Oyster BMP Expert Panel—Progress on the Nitrogen and Phosphorus Shell Assimilation and Enhanced Denitrification Protocols for Private Aquaculture and Restoration Oyster Practices

Update to the WQGIT

May 8, 2017

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OYSTER RECOVERY PARTNERSHIP | ORP

Chesapeake Bay Program
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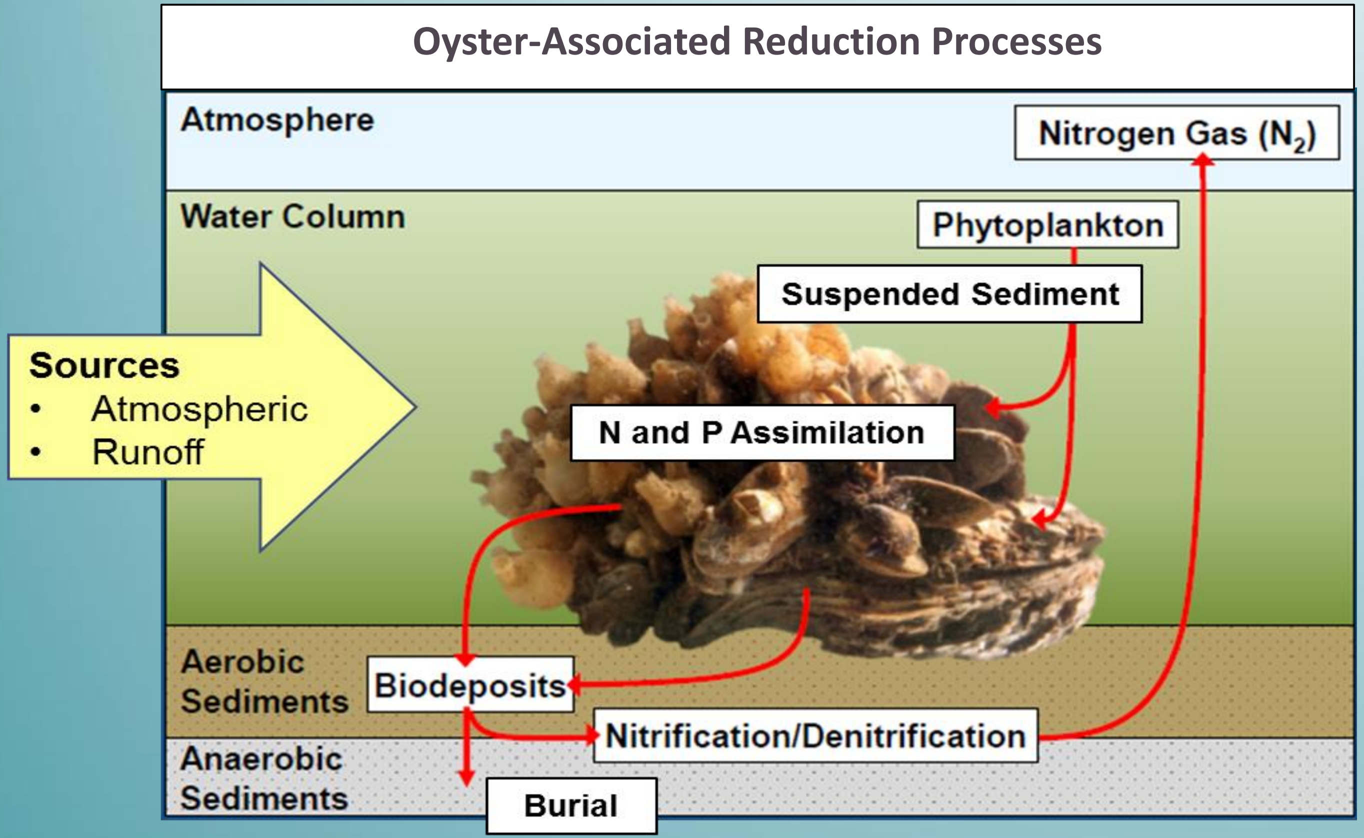
Oyster BMP Expert Panel Charge and Progress

