be credited

Q12: When are oyster restoration projects eligible for credit?
A12: Credit can be given for any eligible restoration activity and gains in biomass after the creation of the TMDL in 2009 (Subchapter 7.4). Any eligible oyster restoration projects that occurred prior to 2009 can be eligible for reductions if they have the Panel-recommended data to determine gains in oyster biomass, AND if the Management Board decision from 2016 is reversed for oyster restoration practices.

K.3 Restoration-Denitrification

Q1: What types of oyster reef restoration practices will be available for credit for nutrient reductions in the Phase 6 Model?
A1: The Panel recommends applying reduction credit in pounds (lbs) for nitrogen removed from the water via enhanced denitrification associated with two oyster restoration practices:

Practice J: Oyster reef restoration using hatchery produced oysters.

Practice K: Oyster reef restoration using substrate addition.

The enhancement activity is the addition of substrate suitable for natural oyster recruitment or the addition of hatchery produced oysters to areas protected from harvest. The reduction credits may only be applied to this practice based on increases in oyster tissue biomass following restoration using small substrate in subtidal areas.

Q2: What are the reduction credits for the oyster reef restoration-denitrification practices?
A2: The Panel recommends applying reduction credits in pounds (lbs) of nitrogen per acre per year, based on the enhanced denitrification rates associated with an increase in oyster tissue biomass per unit area relative to baseline oyster tissue biomass.

Q3: What is needed to calculate the TN reductions?
A3: Calculating the TN reductions requires the following:

- Baseline oyster tissue biomass per unit area
- Post-restoration oyster tissue biomass per unit area
- Panel's default lookup table to estimate enhanced nitrogen removal per unit area per year (Table K.2)
- BMP site area

Table K.2 (*Table 8.6 in report*). Partial lookup table for use in determining the annual enhanced denitrification rates. For full lookup table, see Appendix G.

Enhanced Nitrogen Removal (lbs acre^{-1} yr^{-1})		*Post-restoration Oyster Biomass Range (g DW m^{-2})*												
		15 - 24.9	***25 - 34.9***	***35 - 44.9***	***45 - 54.9***	***55 - 64.9***	***65 - 74.9***	***75 - 84.9***	***85 - 94.9***	***95 - 104.9***	***105 - 114.9***	***115 - 124.9***	***125 - 134.9***	***135 - 144.9***
Baseline Oyster Biomass Range (g DW m^{-2})	***0 - 14.9***	29	51	74	97	120	143	165	169	172	176	179	183	186
	15 - 24.9		23	46	68	91	114	137	140	144	147	151	154	158
	25 - 34.9			23	46	68	91	114	118	121	124	128	131	135
	35 - 44.9				23	46	68	91	95	98	102	105	109	112
	45 - 54.9					23	46	68	72	75	79	82	86	89
	55 - 64.9						23	46	49	53	56	59	63	66
	65 - 74.9							23	26	30	33	37	40	44
	75 - 84.9								3	7	10	14	17	21
	85 - 94.9									3	7	10	14	17
	95 - 104.9										3	7	10	14
	105 - 114.9											3	7	10
	115 - 124.9												3	7
	125 - 134.9													3

Q4. How are the TN reductions calculated?
A4. To calculate the TN reductions, the Panel recommends the following:

Step 1. Identify the BMP site location and determine the BMP site area

Step 2. Document the qualifying enhancement activity and the date it occurred

Step 3. Determine the appropriate baseline approach

Step 4. Assess baseline and post-restoration tissue biomass

Step 5. Determine denitrification enhancement per unit area using either the biomass-based default denitrification rates per unit area or site-specific measured denitrification rates

Step 6. Determine the total nitrogen removal attributable to enhanced denitrification using the estimated denitrification enhancement per unit area and the BMP site area

Q5: What credit may be given if the baseline is not known for (a) progress scenarios, or (b) in hypothetical planning scenarios in the Watershed Model or CAST?

A5. (a) None. The Panel concluded that the empirical data available were too variable and sparse to recommend wide-ranging regional or Bay-wide default estimates for nitrogen removed via enhanced denitrification (see literature review in Subchapter 8.1). Instead, the panel is recommending an approach that can use Table K.2 (Table 8.6 in report) to generate site-specific estimates of enhanced denitrification based on changes in oyster biomass that are measured to report the assimilation BMP. (b) The existing planning-only *oyster reef restoration – enhanced denitrification* BMP can be used in a planning scenario within CAST based on planned acres of restoration activity. The planning-only version of *oyster reef restoration – nutrient assimilation* could be applied in addition to this, using planned acres of applicable projects.

Q6: How would an implementer receive credit for the restoration-denitrification practices?
A6: An implementer would receive reduction credit for enhanced denitrification if oyster tissue biomass increased above the baseline oyster tissue biomass. Credits can be applied annually for 3 years after a post-restoration biomass assessment.

Q7: What should a state report to NEIEN to receive credit for the restoration-denitrification BMP?
A7: States should report these parameters to NEIEN. Additional reporting details for the implementer are in Table 8.7 in the report.

- BMP type/name: Oyster reef restoration – enhanced denitrification
- Measurements
    - Required (parent) - site area or restoration area, Unit = acres, both measurements will be available in NEIEN
    - Required (child) – lbs TN, Unit = lbs
    - Optional(child) - annual reduction from enhanced DNF, Unit = lbs
- NEIEN geographic BMP site location: [Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)]
- Year the annual enhanced DNF occurred

Q8: How will the practice be credited in the Phase 6 Watershed Model?
A8: The Phase 6 Model estimates nutrient loads in shoreline segments that can be reduced by shoreline and tidal water practices. Credit for the pounds of nutrients reduced by oyster restoration practices will go to the shoreline segments closest to the restoration location. If geographic coordinates are not submitted, then the credit will be distributed amongst all shoreline segments in the reported geographic area.

Q9: Can this practice be submitted in non-tidal waters?
A9: No. This practice is only eligible in tidal waters.

Q10: Is this an annual practice?
A10: Yes. Credits can be applied annually for up to 3 years after the most recent post-restoration biomass assessment.

Q11: Are there any qualifying conditions or other key criteria for this practice to be eligible for TN reductions in the Watershed Model?

A11: The Panel recommends the following qualifying conditions (Subchapter 8.5):

- An enhancement activity using hatchery produced oysters and/or substrate addition must occur throughout the BMP site area
- The BMP site area must lie within an area protected from harvest
- Default oyster biomass regressions and default enhanced DNF rates can only be used for subtidal reefs restored using small substrate(s)
- All biomass estimates must be based on field data collected using a survey design that ensures estimates are representative of the entire BMP site
- Only live oyster tissue biomass is eligible for credit
- The post-restoration oyster tissue biomass must be greater than the baseline oyster tissue biomass

Q12: When are oyster restoration projects eligible for credit?

A12: Credit can be given for any eligible restoration activity after the creation of the TMDL in 2009 (Subchapter 8.4).

Appendix L. Why not generate a default estimate to credit large substrates for denitrification?

The Panel's current denitrification crediting approach was based on many measurements of denitrification by researchers at VIMS. These data were collected across a number of subtidal and intertidal sites in Maryland and Virginia and included measurements in different seasons. The Panel developed strict criteria outlined in Appendix F for including data in their analysis and development of default enhanced denitrification estimates. Only data from deeper (>1 m) subtidal sites met the Panel's criteria and were therefore included in the default estimates. The denitrification rates available for shallow intertidal oyster restoration appeared to be lower than those occurring on subtidal restored reefs. The data sets available for denitrification on large substrates are significantly limited compared to those from subtidal and intertidal reefs restored with small substrates. In some cases, denitrification rates on large substrates are high, which has promising implications for crediting restoration using these materials. The Panel is optimistic that a default estimate could be generated for crediting denitrification on large substrates in the future, but consideration at this time is limited by the following:

1. The number of observations are insufficient to develop a default rate.
2. All existing data are limited to two substrate types (ReefBalls™ and Oyster Castles©) in a small area within the Choptank River complex. No Virginia data has been reported.
3. The ReefBall™ data shows elevated rates of denitrification relative to reefs restored using small substrate, but also had extremely high rates of ammonium efflux. Overall denitrification appeared to be relatively inefficient in ReefBalls™; the excess accumulation of biodeposits within the structure resulted in black, sulfidic sediments that hindered denitrification. It is possible that there is a halo of enhanced denitrification around the perimeter of a ReefBall™, but no data is available to test this hypothesis. Given these observations, the net value of ReefBalls™ to nitrogen removal is equivocal.
4. Oyster Castles© deployed in front of an eroding shoreline in the Choptank River also appeared to have high rates of denitrification relative to reefs restored using small substrate. Enhanced denitrification occurred on Castles with and without oysters; without oysters, filtering organisms such as bryozooans and barnacles replicate oyster nitrogen biogeochemical processes. Losses of biomass due to exposure to freezing air temperatures in winter complicated the long-term interpretation and evaluation of net nitrogen removal.
5. Unlike the abundant oyster reef restoration data used to generate the Panel's default enhanced denitrification estimates, the large substrate data are not peer-reviewed. The technical approach to take these measurements involves removal of the ReefBalls™ or Oyster Castles© from the Bay bottom and incubation in large tanks. While the Panel and researchers working on collecting these data believe the rates generated with this approach are realistic, the approach requires scrutiny beyond the one study conducted by investigators at UMCES.

Appendix M. Response to Public and Stakeholder Comments

The Oyster BMP Expert Panel Second Report was available for public and stakeholder review from January 30 to March 10, 2023. A total of 14 responses were received. Overall, there was general agreement with the Panel's recommendations and support for the Panel's endorsement to credit oyster restoration and harvest. Many commenters were satisfied that sufficient science was used to generate the reduction estimates and recommendations.

The Panel carefully considered all comments and suggestions that were submitted. Many of the comments were outside the Panel charge or were requests to expand Panel recommendations for topics where data is currently lacking. Therefore, very few minor changes were made to the report and the Panel's recommendations remained unchanged.

Several commenters questioned why the Panel did not provide a default enhanced denitrification estimate for large substrates. These individuals were concerned that the lack of default estimates would restrict the ability to credit restoration programs utilizing these materials. The Panel provided guidance for how implementers can develop site-specific estimates for oysters growing on these substrates throughout the report. Additional rationale and limitations are outlined in a new Appendix L, which was developed in response to these concerns and questions.

The remaining feedback generally addressed concerns or questions in the following categories:

Feedback Category	**Panel Actions**
Eligible Practices	The Panel discussed suggestions and decided no changes were appropriate to the practices currently described in the report.
Definitions	Minor adjustments were made (described in the tables below).
Clarification & Grammar	Minor adjustments were made to improve clarity (not described in detail here).
Approach & Data	No major changes were made to the report. The Panel has provided additional justification in a new Appendix L and has provided more detailed responses to specific comments in the tables below.
Biomass Assessment & Verification	No changes were made. The Panel has provided responses to specific comments in the tables below.
Future Research	Some future research needs were added to the report.
Implementation, Credit Timeframe, Regulations	Not addressed. These were outside the Panel's charge.

Responses to specific comments are outlined in the tables that follow.

Table M-1. Summary of comments and the Panel's responses that are directly related to the Panel's recommendations in this report.

BMP	Topic	Comment Summary	Panel Response	Revision Made to Report?
Restoration	Eligible Practices	Should consider whether other biomass enhancement activities, including in situ setting of hatchery-produced oyster larvae, qualify as eligible oyster enhancement activities.	Adding the in situ setting of oyster larvae as an eligible BMP practice is not appropriate at this time. There is a lack of data on the efficacy of direct setting as an enhancement activity, as well as a lack of data on the growth and survival of oysters introduced using this method. More research is needed before this could be considered.	No
Restoration	Eligible Practices	Do the results transfer to freshwater or mixed water systems?	This is a tidal BMP only.	No
All	Definitions	BMP site: Specify that the site only includes the footprint of enhancement.	This was intended and is captured in the definition of "BMP site area".	No
Restoration	Definitions	Large substrate: The definition is not relevant to our region. The division between "large" and "small" substrate is unnecessary. The Panel should only list the types and sizes of substrates with sufficient data which are included in the regression data.	The Panel deems data availability for large substrates to be deficient for generating a default denitrification rate and using the default regressions. The Panel concluded it was necessary to distinguish between substrate categories to provide clarity on what was eligible and not eligible to receive credit using default rates and regressions.	No
Restoration	Definitions	No-harvest areas: Does the definition pertain to areas closed due to water quality concerns like sanitary sewer discharges? Definition should clarify the timeline required to be considered a no-harvest area. Should distinguish if closed permanently or closed periodically.	The Panel is implying that an area must be permanently closed to harvest. Ultimately this is up to the States. The Panel added a qualifier to the definition.	Yes
Restoration	Definitions	Oyster reef restoration: Need to add that areas could be closed to harvest due to water quality concerns.	This will be addressed by updating the definition for "no-harvest areas".	Yes
Restoration	Definitions	Suitable substrate: Add examples	The Panel hesitates to over-define this term due to the ongoing development of new substrate types. The Panel added the text "can include but are not limited to…" with examples.	Yes

All	Approach & Data	The geographic scope for developing the regression equations is limited. If approved, the Panel should use additional data that is more spatially diverse to update the BMP reduction estimates.	Figures E-1, E-6, and 8.2 display the spatial scale of data used to generate the Restoration BMPs. The information used to generate the regression equations for the Harvest BMP is in the Panel's first report. Collecting more measurements and refining the estimates provided in this report will require significantly more time and resources. It is up to the CBP and States if they want more data before reviewing or approving these BMPs.	No
Harvest	Approach & Data	Why were observed mortality rates from the Maryland DNR fall survey and other existing databases not used, and why were sentinel monitoring sites in Harris Creek not used to evaluate spat mortality for generating a default spat survival rate? It does not seem that existing oyster density and recruitment were fully considered in this assessment. Suggests an additional assessment should be done on the substrate and seed restoration sites in Harris Creek.	The Panel specifically calculated how many oysters survived from planting (year 0) to year 3 for reefs restored using spat on shell only. These reefs were most similar to harvested reefs (see Appendix D and Ch 6 for details). Data from these two periods already integrate recruitment, survival, etc. rates and processes. The Panel did not need to quantify survival between individual years so did not think this additional data is most appropriate for their needs. The Panel welcomes DNR to use other survival rates based on data they collect to inform MDE BMP criteria.	No
Harvest	Approach & Data	Concerned about extrapolating survival data from planting to harvest from a large-scale restoration area (Harris Creek) to harvest areas due to differences between restoration and harvest areas. Without data from open-harvest areas, approval of this BMP should be postponed. The Panel should include additional recommendations on timelines and protocols for sampling to avoid overestimating spat survival OR should only allow use of the default 3% harvest allowance.	The Panel considered all of these details when developing the 3% default spat survival rate and harvest allowance. They concluded it was appropriate.	No
Restoration	Approach & Data	The stipulations of the timelines associated with the two separate baseline oyster biomass approaches (pre-restoration vs. representative site) are overly strict and could unintentionally limit the use of this BMP. These	The Panel provided two baseline approaches to cover both scenarios of restoration (that were initiated either before or after the approval of the BMP). The Panel deliberated on the conditions specific to each baseline	No

		recommendations should be more flexible and allow the non-restored representative site approach to be used in more situations.	approach. The pre-restoration conditions were developed to minimize crediting increases in biomass at the restoration site simply by closing an area to harvest before enhancement activities take place (Practice L – not endorsed). The representative site conditions were developed to minimize the risk of the site not being representative of the restoration site due to the patchiness of oysters, differences in environmental conditions, natural changes over time, etc. The Panel agrees these conditions are scientifically valid and does not recommend changing them.	
Restoration	Approach & Data	Some ideas/concerns about the statistical model (50^{th} quantile) used to generate the default oyster shell height to biomass regressions: • Could address location effect with a dummy variable and test for a location by shell length effect. Or subset the data to see which locations differ from the original model • Is the design used a nested design? If analyzed independently, could be improperly minimizing variance estimates	The Panel chose the 50^{th} quantile regression for its simplicity and the approach to test effect of location and habitat type was meant to be simple. The Panel recognizes that there is uncertainty in their estimates and that there are limitations to their approach. Data can be made available once the BMP is approved. Others are welcome to improve the Panel's default estimates which can be incorporated into the watershed model and nutrient management framework.	No
Restoration	Approach & Data	The Panel's approach to generating reduction estimates is more descriptive than predictive. A quantity of interest to management is the total amount of N and P removed and uncertainty in that amount. This would require an estimate of the number of oysters as well as the average size and the rate of N/P removal. These quantities all have uncertainty associated with them so there should be uncertainty reported with the total N and P removed.	The Panel assumes that there is uncertainty in all their reduction estimates, but did not quantify it. The Watershed Technical Workgroup has confirmed that uncertainty is not currently reported for any other BMPs in the BMP reporting framework.	No
Restoration	Approach & Data	Does the amount of nitrogen removed depend on other factors that might be included in a more general model (turbidity, temperature, salinity)?	Yes. The Panel tried to incorporate this by using oyster measurements taken at different times of year and from different locations across the Chesapeake Bay. The Panel used data that already existed to generate their estimates.	No

			These data were not collected with the specific intention to be used for developing a BMP.	
Restoration	Approach & Data	The differentiation between substrates based on size seems arbitrary. Relying on the size of the substrate to distinguish between creditable and non-creditable projects complicates the process.	Improved datasets on a range of substrates would be helpful, but were not available to the Panel. The Panel used size to assign whether substrates were creditable using default estimates or site-specific estimates. This distinction has more to do with how an implementer would sample substrate rather than size. The Panel decided that size was the best way to describe or summarize this distinction.	No
Restoration	Approach & Data	For denitrification crediting, suggest the Panel allow large reef substrates to be credited the same as small substrate rates for a default rate. The Panel has emphasized that nutrient removal efficiencies are conservative and therefore there is no ecological danger in building in the recommendations for default large reef substrate credits. The report fails to acknowledge that a baseline denitrification value can and should be applied to larger reef structures and should revise the report to include them. The Panel should recognize that quality work does exist regarding large structures. One shortfall of the Panel's effort relates to decisions about crediting denitrification for large structures. Suggest (at a minimum) using site-specific data being collected for N and P crediting (with respect to oyster tissue and shell biomass) as a placeholder for baseline denitrification credit for large structures. It would be detrimental to wait years until all the appropriate data	The Panel is not discouraging implementers from seeking credit for enhanced denitrification on reefs restored with large substrates, but does not feel that there is sufficient science to generate a default rate for these restoration projects at this time. The scientific community has an incomplete understanding of biogeochemical processes on large substrates – there is an overall lack of data on this subject, or existing data is insufficient to generate a Bay-wide default rate (more details in Appendix L). The Panel is also concerned about not being able to identify negative consequences associated with crediting denitrification on large substrates if using default rates developed for reefs restored with small substrates. For now, the Panel has provided guidance on how implementers can generate site-specific estimates by measuring denitrification and oyster tissue biomass on large substrates directly. The site-specific estimates cannot be applied Bay-wide.	No

		are collected for large structures to mimic the level of information we have for smaller ones. One commenter offered both published and unpublished datasets from their assessments of oyster reef restoration projects within Chesapeake Bay. None include in situ denitrification measurements, but they do indicate that large 3D reef structures exhibited production equal to or greater than 2D shell reefs. Recommend that the Panel include interim baseline denitrification values for large structures that are at a minimum on par with those recommended for small structures.		
Restoration	Approach & Data	Request to include information on how mixed substrate BMP areas (e.g., on bottom SOS and Reef Balls) should be addressed through the suggested protocols. Need to expand protocols for sites that have mixed substrate sizes.	The Panel has added text to Subchapter 7.2.4 to explain how to credit restoration projects using mixed approaches. In short, the implementer would treat the substrates separately.	Yes
Restoration	Verification	Suggests indicating which of the restoration-assimilation examples would best reflect large limestone, granite, or other non-calcium stone as these are mentioned in Section 7.2.3 as examples of large substrates.	The Panel has added text in Subchapter 7.6.2 that describes considerations for sampling oyster biomass on these substrates.	Yes
Restoration	Verification	Recommends a biomass monitoring end date of 6 years to enable efforts to move on to restoration in other locations.	It's up to the implementer to decide how long they want to monitor reefs to receive restoration credits. The Panel is recommending that implementers continue to monitor biomass because we don't know the long-term biomass trends on restored reefs (e.g., > 10 years). Restoration at this scale is still relatively new.	No
Harvest	Future Research	Prior to approving a BMP for licensed oyster harvest, recommends that data on at least 5 years of oyster survival in harvest areas is collected.	This is already included in the Panel's research recommendations for this BMP. It is up to the CBP to decide if not having this data should delay approval of this BMP.	No

Harvest	Future Research	Need to also include discussion of potential negative consequences of increased biodeposition and phosphorus dynamics in the licensed oyster harvest discussion in Section 6.7.	The Panel agrees that this could be an unintended consequence. However, additional research is required to determine whether it is or is not a negative consequence on harvested reefs. The Panel has included this in Appendix I for harvest and on-bottom aquaculture.	Yes
Restoration	Future Research	The Panel needs to prioritize measurements within the 78-267 g DW m^{-2} oyster biomass range in the denitrification regression. An inflection point in the regression plot is likely and should be identified.	The Panel agrees that this would be helpful and has added this comment as a future research need in Subchapter 8.9.	Yes
All	Future Research	Anticipates that future research to address the advantages/disadvantages of using alternate substrate for restoration, and improve the spat survivorship estimates on harvested reefs will be useful. These should be prioritized.	The Panel agrees that these are two of the most relevant needs for additional research. Understanding these processes will help refine the estimates and recommendations the Panel has outlined in this report. We have checked to make sure that these future research needs are included throughout the report.	Yes

Table M-2. Summary of comments and concerns raised by the public and stakeholders that are outside the Panel charge, require additional consideration by the CBP Management Board, or are not relevant to the recommendations in this report.

BMP	Topic	Comment Summary	Panel Response	Revision Made to Report?
All	Review Period	Suggests an additional comment period before review by CBP Management Board.	A 40-day review period was recommended by CBP advisors. There were several opportunities for individuals or organizations needing extra time to conduct their reviews to contact the Panel Coordinator. It is up to the CBP to decide if an additional review period is required.	NA
Harvest	Eligible Practices	Agree that Practice F is similar to previously approved practices, but think verification and accounting associated with this practice is difficult. Does not believe that this BMP should move forward for approval unless alterations to the public fishery are made.	Outside Panel charge.	No
Restoration	Credit Timeframe	The proposed approach for reduction crediting for oyster reef restoration is at odds with other ways the CBP addresses new information and incorporates it into the Bay watershed model and state- or basin-specific allocations. New information should be used to help set the baseline, not credit historical work done. Pre-restoration data dating back to before an oyster restoration BMP is approved should not be permitted. Commenter only supports denitrification credits for projects moving forward from the date the BMP is approved.	The EPA will ultimately decide how oysters are added to the TMDL model. The Panel is providing recommendations on when reefs become eligible for credit based on their knowledge of how oyster restoration activities are tracked. An implementer can track past restoration activities and many of the existing restoration programs in the Chesapeake Bay conducted thorough pre-restoration habitat surveys.	No
Harvest	Implementation/ Regulation	There should be explicit restrictions on harvesting at a BMP site prior to the start of crediting to allow for adequate survival and growth of planted oysters prior to removal by harvest.	This is already partially accounted for in the Panel's qualifying conditions for this BMP. This is also a State management decision and the Panel cannot enforce any regulatory decisions.	No

Harvest	Implementation/ Regulation	To account for undersized oysters included in harvest, 5% of the estimated assimilated nitrogen and phosphorus should be removed at the time of crediting so as not to perpetuate incentives to harvest undersized oysters.	This is inherently included in the qualifying conditions for this BMP that minimize over crediting of oysters that should not be harvested. This is also a State management decision and the Panel cannot enforce any regulatory decisions.	No
Harvest	Implementation/ Verification	Recommends additional requirements be added to steps in reporting process: Step 1: BMP site area be clearly marked and closed to harvest until the default or site-specific time lag has passed Step 2: Add a requirement to document the source of hatchery-produced larvae and/or spat on shell Step 5: Add a requirement to identify who is allowed to harvest from the BMP site prior to beginning harvest after the two-year lag has lapsed.	These additional verification steps and harvest restrictions will be up to the States. Step 1 – outside Panel charge; Step 2 – from nutrient reduction perspective, source of hatchery-produced oysters is not necessary to track; Step 5 – outside Panel charge.	No
All	Implementation	Suggest adding detail to help distinguish BMP site from adjacent harvest and/or no-harvest areas: • 150 ft (or larger) buffer • BMP areas should not cross management boundaries • BMP site should encompass the entirety of a bar or easily distinguishable management unit to facilitate enforcement and verification	It will be up to the implementer/ States to decide how restoration or harvest areas are delineated, and how BMP sites are selected within/among those.	No
Harvest	Verification	Observers or vessel monitoring systems should be required to verify that oysters originated from the BMP site.	Outside Panel charge. It will be up to the implementer/States to decide how harvest is tracked for BMP credit. Many of these systems are already in place in certain areas of the Chesapeake Bay.	No
Aquaculture	Verification	Suggests that including documentation to verify the source of hatchery-produced oysters or to verify substrate additions on aquaculture leases should be mandatory, not optional.	This BMP is already approved. This is also outside the Panel's current charge, but can be considered by the CBP Management Board.	NA
All	Regulations	Approval seems premature given the pending CBP policy decisions and lack of guidance for Oyster BMPs in Phase 6 Watershed Model	No action needed by Panel. This is a decision for the CBP Management Board.	NA

All	Regulations	Need to include rationale in the report why other fisheries should not be credited for nutrient removal.	Outside Panel charge.	NA
Harvest	Regulations	Executing a framework for crediting licensed oyster harvest activities would require structural, regulatory, and statutory changes to implement the BMP protocols.	Outside Panel charge.	NA
Aquaculture	Approach	The recommendation that wild hatchery-produced oysters planted on-bottom with no cages be eligible for credit defeats the model of using triploid oysters only. Was this overlooked as an unintended consequence?	Not relevant – this comment applies to the Aquaculture BMP which is already approved. The Harvest BMP recommendations that the Panel outlines in this report do not allow the use of triploid oysters on harvest areas.	NA
Restoration	Data/ Future Research	Can the compiled data be stored somewhere or shared?	The Panel is willing to share data used to generate their estimates. Others are welcome to refine these estimates and the Panel's approach. Most of the data accessed in this report has been published through the scientific peer-review process and/or in technical reports. The Panel will contact data sources to receive permission to share unpublished data. The Panel will have to confer with CBP to decide where and how data can be hosted online for public access.	NA
Restoration	Future Research	If agencies are spending a certain amount of money on restoration, how should it be applied? For example, ideal number of oysters, design of reef, etc.	The Panel agrees that this information would be useful for designing oyster restoration projects and could provide additional recommendations. However, they agreed that this was beyond their current scope and charge. Individuals seeking recommendations for oyster restoration design should contact State agencies and scientific experts currently leading oyster restoration programs in the Chesapeake Bay.	NA

Appendix N. Panel Meeting Minutes

In a separate 104 p. document.

Appendix N. Panel Meeting Minutes

This appendix contains the meeting minutes from the 30 Panel meetings held between December 2016 and October 2022. The meeting minutes describe discussions the Panel held to define and identify oyster practices and oyster-associated protocols for BMP consideration, and to develop the recommendations described in this report.

Oyster BMP Expert Panel Meeting, December 8, 2016, 1:00-3:00 PM

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

Participation:

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)	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	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)	Not Present
Bill Wolinski	Talbot County Department of Public Works	Not Present
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	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	Not present
Emily French	Oyster Recovery Partnership	In person

Action Items:

1. **Action:** Suzanne will ask Liddel and Grizzle for their original data.
2. **Action:** Matt will send his data to Julie Reichert to compile for Julie Rose.
3. **Action:** Julie Reichert will incorporate Powell and Mann shell data sent by Lisa in Master spreadsheet.
4. **Action:** Once additional shell data is added to Master spreadsheet, Julie Rose will re-run quantile regression analyses.
5. **Action:** Julie Reichert will follow-up with Rich Batiuk on the status of the legal opinion concerning sequestration for in-water BMPs.

6. **Action:** Julie Reichert will follow-up with Ward to see if there is info on how much a bushel weighs and how much shell is returned to the Bay and where it came from (Chesapeake Bay or elsewhere).

Meeting Minutes:

1. **Coordination Updates**
   a. 1st report approval schedule: Watershed Technical Workgroup approved 1st report on 12/1/16; Jeff and Julie Reichert will be presenting the 1st report for approval during the 12/19/16 Water Quality Goal Implementation Team (both Habitat and Fisheries GITs have been invited to this meeting).
   b. Restore America Estuaries Conference: Panel's first report will be presented during the "The Shellfish – Water Quality Nexus" session.

2. **Begin conversation on N and P assimilation in shell protocols**
   a. **Preliminary conclusions from the policy group regarding the crediting of sequestered N and P in shell:**
      i. Julie Reichert: In discussing this with Region 3 council, CBP felt that sequestration could be allowed given that the nitrogen and phosphorus is considered a pollutant only when it's in the water column; CBP has sent request to general counsel at EPA headquarters to produce a memo capturing the agency's legal opinion concerning crediting N and P sequestration.
      ii. Chris asked, do we have any studies about shell degradation thus far, such as 1, 3 and 5 years from being placed in the water? Julie answered yes, a Waldbusser study that Ken Paynter originally mentioned; Suzanne also mentioned a thesis by Beth Darrow that is an analysis of N and P in a 2500 year old shell.
      iii. Matt asked, if oysters are actively growing, is there degradation happening to the shells? Chris said yes, that he has seen some natural oysters growing whose shells are being actively degraded in the Rappahannock; also mentioned that dissolution can be greater in VA due to the presence of boring sponges (Jim Wesson paper).
      iv. Julie Rose asked, I thought the concern with crediting shell for aquaculture was also about it not being returned back into the Bay? Julie Reichert answered, yes, that is also an issue that needs to be addressed; given that shell is an important and limited resource for these practices and the Bay, recommendations shouldn't encourage the unintended consequence of shipping shell away from the Bay; we will discuss this more later during this meeting.

   b. **Julie Reichert presented findings from compiling the shell data already acquired:**
      i. The Liddel data had some inconsistencies when compared to the other datasets (quite of few biomass values were much greater than the other datasets at shell heights less than 100 mm); unclear if this is "real" or if there was a data entry error of some sort (Lisa believes it is an error); for now, this dataset was removed from the preliminary quantile regression analysis conducted by Julie Rose.
         1. Matt asked if the Liddel data aquaculture or restored reef? Julie Reichert answered restored; mentioned that for his and Suzanne's project, the tech noted barnacles and spat on shells; since they add extra weight, could what is being observed in the Liddel data have something to do with this, if they didn't chip extra shell off?
         2. Julie said that the data above 100 mm shell height looked fine, so if it were a copy paste error it would seem that all the data would look odd; this may support Matt's theory.
      ii. In removing the Liddel data, we end up with 10 general locations instead of 22.
         1. Chris mentioned that the Eastern Shore is not as well represented now, which is where he expects more dissolution to be happening, which may affect shell sizes. Suzanne asked why? Chris said boring sponge is more prevalent in saltier water; Jim Wesson published a paper/ report two years ago that found within 5 years shell being researched was gone (in Virginia assuming).

2. Lisa said there is shell dry weight data in the Roger Mann data from VA that may help fill the gaps; Julie commented that we could look at that data especially if the Liddel data is flawed; Lisa said she'd be more interested in the Mann data since it has VA data in it.
3. Suzanne said she would be happy to meet up with Liddel to possibly obtain the original dataset to figure out if a data entry error occurred (Ken's database only included the compiled dataset).

c. **Julie Rose presented shell height to dry weight findings from analyzing the compiled shell data using the same quantile regression approach as tissue (without Liddel data):**
   i. Aquaculture shell data for with gear is lacking; the 50th quantile for the oysters in cages is lower than the rest of the data, potential to overcredit if combine with the no gear data.
      1. Matt asked about the sample size and mentioned that their study is collecting data now until May, so in a few months there will be a lot more data available for the in gear culture; data could shift upwards; when is the deadline for the 2nd report? Julie Reichert responded October to reach consensus, so there may be time to incorporate Matt and Suzanne's data, especially since it will help fill a gap.
   ii. Error around the 50th quantile for the oysters grown in cages is quite large due to small sample size; may need to go with a lower quantile (i.e., 30th) for the entire dataset; however the software produced identical results for the 30th and 50th quantiles (something odd is going on with the combined data; individual datasets looked fine; recommend separate estimates for off-bottom and on-bottom practices; quantiles looked better when data were separated by culture method).
      1. Lisa asked if we tried leaving out oysters larger than 125 mm given that is where the large spread occurs; Julie Rose said we could try that, but quantile regression is generally robust enough to account for the spread.
      2. Matt said he is curious to see how the regression would look with the 400 data points he sent earlier that day; Julie Reichert will incorporate this additional data in the Master spreadsheet for Julie Rose to analyze.
      3. Chris mentioned that he would expect the oyster data from the with gear dataset to be lower than the dataset without gear because contained aquaculture produces oysters with thinner shells; would justify separate estimates.
   iii. Julie Rose presented diploid and triploid data subsets; the triploid data is lacking; when looking at the triploid and diploid data from the same site, the diploid oysters had heavier shells than the triploid oysters.
      1. Matt said that the data is from the same farm and gear but the stocking date was not the same; diploid shell may weigh more but it could take diploids longer to get to that point; anecdotally, anything in a cage grows faster than on the bottom (may also influence dissolution rates); Matt suggests the categories, "diploid with gear," "diploid no gear," triploid with gear," and "triploid no gear" would work since there is a growth rate difference.
      2. Matt said it is difficult to substantiate the claim that triploids grow faster than diploids unless they're in the same areas.
   iv. Chris asked, how separated do farmers keep diploids and triploids?
      1. Panelist mentioned that not a lot of farmers use diploids in gear or triploids on bottom, but can occur.
      2. Another panelist mentioned that the use of diploids may become more popular because it can be difficult to get triploids.
   v. Julie Reichert asked, do we keep all 4 combinations that Matt suggested? Chris felt that culture method has a greater effect than ploidy; therefore separate out recommendations by culture method, but not necessarily ploidy; panelists agreed.

   vi. Panelists felt getting more off-bottom data would be important along with data from VA; Julie Reichert will incorporate Matt and Suzanne's additional data and Powell and Mann data in Master spreadsheet to see if it helps fill in these gaps.

d. **Available literature for % N and % P content in shell**
   i. Panelists agreed to include all Atlantic coast numbers (similar to tissue); Panelist asked why Grizzle et al. not included (New Hampshire data); Julie Reichert explained the Grizzle research was removed because it was an estimation from a graph; Suzanne volunteered to get in touch with Grizzle for actual numbers.
   ii. Matt asked- if the data looks like there is not a lot of N variability, do we need to separate by culture method? Julie Reichert responded that the separation would be needed to calculate the biomass to apply the percentages to.
      1. Julie Rose said that we need to separate the biomass calculation by culture method because the software can't accurately calculate the 30^{th} quantile for the combined dataset with the available sample sizes.
   iii. Panelist asked- the % content in shell is pretty low (less than 0.2%); does it make sense to have a shell crediting protocol?
      1. Julie Reichert said that when looking at the entire oyster, the amount of N is around 60% in the tissue and 40% in the shell (the 0.2% is just based on the amount of N in the shell compared to the other elements in the shell, not how it's distributed in the entire oyster); given that shell weighs more than tissue, it could be a substantial amount; Panelists agreed.
   iv. Julie Reichert asked- should we use the same averaging approach that was used for tissue for consistency? Panel agreed.
   v. Julie Reichert said there is less data available for % P and there is no triploid data; Julie Rose mentioned that they have a chemist that will be evaluating the N and P content in oyster tissue and shell of diploid and triploid oysters and that around the May-July timeframe that the first batch of data should be done.
      1. Julie Reichert remarked on the approval process by the water quality GIT and watershed technical workgroup; 4 week review and 8-12 weeks to get through approval process, so would need data by early July at the latest if looking to finalize approval by December 2017.

e. **Idea on addition/subtraction method to not have to deal with determining shell dissolution**
   i. Julie Reichert asked about whether shell crediting can use a simple addition/subtraction method (record how much shell is put in and subtract that number from what is removed to determine the amount of shell that can be credited)
      1. Matt- unit is in bushels (unclear how much a bushel weighs or how many shells in a bushel); does ORP have any info on this?
      2. Lisa- unclear how long they sat on land (how much deterioration occurred); Julie Rose said some are broken and are not uniform - you'd want to know the weight of all shell going in.
      3. Julie Reichert asked if there is more shell coming out then is put back in?
         a. Matt said that for on-bottom aquaculture shell is used to build up their lease bottom before putting spat on shell on top; they could be at a disadvantage if using this method.
      4. Chris said counting shell would be very complicated; good resolution at farm level but still complicated; Matt and Chris suggested only giving credit to off-bottom aquaculture producing singles since only a tiny fragment of shell is used as cultch; Panelist mentioned that this is still an issue because the shell that they are getting credit for can and should end up back in the Bay.
      5. Julie Rose suggested including a deduction to the shell assimilation credit based on the assumption that 100% of the shell is being returned to the Bay—deduction could be derived from a known dissolution rate over a period of time, e.g., 5 years); having a default

deduction applied to the assimilation credit would account for shell being returned to the Bay and therefore wouldn't discourage recycling because the deduction would be applied regardless where the shell ends up.

   a. Matt suggested using a smaller quantile to account for this.
   b. Julie Reichert mentioned that they are working on getting a legal opinion from EPA on whether sequestration can be incorporated in the estimate; will follow-up with Rich Batiuk on the status.

6. Lynn said that the crediting of shell worries her from an implementation standpoint; shell is a limited resource that is highly competitive; not sure if it's worth having a shell crediting protocol given the potential unintended consequence of not recycling shell.
   a. Chris asked if we have shell acquisition numbers- do we know how much shell is returned to the Bay; Matt asked do we know how much SRA shell is from different places; Julie Reichert will follow up with Ward to see if we have any info on this.
   b. Mark said that there are reports that document that shell is in short supply (2016 Oyster Summit, Blue Ribbon Panel, etc.) - we don't want to dis-incentivize shell being returned to the Bay; this alone could be rationale for not endorsing a shell crediting protocol.
   c. Julie Reichert mentioned that STAC concluded not to give credit for shell because of this concern.
7. Jeff said that there is data available to determine the amount of N and P assimilated in the shell, but data concerning the shell budget and dissolution rates may be less available and that the variability in those numbers will likely be daunting.
   a. Panelist mentioned a Jim Wesson (sp?) paper with shell dissolution rate data.
8. Julie Rose asked about restoration; do we have a sense of reefs increasing/decreasing?
   a. Lisa said biomass increasing; likely adding more shell.
   b. Chris said there isn't really sequestration until burial.
   c. Panelist mentioned that N and P is also sequestered in the reef, but once it reaches a steady-state (no longer increasing) then no more credit should be given.
   d. Panelist mentioned that Jay Lazar (sp?) is collecting reef spatial extent and height data for the 3 year check in (Harris Creek).
   e. Jeff mentioned that there isn't a huge amount of P in the shell.

Oyster BMP Expert Panel Meeting, January 19, 2017, 1:00-3:00 PM

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

Participation:

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)	Phone
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Phone
Chris Moore	Chesapeake Bay Foundation (CBF)	Not Present
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)	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
Matt Johnston (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	Not Present
Guest	**Affiliation**	**Present?**
Carl Cerco	US Army Corps of Engineers	Phone

Action Items:

1. **Action:** Carl will present additional information on the oyster model scenarios during Feb. 16 meeting
2. **Action:** Jeff will put together examples of calculations for a denitrification estimate; will send draft Marinetics paper when done.
3. **Action:** Suzanne will send link to presentations from the watermen's expo

Meeting Minutes:

1. **Coordination Updates**

a. 1st report updates: Press release with CBP, interview with Aquaculture N. America, ORP presenting Panel's recommendations at special session, "Aquaculture to Restore Coastal Ecosystems," at Aquaculture America 2017 (February 19-22).
b. The shell data are still in the process of being collected and cleaned up. We will resume the shell crediting protocol conversation once the data is ready.

2. **Oyster Model Scoping Scenarios**
   a. Carl Cerco presented information on the oyster model scoping scenarios.
      i. Oyster model was developed in 2000 to evaluate potential water quality benefits from a 10-fold increase in oyster population, but was left dormant in TMDL (at that time the oyster population was not large enough to exhibit a noticeable impact to water quality)
      ii. Oyster model has not been calibrated or compared to data for biomass and distribution to consider growth in oyster population from oyster restoration and aquaculture activities.
      iii. Incorporating aquaculture is somewhat difficult given that the conditions may not be appropriate in a cell for oysters to grow; only have MD aquaculture harvest data by counties (actual location could not be given due to privacy regulations); will assign aquaculture locations by salinity and depth criteria.
      iv. When sanctuaries overlap with existing reefs then if will be assigned as sanctuary.
      v. For VA private landings data Mark provided info on decline and increase pattern: In the 1980s, the transplanting of wild stocks from low salinity to high salinity areas stopped due to disease (reason for decrease in landings); in 2009 private leasing started up causing an increase in oyster production.
      vi. Main takeaway from preliminary oyster model scoping scenarios: a significant impact in reducing chla and total nitrogen at tributary scale from increased aquaculture oyster biomass.
      vii. Jeff- important to consider location of reefs; 3% of Harris Creek planted resulting in 30-fold more biomass than surrounding areas; need to consider net biogeochemical processes.
   b. Panelists discussed options in incorporating information as a BMP estimate versus incorporating directly into the model:
      i. Carl- ideally it would be beneficial to compute denitrification and burial in the model and compare with potential BMP estimates; also it would be better to be able to adjust the model to have the oysters placed where there are actually oysters; the model would do a better job incorporating the condition of the water.
      ii. Mark agreed with Jeff that we shouldn't do bay-wide analyses of oysters in model runs, but fundamentally agreed with Carl that it makes sense to incorporate denitrification in the model.
      iii. Panelists agreed that it would be useful to evaluate both approaches (model vs. empirical) to compare results to determine which would be the best approach to consider the water quality effect.

3. **Thoughts on deriving a default denitrification estimate**
   a. Jeff presented his ideas on how to go about calculating a default denitrification estimate for Panel discussion:
      i. Jeff- In thinking about "enhanced" denitrification by oysters, we need to consider not only the footprint area (location of oysters), but also the surrounding area where biodeposits may be transported to; quantifying just at the site may not be appropriate.
      ii. Jeff- Also we need to consider N remineralization that occurs with and without the presence of the oysters; N remineralization does occur in the water column and sediments without oysters; oysters move the organic matter quicker to the sediment where N remineralization is greater; do we subtract what have occurred in the water column and sediment without the oysters (i.e., 50/50 assumption – only credit half the denitrification?).

iii. Jeff- Material that is processed directly underneath the oysters may not help water quality; however, if it is spread out away from the site there could be a benefit; need to consider biodeposit production and distribution; if using just the footprint area you could be overestimating a negative impact; need to figure out what the net enhanced denitrification value would be that considers both the footprint area and surrounding distribution area.

iv. Jeff- Overall we need to consider what makes sense for a BMP; can we develop a conservative default estimate for enhanced denitrification? Potential outcomes could include:

1. Develop framework on how this could be done, but there may not be enough data to determine an estimate.
2. Develop a default estimate that can be applied across all oyster practices/reefs.
3. Recommend a site-specific estimate approach.

b. Panel discussion

i. Mark agreed that physics matter and where biodeposits end up – would make sense to model and included recommendations for model inputs.

ii. Bill- oyster reefs have been shown to clear the water and bring back SAVs (amount of material filtered out of water column is important).

iii. Lew- likes the idea of a system approach; current oyster model is a larger systems approach; staging the model in shallower waters would be better for assessment of the water quality benefit.

iv. Jeff- Marinetics have an 80 ft hole nearby, does denitrify.

v. Jeff- For the stream restoration bmp, the estimate is not based on a regular process, instead a model is put in place to make the calculation; the model allows for site-specific estimates.

