Oyster Best Management Practice Expert Panel—Recommendations on the Oyster BMP Reduction Effectiveness Determination Decision Framework and Nitrogen and Phosphorus Assimilation in Oyster Tissue Reduction Effectiveness for Oyster Aquaculture Practices

WQGIT Approval Decision Meeting

December 19, 2016

Jeff Cornwell, University of Maryland Center for Environmental Science, Panel Chair

Julie Reichert-Nguyen and Ward Slacum, Oyster Recovery Partnership, Panel Coordinators

Innovation for a better future
University of Maryland Center for Environmental Science

Oyster Recovery Partnership | ORP

Chesapeake Bay Program
Science. Restoration. Partnership.

Recommendations in the First Report

The Panel's recommendations found in the first incremental report include:

- A decision framework to incrementally determine the nutrient (nitrogen and phosphorus) and suspended sediment reduction effectiveness of oyster practices for BMP application.

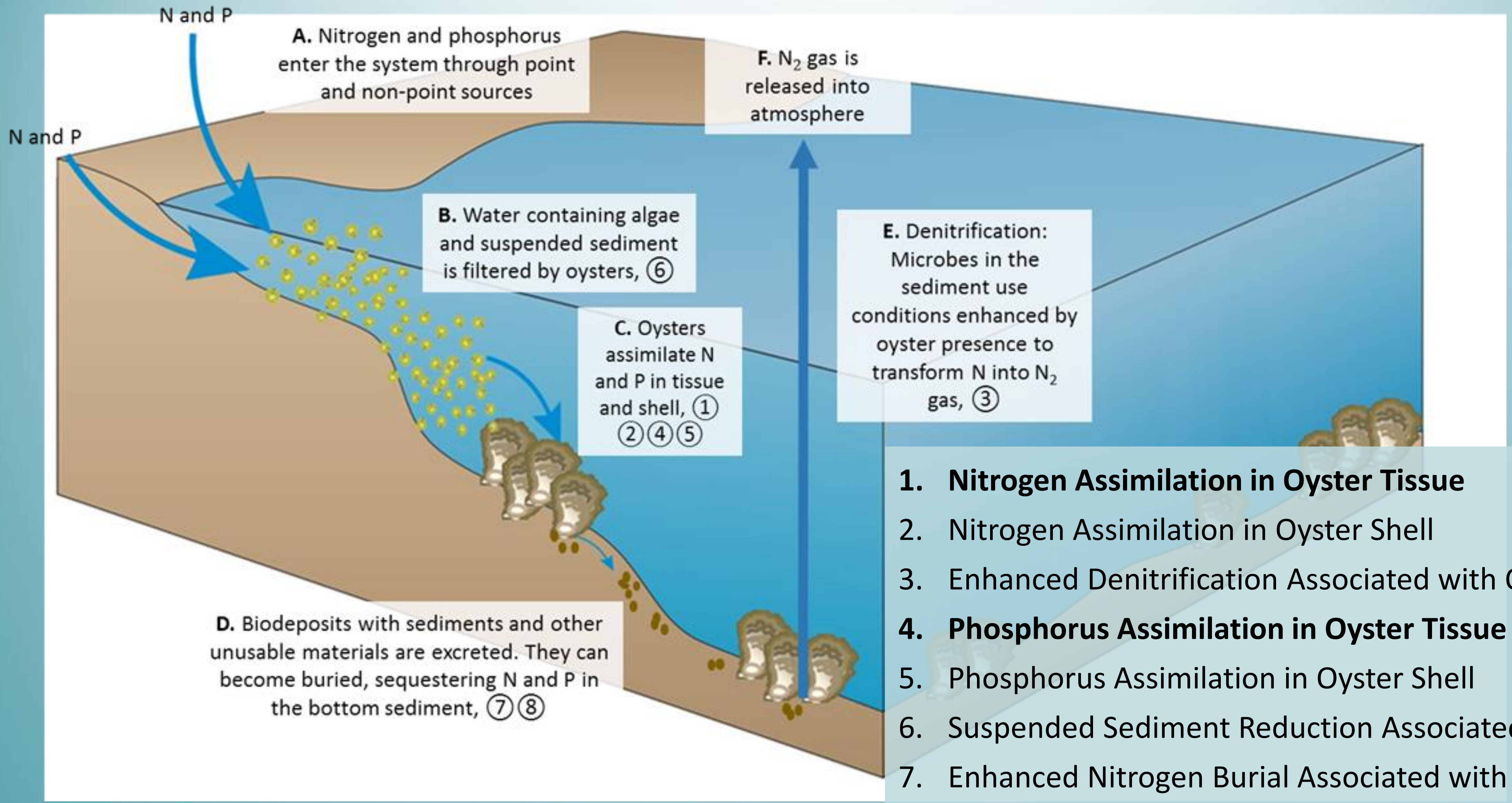
- Default reduction effectiveness estimates for the "Nitrogen Assimilated in Oyster Tissue" and "Phosphorus Assimilated in Oyster Tissue" reduction effectiveness protocols for oyster practices in the following oyster practice categories:
    - Off-bottom private oyster aquaculture using hatchery-produced oysters
    - On-bottom private oyster aquaculture using hatchery-produced oysters
    - On-bottom private oyster aquaculture using substrate addition