- **Panel convened on September 22, 2015; charged with:**
  - Establishing a nutrient and suspended sediment reduction effectiveness determination decision framework for oyster BMPs. **COMPLETED** (see 1st Report)
  - Determining the nutrient and suspended sediment reduction effectiveness of oyster practices using available science. **COMPLETED for some practices/protocols; ONGOING for others**



Framework Decision Points

- Suitable for Consideration
- Sufficient Science
- Verifiable
- Identified Unintended Consequences Manageable

Reduction Effectiveness Determination Matrix

		Private Aquaculture (Harvested)			Oyster Reef Restoration (Sanctuaries)		
	Reduction Effectiveness Protocols	Off-Bottom Culture (hatchery-produced diploid/triploid)	On-Bottom Culture (hatchery-produced diploid/triploid)	Bottom Substrate Addition (wild diploid)	Active Restoration (hatchery-produced diploid)	Active Restoration (wild diploid)	Passive Restoration (wild diploid)
*	1. Nitrogen Assimilation in Oyster Tissue	# (1st)	# (1st)	# (1st)	?-Policy (2nd)	?-Policy (2nd)	?-Policy (2nd)
*	**2. Nitrogen Assimilation in Oyster Shell**	**?-Policy (2nd)**	**?-Policy (2nd)**	**?-Policy (2nd)**	?-Policy (2nd)	?-Policy (2nd)	?-Policy (2nd)
*	**3. Enhanced Denitrification Associated with Oysters**	**? (2nd)**	**? (2nd)**	**? (2nd)**	**? (2nd)**	**? (2nd)**	**? (2nd)**
**	4. Phosphorus Assimilation in Oyster Tissue	# (1st)	# (1st)	# (1st)	?-Policy (2nd)	?-Policy (2nd)	?-Policy (2nd)
**	**5. Phosphorus Assimilation in Oyster Shell**	**?-Policy (2nd)**	**?-Policy (2nd)**	**?-Policy (2nd)**	?-Policy (2nd)	?-Policy (2nd)	?-Policy (2nd)
***	6. Sediment Reduction Associated with Oysters	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy
*	7. Enhanced Nitrogen Burial Associated with Oysters	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy
**	8. Enhanced Phosphorus Burial Associated with Oysters	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy	?-Policy

= approved estimate; ? = estimate under evaluation; 1st = covered in 1st report; 2nd = planned for 2nd report; policy = outstanding policy issue needs to be resolved

Open Feedback Meeting—May 22nd

- **Oyster BMP Expert Panel is hosting an open meeting to offer an opportunity for early feedback on shell assimilation and enhanced denitrification crediting protocols.**
  - In person location: Potomac River Fisheries Commission, Colonial Beach, VA
  - Registration Required: Register at https://oysterrecovery.org/bmpregistration/

- **Looking for feedback on:**
  - Approaches used to determine estimates.
  - Strategies in addressing concerns related to unintended consequences.
  - Thoughts on verification.

Questions Related to Using Oysters as a BMP

- **Science-Related: Reduction Effectiveness Determination**
  - Is there enough data to account for differences across the various oyster practices occurring in Chesapeake Bay?
  - How can the reduction be quantified and verified given the variability in data concerning oyster growth, survival, and denitrification rates?

- **Policy-Related: Removal Versus Sequestration**
  - Should reduction credit only be given to harvested oysters where the nitrogen and phosphorus is removed from the waterbody?
  - How to handle crediting shells given that they need to be returned to the Bay?
  - Can buried biodeposits or sequestered N and P in oysters that are not harvested receive credit?

Shell Assimilation Strategy for Aquaculture Practices

Can shell weight be reliably determined from shell length measurements?

No

Yes ✓

Can N and P content in shell be quantified?

No

Crediting not feasible at this time due to research gap

Yes ✓

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

No

Crediting not feasible due to unintended consequence

Assume 100% of shell removed is returned to the Bay

Yes ✓

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

No

Crediting not feasible at this time due to research gap

~~Yes~~ X

Is the loss rate feasible for a BMP?