Oyster BMP Expert Panel Meeting, February 16, 2017, 1:00-3:00 PM

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

Participation:

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	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)	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
Matt Johnston (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	Phone
Emily French	Oyster Recovery Partnership	In Person
Support Staff	**Affiliation**	**Present?**
Emilie Franke	Contractor, Fisheries GIT, NOAA Chesapeake Bay Office	Phone
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Guest	**Affiliation**	**Present?**
Carl Cerco	US Army Corps of Engineers	Phone

Action Items:

1. **Action:** Kyle and Julie will look into the VCU Rice Center and other locations as a possible public stakeholder location in Virginia.
2. **Action:** Chris will look into sharing VMRC aquaculture data with Carl.
3. **Action:** Matt and Carl will talk regarding max depth criteria of aquaculture in the model.
4. **Action:** Lynn will double-check the data accessibility on MD DNR's aquaculture siting tool.

5. **Action:** Jeff, Larry, and Lisa will work with Julie to capture denitrification BMP estimate information and thoughts to include in the report even if a BMP isn't established.
6. **Action:** Jeff will develop a table of terms to ensure consistent definitions throughout the report.

Meeting Minutes:

1. **Coordination Updates**
    a. Welcome to 3 new support staff from CBP: Emilie Franke, Paige Hobaugh, and Kyle Runion.
    b. ORP presenting Panel's recommendations at special session, "Aquaculture to Restore Coastal Ecosystems," at Aquaculture America 2017 (February 22).
    c. We are hoping to give a progress update at the WQGIT meeting in April in preparation for a public stakeholder meeting in May. Location is potentially Annapolis (CBPO). We can explore another session in Virginia but do not have funds to pay for a meeting location.
    d. Suzanne and Matt are water and oyster sampling at two locations that have potential for aquaculture research: Calvert Bay and Point Lookout. There are some nice experimental design sites with an adjacent natural reef. The farmer has the same strain of triploid oyster at each site and would be willing to put the same strain of spat on shell at each site. We are brainstorming potential research ideas for these sites such as denitrification in a reef next to an aquaculture sites or differences in meat quality.
    e. Andy and Lisa are beginning a new project in the Chesapeake Bay spring 2017 to work with aquaculture growers. This is a part of TNC's global marine strategy Aquaculture by Design program where we examine a range of conservation targets. This project has a partnership with four growers on the western shore of Virginia with both science and outreach aspects. Sites are in the Rappahannock, York, Lynnhaven, and Piankatank. We want to answer the question of is oyster aquaculture providing a service toward restoration of the Bay. Large and medium size operations use each floating gear and bottom cages. Nitrogen removed from shell and tissue, water quality data, sediment effects (organic content and grain size), benthic community structures, and mobile organism behavior will be investigated.

2. **Example of denitrification estimate calculation**
    a. Jeff presented an example of a calculation method for the denitrification estimate.
        i. Continuation from January. Summary of last meeting: We are trying to make estimates of enhanced denitrification associated with aquaculture or restoration. The issue with denitrification is that it occurs naturally to a significant proportion of the nitrogen in the Bay. We typically measure denitrification in the area of the reef, but biodeposit dispersion to the surrounding areas was measured as high as 90% at one site
        ii. Lew – Are you considering an enhanced settling rate of larger particles?
            1. Jeff – We are considering that this nitrogen was taken from the water column or sediments. The total system nitrogen regeneration does not change.
        iii. Components of denitrification: occurs in the water column and sediment in the reef area, and in the surrounding area.
            1. The efficiency of denitrification in each of these areas is an important parameter.
                a. There can be high spatial variability in the efficiency, based on transport to a high/low efficiency system.
        iv. There are conditions where an oyster reef is not particularly helpful in terms of denitrification even if rates seem high (high sediment efficiency, low halo) and vice versa.
            1. Halo: ratio of material transported off reef to that that was deposited within
            2. Because the efficiencies of the sediment and biodeposit processing are not changing, the only change is the net from the oyster reef.
                a. "Reef" is just referring to the area of the oysters – could be called aquaculture facility.
            3. Lisa – There are conflicting views on whether the algae pool is limited or unlimited.

v. Julie – Can you clarify reef efficiency?
    1. Jeff – The proportion of the ammonium that is regenerated on the reef into gaseous nitrogen.

vi. Lew – Would most biodeposits end up in shallow aerobic sediments?
    1. Jeff – The efficiency I used is from these shallow environments but there is a chance they would end up in deep channels where the denitrification efficiency is poor.
    2. Larry – A colleague ran a sediment transport model and found that larger, heavier biodeposits tended to settle in deeper water.
    3. Lew – Could the halo be modified to account for anaerobic activity? Could denitrification be quantified in these anaerobic areas?

vii. Matt – Curious to see how harvesting would effect biodeposit dispersal. Is there a nominal denitrification rate we assign? Unlikely at this stage.
    a. This calculation approach illustrates controls but is not a complete nitrogen model.

3. Oyster model – Denitrification Component

a. Carl presented calculations the oyster model uses for determining denitrification and gave an update on the status of the oyster model scenarios.

i. Aquaculture refers to cages in this presentation.

ii. Nitrogen cycle: Oysters filter particulate organic nitrogen from the water column. Feces and pseudofeces are deposited, some of which are resuspended and the rest into a particulate organic nitrogen (PON) pool. This PON pool is subject to burial or diagenesis to ammonium. A fraction of this ammonium is nitrified to nitrate, which is either denitrified or exchanged with nitrate in the water column.
    1. These processes come from various models: 2005 oyster model, sediment diagenesis model, water quality model.

iii. We are having issues with locating areas in MD and VA where an increase in aquaculture to the desired level is feasible. The ten-fold increase needs to come from areas where oysters self-locate in the model rather than trying to push a ten-fold increase in each cell.
    1. Mark – On leased bottom in Virginia, almost all oysters were wild which declined in the 1980s and some seed was moved from elsewhere.
    2. Matt – The majority of Maryland aquaculture is spat on shell derived from a hatchery.

iv. Bill - Side scan sonar data characterized into bottom habitat may be an important dataset here to show suitability.

v. Lynn - There is, on MD DNR website, an aquaculture siting tool to show where all the active oyster leases, restricted harvest, sanctuary areas. Data accessibility can be an issue though.

vi. Lew - At the small scale, oysters can have a significant impact on reaching local TMDLs.

vii. Mark – Can Carl provide the rates of diagenesis in the model?

4. Denitrification Calculation Method Discussion

a. The Panel discussed their thoughts on which method they feel would best address denitrification (BMP estimate using an empirical approach, incorporating reduction via oyster model, combination, other?).

i. Julie - Based on these models, it seems a conservative, default estimate would be difficult but a site specific estimate could be offered.
    1. Jeff – Agree. It is not clear if there are enough measurements and they do not converge particularly well.
    2. The panel agreed that they need a methodology for determining this.
        a. Larry - Would be difficult to confidently assign a number to the enhanced denitrification. An option is to state the science isn't available to recommend an efficiency.

b. Lew - Hopes there would be an estimate of additional transfer of organics to the sediment to show denitrification to the additional mass. Take conservative estimates and build an efficiency; this would be better than assuming no effect.
    i. Jeff - The fact that this can eventually affect nutrient trading makes this difficult.

3. Julie - Option is to use the retired oyster option in the estuarine model and treat it not as a BMP but allow it to be applied within the estuarine model.

ii. We hope to reach consensus decision regarding the denitrification protocol in next meeting.

Oyster BMP Expert Panel Meeting, March 16, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	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	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)	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	Not Present
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Ed Ambrogio (EPA R3 Rep)	U.S. EPA Region III	In Person
Ralph Spagnolo (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	In Person
Emily French	Oyster Recovery Partnership	Not Present
Support Staff	**Affiliation**	**Present?**
Emilie Franke	Contractor, Fisheries GIT, NOAA Chesapeake Bay Office	In Person
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	In Person

Action Items:

1. **Action:** Jeff will standardize denitrification numbers from the literature and compile data examples from Harris Creek and the Lynnhaven River.
2. **Action:** Julie and staff will work with Jeff, Lisa, and Mark to re-structure the denitrification studies into categories discussed (Restoration = subtidal, below photic zone, subtidal in photic zone, and intertidal;

aquaculture = sediment grain size) and remove studies that used inhibition/slurry techniques to quantify denitrification.

3. **Action:** Bill and Ralph will investigate how the shoreline management and wetland panels derived efficiencies based on geography and environmental condition.
4. **Action:** Julie Reichert will revisit shell assimilation discussion and compile info on the %N and %P in shell.
5. **Action:** Julie Reichert (with help from staff) will conduct literature review for shell dissolution studies.
6. **Action:** Panelists will share any studies relevant to the shell dissolution discussion.

Meeting Minutes:

1. **Coordination Updates**
    a. Presenting Oyster BMP info at Seafood Seminar in Harrisburg, PA on April 4th at 3pm.
    b. MDE communications interested in including information on the approved oyster aquaculture BMPs (our first report) in their internal newsletter the Heron.
    c. WQGIT update scheduled for May 8th to introduce initial decisions by the Panel on how to proceed with shell and denitrification.
    d. An open stakeholder meeting is scheduled for 10am-12pm Monday, May 22nd at the Potomac River Fisheries Commission in Colonial Beach, Virginia, followed by a closed panel meeting until 2pm.
    e. Aquaculture North America recently posted an article regarding the Panel's work.

2. **Denitrification Literature Review,** Jeff Cornwell
    a. The group reviewed existing denitrification values from studies to evaluate whether a conservative estimate is possible for either aquaculture, restoration, or both grouped in the following categories:
        i. Restoration – Chesapeake Bay Studies & Other Location Studies
            1. Jeff- core studies (measured rates from sediment cores near and at the edge of reef sites) don't completely incorporate the complexity of reefs compared to chamber measurements.
                a. Core studies (e.g., Smyth) demonstrated 80-100% efficiency; chamber studies showed around 10-25% efficiency.
            2. Jeff suggested that the estimate should focus on studies that used the chamber method because the entire bottom community is included in evaluating denitrification rates (more reliable); a few studies in our review fit this criterion (e.g. Choptank and Lynnhaven data)
                a. This data did not see denitrification until high biomass was reached; Chris- can a relationship be formed to determine potential denitrification rates based on oyster biomass per square meter?
                b. The physical setting alters the relationship between biomass and denitrification.
                    i. To optimize denitrification – dark, high biomass, deep enough (minimizes wave related re-suspension of materials; keep material on site for higher chance to denitrify; pertains to reef restoration and on-bottom aquaculture).
            3. Jeff felt that the oyster model in the TMDL is not at the needed scale to evaluate local effects from enhanced denitrification from oyster reefs (not fine enough).
        ii. Aquaculture – Chesapeake Bay Studies & Other Location Studies

1. In some studies, up to 90% of the biodeposits were transferred off-site; there is no simple, straightforward calculation of the net benefit of denitrification in aquaculture.
    a. The main difference is the community factor, which you don't see in aquaculture. If you have offsite transport, you can have net benefits but challenging to calculate.
2. Other than oysters, mussels and clams – there are huge numbers of studies that show minimum denitrification and lots of ammonium production
3. Sediment grain size can be used as a crude proxy for the physical environment when categorizing studies.
    a. If we did this, facilities would need to verify their grain size.
4. Jeff – studies that used inhibition/slurry techniques to measure denitrification are not reliable and should be removed from the review.

iii. The wetland restoration BMP and shoreline management BMP derived efficiency estimates based on geography/landscape and environmental conditions. This strategy could be used here.
1. Parsing these studies into different categories may be more effective: Restoration: subtidal, below photic zone, subtidal in photic zone, and intertidal; aquaculture: sediment grain size.

iv. With a limited number of studies, none were excluded by varying factors such as location or season of study.
1. Bill – These factors should be taken into consideration though; such as season which can affect the rate of microbial activity and thus biodeposits and filtering through temperature.

b. Models have been found to be generally not accurately predictive of oyster denitrification. The hope is to find accurate denitrification efficiencies from the literature that we are comfortable assigning to these practices.
   i. The form these efficiencies take may differ but will be standardized to compare and evaluate studies.

c. Next step: Standardize the denitrification rates found in studies with appropriate methods and compare.

3. **Shell Dissolution Method,** Julie Rose and Julie Reichert
   a. Share idea on how to address shell dissolution for aquaculture practices.
      i. Review following studies before meeting.
         1. Waldbusser et al. 2011 (particularly Figure 4)
         2. Powell et al. 2006
      ii. Amount of N and P assimilated in shell can be determined, but need separate estimates for on-bottom and off-bottom aquaculture; unknown whether there is enough information to incorporate dissolution effects when shell is returned to the water.
         1. Chris- Can we develop an accurate number?
         2. Julie Rose- we have a ton of data to develop the shell height to shell dry weight regressions.
         3. Regressions will be rerun with updated data from Mann, Matt & Suzanne, and possibly Liddel (Note: Liddel data were removed from the shell analysis since they were wet weights and not dry weights).
         4. The same approach as tissue assimilation will be used for shell assimilation estimates.

5. Julie Rose- Assume that 100% of shell is recycled; not sure if there is enough data to determine the effect of dissolution on the estimate.
6. Jeff- It is unknown whether the dissolution rate of N and P (no studies were found) is the same as the dissolution rate of calcium carbonate (few studies found).
7. Panelist mentioned that the dissolution rate of shells from off bottom aquaculture may be more rapid due to thinner shells.
8. Chris- also, boring organisms could cause shell to dissolve more rapidly.
9. Mark- stressed that a conservative dissolution rate should be used to avoid over-crediting.

iii. There is concern over discouraging shell recycling based on the potential credit for nutrient removal.
1. Shells currently have high value ($5/bushel in MD, $3.50/bushel in VA), so the resale of shells is going to be more lucrative than removal for credit.
2. Assuming all shell is returned to the Bay (the desired outcome), these concerns should be alleviated.
3. Suggestion was made to look more closely and other BMPs that aren't permanent fixtures, such as wetland and buffers; analogous with wetlands, oyster shell keeps accreting; panelist mentioned that most shell growth occurs in summer when dissolution is maximized.
    a. Bill- The wetland BMP is based on tidal and nontidal (not seasonal) and is a static number applied year-round.

iv. Apply a percent deduction from the shell biomass based on shell dissolution information and lifespan of harvested oyster of all harvested oysters receiving credit.
1. Apply % N and % P to the modified biomass after deduction has been applied.
2. Figure 4 of Waldbusser et al. 2011 provides dissolution time frames for multiple types of shell. A conservative rate is about 50% dissolution over two years when starting with weathered shell. BMP deductions could be based on this rate.

b. Is there enough information on shell dissolution? Julie and staff will review literature.

Oyster BMP Expert Panel Meeting, March 20, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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)	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)	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	Not Present
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Ralph Spagnolo (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	Not Present
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Not Present
Emilie Franke	Fisheries GIT, ERT/NOAA Chesapeake Bay Office	In Person
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	In Person

Action Items:

1. **Action:** Bill will provide which sections of Shoreline Management BMP report covered verification recommendations.
2. **Action:** Jeff will generate examples with Harris Creek and other data with proposed calculation for denitrification.
3. **Action:** Julie Rose will update shell regression
4. **Action:** Julie Reichert will update shell %N and %P content values (check with Grizzle on numbers).

5. **Action:** Emilie Franke will develop simple summary table of dissolution studies and Panel's conclusions.
6. **Action:** Jeff and Julie Reichert will draft May 8th presentation and send out for Panel review during week of May 1st.

Meeting Minutes:
This meeting focused on deciding which information to present during the May 8th WQGIT update related to the shell assimilation and enhanced denitrification protocols.

1. **Coordination Updates, Julie Reichert**
    a. Invited to speak at the Ecosystem services provided by shellfish resources session for CERF 2017 (drafting abstract this week; due on May 1).
        i. Julie Reichert will be presenting work on the first BMP report and initial findings of current panel report. All panelists will be listed as co-authors.
    b. MDE Heron article was canceled due to misunderstanding on what they wanted to cover in the article (more related to aquaculture in general and not the BMP); possibly a different article in the future.
    c. WQGIT update scheduled for May 8th; encourage folks to attend since the content presented here will be the focus of discussions during the May 22nd open stakeholder feedback meeting.
    d. Open stakeholder feedback meeting scheduled for Monday, May 22nd at Potomac River Fisheries Commission; Mike Foreman will be our facilitator. A survey of these presentations will be sent to registrants of the stakeholder meeting in VA on May 22nd. The registration link is open for the stakeholder meeting. Please indicate if you can attend. If you must attend remotely, you may lose some interaction with stakeholders during breakout sessions.

2. **Summary of Other BMPs for Perspective**
    a. Wetland BMP, Kyle Runion
        i. The Wetland Expert Panel's report of recommendations was approved through the CBP Partnership in December 2016. Recommendations were made for TN, TP, and TSS reduction efficiencies and upland acres treated values for nontidal wetland restoration. These efficiencies were determined through a literature review and acreage values through unpublished data and best professional judgement.
            1. The literature review had been specifically categorized by project type, wetland type, location, vegetation, etc., but eventually the panel decided to lump categories back together to a more wide-ranging group with a larger number of studies. The mean retention efficiency, in percentage, from these studies was used as the efficiency.
            2. Acreage values for existing projects were provided by panelists (unpublished data) and these were tweaked using the best professional judgement of panelists. The logic and thought behind these tweaks are well explained in the panel report.
        ii. This panel's recommendation was to use retention efficiencies of 42/40/31% (TN, TP, TSS) for wetland restoration. This was considered a conservative estimate from a large number of studies. Upland acres treated differed by physiographic region.
    b. Shoreline Management BMP, Julie Reichert
        i. Protocol 2: Denitrification
            1. Denitrification rates per area were compiled from a literature review and grouped so that one value was reported per study (18 studies) to define a grand median rate of 78 µmol/m^2/hr as a recommended denitrification rate.
                a. Calculation: Determine total post construction area of net increase of plantings and multiply by denitrification rate.

ii. Protocol 4: Marsh Redfield Ratio
    1. Determined C:N:P ratio, based on one study and adjusted based on median above and below ground vegetation mass of 25 studies. A one-time credit for initial uptake of nutrients from added vegetation was annualized based on the expected lifespan of a marsh (30 years based on this panel's best professional judgement).

iii. Discussion:
    1. Bill: Protocol 4 is a conservative approach as it is based on initial mass of planting and doesn't take into effect the growth of vegetation; Bill was on this panel and didn't agree with this decision.
    2. Jeff: The low number of studies is not ideal.
    3. Chris: Marsh plantings have varying vegetation (high/low marsh species). Are these credited similarly? If so, then this would be another weakness.
    4. Bill: crediting expires after 30 years; inspection and verification is done every number of years to ensure the BMP is functioning correctly; sea level rise was not specifically addressed.
    5. Jeff: Analogous to the stream restoration BMP by using rates per volume and turning them into areal rates; however denitrification in oysters is difficult to measure, but we are confident in our measurements; with oysters, have to consider the fate of nutrients without the oyster practice.

3. Enhanced Denitrification Protocol, Jeff Cornwell

a. Jeff went over standardized denitrification values from studies; he chose studies based on a general rule that they had to have used a modern technique (e.g., in-situ chambers, near/far cores) instead of outdated methods (e.g., acetylene inhibition technique). Table of studies summarize denitrification rates at face value during the warm season.

i. Restoration:
    1. Difficult to encapsulate reef denitrification, but this table does a good job of including all relevant data; particularly Kellogg et al. 2013 and Humphries 2016 appears to be most relevant.
    2. Rates were assigned by the incubation type and averaged by footprint area (values at the reef/aquaculture site) and control or far (representative of halo area outside of footprint area).
    3. These numbers are probably very conservative. It is possible that darker, deeper reefs are much more effective compared to intertidal reefs which involve more movement of water.
    4. Near/far core method had terribly low values compared to the reef community method; capturing the whole community effect is important for reefs, which may rule out near/far core studies.
    5. Looking at tidal; will add Harris Creek 2015 data.

ii. Aquaculture:
    1. Most relevant studies included Higgins 2013, Lunstrum 2015, and Testa.
    2. Core can be representative for aquaculture versus restoration; it gives an image of the footprint of an operation.
    3. Some studies suggest that aquaculture hurts rather than helps in terms of denitrification (Higgins et al. 2013); example of where not to set up an aquaculture operation (poor sediment).
    4. If dispersion and fate of material out of the footprint area is considered, then the net reduction benefit from denitrification could be higher for aquaculture and possibly lower for restoration.

5. Testa study demonstrated that the farm denitrification rate was indistinguishable from the surrounding sediments; important to consider the net value based on enhancing denitrification with oysters present.
6. Panelist asked about mussels and clams; mussels and clams not generating the same level of biodeposits as oysters, so likely doesn't enhance denitrification like oysters do.

iii. Plots of enhanced denitrification ("calculation") and simple subtraction control sediments from rates in the oyster "footprint". ("Denitrification Table April 20 2017 Info")

1. Plot A: With "calculation" approach, denitrification rates would be lower (negative net value) at shallower depths and increase to a positive net reduction at deeper depths compared to the simple subtraction approach, which would be a consistent net positive reduction.
2. Plot B: Denitrification rates slightly lower with calculation method than subtraction method with increasing oyster denitrification efficiency; calculation method considers what's happening in the water column.
3. Plot C: With calculation method, denitrification rate decreases with increasing sediment denitrification efficiency; denitrification that already occurs in the sediment is considered with calculation method (represents enhanced denitrification from oysters being present); simple subtraction method doesn't capture this (only slightly decreases)
4. Plot D: Would offer a net benefit if using the calculation method compared to the simple subtraction method; aquaculture associated- applicable to both floating and caged, but floating disperses more particles than caged; other factors include tides/storms; High flows are a net benefit for everybody; Example: At Marinetics, 90% of biodeposits are transported off site, so if just using the simple subtraction method it would show a very low net benefit, but using the calculation method, you would see a large positive net value for denitrification.
5. Comparing sites and seeing range may help focus in on studies to include and determine what the acceptable range would be.
6. Julie Rose: It would make sense to only apply as a BMP to situations where there is a net benefit. Can we apply this default rate based on these estimates? Are there any scenarios where a conservative default rate could be applied with us saying that these gaps should be addressed?
   a. Jeff: With Lisa and my new datasets, we could run these numbers and examine.
   b. Run 2-3 sites with calculation and look at net effect; extrapolate to whole year.
7. Chris: Rate will change with oyster density (density at Choptank was high). Do we have data to help determine a minimum density unit (e.g., densities less than 25 m^2, enhanced denitrification would not occur)
   a. Jeff: We have some data in VA but are not extremely confident in it. Are we comfortable with assigning general rate and working from that?

b. For the May 8th update, we will focus on background, studies, variabilities, concepts & ideas to create preliminary look of the panel's direction.

   i. Julie Reichert and Jeff will work on these slides over the next week and send out for review in early May.

4. **Shell Assimilation Protocol (Aquaculture Practices)**
    a. **Shell % N and % P content, Julie Reichert**
        i. From December 2016 meeting minutes: Panelists agreed to include Atlantic Coast studies and to use same averaging approach as tissue once Grizzle and Reitsma data were included in table.
        ii. Added Grizzle et al. 2016 and Reitsma 2016 data; Reitsma found that culture method affected the %N in whole oyster. Should we look at the averages by culture method?
            1. Nitrogen – 0.21 mean % N in shell (0.23 if we look at culture method)
            2. Phosphorus – only two studies in three locations – 0.04
        iii. Discussion
            1. Chris: We may want to only look at culture and remove reef due to lack of oyster shell counting during oyster restoration projects.
                a. Julie Rose: Any reason to expect percent of N or P to differ based on culture method?
                    i. We should think about justification for differing of methods compared to how we did tissue.
            2. A triploid site average was included in the Reitsma study, which was higher than the diploid averages. Should this be included?
            3. Mark: Overall data has low variance. We could simplify and use the same approach we used with tissue.
                a. Agreement from Julie Rose, Suzanne. No opposition.
                b. **Decision**: The group will follow the same averaging approach as tissue for determining the %N and %P for the shell assimilation protocol.
    b. **Shell Dissolution, Emilie Franke**
        i. Went over literature review of studies related to shell dissolution/degradation.
            1. Based on shell dissolution review, is there enough information to apply a deduction to the shell credit? Does it make sense for aquaculture to have a shell credit given that the entire shell will eventually dissolve? May be more feasible with oyster reef restoration practices using a similar one time credit approach found in the shoreline management BMP.
        ii. Most studies reported shell loss, which includes dissolution, burial, predation, etc. We are not able to differentiate between these loss mechanisms.
        iii. Grouped spreadsheet into four categories
            1. A: Annual shell loss rates in Delaware Bay, James River
            2. B: Instantaneous shell decay rates based on Smith 2005
            3. C: Instantaneous shell decay rates based on Christmas 1997
            4. D: Daily shell dissolution rates from Waldbusser 2011
        iv. Discussion:
            1. Jeff: No study examines renewed bioavailability of shell N. It is likely that there is a proportional rate between shell dissolution and bioavailability of N.
            2. Lisa: Because some loss due to shell burial, the N is not lost and is decaying at a slower rate. Some of these studies are not directly applicable to aquaculture. Dissolution and burial are opposite fates with regards to the N cycle. This makes Waldbusser study the most relevant.
                a. Chris: Waldbusser study seems the cleanest, but since it is a lab study, there are many ecosystem effects that aren't in play here. It is strong in measuring pH effects but lacking in other senses.
        v. **Decision**: We likely do not have enough information to account for the fate of the shell once returned to the water to allow crediting for shell in aquaculture operations.

1. Will still present findings, but do not have a good sense of the fate and cannot assign credit.

c. For May 8th: update regression, update N and P content, summarize dissolution studies and decisions today. Note that we will have future conversation on restoration regarding shell assimilation.

5. Recap

a. At the May 8th WQGIT meeting, we will present
   i. Progress on shell assimilation for aquaculture practices and enhanced denitrification for aquaculture and restoration.
   ii. There is adequate science for determining the shell height to weight regression and %N and %P content in the shell. There is not enough science to adequately determine the fate of the shell once returned to the Bay.
   iii. Background on the denitrification studies, including a preliminary look at examples when considering the footprint area versus also considering the halo area.

Oyster BMP Expert Panel Meeting, May 18, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	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)	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	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
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not present
Ralph Spagnolo (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	Not present
Emily French	Oyster Recovery Partnership	In person
Support Staff	**Affiliation**	**Present?**
Emilie Franke	Contractor, Fisheries GIT, NOAA Chesapeake Bay Office	In person
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	Not present
Guest	**Affiliation**	**Present?**
Mike Foreman Todd Janeski	Facilitator for May 22nd meeting 2nd facilitator	Phone Phone

Action Items:

1. **Action:** Panel will rovide comments on Dr. Porter's proposal to Julie Reichert (jreichert@oysterrecovery.org).
2. **Action:** Julie Reichert will revise breakout group discussion questions to reflect suggestions.
3. **Action:** Julie Reichert will eend breakout group discussion questions to stakeholders and panelists in advance of Monday's meeting.

Meeting Minutes:

This meeting will focus on finalizing the logistics and content for the May 22nd Open Feedback meeting.

Coordination Updates, Julie Reichert

1. May 8th WQGIT update; went well, only 1 question related to incorporating reproduction potential as a consideration for the reduction effectiveness.
    i. Panel response: The panel is looking at practices individually and protocols are being developed individually, it is not our goal to estimate or model what the effect will be or considering reproduction in reductions. It'd be up to the counties as to what protocol combination they'd like to use.
2. Dr. Elka Porter's research proposal concerning resuspension of oyster biodeposits and fate of nitrogen within.
    i. Dr. Porter would like to know if her proposal will help address research gaps in understanding the nitrogen reduction effectiveness of oysters.
        1. Dr. Porter is looking for a support letter from the panel; the panel will be providing her with one within the next week.
        2. She wants to know its importance to the panel, if the panel had any other ideas, or if the paper isn't addressing something in particular.
3. Open stakeholder meeting scheduled for Monday, May 22nd at Potomac River Fisheries Commission (facilitated by Mike Foreman); if haven't done so already, register at https://oysterrecovery.org/bmpregistration/.

Logistics and content of May 22nd Open Feedback Meeting, Julie Reichert

1. Agenda
    i. Todd Janeski will be assisting Mike with the facilitation of Monday's meeting.
    ii. Survey responses will be presented with previous comments received during the 1st report.
    iii. Attendees will be placed into discussion topics groups based on their expertise.
        1. The webinar group will be covering all three discussion topics.
    iv. 18 stakeholders have RSVP'd thus far with guests continuing to register up until today; list of attendees has been sent to panelists.
    v. 15 panelists will be attending.
    vi. The panel could potentially combine both denitrification topics into one group; they are closely aligned if there isn't enough people to separate into two groups.
        1. If a group is too large, will be difficult for facilitator to control flow of info. Looking to have around 12-15 people per group; more than that would be difficult for the facilitators to manage.
    vii. Following the stakeholder interest process; we will summarize what we see and hear in our groups.
    viii. For panel leads: Offer facts or sound science to the group, otherwise sit back and let conversation play out. Stay with your group after the 30-minute switch; don't spend time rehashing what happened in the previous session.

ix. A closed Oyster BMP Panel meeting will take place immediately after the Stakeholder Meeting (12:30-2pm).

2. Breakout group assignments
    1. Nitrogen and Phosphorus Assimilation in Oyster Shell for Private Oyster Aquaculture
        1. Facilitator: Mike Foreman
        2. Panel Lead: Julie Rose
        3. Note-Taker: Emilie Franke
        4. Panel Participants: Suzanne Bricker, Matt Parker, Karen Hudson?
    2. Enhanced Denitrification for Private Oyster Aquaculture
        1. Facilitator: Todd Janeski
        2. Panel Lead: Jeff Cornwell?
        3. Note-Taker: Paige Hobaugh
        4. Panel Participants: Chris Moore, Mark Luckenbach?, Lynn Fegley?
    3. Enhanced Denitrification for Oyster Reef Restoration
        1. Facilitator: Ward Slacum
        2. Panel Lead: Andy Lacatell
        3. Note-Taker: Julie Reichert-Nguyen
        4. Panel Participants: Bill Wolinski, Ken Paynter?
    4. Webinar (will cover all 3 groups)
        1. Facilitator: Emily French?
        2. Panel Lead: Lisa Kellogg
        3. Note-Taker: Kyle Runion
        4. Panel Participants: Larry Sanford

3. Breakout group questions
    1. Discussion
        1. Question Revisions
            a. 1a and 2a should be more open ended; phrase "Related to the approach that could be used" to assign reduction estimates since we have not yet concluded a reduction estimation.
            b. 2g should also be included after 1f.
        2. Questions should be sent to stakeholders and panelists in advance.
        3. Each group should have a consideration list to reflect on after questions for ideas/approaches that we haven't even thought of yet.
        4. The panel will put together a summary of what's discussed, will send to participants so they can provide further comment in addition to the 30-day comment review of final report that will come later.

4. Survey Comment review/discussion
    1. Shell Assimilation Survey Results
        1. Response Summary
            a. Benefit
                1. Oyster company of Virginia (OCVA) and Norfolk Public Works (NPW) want the Panel to focus on the benefit of shell being returned to the bay as a positive consequence because it can result in more oyster production; don't want the panel to disincentive shell recycling programs.
            b. Crediting protocols

1. OCVA would like the panel to consider the difference in annual and perpetual crediting as applied to some practices, particularly of practices that don't require harvest.
2. Southern Environmental Law Center (SELC) would like the panel to consider that shells from caged aquaculture can be thinner. The panel has addressed this.
3. SELC would like the panel to consider how growth can differ between months/seasons. The panel has denitrification data for only warm months, has shell data for months outside of summer.

c. Unintended consequences
   i. Citizens Advisory Committee (CAC), Chesapeake Bay Commission (CBC), Chesapeake Bay Foundation (CBF), SELC are concerned with the unintended consequences of using shellfish as in-water BMPs; shell not being returned to the bay, basing water quality on organisms that could die.

d. Individual response from Dr. Lynton Land
   i. Policy related
      1. Dr. Land would like to see oyster BMP's compared with on-land BMPs, such as those relating to fertilizer; this is outside the Panel's charge.

2. Discussion
   a. The panel may take shell out of the equation of nutrient sequestration entirely given the uncertainties.
      i. Conclusion: we can quantify amount going INTO the shell, but longevity of the shell in the environment is what is in question.
      ii. Crediting is unfeasible at this time due to a gap in research- just allow shell to remain; its value alone as substrate is enough.
      iii. The panel will present this information at the Stakeholders meeting, leaving the conversation open ended.
   b. Stakeholders will receive notecards to write in the top 2 areas of research they'd like to see the panel analyze.
      i. Allows stakeholders to identify research gaps.
      ii. Stakeholders in the webinar can type their responses into the Adobe Connect chat box for record of response.

2. Enhanced Denitrification Survey Results
   1. Response Summary
      a. Baseline
         i. SELC hopes the panel considers burial and denitrification that would occur in the absence of oysters. This is being considered by the panel.
      b. Crediting Protocol
         i. Lynnhaven River Now (LRN) would like the panel to continue to consider crediting protocol for sanctuary oyster reef nutrient and sediment removal.
      c. Data concerns
         i. CAC, SELC, et al. find temporal and spatial limitations of the data used in the 2013 STAC report. The Panel are considering these questions, but have a process to follow as a panel ourselves.
      d. Unintended consequences
         i. SELC et al. wants to know how the panel is addressing heavy biodeposit accumulations that could result from heavy aquaculture operations.
      e. Verification

            i. CBF thinks crediting should be accompanied by verification guidelines given that much variability exists among sites.
         f. Individual response from Dr. Lynton Land
            i. Dr. Land finds the concept of estimating reduction premature given available data. Biodeposit accumulation during low tide that could be detrimental; fate of them must be considered.
    2. Discussion
        a. Crediting denitrification will likely be site-specific.
        b. Verification guidelines could vary depending on the site.

Additional Shell Assimilation Protocol Analysis, Julie Rose

5. Gear differences in shell dry weight are as expected.
    1. Higher shell weight in oysters grown without gear than with gear.
6. Ploidy differences in shell dry weight at a single site with common gear- Orchard Point Oysters
    1. Triploids lighter than diploids
        1. Julie Rose- Triploids don't spawn, therefore have more tissue mass; why are their shells thinner than diploids?
            a. Lisa mentioned that triploids are selected for fast growth and therefore, likely grow faster than diploids.
        2. Differences in shell thickness exist in diploid oysters grown on bottom versus in gear.
    2. Julie Rose- from preliminary analysis, we should take into account gear vs. no gear and ploidy, they may need to be credited differently.
7. There is no large difference in dry weight between seasons.
    1. Julie Rose- We likely would not need to take season into consideration; should follow the same recommendation as tissue.

Oyster BMP Expert Panel Meeting, May 22, 2017, 12:30 PM – 2:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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)	Phone
Andy Lacatell	The Nature Conservancy (TNC)	In Person
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	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	Not Present
Ralph Spagnolo (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
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	In Person
Emilie Franke	Fisheries GIT Staffer, ERT/NOAA Chesapeake Bay Office	In Person
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Guests	**Affiliation**	**Present?**
Mike Foreman	Facilitator from Open Meeting	In Person
Todd Janeski	Facilitator from Open Meeting	In Person

Action Items:

1. **Action:** Include list of science priorities for practice-protocol combinations where there are data gaps to assign an estimate (i.e., shell assimilation protocols).

2. **Action:** Rich will check with EPA headquarters to see the status of the legal opinion on whether sequestration can be credited for an in-water BMP.
3. **Action:** Sort out definition of public fishery and oyster reef restoration practices.
4. **Action:** Jeff and Lisa- categorize denitrification data according to intertidal, subtidal, photic, and non-photic and run examples with enhanced denitrification calculations.

Meeting Minutes:
This meeting focused on reviewing and discussing the feedback from the open stakeholder meeting.

1. **Group 1 Discussion (N and P Assimilation in Oyster Shell for Aquaculture Practices)**
   a. Julie Rose commented that the stakeholders are interested in a list of science priorities in the Panel's 2nd report concerning this protocol (what should they focus on first to fill in the knowledge gaps); industry representatives mentioned that could help fund projects.
   b. The differences concerning % N and P in shell for the different culture methods was of interest to the stakeholders; the Panel is currently including this in their analysis.
   c. Panelists commented that the stakeholders were also interested in possible geographic differences related to % N and P: Chesapeake Bay versus New England versus Pacific coast.
   d. Suzanne commented on Brad Rodgers suggestion about giving the shell credit to the person who puts the shell in; she thought it was an interesting concept, but wasn't sure how it would work in application from a nutrient reduction standpoint.
   e. Panelists agreed that shell tracking would be important if there is to be a shell crediting protocol and should include such a statement in the recommendation report.
      i. Chris- what does our on land shell budget look like?
      ii. Rich recommended looking at the manure model to see how tracking could function (manure is transported between states).
      iii. Julie Rose suggested that the report can include recommendations for both the dissolution piece and the tracking piece (present both options).
   f. Jeff commented that what we care about is actually preservation (amount of N and P stored in the shell and for how long; what gets buried); Emilie Franke mentioned that this appears to be a time-sensitive BMP.
   g. Bill asked about whether we will be considering nutrients that are stored in an oyster reef in sanctuaries.
      i. Julie Reichert- yes, but it is a different practice-protocol combination; currently it's on hold waiting for the legal opinion from EPA headquarters on whether sequestration can be credited for an in-water BMP.
         1. Rich will touch base with the lawyers to see where they are at with this evaluation.
      ii. Panelist mentioned that this could be done by determining the standing stock (oyster biomass) of the reef and give a one-time credit; also can figure out % buried per year to receive a continuing credit.
         1. Jeff mentioned it would be a longer period of time for burial (3-4 years).
      iii. Jeff- reef structure will increase (grows over time); would need to determine the lifespan of the practice; not certain about the time constant for dissolution.
   h. Panelists mentioned that it will be important to build public-private partnerships to implement BMP; CBP should loop in the Oyster Advisory Committee, county oyster committees, aquaculture coordinating councils, Shellfish Grower's Association, seafood councils, and watermen associations; some of these groups may be less informed about CBP's goals.
   i. Panelist asked when it comes to the public fishery, who would get the credit?
      i. Lynn- in Maryland, the county pays to have spat-on-shell planted on public grounds; planting and harvesting in these areas are akin to on-bottom aquaculture.

ii. Matt- Depends on who pays to put the oysters down.
iii. Julie Rose- in Mashpee, MA, the credit goes to the city (they are paying to plant the oysters).
iv. Matt- the County takes the harvest tag data.
v. Lynn- there are records for the landing tax, but there will likely be a need for a different set of record keeping for the BMP; currently, MD does not have bar specific data.
vi. Panelists agreed they need to sort out the definition of public fishery.

2. **Group 2 and Group 3 (Enhanced Denitrification for Aquaculture and Restoration Practices)**
    a. Panelist mentioned that, for aquaculture, some stakeholders felt that there's not enough data to determine a default estimate (there is a need for more research); there wasn't a lot of agreement about using a minimum default number; more interested in making the determination on an individual basis.
        i. Panelist mentioned that one of the wild harvesters suggested that the denitrification assessment could be done at point of the permit (industry could foot the bill to collect the necessary information).
        ii. Panelist suggested that the restoration denitrification value could work for on-bottom aquaculture.
        iii. Chris mentioned that outside groups define/perceive aquaculture differently; clear definitions and terminology will be important for the report.
    b. Panelist mentioned conflict of use- where there is good sediment quality to set up an aquaculture operation, the public fishery would also want.
    c. Panelist mentioned that stakeholders were very interested in what they need to consider from a management, research, and legal perspective (applies to aquaculture and restoration practices).
        i. Panel is responsible for the research aspect, but can provide recommendations related to application and verification guidelines.
        ii. Panelists agreed that the type of sediment condition (sandy, muddy, etc.) is important to consider.
        iii. Lisa and Jeff will be looking at the data using intertidal, subtidal, photic, and non-photic characterizations.
            1. For restoration, the expectation is that water quality benefits are occurring; however, need to understand the performance of the project related to the improvement of water quality.
            2. Planning to use Harris Creek, Upper and Lower Choptank, and Lynnhaven data to run examples with the enhanced denitrification calculation.
                a. Lisa mentioned that for intertidal, the Harris Creek data was manipulated, so it would be better to use the Lynnhaven data.
    d. Rich emphasized that it will be useful from a BMP standpoint for the Panel to provide recommendations regarding the general characteristics of the site that would qualify for enhanced denitrification.
    e. Chris- acreage versus structure of the reef should be considered.
    f. For restoration, need to reach agreement on how many sites will produce sufficient confidence for a default estimate.
    g. Panelist asked about wave consideration and effect on fate of biodeposits.
        i. Jeff- the Bay model characterizes hydrodynamics, but not at the level we would need.
        ii. Larry- upper mesohaline- silt coming from river doesn't mean it doesn't flow.
    h. Need to understand sediment-oxygen demand to understand denitrification; sediment-oxygen demand is highly variable.

i. Jeff- it would be good to provide suggestions in report how this may be done cheaply.

3. Adjourn

a. Panel will reconvene on June 15, 2017.

Oyster BMP Expert Panel Meeting, June 15, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	Not Present
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
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Not Present
Ralph Spagnolo (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	Not Present
Emily French	Oyster Recovery Partnership	Not Present
Support Staff	**Affiliation**	**Present?**
Emilie Franke	Contractor, Fisheries GIT, NOAA Chesapeake Bay Office	Phone
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Kyle Runion	Habitat GIT Staffer, Chesapeake Bay Program	Not Present

Action Items:

1. **Action:** Lynn will look in to Maryland's public fishery planting rate.
2. **Action:** Julie will look in to if "addition" is necessary of an enhancement activity.

Meeting Minutes:

This meeting will focus on reviewing and determining which oyster practices should undergo BMP implementation concerning the public fishery and oyster reef restoration practices and drafting definitions for these practices.

1. **Coordination Updates**
    a. The meeting summary report was sent out to stakeholders for review. Their comments are due in two weeks, by June 30th.
    b. This is Emilie Franke's last meeting- she is headed to graduate school at the University of Washington. Thank you for your help Emilie!

2. **Go over oyster practice table to determine which practices should undergo BMP consideration**

    <u>Public Fishery (Oysters Removed from waterbody)</u>

    a. **F- On-bottom public fishery oyster production using hatchery-produced oysters: Panel decided that it should undergo BMP consideration.** This practice can result in a reduction due to enhancement. The Panel will discuss its effectiveness and qualifying conditions in future meeting.

        Discussion:
        i. Panelist asked who manages the public fishery; panelist answered that the State manages the public fishery.
        ii. Chris: Virginia and Maryland differ in their public fishery management; VA adds substrate to their public grounds (40-50%) while MD enhances the public fishery by planting hatchery-produced spat-on-shell.
        iii. Lynn: Sees no difference between what is happening on bottom aquaculture leases and public bars in terms of N and P reduction from assimilation- the only difference is who has access to the oyster; stressed that if any similar public fishery practices are not considered then the Panel would have to have a scientific reason to justify that decision.
            1. Panelists discussed how for aquaculture leases there are minimum to no oysters present (non-productive bar), while on the public grounds these practices are occurring in areas where there are oysters present and on productive bars; how would enhancement on public grounds be determined (oysters harvested due to addition versus oysters that were already there)?
            2. Lynn: In MD, they don't get natural spat set like in VA; no all public fishery areas already have oysters present; a designated public fishery area doesn't necessarily mean it is a productive bar.
            3. Lisa asked whether there are private leases in any areas that were historically productive. Lynn answered no.
        iv. Lynn: There is specific accounting of kinds of oysters being put in MD public fisheries- boats spreading spat-on-shell are equipped with GPS to define the areas. Not all public fishery areas are naturally productive, some are more than others. Fishermen pay surcharge (bushel tax) on each bushel harvested which goes back to the State for the county to purchase spat-on-shell to put back on the public grounds. There is a complete accounting of what's going out and they know which bars are being harvested on. The bushels are tagged on the water.
            1. Chris: For verification, you would need GPS tracking of plantings in well-defined areas.
            2. Panelist mentioned you would have to survey the bar to determine what's there already.

v. Panelist asked whether for the spat-on-shell practice if planting rate or volume planted could be used to determine how many oysters resulted from the enhancement activity.
    1. Matt: Build into the estimate considerations of how many oysters were planted.
    2. Chris asked if the planting rate per acre is known; Lynn answered yes.

vi. Chris: Enhancement will be difficult to measure; need to know what you put down, possibly will need to estimate a mortality rate, come up with a detrimental/maximum return. Accountability measures will likely need to be developed; no one can receive credit for more than they put down. Does on bottom aquaculture also need to consider mortality and held accountable as well? Panelists felt this would not be needed since aquaculture leases are in areas where there are minimum to no oysters (non-productive area).
    1. Panelist mentioned that plantings occur over plantings on an annual basis; recommendation needs to take this into account.

vii. Matt: Agrees that a state/county putting down spat on shell is no different than on bottom aquaculture receiving credit for oysters.

viii. Julie: Might be easier to not focus as much on what is already there; give credit on what was planted. No one may receive credit for more than what was planted.

ix. Panelist asked who would be receiving the credit; don't want productive public bars being exploited to receive more credit; Julie Reichert: It isn't up to the panel to decide who ends up with the TMDL credit, but we can preface this concern by using "the panel feels that…"; overall, EPA has oversight role on how jurisdictions implement.

b. **G- On-bottom public fishery oyster production using transplanted wild oysters:** Panel decided that it shouldn't undergo BMP consideration. Consensus is that moving wild oysters form one place to another is not an enhancement activity.

c. **H- On-bottom public fishery oyster production using substrate addition**: Undecided- the Panel will consider for now. The addition of substrate makes this an enhancement activity with the potential for new oyster growth. Qualifying conditions would likely differ from aquaculture; topic will be revisited with the option of not considering it in the future.