- Methodology to establish site-specific estimates.

Decision Framework—Chesapeake Bay Oyster Practices

Oyster Fate	Oysters removed (harvested) from Bay									Oysters remain in Bay		
Fisheries Management Approach	Private oyster aquaculture (permitted)					Public fishery				Oyster reef restoration (sanctuaries)		
Oyster Culture Type/Ploidy	Hatchery-produced oysters (diploid or triploid)		Wild oysters (diploid)			Hatchery-produced oysters (diploid)	Wild oysters (diploid)			Hatchery-produced oysters (diploid)	Wild oysters (diploid)	
Activity/Culture Method	Grown off the bottom using some sort of gear	Grown on the bottom using no gear	Moving wild oysters from one location to another	Addition of substrate to the bottom to enhance recruitment of wild oyster larvae	None	Addition of hatchery-produced oysters (e.g. spat-on-shell)	Moving wild oyster from one location to another	Addition of substrate to enhance recruitment of wild larvae	None	Sanctuary creation followed by addition of hatchery-produced oysters	Sanctuary creation followed by addition of substrate	Sanctuary creation
Oyster Practice Title	Off-bottom private oyster aquaculture using hatchery-produced oysters	On-bottom private oyster aquaculture using hatchery-produced oysters	On-bottom private oyster aquaculture using transplanted wild oysters	On-bottom private oyster aquaculture using substrate addition	Private oyster aquaculture with no activity	On-bottom public fishery oyster production using hatchery-produced oysters	On-bottom public fishery oyster production using transplanted wild oysters	On-bottom public fishery oyster production using substrate addition	Public fishery with no activity	Active oyster reef restoration using hatchery-produced oysters	Active oyster reef restoration using wild oysters	Passive oyster reef restoration
***Panel Recommends for BMP Consideration**	**Yes**	**Yes**	No	**Yes**	No	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Decision Framework: Oyster-Associated Reduction Effectiveness Protocols



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

Decision Framework: Panel’s Incremental Approach

	Private Oyster Aquaculture				
Oyster Practice-Reduction Protocol Combination	Off-bottom private oyster aquaculture using hatchery-produced oysters	On-bottom private oyster aquaculture using hatchery-produced oysters	On-bottom private oyster aquaculture using transplanted wild oysters	On-bottom private oyster aquaculture using substrate addition	Private oyster aquaculture with no activity
Nitrogen Assimilation in Oyster Tissue	1st (#)	1st (#)	1st (x)	1st (#)	1st (x)
Nitrogen Assimilation in Oyster Shell	Future Report	Future Report	Future Report	Future Report	Future Report
Enhanced Denitrification Associated with Oysters	Future Report	Future Report	Future Report	Future Report	Future Report
Phosphorus Assimilation in Oyster Tissue	1st (#)	1st (#)	1st (x)	1st (#)	1st (x)
Phosphorus Assimilation in Oyster Shell	Future Report	Future Report	Future Report	Future Report	Future Report
Suspended Sediment Reduction Associated with Oysters	On hold	On hold	On hold	On hold	On hold
Enhanced Nitrogen Burial Associated with Oysters	On hold	On hold	On hold	On hold	On hold
Enhanced Phosphorus Burial Associated with Oysters	On hold	On hold	On hold	On hold	On hold

- First report includes recommendation for 10 of the 96 oyster practice-reduction protocol combinations:
  - “#” indicates that there was enough existing data to determine a reduction effectiveness estimate.
  - “x” indicates that the Panel felt the practice would not result in net reduction of pollutant.
- For same pollutant, reduction effectiveness would be additive (e.g., N assimilation in tissue + N assimilation in shell + enhanced denitrification + enhanced N burial = total N reduction).
- Public fishery and oyster reef restoration practices will also be covered in future reports.