No

Crediting not feasible because loss rate outweighs sequestration benefit

Yes ?

Recommend appropriate estimate that includes deduction for dissolution

Shell Assimilation Method to Determine Conservative Default N and P Estimates for Aquaculture Practices (Similar Approach as Approved Tissue Estimates)

Step 1: Determine the oyster shell height to shell dry weight quantile regression equations

- Analysis to include considerations 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 shell dry weight for BMP (using same size classes as tissue)

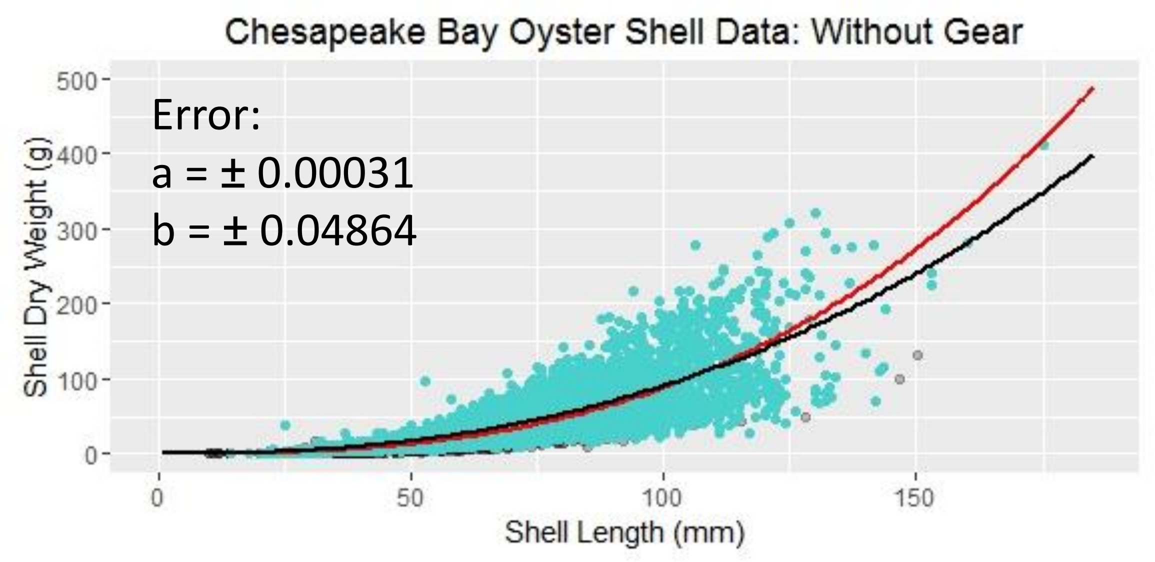
Step 3: Apply the percent nitrogen and phosphorus content in oyster shell to determine the reduction effectiveness estimates

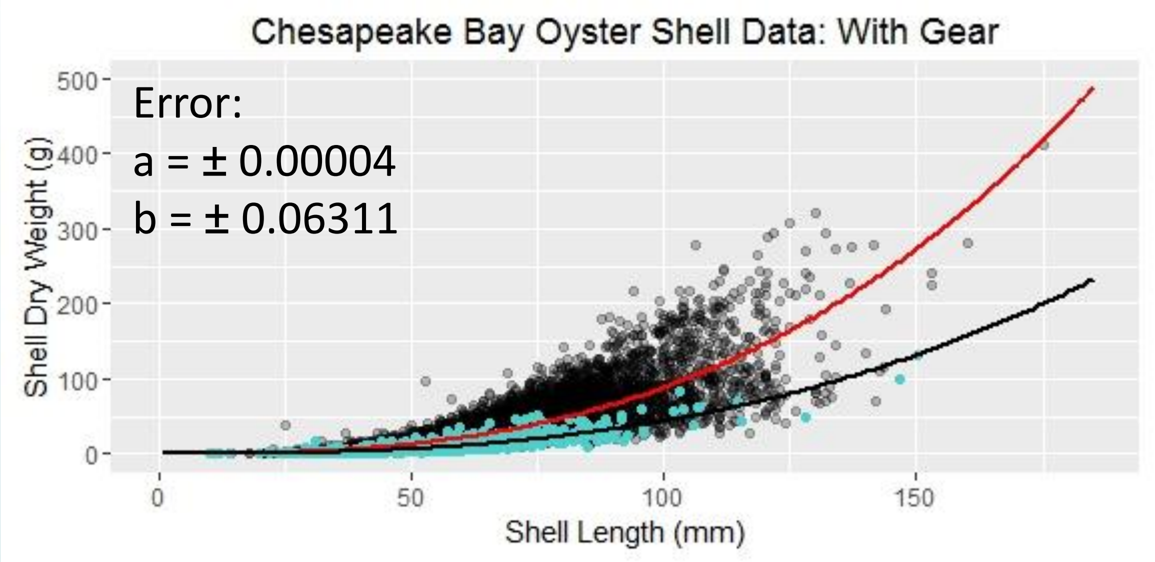
Shell Assimilation: Literature Review for Quantile Regression Equation (Step 1)