Discussion:

i. Matt: This occurs more often in VA than it does in MD. If substrate wasn't placed in an area, oysters wouldn't grow in that area- this is enhancement; Suzanne agreed; Lynn mentioned that some bars would disappear without adding shell back.

ii. Mark: This substrate goes onto reefs that have been productive but cannot sustain natural and harvest shell loss. This enhances the productivity of those reef; without substrate addition, the net shell budget of these areas would be zero; need to understand more what component of the harvest is attributed to the substrate addition.

iii. Bill mentioned that there are bottom conditions that limit oyster production; Chris mentioned that substrate addition can be used to convert a nonproducing area due to poor bottom conditions to a more productive area by adding substrate to improve the bottom condition; this is a bit different than adding substrate to already productive bars.

iv. Matt: This process should mirror the aquaculture example. This is an enhancement activity from a reduction standpoint; it should come with different application guidelines, qualifying conditions to employing the BMPs (no credit given for more than is put in, credit is given only for removal, no credit until oysters are harvested).

v. Chris: Doesn't see adding substrate to productive bars as an enhancement activity that rises to the occasion of significant reduction.

vi. Lynn: Comfortable having this mimic the aquaculture example, otherwise we must be extremely clear as to the difference between the two. Still unsure what the difference is.
vii. Lisa: Should the total harvest be discounted though, since shell is being added back? Panelist answered no since tissue is a separate estimate; also adding shell back has many benefits to the shell budget and habitat.
viii. Panelist felt that the focus of shell usage should be for spat-on-shell practices.
ix. Suzanne: For non-productive areas where there are little or no oysters, enhancement is occurring from substrate addition.

d. **I- Public fishery with no activity: Panel decided that it shouldn't undergo BMP consideration.** Consensus is that no enhancement is occurring to produce more oysters.

<u>**Oyster Reef Restoration (Oysters remain in waterbody)**</u>

a. **J- Active oyster reef restoration using hatchery-produced oysters: Panel decided that it should undergo BMP consideration.** Consider change to oyster practice title: "Oyster reef restoration using hatchery-produced oysters."
b. **K- Active oyster reef restoration using wild oysters: Panel decided that it should undergo BMP consideration.** Consider change to oyster practice title: "Oyster reef restoration using substrate addition."
c. **L- Passive oyster reef restoration: Undecided- the Panel will consider for now.** Consider change to oyster practice title: "Oyster reef conservation." Panel would like more information on whether there are other BMPs based on conservation.
d. **Discussion:**
    i. Bill: Eliminating harvest pressure from conservation implies that an activity is involved; would expect population to improve with time.
    ii. Lisa: Sanctuaries have the potential for enhancement; areas closed off to harvest have seen increases in population.
    iii. Julie Rose: Remove restoration from title, replace with conservation. Simplify other titles (remove active, passive).
    iv. Chris: Unsure that this practice leads to enhancement as there are no additions.
    v. Julie Reichert: Thinks that enhancement doesn't necessarily need to be associated with addition, sanctuary enhancement can be defined as a "no-take" area.
    vi. Mark: Look into terrestrial conservation easements as an example; another panelist recommended looking into buffer strips, since they are left alone to regrow.
    vii. Larry: Would credit be given for soft tissue since it's never taken out? Credit would have to be from either shell or denitrification, neither of which estimates have been determined for yet.

3. **Decide which practices will be covered in the 2nd report concerning the shell, tissue (public fishery) and denitrification protocols**
    a. The panel is in a good place with shell to begin writing it up for private aquaculture.
    b. Tackling public fishery practices in the second report could be easy if it aligns well with the aquaculture model. Nuances may slow down the approval process, putting denitrification progress on hold as well.
    c. The third report would cover everything dealing with sequestration and is slated to begin around this time next year. The EPA lawyers are still deciding the legality of sequestration; their decision may impact whether a third report occurs. This provides a good argument for including every other practice in the second report.

4. **Define oyster practices that will be covered in the 2nd report**
    a. This topic will be addressed via email.

Oyster BMP Expert Panel Meeting, August 17, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	Remotely
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Karen Hudson	Virginia Institute of Marine Science (VIMS)	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remotely
Andy Lacatell	The Nature Conservancy (TNC)	Remotely
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	Remotely
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Remotely
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
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	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	In Person
Emily French	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person

Action Items:

1. **Action:** If any panel member's commitments no longer allow them to participate, please inform Julie Reichert.
2. **Action:** Final definition comment consensus will be done via email. Feel free to send Julie emails if you have any comments for revision.
3. **Action:** Jeff will work at determining realistic criteria for site-specific assessment in time for the September meeting.
4. **Action:** Julie will draft and distribute summary notes of this discussion and send to the panel; the conversation will continue through email.

Meeting Minutes:

This meeting will focus on reaching consensus on the definitions for oyster reef restoration and public fishery practices and to review the denitrification analysis to determine if a conservative default estimate is feasible. If time permits and information is ready, then we will also discuss the updated shell quantile regression analysis and public fishery BMP concepts.

1. **Coordination Updates**
    a. CERF abstract accepted: Presentation on Monday, November 6, 2017 at 1:15 PM during the Ecosystem services provided by shellfish resources session.
        i. The session will be co-led by Suzanne and Julie Rose. They hope to present something on denitrification if possible; Julie Reichert's preference is to present to the Water Quality GIT beforehand and incorporate any updates before CERF presentation. Harris Creek information will be presented in addition to an enhanced denitrification presentation (Thursday morning) at CERF as well.
    b. Draft report timeline.
        i. Before the panel decided to include public fishery practices, the draft report was expected to be complete by October. It may now take longer to complete.
2. **Review definitions –** See Definition file with Panel edits.
    a. **Comment:** Lisa sees the Marylanders Grow Oysters and CBF's Oyster Gardeners programs as falling under the "Oyster Reef Restoration using Hatchery-Produced Oysters" category as both programs distribute small oysters for grow-out by individuals at their docks and then collect those oysters and plant them in sanctuaries.
    b. **Discussion:**
        i. Julie Reichert agrees.
        ii. With respect to how many oysters are placed in the water, panelists should be cognizant that the numbers are estimates. Individual oysters are not being counted; sometimes they move 2-3 times before they are planted.
        iii. If it is possible to assign enough caveats to oyster garden oysters (since they move around so often), then we should count them.
        iv. Biomass estimates should be done every 2-3 years on restoration reefs to quantify how large the oysters get.
        v. The Marylanders Grow Oysters program counting protocol is heavily estimate based and very site specific; volunteers don't all care for their oysters the same way.
    c. The panel needs to create Qualifying Conditions that addresses the need to know how big the oysters are when they are removed from their initial grow-out location.
        i. If an oyster is less than two inches once it reaches location, then its benefits translate to where its transplanted to.

Action: Final definition comment consensus will be done via email. Feel free to send Julie emails if you have any comments for revision.

3. **Denitrification estimate analysis**
    a. Jeff will present his findings from his evaluation of whether the data supports a conservative default estimates for enhanced denitrification.
        i. Jeff created a flow chart to determine which data to use for this analysis (see figure on page 2 of Jeff's handout).

On-Bottom Aquaculture

i. Whole Community Consideration
    a. Sediments in reefs receive large amounts of organic matter and it turns into ammonia; it needs to be turned to nitrate and be kept around for

denitrification to occur. Sediments don't nitrify very well. The process isn't entirely understood, but denitrification is very localized and happens through the oyster shell. Huge amounts of activity by other animals (polychaete worms) even if the shell is empty.

b. Gene Caffrey has gulf coast data that says the same. If you do not consider the entire community (including the sediment), you will not get the correct estimate.
c. Most literature seems to be missing most of the denitrification occurring in the entire community.

ii. Acceptable Protocol
   a. ^{15}N and N_2:Ar method studies might be appropriate – data from these studies is robust.
   b. Must look at m^2 of the reef, that is where the denitrification is happening. Area rates or oyster biomass are the only data we can accept.
   c. Jamaica Bay/NYC data – N to N_2O to NO method may or may not provide a realistic estimate as they flood their systems with nitrite.
   d. Denitrification rates might be different in communities that are continually disrupted (e.g. dredging).

iii. Sufficient Data
   a. Harris Creek, Lynnhaven, Hillcrest, Nanticoke provide a lot of data.
   b. Probably cannot provide a generic, low number for what a reef does.
   c. We need site specific data to determine estimates. This fall the panel can create a spreadsheet with specifications – For example, If Harris Creek does X, Y, and Z, it'll provide the net decrease associated with denitrification. Lynnhaven might be too diverse within its bounds for a protocol.
   d. There are no plans for this kind of data gathering at this stage in restoration areas.

iv. Enhanced vs. Total Denitrification
   a. Recent study (will be submitted to journal next week) looks at the alternative fates of particulates with or without oysters – are either breaking down to ammonia in the water column or falling out somewhere else. Harris Creek is currently the only place in the world where this calculation can currently be made.
   b. In a restoration setting, it is highly likely that only half of the denitrification is from enhancement. This rate could be beneficial from an aquaculture standpoint.

Follow on-bottom aquaculture protocol for site specific denitrification rates. Data preference is surface area (as it can be related to oyster biomass). The geometry of the reef has impact on the rates.

Water Column Aquaculture

i. Consider Inside/Outside Footprint
   a. Biogeochemically, the panel is most concerned about what is happening in the sediments. Should it consider what is happening inside or outside of the footprint? It could look terrible under the floats, but it could be adding benefit elsewhere. There is no value unless physics spreads the detritus around (e.g. no water circulation in Horn Point, but there is circulation at the Marinetics site).

ii. Light/Dark Incubations

a. Not amenable to doing light incubations. Denitrification generally decreases in light.
b. Jeff believes the panel can make reasonable estimates with the Marinetics site, but not the Virginia Commonwealth site.

iii. Sufficient Data

a. Literature spreadsheet needs to be included in the report

From a policy standpoint, CBP has restoration objectives, a strong argument could exist to promote this BMP alongside of it – can be used as incentive. A site-specific estimate approach is the way to go unless the panel gets more data that will allow it to determine a reduction baseline.

Restoration clumps are where the denitrification action is; reductions will likely be depicted with biomass units and eventually dollars per pound. Scott Knoche at Morgan State University is studying this.

Matt has funding for Jeff for Maryland aquaculture research.

Action: Jeff will work at determining realistic criteria for site-specific assessment in time for the September meeting.

4. Shell Analysis Revisited

a. New data (Mann et al. and Parker and Bricker unpublished) has been added to determine the quantile regression equations for shell N and P assimilation.
   i. Julie did not present this information at the meeting; there were issues analyzing the new data. This discussion will be postponed until the next meeting. The panel already decided that due to research gaps, it will not be moving forward with creating a shell assimilation estimate. The science will be presented though, to explain future possibilities.

5. Public Fishery BMP Concepts

a. Ward and Julie will present a couple of ideas for the Panel to consider concerning the public fishery practices.

Of the 4 Public Fisheries practices, the panel agreed that “On-bottom public fishery oyster production using transplanted wild oysters” will not be considered for a reduction estimate as it does not result in the creation of new oysters. The practice “Public fishery with no activity” will also not be considered for an estimate.

The panel was undecided on the practice “On-bottom public fishery oyster production using substrate addition”. Julie presented a study “Maryland Substrate Addition Practice on Public Grounds” who’s authors see the practice as an enhancement activity. It wasn’t made clear how the authors reached their enhancement determination. If the panel would like to consider this practice as a BMP, it will need to reach out to the authors and analyze their process.

Julie also presented analyses of shell planting/oyster biomass data from Mann and Southworth

i. **Analysis 1:** No activity the previous year, no SOS or seed, no shell planting or harvest in sampling year (unless sampled prior to harvest), no harvest 2 years prior to sampling

a. The addition of shell should provide enhancement two years down the road. More shelling on sanctuary than on harvest areas

ii. **Analysis 2:** No activity previous year, no SOS or seed, no harvest 2 years prior to sampling

iii. **Analysis 3:** No activity previous year, no SOS or seed

a. The results follow a similar pattern, only difference is added harvest bars (are likely open on a quicker rotation, tend to be better bars). There seems to be no effect on harvested bars.

b. States are making up for the harvest when they put shell out. Not "wasted" in practice, but from WQ BMP standpoint, states looking for harvest enhancement to be able to determine/apply a reduction.

c. The data does not convince the panel that consistently added shell yields more future market sized oysters.

Discussion:

i. Is it possible to suggest a delayed crediting process?

ii. Possibly in Maryland, but what Lisa presented about Virginia does not support this pattern. Panel would need more information on the subject.

iii. Matt: No credit should be given for throwing shell down, but that should not dissuade someone from putting shell down. Make aware the benefits of adding shell.

iv. Ward: The practice of adding shell is historic, it is unlikely that BMP news would change that.

v. Julie Rose: In Virginia, public grounds are historically productive sites that need surveying to understand what happens there. Is confident that activity is happening with recruitment at aquaculture sites.

vi. Lisa: There needs to be some accountability – if credit is given for shells added, are there penalties for taking shells out/removing recruitment substrate? How can it be determined if oysters are already present at sites that shell is being added?

vii. Jeff: It's not a matter of spat being there, it's the extra spat that's settled (enhancement) and beyond that even since oysters cannot be credited until they grow.

viii. Panel will put more thought into this if it is determined that it can be approached from a site-specific way. The way aquaculture leases are distributed may make it difficult to determine site-specific approaches into the future. The panel needs to decide if there is an approach to even determine a site-specific estimate that could count as crediting.

Action: Julie will draft and distribute summary notes of this discussion and send to the panel; the conversation will continue through email.

6. Next Meeting

a. Julie Reichert: Will likely have more shell data sorted by next meeting. Will be tying up loose ends with shell, denitrification, public fishery definitions and discussion. Panel will then be able to explore practices it does think could result in an estimate.

Oyster BMP Expert Panel Meeting, September 19, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	No
Karen Hudson	Virginia Institute of Marine Science (VIMS)	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remotely
Andy Lacatell	The Nature Conservancy (TNC)	Remotely
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remotely
Chris Moore	Chesapeake Bay Foundation (CBF)	No
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	In Person
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remotely
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	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	In Person
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Margot Cumming	Habitat GIT Staffer, Chesapeake Bay Program	In Person

Action Items:

a. **Action:** Paige and Margot will consider comparable BMPs, Bill will provide switchgrass BMP literature to aid in Column H decision.
b. **Action:** Julie Reichert will touch base with WQ GIT on baseline guidance for Oyster Reef Conservation.
c. **Action:** Julie Reichert will confer with Lucinda Power on Choice 2 approach

Meeting Minutes:

This meeting will focus on reaching consensus on the site-specific estimate methodology for the enhanced denitrification protocol for on bottom (includes restoration and aquaculture) and off bottom practices (includes aquaculture only), default shell estimates concerning how much N and P is stored in the shell (Step 1 and 2 of pending shell estimate; step 3 concerning dissolution is unknown due research gap), and finalize decisions concerning the public fishery practices for the tissue estimate.

Coordination Updates, Julie Reichert

a. Jeff- BMP presentation to agriculture group.
b. Aiming to have a draft of the report for review by 1st week of October.

Julie created a matrix to organize panel decisions on moving forward with determining estimates for certain practices – See "practice protocol combinations" PowerPoint document

- Dark gray – Practices covered in the first report
- Light gray – Practices that will potentially be covered in the third report
- Medium gray – Practices covered in the second report
  a. Nitrogen assimilation in oyster tissue
    i. Public fishery/Column F
      - Possible to use estimate from quantile regression, but with site specific qualifying conditions (e.g. exclude productive oyster bars).
      - Counties would receive the credit (they plant the oysters in MD). In VA, harvest records are kept by county, not by oyster bar. Oysters are counted by bushel (sizes between MD and VA differ). MD would like credit for this practice, VA unsure.
      - Credit will be based on harvest, not what is put out.
      - Panel should decide how to treat an area with an existing population; create an equation that will consider what is planted, harvested, and mortality.
    ii. Public fishery/Column H
      - VA practices fall under Column H (substrate addition) – state adds shell to productive bars where shell growth doesn't keep up with loss. No good way to determine how many oysters would have been there in the absence of the new shell.
      - MD doesn't apply much substrate without spat – resource too valuable not to ensure oyster growth.
      - There is alternative substrate being put down in the Nanticoke with an envisioned natural strike, benefit.
      - Even if shell is planted, you cannot consistently predict an increase in harvest. Would also require a reasonable mortality estimate – very difficult. If shell is planted and no oysters are attaching to it, no reduction activity is happening
      - Language in first report gives credit for substrate addition but specifies that it must be put in areas with no oysters present, requires a bottom assessment beforehand. No one gets to lease former or current oyster bars.
      - Site specific qualifying condition: survey with a reasonable estimate required before substrate is put down – must assess oyster presence and determine how that number factors into the reduction.
      - Similar CBP approved BMPs may provide insight on how to handle this practice. Decision needs to be made on Column H by end of next week.
    iii. Oyster Reef Conservation
      - Three possible qualifying conditions: Is it closed to activity? Is it being harvested? Have you had an increase in oyster production?
      - Panel will remove asterisk if it can decide on qualifying conditions – will be site specific.
      - Joyce Kilmer National Forest in North Carolina may serve as comparison.

Action: Paige and Margot will consider comparable BMPs, Bill will provide switchgrass BMP literature to aid in Column H decision.
Action: Julie Reichert will touch base with WQ GIT on baseline guidance for Oyster Reef Conservation.

Enhanced Denitrification Measurements, Jeff Cornwell

c. Jeff will present additional information on what measurements are needed for on bottom (aquaculture and restoration) and off bottom practices (aquaculture only).
    - Now that it is determined that denitrification measures are site specific, panel must decide on qualifying conditions. Panel must be careful how it provides guidance to people seeking out credit.
    - It will take a month or two to get together a paper on oyster denitrification literature numbers.
    - Denitrification takes place within reefs within oyster clumps, sediments themselves do virtually nothing. Material being brought to the bottom and remineralized under the reef had other potential fates – denitrification calculations must reflect that; net enhancement rate for a reef ecosystem.
    - Jeff will focus on key things that need to be measured, will diagram that approach to show how to make the calculation. The calculation method is going into peer review this week, should have feedback by the end of October.

Shell analysis (ploidy, culture method, season, and location considerations), Julie Rose

d. Julie Rose will present additional information on the shell analysis for determining the amount of N and P stored in the shell (could eventually be used for a default estimate once dissolution research gaps are filled).
    - Shell assimilation recommendations – quantile regression analysis
        - We are not recommending that credit be given at this time due to the unknown fate of shell after harvest
        - It is worth the time and investment now to generate equations with data available (initial leg work) if in the future there is more data on fate of shell
        - Diploid vs triploid
            - Triploids have lighter shells
        - With gear (off bottom) vs without gear (on bottom)
            - Shells grown in gear are lighter
        - Diploid all vs with gear
            - Limited amount of info on diploids in gear, but enough to do regression
            - Gear has strong effect on shell dry weight regardless of ploidy
            - There is no data for triploids grown without gear
        - Seasonal effects without gear
            - Not much of a difference
            - Biggest difference is seen during fall; equation is above mean of entire dataset (OK from management perspective)
        - Locations/salinity – diploid without gear/on bottom
            - Open water yields high weights
            - No location that skews significantly low
        - Recommendations
            - Use separate equations for diploids with gear and diploids without gear
            - Use one equation for triploids (no data for triploids without gear and if someone were to grow oysters without gear, they would be undercredited (based on diploid analysis) which is ok from a management perspective)

        - Because gear and ploidy have a strong effect on data, we just use the diploid without gear subset to look at seasonal and habitat differences (over 4,000 data points, robust set)
    - When there's enough science to understand fate of shell/return to bay, we can use these equations
    - Values of N and P stored in shell, not a reduction estimate as shell dissolution is not yet included in equation. Used similar approach as tissue.
        - Julie Reichert: Don't convert data to pounds/million oysters; could be deceiving. Leave amount stored in shell as g/oyster; explain the gap/missing research piece. Report will be clear that you cannot use numbers presented.

Public Fishery Tissue Assimilation Estimate, Julie Reichert

e. Julie will present options on how to handle the N and P tissue assimilation estimates for the public fishery practices.
    - It's possible that panel could be overestimating reduction due to oysters grown without gear data included in dataset analysis.
    - 1st report: with gear dataset is too small to run quantile regression. Additional tissue data could allow culture method to be re-evaluated.
    - Diploid with and without gear might need to be analyzed separately of all diploid subset – could overestimate reduction if lumped in with other categories.
    - Possibly undercrediting groups growing diploids in gear – it's possible the curve could be steeper due to anything being tumbled/rolled is going to develop a deeper, rounder cup, affecting the relationship between shell height and depth, showing a higher biomass.
    - Options
        - Choice 2 – Include addendum to numbers from first report in the second report
            - Section out estimates due to gear method and ploidy.

Action: Julie Reichert will confer with Lucinda Power on Choice 2 approach

2nd Draft Writing and Review Schedule

- Julie will be writing the 2nd draft within the next two weeks – core part of the report including recommendations and rationale, figures and tables will need to be cleaned up.
- It will be sent to the panel chapter by chapter.
- The shell section will be done by the end of next week.
- October will be review month
    - Jeff: more available than usual
    - Julie Rose: available this/next week to rerun plots
    - Lisa: available mid-late October
- Schedule will be adjusted
    - Panel will present update to Water Quality GIT before CERF in November
    - Report 2 draft will be made available in January
    - Schedule update will be made to website

Oyster BMP Expert Panel Meeting, October 19, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Karen Hudson	Virginia Institute of Marine Science (VIMS)	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remote
Andy Lacatell	The Nature Conservancy (TNC)	Remote
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	No
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remote
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remote
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
Bill Wolinski	Talbot County Department of Public Works	Yes
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Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Action:** Cornwell will review Marinetics data to determine a site-specific estimate for example.
2. **Action:** Reichert will work with Kellogg on this calculation in November for Harris Creek
3. **Action:** Panel to read through Reichert's document. She will initiate a conversation via Email.

Meeting Minutes:

This meeting will focus on reaching consensus on the denitrification write-up and finalize decisions concerning which public fishery and restoration practices the Panel would recommend for BMP consideration.

Coordination Updates

1. **Presentation Requests:**
    a. MDNR Aquaculture and Shellfish Division for presentation on 1st report – scheduled **10/27/17**
    b. CBP Offset and Trading workgroup – scheduled **12/20/17**
    c. Water Quality GIT Update – looking to reschedule for **11/13/17** or **11/27/17**
    d. Fisheries GIT Meeting – looking for update on status of the 2nd report (recycle WQ GIT update). Scheduled for **12/18/17**.
2. **CERF Presentations:**
    a. Reichert-Nguyen et al. Quantifying Water Quality Benefits of Oyster Practices for Regulatory Use in Chesapeake Bay - Ecosystem services provided by shellfish resources, Monday, 11/6, 1:15 PM
    b. Kellogg is presenting Monday morning
    c. Bricker presentation on CBP Farm Model Calibration – 11:15am Monday
    d. Cornwell presentation focusing on denitrification concepts – Thursday, 11/9
    e. Rose is presenting on Monday
    f. Jeff's PhD student is presenting on Denitrification in Harris Creek – Monday morning

Enhanced Denitrification Write-up, Jeff Cornwell

3. Jeff will present denitrification write-up for the report, including additional information on what measurements are needed for on bottom (aquaculture and restoration) and off bottom practices (aquaculture only).

    Table of recommended approach for measurements of denitrification – Water Column Aquaculture

    Not enough data available to determine a number for denitrification – the data varies greatly. The fuel for the denitrification process is biodeposits – the fate of that material is key to the amount of denitrification that'll occur. Good techniques for measurements exist, no need for new technology to make these assessments. The difficulty in measuring denitrification is that biodeposits usually denitrify more efficiently in sediments than in reefs. Masses of biodeposits under reefs overwhelm the system, depletes the oxygen necessary for the deposits to nitrify. Measured denitrification does not necessarily equal enhanced denitrification.

    Page 2 of handout – diagram with blue arrows. We need to know that denitrification is happening in reefs and its efficiency. Kellogg 2013 study defines this.

    a. Figure JC3 - Enhanced denitrification doesn't occur under aquaculture facilities, but it's possible the biodeposits denitrify at an efficient rate offsite.
    b. Figure JC5 - If the sediments that biodeposits are moving to are efficient at denitrification, there is a huge net positive benefit. Aquaculture could be useful. Panel needs to determine the size and location of the halo/offsite landing area.

    Discussion

    a. Linker: If material is exported to sediments with overlying aerobic waters, that will also yield a positive net benefit.
    b. Reichert: Will the footprint/halo water quality cause issues with respect to crediting? Are there other BMPs that fit this model (water taking biodeposits elsewhere)?
    c. Linker: This would be a useful discussion for the CBP Trading and Offsets Workgroup. I believe this is fairy unique situation. If we can demonstrate that enhanced filtration and settling of organics that would largely not fall into trench, I think that'd be in positive favor.

d. Cornwell: We don't understand particles, how they're going to move, what they're going to do. At this stage, the scale of particulate modeling and resuspension modeling will not help at the scale of the farm (depending on size of farm). Could be developed, though.
e. Paynter: Deposits will fall into two pots on either side of a hypothetical farm of fecal matter. Oyster fecal material is large and not microscopic – it will be transported long ways.
f. Kellogg: Virginia perspective. The flow is not as clearly defined as you might expect. Not as simple as ingoing and outgoing tide. Lots of variance between 4 sites being studied. Growers spacing oysters out far, too – biodeposits aren't as concentrated/unit area as you might think, either. Measurements are site specific and very complex.
g. Cornwell: Putting cages on bottom can create depleted oxygen, too.
h. Reichert: Recommended conditions: e.g. the site needs to look like this.
    i. Location: Needs to look like halo in aerobic waters. Sites could be weighted/ranked for crediting. Portions of halos can be credited as well, if only certain portions fall within aerobic waters.
        1. Panel can rely on depth for the most part to determine areas of aerobic/anaerobic water. Nearshore respiration rate efficiency variations are low.
        2. Cornwell concerned this may be more of a research project than a BMP – we need tracers on the biodeposits to determine halo.
    ii. Cornwell: Include this as a model of what we need to do (regarding water column aquaculture). Would argue for restoration – we have enough here and can recommend something right now and find a number that's defensible. Treat on bottom aquaculture the same a restoration. There is not enough information for water column aquaculture.

For Report: We need a roadmap for the restoration section. The roadmap will need the Water Quality GIT's approval. Use similar language as first report – work with CBP to determine site specific estimate for inclusion in the model.

Action: Cornwell will review Marinetics data to determine a site-specific estimate for example.
Action: Reichert will work with Kellogg on this calculation in November for Harris creek.

Practices for BMP consideration, Paige Hobaugh and Julie Reichert

4. Paige will present information she found concerning other BMPs where the activity is to no touch an area (follow-up from discussion on whether oyster conservation under restoration practices should undergo BMP consideration).
   a. It'd be difficult to give credit to a practice for merely "existing" just because it could "not exist" and be something worse (e.g. a tract of land just standing still instead of having become developed).
   b. As for restoration on a forest sanctuary, as new trees are planted (much easier to account for than new oyster growth), they are credited toward Forestry BMPs.
   c. If there's a way to credit new oyster growth minus what already exists in a bed (as existing oyster beds are a built-in element of the estuary model), then that number can be included in the model.

Discussion

a. Possibly consider agriculture buffers for comparison – land use change receives credit.
b. Linker: Estuary model doesn't count wild oyster population as a reduction or BMP, it is part of the baseline. Aquaculture issues will also become baseline/background information upon CBP Principal Staff Committee decision. Isn't a current mechanism that will start to decrement

quantitatively a loss of resources like forests – will be a change in the way we count things. CBP thinking about establishing future baseline of degradation into the model.

c. Likely to be valuable in Virginia
d. Panel would like to change the name of the practice – possibly “Oyster reef conservation through reduced harvest”
e. Parker: Does CBP model assume a steady state of oyster population, account for growth?
f. Cornwell: Mike Willberg of Oyster Futures models the potential success of future reefs.

Action: Reichert, Parker, Wolinski, Kellogg, Hobaugh, and Linker will continue this conversation**.** A white paper detailing the discussion will be created for the end of October.

5. Julie Reichert will present merged Panel ideas for qualifying conditions concerning public fishery practices (spat-on-shell and substrate addition).

Discussion

a. Is there a way to consider the public fishery practice? If a jurisdiction is only adding substrate, yes.
b. Reichert: Designate an area where public fishing is occurring, assess the density and presence of shell for a “pre-substrate addition” baseline. First harvest credit would occur two years after planting

Action: Panel to read through Reichert’s document. She will initiate a conversation via Email.

Procedure to update tissue estimates from approved report, Julie Reichert

6. From discussions with Lucinda, it is recommended that track changes are used to update the estimates and any pertinent info within the 1st report and re-submit for WQGIT approval (changes do not require 30 day review).

Discussion

a. Current tissue estimates are diploids grown in gear – this doesn’t occur in nature, so panel must rethink its calculation/baseline.
b. Reichert: Possibly beneficial to wait for data to fill in the gap.
c. Crediting will be broken down by culture method and ploidy.
d. Can include in report the rationale: Current diploid estimates do not overestimate. Have identified that in the future, it’d be beneficial to gather more data for diploids grown in gear.
e. Panel can recommend the update in the report, but not necessarily perform it.

Oyster BMP Expert Panel Meeting, November 16, 2017, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	No
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Action:** Bill will explore the policy context and amount of N removal further, will send data to Lisa and the Panel.
2. **Action:** Julie and Lisa will work together to create slides for the WQ GIT presentation.
3. **Action:** Panel will use Ward's charts to determine how implementers will estimate a biomass number.
4. **Action:** "Designated Oyster Reef No-Harvest Area" consideration will be reviewed during a Panel phone call on 11/21/17.
5. **Action:** BMP considerations will be reviewed during a Panel phone call on 11/21/17.

Meeting Minutes:

This meeting will focus on reaching consensus on the denitrification site-specific method for restoration practices and finalize decisions concerning which restoration practices the Panel would recommend for BMP consideration.

Coordination Updates, Julie Reichert

1. **WQGIT update**
    a. Scheduled for Nov 27th
2. Discussion
    a. Julie wants the presentation to focus on the framework of how to determine a shell estimate (using the same strategy as tissue), less on showing the data.
    b. The Trading and Offset Workgroup presentation (11/15) went well. Based on feedback, the panel should make sure there are recommendations in report that will bar someone from having a lease and harvesting their own oysters for credit.
    c. The CERF presentation went well. Other groups presented on N removal and their rates were very high, they likely use less conservative approaches.

Enhanced denitrification site-specific method for oyster restoration practices

3. **Lisa Kellogg** – Presentation on method to determine site-specific estimate
    a. These recommendations only apply to oyster reefs
    b. Consider only methods that look at production of N_2 gas (net flux from the sediment to the water column). Must be scalable per unit area.
        i. N_2:Ar measurement in water column over time for reefs or reef sediments
        ii. Ion pairing is only appropriate for reef sediments (no samples with oysters or oyster shells)
    c. Oyster reefs exhibit high rates of restoration, batch incubation is appropriate. Flow through method incubation is potentially appropriate for sediments, but not for reefs.
    d. Light availability must be considered at each site – all measurements should include a dark incubation and a light incubation if reef is in an area of sufficient light.
    e. Data must be gathered from a reef and a nearby control site in order to measure enhancement
        i. Minimum three samples of each site
        ii. Each site must be measured during at least three seasons (Fall, Spring, Summer, 0 for Winter)
    f. O_2/N flux graph slope should be about 6.625 (Redfield ratio), plus or minus 25% of that number is acceptable to ensure validity of data.
    g. Statistics should show reef samples to have higher denitrification rates than the control samples.
        i. Measure N2/N flux for a reef sample and subtract the average of the control to get the enhancement rate (to retain variance in measurement and remain conservative)
    h. Credited enhancement rates
        i. Reefs: Credit at mean enhancement minus one standard deviation
        ii. Reef Sediments: Credit mean enhancement (already conservative measurement)
    i. Scaling measured rates
        i. Daily Rates: Multiple CER by 24 hours (reefs below eutrophic zone)
        ii. Scale night and day incubations depending on hours of day/night at each site
    j. Scaling measured rates by biomass/space

i. Those that don't measure denitrification with respect to biomass cannot be credited for any portion of the reef that doesn't meet a specific density of oysters at which measurements were taken

Discussion

a. It takes a significant biomass density beyond 50g/m^2 to see an effect on N_2 flux. Some sites experience densities higher than that.
b. Understanding what proportion of denitrification is attributable to oysters, other parts of reef community: Harris Creek data is available, but it hasn't been delved into yet. As of now, rates/considerations are likely to be site specific.
c. Some reef studies go autotrophic once light becomes available (O_2 inundation leads to bad denitrification estimates), data should be tossed out.
d. If an implementer is able to establish a density curve for each season, they should mimic the biomasses in the lab. The Kellogg lab intentionally stocks trays with a range of oyster biomasses (low, medium, high densities) and places them on the bay floor.
e. What is considered a season is not entirely clear currently. The Kellogg lab tends to measure 4x a year (April, June, August, October) and not in winter. There is evidence that seasons are defined by more than just water temperature.
f. Implementers should be sure to distribute their measurements evenly across months of the time window during which they measure.
g. Context of mass of N removal for policy purposes? Based on data, hundreds of pounds of N/acre/year (1-600 for tidal reefs).
    a. **Action:** Bill will explore the policy context and amount of N removal further, will send data to Lisa and the Panel.
h. Not many implementers have the equipment to make these measurements; a mass spectrometer is necessary to measure micromoles of N gas/liter.
i. The flow through approach could be useful on the finishing end of a large scale tributary project. It could be cost effective in places where an entire tributary is being considered at one time.
j. For estimate to be valid, implementers need to be sure that reef sustained at least its original biomass. If the function of biomass still works and implementers see an increase, they should project the new crediting outward. This is unlikely since densities in experiment examples are already very high.
k. Concerning die offs, poaching issues, how often should implementers check for biomass stability? MD samples restoration sites annually. Panel needs to examine available data, decide how much biomass changes from year to year and whether it changes with different parts of the bay.

The panel is comfortable with presenting this information to the Water Quality GIT.

Action: Julie and Lisa will work together to create slides for the WQ GIT presentation.

4. **Ward Slacum** – Presentation on method options to determine oyster density and shell heights
    a. Assumptions: Biomass is the estimated parameter used to scale reef size. It is a reflection of heights of oysters measured in the field.
    b. Recommendations:
        i. Implementers who want credit must consider rates at different densities.
        ii. No implementer may receive credit for measurements from reef densities higher than the highest density they measured for.
        iii. Performance metrics should be measured at the reef scale.
        iv. If a picture of the bottom exists, an implementer can do stratified random sampling. Without a picture, it is best to do random sampling.

   v. Sampling size requirements are yet to be determined, it will depend on acreage

c. **Discussion**
   i. Every sample point is generated randomly in GIS, divers navigate to that area to sample. To remove bias, the vessel tries to anchor exactly on the site and the diver places the quadrat adjacently.
   ii. The area sampled by patent tons is twice the quadrat size that divers use. Divers are counting spat/natural recruitment, lends variability to sample.
   iii. Metrics are reef based, scales are applied to sample sizes to level sampling regimes. Reefs are monitored 3 and 6 years from restoration.
   iv. How many samples are necessary to determine biomass?

Action: Panel will use Ward's charts to determine how implementers will estimate a biomass number.

5. **Julie Reichert** – Presentation on available oyster data to determine regression equation to use with oyster restoration practices
   a. **Decision Needed: Does the Panel agree with this approach? What would we like to include in the WQGIT update?**
      i. The Panel is okay with using diploid estimates from the first report.

6. **Restoration Practices for BMP consideration, Paige Hobaugh and Julie Reichert, 2:00 – 2:45 PM**
   a. **Paige Hobaugh** – Present findings from Panel subgroup concerning the "Designated oyster reef no harvest area" category (formally known as "Oyster Reef Conservation" category)

   Action: "Designated Oyster Reef No-Harvest Area" consideration will be reviewed during a Panel phone call on 11/21/17.

   b. **Julie Reichert** – Lead consensus discussion on which oyster restoration practices will undergo BMP consideration.
      i. **Decision needed on which restoration practice categories will undergo BMP consideration**
      ii. **Decision so far**
         1. YES – Oyster reef restoration using hatchery-produced oysters
         2. ? – Oyster reef restoration using substrate addition
         3. ? – Designated oyster reef no harvest area (panel sub-group has recommended that yes, this category should undergo BMP consideration)

   Action: BMP considerations will be reviewed during a Panel phone call on 11/21/17.

Oyster BMP Expert Panel Meeting, January 4, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	No
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	Yes
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Action:** Panel will move off-bottom aquaculture using hatchery produced oysters into the research gap section.
2. **Action:** Bricker and Fegley will work to determine any additional requirements for Categories F, G, and I (particularly from a public fisheries standpoint).

Meeting Minutes:

This meeting will focus on the site-specific measurement strategies to determine the reduction effectiveness associated with enhanced denitrification and decide whether to include N and P assimilation protocols for restoration in the 2nd report (tentative; pending on EPA lawyers' decision).

1. **Enhanced denitrification site-specific method (restoration and aquaculture)**
    a. Jeff Cornwell – Go over the strategies to measure enhanced denitrification for restoration and off and on bottom aquaculture.
        i. **Need to finalize recommendations on methods to measure denitrification and verify via biomass.**

Comments:

- Panel should point out in the report that some cases will result in the need of additional requirements. When oysters are left untouched, there is more confidence in the denitrification rate. Harvesting practice disturb sediments and the nitrogen flux of the system.
- Panel needs a denitrification number attached to the biomass at a site. Biomass changes over seasons in a substantial way, grows larger through a season, making finding denitrification rates more difficult.
- In a restoration setting, it is likely that the practitioner wouldn't begin measuring denitrification until the oyster population has established.
- Panel has little information about off-bottom aquaculture; it knows there is likely to be denitrification enhancement associated with aquaculture, but it doesn't know how to make that assessment (Assess in the 2nd year? Once oysters are harvest size? What happens after removal?)
- It is not likely that someone would find assessing denitrification rates financially worthwhile unless they research it under a limited duration.
- **On-bottom aquaculture** generally results in positive denitrification, though it is not a perfect, 100% assessment of all denitrification.
- **Off-bottom aquaculture** is a range of practices; sometimes in cages only 1-2ft off the bottom, no higher than reefs.
- Panel will move **off-bottom aquaculture** using hatchery produced oysters into the research gap section.

On-bottom public fishery:

- Panel can suggest: In order to qualify as BMP, choose an area, conduct a pre-denitrification survey, plant spat, leave it for three years to receive credit.

Determination of suitability of denitrification studies for consideration:

- It'd be okay for a practitioner to spend less money on denitrification study and get a lower rate- underestimating is okay for credit.
- Panel will not accept rates acquired by just any technique, though.
- Panel should explain which techniques are unacceptable; stating the pros and cons of using each method. Add background text about assumptions/issues with techniques (e.g. don't drive sample to anoxic conditions during incubation). Include images of the methods. Note that a practitioner would likely need to partner with a lab based on equipment requirements.
- The existing chart should be changed: practitioner can use sediment cores instead of the entire community resulting in an underestimation of denitrification rate.
- Table XX:
    - Rationale column items need additional information; change to "explanation"
    - What is a better control for this?
    - Start credit when practitioner measures enough creditable biomass

- How long to credit for? Need to reassess over time? Change crediting to "on the basis of your success"
- Site Specific Estimate Experiment Design:
  - Is the denitrification/biomass relationship determined by size and location?
  - Panel can say these are considerations that need to be made; must be reviewed with someone with survey design experience, knowledge of the site.
  - Variance threshold? If a practitioner's rates vary wildly among similar reefs, they cannot expect to use those numbers as a reasonable estimate. How do other BMPs deal with this?
  - Possibly add experiment/estimate review requirement? There is a precedent set up for that within the CBP partnership.

b. Get Panel's thoughts on baseline and timeframes for the BMPs
   i. Thoughts for January 18th meeting (see BMP Report Requirements document)
   - For new practices, panel should recommend that practitioners make measurements before they start the activity if they want credit. Establish the baseline, instead of finding a similar control site.
   - What time frame makes sense for the denitrification protocol? Is a certain size area optimal for enhanced denitrification?
   - Would time frames be different for on-bottom versus off-bottom?
   - The BMP is useful as long as oysters are filtering and enhancing denitrification. Assimilation useful life may be different.
   - What are the unintended consequences?
   - What timeline does the panel propose for the reevaluation of the panel recommendations based on new data/information?

2. Decide on whether to include N and P assimilation protocols for restoration practices in 2nd report (tentative)

a. The idea is to use the method from the biomass verification component of the enhanced denitrification protocol.

Comments:

- Panel is evaluating 6 BMP combinations. Upon reviewing the notes, Julie Reichert thinks the panel can potentially also accomplish more.
- Categories F, G, and I could be included – Bricker and Fegley will work to determine any additional requirements (particularly from a public fisheries standpoint). As long as there is data on what the oyster populations look like, this sounds doable.
- Challenge with Category F – what value to estimate about the baseline on a public bar? Most public bars in VA have shell addition when funding is available, not unlike with aquaculture. It'd be hard to determine what the estimate of increase above the baseline is.
- Leave Category H off for now.
- Panel to at least open the door for practitioners to use these practices; there are systems in place with counties and the locations they choose, data must be recorded.
- Now that the Panel has the legal opinion and will have to do no additional work, there is the potential to also include Categories J and K.

The target date for the second report draft is by January 31st. The panel will review in February and will set up a webinar for the beginning of March. Ideally, everything will be approved of and wrapped up by April.

Oyster BMP Expert Panel Meeting, January 18, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	No
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Decision:** Recommend to assess each year for site specific denitrification rate, every 3 years for assimilation credit only, apply credit every 3-4 years for reef growth rate.
2. **Decision:** Default approach for whole oyster estimate – panelists are comfortable with this.
3. **Action:** Emily will distribute Oyster Sanctuary monitoring reports to panel; will work with Bill to review; will go over with panel at 2/15 meeting.
4. **Decision:** There will be no changes to the chart provided at today's meeting; this is how the report will be structured.
5. **Decision:** Panel recommends measuring biomass at least every 3 years. Can be done yearly to potentially gain higher crediting based on annual rates. Frequency at which to assess must be established and stated in the WIP.

Meeting Minutes:

This meeting will focus on finalizing which oyster practice-protocol combinations will be in the 2nd report. We will also go over some ideas for including N and P assimilation protocols for restoration (received ok from EPA lawyers that N and P sequestration from in water BMPs can count towards reduction effectiveness.