Oyster Practice Categories Defined

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

Note: Definitions were modified after comments from WQGIT during November 28, 2016 meeting to clarify what is meant by "private oyster aquaculture." Private refers to designated oyster aquaculture areas where public fishing is not allowed, such as State-permitted oyster aquaculture leases to private oyster aquaculturists.

Reduction Effectiveness Qualifying Conditions

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

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

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

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

Panel's Method to Determine Conservative Default N and P Reduction Effectiveness Estimates

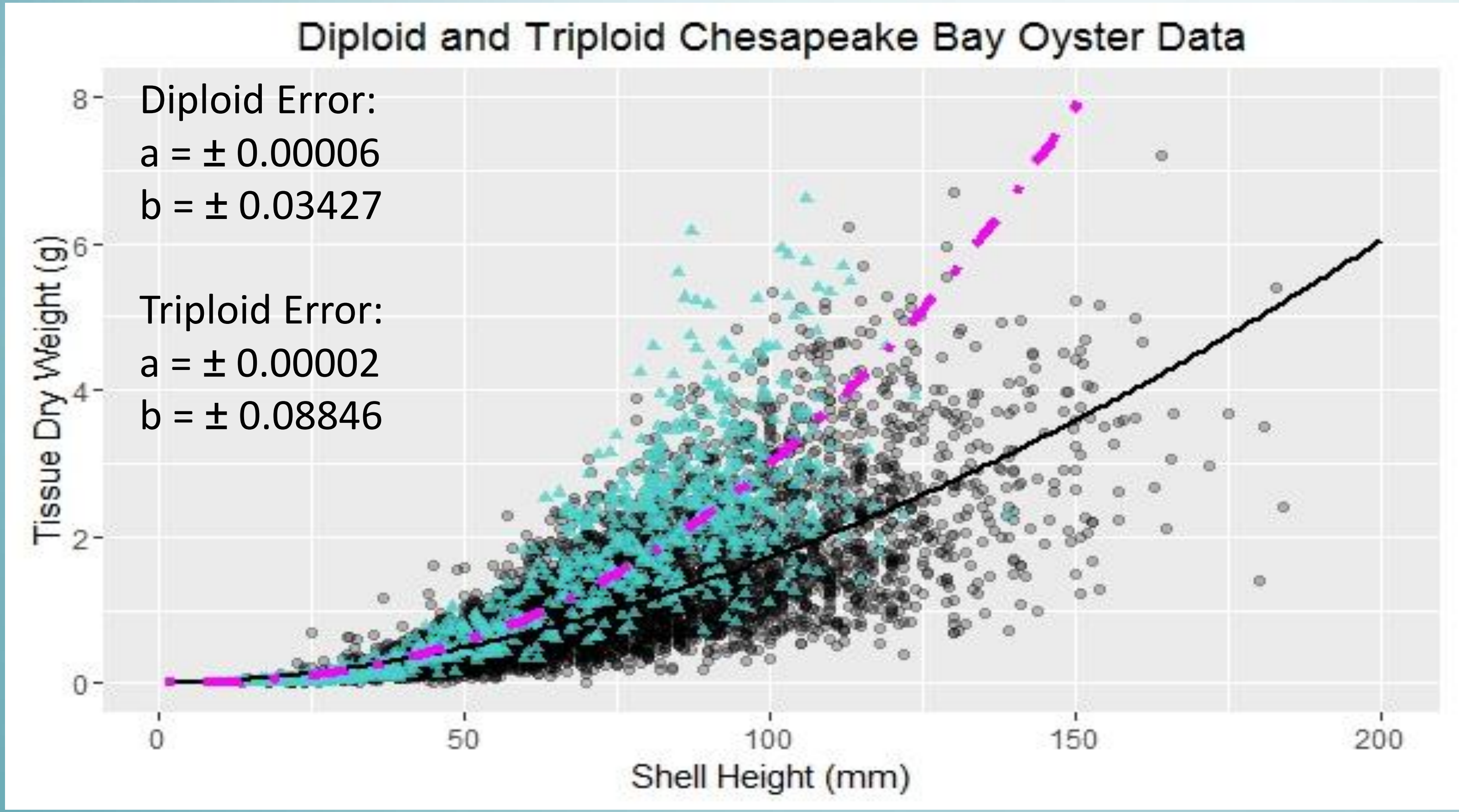
Step 1: Determine the oyster shell height to tissue dry weight quantile regression equations for diploid and triploid oysters

- Analysis included consideration of various oyster growth influencing factors: ploidy, culture method and type, location/environment, and season.
- Quantile regression uses the median of the data—less influenced by extremes (good statistical approach to use with highly variable data).