Category	# of Data Sources	# of Locations*	# of Seasons	# of Diploid Oysters	# of Triploid Oysters
Off-Bottom with Gear	2	6	4	317	1325
On-Bottom without Gear	6	>11	4	4296	0

*Location coordinates being confirmed with researchers

Shell Assimilation: Quantile Regression Equation (Step 1)





Without Gear 0.5 Quantile Curve, $y = 0.0015x^{2.40}$ (n = 4296 oysters)

With Gear 0.5 Quantile Curve, $y = 0.0002x^{2.71}$ (n = 1642 oysters)

All Data 0.5 Quantile Curve, $y = 0.0003x^{2.77}$ (n = 5938 oysters)

All data

Data subset

Panel conclusions thus far:

- Agreed that there is sufficient data to reliably determine shell weights from shell height data.
- Agreed that culture methods with and without gear should have separate estimates (with gear produces thinner, lighter shells; using all data would overestimate reduction for off-bottom aquaculture practices).
- Still evaluating seasonal and ploidy differences, but appears that culture method is driving the weight differences.

Default Percent N and P in Oyster Shell (Step 3)

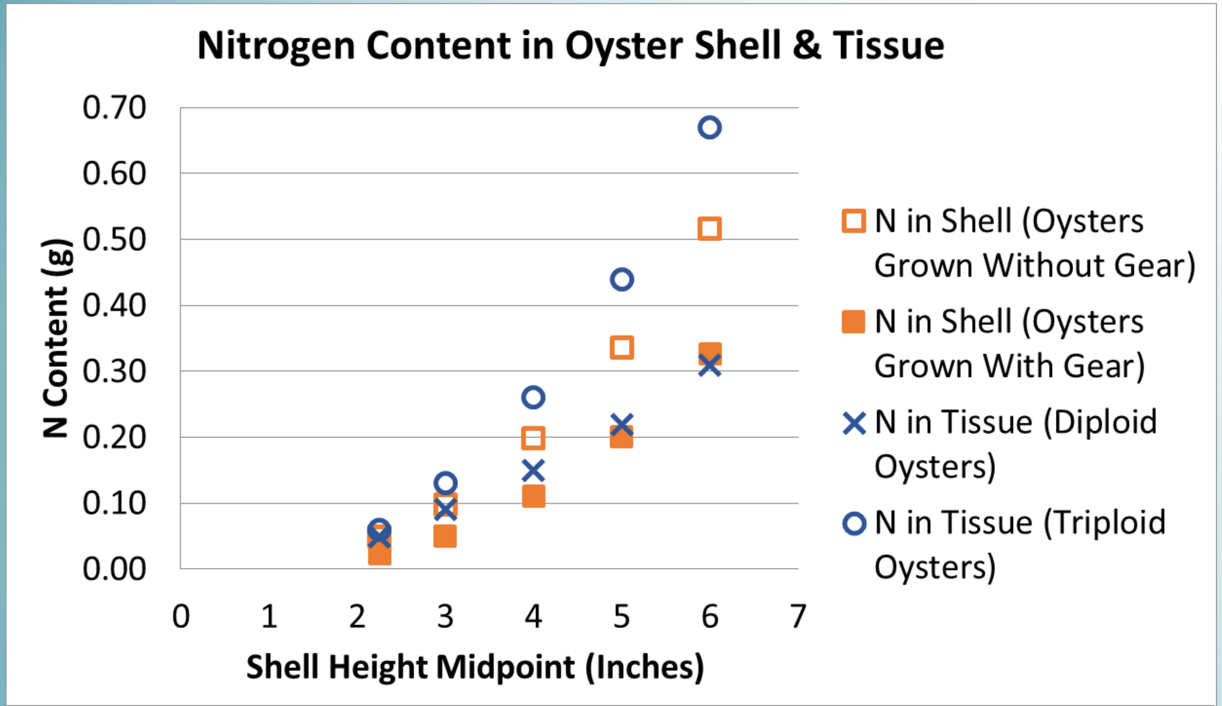
Nitrogen: 0.20% average nitrogen content in oyster shell dry weight