Practice-Protocol Decisions for 2nd Report

We will review decisions thus far and by end of meeting aim to reach consensus on what to include in the 2nd report (see progress table in Excel file)

Table –

- Darkest gray – Practices included in the first report
- Lighter gray – Practices being considered for the second report
- Lightest gray – Practices on hold for the third report
- Bolded – Practices panel may be able to include in second report

Second Report – see updated panel report schedule document

- If panel decides to add additional practice categories, it needs more time to complete report.
  - March – incorporate edits from panel; put together webinar
  - April/May – draft out for public comment
  - June – review comments
  - July – Second report approval
- For Approval –
  - A methodology to determine site-specific estimates for the "Enhanced denitrification associated with oysters" protocol to apply to endorsed oyster reef restoration practices.
  - Application of the approved default nitrogen and phosphorus tissue estimates from the first report for the endorsed oyster practice category, "On-bottom public fishery oyster production using hatchery-produced oysters."
  - Recommended default estimates for the amount of nitrogen and phosphorus sequestered in live oysters for the endorsed oyster reef restoration practices.
  - A framework to determine the reduction effectiveness estimates for the amount of nitrogen and phosphorus assimilated in oyster shell of harvested oysters (applies to endorsed private oyster aquaculture and public fishery practices).

  Discussion –
    - Regarding the information in parenthesis in the 4th bullet – it should be noted that harvest from public grounds with no activity is not endorsed by the panel.

- Informational –
  - Clarification on the intended qualifying condition of approved tissue estimates for the endorsed private oyster aquaculture practices concerning the presence of oysters before practice implementation.
  - Identification of research gaps associated with developing site-specific enhanced denitrification estimates for practices where oysters are harvested (i.e., endorsed private oyster aquaculture and public fishery practices).
  - Analysis on the effect of culture method on tissue biomass from new data that became available after December 2016.

  Discussion –
    - Explicitly state that at private aquaculture lease areas, panel expects there to be few, if any oysters present. If there are oysters present, lessee must perform an

assessment of the baseline population and deduct it from the total biomass at harvest.
  - Regarding 2nd bullet, there are many other factors that could influence denitrification rates
  - New data as of 12/2016 makes it worthwhile to reevaluation the relationship between ploidy and biomass

- Is the Panel still envisioning drafting a 3rd panel report and, if so, what would be included in this panel report?
  - Jeff Cornwell, Julie Reichert, and Ward Slacum think it'd be best for the panel to take a year or longer hiatus to allow the report proceedings to catch up before pursuing a 3rd report.
  - There isn't much available information on 3rd report categories.
  - Panel will inform CBP it is going on hiatus; when reconvening, just put request out to panelists for availability/interest.
  - Google Drive folder with access to literature will be established. Panelists should create folders for new categories with new data/studies.

- CAC Communication –
  - Ongoing policy issue with practice L "Designated Oyster Reef No Harvest Area". Panel is divided; majority feel it fits BMP model, some think otherwise. Science doesn't dismiss crediting for this practice, but policy seems to. Will be put forward as a policy issue.

Thoughts concerning N and P assimilation protocols for restoration practices in 2nd report – see powerpoint presentation

- Legal opinion –
  - Panel is assuming that sequestration falls under the legal opinion.
  - Nothing in Clean Water Act that would prevent in-water partnership approved BMPs – some already exist e.g. floating wetlands, Baltimore trash interceptors
- What to recommend for the N and P assimilated in oysters concerning oyster reef restoration practices –
  - Can the biomass determination from the enhanced denitrification verification guideline be used to estimate sequestered N and P in tissue?
    - Default, not site specific estimate.
  - Can we give credit to both tissue and shell if credit is only given to live oysters?
    - Shell dissolution shouldn't be a huge issue since the oysters are alive; panel can provide stipulations like timeframe.
    - Can count shell from oysters harvested as long as they're still alive, still growing. Reef will reach a stable state.
  - Timeframe –
    - Checking yearly would work nicely with denitrification (verification based on biomass; check oyster density, calculate biomass, apply denitrification rate based on that).
    - Biomass should be the rate of growth averaged over a period of time. Over crediting could occur if you were to credit each year.
    - Generally, we assume 100% return of shell. Would have to create a plan to determine where all of the shell goes; difficult to do, unsure of how to do so.
    - Protocol for Sanctuaries says to measure every 3-6 years.

Decision: Recommend to assess each year for site specific denitrification rate, every 3 years for assimilation credit only, apply credit every 3-4 years for reef growth rate.

- Method –
  - Quantile regression equation should be used to determine biomass; monitor for shell height, oyster size class.
  - Tissue: Panel could use diploid equation from first report for on-bottom restoration practices.
  - Shell: Whole oyster estimates for on-bottom reef restoration.
  - Credits for shell and tissue (growth rate) are different for denitrification (biomass as a proxy).

Decision: Default approach for whole oyster estimate – panelists are comfortable with this.

Action: Emily will distribute Oyster Sanctuary monitoring reports to panel; will work with Bill to review; will go over with panel at 2/15 meeting.

Decision: There will be no changes to the chart provided at today's meeting; this is how the report will be structured.

Enhanced denitrification site-specific method progress

Update Panel on edits to the enhanced denitrification chapter – see diagram.

- The panel learned enough to specify methods with which to make valid site specific rates.
  - 2 practices the panel can specify techniques that will yield a valid number.
- Aquaculture Practices
  - On-Bottom: Will harvest oysters as opposed to leaving them. Research gap that needs to be met.
  - Off-Bottom: Site specific based on where biodeposits land.
    - There isn't enough information currently to make any decisions with regard to the fates of materials.
- Oyster Reef Restoration Practices
  - Whole community testing is preferred; cores are acceptable with recognition that lessee is not getting as much possible credit.
  - If oyster reef, no harvest is eventually considered as a BMP, which category form the chart would it follow for crediting?
- The panel faces a challenge in being precise enough to specify an approach acceptable for oyster reef restoration and at the same time developing guidance and information for research gaps for Aquaculture.
- Denitrification process seems to be variable in ways not entirely understood by the panel.
  - Relationship between biomass and denitrification is not linear.
  - Relationship between biomass and denitrification reaches a maximum, may not be persistent across seasons – very site specific.
- If someone wants more crediting options, they can create denitrification rates at different biomass values. If not, they can measure one median biomass rate and receive credit based on that.

Decision: Panel recommends measuring biomass at least every 3 years. Can be done yearly to potentially gain higher crediting based on annual rates. Frequency at which to assess must be established and stated in the WIP.

Next Meeting –

Julie plans to begin work on the denitrification chapter next week. Emily and Bill will work on the assimilation chapter. The panel is looking for approval for the framework it developed (based on the literature review) for the shell chapter.

Oyster BMP Expert Panel Meeting, February 15, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Yes
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	No
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Action:** Jeff will work with Emily and Ken on a strawman crediting protocol and disperse it to the group for thoughts and comments in the next week.
2. **Action:** Emily will send the Oyster Metrics document that explains periodicity of monitoring and why year 3 was chosen for biomass, and the 10 Tributaries by 2025 2016 Monitoring Report to the panel.
3. **Decision:** The panel will not be prescriptive. It is up to the BMP Implementer to choose the useful life of the BMP for assimilation purposes (when to stop monitoring).
4. **Action:** Lew will send technical memo examples to the panel.
5. **Action:** Panel will to continue discussion on how prescriptive to be.
6. **Action:** Jeff will write up some sample text and send it to the panel for reaction.

Meeting Minutes:

1. Coordination Updates, Emily French

- **a.** ORP will provide update on panel progress to Citizen Advisory Committee (CAC) at their Feb 23rd meeting.
    - I. Ward will be presenting.
- **b.** Panel has been invited to present progress on Oyster BMPs at the Interstate Seafood Seminar on March 29th.
    - I. Julie Reichert will likely be presenting.

2. Restructured enhanced denitrification chapter and implications for report structure, Emily French and Jeff Cornwell (See table of contents document)

It was recommended by CBP representation that we structure each chapter in such a way that makes it clear what we are asking the WQGIT to make decisions on for BMP approval.

- a. Some content of the denitrification chapter is therefore being shifted.
- b. Implications for the report: Put recommendations panel is seeking approval on in its own subchapter under 'Complete recommendations', move informational items (ways to improve oyster reef restoration estimates; research gaps for aquaculture/public fishery practices) in a different subchapter under, 'Informational recommendations', and have content where framework is recommended but a complete recommendation will not be provided under 'Framework only recommendations'.

The Panel likes this structure.

3. Thoughts concerning verification for the N and P assimilation and enhanced denitrification for restoration practices subchapters, Emily French, Jeff Cornwell and Bill Wolinski (See Powerpoint presentation)

Looking for Panel input on the 'Recommendations for application and verification' sections within both the following chapters:

- a. Nitrogen and phosphorus reduction effectiveness associated with assimilation in oysters for restoration practices
    - I. Slide 4 – Concern about double counting
        - After original biomass measurements, only appreciation beyond amount originally credited can receive credit. No credit given for no appreciation.
            - Jeff: The challenge is with the increase/decrease associated with biomass. We don't have enough information to understand if the shell is coming and going. If biomass decreases, there is no crediting.
            - Jeff: There is no evidence yet that supports the idea of biomass increasing with time in sanctuaries with restoration activities.
            - Bill supports crediting only the appreciation in biomass.
            - Julie: Is okay with giving more than one credit based on difference from the original baseline.
            - Lynn- Be careful not to credit variability, which could look like appreciation.
        - Jeff: What is the timeline for this? Do we need to consider not using the first year's biomass when it's highest and think about using a year or two after restoration has occurred instead? What is the period over which observations will be averaged? Do we credit at the beginning of BMP implementation or should back crediting be possible?
            - Jeff: This may take an inspection of trends. After the first assessment, credit could be given to a proportion of the existing biomass and if the subsequent assessments are consistent with higher levels, then you credit that in full.

What is the average change between assessments? There won't really be any negative numbers if we average.

  - Emily: Not much data exists on biomass density over time of the same oyster population, therefore the question of 'when is a reef established enough to credit?' is difficult to answer. There are '10 Tributaries by 2025' sentinel site density and biomass data in annual reports; this may be the only data the panel has to refer to. Is there any other per meter squared oyster data available for the same sites sampled over time?
  - Ken: We can use the sentinel site data as an indicator of population health and density in Harris Creek. Should be able to detect large scale mortality event if monitoring correctly. We will be able to estimate the percent of mortality, make determination in other areas to confirm the mortalities. Provides a "snapshot" of what's going on. We cannot quantify impact of illegal harvest, though.
  - Mark: VA restoration sites not well established for annual monitoring yet, and not much data exists on biomass density over time of the same oyster population in VA.
  - A panelist mentioned that the sentinel site graph shown in the presentation/ accompanying report were in density and not biomass. Emily said she would find the equivalent biomass.
- Mark: How do you take back credit if restoration site experiences drought/diseases and loses all oysters?
  - Julie: Sounds analogous to BMPs dependent on the establishment of new environments; wetlands, floating wetlands, buffer strips. Will always be potential for loss; how do they deal with it?
  - Lew: If a riparian buffer is torn up by a flood, it is entirely taken out of crediting. Oysters will be no different. Fate of resource (possible N and P back into environment) not considered.
  - Ken: When oysters die, tissue is consumed quickly by foraging animals.
  - Bill: Oyster credit is analogous to living shorelines credit. If things change, credit will be adjusted.

II. Slide 7 – Back-crediting Oyster Restoration

- Chris: why consider going back and crediting a practice that was done before the BMP was approved?
  - Julie said she thought CBP suggested to include large restoration projects like Harris Creek due to such thorough ongoing monitoring. CBP didn't want to discount idea of crediting well-funded and monitored programs.
  - Bill: Concerted effort done in 2010 to establish sanctuaries and monitor them, but there was a commitment of resources to establish conditions for an extended period of time. Might have been positive changes in these areas that should be considered for crediting.
- Emily: Is 2010 a reasonable date to consider? Why?
  - Lew: Unsure. What if panel were to say it's not a particular practice, but a process based determined by quality of baseline. Consider multiple density estimates over an area. Year doesn't matter if baseline data is good?
  - Julie: June 15th, 2016 meeting discussion on TMDL refers to 2009 as baseline.
  - Lew: Use any 2009 restoration projects plus additional quality baseline data taken after 2009.

  - Bill: 2009 monitoring not as good as now, judgement call on what constitutes good data. Panel doesn't make that judgement. Panel needs to create guidelines to assist with that judgement.
- Emily: The text of the chapter currently reads that the BMP implementer should determine when biomass year 1 measurements should occur after restoration activities. Does this sound right to the panel?
  - Jeff: Could support that is crediting occurs the first year at a proportion, and full credit is given if subsequent years are consistent. In first assessment, don't give credit for all N sitting there. Take a second and third assessment to give total credit.
  - Lew: This sounds like the right track. Presumably the panel will come up with some protocol for baseline assessment. Some proportion of that baseline is the credit, then there are other protocols for how to assess going forward how that biomass changed and whether it's a multi assessment average. Must be checked every year to be sure.
  - Panelists say it's a reasonable compromise. However, it could be expensive to measure biomass for multiple years in a row.

Action: Jeff will work with Emily and Ken on a strawman crediting protocol and disperse it to the group for thoughts and comments in the next week.

Action: Emily will send the Oyster Metrics document that explains periodicity of monitoring and why year 3 was chosen for biomass, and the 10 Tributaries by 2025 2016 Monitoring Report to the panel.

III. Slide 8 – Lag time from implementation to fully-functional concerns
- Should there be more smaller size categories to account for fact that restoration has higher variability in size? Do we need to account for biomass dry weight variability? Could observations of shell height be fed directly into the regression instead of put through the size class table?
  - Jeff: Data dense quantile regressions are the best way to account for biomass.
  - Lisa: Were previous quantile regressions from restoration? All over the bay in different kinds of environments?
    - Julie: We can use the diploid equation from the first report and feed the shell height observations directly into it. There is no discernable difference between on-bottom diploid restoration oysters vs. the entire regression.

IV. Slide 6 – Declining biomass
- At what 3-year interval, if biomass has stagnated or declined, does measurement stop occurring?
  - Larry: This should be up to institution running restoration site.
  - Jeff: proportional crediting in beginning adds incentive for sustained monitoring.
  - Bill- Panel should follow '10 Tribs by 2025' monitoring protocols.

Decision: The panel will not be prescriptive. It is up to the BMP Implementer to choose the useful life of the BMP for assimilation purposes (when to stop monitoring).

V. Slide 9 –

- Mark: Is it common to see details of protocols for sampling inside a BMP document or more common to reference protocols for sampling? Might be worth getting background on sampling design.
- Lew: once a BMP is approved, there is a technical memo that goes out… "this is exactly what we expect to see with respect to how to develop this credit" based on info in panel report.
- Chris- we can include citation in the text of the report to specific approaches.

Action: Lew will send technical memo examples to the panel.
Action: Panel will to continue discussion on how prescriptive to be.

b. Nitrogen reduction effectiveness by the process of enhanced denitrification associated with oysters for restoration practices

I. Slide 10 –
   - Highlights differences between denitrification and assimilation chapters.

II. Slide 11 –
   - Does panel agree with 3 year intervals?
     - Jeff: Don't credit overages of biomass, defer to percentage of full crediting again. Lower biomass will still have significant effects on water quality.
     - Lisa: Agrees. Becomes non-linear at higher biomass (biomass vs. DNF) – what is threshold?
     - Bill: It will be valuable to expand on rationale for clarification.
     - Jeff- will include this information in a figure like the example in slide 11.
   - Does panel agree with idea that 1st year biomass taken, same would go for denitrification measurements and would be good for 3 years afterward? Is panel comfortable with the assumption that biomass stays same for 3 years?
     - Jeff: Is comfortable with this.
   - When reassessed at year 4, no rate analysis takes place, use year 1 rate again as long as biomass is similar or higher than year 1?
     - Jeff: we'll assume that it is good.
   - Proportional scaling credits?
     - Intertidal reefs pose a bit of an issue, need to look back at data.
       - Biomass would be function of sampling design of that process.
     - Jeff: We need to create language as to caution people from making investments in these areas for now.

III. Slide 14 – On bottom restoration studies (refer to chart)
   - Jeff: Reefs are more complicated than the reef in this chart. In the end, there was no export in biodeposits, this would be an overestimate. Is comfortable with this rate at this stage. Net denitrification rate between control and reef is 250.

IV. Slide 15:
   - Emily: Not many people are set up to be able to make denitrification assessments at these rates.
   - Jeff: Will describe here what techniques are appropriate. Need to put some thought into this.
   - There is no need to overprescribe in the second paragraph. State "this is the way we believe these studies should be done".
   - Put broad guidelines in this and leave it up to technical implementation the bay program would do.

   Action: Jeff will write up some sample text and send it to the panel for reaction.

Oyster BMP Expert Panel Meeting, March 15, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Remotely
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	No
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Remotely
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remotely
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remotely
Chris Moore	Chesapeake Bay Foundation (CBF)	Remotely
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remotely
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Remotely
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	No
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Emily French	Oyster Recovery Partnership	Yes
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:

1. **Action:** Bill and Emily will research BMP verification guidelines to develop a less prescriptive approach for report.
2. **Action:** Lisa created a spreadsheet that shows real sentinel site data used for assimilation partial crediting approach scenarios and will send it out to the group.
3. **Action:** Emily will connect with Lisa for sanctuary reef raw data.
4. **Action:** The panel will include a footnote of disturbance event guidelines in the assimilation chapter.

Meeting Minutes:

1. Coordination Updates, Emily French

a. ORP will provide a quick update on the Citizen Advisory Committee (CAC) Feb 23rd meeting.

b. Next oyster BMP Expert Panel meeting will take place April 19th; Julie will be in attendance
c. 2nd report draft should be done in April, public review period in May
    i. This draft/review schedule needs to be double checked with Julie
    ii. Bill asked if the first paragraph of the assimilation chapter, 'algae and organic matter' could be added to oyster filtering sentence.
d. CAC Meeting- Emily presented for Ward. CAC had two main concerns:
    i. With a decrease in potential budget, they are worried verification for restoration (monitoring) wouldn't be able to happen as outlined thus far in 2nd report.
    ii. Concerned about oyster aquaculturists not knowing how to adequately report the number of oysters in their farms, potential for overcrediting because reports on number of oysters could have incorrect figures.
e. There will be one or two more meetings before panel draft report review.

2. Thoughts concerning verification for the N and P assimilation and enhanced denitrification for restoration practices subchapters, Jeff Cornwell and Emily French

a. Denitrification Subchapter Crediting Approach Presentation – Jeff Cornwell
    i. Slide 3
        - Jeff: With any denitrification crediting scenario, it's a necessity to make measurements and have site specific data. There is no baseline data that says oyster reefs always behave in a certain manner, they're highly variable. Panels A, B, and C are biomass assessments over time. The red bars are the N credits associated with biomass. If biomass increases over time, we cannot exceed the initial measured amount and must give the same amount of credit. We do think there's a reasonable linear relationship with the decrease in biomass, therefore crediting will decrease. This is a broad proposition at this point, a draft figure. Assimilation crediting is even more complicated.
        - Jeff: Outstanding questions – What are these time periods? How long do we keep crediting denitrification?
        - Lynn: On Panel C, if you have biomass degrading, at what point do you stop crediting entirely as opposed to just decreasing credit?
            a. A panelist proposed at 50% biomass, credit is revoked entirely. Panelists agreed. Jeff mentioned, or they could do another DNF assessment.
            b. What behavior does this decision incentivize?
        - Lisa: Wants to review biomass decrease data once more.
        - Julie Rose: From an implementation standpoint, it seems unusual that you'd have decreases and increases steadily. It might jump around from year to year. If biomass decreases between T1 and T2 but increases at T3, it should be back to T1's credit.
        - Bill asked if benthic infauna and other small oyster reef residents enhance DNF, Jeff said yes.
        - Lew asked what this topic is relative to. Emily answered this discussion is only on sanctuaries, not aquaculture.
        - Lew: If biomass is stable for 10 years, does crediting continue or does it need a recheck?
            a. Jeff: Denitrification for that is on a constant basis. The intention in all of this is to achieve a balance in prescribing how things should be done but not overprescribing as not to exclude potential method advancements, innovation, etc.

b. Nitrogen and phosphorus reduction effectiveness associated with assimilation in oysters for restoration practices - Partial crediting approach

   i. Slide 8

      - Emily: This figure is what we have so far for biomass over time a restoration site. Other than this haven't found examples of density/ biomass data over time taken from the same oyster reef. Another idea for the sanctuaries with no restoration occurring is to look at fall MD survey data. It has no area measurement but there is a formula in a report for converting the second of dredge tow to an area. It tries not to sample areas where hatchery spat on shell has been planted.
      - Lisa: There should be data from Virginia, sanctuary reefs are sampled yearly, collected by patent tong. Same restoration reef over time. Roger Mann and Missy Southworth can provide raw data – summary data can be found online.
      - Emily: Will connect with you to find those data.

   ii. Slide 9

      - Emily: Here is the skeleton of recommended sampling that assimilation chapter would offer. Is it too prescriptive to apply to this or if this is enough of a skeleton to remain in the chapter?
      - Lisa: Year 1 should be Time 1. Implementer gets to pick when they do their first assessment – reflects language used in report.
      - Chris: There needs to be guidelines for what to do during disturbance events.
      - Emily: We will include a footnote for disturbance events.

   iii. Slide 10:

      - Emily: Is 6 years too long for BMP implementer to receive credit? Alternative is 50% at time 1, 100% at time 2 if there's an appreciation?
      - A panelist mentioned that any local government thinking about using oysters are assuming they are receiving continuous credits.
      - Emily: This credit has to do with standing stock, potential concern for double counting.
      - Lynn: Any discussion as to what to do at Time 2 if biomass has decreased? We need equations so that we're understanding the situation the same way.
         a. Default: no credit given, but no credit is revoked. Only credit oysters there at that moment in time. Not automatically giving credit for next year unless implementers can show that reef has grown.

c. Review '10 Tributaries by 2025' approach to collecting biomass measurements

   i. Slide 4

      - First bullet point: Stratified random sampling, does panel want to make assignment on sample design? Too prescriptive?
      - Second bullet point: Assessment intervals.
         a. Emily: Is there any biological basis for 3-6 year assessment intervals?
         b. Ken: Substantial overplanting of bars would happen if natural recruitment wasn't assessed. Oysters are assessed at year 3 to figure out how many survived up to that point, and to assess oysters of a known age. If oysters are not surviving at a known threshold, more seeding occurs.
         c. Mark: this was mostly to add accountability that oysters are there; to monitor restoration sites and not just forget about them.

ii. Slide 6
- Review of 2016 Oyster Reef Monitoring Report.
    a. Survey design: Systematic grids created in ArcGIS.
    b. Sampling methods: Patent tongs for spat on shell, etc.

iii. Slide 7
- Emily: Current version of assimilation subchapter; does panel agree with this language?
- Chris: Diver language for monitoring is a little MD centric, lower parts of the bay can be restored/sampled without diving. Loosen up the language a little bit.
- Mark: Reefs aren't property of individuals, surprised we're saying how agencies should sample the reefs.
- Ken: Monitoring protocols have been developed through long efforts of trial and error; don't see that us describing how to do this is appropriate.
    a. A panelist mentioned, what about providing guidelines for small community restoration?
    b. Jeff: It is up to agencies how to implement this anyhow; simplify by saying use approaches approved by different agencies.
    c. Chris: Good for entities that have done restoration thus far. New implementers won't know the protocols that have been developed and may need the guidance. We need something in this chapter to address that.
    d. Lew: This track makes sense; up to panel to establish expectations for minimum level of monitoring for restoration sites.
    e. Mark- isn't there a technical appendix CBP writes that says this type of specific monitoring info? Chris responded yes, but allowing CBP to write the verification procedures for this report could result in a knowledge gap.
- Emily: language of paragraph is pretty general to begin with- should we be more prescriptive than this or leave this as it is, or less prescriptive? Do we need a technical appendix instead of this language?
    a. Jeff: Including a technical appendix sounds fine. We don't need to specify HOW to sample (e.g. with patent tongs). Make this paragraph more generic; include more approaches in technical appendix.
    b. Ken: take everything out after the first sentence.
- Emily: Do we keep that it is recommended that BMP implemented should collaborate with research institution? Keep?
    a. Lynn: If private groups want to embark on this, who is going to be the overseeing body?
    b. Chris: No matter the implementer, there needs to be a verification process in place. A process set up by the state.
    c. Lynn: Don't know enough about how this works in MD. Some private implementer might come up with a process really creative that we haven't thought of – system needs to be in place to review what they think of.
    d. Bill: Because of our mission to evaluate crediting for BMPs we have basic responsibility to reference some approach to sampling, verification. Oyster Metrics document seems to be the piece right now that bay is using, seems logical prescribe this.

e. Ken: Seems like we're getting into permitting process, would it not be appropriate to have language that the appropriate permitting agency should use specific guidance document to dole out recommendations?
f. Emily: Sounds like panel should play around with less prescriptive approach up front in chapters, include technical document, get information on approval practices/techniques.
g. Bill: Emily and I can research BMP verification guidelines. Shoreline Management BMP isn't too prescriptive. But since so many resources go into oyster restoration, maybe it would be better to have prescriptive approach, less room for error.
h. Lisa has created a spreadsheet that shows real sentinel site data used for assimilation partial crediting approach scenarios and will send it out to the group.

3. Will cover at next meeting: Nitrogen reduction effectiveness by the process of enhanced denitrification associated with oysters for restoration practices
   1. Discuss measurements related to biomass relationship with DNF
   2. Discuss guidance for when to take DNF measurements and with what method

Oyster BMP Expert Panel Meeting, May 17, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	Remotely
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Remotely
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remotely
Andy Lacatell	The Nature Conservancy (TNC)	Remotely
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remotely
Chris Moore	Chesapeake Bay Foundation (CBF)	Remotely
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remotely
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remotely
Frank Marenghi (Guest)	Maryland Department of Natural Resources (MD DNR)	Remotely
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	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Guest	**Affiliation**	**Present?**
Frank Marenghi	Maryland Department of Natural Resources (MD DNR)	Remotely

Action Items:

1. **Action:** Julie will send doodle poll to schedule another call for the public fishery discussion.
2. **Action:** Julie will send out a draft of the second report for review; panel members should review the definitions and consider the BMP decisions/rationales.
3. **Action:** Lynn Fegley will continue conversation with MD DNR scientists, will report to the Panel about discussions on survivorship rates and timeframe.
4. **Action:** Julie, Lisa, and Jeff will discuss baseline scenarios, minimum timeframes for crediting and communicate with Panel via email.

5. **Action:** Jeff and Lisa will speak to the technical details of baseline denitrification rate within the next few weeks.
6. **Action:** Panel should read through all PowerPoint slides, reach out via email with comments and concerns.

Meeting Minutes:

Coordination Updates

a. Emily French was awarded a post-graduate fellowship at U.S. EPA in D.C. Her last day was May 4th.
b. **Action:** Julie will send doodle poll to schedule another call for the public fishery discussion.
c. Aiming for end of July to release draft of 2nd report for 30-day CBP Partnership/public review.
d. Should have beginning sections of report ready for Panel review next week (intro, report structure, panel effort, summary of determination framework, evaluation of oyster practices for BMP consideration and definitions).
e. **Action:** Julie will send out a draft of the second report for review; panel members should review the definitions and consider the BMP decisions/rationales.
f. New shell budget data from Roger Mann.

Application and verification for the N and P assimilation (restoration and public fishery) and enhanced denitrification subchapters, Julie Reichert and Jeff Cornwell

a. Resolve outstanding BMP report items for practice-protocol combinations for approval (public fishery-assimilation, oyster reef restoration-assimilation, oyster reef restoration-enhanced denitrification):

Practice-protocol combinations putting forward for BMP approval (need complete recommendations covering all the BMP Review Protocol items further below):

Nitrogen and phosphorus reduction by assimilation for endorsed public fishery practice:

- **On-bottom public fishery oyster production using hatchery-produced oysters**
  1. Baseline Recommendation
     a. Language from first report: Only include oysters removed moving forward from the time the BMP is implemented, practices are in areas with no oysters or <1 oyster/m^2. Reduction credit should only result from enhancement activity.

  Discussion

  i. Frank: Public fishery areas are not without oysters. Should have recommendations in place to address oysters that already exist in these areas.

     b. Decision needed –
        i. (1) Base crediting on monitoring data of oyster density pre-BMP and pre-harvesting (deduct existing population from overall harvest). Should baseline deduction be applied all at once or distributed evenly throughout the lifespan of the BMP?
        ii. (2) Base crediting on an estimate of survivorship from plantings (put and take; e.g. 1,000,000 spat-on-shell planted, 5% survivorship, only 50,000 oysters can be counted for reduction effectiveness credit the following x years (would need to choose a timeframe; would not need to know oyster population pre-BMP)).

     Discussion

        i. Ken: Who would get credit in MD? Firm believer in option #1. A 5% survivorship rate would possibly under credit the credit receiving jurisdiction. Would behoove both states to know that condition of these sites so they're not overplanting an already robust population.

ii. Lynn: Unsure who would get credit. Part of it depends on the administration in place at the time, unsure how funding would flow; possible that it may go back to the county through DNR.

iii. Julie: Can we do a combination of both options? 5% knowing we're likely to be under crediting, until implementer can prove through time they have better survivorship rate.

iv. Frank: Agrees with option #2 for now. If the survivorship rate needs to be tweaked based on data overtime, then that should be no issue. Implementers should only receive credit for one year for a planting. Would be best to do pre- and post-monitoring to be decisive, but I think moving forward with 5% for now is reasonable.

v. Mark: Leaning toward option #2. Regarding option #1, what would be the most accurate way to understand what an increase might be?

vi. Lynn: It'd be ideal if we could monitor productivity of every area pre- and post-planting, but it's difficult to do. The idea of pre-harvest is we know for a fact that we placed 1 million oysters in a certain area – no one will get credit for oysters coming from a section that wasn't planted, but people can receive credit for 50,000 oysters at 5%. We need to know from where on the bar the oysters are being harvested – this is not typically reported information.

vii. Frank: Not as worried about people getting credit from non-planted oysters. Most bars are planted each year and open for harvest during the entire regular season.

viii. Lisa: For Ken – Would you agree that if a county is willing to close a bar to harvest until large enough, you would be able to come up with the proportion of hatchery vs non-hatchery oysters?

    a. Ken: Yes, but the issues with that is you don't know how much they've been exposed to gear. It'd be beneficial to get bars into rotational practice.

ix. Frank: I'm more comforted by the harvest numbers because survival is so variable.

x. Lisa: A jurisdiction should only get credit for oysters that could potentially have been harvested off a bar. A pre-harvest survey will allocate the proportion of natural/planted oysters, determining what someone could get credit for regardless of what happens during harvest.

xi. Mark: The panel should be mindful of the credits people will receive under these scenarios, relative to the cost of the pre- and post-surveys.

Action: Lynn Fegley will continue this conversation with MD DNR scientists, will report to the Panel about discussions on survivorship rates and timeframe.

2. Qualifying Conditions/Temporal Performance
    a. Language from first report: Only include oysters removed moving forward from the time the BMP is approved for credit in the TMDL; Oysters had to have been grown from initial sizes < 2 inches shell height; Oysters have to be alive when removed for credit to count.
    b. Decision needed –

i. Should we include that the credit is only applicable after x years from planting?

Discussion

i. Julie: Is 3 years post planting okay? Does the panel prefer 4 years?

3. Useful life of BMP
   a. Language from first report: Oysters remain useful until they die or are removed from the water.
   b. Decision needed –
      i. Should this read "remains useful as long as planting activity occurs x years (need to pick a timeframe; 3 years?) before harvesting?"
4. Cumulative or annual practice
   a. Language from first report: Annual based on removed live oysters.
   b. Decision needed –
      i. Should this read "annual based on removed live oysters resulting from enhancement activity"?

Discussion

ii. Julie: This would likely be more of an annual basis, I will need discussion with Matt Johnston at CBP for this.

5. Reporting –
   a. Language from first report: Single Grow-out and Multiple Grow-out Location; Default and site-specific credit.
   b. Decision needed –
      i. Does it make sense to include a site-specific method to determine the biomass estimate for this practice given that it can occur in productive oyster areas? Samples may include natural and hatchery-produced oysters.
      ii. Does it make sense to keep the multiple grow-out recommendations? Spat-on-shell is typically planted with this practice, which means oysters are less than 2 inches; Lynn is pretty sure oysters are not moved.
6. Miscellaneous
   a. Queen Anne's County plants triploid oysters on public fishing grounds.
   b. Decision needed –
      i. Should only default diploid oysters apply to this practice is baseline shows existing oysters in areas?
      ii. Should triploids in this practice even be considered a BMP?

Nitrogen and phosphorus reduction by assimilation for endorsed oyster restoration practices

- **Oyster reef restoration using hatchery-produced oysters**
- **Oyster reef restoration using substrate addition**

1. Partial reduction effectiveness crediting approach
   i. Biomass Scenarios (see Excel spreadsheet)

Discussion

i. Julie: Panel doesn't necessarily need to determine timing of biomass increase monitoring (2 years on spreadsheet).

2. Baseline Recommendation
   i. Scenario 1 – Oyster restoration occurred between 2009 and when BMP is approved.
      i. Decision needed –
         1. Can Panel's regression equations be used to convert shell height to biomass if there are datasets on oyster density/shell height from BMP location?

2. If existing data can't be found from BMP location, can a reference location that mimics the BMP location be used?

ii. Scenario 2 – New restoration work after approval of BMP.

3. Qualifying Conditions/Temporal Performance
   i. Suggestions: Credit only applicable for live oysters >/= 2 inches; First crediting time-period to occur a minimum of 2 years after enhancement activity; Credit only given if estimated biomass from regression is more than the baseline biomass.
4. Useful life of BMP
   i. Decision needed –
      i. Suggest we set it at 6 years after each enhancement activity so the practice has a timeframe, but possible to expand its life past 6 years with additional plantings.
      ii. Useful as long as biomass is appreciating. Partial credit will be given based on a schedule that buffers against over-crediting.

   Discussion
      i. Lisa: I assumed only crediting after monitoring happens.
         a. Julie: This is true.
      ii. Julie: The panel must give CBP a qualifying condition, may not need 6-year timeframe.
      iii. Jeff: Implementers would need enhanced monitoring to keep crediting happening.
      iv. Julie: Additional plantings is adaptive management – if implementers are not getting biomass they want, they plant more oysters.
      v. Julie: Leave the time frame open, but determine the minimum of lag time. Should we only credit oysters greater than 2 inches? Monitor at a minimum of every 2 years? If implementers want to monitor every year, leave them that option?
      vi. Lisa: Unsure if I fully understand the data supporting only counting oysters greater than 2 inches.
      vii. Julie: 2 inches is past high chance of mortality. We want to make sure were crediting oysters that'll be there the next year.

Action: Julie, Lisa, and Jeff will discuss baseline scenarios, minimum timeframes for crediting and communicate with Panel via email.

5. Cumulative or Annual Practice
   a. Decision needed –
      i. This is a cumulative practice with a recommended partial crediting scheme throughout the lifespan of the BMP.
6. Reporting
   a. There are miscellaneous oyster growing programs established in VA and MD.

   Discussion
      i. Ken: Oyster gardening yields small numbers. It'd make sense to capture those numbers if they add to a reef.
      ii. Julie: Any multiple grow out locations are removed from this protocol. Not possible to divide up credit for multiple docks, only consider if they decide to build a reef.
      iii. Julie: Regarding the site-specific method to determine biomass, are we using the table of size classes to pre-determine estimates of removal or having implementers plug them into our regression equation and take the average?

iv. Jeff: Either way is sufficient. Giving people option of how they want to approach this is fine, too.

7. Miscellaneous
   a. Stakeholder wants panel to consider role of substrate in oyster reef restoration practices for sequestration credit.
      Discussion
      i. Julie: How credit is divided amongst those involved is up to policy and implementation, not for the panel to decide. If an implementer wants to make an arrangement with a substrate provide, that is up to them to work out.
      ii. Julie: The Panel is putting forward a framework that dead shell/substrate could be considered in the future with more information based on dissolution.

Nitrogen reduction by enhanced denitrification for endorsed oyster restoration practices

- **Oyster reef restoration using hatchery-produced oysters**
- **Oyster reef restoration using substrate addition**

1. Reduction Effectiveness Crediting Approach –
   Discussion
   i. Jeff: If biomass increases, we don't feel we have sufficient information to give credit to that. Shape of increasing curve unclear. As biomass decreases, credit decreases. Once biomass is below 50% of original, no credit given.
   ii. Lisa: Not discounting anything on the front end.
   iii. Jeff: 100% of increase over background shouldn't be entirely credited because biodeposits can land elsewhere. We can simplify the fate of the particles. Any assessment we do misses a substantial amount of nutrient processing and denitrification.
   iv. Jeff: A whole ecosystem method is preferable. If people want to take a lower number and do cores or oysters, that's fine, but we're not doing any multiplier to bring them up to the entire system.
   v. Lisa: How can you measure denitrification from oysters without disturbing the entire system?
   vi. Jeff: Most denitrification moves with clumps, it's the entire community, not just the oysters.
   vii. Julie: The Panel can explain methods with which people can take their measurements, explain the pros and cons of each method in the report.

   Action: Jeff and Lisa will speak to the technical details of baseline denitrification rate within the next few weeks.

2. Baseline recommendation
   a. Two Scenarios –
      i. (1) Oyster restoration occurred between 2009 and when BMP is approved. Must use an existing dataset approved by CBP to establish baseline for denitrification rate which would be subtracted from first crediting time period.
      ii. (2) New restoration work after approval of BMP. Establish a pre-restoration baseline survey to include oyster densities, shell heights, and measured denitrification rate.

Discussion

  i. Julie: As long as an implementer can prove their baseline, we are crediting restoration that occurred between 2009 and set up of BMP. Baseline must be based off of biomass density/rate, not denitrification rate.

3. Qualifying Conditions/Temporal Performance
4. Useful Life of BMP
   a. Decision needed –
      i. Suggest we set it at 6 years after each enhancement activity, can be expanded past 6 years if there are additional plantings.
      ii. Useful as long as credit is above baseline.
5. Cumulative or Annual Practice
   a. Decision needed –
      i. This practice can be credited continuously on an annual basis 2 years post first enhancement activity throughout the lifespan of BMP as long as denitrification rates are above the baseline.
6. Reporting
   a. Decision needed -

      Discussion

      i. Julie: Could people develop their own site-specific equation? How many options do we want to present in the report for these protocols?

Action: Panel should read through all PowerPoint slides, reach out via email with comments and concerns.

Outstanding CBP BMP Report Protocol Items (still need to finalize decisions)

1. Description of pre-BMP and post-BMP circumstances and individual practice baselines
2. Conditions under which the BMP works/not works (qualifying conditions)
3. Temporal performance of BMP including lag times between establishment and fully-functional
4. Useful life of the BMP
5. Cumulative or annual practice
6. Description of how BMP will be tracked and reported

Oyster BMP Expert Panel Meeting, June 8, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	Yes
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes
Guest	**Affiliation**	**Present?**
Frank Marenghi	Maryland Department of Natural Resources (MD DNR)	Yes
	EPA R3 ORISE Fellow	Yes

*Matt Parker provided written comments afterwards

Action Items:

1. **Action:** Lynn Fegley is going to meet with folks at DNR to get more data/information to help inform the percent to use (5% has been suggested so far) and the timeframe (minimum of 3 years have been suggested). Also, will discuss with folks potential verification measures. Will report back to the Panel during meeting in next couple of weeks.

2. **Action:** Julie Reichert will schedule a call with Lisa and Jeff to go through baseline suggestions (e.g., use of a reference location for post-TMDL/pre-BMP restoration projects) and whether there should be a

minimum time frame after the enhancement activity before the first crediting year (2 years have been suggested). Obtain Panel consensus decision through e-mail.

Meeting Minutes:

Practice-Protocol Combinations for BMP Consideration

1) Nitrogen and phosphorus reduction by tissue assimilation for endorsed public fishery practice:

- **On-bottom public fishery oyster production using hatchery-produced oysters**
- Discussion:
  - The Panel has not reached consensus yet. Discussions leaned towards the reduction credit being based on an estimate of survivorship from spat planted (e.g., 1,000,000 spat-on-shell planted, 5% survivorship, only 50,000 oysters can be counted for reduction effectiveness credit the following x years). Also, folks were considering a verification measure that evaluates the pre-harvest population survey after planting to ensure that the oysters are there for credit (oysters harvested from the bar may not be from the location where the oysters were planted; aiming for harvest to reflect what could have realistically survived from the planting even if not the actual oysters) and post-harvest surveys to help refine the % survivorship of spat planted. Jeff recommended a verification measure that x% of the bar should be assessed for ground-truthing (we could use similar language that an expert helps with the sampling design). Ken emphasized that verification measures should allow for assessing the success of the practice (oysters are surviving). Some panelists felt that verification would be easier if after planting the area is closed to harvest and opened only after the pre-harvest survey is done (could tell the hatchery-produced oysters from the natural oysters; similar to management reserve approach).

Action: Lynn Fegley is going to meet with folks at DNR to get more data/information to help inform the percent to use (5% has been suggested so far) and the timeframe (minimum of 3 years have been suggested). Also, will discuss with folks potential verification measures. Will report back to the Panel during meeting in next couple of weeks.

Discussion with Frank Marenghi, 6/7/18 and decisions during 6/8/18 Panel Meeting:

Frank and Lynn discussed this BMP more. Both agreed that an approach that requires the least amount of surveys, but still adequately addresses crediting the enhancement, would be better suited in implementing this BMP.

Frank and Julie Reichert discussed further and sorted out an approach that may work requiring only one initial survey. This approach was furthered discussed by the Panel during the 6/8/17 meeting and has been edited to accommodate the below decisions/feedback:

Decisions:

- The Panel agrees to a minimum timeframe of at least one year before opening bar to harvest.
- Credit must be paired with prior planting.
- Baseline is based on the density of oysters that are ≥ 2 inches.

Discussion:

- Lisa: Option 2 should be clearer in its language that credit goes to the number of harvested oysters minus 5% of the initial ≥ 2 inch oyster density.

- Julie: Spat must be sourced from hatcheries for credit to be given (transfer of wild spat does not qualify).
- Frank: 5% survival rate comes from a Ken Paynter technical report. Lisa: Mention that all data are from Maryland.
    - Matt Parker—Mike Congrove's Thesis from VIMS has Virginia spat on shell aquaculture estimate. For lack of other data, this could be substituted.

Edited Approach:

Recommendations are based on harvesting oysters that are ≥ 3 inches; Julie Nguyen—there are estimates for 2 inch oysters—shouldn't it be up to the implementing programs and regs to set what size oysters are harvested at?

- **BMP location:** Designate area on bar as a BMP area (report latitude and longitude).
- **BMP unit:** lbs of N and P from harvested oyster tissue from BMP location.
- **Baseline:**
  Two BMP location scenarios:
    1. BMP designated area is located where hatchery-produced oyster plantings have occurred.
    2. BMP designated area is located where there has been no hatchery-produced oyster plantings.

  Do an initial survey of the designated area to determine pre-BMP oyster density of oysters that are ≥ 50 mm (≥ 2 inches) (oyster size is based on shell height) per area unit (typically, surveys are in square meters; sampling design should reflect the BMP area). Julie Nguyen—Can past harvest data be used for initial survey?

  Two possible outcomes:

    1. The total of ≥ 50 mm (≥ 2 inches) oysters from the initial survey of the designated BMP area is zero or ≤ 1 oyster/m^2 (4057 oysters/acre). Indicates a non-productive/poor oyster recruitment area. The Panel recommends using the same requirements as the approved, "on bottom private oyster aquaculture using hatchery-produced oysters" BMP. All oysters harvested from this area would be eligible for reduction effectiveness crediting. It is expected that without the enhancement activity there wouldn't be harvest from this area.

  The total of ≥ 50 mm (≥ 2 inches) oysters from the initial survey of the designated BMP area is greater than 1 oyster/m^2 (4057 oysters/acre). Cap the number of harvested oysters ≥ 3 inches that would be eligible for reduction effectiveness credit at 5% of the number of spat planted (e.g., 10 million oyster spat planted per acre would equate to 500,000 harvested oysters ≥ 3 inches per acre eligible for credit). The spat survival of 5% is from [cite reference(s)—unclear where this number comes from; Matt Parker—there is actually quite a range in Paynter's reports]; the reports up to 2013 season are available for download on his lab website; personally I feel 5% is a touch too low]. To receive reduction effectiveness credit after the first planting, the number of harvested oysters equal to or greater than 3 inches from the BMP area must be more than the initial survey density of ≥ 50 mm (≥ 2 inches) per unit area. Reduction effectiveness credit after first planting would be on the increase in oyster density from the initial survey baseline. Any subsequent planting, credit would at the 5% spat survival rate. To adjust the 5% survival rate, optional pre-harvest and post-harvest surveys could be done to determine how many planted oysters are surviving to harvestable size.