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

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

Default Calculation: Shell Height to Dry Tissue Weight Regression Equations for Diploids and Triploids



Diploid 0.5 Quantile Curve, $y = 0.0004x^{1.82}$ (n = 5,750 oysters)

Triploid 0.5 Quantile Curve, $y = 0.00005x^{2.39}$ (n = 1,066 oysters)

Conclusions:

- Enough data were available to establish shell height to tissue dry weight regression equations.
- Differences in biomass between diploid and triploid oysters warranted the use of separate regression equations.
- 50th quantile conservatively accounts for differences in culture method and type (off-bottom/on-bottom, hatchery-produced/wild) location/environment, and season (see report for details).

Default Reduction Effectiveness Estimates for N and P Assimilated in Oyster Tissue

Nitrogen: 8.2% average nitrogen content in oyster tissue dry weight (based on 7 studies in waterbodies along the Atlantic Coast; used the average of the site means for studies outside of Chesapeake Bay; site-specific averages were used for studies within Chesapeake Bay)

Phosphorus: 0.9% average phosphorus content in oyster tissue dry weight (based on 3 studies in Chesapeake Bay; same averaging approach as nitrogen, but only studies in Chesapeake Bay were found)

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

Methodology for Site-Specific Estimates

The Panel is recommending an option where the BMP implementer can apply for a site-specific estimate.

- The oyster BMP implementer works with the reporting jurisdiction and CBP Partnership to define:
  - Practice-specific oyster size class categories if using different categories than the default estimate
  - Two timeframes set by the State to reflect seasonal differences ~ 6 months apart.

- Once approved by the CBP Partnership, the operation will have 50 random oysters per size class per season analyzed to determine the average tissue dry weight.
  - Samples are sent to a lab that uses standardized methods to acquire the tissue dry weight in grams (e.g., tissue heated at 60°C until samples reach constant weight).

- The average tissue dry weight for each size class is multiplied by the default 8.2% N content and 0.9% P content in oyster tissue to determine the site-specific reduction effectiveness estimates.

- Review and approval of site-specific estimates follow a similar approach as the re-evaluation procedure of existing estimates described in the CBP Partnership BMP Expert Review Protocol. Same goes for re-evaluation of the site-specific estimates.

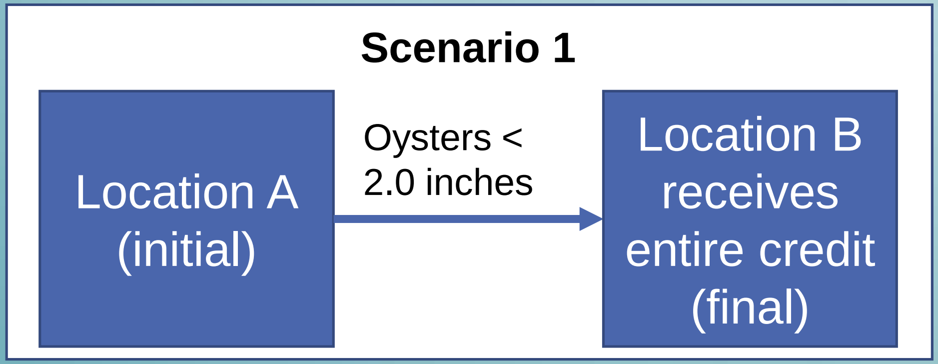
- Once approved by the CBP Partnership, the estimate would be applicable for that practice as long as they continue growing oysters under the same conditions when the reduction effectiveness evaluation was made.

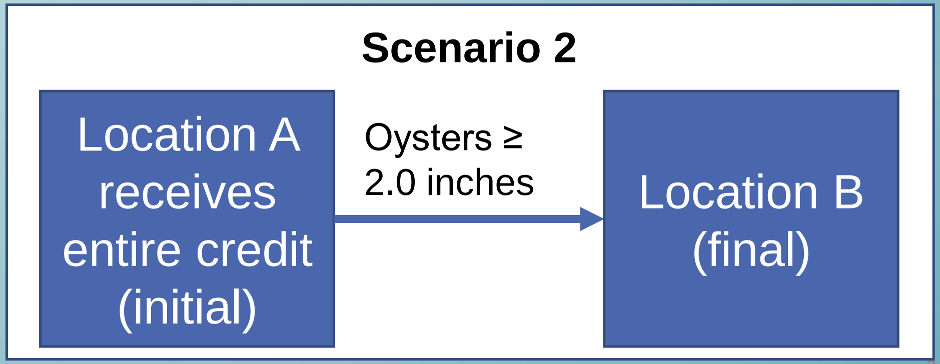
Recommended Application Guideline—Movement of Oysters

The Panel identified instances where oysters are moved from their initial grow-out location to another location in the Bay or elsewhere. Reasons for moving the oysters include:

- Changing the taste by moving oysters to an area with higher salinity
- Water quality problems in the initial grow-out location.

Panel Recommendation: The Panel decided that partitioning the credit wouldn't be necessary because oysters are either moved when they are less than 2 inches (entire credit would be applied to the final grow-out location) or they are moved for only a short period of time to the final grow-out location (entire credit would go to the initial grow-out location). The Panel recommended the below crediting scenarios instead using the average shell height verification check of 50 random oysters when oysters are moved to determine whether the credit is applied to the initial or final grow-out location.





Recommended Reporting Guidelines

Individual oysters would be the preferred reporting unit. However, since there are varying units (e.g., bushels, boxes) currently being used to report oyster harvest, the Panel recommends that the following information be reported to account for this in order to offer flexibility to reporting jurisdictions (i.e., State agencies) in verifying the reduction effectiveness in a scientifically-defensible manner.

1. *Type and total # of containers*- The type (bushel, box,) and total # of containers used to package oysters.

2. *Average # of oysters in each container type*- Needed to figure out the total # of removed oysters to apply the reduction effectiveness estimates to on an annual basis.
   - **Verification Guideline:** Quantify average # of oysters in a container by counting and documenting the total # of oysters in 10 containers two times a year (~ 6 months apart) to account for seasonal differences.

3. *The average size of oysters in each container type*- Needed to figure out which oyster size class estimate to use.
   - **Verification Guideline:** Quantify the average size of oysters in containers by measuring the shell heights of 50 randomly selected oysters from representative containers two times a year (~ 6 months apart) to account for seasonal differences.

Recommended Default Approach to Deal with Missing Verification and Ploidy Information

Missing Verification Measurements

Panel Recommendation: If average oyster shell heights and average numbers of oysters in containers are not known then a default approach where the minimum legal size of oysters and State documented information specifying the average number of minimum legal sized oysters can be packaged in a specific container is used.

Example: State minimum legal harvestable size is 3 inches and they define bushels as 300 individual oysters. If verification measurements are missing, then all bushels would be multiplied by 300 and individual oysters assigned to the 2.5-3.49 inch oyster size class reduction effectiveness estimate for diploids.

Missing Ploidy Designation

Panel Recommendation: If ploidy is missing, then apply the diploid estimates.

Reduction Effectiveness Options—Offers Scientifically-Defensible Flexibility to Implementing Programs

Most Simple Approach (estimates conservatively-derived; likely under-estimates reduction)

Most Complex Approach (most representative of the actual reduction)

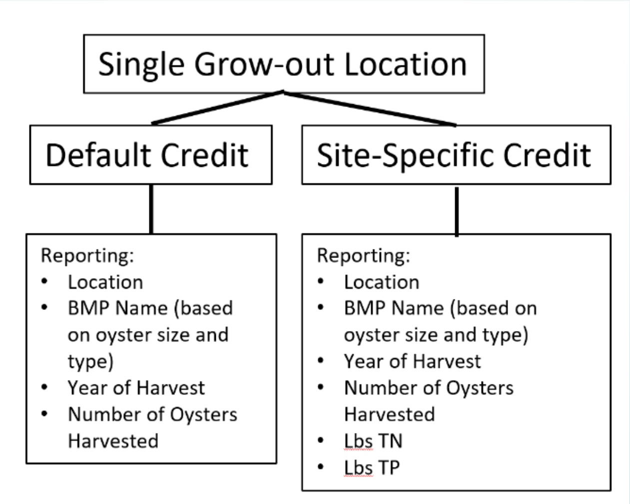
- Apply minimum default estimate
- Use ploidy identification and size class verification measurements to apply the corresponding default diploid or triploid size class estimate
- Use Panel's recommended methodology to establish a site-specific estimate for the practice