- **Qualifying Conditions:**

1. Enhancement activity is the use of hatchery-produced spat-on-shell planted in the designated BMP area. Use of wild spat would not qualify. Reporting would include documenting how many spat are planted and dates planted.
2. Reduction effectiveness credit must be paired with a prior planting.
3. Reduction effectiveness credit becomes available after a minimum of 1 year of the area being closed to harvest and would be applicable during the year the area is open to harvest. [Matt Parker—Why is there a cap? There is no cap for aquaculture]
4. Only includes harvested oysters equal to or greater than ?-inch shell height moving forward from the time the BMP is approved/implemented for reduction effectiveness credit in the TMDL. In non-productive (zero oysters per square meter) or poor productive (≤ 1 oyster/m^2 or 4057 oysters/acre) areas, all harvested oysters equal to or greater than 3-inch shell height would be eligible for reduction effectiveness credit. In productive (> 1 oyster/m^2 or 4057 oysters/acre) areas, the baseline oyster density would be subtracted from the harvest of the first crediting period and capped at 5% of the total spat planted unless a site-specific spat survival rate is determined with pre-harvest and post-harvest surveys.
5. Oysters had to have been grown from initial sizes < 2.0 inches shell height.
6. Oysters have to be alive when removed to count toward the reduction effectiveness.

- **Temporal Performance of BMP:** In order to increase confidence that the harvest includes oysters from the enhancement activity, the designated BMP area should be closed to harvest at least a minimum of 1 year after planting the oyster spat [Matt Parker—for spat on shell oysters, you are looking at more like 36 months for oysters to reach "market" size. 18-24 months are for oysters grown in gear off the bottom]. The total closed timeframe beyond 1 year would be decided by the implementing programs based on type of oyster planted (diploid or triploid), environmental condition of location, or to meet any regulatory requirements. Past harvest information from the area or nearby similar area could be used to help determine the timeframe needed for oysters to reach the required harvestable size. The implementing program would decide on the minimum harvest size (must meet State's minimum size regulations). As long as the oyster shell height is equal to or greater than 3 inches, the harvested oysters could receive reduction effectiveness credit based on the corresponding on bottom estimates from the first report and qualifying conditions for this BMP.
- **Useful Life of BMP:** Planting equates to one available crediting period (credit paired with prior planting). [Matt Parker—why a cap?]
- **Reporting:** Include latitude and longitude of designated area, number of spat planted, BMP estimate (based on oyster size and ploidy type), planting year, initial survey density of oysters equal or greater than 2 inches, closure timeframe, year of harvest, number of oysters harvested.
- **Verification Guideline:** Include where spat came from to verify that hatchery-produced spat were used.
- **Example:** Credit would be applicable on the year the area is open for harvest.
    1. For outcome 1: All harvested oysters from the area would be eligible for reduction effectiveness credit.
    2. For outcome 2: Check whether harvest count is greater than the initial density of oysters equal to or greater than 2 inches. If greater, then credit harvest up to 5% of spat planted. Harvest from subsequent plantings within same designated timeframe, up to 5% of spat planted would be eligible for reduction effectiveness credit

2) Nitrogen and phosphorus reduction by assimilation for endorsed oyster restoration practices

- **Oyster reef restoration using hatchery-produced oysters**

- **Oyster reef restoration using substrate addition**

The Panel reached consensus on using a partial crediting approach for the standing stock of whole oyster biomass (tissue and shell) on the restored reef. Credit would only occur if monitoring demonstrates that there is appreciation of biomass over baseline biomass. For any given crediting year, the BMP implementer can receive 50% of the appreciated biomass and the other 50% in the following crediting year as long as the biomass remained the same or increased. If there is a depreciation in biomass, no credit is given.

In an e-mail after the Panel meeting, Lisa suggests that the Panel does not put a size restriction for the qualifying conditions (2 inches was suggested), but instead, in the application guidelines, include language that it may be more time/cost effective to limit survey data to larger oysters (i.e. leave it open to the surveyor to determine the size down to which they believe it to be worth measuring oysters). Lisa feels there is a safety net already built into the numbers because we are only crediting 50% for live oysters above baseline which is roughly equal to shell which will continue to sequester long after the oyster dies.

Panelists on the call were in agreement that programs like Oyster Gardening in VA and Marylander's Grow Oysters in MD should be credited as part of the reef restoration practice at the reef's location.

Action: Julie Reichert will schedule a call with Lisa and Jeff to go through baseline suggestions (e.g., use of a reference location for post-TMDL/pre-BMP restoration projects) and whether there should be a minimum timeframe after the enhancement activity before the first crediting year (2 years have been suggested). Obtain Panel consensus decision through e-mail.

Need to schedule follow-up discussion

3) Nitrogen reduction by enhanced denitrification for endorsed oyster restoration practices

- **Oyster reef restoration using hatchery-produced oysters**
- **Oyster reef restoration using substrate addition**

Panelists at the meeting were in agreement concerning the following reduction effectiveness recommendation:

The Panel is in agreement that this BMP will need site-specific measurements of denitrification rates at known biomass. To determine the reduction effectiveness credit, the implementer will have to establish a site-specific denitrification rate at a known biomass. To receive credit, verification of biomass is needed. The biomass can be determined from either oyster densities/shell heights using the first report's diploid shell height to tissue dry weight regression equation or actual biomass measurements. If the biomass is at the level that the denitrification rate was determined, then full credit is applicable based on the denitrification rate. If biomass increases, then the enhanced denitrification credit would be at the rate that was measured at the known biomass unless a new site-specific denitrification rate is established at the increased biomass level. If biomass decreases, then the credit would be reduced linearly as long as 50% of the known biomass is present. If less than 50% of known biomass is present, then no credit would be given unless a new denitrification rate is established at the lower biomass.

Action: Lisa and Jeff are going to go over some data to see what can be recommended in determining the baseline denitrification rate (e.g., use of reference sites for existing restoration projects post TMDL, but pre-BMP approval; denitrification assessment pre-BMP implementation for new restoration projects). Also, need to discuss timeframes for when the BMP is considered fully functional and the useful lifespan of the BMP.

Summary of phone conversation with Lisa and Jeff on 6/5/18:

Components needed to determine the site-specific enhanced denitrification estimate:

- Must have a measured denitrification rate at a known biomass for the site seeking BMP credit.
- Must have a measured control at a reference site that is representative of the environmental (temp, salinity, and dissolve oxygen) conditions and oyster biomass characteristics as the BMP restoration site before the enhancement activity (planting spat-on-shell or substrate).
- Consult with an expert to determine the sampling design and number of sampling points that will adequately capture the size of the BMP restoration site (this could influence the cost to implement).
- At a minimum, sample 3 times during the year that includes spring, summer, and fall time periods when active oyster filtration occurs. Can include winter if sampling is done. If not, then winter is set as zero for those months (Lisa and Jeff are planning to use a weighted average approach).
    - Discussion
        - Lisa: An average temperature across all months doesn't make sense, temperatures rise and fall rapidly.
        - Jeff: Implementers can collect winter month data if they want, but it will likely be cost inefficient for credits they'd receive.
- If light reaches the bottom then both dark and light incubations are needed to apply the denitrification rate for the full day. If there are only dark measurements then only dark hours in the year can receive credit.
    - Discussion
        - Jeff: If you have 14 hours of light measurements, calculate the light rate x 14 and the dark rate xv10. It'll be sufficient to get a 24-hour rate and extrapolate it.
        - Lisa: We generally see similar rates in dark/light on restored reefs. We haven't worked where there are loads of algae in most cases.
        - Jeff: It could be useful to know how much light a bar is receiving – possibly record using Secchi disks? Will pull literature together for guidance on this.
- QA/QC for the denitrification rate by measuring other fluxes (ammonium, nitrate, oxygen, and dissolved inorganic carbon; Jeff is writing details on this).
    - This topic will be discussed at the June 28th meeting.

Baseline for Denitrification Rate: Include in sampling design a reference site that is representative of the environmental (temp, salinity, and dissolve oxygen) conditions and oyster biomass characteristics as the BMP restoration site before the enhancement activity (planting spat-on-shell or substrate).

- **Qualifying Conditions:**
    1. Must have at least one planting of hatchery-produced oysters (amount of oysters to plant is dependent on area of BMP and sampling design to achieve desired oyster dry tissue biomass for the site-specific enhanced denitrification rate).
    2. Measured reference denitrification rate for baseline. Must be representative of the environmental (temp, salinity, and dissolve oxygen) conditions and oyster biomass characteristics as the BMP restoration site before the enhancement activity (planting spat-on-shell or substrate).
    3. Measured site-specific enhanced denitrification rate at known oyster dry tissue biomass.
    4. Credit only applicable if the site-specific denitrification rate is more than the reference site (baseline) denitrification rate.

5. Credit only applicable when biomass is determined during that crediting year. Biomass is a proxy to verify the enhanced denitrification rate.
6. If the biomass is at the level that the denitrification rate was determined, then full credit is applicable based on the denitrification rate. If biomass increases, then the enhanced denitrification credit would be at the rate that was measured at the known biomass unless a new site-specific denitrification rate is established at the increased biomass level. If biomass decreases, then the credit would be reduced linearly as long as 50% of the known biomass is present. If less than 50% of known biomass is present, then no credit would be given unless a new denitrification rate is established at the lower biomass.

- **Temporal Performance BMP:** The enhanced denitrification rate can be determined any time after planting, but it is recommended that an expert is consulted to determine the timeframe where oyster tissue biomass will be at a level that it would be beneficial to measure the denitrification rate. Higher biomass would likely result in higher denitrification rates. Typically, it would be advantageous to wait a year or more after planting before making denitrification measurements.
- **Useful life of the BMP:** The denitrification rate is good as long as the biomass is was measured at is present.
- **Type of Practice:** This practice can be credited annually as long as biomass is measured during the crediting year.
- **Reporting:** Lat and long of restoration site, lat and long of reference site, number of acres, oyster tissue biomass, mean reference site denitrification rate (minimum, dark incubation; optional light incubation), mean hourly enhanced denitrification rate (minimum, dark incubation; optional light incubation), number of dark and light hours (if applicable); mean annual enhanced denitrification rate in lbs/acre/year.

Rough Example using Data from Kellogg et al. 2013 from Little Choptank (will provide more complete example in report using hypothetical data to cover each scenario):

- **Location:** Little Choptank
- **Sampling Design:** Experimental plot was 4 m by 4 m (16 m2). Prior to the initial deployment of sampling trays (described below), each 4 m × 4 m experimental plot was subdivided into 4 equal subplots. Within each subplot, 5 potential deployment sites were identified and the sampling sequence was randomly assigned (Fig. 3 in paper). 4 samples were collected from each plot during each sampling period. This sampling design may not be adequate to extrapolate out to 1 acre, so caution should be exercised when discussing the N reduction from this example.
- **Season:** Included 4 samples at control and restoration sites during each seasonal sampling period. Average hourly fluxes for the year were estimated by applying the average of the 4 measured rates to the 8-month period from April through November, assigned zero values to the winter months and divided by 12 [this approach may be changed to a weighted average approach]. This method was intentionally chosen to generate conservative estimates.
- **Oyster Tissue Biomass:** Reference = 0 oysters m-2; restoration site not reported, but had an average of 131 oysters m-2 with average shell height of 4.5 inches. Using the Panel's estimate for 4.5 inches, tissue biomass would be around 353 g m-2 (2.7 g/oyster x 131 oysters).
- **Mean Reference Site Denitrification Rate:** 0.04 mmol N m-2 hr-1
- **Mean Restoration Site Denitrification Rate:** 0.5 mmol N m-2 hr-1
- **Hourly Enhanced Denitrification Rate:** 0.46 mmol N m-2 hr-1 (restoration site minus control site)
- **Number of Dark Hours in 2010:** 4,013 (study only did incubations in the dark and was in the euphotic zone, so can only credit dark hours)

Annual Enhanced Denitrification Rate for crediting: 231 lbs N per acre per year (as long as the oyster tissue biomass remains at or is above 353 g m-2). Multiplied the average hourly enhanced denitrification rate by the number of dark hours in the sampling year.

- This example will be examined further before the June 28th meeting.

Outstanding Questions:

- What if a denitrification experiment has been done recently (within 5 years?) that have all the BMP conditions met? Can this be used or would the experiment have to be repeated?
- What if the restoration site had existing oysters? Does oyster biomass have to be above this baseline value to qualify for credit?
- When determining the biomass to verify the enhanced denitrification rate, when in the year do you make the assessment (one time; which season; all 3 seasons)?

Oyster BMP Expert Panel Meeting, June 28, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

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	Remotely
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remotely
Andy Lacatell	The Nature Conservancy (TNC)	No; follow-up call on 7/17/18
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	No; follow-up call on 7/16/18
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Remotely
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remotely
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remotely
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remotely
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	No
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	In Person
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	No
Megan Munkacsy	Oyster Recovery Partnership	Remotely

Action Items:

1. **Action:** Julie Reichert—Follow-up with panelists who couldn't attend on decisions made during meeting; discuss new public fishery recommendations with Frank Marenghi for input.
2. **Action:** Jeff—Fill gaps in denitrification chapter (use reorganized version from Julie Reichert).
3. **Action:** Jeff and Lisa—Discuss seasonal time frame for denitrification rate recommendation.
4. **Action:** Jeff and Lisa—Sort out guidelines for when light denitrification rates are needed.
5. **Action:** Look into whether guidelines exist on how much spat to plant in an area to get the most out of the practice.

Meeting Minutes:

1. **Key Decisions:**
    a. **Public Fishery-Assimilation:**
        i. Panelists decided that a pre-BMP assessment wouldn't be needed if the first eligible crediting year in the designated area is a minimum of 3 years from the first planting. Rationale included that by 3 years, you'll be harvesting oysters influenced by the enhancement activity.
        ii. Panelists felt if the timeframe above is implemented then you would not have to have a cap on harvested oysters based on spat survivorship.
            1. Follow-up call with Chris Moore—concerned that regulators not familiar with oysters would interpret no cap equaling a scenario where 100% of the spat planted can survive. Even though oyster experts know that there is always mortality, which would be reflected through harvest, we should include text that makes it clear that there is mortality.
    b. **Restoration-Enhanced Denitrification**
        i. Panelists agreed to base recommendations on seasonal denitrification rates that could be used for that portion of the year instead of requiring 3 seasons to develop an annual rate and doing a weighted average.
            1. Need to sort out the definition of the seasonal timeframes (set months for spring, summer, fall, and winter, ± 1 month, etc.)
            2. Julie Rose expressed concern in phone call afterwards about the potential unintended consequence that someone could set up a sampling design that occurs in a week that has August and September dates and try to use one estimate to get credit for July, August, September, and October. She suggested we make it clear that a seasonal estimate can only be extrapolated out for a total of 3 months and no more.
            3. Chris Moore—asked whether the seasonal time frames would differ for different areas of the Bay (upper, mid, lower) because of differences in temperature.
        ii. Panelists agreed that light rates are needed for areas where the light reaches the bottom; need to sort out guidelines for when light denitrification rates are needed (not all areas have light hitting the bottom to cause concern over denitrification rate).
        iii. Existing data can be used to determine site-specific, seasonal denitrification rates as long as biomass was known/can be determined and rest of required components are met.

2. **Coordination Updates**
    a. CBF hosting Mussel Restoration Discussion and Luncheon on July 24, 2018 (exploring the possibility of a freshwater mussel BMP).
        i. Panelists planning to attend: Julie Reichert-Nguyen (presenting), Jeff Cornwell, Chris Moore, and Julie Rose

3. **Address remaining questions on endorsed public fishery practice**
    a. **Baseline:** For oyster aquaculture BMP, the baseline definition allows for planted oysters before approval of the BMP to be eligible for crediting. How should areas where plantings have occurred this year be handled with the endorsed public fishery BMP?

i. Aquaculture baseline definition: Only includes harvested oysters moving forward from the time the BMP is approved/implemented for reduction effectiveness credit in the TMDL.
ii. For public fishery practice, Panel recommended an initial survey to determine the pre-BMP baseline.
iii. Discussion:
    i. Panelists agreed that there must be a prior planting of hatchery-produced oysters in the BMP-designated area to allow harvest to be eligible for crediting.
    ii. Matt suggested instead of a pre-assessment survey, you just make a rule that the first eligible harvest for crediting would have to be 3 years after the first planting and any subsequent planting within 3 year timeframes would keep the BMP active (harvest each subsequent year could qualify for reduction credit).
        1. The Panel agreed to this approach stating that this time frame would represent harvest influenced by the enhancement activity.

b. **Qualifying Condition:** Based on my notes, folks were ok to only do an initial survey of oysters ≥ 2 inches because they would be at harvestable sizes a year from the first planting. Does that mean the reduction effectiveness is based on the harvested oysters that are ≥ 3-inch shell height.
  i. **Concern:** Since it's up to the implementing programs to establish harvestable sizes based on regulations, I recommend not setting a specific size for the baseline assessment. Instead the qualifying condition could be more generic, such as 1 inch smaller than harvestable size.
      i. Matt Parker: Ken Paynter has some size frequency distribution data in his annual sanctuary reports that might be helpful for this.
  ii. **Concern:** I thought it takes around 18-24 months for oysters to reach 3 inches. Is a year closure too short?
      i. Matt Parker: On bottom wild and on bottom spat on shell would be closer to 36 months. 18-24 months are for oysters grown off bottom in cages.
  iii. Discussion:
      i. Panel agreed that it would be up to the implementing programs and regs to determine harvestable sizes. For reduction effectiveness purposes, there are estimates for oysters ≥ 2 inches.

c. **5% spat survivorship value:** I could not find a reference where this is explicitly stated.
  i. NOAA 2016 Oyster Reef Monitoring Report suggests an average of 3.09% with a range of 1.75% to 5.13%. Is there another source that would support 5%.
      i. Matt Parker: Paynter estimates 90% of spat die in the first year and 15% every year thereafter. That works out to about 7% survival after 3 years. Mutt Merrit says 70% of spat on shell die in the first year and 10% every year thereafter. That works out to around 24% after 3 years. Mike Congrove's thesis says you could expect around 18% (I'd have to double check the number) survival of spat on shell oysters.
  ii. **Food for thought:** We may want to re-think having a cap based on a percentage of survivorship. Since a baseline assessment is needed to implement this BMP, it essentially defines how many oysters are there before the BMP is implemented. It would seem subtracting this baseline from the harvest would be adequate. Are we being too restrictive (see example)?

i. Discussion:

1. Matt Parker: I would base this on reported harvest, just like for aquaculture. There will be good years and bad years, sometimes you will have better survival.
2. Panelists discussed a qualifying condition where the first eligible harvest for credit would be 3 years after the first planting of hatchery-produced oysters; Matt stressed that the Panel should not require the area be closed to harvest since that's up to the implementing programs. However, the Panel can state a timeframe for when harvest would be eligible for reduction credit; Panel agreed on 3 years and felt that if this eligibility timeframe is required then you wouldn't need a pre-assessment survey.
3. Panelist emphasized that the qualifying condition needs to explicitly state that only harvest from the designated BMP area is eligible for credit.

d. **Credit Cap:** Regarding Panel recommendation that planting equates to one available crediting period.

i. Should this be the case with non/poor productive area that resembles the on bottom aquaculture BMP?

ii. What if the cap isn't met? Can it be open for another year to receive the rest of the credit without doing another planting?

iii. Discussion:

i. Matt Parker: Why is there a credit cap? There is no cap for aquaculture? Harvest gear is inefficient. There will be oysters from a planting period that are missed and harvested with the next "group"

ii. Lisa: The cap was proposed since some areas may be productive areas.

iii. Panelists agreed cap wouldn't be needed if first eligible crediting period of harvest is at least 3 years from the first planting.

iv. Panelists agreed that reporting should include the number of spat planted in the area.

1. Panelist asked if there are guidelines for how much spat to plant; will look into for next meeting.

4. Go over enhanced denitrification components for determining the site-specific estimate

a. Using existing data: What if a denitrification experiment has been done recently that have all the BMP conditions met? Can this be used or would the experiment have to be repeated?

i. Jeff recommends that existing data can be used if it includes site-specific components and appropriate scale to extrapolate.

1. Panel agrees; guidelines should include similar salinity, depth, oyster biomass, and reasonable area to extrapolate (within tributary/embayment).

b. When determining the biomass to verify the enhanced denitrification rate, when in the year do you make the assessment (one time; which season; all 3 seasons)?

i. Jeff recommends a verification guideline that at least one measurement is done; the Panel agreed it could be up to the implementing programs when to make this measurement.

c. **Food for thought:** There is concern that the minimum requirement of 3 seasons to establish a site-specific rate would be too cumbersome for implementing programs to do right away. Instead of an annual rate, could seasonal rates be used and only the hours in that season be eligible for credit? This would allow flexibility to the implementing programs in establishing site specific estimates.

i. For instance, if an implementer can only budget one season to measure denitrification rates (light, dark or both), then they would establish a rate in that season and only the hours (light, dark, or both, depending on rates that were established) within that seasonal time frame would be eligible for credit during that year.
ii. If a seasonal rate approach is used then a weighted average would not be needed since they are only getting credit for the hours in the seasons they have rates for.
iii. **Discussion:**
    1. Panel agreed to change recommendations to allow seasonal rates to be used to receive reduction credit only during that portion of the year.
    2. Panelists suggested two approaches to define seasons:
        a. Fixed months based on temperature profiles
            i. Chris asked if this would be the same across the Bay (upper, middle, lower) seeing how temps may be different.
        b. ± 1 month from sampling month
            i. Julie Rose expressed a potential unintended consequence of implementers using one seasonal rate across multiple seasons if they sample in a week where two months fall into. Should be clear that one seasonal rate applies to only 3 months.
iv. Other:
    1. Need to provide guidelines on when light rate measurements are needed; Secchi? Depth of site? Light meter? Etc.?
    2. September has shown the highest denitrification rates in some studies.
    3. Harris Creek and Lynnhaven may have existing data that can be used to determine site-specific, seasonal denitrification rates.

Oyster BMP Expert Panel Meeting, August 16, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Remote
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remote
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remote
Chris Moore	Chesapeake Bay Foundation (CBF)	Remote
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remote
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
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	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Remote
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	In Person
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	In Person
Guest	**Affiliation**	**Present?**
Frank Marenghi	Maryland Department of Natural Resources	Remote

Action Items:

1. **Action:** Julie Rose and Julie Nguyen - Julie N. will send Julie Rose data spreadsheet for the tissue-restoration quantile regression equations. Need to run seasonal and habitat grouping analysis to determine if a lower quantile is needed.
2. **Action:** Jeff C. and Lisa - Refine denitrification rate QA/QC
3. **Action:** Jeff C., Lisa, and Julie Nguyen - Work on revising the appropriate methods to measure reef denitrification (e.g., core measurements)

4. **Action:** Cornwell will load enhanced denitrification with restoration practices references onto the Google Drive folder.

Meeting Minutes:

Coordination Updates, Julie Reichert-Nguyen

- Jeff Sweeney is replacing Matt Johnston as Panel's Watershed Technical Workgroup Rep.
    - Matt took another role, Jeff will help write technical appendices; explain how to apply our recommendations to the TMDL model.
- Julie Reichert did some overhaul on draft report; will be close to 300 pages. She created a separate informational recommendation section for recommendations we are not seeking approval for; will be in the appendix. Each of the core recommendations will have their own clear, separate chapters to make approval easier.

Public Fishery-Tissue Assimilation: Go over recommendations from smaller Panel group

- **Group: Frank, Matt, Chris, and Julie Reichert; Met on 7/27/18**
    - Agreed that a pre-BMP assessment wouldn't be needed if the first eligible crediting year in the designated area is a minimum of 3 years from the first planting. Rationale included that by 3 years, you'll be harvesting oysters influenced by the enhancement activity. These areas have been heavily harvested and planted already so establishing true baseline populations is not practicable.
        - **New baseline guideline:** Where records of date and amount of spat planted exist at locations pre-BMP approval, harvested oysters can be credited 3 years after that date. E.g., harvested oysters planted during May-June this year (2018) can be eligible for reduction credit in 2021.
        - **New qualifying condition:** Where implementing programs have oyster growth data that demonstrates faster growth than 3 years at the BMP location, then the minimum 3-year timeframe can be adjusted to reflect the mean of this data.

    Discussion:

        - No dissenting Panel members.

    - **Old:** Panelists felt if the timeframe above is implemented then you would not have to have a cap on harvested oysters based on spat survivorship.
        - **Follow-up call with Chris Moore**: Concerned that regulators not familiar with oysters would interpret no cap equaling a scenario where 100% of the spat planted can survive. Even though oyster experts know that there is always mortality, which would be reflected through harvest, we should include a qualifying condition that makes it clear that there is mortality.
        - **New qualifying condition:** Group agreed to a cap of 30% of spat planted for how much harvest is eligible for reduction credit given the uncertainty in the possibility that existing oysters could be harvested since this practice occurs in productive areas. If harvest indicates more than a 30% spat survivorship from what was planted, then optional population surveys can be done to see if the higher survivorship percentage is real. At a minimum a pre-planting survey and pre-harvest survey should be done to establish survivorship at that location for the

next crediting year. If no population surveys are done, then 30% spat survivorship would remain as the cap for how many harvested oysters can receive credit.

Discussion:

- Wolinski: Is this 30% cumulative? Not very clear as written.
  - Moore: If you plant something every year, you can get up to 30% for each planting.
  - Reichert: It is cumulative. It can carry over is not fully met. Will make this clearer in the draft document.

- **Suggestion concerning use of first report tissue estimates:** Only diploid tissue estimates from the first report are used regardless if triploids are grown given the possibility of existing diploid oysters being present. If population survey indicates the absence of existing oysters, then triploid estimates can be used.

Discussion:

- Panel accepts this suggestion.

Restoration-Enhanced Denitrification: Go over recommendations from smaller Panel group

- **Group: Jeff, Lisa, and Julie Reichert-Nguyen; met on 7/30/18 –**
  - **Enhanced Denitrification Rate Determination:** Agreed to base recommendations on site-specific daily denitrification rates with dark and light (if needed) considerations built into the rate. A daily denitrification rate can be extrapolated based on defined seasonal timeframes and the following qualifying conditions and guidelines:
    Seasonal Timeframes
    - Spring: Mar, Apr, May (92 days total)
    - Summer: Jun, Jul, Aug (92 days total)
    - Fall: Sep, Oct, Nov (91 days total)
    - Winter: Dec, Jan, Feb (90 days total)

    Qualifying Conditions
    - The site-specific rate is on the day the flux measurements were initiated and would correspond to that season.
    - If there are more than one flux measurements within a season, first apply the month-specific rates to their corresponding amount of days from that month and use the lowest rate to extrapolate to months without a rate in that season.

    Guidelines:
    - Aim to conduct flux measurements on a day close to the mid-point of the season
- **Discussion (refer to PowerPoint presentation):**
  - Cornwell: There's a need for more data on aquaculture denitrification rates, we're not quite there yet. Only considering restoration in this report.
  - Reichert: Will remove y axis from graph on slide 2. X axis is "more confidence on use of this practice" as opposed to "data availability". Both axes will be updated for report.
  - Cornwell: Slide 3 – Impact of oyster restoration may be widely spread beyond the footprint of the reef itself; any transport of biodeposits will always lead us to underestimate reduction amounts.

- Cornwell: We are doing site specific rates because we are not at a place where we can determine a bay wide rate.
- Cornwell: **Establishing reference rate –** If you did 3 measurements at 2 restoration sites, you can pick reference site with stronger information.
    - Kellogg: When people identify their restoration sites, they should also identify their reference sites. Go out and figure out what looks like a comparable site in advance of doing measurements three years later.
- Cornwell: **Number of sampling sites** – statistically the more the merrier.
    - Kellogg: 5 is a great number, realistically, though, 3 at minimum is recommended.
    - Bricker: I like this table, but I'm curious about the 3 sampling points, what is this referring to? Not made very clear by this table.
    - Cornwell: This is referring to both reference site and restoration site.
- Reichert: For BMP are we recommending they can use average or median rates?
    - Kellogg and Cornwell: We recommend using average.
- Cornwell: **Light and/or dark incubations** – Algae not a huge issue at reef sites, worse at control/incubation sites, reduces denitrification rates.
    - Reichert: Is it a BMP requirement that you have to establish light measurements?
    - Cornwell: If someone want 24hr credit for dark rates, they must ensure light is not getting to bottom. If they think light is getting to bottom and you use light and dark, that's fine.
- Wolinski: **QA/QC** – Oxygen criteria, enough info available to determine if O_2 levels are 4mg/L? Not clear if this is in reference to incubation or reef/field conditions.
    - Cornwell: When water slows down and its dark, respiration slows down. During daylight, O_2 tends to stay up high.
    - Kellogg: Thought this was a recommendation for incubation of reef itself, not relevant to reef conditions. Don't want to drive O_2 levels below 4mg/L.
    - Reichert: Will make this clearer in draft document.
- Cornwell: 6.625 slope recommendation is more confusing than it is useful. Not essential. Mention that it's a summation of nitration.
    - Kellogg: Explain relationship of nitrogen/O_2 concentration slope (positive, negative), where it should be.
- Wolinski: For total nitrogen concentrations, should nitrite be included in sum? Not clear in definition of nitrogen summation.
    - Cornwell: Total N ratio here would be summation of nitrite plus ammonium nitrate and N_2 gas. Total N related to water quality means something totally different than this, this terminology will be confusing. Cornwell will redefine this term.
- Reichert: We need to be clear in what is expectation of reporting, too. Which fluxes we want them to report.
    - Cornwell: Take O_2/N summation from 2013 paper and refer to a figure after this note that shows a table of that particular relationship in action. Just describing it here may be insufficient for readers. Suggest we tone this table down a bit and make sure the explanation after this has the detail we need to explain it.

- Kellogg: More concerned about people reporting slopes that are very different from 6.625 or a $4r^2$ between the two.
    - Cornwell: A $4r^2$ would raise big warning flags. A strong relationship between the two would be sufficient for me.
- Kellogg: Write correlation between N and O_2 flux should be strong. Would be concerned if you have data that is all over the place.
    - Kellogg: Hadn't thought about time course, this is significant. Will discuss this later.
- Cornwell: **Season** - Originally talked about 10 degrees C, oysters stop filtering there but other animals that comprise the community can filter at lower temperatures.
    - Cornwell: Suggests someone does 3 runs/measurements a season. Each season has a defined number of days. Went with the simplest way of thinking about it.
    - Reichert: More manageable from a BMP standpoint when we have defined seasonal timeframes.
- Cornwell: **Biomass assessments** – Idea that when you do these incubations, you get shell height and do dry biomass of oysters you incubated. We're less concerned with biomass in the reef (we don't want it to flux dramatically, though).
    - Kellogg: We want people to measure shell height and determine biomass.
    - Reichert: What about sediment cores? Are oysters in there?
    - Cornwell: No oysters.
    - Reichert: How will we do biomass for that situation?
    - Cornwell: We can't do it this way.
    - Reichert: Would someone use a subsample of biomass from the site area?
    - Kellogg: I vote that we say you can't use cores.
- Cornwell: The other need for biomass is to determine whether reef is building or degrading.
    - Kellogg: There's no study that demonstrates that sediment denitrification rate scales with surrounding biomass.
    - Cornwell: How do we move forward beyond first assessment? What is the rate an implementer comes up with related to? There is nothing developed to say denitrification and biomass are related linearly.
    - Reichert: That would mean when people are using sediment cores, they would have to measure denitrification rates every time.
    - Cornwell: As it's written, you can't say reef has changed or stayed the same. I think that's another layer of complication to this.
    - Kellogg: For some core data out there already, there is no biomass estimate, measurements of surrounding reefs.
    - Cornwell: When taking sediment cores, you measure the edge and extrapolate to entire reef. Could be underestimating rates of denitrification.
    - Kellogg: Make sure implementers can push a core into the sediment, mark location, get pieces of shell out of the way. Come back at least two weeks later and core in the areas where they know they can get core in the sediment; there are oysters around the reefs.
    - Reichert: How big are these trays for the other method? Could you use a quadrat for oysters in conjunction with taking core samples?

- Cornwell: Lisa is working on reducing variability on biomass vs. denitrification rates. If you incubate oysters, denitrification doesn't move with biomass in a predictable way. From BMP viewpoint, cores might be problematic.
- Reichert: Not opposed to mentioning core method, however to meet BMP review criteria, cores would not be manageable. How do you verify core estimates year after year moving forward?
- Kellogg: How bout measuring it per season? We can extrapolate over time, but can't scale it to biomass.

▪ Wolinski: Is there a set frequency for monitoring biomass on restoration sites?
  - Cornwell: Not biomass, but oyster density and shell heights.
  - Kellogg: Only monitored every 3 years with exception of a few that are monitored every year.

▪ Cornwell: Three of us (Kellogg, Cornwell, Reichert) need to convene again and think about this core issue. Its relatability to biomass is difficult; even after clearing out shell and making an area easier for core taking, it might be more worth it to set trays. In literature, cores are taken on periphery of oysters, not within a reef. Question remains, is it safe assumption that values you get there same as sediments you'd find in a reef? We don't know. Equivalence between edge and rest of system is unclear.
  - Wolinski: Make this a recommendation for future research.
  - Reichert: Leave cores as a valid option to obtain denitrification rates, but not a recommended option for the BMP given verification is based on biomass. Put this in future work section. Explain we don't have a way to relate it to biomass, BMP is set up to use biomass as verification.
  - Cornwell: It is possible that literature uses industrial strength corers, otherwise not generally possible. Make that apparent up front in text.

Chapter needs:

1. QA/QC needs to be fleshed out more, should take perspective of person who has to verify rate qualifies for TMDL. Cornwell will work on this.
2. Cornwell will work on sediment core section.
3. Wording changes on seasonality, remove temperature criterion.
4. More explanation of biomass.
5. Additional writing on required documentation.
6. Some word-smithing, organizational issues.

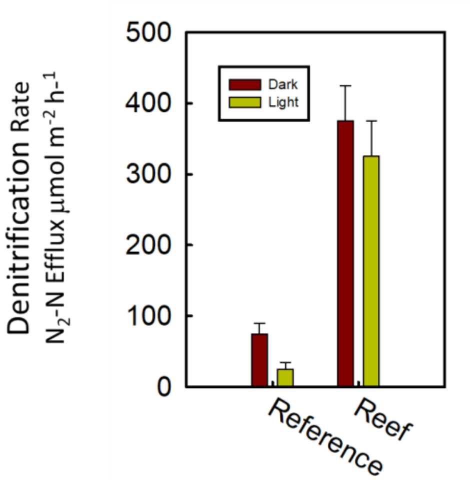
Additional Concerns:

- Luckenbach: My issues with the document were settled by this conversation. Did some word crafting and will send edits to Reichert. Thought it was good discussion, learned a lot by listening.
- Wolinski: Are these references accessible?
  - Reichert: No. We will work on making them accessible. I don't have all the papers Cornwell referenced in the chapter and will work on getting them.
  - **Action:** Cornwell will load enhanced denitrification with restoration practices references onto the Google Drive folder.
- **Action:** Reichert will reach out to Rose about tissue data and habitat (salinity, etc.) to look at differences that would change the quantile regression.
  - Rose: Has availability for this discussion in 2 weeks.

- Reichert**:** Will set up the data, find what is missing. Has nothing on location, habitat groupings, etc. Do we need to use a lower quantile for these regression equations?

Rate Calculation Example:

Figure xx. Example of calculation of denitrification using a reference sediment site. <u>This example uses both dark and illuminated incubations.</u> Rates are estimated on a 24 hour (daily) basis taking into account the day length estimated from the US Naval Observatory using the site location and date (http://aa.usno.navy.mil/data/docs/Dur_OneYear.php/).



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

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

Daily Rate if 14 hours light, 10 hours dark

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

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

Assumptions:
- Rates are typical warm season rates
- Reef biomass same as incubations or…
- If oyster biomass in the whole reef is lower rates get adjusted down in direct proportion. Data cannot be adjusted up for higher biomass.

- **Other:**
  - Chris Moore—previously asked whether the seasonal timeframes would differ for different areas of the Bay (upper, mid, lower) because of differences in temperature.
    - Jeff felt that these timeframes could be used throughout the Bay.
  - Panelists agreed that light rates are needed for areas where the light reaches the bottom
    - Guidelines on how to determine if light denitrification rates are needed (not all areas have light hitting the bottom to cause concern over denitrification rate):
      - Jeff and Lisa agreed that PAR measurements would be needed. Light incubations should be included where benthic light levels ≥2% of incident light levels.
  - Existing data can be used to determine site-specific denitrification rates as long as biomass was known or can be determined and rest of required components are met.

Oyster BMP Expert Panel Meeting, October 18, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remote
Chris Moore	Chesapeake Bay Foundation (CBF)	Remote
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Remote
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remote
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remote
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remote
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Remote
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Stephan Abel	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes
Guest	**Affiliation**	**Present?**
Frank Marenghi	Maryland Department of Natural Resources	Remote

Action Items:

1. **Action:** Please let Julie Reichert know if you are unable to attend the 11/15 Panel meeting.
2. **Decision:** Panel agrees to use Carry-Over with Expiration Approach to address Public Fishery harvest allowance and time lag. Time lag would apply to all plantings not just the first planting.
3. **Action:** Julie Reichert will write and distribute a one-page paper on the Panel's decision on the Public Fishery harvest allowance and time lag.
4. **Action:** The revised denitrification chapter will be distributed to the panel for review 1st week of November.

5. **Decision:** After reviewing the individual season and habitat 50th quantile equations, the Panel has no concerns using the 50th quantile of the entire dataset (representative of on bottom reefs) for converting shell height to tissue biomass for the restoration-assimilation and denitrification recommendations. Use equation on slide 1 with 50th quantile. Same conclusion for shell.

Meeting Minutes:

Coordination Updates, Julie Reichert-Nguyen

Report Schedule Proposal—Complete a full Panel review of the entire report before the holiday break in December and work through the EPA approval process afterwards.

- Potential Review Schedule (extra time in December would be used to address any issues discovered during review):
  - Restoration Denitrification Chapter: October 29-Nov 5
  - Restoration Assimilation Chapter: Nov 5-12
  - Appendices: Nov 26-Dec 3
- November 15 – Schedule Panel meeting to go over comments on restoration chapters (denitrification and assimilation recommendations)

Action: Please let Julie Reichert know if you are unable to attend the 11/15 Panel meeting.

Review first half of main body of 2nd report, Julie Reichert

- Chapter 6: Public Fishery-Assimilation Recommendations
  - Agree with qualifying conditions, application and verification guidelines, and example?
    - Conflicting opinions concerning the application of the harvest allowance based on the 15% cap. We would like to reach consensus on which approach to use. Potential Options (based on conversations with individuals):
      - **Carry-Over Approach**—Allows for the harvest allowance from a planting to be carried over in subsequent years until used up. This is the approach in the current draft document.
      - **Use it or Lose it Approach**—Each planting would be associated with a harvest crediting year. For instance, 15% of the first planting would only be available for credit during the first credited harvest. If a part of the harvest crediting allowance is not used, then it would be lost (no carry over to the next credited harvest year).
      - **Carry-Over with Expiration Approach**— Allows for the harvest allowance from a planting to be carried over in subsequent years, but would expire after 5 years.

Discussion:

- Julie Reichert: Stephan found issue with respect to the harvest time lag of 3 years and expiration date of BMP. This forces people to harvest right after the planting based on timing. We are looking to revise language on this.
- Julie Reichert: Conflicting opinions based on review comments
  - Panel has differing thoughts on approach of how much to allow for harvest.
  - Julie will get draft with everyone's comments in one place and then apply it.

        - In our recommendations, we have criteria/qualifying conditions in place based on time lag.

    Original concept = Harvest 3 years after first planting to increase likelihood of harvest coming from site that is influenced by BMP activity.

        - BMP lifespan of 5 years encourages maintenance of BMP through repeated plantings.
        - 5 years seems like a more defensible timeframe for BMP influence on harvest.
    - Julie Reichert: Other criteria with conflicted Panel member opinions – Harvest Allowance: Implementers can claim up to 15% of what they plant.
        - See three potential options above
    - Julie Reichert: A bit of a compromise based on feedback: Allow carry over with an expiration date of 5 years.
    - Lisa: So little bottom exists, do we allow overplanting of the same place? Is there a reason for allowing overlapping of plantings?
        - Stephan: Is there enough bottom to square off specific acreages? Close the bar, plant it, wait 4 years, open it.
        - Lisa: Main concern is allowing harvesters to get credit for wild harvest. No crediting criteria in place to know whether harvest comes from your planting. More comfortable with confidence that what is being planted is what is being harvested.
        - Stephan: Make it a requirement to know what's on bottom before you plant.
    - Frank: Leases in Maryland are NOT only given unproductive oyster bottom. Bottoms are leased with oysters on them; we don't know the density of oysters there because surveys aren't done in most cases. Overlap is important. There's not enough bottom to enforce single year class plantings in most cases in areas we've been planting. The industry believes replanting is more productive due to the quality of bottom and differences in growth between years. I understand the accounting, but I don't see people trying to plant oysters in areas already productive or natural recruitment to have a significant effect, particularly with 3-year lag time and 5 years BMP lifespan.
        - Mark: how often are you planting spat on shell in these areas?
        - Frank: It varies, we are usually short on funding or spat so counties may plant every 2-3 years. Areas doing well are planted every year or every 2-4 years. Harvest is variable as well. In most cases, they're open every year. It depends on how oysters grow and how many viable year classes there are.
        - Lisa: Generally, harvest everything within a single year from a single planting?
        - Frank: To the extent possible. Everything that's market size in a certain area tends to be harvested, but not necessarily all from year class that was planted 3 years prior. Harvesters don't want to work on areas that have just been planted. It's possible to have areas without overlap in a BMP area, but not likely to be entirely discrete.
    - Julie Reichert: We don't want to set up a BMP that's so restrictive that were dictating when to plant, to harvest, size to harvest at. We do want to make sure that qualifying conditions capture the enhancement activity that's occurring. Depending on area, oysters growth rates are different. There are areas where they grow faster and areas they grow slower. Shouldn't be too prescriptive.
        - Chris: There are lots of BMPs that are very prescriptive, I don't think we should worry about being too prescriptive about creating a BMP that is scientifically defensible. Worrying about being prescriptive isn't a consideration for me. Needs to be scientifically defensible and verifiable.

        - Julie Reichert: Trying to find sweet spot where a BMP is defensible while not being too off putting/restrictive for implementers, like we did with the first report.
    - Bill: Would entail state of MD to implement harvest time of year amongst multiple harvesters in order to manage it. Is it realistic that state would undertake that?
        - Julie Reichert: They'd definitely have to do more reporting than they currently do.
    - Lisa: How is it determined if harvest came from BMP area?
        - Julie Reichert: It is up to implementing agencies. They'd have to figure out how to implement them and create a plan. Would definitely require additional recording.
        - Matt: MD Shellfish tag requires a bar ID.
        - Frank: MD requires bar reporting, we would maybe have to require bar and specific BMP area as well. Reports are not 100% accurate, but for the most part, people report accurately. That level of specificity is hard to get at. With small plantings, you find there is not much harvest being reported from these areas at all.
    - Julie Reichert: Implementation procedures come after panel decisions, we provide what the reduction effectiveness is. That is our goal. What I'm hearing is compromise; the expiration method is best.
    - Matt: We are talking about hatchery produced seed to put on bottom for waterman to catch and harvest, correct? How is this different than bottom spat on shell aquaculture and why would it be treated differently?
        - Jeff: Different person harvesting it.
        - Chris: Huge difference between public fishery and aquaculture.
        - Matt: jurisdiction/municipality receives the credit either way. No watermen get the credit.
        - Julie Reichert: It is not the charge of the panel to decide that.
        - Lisa: Potential in public fishery to place spat on area with large preexisting oyster population. Fundamental difference in assumption that lease has fewer oysters on it to begin with than public bottom.
        - Frank: Assumption that needs to be examined in more detail. No incentive to add to already productive oyster bottom.
    - Julie Reichert: In the first write up, we recommend a pre-survey to see what's there and had different scenarios based on number of oysters there. If it looks like on-bottom aquaculture, go with on-bottom aquaculture recommendations for that scenario. If there are lots of oysters there, we add additional qualifying conditions for that site. Would this be feasible?
        - Lisa: This requires initial survey and that's why we dropped it in the first place.
        - Stephan: if someone doesn't want to do the survey, they can follow the on-bottom aquaculture protocol.
    - Lisa: What are the procedures in each state for declaring something leasable bottom? Are there true written rules about whether something can be leased?
        - Mark: If it exists outside of the Baylor survey, it can be leased in VA.
        - Frank: MD has Yates bars in sanctuaries off limit to leasing and public shellfish areas that are reserved for fishery based on historic productions. There are cases where oysters are not on Yates bars in sanctuaries or not on public shellfish areas that are in the fishery that do have oysters on them.
            - Two Rules:
                1. If it's in a sanctuary, can't lease on Yates bar.
                2. If it's in a non-sanctuary area, can't lease in public fishery areas.