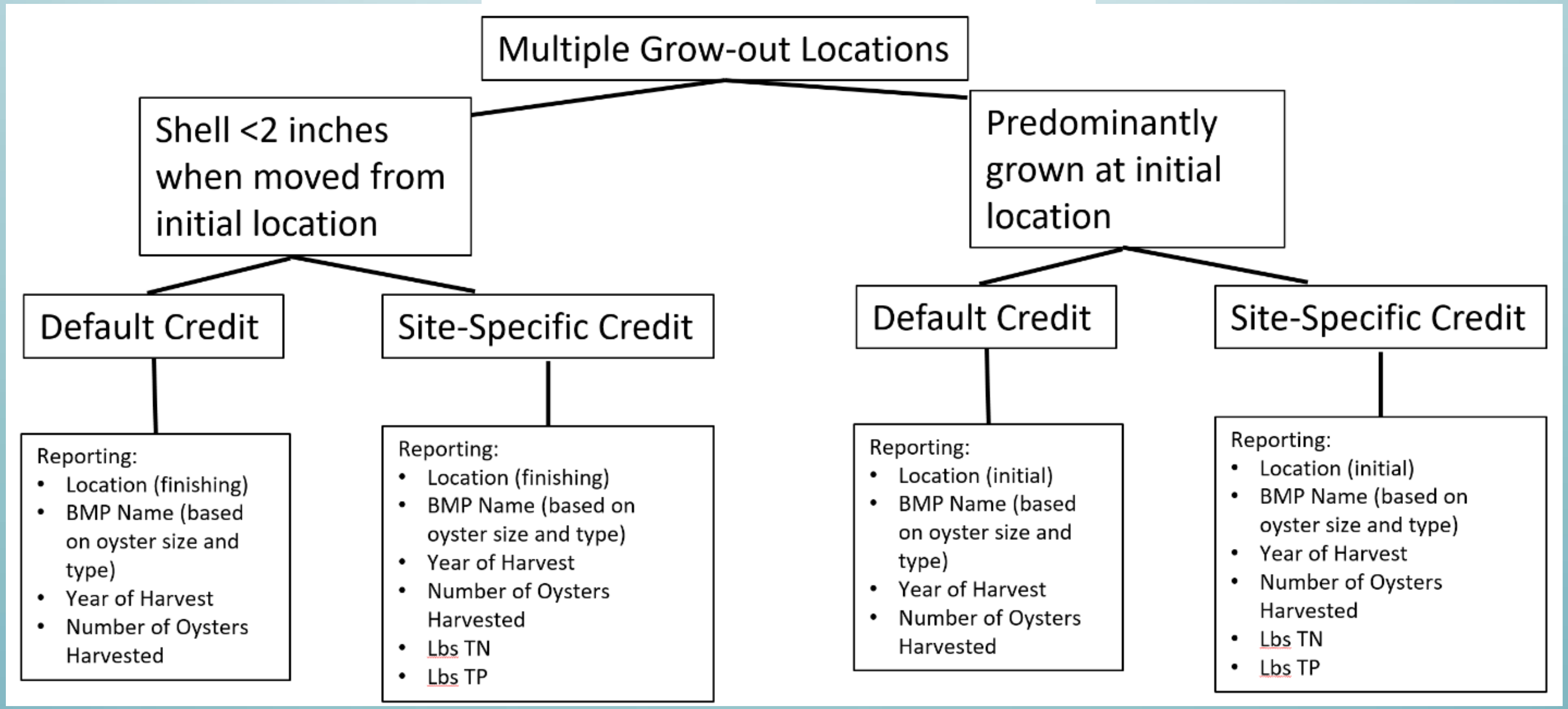
Technical Appendix: Reduction Effectiveness Estimates for N and P Assimilated in Oyster Tissue (Summarized for use in Model from Panel's Findings)

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

Above BMPs would be reported annually and are only eligible in tidal waters

Technical Appendix: Reporting Requirements





Technical Appendix: Additions by WTWG—Approved on December 1, 2016

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

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

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

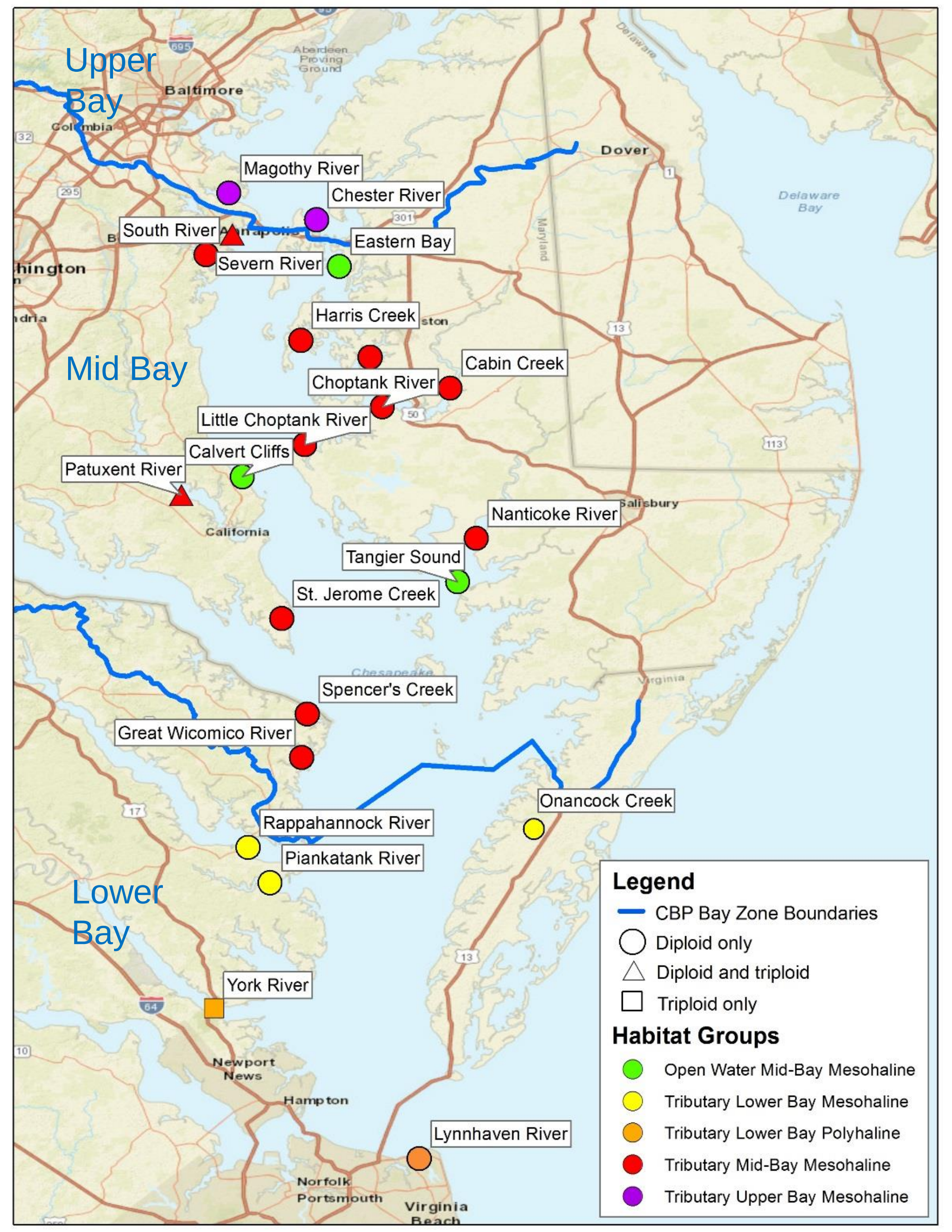
The WTWG will work with the Modeling Workgroup to determine if a cap on load reductions is appropriate for this and other site-specific pound reduction BMPs including stream restoration, shoreline management, and algal flow-ways.

How to Keep Informed of the Oyster BMP Expert Panel Efforts

Oyster Recovery Partnership webpage summarizing Panel progress:

oysterrecovery.org/water-quality-improvement/

QUESTIONS?