Areas can be conditioned to be leased if they're shown to be unproductive. There are areas reserved for public fishery that have less than commercial harvestable amount of oysters present.

        - Julie Reichert: For the most part, it sounds like the goal is that leased areas have very few if any oysters.
    - Julie Reichert: We need a decision. Is everyone ok with the carry-over expiration approach? Panel agreed yes; Chris: Do we include a time lag for each planting? Panel agreed yes, but can be adjusted upon individual surveys.
    - Chris: Can you send out a one-pager with the new decisions before consensus?
        - Julie Reichert: Yes, I will write a one pager on what we decided today to make sure everyone's in agreement.
        - Jeff: To communicate this will not be easy. We're likely to have to double back on this one way or another once public comment and CBP comment comes into play.

Decision: Panel agrees to use Carry-Over with Expiration Approach to address Public Fishery harvest allowance and time lag.

Action: Julie Reichert will write and distribute a one-page paper on the Panel's decision on the Public Fishery harvest allowance and time lag.

Upcoming reviews and chapter status

- **Restoration-Assimilation Quantile Regression, Julie Rose**
    - Question Raised at Last Panel Meeting: Since we are using reef-specific quantile regression equations that includes new data, does the 50^{th} quantile still work? Do we need a lower quantile? Julie Rose and Reichert evaluated this and will go over results with Panel.
    - Analyses for both tissue and shell (shell height to dry weight regressions and percent content completed); chapter intro done, working on writing up analyses and verification guidelines

Discussion:

- Julie Reichert: We're putting forward recommendation for reduction effectiveness of entire oyster. Shell and tissue. Sequestration standpoint, will count if oysters are not harvested.
- Julie Rose: See accompanying Powerpoint presentation.
    - Same analysis run last year for tissue recommendation that we put forward.
    - We left out aquaculture data. This brings us to 7k data points.
    - Tissue
        - Slide 1: Median of data
        - Slide 2: Season
            - Black line equals data subset, red line the entire dataset.
            - Black line above red line, under crediting using 50^{th} quantile.
            - Black line under red line, over crediting using 50^{th} quantile.
            - Winter virtually identical to entire dataset.
            - Spring falls above full dataset, tend to be a bit heavier on average than average of all full seasons together.
            - Summer falls slightly below entire dataset. For the most part, the red lines are near the entire dataset for sizes you'd typically encounter on a reef, so you wouldn't be consistently over crediting by very much based on season. Only potential for over crediting would be in summer and only by a tiny bit (~30 lbs per 1 million oysters).

        - The Panel agreed to use the 50^{th} quantile equation of the entire dataset for all seasons.
    - Slide 4: Habitat type (Upper, middle, lower bay; tributary vs. open water; salinity)
        - Bay mesohaline mid-bay, tributary mesohaline mid-bay – both ok to use 50^{th} quantile equation.
        - Lower bay mesohaline, lower bay tributary polyhaline – both ok to use 50^{th} quantile equation.
        - Open water mid-bay mesohaline – ok to use 50^{th} quantile equation.

Decision: Panel has no concerns using the 50^{th} quantile of the entire dataset.

- Shell
    - Potential for over crediting for largest oysters in winter, Julie Rose is ok with using a single regression equation, though.

Decision: Panel has no concerns using 50^{th} quantile of the entire dataset.

- **Denitrification Chapter Status**, **Jeff Cornwell**
    - Modifying text to capture different requirements if core method is used since there hasn't been any data directly relating it to oyster biomass.

Discussion:

- Jeff: Mostly in final editing and writing part of this. Still lots of work to be done, getting enough information for guidance without being restrictive with respect to techniques to use. Looking at practice of using entire community vs. cores (where most of the literature exists). In the end we believe you leave a lot of denitrification behind using cores, but cost goes down.

Action: The revised denitrification chapter will be distributed to the panel for review 1^{st} week of November.

Oyster BMP Expert Panel Meeting, November 15, 2018, 1:00 PM – 3:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	No
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
Bill Wolinski	Talbot County Department of Public Works	Yes
Frank Marenghi	Maryland Department of Natural Resources	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Yes
Matt Johnston (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Rich Batiuk (BMP Verification Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes

Action Items:
Action: Panel will include the other terms used for "public fishery" practice (e.g. "put-and-take fishery") and establish their equivalencies.

Meeting Minutes:
Coordination Updates

1. December 17th—Courtesy update to Fisheries GIT. Looking into inviting stakeholders and WQGIT to also participate to give a preview of recommendations focusing on reduction effectiveness determination strategies.

Review terminology and definition changes concerning "public fishery" practice

1. The Panel has expressed views that this practice of planting hatchery-produced oysters on commercial fishing grounds is an aquaculture-like practice. The current characterization of “public fishery” does not adequately represent this. Instead of characterizing this as “public fishery” we are proposing to change the title (see examples in decisions document) under “cultivation.” See proposed changes in revised oyster practice table.
2. Discussion
    a. Cornwell: This is a problematic description – “aquaculture like practice”. Occurs on public fishing grounds and includes multiple public fishers. Do we leave it as it is as approved in first report? Lisa suggested new variant on some of this, Matt backed it. She suggested “on bottom put-and-take harvest using hatchery produced oysters”.
    b. Kellogg: The new suggestion makes it clear you're actively putting oysters out to harvest later. Might resonate better with people since they’ve heard it before.
    c. Marenghi: "Put and Take" rubs me the wrong way. It does characterize what happens in our program, but it has a negative connotation in Maryland. Especially since we're trying to differentiate it from lease harvest. Including something with “public” in there is important because it's not only public fishery, also publicly funded as opposed to private aquaculture. With regard to "licensed oyster harvest", are we saying there are unlicensed harvests we’re not talking about? I don’t like "public aquaculture", either, but I see how it makes sense. I prefer "aquaculture practices on public fishing grounds” or “public oyster harvest using hatchery produced oysters”.
    d. Kellogg: What about "on bottom put-and-take using hatchery produced oysters"?
    e. Marenghi: I am opposed to put-and-take. Leasing is also put-and-take and has negative connotation with watermen. It puts negative bias on fishery way its been used in the past, makes it seem like it’s not a true public fishery.
    f. Moore: I don’t agree with stance that you’re lumping put-and-take designation with entire public fishery. We're better off removing word "public" - maybe its opposite concern, but people think "public" means "natural supported fishery". "Public" as a whole will lead us to confusion and more problems later.
    g. Reichert: I agree with Chris, it has to be differentiated from private oyster aquaculture. Just putting shell out there isn’t necessarily representative of put-and-take.
    h. Cornwell: It seems like were running in circles.
    i. Marenghi: Possibly, "harvest of hatchery produced oysters from public fishing grounds". I cant get away from use of public. Trying to distinguish between that, lease, and restoration.
    j. Moore: What about for managed bottom?
    k. Marenghi: State managed bottom? Leases would fall under that as well.
    l. Wolinski: In the revised oyster practices document, in the licensed oyster harvest section it lists 2 categories “wild” and “hatchery produced” followed by a practice. To me, this seem compatible with what's in revised practice table.
    m. Marenghi: I'm okay with that.
    n. Cornwell: I think that captures what we’ve been talking about. When I look at those columns, I have a clear idea of what this is, it's just the overarching label were struggling with. Is that the consensus with everybody? Follow the revised Chesapeake Bay oyster practice table.
    o. Kellogg: Put-and-take fishery is something people understand, let's mention that in the text somewhere so that people can equate the two, doesn’t have to be in the title.
    p. Cornwell: Put it in description line of excel table or in text somewhere. Sounds like we’re in agreement. In the write up, we will make sure we include the other terms used for this practice and establish their equivalencies.

Action: Panel will include the other terms used for “public fishery” practice (e.g. “put-and-take fishery”) and establish their equivalencies.

Review edits to licensed harvest recommendations (see Other Decision Public Fishery Example tab in Harvest Recommendations document)

1. Those who provided comments have been incorporated into the revised draft. We will review for consensus.
    a. Biggest change was to the reduction time lag recommendation. Instead of 3 years after a planting, changed to 2 years (allows for 3-year carry over instead of 2 years).
2. Discussion:
    a. Kellogg: This document is similar to the table Julie sent out before, with changes that I suggested and made more complicated. More detail in here now. If you follow the table, start at top of t0 (2019); I asked Julie to make it more specific about what t0 means and planting time. That value is the spat planted times 15%, then translated into bushels harvested. The table in yellow gives information about when oysters are harvested; in terms of bushels in row 12 and number of oysters in row 13. The table also denotes which planting the values refer to. Row 16 tells you the available harvest; you can look at blue table line 5 and get the same number in row 16 of yellow table. You can see how much of the harvest is claimed in row 13 if you're looking at year t2 (all are claimed). Reduction credits are at the bottom of the Harvest Running blue table. Incorporated in this is the two year time lag we've seen by email, 2nd page of the worksheet is justification for that (data collected in 2006 from plantings of known age that were not overplanted/zero recruitment). Rows highlighted in green and blue are actually of the specific ages were talking about in tables of previous tab (t0=40mm, t1=52, etc.). We didn't want to mandate that you couldn't harvest at t2 if your oysters are large enough.
    b. Cornwell: Anyone who wants to implement this, they may want to talk to Lisa or anyone else who has had practice with it.
    c. Kellogg: It's just a counting, pluses and minuses, just making sure you do that math right. I think being really clear and explicit in as small and as many steps as possible will make tracking from year to year all the easier.
    d. Cornwell: Is everyone alright with this? Every aspect of this is more complicated that many of the other BMPs out there and will be scrutinized at every turn.
    e. Panel is okay with this decision.
    f. Linker: No objection to name change or this going forward for review. Happy to discuss further my other concerns, but go forward with it and see how the CBP finds it.

Oyster BMP Expert Panel Meeting, April 18, 2019, 1:00 PM – 4:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lynn Fegley	Maryland Department of Natural Resources, Fisheries Service	No
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	No
Andy Lacatell	The Nature Conservancy (TNC)	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes
Guests	**Affiliation**	**Present?**
Frank Marenghi	Maryland Department of Natural Resources	Yes
Jason Bernagros	U.S. EPA (on detail at Chesapeake Bay Program Office)	Yes
Sara Coleman	Oyster Recovery Partnership	Yes
Kaycee Coleman	Oyster Recovery Partnership	Yes
Jeremy Hanson	Virginia Polytechnic Institute and State University	Yes

Action Items:

1. **Action:** Julie Reichert will send out a doodle poll to reschedule May 7th Chapter 7 and 8 review meeting
2. **Action:** Julie Reichert will make language regarding timeframe under which implementors can receive credit for harvest clearer in Chapter 6 Technical Appendix
3. **Action:** Julie Reichert will provide clarifying information with respect to harvest crediting, simplify calculation spreadsheet
4. **Action:** Julie Reichert will revise language regarding the partial crediting approach for oyster reef restoration practices.

5. **Action:** Julie Reichert will remove Chapter 5 reference of triploids oysters occurring in the wild.
6. **Action:** Julie Reichert will remove Chapter 5 language about developing site specific triploid estimates for this practice.
7. **Action:** Julie Reichert will remove reference to Lower Rappahannock Oyster Management Plan about harvesting hatchery-produced oysters.
8. **Action:** Julie Reichert will revise language to make it more of a suggestion to include who harvested oysters/who they were sold to.
9. **Action:** Julie Reichert include "underestimates" compared to 50th quantile of data subset in Chapter 6.
10. **Action:** Julie Reichert will rewrite averaging approach for percent nitrogen/phosphorus content in oysters.

Minutes:

Coordination Updates

1. April 22 – Send out revised Chapter 7 (restoration-assimilation)
    a. This may change based on today's conversation.
2. April 29 – Send out draft of restoration-denitrification chapter for Panel Review
3. May 7 – Schedule Panel meeting to go over comments on denitrification and assimilation recommendations (Chapters 7 and 8)

    Action: Julie Reichert will send out a doodle poll to reschedule May 7th Chapter 7 and 8 review meeting

4. May 21 – Tentative date to release draft report for public comment
    a. Panel will likely host webinar May 21st as well
5. Maryland WIP available for public comment: Includes use of approved oyster BMPs
    a. Hanson: Webinar is part of BMP Panel protocol now, helps to record webinar as well.

Discussion on Technical Appendices for Application with the TMDL model

1. Part 1. Chapter 6: Licensed Oyster Harvest-Assimilation Recommendations
    a. How to address the site-specific recommendation concerning the reduction time lag (time lags could vary); need to establish clear-cut crediting timeframe (when harvest is eligible for credit)
    b. How to address multiple plantings in a year producing eligible harvest for reduction credit over multiple years

    Discussion:
    c. Reichert: (Ref. Q2 Reduction Credit Time Lag bullet point) Could there be different sites with different time lags associated with each site? That would require a lot of tracking.
        i. Hanson: Depends on what balance is for states/whoever is tracking that information and reporting to CBP. For BMPs, panels make recommendations based on how permits work (e.g. permit timeline
        ii. Bernagros: Would be good to have sense of what available options are for how frequent assessments can be done. On CAST, we want to be able to report out 1-2 years. Depends on how it will be reported within the model.
        iii. Hanson: Reporting on an annual basis becomes difficult; e.g. tracking plantings and harvests each year.
    d. Reichert: Can we have a default timeframe? Do we need to offer that much availability?
        i. Slacum: 2 years is 2 years after planting, about 2.5 years of growth. 2.5 years gives low probability of need to harvest before that time frame. Potential is there, though.
        ii. Marenghi: Agree with that. 2 years will cover most scenarios, not likely that assessments will be done on some small percentage of BMP areas every 2 years.
    e. Reichert: I propose that we omit "unless an assessment is done demonstrating a timeframe less than two years is appropriate".

    i. Marenghi: I'd rather leave it in. Wouldn't be a problem tracking it if we did have assessments. Good to have the flexibility.
    ii. Reichert: As long as people can track and report appropriately, there shouldn't be an issue including it in TMDL/estuary model.
    iii. Hanson: It never hurts to leave flexibility. States will give feedback on this language. MDE and VADEQ report the data to CBP and will have thoughts as well.
    iv. Reichert: Will keep this language until we hear back during public review.
  f. Reichert: We might want to make sure the timeframe that people can receive credit for harvest is clear e.g. Lifespan of Oyster Harvest allowance MINUS Time Lag (two years before ability to harvest/growth period). Time window for harvest is not 5 years from day of planting.
    i. Hanson: "Lifespan" might be confusing, maybe use "harvest timeframe" or "harvest window" instead.
    ii. Sanford: This is a little confusing. Suppose a site is planted every year, is harvesting immediately after planting precluded?
    iii. Reichert: Implementors can harvest immediately, but that cannot be applied toward reduction credit.
    iv. Sanford: Separate table for each planting would make it less confusing, easier to track, then sum all tables together.
    v. Marenghi: Unsure I see a clear winner in this scenario right now. Showing the equations might be easier.
    vi. Sanford: That was my initial thought as well. Can have identical table but write equations down below. Can annotate tables in Excel.
    vii. Marenghi: Would help reader clarify any confusing from reading one table.
      1. Sanford: Label rows, make it more like an annotated spreadsheet. Refer to column combinations to explain how calculations were done.

Action: Julie Reichert will make language regarding timeframe under which implementors can receive credit for harvest clearer in Chapter 6 Technical Appendix

Action: Julie Reichert will provide clarifying information with respect to harvest crediting, simplify calculation spreadsheet in Chapter 6 Technical Appendix

2. Part 2. Chapter 7: Restoration-Assimilation Recommendations
  a. Reduction effectiveness approach needs to be revised to allow use with TMDL model (particularly the 50% partial crediting approach.

Discussion:
  b. Reichert: This is site specific. Implementors monitor oyster counts and shell heights to determine appreciation in tissue/shell biomass in order to receive credit. There will be no lookup table. Implementors need to calculate tissue and shell reductions using regression equations on their own. One step of this process needs to be rethought – partial crediting approach.
  c. Reichert: With respect to Step 1 – most folks will likely use option 1.
  d. Reichert: With respect to Step 2 – partial crediting approach where you only receive credit during crediting year for biomass over baseline. Eligible biomass would equal 50% of that crediting value, the remaining 50% would be given the following year if you could prove you retained that biomass. This is not how it works with other BMPs within the TMDL.
    i. Hanson: BMP receives credit right away, clearly forest buffer takes many years to be at full performance/maturity. Were crediting at full maturity right away, becomes complicated otherwise due to policy/planning decisions made based on this model. Entirely up to panel what is reasonable, though. Can choose to discount something based on lack of data variability, but don't need to base on lifespan/maturity of resource.

e. Reichert: Option 1 or Option 2 – discount all the time, always going to take off 10% to account for variability. Trying tot do 50% now and 50% later is so complicated to convey, lots of rules. Becomes a headache to track. Thoughts knowing TMDL is longer timescale? You still have to go out and monitor, but you get credit for what you have when you have it.
    i. Cornwell: Shell seems longer lived, do worry about variability in tissue a little more. If you monitor at a given year and things go up as opposed to down, it probably comes out a wash.
f. Wolinski: What is the monitoring protocol for sanctuaries?
    i. Marenghi: Generally, every 3 years for restoration projects.
g. Slacum: Those are for sites part of the Bay Agreement. No real known standard for all other reefs. For planting trees, idea is that there isn't a measured verification component. Most restorations I've seen recently have support and momentum behind them, idea not to plant and let them stay/be, there is a concerted effort to monitor and maintain. Monitoring occurs because it isn't like planting trees, reefs are more variable. I wonder if trying to discount it is discounting a small amount to begin with. Is there a potential for any conditions for these BMPs that have a plan that look into the future? Does it have to come with a monitoring plan to become BMP?
    i. Hanson: No. The implementing program decides what is worthwhile. It comes down to resources. If you are spending millions on projects, what's another 10k to monitor it. Using stream restoration as an example, there are many different permits involved at the federal level with specific requirements for monitoring/remediation, can vary by state, etc. If these oyster practices have permit requirements build into them, write them in and build on them if its something you find very important. Panels don't dictate what states do. Lack of monitoring/reporting sometimes means a BMP stops receiving credit.
    ii. Slacum: There is proper vetting that happens at implementation program level that ensures no overcrediting.
h. Moore: Were not talking about changing monitoring protocol but changing when people receive credit for this. We recommend that programs will present monitoring program to CBP, but they dictate the amount/times per years they monitor biomass. I am not as worried about time of crediting, especially if we write more in that chapter about monitoring to make sure it happens adequately. You get credits in increments of years you do sampling, nothing ahead of what you're monitoring.
i. Cornwell: Some projects will overcredit and some will undercredit, what we want is a system that will come out as a wash for entire bay system. Im confident that nitrogen and phosphorus will still be retained there, kind of a failsafe for decimation of population in shell.
j. Reichert: I propose we get rid of 50% now, 50% later language. Monitor now, what you have now that you didn't receive credit for over baseline, that is your nitrogen and phosphorus reduced. If it decreases, you get nothing.
    i. Panel OK with this decision

Action: Julie Reichert will revise language regarding the partial crediting approach for oyster reef restoration practices.

k. Bernagros: Would we still use regression equations as is?
    i. Reichert: Yes. Still convert everything to biomass and adjust based on appreciation.
l. Hanson: In how often assessments occur, suggest a minimum frequency of monitoring if you're leaving it up to states. We have cumulative BMPs that you get credit for every year until it dies/monitoring lapses – in agriculture sector it's 10 years. Annual BMPs like cover crops are done year to year on management basis. Other BMPs vary with respect to amount, e.g. street sweeping. We could make this a 3-year credit duration or can make it annual.

   i. Reichert: This is annual then, otherwise we'd be double/overcounting.
   ii. Marenghi: Language could be confusing. Section 7.2/Step 2: readers might think you can count it every time.

Go Over Substantial Panel Comments on Chapter 1-6

1. See below documents:
   a. For Discussion_Chapters 1-6
   b. Oyster Practice Definitions for 2nd Report_revised_4-16-19
   c. Oyster BMP 2nd Report_current_2019-04-19
2. For Discussion_Chapters 1-6 Discussion:
   a. Chapter 1 –
      i. Reichert: We don't want people to think public fishery BMP is crediting historical wild population. This is more of a MD practice, counting by counties. Category I is wild harvest with no activity – that is the wild fishery. Why we explained differences with wild oyster aquaculture; why we don't have 15% cap on what's planted, etc. Not worried about existing populations. I was trying to capture the policies in VA and MD that gave us the impression of less concern with/focus on wild fishery.
      ii. Cornwell: I like this 1st paragraph, really defines it in a way we didn't before.
      iii. Marenghi: I agree. I like where the language that was decided on using hatchery produced oysters, like how that reads, the Distinction between fishery and aquaculture.
      iv. Luckenbach: Who would BMP implementor? Who would get credit for this/apply to do thi
      v. Reichert: State would work at county level counterparts, county level plantings would go into local WIPs, eventually compiled into statewide WIP. State would have to report it to CBP based on what counties are doing.
         1. Reichert: Panel sounds like they're ok with this language. Will keep it as is unless I receive more feedback by Tuesday.
   b. Chapter 5 –
      i. Reichert: Reference for triploids occurring in wild. No reference/citation here, this is text carried over from first report.
      ii. Moore: Not big enough issue that it needs to be in report.
         1. Bricker: I agree.
      iii. Reichert: Do we want recommendations around triploid oysters? Not something we want to encourage to happen on public grounds. You still get credit for these oysters, but at diploid estimates (more conservative value).
         1. Panel okay with removing this language.
         2. Action: Julie Reichert will remove Chapter 5 language about developing site specific triploid estimates for this practice.
      iv. Reichert: Found one example in the Lower Rappahannock. Oyster management plan, they'd plant hatchery produced spat on shell oysters on public ground – is this information outdated? Wanted to emphasize thought it might not occur in VA it doesn't exclude them from using this BMP.
         1. Marenghi: Write it how you said it instead of Virginia Oyster Heritage Program, probably outdated.

Action: Julie Reichert will remove Chapter 5 reference of triploids oysters occurring in the wild.

Action: Julie Reichert will remove Chapter 5 language about developing site specific triploid estimates for this practice.

Action: Julie Reichert will remove reference to Lower Rappahannock Oyster Management Plan about harvesting hatchery-produced oysters.

   v. Marenghi: Last bullet point in for discussion document. Reporting guideline in licensed oyster harvest practice. Concerned about people wanting to share proprietary information.
      1. Bricker: Proprietary if released to public. Having worked with growers, they are sensitive about that kind of information.
      2. Marenghi: They report who they sold to, what they cost. We don't release that info to public unless we have to. We wouldn't release individual harvest information to public.
   vi. Moore: To explain my comment, getting out of fishery part by opting into trading, that is public removal of pollution from waterways. In addition, public information for those who have permit? Someone worried about proprietary impacts don't need to participate in this program, its not mandatory. If we require folks who put pollution in to be public, important to require those who say they're taking it out to be public as well.
      1. Marenghi: Can see that for leaseholders, if states want to do credit trading with individual leaseholders. Not form public harvest spat on shell BMP areas.
      2. Moore: Doesn't matter if it's public or private credit, public deserves to know who is being accredited. Not considered confidential or anything like that.
      3. Marenghi: Possibly an issue for lawyers to sort out.
      4. Reichert: This goes outside purview of panel because it doesn't have to do with reduction effectiveness. These are just suggestions, states may do things differently depending on laws in place.
      5. Matt Parker is concerned about who oysters are sold to, make it more clear that this is optional for verification purposes (how many are sold for harvest), but not required for crediting process.
      6. Moore: Will need to see new language before agreeing.

Action: Julie Reichert will revise language to make it more of a suggestion to include who harvested oysters/who they were sold to.

c. Chapter 6 –
   i. Reichert: First bullet point – description on quantile regression was complex to write. Not influenced by outliers, quantile regression approach. Did comparison analysis with 50% quantile of entire Chesapeake dataset and 50% quantile curves for subsets of the data.
   ii. Difference in pounds N and P reduced in summer subset negligible
      1. Bricker: Need to include that you did a sensitivity analysis
      2. Rose: Error around estimate is well constrained. For the purposes of appendix, this could be reasonable justification for not doing a separate crediting for those instances where subset quantile fell below entire dataset quantile (we're NOT overcrediting), were within error curves. Subset red lines below black lines fell between error curves, not that much of a difference in crediting values. This gives strong justification for providing a single default estimation value.
      3. Bricker: Confused by the averaging approach language.
   iii. Bricker: Confused by "more weight in value than sites in Chesapeake Bay" line.
   iv. Reichert: Usually BMPs don't to their own analyses, we're concerned as a group, but CBP isn't concerned at all. We've taken a robust approach.
   v. Reichert: For nitrogen for example, there were 6 total studies, out of 6 studies, there were 3 studies that had CB specific information. Form that, we took site averages reported. We averaged all study sites as one, then averaged them together for CB. We

could make it clearer that we averaged their overall overage, didn't have as much weight as it would with high or low values reported. Waterbody level vs. site level.

Action: Julie Reichert include "underestimates" compared to 50th quantile of data subset in Chapter 6.
Action: Julie Reichert will rewrite averaging approach for percent nitrogen/phosphorus content in oysters.

d. Chapter 7 –
   i. Reichert: Lisa mentioned this is for subtidal practices, but our calculations include intertidal data.
   ii. Cornwell: Denitrification in intertidal is lower, we don't have enough data to separate them. Keep them together is fine.

3. Oyster Practice Definitions Discussion:
   a. Definition J
      i. Reichert: Chris had a comment about sanctuary reefs vs. sanctuaries.
      ii. Moore: In MD when you talk about sanctuaries, you talk about whole systems. In VA, sanctuary reefs/areas that have harvest right next to them. General public thinks whole systems in MD, we don't have that in VA and don't see us doing that. In addition, sanctuary has legal definition behind it that's different than what they are in MD. Trying to be broad in order to capture nuances between each state.
      iii. Marenghi: how about no harvest areas? Something that doesn't have sanctuary in it.
      iv. Moore: Seems that sanctuary language is ingrained in some places, no harvest areas seems more like what we're talking about.
      v. Marenghi: Definitions J and K say "area where removal is not permitted", seems fine to me.

Oyster BMP Expert Panel Meeting, May 10, 2019, 1:00 PM – 4:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Remote
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remote
Andy Lacatell	The Nature Conservancy (TNC)	No
Frank Marenghi	Maryland Department of Natural Resources	No
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	Remote
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remote
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remote
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remote
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Remote
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Remote
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes
Guests	**Affiliation**	**Present?**
Sara Coleman	Oyster Recovery Partnership	Yes
Kaycee Coleman	Oyster Recovery Partnership	Yes
Jeremy Hanson	Virginia Polytechnic Institute and State University	No

Action Items:

1. Timeline:
    a. Chapter 7 draft to be sent by 5/14, panel has 1 week to provide comments.
    b. Chapter 8 draft will be sent to panel June 7th, 2nd week of June for meeting to discuss chapter.
    c. Draft report out for public comment end of June, webinar first week of August.
2. Chapter 6 Review:
    a. **Action:** Julie is writing a sentence regarding potential increased fishing pressure due to restoration sites – that the panel will put a limit on credit, not harvest, and that it's up to resource managers will manage an area to prevent overharvesting – and will send to panel for review.

3. Chapter 7 Review:
    a. **Action:** Julie will avoid including regression analysis information in report to avoid confusion.
    b. **Action:** Title will omit “production” but include “biomass”.
    c. **Action:** “Literature Review” section will be renamed “Background”.
    d. **Action:** Panel should send Julie important reports and information that should be included in “Background” section.
    e. Reduction effectiveness determination
        i. **Action:** “50m away” will be removed from this section as “basin” remains undefined.
        ii. **Action:** Julie will include same language from other chapters describing need for expert help/justification of reference site choice before baseline is established.
        iii. **Action:** Julie will add language with respect the complexity of ways to monitor restoration sites/how different factors influence methods/require technical review.
    f. Biomass determination options
        i. **Action:** Julie will include language from other chapters/report making sure the panel communicates that only live oysters/biomass will be credited.
    g. Step 2
        i. **Action:** Julie will include language that conveys that to continue receiving credit, monitoring should be complete in 3 years. To receive additional credits, implementors must monitor every 3 years minimum. Will reference CBP documents on this protocol.
    h. Step 4
        i. **Action:** Language will be included at the beginning to define sampling points within BMP site, Julie will make sure its consistent that report talks about BMP site area.

Minutes:

Coordination Updates

1. Chapter 7 draft to be sent by 5/14, panel will have 1 week to provide comments.
2. Chapter 8 draft; send to panel June 7th, 2nd week of June for meeting to discuss chapter.
3. Draft report hopefully to be out for public comment end of June, webinar first week of August.
4. Happy Birthday, Mark!!
5. Sara Coleman and Kaycee Coleman are new to ORP and might be helping with the Oyster BMP Expert Panel. Sara focuses on oyster restoration and monitoring while Kaycee helps with electronic reporting for fish.

Review of Chapter 7

1. **Literature Review (Subchapter 7.1)**
   Discussion
    a. Reichert: Could use help on what we want to include in this section. Most reduction effectiveness based on dataset we compiled, not literature. Any studies out there that demonstrate success of restoration efforts we want to include?
    b. Wolinski: Ongoing work with sanctuaries and reports that are issued. Controversy of efficacy of sanctuaries, should include stuff that highlights success of sanctuary efforts.
        i. Reichert: Will include NOAA reports.
    c. Slacum: ORP has several reports that document mortality in Harris Creek.
    d. Bricker: Include Kennedy et al. report.
    e. Luckenbach: Rename section, call it “background”, not literature review. Stuff going back to publications from decades ago on successful restoration efforts. Pull out examples that make that point, geographic and message breadth that provides background makes a lot of sense.
    f. Reichert: Panel should send Julie key studies and highlight key information we want to include in this section.
2. **The steps to determine the reduction effectiveness (Subchapter 7.2)**
    a. **Baseline Determination Approaches Discussion**
       Discussion

i. Reichert: If practitioners have data and justify baseline using that data, that is their baseline. However, there are situations where they don't have that data, then can use reference site approach using existing or new data on sites representative of conditions at restoration site 50m away.
ii. Wolinski: Is basin defined in document?
iii. Julie: No, it isn't, how should we define basin?
iv. Moore: There are basins defined, e.g. riverbasin in state of VA. Too big because they'll always be more than 50 m away.
v. Cornwell: Rationale was we were concerned that biodeposits at bottom of reef could change things close to reef. Unsure this applies here as this is a different process. 50m is a guess, looking for halo effect near reefs, 50m isn't exact.
vi. Reichert: I'll delete that part, how we define basin is still up in the air.
vii. Cornwell: With application of our approved BMP, is dealing with crediting within same system meaning you can't plant oysters in Honga and help in Baltimore harbor. Definitions mean a lot with respect to implementation. Our context for basin here is little Choptank or Harris whereas TMDL boundaries could be different and not relevant to this question. Agencies implementing these will make their own decisions wrt definition of basin.
viii. Reichert: We will leave as is but take out 50m away.
ix. Reichert: No need for reference site approach if you already know you need to establish a baseline. If you don't collect baseline data, you cannot receive credit in this situation.
x. Cornwell: You're not allowed to bury reasonably successful oyster communities, any instances where there won't be assessments?
xi. Paynter: Restoration doesn't suffocate what's underneath, no chance unless you increase rest density by order of 2. See upwards of maybe 30-40 shells/m2 at highest, doesn't even cover bottom. We don't need to have worries about covering existing population as there isn't enough shell to do that.
xii. Slacum: Criteria to do assessment in areas that determines where and whether restoration can occur. With enough oysters in an area, there won't be resources allocated to plant more in those areas. What Julie is alluding to with respect to the baseline, pre-survey was done to assess Harris Creek information used to determine where restoration occurred.
xiii. Paynter: Worth mentioning that when my lab does ground truthing, we count live oysters we come across on 200m transects so we have rough estimate of what live oysters are at that site.
xiv. Reichert: What about VA projects? Established baseline before planting on those sites?
xv. Luckenbach: They're not planting on site they've taken samples from. The data sit in a notebook somewhere, they're not published. In making decisions with respect to where to add shell for restoration sites, data come from fall surveys and are posted on vims website. Pre-samplings used to determine what Julie is asking, I'm unaware.
xvi. Moore: I'm unaware of that as well. We'll sample an area generally to determine no large oyster biomass, pick up oysters that are there, and move them. Biomass that is there are never recorded to my knowledge.
xvii. Reichert: That's why we're thinking of allowing reference site approach to existing projects, practitioners could select site nearby that is representative, they assess reference site to establish a baseline. Oysters put in water post-2009 can be considered for BMP credit.
xviii. Kellogg: Same language warranted here from other chapter describing expert help/justification of reference site choosing before baseline is established.

xix. Reichert: Yes, I will include this language.
xx. Bricker: Does the reference site need to be approved by state? Years of sampling after restoration, what is time period and does that need to be approved? Any approval process that should take place?
xxi. Reichert: Any approval would be run by CBP so they'd allow it in their TMDL model.
xxii. Wolinski: Any language about comparing adequacy of baseline?
xxiii. Paynter: Imagined there'd be a scientific committee overviewing these baseline establishments.
xxiv. Reichert: CBP required a technical review in past, if panel recommends that such a review happens, CBP will lean more toward requiring that.
xxv. Wolinski: It seems appropriate to establish framework for analysis that is consistent.
xxvi. Reichert: That might be difficult, restoration projects differ majorly. Might want to write this more from case-to-case, more site specific.
xxvii. Luckenbach: They'd just need an approved monitoring plan, should be sufficient.
xxviii. Reichert: Will add language, due to complexity of ways to monitor restoration sites/how it's done differently per different factors, implementation plans require a technical review for verification.
xxix. Moore: Make sure language is consistent with oyster restoration activities in CBW.
xxx. Reichert: CBP does reach out to experts in field to put plans together, review plans. Possibly STAC or even ORP.

3. **Biomass Determination Options Discussion**
   a. **Quantile Regression**
      Discussion
      i. Reichert: Pulled out data for on bottom aquaculture. Gave us 6,888 tissue data points. For shell it was less, 4,296 datapoints.
      ii. Reichert: Also made a distribution map for shell and tissue datapoints… spread of the Chesapeake for shell regression. More representation from VA waters than MD. More data from MD for tissue map.
      iii. Bricker: Have any measurements been done on reef oysters? Or all aquaculture oysters?
         1. Reichert: All reef oysters. For bottom aquaculture analysis, only data we have were from reefs for restoration BMP regression equations, except your dataset that we added later.
      iv. Reichert: Julie Rose ran quantile analysis for these two datasets, made graphics for inclusion in report. Made some with subsets of the data with respect to influencing factors (e.g. season, salinity) compared to entire dataset for inclusion in report, too. If black line falls below red line, potential for overcounting, but falls within error for entire CBW. We're underestimating in more situations than not. Did this analysis for both shell and tissue. What we are over crediting is negligible, did analyses, will include in appendix to justify our decision.
      v. Luckenbach: Correct wording is to say this difference is within error range of our estimates anyway. This difference lies within whatever the confidence range is.
      vi. Paynter: Agree with Mark. Take it even step further, say the outcome isn't different from mean. Reality is that it's not significantly different.
      vii. Rose: Agree with this. Point out that because its within error, we don't know if it's over or under crediting. It looks like it's over crediting, but due to the error all we can say is it's not significantly different from error. We can't say with confidence that its over crediting due to the error associated with that.
      viii. Reichert: Will not include this analysis to avoid confusion. Anyone who wants to do that assessment can verify it for themselves.

b. **Measured Oyster Biomass**
Discussion
  i. Kellogg: Need to determine if we're using baywide or site-specific biomass. Need to shuck oyster to get biomass, no real shortcut to doing it in bulk that im aware of. Use default or site-specific number if implementor doesn't think site specific number is representative of their site. Would be rare to sample 3,000 oysters and do biomass on all of them.
  ii. Reichert: Ever a situation where you shuck and dry tissue and weigh as a group?
  iii. Kellogg: Could do it but it's a lot of shucking.
  iv. Bricker: Did that with 100 oysters to get average for tissue and shell, agree with Lisa that over one acre is a lot of work. M2 would be more reasonable. Doesn't sound like something people would do but can't say for sure.
  v. Kellogg: I'm sure it happens, but not a standard you want to set.
  vi. Paynter: Resource community wouldn't provide lots of information on that. I don't see that as being common.
  vii. Reichert: Want to make sure it's clear they're measuring shell and dry weights to do sampling.
  viii. Reichert: Will use language from other chapters. Want to make sure we're communicating that we're only crediting live oysters/biomass, will use biomass language.

4. **Step 2 -**
Discussion
  a. Kellogg: How long do we allow for monitoring after restoration activities?
  b. Wolinski: To retain credit, must maintain set frequency of monitoring – exists in some programs.
  c. Reichert: Thinking we could allow more flexibility for implementing programs, were thinking 3-5-year time frames for monitoring would make sense. Is there a time frame we want to say that you want to monitor before a certain time?
  d. Moore: CBP credit efficiencies kept if monitored every 5 years. Referring to past language used, 3 years might be best model to use for this.
  e. Reichert: What if someone wanted to monitor every 2 years?
  f. Moore: That's fine, say to continue to receive credit, monitoring should be completed in 3 years. Reference CBP documents on that. To maintain and receive additional credits, say must monitor every 3 years minimum.
  g. Reichert: Will revise language to reflect this.

5. **Step 4 -**
Discussion
  a. Reichert: Will define sampling points within BMP site at beginning, will make sure it's consistent that we talk about BMP site area.

Chapter 6 Review

1. **Addition of the following unintended consequence:**
  a. From Lisa Kellogg: What about locally enhancing harvest pressure? I assume an area planted with spat on shell is subject to more harvest activity per unit area. The background oyster population may be reduced beyond what it would have been if the spat-on-shell (SOS) had not been planted.

Discussion
  b. Kellogg: This practice normally happens in place good for oysters to begin with, might be significant population to begin with. Hence monitoring requisites. if you already have oysters in area and do practice on top, what is net impact on what was there before you started

practice. Prob enhancing local fishing pressure in that spot. Throwing that out there for thought

c. Panelisst: You wouldn't put SOS down and wait two years, I might be off base. Legitimate question to bring up. Generally open harvest areas not high enough to open harvest, necessitates planting SOS.
d. Kellogg: No major objections to not putting it in there. We put thought into what data necessary to collect if we wanted to credit this. Just throwing it out there.
e. Reichert: Maybe something to run by Frank to see if it's something he's familiar with.
f. Luckenbach: In MD, what gear are they allowed to use? Dredge?
    i. Reichert: Yes, during certain time periods.
    ii. Slacum: Regulations in place, SOS not designated to specific gear type. Up to discretion of county. Within county boundaries may be areas for certain harvest method. Dredging could be use in this scenario, also patent and hand tong, depends on county.
g. Reichert: Do we put statement in there that put in take fisheries it'd behoove managers that they choose management plan that area remains self-sustaining instead of overfishing.
    i. Panelist: Put in comments that this practice isn't for areas with self-sustaining populations.
h. Paynter: Older populations are likely from plantings in past. Areas that don't have natural spat set or oysters.
i. Reichert: Looking at this from POV of all of our qualifying conditions, there are quite a few.
j. Kellogg: Include note that says bear this in mind. Am I wrong about what is supposed to be in unintended consequences?
k. Reichert: I wonder if it will cause more fishing pressure. Just something to think about. Because we have harvest caps in place, do we even keep this as unintended consequence?
l. Kellogg: There will be more fisherman there for the fact that we will be putting oysters there. We're putting limit on credit, not harvest. Harvest isn't managed on site specific basis.
m. Slacum: I think what you said is important point. Credit isn't going to be so great they're going to overfish if return in investment, might not be unintended consequence.
n. Reichert: We can write statement to that. Resource managers will manage area to prevent overharvesting. Will write a new statement and send to the group for review.

Oyster BMP Expert Panel Meeting, June 21, 2019, 9:30 AM - 12:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Remote
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	No
Andy Lacatell	The Nature Conservancy (TNC)	Remote
Frank Marenghi	Maryland Department of Natural Resources	Remote
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	No
Chris Moore	Chesapeake Bay Foundation (CBF)	Remote
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	No
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Remote
Bill Wolinski	Talbot County Department of Public Works	No
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Remote
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	Remote
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Habitat GIT Staffer, Chesapeake Bay Program	Yes
Guests	**Affiliation**	**Present?**
Jeremy Hanson	Virginia Polytechnic Institute and State University	Yes

Action Items:

1. **Action:** Julie Reichert, Larry Sanford, Lew Linker, CBP modeling team will discuss the use of Oyster BMP in watershed vs. estuary model.
2. **Action:** Julie Reichert will work with Jeff Sweeney to put together a scenario with respect to crediting oyster restoration all at once, will present that to the panel.
3. **Action:** Julie Reichert will put together examples for the Panel on restoration sites with post-restoration, baseline data of varied ages.
4. **Action:** Julie Reichert will add statement regarding lack of knowledge of confounding factors that influence oyster reef densities (could be outside of substrate) to reporting requirements section.
5. **Action:** Will provide ranges seen in data for context to emphasize that reduction values are site specific, will show more conservative values in reporting requirements section.
6. **Action:** Julie Reichert will schedule hour long meeting, send doodlepoll. Will try our best but we may have to proceed with google doc in order to have draft ready by late July.

7. **Action:** Panel should send thoughts on Enhanced Denitrification Interim BMP documents to Julie Reichert ASAP. Jeff Cornwell will put together a presentation on planning estimates for next meeting.

Minutes:

Coordination Updates –

1. Licensed Oyster Harvest Using Hatchery Produced Oysters BMP—Meeting with EPA
    a. EPA requested to meet with Panel to better understand practice, discuss how it'd qualify as BMP. Meeting will take place 6/27.
2. July 8th—Tentative meeting with WQGIT to approve use of interim restoration BMPs (denitrification and assimilation) in Phase III WIPs for planning purposes only
    a. WQGIT is interested in pursuing Interim Oyster Restoration BMPs to allow for a placeholder in WIPs. CBP is working through the technical requirements for applying this to the model. Interim BMP numbers will likely be different than the one that'll be officially adopted.
        i. Cornwell: Will give update on this to Fisheries GIT next week at their spring meeting in Cambridge, MD.
    b. Interim BMP explanation: Interim BMPs exist as values/estimates available when CBP partners want to create "what if" scenarios for planning purposes, but these values cannot be used or reported for progress scenarios where any partner would get credit toward TMDL goals.
3. Bill Wolinski is retiring at the end of this month but is still hoping to attend panel meetings. Congratulations Bill!
4. Frank Marenghi taking over for Lynn Fegley as an official Panel member.
5. Paige Hobaugh is leaving the Bay Program early next month, will volunteer with ORP and continue helping the Panel.

Review Chapter 7 Technical Appendix and Panel's Comments (Restoration-Assimilation) –

a. Review technical appendix for application in the TMDL watershed model (**document that looks at recommendations and says how it can be applied in watershed model, have to be sure what we're recommending can be implemented in this process)**

1. **Discuss credit duration (See PowerPoint example):**
    a. Considerations for application: Converting the site-specific incremental credit to an annual estimate
        i. The way practices would be credited would be different than how panel originally envisioned.
    b. One-time credit to be distributed incrementally. Would be modeled after cumulative BMPs, but a little different.