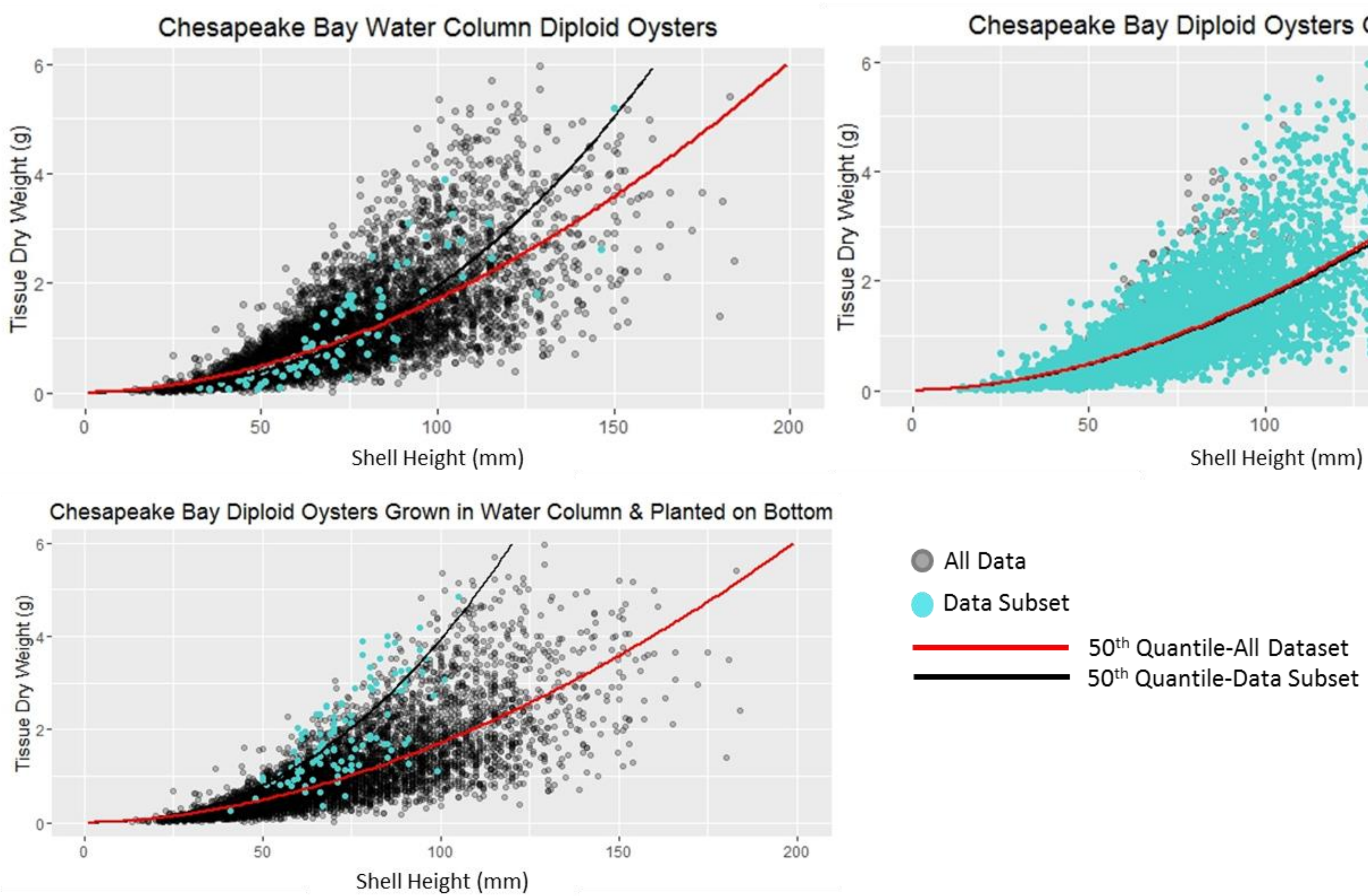
Data Locations Used for Regression Equations

- 22 general locations (1 triploid only site, 19 diploid only sites, and 2 sites with triploid and diploid oyster data).

- Location/, the oyster data were also grouped by where the location fell in the Chesapeake Bay Program Bay zones (Upper, Mid, and Lower) and by the its salinity characteristic (mesohaline or polyhaline).

Comments on Reduction Effectiveness

Oyster Culture Method Considerations



The shell height to tissue dry weight 50th quantile equation was derived from data representing both off-bottom (water column) and on-bottom culture methods.