    Discussion

    c. Hanson: With similar site specific practices like stream restoration, planners know the information to do calculations when the practice goes into the ground, are able to report numbers the years it's installed to receive credit immediately. This one requires you to do monitoring years later to get the number. Rather than try to make it confusing to apply credit retroactively, we can treat that monitoring/sample collection as the year you'd first start to get credit for the practices.
    d. See application guideline for explanation of this concept for inclusion in watershed model.
        i. Hanson: For instance, practitioner does initial planting, goes back years later to take samples/calculate reduction, that's when they can report their reductions for credits,

that's when they get their crediting for the next x-many years (credit duration). Would be provided annually for x-amount of years.

ii. Reichert: t0 is establishing baseline/pre-restoration survey. Next comes the planting activity. Biomass isn't monitored until t3, then do post-restoration biomass/shell survey and calculate estimated reductions/credit at t3 by dividing by 3. In t4 you can qualify for 1/3 of calculation in t3, at t6, the estimate wouldn't be good the following year and you would need to go back and monitor for appreciated tissue/biomass from t3. This allows practitioners to use site specific reductions.

iii. Moore: Looking backwards, seems better to back credit t1-t3 instead of estimating into the future.

1. Hanson: That makes sense from accuracy perspective, but for how model is used, there's no BMP that we credit to previous years. You'd only ever get credit/see benefit when we update model every few years for progress runs. This is run so that states can get idea of reductions they've achieved in that year.
2. Moore: Potentially providing a false sense of hope this way. You're putting in reductions not there, haven't been verified yet for forward looking years. This is the first in-water BMP, seems like a bad road to go down. Credit t3 to t1-t3, we shouldn't assume that number will be the same from t3-t6.
3. Reichert: Saw this as more of a delay/lag. You won't be able to understand real-time what is happening in the system. We want to credit if we saw progress/verifying it also by requiring monitoring data to even establish the estimate. Think of it as a delay. Maybe biomass at t4-t5 doesn't look like it did in t1-t2, then just take it out of the model.
4. Moore: Should we actually credit something that's not there or do we tell permittee you did get x-lbs credit because biomass came back? Seems like a very bad precedent to set to credit stuff that isn't there yet.
5. Hanson: There is no ideal solution to this. Weighing extremely retroactive crediting that's hard to communicate vs. not accurately crediting biomass in proper years. Something to keep in mind – with other BMPs (e.g. forest buffers), practitioners are getting credit for full grown trees/buffers immediately the year it goes in. No BMP is 100% accurate when there are living structures/resources involved. Model is set up to get the sense of what BMPs are providing, more about understanding improvements on ground than it is having every pound correct.
6. Marenghi: I think I agree with Chris Moore. Why wouldn't you just get all credit in t3 for what was already done, you get that credit because its already in the past? Going forward to t4-t6 for projected, either say there's no credit because there's no monitoring or project forward the incremental amounts based on t3, but you wouldn't get any actual credit from t6 until its verified. Get bulk amounts in year of monitoring, it wouldn't be spread out annually.
    a. Hanson: This could be an option.
7. Cornwell: Point of model is to do inventory every year; credit is environmental benefit of whatever your management action was. Think of it that way. We want it to be credited annually if the oysters are there annually providing a benefit. Most BMPs have 10-year credit life – stays in model for 10 years

without verification/inspections, drops off after 10 years if it's not inspected again.

8. Cornwell: When I think about a large scale restoration with multiple rates, the integral of this makes a lot of sense. It's hard to wrap your head around crediting later for things accomplished earlier. Conceptually, it's evening out reef-to-reef annually which is more reflective of reality with variability between reefs on a large scale restoration site.

iv. Sanford: Agreed with Jeff Cornwell. Is this supposed to be applied in the watershed model?
    1. Hanson: Yes, using the shoreline land source.
    2. Sanford: From environmental impact POV, it's not clear the amount of nitrogen taken and put into oyster tissue has same affect if it never entered the bay in the first place. It's misplacing the environmental effect of nitrogen consumption entirely.
    3. Sweeney: You're right. Effect on tidal waters, not on loads.
    4. Sanford: Essentially nutrient trading in a sense. If a reef is restored, there are oysters in bay model as well. Do those oysters not get put into bay model because of their benefit?
    5. Reichert: If state decides to implement it in BMP scenario, would need to remove it from estuary model as to not double count it. State would prefer for oyster restoration to be directly related to their program/load reduction as opposed to global application as it is in estuary model. States want this effort to be recognized toward their reductions.
    6. Sanford: We were going to consider the effects of turbidity as well. Putting impact of tissue formation and filtration on nitrogen and putting it in watershed model removes its effect on turbidity.
    7. Reichert: Will check with Lew on this. He said for certain processes, they'd still leave in filtration part with the sediment component but assimilation/sequestration would have to be turned off somehow in model.
        a. Sanford: interested in having offline discussion with Lew, you, and modeling team on this.
    8. Sweeney: This is simply a way of doing bean counting for TMDL. Solely just for accounting now, science needs to stay correct.

v. Hanson: This is the preferred approach based on how other BMPs are credited. Most logical and acceptable to folks on Watershed Technical Workgroup and the Water Quality GIT. They have most stake/interest in how these practices are tracked and reported in watershed model. Not saying retroactive reporting can't happen, just don't know how it'd possibly work.
    1. Marenghi: No problem with taking same amount of reduction and spreading it over 3 years, just seems different than other scenarios we've previously discussed. Issue with projected aspect vs. when credit is actually given. In other examples, we talked about giving credit in monitoring year.
    2. Reichert: We've had conversations about that with the Watershed Technical Workgroup. There is concern that they can't actually review all data in timeframes necessary to report in CAST.
    3. Moore: We've dealt primary in what a state would get on a timeline, different from model world. Agree that is confusing that there's a mismatch between

what model is saying and what input decks/states are saying. Different conversation between crediting for states and model, want both things to be congruent as possible.

a. Reichert: Jeremy and I can meet offline to throw together example of crediting in bulk.
b. Marenghi: Agree regarding having the two be more congruent, but okay with having them separate if modeling is that different. As long as this isn't in lieu of crediting model for states we discussed earlier. No reason for states to wait 6 years to receive 3 years of credit. If they exist as two separate streams, then I'm okay with this.

vi. Hanson: Added complexity to acknowledge – progress runs/years of BMP implementation aren't calendar year, it's June-July.

vii. Julie: To clarify – this isn't a rate, it's more of a one-time credit. It's based on appreciated biomass. You don't keep getting credit. Unless you keep monitoring and notice you have appreciation over the amount of what you already got credit for. Reef will reach stable state; won't receive credit for maintaining it if it's not appreciating for assimilation. Denitrification is another story, happening every year and credited by biomass, making it worth it to monitor every year. It would benefit state to do both because you have to monitor biomass for both anyway. Until we gather more research with respect to what the give/take and store/release rate looks like, we can only credit to a certain point. With this clarification, are we okay with this is distributed out with 3-year timeframe or do we still want to evaluate what it looks like with crediting full amount and leaving other years out of crediting until monitoring occurs again? Should we do extra evaluation?

1. Moore: Let's continue to look at this. I'm not quite on board yet.
2. Reichert: Will put scenario together with respect to crediting all at once, will present that to the panel. Jeff Sweeney will work with me on this, we'll list the pros and cons.

viii. Hanson: Then it would become strictly annual BMP, receiving credit in only year you monitor/report it.

2. **Discuss monitoring timeframes:**
   a. How old can baseline data be?
   b. How long can you wait to monitor after restoration activity to apply for credit?

Discussion

c. Reichert: Some restoration projects that have been ongoing since 2009, no BMP at the time so they didn't monitor baseline the way we hope for. Some options for those situations – 1) they can use existing data from the area (e.g. baseline for Harris Creek pre-restoration) or 2) could then choose reference/representative location nearby they can establish a baseline that way. Is there a timeframe we think is too old? I think if its post 2009 that should be fine.

d. Hanson: What are those constraints for being able to report this as a BMP as the Panel defines? How long to wait to monitor to receive credit?

i. Reichert: Harris Creek ongoing for 6 years now, they don't necessarily have monitoring data.

ii. Moore: In VA, nothing that's complete yet in terms of monitoring data.

e. Reichert: Any reefs in MD that don't have monitoring data 3 years post restoration?

i. Slacum: Most effort has been on reefs in tributaries, still done at state level. Unlikely to work with reefs planted over 10 years ago.

ii. Reichert: Would it still be ok to receive a restoration credit for work done 10 years ago?
iii. Hanson: Once you're beyond 3-year window, then you'd likely have to use baseline/reference site approach. What do we say if there's a project and funding runs out in year 3 and can only go out to monitor in year 4 or year 5, what is our response to that?
iv. Reichert: Will put some examples together for this one, present to everybody and see how it plays out. One we have to think a little bit more about.

3. **Review Reporting Requirements – see Interim BMP document:**
   a. See restoration-assimilation interim BMP example
      i. Should BMPs be based on the type of substrate used too?

   Discussion

   b. Reichert: Will try to send something to Fisheries GIT on Monday. This document breaks it down into 3-year timeframe. For planning BMP that should be fine because it's just numbers, even a little bit conservative. Could look very different from approved BMP. Dividing by 3 and distributing along longer timeframe might be better.
   c. Reichert: Something to note – looking Harris Creek data, big difference in oyster density/biomass between different substrate sites. Grouped by stone/fossil shell (larger reductions) vs. shell based. We don't mention anything in our recommendations right now about having different substrate act as different BMPs – this might be a really important point. Instead of averaging all sites together? Leave it up to implementers to separate by substrate type?
      i. Cornwell: Most of our data falls within shell base, denitrification is just limited to shell base. Want the protocols to be able to work together. Might not be worth separating.
      ii. Moore: Is it oyster density or substrate that makes the difference, driving difference in biomass?
      iii. Reichert: What drives N and P reduction is oyster biomass at a site. Higher density generally means higher biomass, more reduction associated with that. A program that uses alternate substrate that's stone like, get credit for acres that they plant at higher reduction/year, shell based would get a lower one. If they're planting SOS only, if they're just planting substrate they automatically get lower value.
      iv. Marenghi: If it's just from oysters, not some chemical from base itself, leave this part out. Lots of variability in densities these are planted at, don't understand differential mortality between different bases and potentially issues with sampling, substrates are sampled using different techniques. Not clear to me that we'd expect large differences in density based solely on substrate base without having a full understanding of other variables.
      v. Reichert: If we don't care what treatment type you're using and you get credit for what's there, it may just look at individual reef in Harris Creek vs. all Harris Creek reefs averaged together.
      vi. Slacum: Question itself about presenting this as shell based vs. alternate substrate was more important when we had this broken up into market categories. If you in future biomass estimate done at reef level, wouldn't need to worry about this.
      vii. Reichert: This is just to provide a conservative average number. This is a site level estimate, regardless of stone/shell based, would be assessing at reef level what estimate looks like.

viii. Moore: Did sampling in one VA restoration tributary; biggest indicator of success was placement along river. Hardly any correlation with substrate type. Site specific piece is the right way to go.

ix. Reichert: Will add statement we don't know confounding factors that are influencing densities (could be outside of substrate). For planning purposes we could keep these separated.

x. Hanson: Purpose of planning BMP is doing "what if" scenarios, we can't predict future. Having just one number is the way to go – averaging or using a more conservative value unless people know exactly what kind of substrate they plan to use. Keep it simple because it's just a planning BMP.

xi. Moore: We're oversimplifying. We're using Harris Creek to be representative of entire Bay system and we know that is not the case for whole Bay. Have to go with most conservative number.

xii. Reichert: CBP needed a number ASAP for planning. We recognize it could look very different at a site level. Will modify this to show more conservative value. Will provide ranges we've seen in data for context, to send home that point values will be site variant/specific.

4. **Substantial Comments from Panel Review:**
   a. Reichert: I could send this section as google document that people could add comments under each question I had or schedule another shorter meeting to handle them.
      i. Bricker: I prefer meeting so we can discuss.
   b. Reichert: Will schedule hour long meeting, send doodlepoll. Will try our best but we may have to proceed with google doc in order to have draft ready by late July.
   c. Comments to Consider:
      i. How to determine which acres the average N and P reduction (lbs per acre) apply to? Do we need a minimum amount of spat or substrate that should be planted to qualify for BMP?
      ii. Refers to example: When determining how many oysters to measure from the samples, what is considered "small." Do we want a lower size limit, e.g., all oysters >25mm since smaller oysters have minimal biomass?
      iii. What constitutes a sample for the recommendation, "a minimum of three samples should be used to establish the average pre-restoration and post-restoration live oyster tissue and shell biomass."
      iv. Who do we mean by "reef expert;" include such as…

Review of Enhanced Denitrification Interim BMP –

   d. Discuss change to averaging approach to minimize estimates that would be needed for reporting in the watershed model (current approach could result in a total of 12 estimates per site if sampling is done during all the months)
      i. See enhanced DNF interim BMP example for a possible averaging approach.

Discussion

5. Cornwell: Made a planning document for planning/interim BMP for Fisheries GIT Chair Sean Corson. Using Harris Creek data, I parsed out low med high biomass to split up denitrification. Lisa split up between dark/light hours and seasons. Came up with average between seasons as 57 pound/acre for denitrification. We are not 100% on same page that light may not be driving factor. Bottom line provided season number on low end, confident that it'll hold up to level of scrutiny necessary for planning.
6. Bricker: What are the thresholds between biomass categories?

    a. Cornwell: Low: less than 75, medium: 75-225, high: <225 grams/m^2

7. Cornwell: Any thoughts you have on these documents, send to Julie Reichert ASAP so we can modify. These are supposed to be simple, conservative planning estimates. Will put together presentation for meeting.
8. Reichert: These exercises have been helpful in providing recommendations with respect to how to apply these credits/practices. Gave me confidence we could implement these moving forward.
9. Reichert: Currently, enhanced denitrification chapter is written in way of seasonal timeframes (3 months – spring starts in March, April, May). Eye opener to me with respect to Jeff's approach averaging over warm months gave same results as we did with smaller time frame. We can provide twelve estimates per site way its written right now. In working with interested Watershed Technical Workgroup members, I realized that it might be more difficult for them to work into model with twelve different estimates for each site. If I sample in spring summer fall, can I average one value that'd work for those seasons for easier implementation into model? Maybe more simplified approach is fine, modeling folks would be thankful.
10. Moore: They'd have to do at least 3 samples per year for a baseline right?
    a. Reichert: For denitrification, they'd use a reference site for baseline. Do that one time to establish baseline at restored rate. But it's based on biomass – for verification standpoint, have to go back out and monitor level of biomass. If values are retained they can keep rate of reduction for credit, any less and they lose credit.
11. Marenghi: I support using one number for denitrification vs. twelve. Maybe some percentage would be more appropriate vs. an average. Wouldn't be minimum, but likely wouldn't be average either.
12. Reichert: Something we can meet up with Lisa and talk about, present new approach to panel.

Oyster BMP Expert Panel Meeting, July 24, 2019, 9:30 AM - 12:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Remote
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Remote
Andy Lacatell	The Nature Conservancy (TNC)	Remote
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Remote
Frank Marenghi	Maryland Department of Natural Resources	Remote
Chris Moore	Chesapeake Bay Foundation (CBF)	No
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Remote
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Remote
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Remote
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	No
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeremy Hanson (WTWG Rep)	Virginia Tech (CBP)	Remote
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Remote
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Paige Hobaugh	Volunteer, Oyster Recovery Partnership	Yes

Action Items:

1. **Action:** Panel will stick with site specific denitrification estimate approach for each of the 4 seasons; add to Research Gap section what'd be helpful data wise to develop future default estimate.
2. **Action:** Julie Reichert will include a statement in reassessment section stating that if those who evaluated light and dark in summer and determine that light doesn't matter after 1 year can apply just the dark rate to summer. This is seasonally dependent.
3. **Action:** Panel will recommend reassessment of Enhanced Denitrification BMP every 6 years.
4. **Action:** Julie Reichert, Jeff Cornwell, and Lisa Kellogg will look into recommending the use of biomass ranges/thresholds when assigning denitrification credits.

5. **Action:** Panel agrees to add a note regarding the lack of information on alternate/artificial substrates and reef ball denitrification to research gap section.
6. **Action:** Lisa Kellogg will send Oyster Restoration Workgroup website link to Julie Reichert.

Minutes:

Coordination Updates

1. July 8th—WQGIT approved interim restoration BMPs (denitrification and assimilation) for planning purposes only
2. Panel review of denitrification chapter—August 5-August 19
    a. Julie Reichert is aiming send this chapter out August 5th, depending on the outcome of this meeting. Chapter will be about 60 pages long, will take time to review. First two sections are complete, application and verification samples will be done after decisions are made today.

Enhanced Denitrification BMP Discussion, Jeff Cornwell

1. Can we simplify seasonal calculations?
    a. Discuss seasonal timeframes—can there be an option for just evaluating a warm season?

   Discussion

    b. Cornwell: The balancing act of this chapter is applying what we know about influences (e.g. light, season) and recommending something that is useful from a management perspective for implementation. We need to make sure we capture elements that make quantitative differences with respect to calculating annual rate while at the same time not making it complicated. For the interim BMP calculation that we provided NOAA to bring that forward to Water Quality GIT (WQGIT), we used warm season data - Lisa split datasets into low/medium/high biomass, used biomass numbers for 6-month period. For this number, what is important for seasons? How should we parse out seasons? This needs to be a number less than 12, but more than 1. We can't expect people to be monitoring on a monthly basis. My preference is to push for seasonal part of this, but to allow for warm season series of measurements to extrapolate to a 6-month period – this would account for 60% of the denitrification if not more.
    c. Reichert: We can calculate that reduction using different rates. We could assign the BMP by season - e.g. "Summer Season X BMP". This is one idea of Jeremy's. It would provide more flexibility.
        i. Hanson: There could be other ways to approach it.
        ii. Reichert: The warm season option would be for a group that didn't want to measure in winter. If they wanted to do winter, they'd have to sample for all 4 seasons.
        iii. Cornwell: This essentially becomes subset of annual. The months would have to be rearranged.
    d. Cornwell: We began by going out 4 times/year to measure denitrification rates per season. If you don't do all 4 seasons, you stand to keep denitrification behind on site. How could we extrapolate this to one number to simplify process?
    e. Cornwell: Based on what Lisa and I did earlier, warm season would be May-October. A few of those months are in fall and one is in spring. That is how we would parse out a half year assessment for warm season. We don't have a sense of what in the end someone implementing this will choose to do.
    f. Kellogg: Are we rejecting the seasons we originally established?
    g. Cornwell: The seasons we have now on annual basis make a lot of sense based on data we have, but if you were to pick 6-month warm season with # of measurements, what would that look like?

i. Reichert: To be conservative, can we use these seasons, cut out May? Possibly truncate the fall season, make measurements in June, July, or August, then one in October or September.

h. Cornwell: Leaving May out will leave denitrification behind, including October would result in an over-credit. The net of this probably doesn't matter at all. If we stick with original arrangement, in the end we'll come to exactly same place. The measurements are variable enough, it probably won't matter if we say use these same groupings of months.

i. Reichert: For application, we want to offer flexibility in options, but offering too many options may overload practitioners. Maybe provide guidance paragraph about optimal measurements (e.g. summer, fall for 6-month warm period).
   i. Cornwell: We don't have detailed measurements to base number this off for every month.

j. Paynter: Has there been consideration of contribution of gametes to water column? They lose body mass.
   i. Cornwell: That nitrogen loss from oysters will likely pale in comparison to denitrification. We should take a look at this.
   ii. Reichert: More likely related to assimilation. We only credit live tissue biomass.

k. Cornwell: Are people comfortable with spring, summer, fall, winter parsing? If need be, would a subset of summer and fall would be adequate?
   i. Wolinski: Is this only applicable for 6 months of the credit?
   ii. Cornwell: Correct, would zero out winter and spring.
   iii. Kellogg: If they take measure in season, they get credit for that season, if not, they don't get credit for that season.
   iv. Reichert: Small timeframes will force people to go out and take more measurements, will help seasonal data.
   v. Cornwell: Will benefit all future reiteration to have season sample data, but from an implementation/enforcement standpoint, it's not necessary.

l. Luckenbach: Is there a low-end from studies that have been done that you could say with no measurements, we could count the fall in? In the spirit of what you're talking about now - opt in for something that'll provide less credit, but is less costly.
   i. Cornwell: I think so, yes. Maybe we can add a note saying that at some point with more information a default can be implemented.
   ii. Reichert: Would that be similar to what we did for the interim BMP?
   iii. Rose: To build on that, perhaps in the future you have baseline level of biomass, you can assign very conservative default estimate to denitrification. Would provide a pathway moving forward that a future panel could assess.
      1. Cornwell: We need a statistical basis for picking that number.
      2. Kellogg: Doable, but the challenge will be that biomass threshold is different for intertidal vs. subtidal reefs. Rate assigned would be different for shallow light reefs vs. deep reefs. Would end up being 3 default estimates.
      3. Rose: Could have 1 default number, but we'd use the most conservative rate.
      4. Kellogg: Problem with that. Intertidal numbers require a high amount of biomass to estimate, most restoration sites would have a hard time reaching that.
      5. Rose: If we see pathway forward for future panels, path of least resistance to default estimates, we should include that in the report.

b. Luckenbach: Worth articulating at least that like other BMPs, we can put a number on this. For now, it's simply based on too few experiments. Should include this in moving forward section.

c. Cornwell: I envision in 5 years we could prescribe a default estimate with enough data from practitioners. Somewhere down the line it'll be helpful for implementing this more widely.

Action: Panel will stick with site specific denitrification estimate approach for each of the 4 seasons; add to Research Gap section what'd be helpful data wise to develop future default estimate.

2. Discuss light and dark requirements. Include caveats about light denitrification rates if light is shown to have little effect on reef incubations?

Discussion

- **a.** Cornwell: The only dark and light information anywhere is created by our two labs. Light makes huge difference with respect to net denitrification. With respect to Harris Creek data, 53% of the time we get a higher rate on daily basis if we take only dark into account. Turning on lights in sediment creates autotrophic uptake of ammonia, decreasing bioavailability for N_2 production.
- b. Kellogg: Are the numbers that make no sense we get doing light incubations included in calculation of percentage?
    - i. Cornwell: No.
- c. Kellogg: I think your values of about 50-50 are skewed. We have fewer values for light than we do dark.
    - i. Cornwell: Light is dominant. If in a system if it's clear that light doesn't make a difference, do we continue to require it? They could eventually make the argument that light incubations are not necessary, until we have a compelling amount of data to exclude in our recommendation.
- d. Kellogg: Does it make more sense to say in the future this can be considered or should we put it in now?
    - i. Reichert: We could put this in application guidelines, say this is to be re-evaluated.
    - ii. Cornwell: The reason to not take dark data from outset, we don't have large enough sample or good enough understanding to immediately exclude light as an influence.
- e. Parker: Is there any situation where someone would only make light measurements and apply to light hours and never take dark estimates?
    - i. Cornwell: We're still developing basic understanding of these processes, excluding light is a problem at this point.
    - ii. Reichert: Will add recommendation saying not to do just light measurements.
- f. Paynter: The presence of benthic algae can reduce denitrification rates. Is that number anywhere close to the assimilation rate of oyster tissue itself?
    - i. Cornwell: Not sure the answer to that
    - ii. Kellogg: I hesitate because we have data from intertidal sites with lots of microalgae present that shuts down denitrification - it sucks up ammonia that allows denitrification to happen. It'd be hard to describe it as anything long term with respect to nitrogen removal - microalgae lasts usually a year.
    - iii. Cornwell: Algae moves around, decomposes to its original constituents. It's removing nitrogen, but where it decomposes you add it right back.
    - iv. Luckenbach: It's very much the case in high density clams, that seasonally, there's as much nitrogen in standing stock of algae as there is in clams. Since standing stock overturns a lot, there's a high uptake rate, but the rate of turnover of algae just put the nitrogen right back in the system.
    - v. Cornwell: Whether buried or denitrified, nitrogen goes back into the system.
- g. Cornwell: Assessment of light should be part of recommendation. It's up to those making measurements to determine whether light is unimportant before it gets deleted. Cost of doing dark and light is a tiny fraction of total cost. Just a few more hours of incubating is a drop in the bucket compared to other costs of assessment.

Action: Julie Reichert will include a statement in reassessment section stating that if those who evaluated light and dark in summer and determine that light doesn't matter after 1 year can apply just the dark rate to summer. This is seasonally dependent.

3. Discuss timeframe when estimates should be re-evaluated. Five years has been proposed.

Discussion

a. Cornwell: Credit can't be run on forever even if biomass persists, what is that cutoff number?
b. Reichert: When do these values need to be reassessed? CBPO is looking for a credit duration. How long can they apply this during the model, is there anytime this expires/needs to be reassessed? For example, floating wetland BMP requires 6-year verification.
c. Cornwell: Harris Creek has a 3-year rotation for assessing biomass. Some multiple of that time frame - possibly 6 like other BMPs, make it some multiple of 3.
d. Luckenbach: The frequency with which things are being assessed is variable. Biggest amounts of money going into sanctuaries in VA are USACE dollars and like any of their restoration projects, they require to monitor out to 10 years post restoration, but not beyond that. Would be necessary to put in minimal reassessment by X number of years or it gets taken out of model.
e. Paynter: 3-year rotational survey would take care of most of data needs we have to determine denitrification rates and other things.
    i. Reichert: Denitrification rates are associated with tissue biomass. Denitrification rates are expensive to measure right now, why were linking it with biomass (much easier to assess). Maybe the 6 years makes sense, long enough window for money invested to receive credit. We don't have long term datasets for denitrification rates. Reassessment at 6-year mark would be helpful.
    ii. Hanson: Some BMPs have a lifespan of 30 years or longer, but credit duration is only used in the model. How long cumulative BMP stays in model until it's verified again or it's removed from model.
    iii. Paynter: Difference in life cycles - we have oysters that live 10-15 years, but we don't have recruitment to replace the animals. In south VA, oysters have 2-3 lifespan but natural recruitment that replaces that. How are those different types of environments encompassed by what we're doing here?
    iv. Rose: Ok with denitrification being longer, 6 years is fine. Good to tie it in with other activities, like both of those ideas.

Action: Panel will recommend reassessment of Enhanced Denitrification BMP every 6 years.

4. Discuss using biomass ranges to assign denitrification credit

Discussion

a. Reichert: Per the biomass recommendation, practitioner establishes the denitrification rate at a known biomass and verifies that biomass anytime they want to claim a denitrification rate. If biomass decreases, they can proportionally decrease the denitrification rate and still get credit. They can only receive credit if the measurement is above 50% of the original biomass. This is different than the interim BMP rates. I'm wondering if there is a range of biomass that as long as you maintain that range of biomass you can apply the same rate instead of proportionally decreasing it? Can be complicated to have to work with different rates/season.
b. Kellogg: the Interim BMP low, medium, and high categories are arbitrary. They represent natural breaks in dataset where we had a gap in biomass values between 75 and 150 and another between 225, an artifact of the study we had in hand when we chose the categories. Biomass categories will end up being site specific, the same reason we can't give a default minimum estimate. Curves are different for different sites, where to put breakpoints varies by what site you are working in.

c. Reichert: This might complicate things for technical appendix. May have different rates you're working with in one season depending on which season. Using average biomass for verification, but comparing it with biomass used to determine denitrification rate. If the biomasses aren't the same, we have prescribed rules that require practitioners to adjust/reduce rate.
    i. Hanson: My confusion was for assimilation BMP to get reduction credit you need appreciation of biomass sequestered in shell, is it the same for enhanced denitrification?
        1. Reichert: No. Totally separate from assimilation. We are measuring new denitrification annually. New reduction happens on an annual timeframe as long as you maintain oyster biomass vs. one-time credit of what's stored in tissue and shell in the assimilation BMP. Annual vs. one-time credit.

d. Reichert: We need to consider simplifying this, no other BMPs do this. Not sure how to do this; +/- 25% with change in biomass?

e. Cornwell: The issue here is that we need to establish a threshold number.
    i. Reichert: If I create my denitrification rate at 100g/m^2 and it's at 75g at reassessment, are we okay with 25% mass decrease and ok with applying the same rate? Is there a window you'd be comfortable allowing? A range that's acceptable for rate of denitrification to be used?
        1. Cornwell: I'm comfortable with 75% of the original biomass baseline.
        2. Kellogg: 75-100%, 50-75% seem like reasonable thresholds to consider.
    ii. Luckenbach: Pay attention to levels of 15g biomass/m^2 and 50g because those numbers are embedded in the metrics document and plenty of folks have accepted that as threshold.
        1. Kellogg: We had a hard time getting rates at less than 15g biomass in our study trays.
        2. Reichert: Maybe we should prescribe minimum biomass before even going out to measure for denitrification rates.

Action: Julie Reichert, Jeff Cornwell, and Lisa Kellogg will look into recommending the use of biomass ranges/thresholds when assigning denitrification credits.

5. Discuss which acres estimates apply to acres with alternative substrate?
    a. Large-scale oyster restoration projects include a mix of treatments (planting shell substrate, planting alternative substrate, planting spat-on-shell, no plantings if biomass is at target amount).

Discussion

b. Reichert: State representatives are looking at total goal of restore acres, e.g. there are 350 acres at Harris Creek, and are looking to apply estimates for the entire 350 acres even with different substrate types. Rates could vary quite differently - it may not be appropriate to extrapolate estimate derived from granite site to shell based area. If someone is developing a rate at shell based substrate can they extrapolate out to alternative substrate types or do they need a rate for each type?

c. Kellogg: Total lack of data with respect to denitrification and artificial/alternate substrate. Haven't figured out how to study it. Sny decision being made is being made in complete absence of data.

d. Paynter: To give credit to type of substrate down there will be hard to quantify.

e. Luckenbach: Possibly more of an issue with scaling up and distribution of substrates than with the type. For example, a project not on the ground yet, Virginia Beach/USACE joint application for restoration in Lynnhaven River, depending on how far dollars go, anticipate the project being 4-8 acre scale with cylindrical hollow concrete structures that will cover 14% of the area.

If nothing else, we have to consider how one scales up from something like that. Even with a measurement, someone needs to multiply that by 8 acres when in fact it's only 14% of 8 acres. Not sure what arrangements been done with granite, but reef balls/oyster castles make no attempt to create something that looks like full coverage. Commentary might need to be as much as scaling up your measurements as what the substrate type is.

f. Wolinski: In Harris Creek restoration project, they are big sites. Isn't there a metric established to determine biomass in different areas and they are averaged?
    i. Cornwell: Yes. We don't have those numbers, but I'd expect that we're not going to be terribly different than other kinds of substrate.
    ii. Reichert: Is there a metric that says we need to cover X-amount of area in your restoration activities? Ward would know this.
    iii. Kellogg: Success measurement is that restoration covers 30% of the bottom. Are we to say that if a successful reef that doesn't reach 30% it doesn't receive credit?
g. Paynter: We have to be careful about crediting substrate vs. oysters.
h. Kellogg: All credits come from reefs that don't come from artificial substrate, we should add caveat saying that these are the best findings we have. No data for SOS on granite or else, but because we don't have data and no reason to believe the values would be different in those instances, to the best of our knowledge, this is what's happening on granite reefs until we can say otherwise. Regarding the reef ball/castle question - fundamentally different from materials planted on bottom with no large space in the center like a reef ball.
    i. Paynter: Reef balls increase surface area upon which animals can recruit to including oysters. Construct is in another dimension compared to shells and granite.
    ii. Luckenbach: What lisa said needs to be in this document. Virginia Beach would be someone who wants to apply for this. 2 concerns: 1) these estimates do not apply or need to be applied with caution and 2) needs language about the care that must be taken when extrapolating to full areas because these structures are placed distances apart from one another.
    iii. Wolinski: On larger scale ball installations, would be easy metric to calculate surface areas and extrapolate out to surface area or projected area.
    iv. Cornwell: Mark is right. They can't put enough out there and extrapolate to make sense with respect to other substrates when considering denitrification. 450 at site covers hardly any area, but rates are high per ball, just not enough of them. Numbers need to be higher for denitrification to be quantitatively important.
    v. Kellogg: Justification for not crediting reef balls in the same way - those oysters are living above substratum and when we look at oyster aquaculture numbers, we don't see a lot of enhancement.
    vi. Cornwell: Larger structures are not part of this current BMP. This will be site specific, literature is just not there.
    vii. Paynter: Fundamentally, it's an improvement of bottom were talking about, enhancing the benthic community.
i. Recihert: As a compromise, we can add this to research gap section. Not saying this can never be credited, we just don't know how to credit it right now. More data needed to understand. Our definitions are more suited to on bottom plantings with oysters in contact with substratum.
j. Cornwell: On alternative substrate, best professional judgement, use numbers used for more standard approaches to those barring some assessment that shows its out of whack.
k. Kellogg: We need to make a clear definition of artificial substrate.
l. Paynter: Name a few specific examples and include "until further notice" statements.

m. Reichert: Panel agrees that if someone measures denitrification rate at site where they planted shell, they can apply that to a site they planted SOS to granite. They must tie substrate to oyster biomass.

Action: Panel agrees to add a note regarding the lack of information on alternate/artificial substrates and reef ball denitrification to research gap section.

Review Chapter 7 Technical Appendix and Panel's Comments (Restoration-Assimilation)

6. Technical appendix for application in the TMDL watershed model
    a. Revised example to reflect that crediting of monitored assimilated live oyster biomass can be credited within that year.

Discussion

b. Reichert: To apply to model, it's the monitored amount, not the planted amount that generates site specific estimate and when BMP becomes active. For example, at t0, I did my pre-restoration survey to establish my baseline. Have my sampling plan reviewed and approved by CBPO and going out there to do plantings, designated my area that this could apply to. Then I plant in designated BMP area (must be in place to make sure you can scale up your measurements to that area - we recommend that you consult with an expert to acquire enough sampling points to be able to scale up). t3 is the time for post-restoration survey for biomass. You only get credit for what is appreciated over the t0 baseline. It becomes active for crediting, apply that amount by multiplying by percent contents. That biomass is then complete. I get a one-time credit in t3. The reef could still be growing, so no activity at t4 or t5 - could plant more if you'd like, but you receive no credit in t4 or t5 because there's no evaluation. You evaluate in t6 and compare appreciated biomass over t3 numbers - would receive credit in t6. This situation better matches what panelists at last meeting were talking about.

c. There were no Panel objections.

7. Substantial Comments from Panel Review:
    a. How to determine which acres the average N and P reduction (lbs per acre) apply to? Do we need a minimum amount of spat or substrate that should be planted to qualify for BMP?

Discussion

b. Rose: My initial reaction, given that credit is proportional to biomass, is if biomass is limited, credit will be negligible. There's an administrative burden that'd keep those from even filing if credit would be little.

c. Reichert: A concern we need to add a definition for?

d. Reichert: If I want to achieve 50g of tissue/biomass, is there any guidance on how much SOS I need to be planting? It'd be nice if we could provide general guidance.
    i. Kellogg: Concerned that this is more site specific than just Harris Creek numbers. Concerned that this is a deviation from our charge; the range is going to be so broad as to not be useful.
    ii. Paynter: I have tried to help with aquaculture ventures. Someone with a fair amount of money asks how many SOS do I need to plant my 10 acres. The answer always depends on where, on what substrate.
    iii. Reichert: We'll just say to defer to an expert.
    iv. Rose: Are there restoration best practice guides that exist? We should point people to existing literature instead of creating something new.
    v. Paynter: MDSG has publications for how much shell to use, something we used in previous reports.
    vi. Kellogg: Information on Oyster Restoration Workgroup site as well - will send Julie link.

Action: Lisa Kellogg will send Oyster Restoration Workgroup website link to Julie Reichert.

e. Refers to example: When determining how many oysters to measure from the samples, what is considered "small." Do we want a lower size limit, e.g., all oysters >25mm since smaller oysters have minimal biomass?

Discussion

i. Reichert: Situations with samples that you'd have subset of measurements that can be extrapolated out to full sample.
ii. Kellogg: Don't want someone to measure 50 tiny spat and 3 large oysters and develop a regression from that.
iii. Paynter: I think that Rogers surveys are binned into 5ml science bins?
    1. Kellogg: Report to 1ml but bin them into 5ml bins on the website.
iv. Reichert: To simplify, add statement that larger oysters have larger biomass. If people end up measuring small oysters, they can add them in. It's up to their discretion.
v. Paynter: Is there any document that tells oyster growers/managers that would represent a simple graph of size vs. denitrification?
    1. Cornwell: Table from first report that does that. It would tell people whether it's worth looking at lower size classes.

f. What constitutes a sample for the recommendation, "a minimum of three samples should be used to establish the average pre-restoration and post-restoration live oyster tissue and shell biomass."

Discussion

i. Reichert: Whatever your random sample is, we don't want to put a requirement on it. Use random sampling design.
ii. Cornwell: For larger restoration projects, is that 3 per reef?
    1. Reichert: Yes. We can make that clearer in here.
    2. Paynter: 3 per cohort not per reef.
iii. Bricker: Oyster growers in Maryland started using 100 oysters/sample when small, 50/sample when larger. Just curious, is 2 oysters per sample enough? What is representative?
    1. Paynter: Not sure how much we discussed this yet. For example, MD DNR performs dredge pull, scrape, or patent tong sample and will push that sample into 5g bucket and level it off. The count becomes how many spat, small, and market size in that bucket. Volumetric way of doing the sample, not representative spatially. Important if possible to say there needs to be aerial/spatial estimate of abundance to some degree.
    2. Cornwell: Aerial is our metric. Established by experts to help you extrapolate that.
iv. jeff: When we say "reef expert", states will likely identify the expertise.
v. Reichert: Will address this definition if it comes up in public comments.

g. Outstanding Items
    i. Will be finished via email, there's not enough free time for everyone to meet again soon.

Discussion

ii. Rose: Folks want biomass and denitrification credit. We recommend temporal baseline for biomass, we might want to consider recommending a temporal baseline for denitrification.
iii. How old can baseline data be?
iv. How long can you wait to monitor after restoration activity to apply for credit?

Oyster BMP Expert Panel Meeting, September 5, 2019, 1:00 PM – 3:30 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Frank Marenghi	Maryland Department of Natural Resources	No
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	No
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeremy Hanson (WTWG Rep)	Virginia Tech (CBP)	Yes
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	Yes
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership	No
Support Staff	**Affiliation**	**Present?**
Guest	**Affiliation**	**Present?**
Jennifer Walters	Oyster Recovery Partnership	**Yes**

Action Items:

1. **Action:** Include statement in report outlining that you can incorporate higher rate if it applies
2. **Action:** Will clarify habitat characterizations in text (e.g., "Expert that can help assure that at least one sample is taken in areas with different habitat characteristics such as…..")

3. **Action:** Julie will add language to clarify that sampling design should reflect habitat characteristics. Also add comment that baseline can have fewer replicates than restored site
4. **Outcome**: Vote to remove time-based approach to remove confusion (unlikely that this process would be used)
5. **Outcome:** At a minimum going out at least every 3 years to reassess biomass – make changes in text; CBP could expect data at 3-year mark and if not, remove BMP, if data qualifies then they would allow it for additional 3 years
6. **Outcome:** Do light measures to prove that light is not hitting the bottom
7. **Outcome:** Add language to requirements that if you are previously stating that light is not reaching the bottom that you would need to confirm this at 3 year reassessment

Minutes:

Coordination Update

- **Goal**: Submit draft report as of September 30th; have another follow up meeting in November after submission

Review of Enhanced Denitrification BMP Chapter

Discussion:

- Oyster BMP for Denitrification is unique compared to other BMP's
- Using oyster tissue biomass as a way to verify denitrification rates
- Julie comments on misunderstanding of reassessment by clarifying that reassessment means re-opening panel
- When establishing site-specific rate, if you maintain that biomass you can then get credit for that rate (pg. 25, 42, 53)
    - Should be an option to apply new rate
    - Jeff and Mark agreed that wording was safe to say that when new data was available there can be a re-assessment
    - **Action:** Include statement in report outlining that you can incorporate higher rate if it applies
- Pg 28: (Comment brought up by Chris) – Comment about consulting reef expert to determine sampling plan (dependent upon how much area that reef covers)
    - Chris had asked if there were general guidance or size ranges of reefs vs. having too much variability in reef sizes
        - Lisa – Votes for consulting expert; gave example of variability in size of reef that are within 100m of one another
        - Chris – What are guidelines for consulting an expert?
        - Mark – How is an expert going to set a starting number/make an estimate
        - Lisa – There can be large variance in environmental conditions for reefs that are not that far apart – even if the biomass is the same there may be different rates for denitrification (ex. Difference in amount of macroalgae cover; would need to take samples in different sections of the reef); concern is that there is not that much data
        - Julie comments on updates to text that better defines expert as one who understands BMP compliance or denitrification process versus just expert in oysters
        - Ken suggests expert as statistician

    - Lisa Kellogg – should have one person look at the reef and outline what habitat types exist and the sampling procedures that correspond – concern is trying to get the person to do that (statistician alone would limit expertise)
    - Chris agrees for one sample collected for each habitat type in the area
    - Julie – Can key elements for habitat type be included in report (i.e. sediment type, depth, substrate, light availability, biomass etc.)?
      - **Action:** Will clarify habitat characterizations in text (e.g., "Expert that can help assure that at least one sample is taken in areas with different habitat characteristics such as…..")

Review Comments from panelists

From Frank:

- Pg 37 – Using representative site as baseline to determine restored denitrification site rate
  - Want to clarify that you only have to go once to determine baseline
  - From resource standpoint, denitrification project done all at once versus the timeline approach (where this is not an issue)
  - Jeff thinks this is an issue where you have very low points in the reef that are not much above baseline – if using cores, he agrees that using 3 or 4 of those is plenty
  - Julie - Is it different depending on site characteristics on how many samples and reference points you need? – should this go back to consulting an expert? Is it confusing stating that you need a minimum of three replicates?
  - **Action:** Julie will add language to clarify that sampling design should reflect habitat characteristics
    - Also add comment that baseline can have fewer replicates than restored site
  - Possibly a non-issue when removing 6 year follow up text – once you establish baseline there is no need to reassess the baseline site/reference rate at 6 year mark but instead just measure restored site and compare to original reference rate to determine denitrification rate
  - **Action**: Julie decides that she is adding clarification sentence to only have one rate for reference from original baseline site that they can then compare to future restored sites; Text clarification about Size of MP area is up to influencing program

- Pg 43: "If the difference is more than 25 grams (at the low end) you can use that rate

From Lisa:

- Opinions on switching between approaches
  - Jeff says it would be a problem if they did the time based approach and saw large differences with reference sites
  - Jeff states that denitrification is greater in certain seasons
  - Lisa comments that there is a lot more variability annually than what is being considered
    - Better to have reference points at same point of year
  - **Outcome**: Vote to remove time-based approach to remove confusion (unlikely that this process would be used)
- Pg 42: If a denitrification rate is established at a known biomass can that same rate be used for 3 years – reassess after 3-year mark and can continue to use that rate unless it drops below a point where that rate would not apply anymore (5?)

- Lisa does not think its viable to ask people to go out every year to reassess in order for them to get the credit
- Julie brought up comment from Jeff Sweeney that the CBP looks on a decade scale rather than annual scale (not as concerned about over crediting from year to year)
- **Outcome:** At a minimum going out at least every 3 years to reassess biomass – make changes in text; CBP could expect data at 3-year mark and if not, remove BMP, if data qualifies then they would allow it for additional 3 years

- Pg 42: Qualifying condition that if there is light hitting the bottom you need to measure the rate of light
    - If you have macroalgae present at site, light is hitting bottom – would not need to measure light – need to prove that you don't have to do light incubation
    - **Outcome:** Do light measures to prove that light is not hitting the bottom
    - If there is a change where previously only using dark rates but now light is reaching the bottom – prove at 3 year assessment that light is still not hitting the bottom?
        - If restoration is successful, turbidity should decrease allowing light to reach further
        - **Outcome:** Add language to requirements that if you are previously stating that light is not reaching the bottom that you would need to confirm this at 3 year reassessment
- Pg 45: Seasonal prioritization – summer is clearly the highest priority but other seasons cannot really be ranked due to variability among regions
    - Leave the text as open ended as possible to not restrict people from doing it in the season that they would like
    - Change: We can recommend that if funding is limited to do Summer only but any additional season is up to person
- Pg 45: Choosing the reference site could be qualitative instead of quantitative - might not need as many
    - Remove biomass requirement? – not necessarily capturing all of the information needed
    - How do you constitute what establishes a good reference site and what are the requirements besides biomass
    - What is the appropriate reference point for a site that has granite on it?
    - The problem for assessing sites with alternate substrate is that there is a lack of data
    - Ken brought up whether there is an idea of how many municipalities versus oyster farm participants
        - Municipalities might be more expected to use sites with alternate substrate than an oyster farmer so that they can maintain their credit
    - Lisa made point that reference site should be same bottom type as restoration site- don't want someone comparing a shell bottom with good restoration capabilities to a mucky bottom reference site
    - Move away from biomass alone as a qualifying characteristic for reference site and refer to Lisa and Jeff for more qualitative requirements based on bottom/habitat characteristics
    - Remove biomass measurements requirement table from report
    - Still a need to know biomass but not for selection of reference site

Check Text with Panel

- Pg 29 – Removing time based approach – no longer applicable
- Pg. 29 – Expanding on biomass requirements – no longer applicable
- Pg 30 – If there "**are**" existing denitrification …..

- Pg 35 – Measure the actual biomass concentrations in the chambers versus using regressions
    - Lisa made a comment that it is a lot of work to collect those biomass concentrations – reason why they take subsample of ~30 oysters and then run regression – collecting biomass concentrations for all of the oysters in each chamber is a lot more costly
    - Lisa suggests recommending a site specific biomass regression (NOT requiring it)
- Pg 45 – discussed summer as priority and no other ranking after that for other seasons
- Pg 28, 42, 53, 54 – "molded engineered substrate" – include this method in report?
    - Jeff comments that there is a lot of variability in these structures – suggests to keep wording loose in report but good to include it
    - Not likely for someone who is trying to generate a credit – not most cost efficient method
    - Strategy that is being used by CBF and TNC (reef balls)
    - Good suggestion and educational piece to include especially if this becomes a bigger trend

Next steps:

- Julie will make edits and send back out for review
- Look for insight on benefits – shoreline protection, etc. to add in text
- Look to panel for any final thoughts/comments – changes will be highlighted for review
- Goal to submit draft on September 30th
- Webinar for recommendations within 2 weeks of release of report (Julie will schedule with Jeff; Julie will send out doodle poll to try to get anyone available for webinar)

Oyster BMP Expert Panel Meeting, July 29, 2020, 1:00 – 3:30 PM

Location: Remote conference only

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
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Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership, NOAA Chesapeake Bay Office	Yes
Support Staff	**Affiliation**	**Present?**
Sara Coleman	Oyster Recovery Partnership	Yes
Jennifer Walters	Oyster Recovery Partnership	Yes
Guest	**Affiliation**	**Present?**
Sean Corson	NOAA Chesapeake Bay Office	Yes
Bruce Vogt	NOAA Chesapeake Bay Office	Yes
James Davis-Martin	Virginia Department of Environmental Quality	Yes
Michael Vogel		Yes

Minutes

- Jeff opened the meeting with a summary of where the panel stands
    - It has been almost 4 years since the first part of the BMP approved (oyster harvest)
    - Denitrification has been the biggest hang-up
        - Feeling data-limited
    - History: started out with idea that we do not have sufficient info for default number
        - Full workup on every scrap of data- pretty similar denitrification rates (Harris Creek not hugely different than sites in VA)
        - Original idea of site-specific approach
    - We are in good shape – want 2nd report out by September for public comment
        - Some delays, difficult logistics
    - Main goal after Lisa's presentation, does everyone agree that this a valid approach?
        - Jeff and Lisa would like buy-in from the panel before moving forward modifying the report
- Helpful to take a step back and brief everyone on status of report
    - Fairly straightforward- waiting on resolution of denitrification chapter
    - After text of report is completed, panel approves, next step is review by EPA
- Julie: excited for Lisa's presentation
    - Report will come together well once denitrification protocol is settled
        - Panel will need to do thorough review again
        - Working with Jeremy and Jeff on technical appendix
- Lisa gave a presentation on the denitrification protocol
    - Context: we have agreed to only consider denitrification estimates based on site-specific measurement (technically and logistically challenging)
    - Initial review of data: not enough data to feel comfortable with recommending a value
    - Jeff and Lisa have been collecting data for years
    - Caveats
        - Vast majority of data are from Harris Creek
        - All data come from single research team
        - Most data have not been peer-reviewed or published
        - Amount of data per season varies widely
    - Seasonal regressions: tissue biomass on x-axis, N_2-N flux on y-axis, each graph only contains data from a single season
        - each graph highlights points NOT from Harris
    - Spring regression: large gap in mid-range biomass for spring data
        - Fit two regressions
            - 80g or les: fit is better for dark incubations
            - High biomass: 3 outliers were removed
                - Significant fits for both dark and light incubations
                - Reduced denitrification as biomass gets very high
        - Julie Rose had several comments about the regression methods:
            - did Lisa use ordinary least squares? Not sure (default in most stat programs but very sensitive)
                - Comfortable with limited amount of data and marginal p-value
                - Other more robust regression methods we could use
            - There are other statistical outlier detection methods to flag values if we want

            - Holding value constant in spring is a great idea
        - For some regressions, outliers fall above other data points
            - Throw them out? most conservative to ditch high values
            - Lisa planned on reaching out to Julie for other methods (easier way to justify analysis)
        - Mark L: could negative slope at higher density be a lab artifact of those densities driving oxygen down?
        - Jeff: looking at broader sediment lit
            - In many situations, denitrification goes up with oxygen uptake bc more nitrogen is coming into system
            - Up and down pattern is expected from sediments
            - Exaggerated scale compared to sediments
            - Have to move quickly
            - In other systems, you see denitrification go up until 2 mg/L oxygen levels
        - Larry referenced Roger Newell's paper from 2004: curve looks very similar
            - Straight line where there are no data- should avoid from a regulatory view
                - Could create ambiguity in crediting based on inputs
                - Fit a single non-linear curve to whole thing?
                    - Lisa: fit is not great because the data are not symmetrical
        - Chris Moore expressed concern if we have enough data
            - Want to get this right as it's the first time
            - This will apply lots of other places (might be different about Harris Creek)
            - Lisa would like to see that debated today
    - Summer regression (has more data but not as widely distributed geographically)
        - 3 outliers from Choptank River not included (highest anywhere in literature)
        - Both light and dark regressions are highly significant
        - Low slope, lots of variance
        - Questions: is it reasonable to give default credit with limited geographic range?
        - Frank M: What would be the process for changing only the regression equation after the report comes out, after more data becomes available, say in a few years?
            - Julie: might differ depending on the review board at CBP
            - Jeremy: if we see updates coming down the road, good include simple recommendations
        - Sean asked if the outliers in spring and summer came from same location
            - Lisa: it's possible but need to go back and look
    - Fall regression: less data than summer
        - Dark regression is significant, light is not
        - Prosing a default credit in the dark
        - Jeff: should we look at light and dark hours and do a daily rate?
            - Could be an issue if reefs are opaque at greater depths
            - Surprising that in a system where we don't see big shift in respiration, we see breakdown of the relationship
        - Julie Rose: interesting idea – but apply daily rate for all seasons
        - Larry: difference between what has been done here and what we're after with default values
            - Trying to fit a model

                - But what about reef that might never see light?
                - Lookup table might address concerns
    - Winter data: limited dataset (some potential in the dark for crediting)
        - All from Harris Creek
        - No default credit recommended for winter
    - Combined regressions
        - Annual DNF rate in lbs per acre per year based on midpoint of bin to create lookup table
        - Mark L: what was rationale for using dark rates only in fall?
        - Sean: clarification on control sites… in some cases, when we do pre-restoration surveys there can be lots of variety in existing condition
            - Lisa: if you have not reached threshold biomass, you will not get credit for restoration (from oyster metrics criteria)
                - Binning values was used to simplify crediting process
        - Jeremy asked why the lookup table cuts off at 454.9g DW biomass
            - Very high biomass levels lead to negative values – will not get credit
            - Lisa explained that denitrification is measured at sub-meter scale then extrapolated to mean value for reef
            - Jeff: controls is a vexing question in oyster restoration
                - Conservative component built in
        - Mark L: Is control DNF rate from beginning of restoration?
            - If we had not restored these sites, would there be significant changes in biomass?
            - How frequently would control site be measured?
            - Chris M: some sites may change significantly (maybe weather impacts, poaching related)
                - These lookup values might only apply to subtidal reefs
            - Ward added that controls are monitored with more frequency than cohort reefs in the Maryland tributaries
            - Julie: would be nice if implementers could use easily both protocols (denitrification and restoration assimilation)
            - Jeff: default number will not preclude site-specific approach
- Ward was pleased to see great discussion from the panel – we have landed at a spot where we need to think about next step
- Jeff posed the big question – what do people think about adding this approach to 2nd report? Do you feel comfortable with the science?
    - Lots of work to get this section into report
    - This will not be final consensus on report – as a panel we need to review all 3 sections
    - Does everyone understand the changes? Do you approve of them?
    - Substantial DNF effect in all seasons over controls
        - Site-specific approach is attractive
    - Chris: did you discuss biomass differences for three areas surveyed?
        - Harris Creek: 8 sites (3 controls)
        - Lisa: in second and third years, trying to reduce variance
    - Mark L: Chris said we were not ready for default number based on geographic range of data, what about now?

        - More comfortable now, still a bit worried about lack of info on western shore of Bay
        - Lisa: spring dataset includes data from 1 place on eastern shore (bayside)
            - Ways that we can use existing data and make it more conservative
    - Julie asked if there was a way to change the lookup table
        - Percent reduction seems arbitrary
    - Mark L: bin of 95-105 g DW biomass – 264 lbs of N per acre
        - Lisa: obtained years' worth of monitoring data for Rappahannock, lumped number of acres into each biomass category
            - Convinced her that bins needed to be smaller
            - Most acres fall into 0-14.9g per m^2 (abundance of small and market oysters)
        - Chris is concerned with how lookup table will be perceived
    - Do we need additional discussion/data?
        - Jeff- can advocate for more refinement going forward
            - Fairly convinced that this a reasonable start
            - Systems do not fully retain biodeposits
    - Julie Rose: agree with Julie's assessment on conservative nature of data interpretation
        - Fine with re-evaluating in a few years
    - Mark L: Julie and Lisa work together on statistical approach
        - Compare annualized regressions with single, smooth curve
    - Suzanne had a question about the graph Lisa produced based on Virginia monitoring data: abundance vs. biomass?
        - Not comparable, Lisa just wanted a quick breakdown
    - Bill W: impressed with the amount of work that went into it
    - Jeff: silence means agreement? More formal roll call process needed for full report
    - Julie: can we get a task list?
        - Do we know how long it would take to complete additional analyses?
        - Are other approaches more robust?
        - Really like lookup table but if we have mix of default and site-specific values, would we need lookup table for each season
            - How many lookup tables will be needed?
        - How would this look in CAST?
    - Jeff: can get started on writing as data analysis is underway
        - A lot of this work will become an appendix
    - Chris Moore: how clean is the difference between light and dark?
        - Jeff: with sediments, typically when you illuminate them, DNF decreases
        - Are there reefs that might be light in spring and summer then dark in fall?
            - Jeff: yes all the variability exists
    - Matt Parker: if you were able to go out and count number of oysters on reef and determine sizes, would that make it easier?
        - All oysters in trays were processed
        - Underwater robots to count and measure oysters on reefs are currently being researched

Oyster BMP Expert Panel Meeting, December 15, 2021, 10:00 AM – 1:00 PM

Location: 1805 A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Lisa Kellogg	Virginia Institute of Marine Science (VIMS)	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Frank Marenghi	Maryland Department of Natural Resources	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	No
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	Yes
Jeremy Hanson (WTWG Rep)	Virginia Tech (CBP)	Yes
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Ralph Spagnolo (EPA R3 Rep)	U.S. EPA Region III	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Julie Reichert-Nguyen	Oyster Recovery Partnership	Yes
Ward Slacum	Oyster Recovery Partnership, NOAA Chesapeake Bay Office	Yes
Olivia Caretti	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Sara Coleman	Oyster Recovery Partnership	Yes
Elizabeth Franks	Oyster Recovery Partnership	Yes
Guest	**Affiliation**	**Present?**

Action Items:

<u>Chapter 7</u>

- Engineered Structures – Olivia include examples of how to sample and scale up biomass on engineered structures.
- Engineered Structures – Leave options 2 and 3 as only options currently appropriate to estimate biomass of oysters growing on engineered structures.
- Baseline – Revisit wording on Baseline measurements
    - Revisit old meeting minutes to determine whether/what decision made about when pre-restoration biomass should be collected (can data be used from prior to report publication?)
- Crediting – ORP discuss whether credit can be applied on a rolling basis with EPA

Chapter 8

- Engineered Structures – Incorporate new data from Jeff into appendix, include comment on how we need more research on denitrification rates for ES
- Baseline – clarify and revisit wording on baseline measurements

Other Chapters/ Full Report

- Edit for consistency and conciseness (e.g., tables)
- Chapter 6 – confirm whether 50^{th} quantile regression differs from Chapters 7/8
- Update other chapters (2 and 10) once Chapters 6-8 are complete and recommendations are agreed upon by Panel

Timeline

- Panel members to complete reviews by Friday, Jan 14^{th}
- Possible Panel meeting for late January/early February 2022 to seek agreement on scientific content

Minutes:

Introduction and Coordination Updates

- Olivia Caretti is new to ORP and will be coordinating BMP report moving forward. Sara Coleman (ORP) and Beth Franks (ORP) will be supporting Olivia
- Jeff reminded panelists of the history of the work and reiterated the importance of the work going on, reiterated that we need to stay focused on science
- Meeting Goals:
    1. Review major revisions to Chapters 7 and 8
        - Five major themes:
            - Engineered structures: require their own separate section?
            - Baseline/pre-restoration measurements
            - Crediting: old text regarding timelines
            - Sampling plan/Sampling design
            - Reporting
    2. Discuss report timeline

Chapter 7 Revisions

- **Engineered structures (ES)**: Refer to table summarizing panel comments and actions taken by ORP

- Challenges:
  - Some people wanted to create new section with info on how to sample oysters on structures
  - How to scale up biomass estimates to avoid over/under-crediting?
- Solution: New Section 7.5 addresses all these questions

  Discussion:
  - Lisa: main thing missing in this section is examples on engineered structures
    - Would be helpful to have examples with reef balls and oyster castles
      - Jeff: I will show slides of unpublished data- structures without oysters also do a lot of denitrification (barnacles and bryozoan)
        - ES may have set of benefits that have nothing to do with oysters (philosophical question)
      - Outside scope? Jeff says biomass is biomass
  - Chris: generally structures we have seen are reef balls/oyster castles, but several new designs coming out
    - Olivia: Can we make text non-descriptive of type of structure (maybe discuss structures that are widely dispersed or densely placed/stacked)
  - Julie: could give examples of ES for implementers in Chapter 5
    - Regarding sampling plan: would implementers need to sample every structure to measure oysters or just select representative?
      - Lisa concerned about scaling measurements up based on sq m
  - Larry: surface area of structure times number of structures? Has Jeff looked at this?
    - Jeff: seeing big range of coverage of oysters, sometimes they fall off
      - Let's say we have 100 reef balls, what is sampling plan to determine average? Might require underwater drone or other means
      - Beauty of working in largescale projects is we sample trivial portion of oysters – big investment in coming up with appropriate numbers for these structures
    - Lisa: is all surface area available to sample? – if you can't actually sample the inside of it, you can't assume that the numbers of oysters inside is the same as those outside
      - Larry: Suggest create estimate of efficiency of coverage for each type of structure
    - Mark: obvious answer is normalizing across one location (oysters per structure)
      - Need to get valid estimate of average oysters per structure, whether that's subsampling or measuring every oyster on structure
      - Not sure we can go into lots of detail here, may change in future as new structures available
      - Larry: Mark's point is a good initial approach, studying scaling between structure type and size and configuration is a step beyond simple oysters per structure
      - Olivia agrees this is most reasonable approach
  - Other outstanding item: what is best method to calculate biomass? No data to suggest oysters grow differently on ES, can incorporate into Section 7.7

        - Oysters tend to be elongated, Jeff thinks using length might be tough on reef balls
        - Currently report says people can use biomass estimate option 2 or 3
  - **<u>Action/Decision Item</u>** – Olivia include examples of how to sample and scale up biomass on engineered structures.
    - Include example for (a) densely stacked and (b) widely dispersed structures
    - Explain that oysters should be sampled from surface, consult experts for whether subsampling or measuring every oyster – acknowledge that high variability in # oysters per structure and need to take enough samples at multiple areas to get reasonable estimate
    - Scale up by multiplying average oysters per structure by # structures, NOT area
  - **<u>Action/ Decision Item</u>** – Leave options 2 and 3 as only options currently appropriate to estimate biomass of oysters growing on engineered structures. Leave need for research on how oysters grow differently (or not) on engineered structures in Future Research (section 7.7).

- **Baseline**: how to measure pre-restoration biomass?
  - Challenge: Lots of confusion on number of options, section in text was wordy
  - Panel suggested emphasizing one consistent approach with exception for areas that lack pre-restoration data

  <u>Discussion</u>

  - Julie Rose: non-time-based can only be applied for projects prior to 2009?
    - Olivia: Non-representative site can be used for any project that does not have pre-restoration data, regardless of when the reef was restored
    - Julie: Opposite of how she interpreted text, will need to revisit chapter
    - **<u>Action item</u> –** Olivia re-examine wording to make sure this is clear
  - Chris: continue to think 2009 date is something we should look at again
    - Say reference site has no restoration, but some biomass of oysters may have built up since 2009 – can people get credit for any biomass that accreted since 2009? Are we crediting from that first sample, or any biomass that accreted between 2009 and when you took your first sample?
      - Jeff: does this mean in reference site? Can also be moving target
        - Do we need to define as initial sampling?
      - Don't have ability to generate credit until first measurement
    - Julie Reichert-Nguyen clarified 2009 is when TMDL became active
      - Does not mean you have to go back and assess biomass from that point (nothing applies before that time – would not allow pre-2009 data to establish baseline conditions)
    - Chris: to get credit, implementers must do the work in this report
      - Ex: for Harris Creek, you'd have to take your baseline sample once this report is published (e.g., June 2022) and move forward from there
      - Julie says that's not how the report is currently written
      - Chris: Would we be double-counting?
      - In first report, we did not say you can go back and count oysters from 2009
      - Julie: that eliminates existing data requirement

            - Ward: rely upon Julie, this is an area where the panel had previously agreed, he assumes this would have come up already
                - Julie: when we developed interim BMP report, it was agreed upon that we could use existing data (3-4 yrs ago)
                - If no existing data, then you would go to reference site to understand baseline condition (reference site might be influenced by restored site – possible to underestimate overall credit)
            - Chris thought interim report was more for planning – go back to minutes?
        - Lisa: recalls that we agreed on reference site, but 2009 seems like too long ago
            - Go back x number of years from when BMP is approved? Chris's issue is that this is somewhat arbitrary in nature
                - How do we put all projects on same footing?
                - Best way is to start when report is published
        - Julie: what is actual reduction effectiveness of this practice? More accurate to use data from same location
            - Initially we allowed for existing data since that would be more representative of reduction effectiveness
        - Mark: arbitrary date but if change, we are giving up situations where we had good pre-restoration samples
            - Pre-restoration data is more important than an off-site reference site
            - Chris: not saying any of those data are better or worse, more of a fairness issue (vast majority of projects do not have Harris Creek-level of data)
                - Different goal now – to credit in Chesapeake Bay, not just for ecological restoration
                - Other BMPs don't allow for back-crediting and are credited at the date the BMP was approved
            - Julie reiterates that 2009 is just regulatory timestamp
        - Lew: we use estimated biomass from aquaculture
            - Restoration is not integrated into current model
            - In phase 7 we'll include best estimates
                - Water quality benefits would count to water quality standard
            - Mark agrees!
    - **Outstanding item** – Olivia summarizes: we need to consider having more discussions regarding baseline data, will follow up via email
    - **Action item** – Olivia revisit old meeting minutes to find whether/what decision was made about baseline

- **Crediting** (ties into previous discussion): monitoring within 3 year or 1 year timeframe?
    - Report states: Must have data within 12 months to apply for credit of accreted biomass
    - Olivia: Does credit expire? Can be applied on rolling basis?
        - Lew has no idea
        - Julie: technical appendices are best place to discuss this. Thought is you only get credit for appreciated biomass
    - Olivia: Is there a concern about over-crediting if you have reef that appreciates biomass then loses biomass? – unintended negative consequences

  - **<u>Action Item</u>** – Need to investigate if credit can be applied on rolling basis or other timeframe? ORP will discuss with EPA when working through technical appendices

- **Sampling plan vs. Design**
  - Report terminology: Reporting and review of plan
  - Likely will have conversations about this with Jeremy, EPA requirements might change things
  - How many samples are sufficient for sampling to estimate biomass? Increased minimum from 3 to 5, but sufficient spatial coverage is needed for larger sites
  - Outstanding question: what is realistic for minimum sample number? Must be statistically significant but also feasible
  - Lisa: confusion on what has to be reported in advance vs. at the end (e.g., planned sampling points vs. actual sampling points)
    - Section 7.4.2- Mark likes terms "proposed sampling design plan"
      - 5 reps should be minimum
      - Recommend emphasizing need to consult with an expert (we do – this is sufficient)
      - Other recommendations for reporting need to come from reporting agencies
  - Jeremy: multiple layers to reporting, with some needs for partners, Bay Program. Some details not reported to EPA. These recommendations need to go to agencies that are doing monitoring

- **Reporting**: additional questions on what is reported to who, need for overall consistency

- **Other items**
  - We need to fill in actual data in examples in section 7.4.3
  - Intertidal data for calculating baywide regression missing from Appendix
    - Julie Rose remembers adding intertidal oysters to quantile regressions (should be in appendix D)
    - **<u>Action</u>** – Olivia needs to track down missing data
      - Small dataset from Lynnhaven River
      - Mark: shape of oysters not typical for most intertidal oysters in VA, more similar to subtidal
      - Olivia needed confirmation that oysters grew similarly – don't need to have extensive discussion
  - Need overall updated literature citations throughout report and appendices
- Any other outstanding questions/concerns? Does Panel approve of these changes?
  - No concerns, Panel approves

Chapter 8 Revisions

- Many of the same revisions discussed in Ch 7 also apply here
- **Baseline**: sounds like we need to revisit this given earlier discussion
  - Same standard followed to resolve confusion on options
- **Reporting**: added info on what needs to be reported to who and when
  - Need further discussions with Jeremy

Jeff's presentation on Engineered Structures

- Point is not to add lots to the report
- Looked at reef balls and oyster castles
    - Reef balls are single structures (over 1000 in Choptank complex)
    - Methods:
        - Structures were removed from water submersed in a large tank of ambient river water
        - Short incubations to examine denitrification (1 hr)
        - High biomass: ~1000 oysters per reef ball (lots inside as well)
        - Not measuring surrounding impact in sediments
    - Denitrification fluxes dwarf that of sediments
        - We've talked a bit about surface area, but in the end we'll count per structure
    - Very high rates of denitrification
        - Crediting could alleviate costs of deployment (20-fold higher DNF on sq m basis)
        - Many questions about assessing biomass
    - Likely not this panel that would need to push this down the line
    - Plastic discs in Baltimore Harbor: many fouling organisms

    Discussion:

    - Bill: were these structures covered with spat first? Yes
        - Variable set rate
        - People are investigating direct setting with boom in situ
    - Lisa has point that as we stack these structures, surface area declines
    - What do we want to include in ch 8? Jeff does not see how we can incorporate
        - Could stop momentum
        - Important thing to consider in the future
        - If we can put out concrete and get high DNF levels without oysters, this complicates things
    - Bill: due to nature of ES, you get a more 3D aspect – expect higher accretion of biomass in the long run
        - Jeff: in Ch 7 opportunity is there to assess
        - What is baseline? Bare oyster castle?
    - Goal is to submit to journal – this could be placeholder in report for now
        - Some write-up and figure included to show potential
        - Keep in mind these are co-benefits (reef balls and castles are mainly deployed for fish habitat and shoreline stabilization)
    - Julie feels that this info should go in appendix, not main body of report – Jeff agrees
    - **Action/Decision item** – Include a figure and brief write up (1-2 paragraphs) in Appendix associated with literature review for DNF rates. And again, emphasize that need more research on understanding processes on engineered structures

- Sounds like we have a plan to incorporate data into appendix, include comment on how we need more research on denitrification rates for ES
- Some work to do on clarifying baseline

- Jeff: we'll need to reconvene once, approval can come in January once folks have time to review
- We evolved from a site-specific approach to one that allows crediting based on biomass of oysters, turning point is Lisa taking datasets and recognizing that VA and MD data were pretty consistent (gratitude to Lisa and Julie)

Chapters 1-6 Review

Discussion:

- Mark: Need to simplify title and clean up tables with standard format. Provided a more readable title, included a more readable alternative
        - No more styles of tables than absolutely necessary- strive for consistency
        - Table details below some tables?
            - Julie thinks implementers would want details near table, we can simplify explanations but keep them near tables so folks do not need to jump around (keep in mind these are complex BMPs!)
            - Matt Parker put in chat: Would it be possible to make an excel or google sheet page people could download as a template for all the calculations since this is quite complex?
        - Olivia: if you want to send me styles, or can edit based on this conversation
        - **Action item** – Olivia update table format to make consistent throughout report
    - Matt Parker wrote in chat: Perhaps those table details could be an appendix or section at the end of the chapter
        - I would also suggest following the format of the first report we did several years ago for consistency
- Very broad needs for each remaining chapter (lots of this will depend on final decisions for Ch 7 and 8)
    - Ch 2 is summary of recommendations: cannot complete yet
    - Ch 5 is oyster practices for BMP consideration – any updates that were previously pending approval? Ward thinks they're all good
    - Ch 6 licensed oyster harvest
        - Lots of detail on calculating oyster biomass using 50^{th} quantile regression equation – is this already in appendix D?
            - Julie: different equations? For restoration we removed all aquaculture data
            - Chris: we include oysters smaller than 3 inches? Knock out a few lines
        - Unintended negative consequence: deploying SOS on fished reef could increase harvest pressure – should this be included?
            - Lisa: based this on some areas in MD where county oyster committees pay for SOS, there is natural background oyster population – are we then harvesting background population? (Chris agrees)
            - Harvester would not get credit – state or county would
            - Ward: Time is not on our side with this chapter. There is caveat built into this practice that limits credit
            - Mark: reason SOS is placed there in the first place is for harvest – not nutrient credit
            - Ward: in general, counties are placing SOS in locations where there are existing populations, already that incentive

            - **<u>Action/ Decision item</u>** – remove extra information about oysters less than 3 inches to shorten text
            - **<u>Action/Decision item</u>** – review whether 50th quantile regression for Ch 6 differs from Ch 7/8
            - **<u>Action/Decision item</u>** – do not include additional harvest pressure as an unintended negative consequence, since additional harvest is the goal of SOS planting on public reefs
        - Chris: licensed oyster harvest wording – as written now, applies to both states
            - Pg 8 definitions – need to add qualification
            - Only practice we have approved is licensed harvest with spat on shell addition
    - Ch 9: Ancillary benefits
        - Only 2-3 paragraphs currently, is more info needed?
    - Ch 10 will be done once all other chapters are complete

Timeline and Next Steps

- Deadline for final review of Ch 7 and 8 – January 14th
- We want to first make sure all scientific content is addressed
- Another meeting in late January/early February?
- We need to resolve outstanding item of baseline biomass – Olivia will follow up via email

Oyster BMP Expert Panel Meeting, October 6, 2022, 10:00 AM – 12:00 PM

Location: 1805A Virginia Street, Annapolis, MD 21401 and remote conference

Participation:

Attendance		
Panelists	**Affiliation**	**Present?**
Jeff Cornwell (Panel Chair)	U. of Maryland Center for Environmental Science (UMCES)	Yes
Suzanne Bricker	NOAA, National Centers for Coastal Ocean Science	Yes
Andy Lacatell	The Nature Conservancy (TNC)	Yes
Mark Luckenbach	Virginia Institute of Marine Science (VIMS)	Yes
Frank Marenghi	Maryland Department of Natural Resources	Yes
Chris Moore	Chesapeake Bay Foundation (CBF)	Yes
Matt Parker	Sea Grant at U. of Maryland, Prince George's County Office	Yes
Ken Paynter	U. of Maryland Marine, Estuarine, Environmental Sciences	Yes
Julie Rose	NOAA Northeast Fisheries Science Center, Milford Lab	Yes
Larry Sanford	U. of Maryland Center for Environmental Science (UMCES)	Yes
Bill Wolinski	Talbot County Department of Public Works	Yes
Advisors	**Affiliation**	**Present?**
Lew Linker (CB Modeling Team Rep)	U.S. EPA Chesapeake Bay Program Office	No
Jeremy Hanson	Chesapeake Bay Program	No
Jeff Sweeney (WTWG Rep)	U.S. EPA Chesapeake Bay Program Office	No
Lucinda Power (WQGIT Rep)	U.S. EPA Chesapeake Bay Program Office	No
Coordinators	**Affiliation**	**Present?**
Ward Slacum	Oyster Recovery Partnership, NOAA Chesapeake Bay Office	Yes
Olivia Caretti	Oyster Recovery Partnership	Yes
Support Staff	**Affiliation**	**Present?**
Elizabeth Franks	Oyster Recovery Partnership	Yes
Jennica Moffat	Oyster Recovery Partnership	Yes
Guest	**Affiliation**	**Present?**

Action Items & Highlights:

- Use *BMP Site Area* in text as it's own term.
- Specify BMP site is a location, but it is also an area not a point location
- Make a few minor adjustments to definitions:
    - Potential negative effects
    - LOH as an activity – remove anything about substrate addition, specify these are state managed areas

- Olivia will draft a write up that walks through calcs for the default 3% survival rate and will circulate to group. The Panel can then decide whether to include it in main report or in appendix
- In Chapter 7 – adjust the qualifying condition to state *less than 1 inch when planted*,
- In Chapter 8 – remove size qualification since oysters are denitrifying regardless of size.
- Add text in Conclusion to discuss which protocols were not addressed by the Panel (given designation of "Later") and when/how this could be done
- **The Sept. 2022 BMP report has been officially approved by the Panel, with minor "tweaks" discussed in today's meeting – Congrats!**

Minutes:

1. BMP status update

- Report Appendices are a work in progress as we check references, tables, formatting, etc. No content within Appendices has changed and we hope to send those off shortly for panel review.

2. General housekeeping

- Panel Chair, Jeff, expressed his gratitude to everyone who has contributed their time over the years. Jeff acknowledged Bill Wolinski who has retired but is continuing involvement with the Panel. Bill was present at the ORP office for today's meeting.
- Olivia provided an overview of what's happened since the panel last met.
- Authorship – agreed that Jeff will be listed as lead author as Panel Chair, with all panel members listed alphabetically after that
- Jeff noted that many of the key elements of the report and much of the data came from Lisa Kellogg, and that she will be acknowledged as well.
    - Jeff will draft the text for the acknowledgement and send out for review.
    - Julie and Matt agreed that this was a good approach.

3. Review current BMP draft (v. Sept. 2022)

- Olivia noted that in the most updated draft, no concepts or recommendations have changed, except for the change in default survival rate from 15 percent to 3 percent in Chapter 6. The panel approved these changes via email in August 2022. No other concepts have changed.
- Over time, we have had many discussions of protocol definitions. We have reverted back to the original practice and protocol names in the current draft - those are the major changes herein.

4. Discussion of revisions and outstanding needs

- Outstanding needs to discuss during today's meeting include:
    - Firming up some terms or definitions
    - A few small questions on qualifying conditions
    - Revisiting the change in default survival rate from 15% to 3%. How do we want to convey the methods used to get to that 3%? Should this be an additional appendix or other?
- Main goals of today's meeting:
    - Does Panel agree with new draft?
    - Does the Panel wish to add a new appendix to describe calculations for the 3% default survival rate in Chapter 6?

4a. Definitions/Terms

- Olivia went over several updates to definitions and terms, including three that were revised, two that need approval/discussion, two that were added, and two that were removed since they weren't used in the text:
    - Revised three terms: Licensed Oyster Harvest, Ancillary benefits, Unintended Consequences
    - Two terms need approval/discussion: Licensed Oyster Harvest, BMP Site vs. BMP Site Area
    - Added definitions for Batch incubation (Ch 8 and Appendices) and no-harvest area to represent all of the terms used
    - Removed terms not used in text: Cultchless oysters, oyster sanctuary

BMP Site vs. *BMP Site Area*

- Mark Luckenbach doesn't think that "BMP Site vs BMP Site Area" needs to be a one or the other. The area is the actual area in which the restoration or enhancement took place. Mark suggests this change: Define *BMP Site Area* as the area of the actual enhancement activity. It may be smaller than the *BMP Site*. Mark has drafted this text and has added it as a comment in a draft he will be sending.
- Olivia questioned whether we need to define *Site Area* in the definitions?
    - Mark countered with whether we needed to have a definition for *BMP Site*? - if there was a desire to only have one or the other?
- Ken Paynter commented that Mark raises a good set of points.
- The question was raised whether the panel should stick with using *BMP Site Area* instead of *Footprint*?
    - Chris Moore commented that he thinks *Site Area* might be a little more descriptive because when we think of *Footprint* we might be thinking of a larger area. We need to be prescriptive to ensure we don't count a smaller area as a much larger one.
    - Jeff agrees – He has been using *Footprint* when referring to a larger area, and thinks using *Site Area* is a lot more precise.
    - Frank Marenghi also agrees with the previous comments and agrees with using *Site Area*. He doesn't think we need to use both *Footprint* and *Site Area*. He has one other comment on *BMP Site*, but it might be taken care of in the definition. He emphasized that it is important to clarify that these are AREAS – measured in meters^2 etc., not points. It is important to measure what's going on throughout the area where the enhancement occurs which would theoretically require multiple samples within the area.
- Ken asked whether it would be helpful to use *BMP Location* instead of *BMP Site*?

➔ **Olivia concluded that the document will use *BMP Site Area* instead of *Footprint*. ORP will add a phrase to the definition to clarify that it is not a site, but an area.** She asked whether there were any concerns with this approach from the panel and none were voiced

Additional terms

- Additional terms that were revised included *Unintended consequences* and *Ancillary benefits*, where definitions were adjusted to make sure the text was clear.
- Matt Parker asked about "*Unexpected Negative Consequences*" wondering wouldn't it be inferred that it was unexpected and suggests suggest changing to "*Potential Negative Effects*". Suzanne Bricker agreed.

➔ ***Unexpected negative consequences*** will be changed to ***potential negative effects***

Licensed Oyster Harvest (LOH)

- Jeff and Olivia reached the conclusion that *LOH* is the activity of removing oysters and is not necessarily referring to the LOH practices discussed in the report. Olivia proposed a change for the definition of *LOH* and provided some context with how it is used in the report.
  - *Licensed oyster harvest* specifically refers to oyster harvest from a managed fishery by individuals holding the proper harvest licenses; BMP crediting occurs only in areas that are supplemented with hatchery produced oysters (e.g., spat on shell or single oysters) or substrate addition.
- Mark – agrees with the term LOH. However, he finds the "or" in the sentence about crediting to be confusing. In this part of the report, we haven't yet established crediting. The phrase "*or substrate addition"* would include almost all of the traditional planting on leases throughout VA and most public harvest. He realizes it's clear later in the chapter, but in this early part, crediting occurs only or crediting is endorsed – He thinks this portion of text should be deleted or changed to "and substrate addition".
- Ken finds *LOH* ambiguous and open to interpretation. He questioned whether *Licensed Oyster Production* could be better?
  - Olivia described concern for maintaining consistency with terms already agreed on and with those used in the previous report. The part that's getting credited is the removal of those oysters.
  - Julie cautioned that *LO Production* could be confused for aquaculture.
- Frank likes the proposed definition for LOH. He suggests defining how it is applied to crediting later.
- Chris Moore echoed concern with how LOH could be interpreted down the road. He suggested including a note (e.g., *See section xx for a more detailed description*). Is Managed Oyster Harvest a Better term?
  - Mark asked if "managed" might be questioned as "managed by whom?" which could be aquaculture. Mark thought "Licensed' might better capture that.
  - Matt said he doesn't necessarily agree with Chris, suggesting that maybe the wording could be re-worked to include individuals holding the appropriate license from the appropriate entity. We want to specify that it is oyster harvest by individuals holding proper licenses from fishing areas managed by the state versus private aquaculture.
  - Mark – is it necessary at the definition stage to go into WHO manages it? Thinks we could leave it shortened here in the definition.
  - Matt suggested adding a comma or semi colon after area.

➔ Olivia summarized that **ORP will remove from the text any references to substrate addition and will think a little more about small changes to make this definition clearer, including adding a state managed fishery area to it.**

- Jeff reminded the panel to remember who the audience is. People translating this to policy will have a good understanding.

4b. Practice and protocol names and definitions

- Practice and protocol names have not changed from earlier drafts that were approved by the Panel
- Practice definitions have also not changed

- We wanted to make sure all were consistent with what panel had already reached consensus on.

4c. Recommendations

- Olivia briefly ran through the main panel recommendations for each of the recommendation chapters (Chapters 6, 7, and 8).

Chapter 6

- Most substantial change was the default survival rate from 15% to 3%. The Panel will need to review and approve new text on 3%. The Panel needs to discuss how best to present that – should this be an Appendix?
- Mark thinks an appendix is appropriate because people might initially think the rate is very low.
    - Jeff agrees.
    - Ken and Andy agree via Chat.
    - Larry Sanford agrees.
    - Frank thinks reasonable.

- Suzanne was anecdotally talking to bottom growers and learned the same thing about high mortality. She thinks 3% is realistic and agrees that an appendix would be useful but brevity would be good.

➔ Olivia has the spreadsheet and can **build a brief appendix to share with everyone to review**. She asked whether there were any concerns about doing this or if anyone disagreed.
    - Matt suggested reviewing how short it ends up, and then deciding if it should be an appendix or incorporated within the text.

Chapter 7

- Major change – There are new qualifying conditions for each baseline approach which were approved by the Panel in January 2022.
- There is a qualifying condition listed for Chapters 7 an 8 that says that shell height of oysters at the time of restoration must be less than 2 inches. Olivia asked whether this was an original condition that the Panel agreed on or was this added later with or without discussion?
    - Mark says it was discussed but he is unsure whether it was voted on.
    - Julie Rose says it was included as a qualifying condition for the aquaculture report. Suzanne agreed.
- Olivia asked whether this condition was necessary for the restoration practices?
    - Mark said it was a question for Chris, and wondered how much CBF is still doing regarding planting oysters that are larger than spat?
    - Chris explained that oysters can be bigger than 2 inches, and that a lot are right around 2 inches.
    - Jeff explained that this came in to play during the middle of COVID pandemic and shut-downs, TNC purchased oysters – SOAR program.
    - Matt added that this is coming up in Gulf of Mexico as well. It is a new potential market that we didn't envision when we first did this. He suggested the Panel may need to put additional text in the document that we didn't anticipate happening.
    - Frank asked whether the initial biomass would have to be measured after the planting of the SOAR oysters? If not, he felt we need to clarify.

 - Ward – It seemed highly unlikely that there would be any project with SOAR oysters comprising the majority of oysters at a site.
 - Andy agreed that the numbers of large oysters are low. He suggests we include an asterisk and state this and not provide a recommendation.
 - Frank asked who is determining things like site, site area, how many would there be, how many new ones are there, etc.? If they're being added to a sanctuary but the sanctuary is 20,000 acres and we're adding ½ an acre.
 - Larry suggested we could say "increases due to additions of adult oysters can't be credited."
 - Ward – since the aquaculture BMP has now been approved, these projects wouldn't be eligible for more credit if they are moved to a restoration reef
 - Matt cautioned that considering the many hours we discussed overcrediting for aquaculture, we need to include more than just an asterisk in this case.
 - Ken thinks we should avoid terms like "adults" because of the ambiguous definition. He cautioned that the real concern is that we unintentionally endorse the movement of large oysters. There is a history of a lot of other negative consequences with moving oysters around. Diseases, epifauna, etc. We need to ensure we don't say anything in this document that says moving big oysters around is a good idea.
 - Mark agrees with Larry's suggestion and adds that we should state in this chapter that if using individual oysters larger than spat-on-shell, only incremental growth beyond the planting size can be credited.
 - Olivia stated that we will move forward to keep this qualifying condition. We will state that if using individual oysters larger than 2 inches, only incremental growth beyond the planting size can be credited. She asked for agreement from the Panel.
 - Mark stated it should be larger than SOS, not larger than 2 inches.
 - Frank says we need to pick a size and suggests using greater than 1 inch.
 - Chris asked whether it is the site we're worried about not the individual oyster?
 - Ward said when you measure the oysters that went down (whatever size) do you then remove that biomass from the resulting biomass you want credit for at the site level?
 - Mark – Yes and added that's why he wants to include a statement of only getting credit for incremental growth beyond the planting size.

➔ **Olivia will adjust to: "Shell height of oysters at time of restoration be < 1.0 inches. For oysters larger than 1.0 inch, only incremental growth beyond the planting size can be credited"**

Chapter 8

- There is the same question about Qualifying condition for this chapter. Olivia asked if we want to apply same approach we just agreed on for Chapter 7 for this Chapter as well?
- Mark said he doesn't think we have to say anything about the size of the oyster here. Matt and Ken agree. The way that crediting works, you measure biomass at particular time and then use seasonal rates.
- Jeff agreed stating that we are worried about the process here.
- Larry added that a certain biomass of oysters produces a certain amount of biodeposits - why make a requirement that they have to be any certain size when planted? It doesn't make sense for this particular BMP.
- Larry – Why not credit reefs before 2009?
 - Olivia explained that we had that conversation at our last meeting. The 2009 date is a legislative boundary set by EPA that we likely can't work around.

  - Chris added that the 2009 date is the date the Chesapeake Bay Program wanted to use.
  - Larry added that he would withdraw the comment as he knows the Panel wants to get this report finished.
- ➔ Olivia summarized the discussion, stating that we will **remove the size qualification for Chapter 8 because oysters are denitrifying regardless of their size.** She asked for any comments, and there were none, the Panel was in agreement.

4d. Other needs/concerns/comments

- Larry – Suspended sediment was included as part of the charge – but is not mentioned it again. He says we need to address those things in Table 1.1 that were just labeled "later". In particular, we need to address suspended sediment, as well as burial and nitrogen and burial and phosphorus.
  - Jeff suggested that these could be addressed in a section where we make recommendations for future assessments
  - Larry added that this is a big enough hole that the Bay Program could even initiate another Panel for this. He said we could ask STAC to convene a workshop to see if there is enough data to pursue that. Larry thinks it needs to be addressed somewhere because it is an unclosed loop in the existing report.
  - Olivia suggests we could put this in the conclusion section. This would be a logical place to say What's Next and put our recommendations for What's Next.
  - Jeff can help craft text working with Olivia to discuss these points and will send to group for review.
- ➔ **Add text in Ch 10 (Conclusions) briefly discussing which practices and protocols were not addressed in this report, and recommendations for how they could be addressed later**
- Larry added an overall statement that he thinks the BMP Document is incredible! He stated that he hadn't read through it completely for a while and did before this meeting. He praised the logical layout, the tables, the structure, and the logical sequence of information, and the completeness. He asked whether there were going to be any papers coming out of this?
  - Jeff stated that would be a goal and that we were probably remiss in not doing that from first report.

5. Discuss next steps

- Jeff asked whether there were any questions moving forward. Do any panel members have any objections? Or Anything they've like to speak about?
- Larry asked whether there will be a Public review AND Expert Review committee?
  - Jeff explained that we will be making presentations to Water Quality Goal Implementation Team (GIT) and Fisheries GIT. There will also be at least one public session open to anybody to comment on the document. He noted that the process the last time was NOT particularly onerous.
  - Olivia added that we are grandfathered in under the old BMP Protocol rules so we are not required to go through more substantial additional steps for review and approval.
- Ken suggested we invoke Robert's Rules and motioned that the Board move forward with the draft with modifications discussed during today's meeting. Andy Lacatell seconded the motion. No objections were received.

- ➔ **The Sept. 2022 BMP report has been officially approved by the Panel, with minor "tweaks" discussed in today's meeting – Congrats!**
- Jeff thanked everyone and suggested that we should have a celebration, including Julie, since she worked so hard on this effort even while juggling many health issues.

The meeting ended at 11:40 am

- Following the meeting, Chris followed up with Olivia regarding the bulleted list of panel recommendations on Page 34 of the document, under Practice F. Chris emphasized that the most important part of this is the site area, and suggested that it should be included as a bullet too.
- ➔ **Revise to read: Designating a site area before enhancement begins in order to prevent overcrediting.**