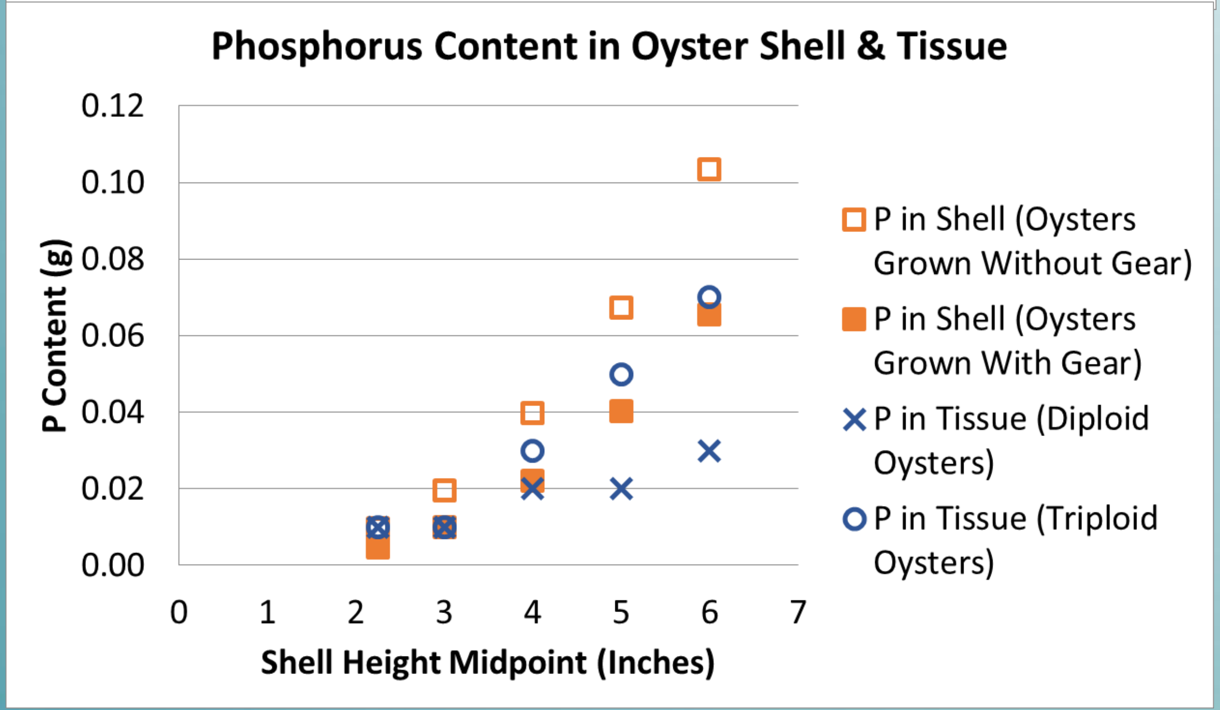
- Based on 7 studies in waterbodies along the Atlantic Coast (non-Chesapeake Bay, n=12 sites, 4 locations; Chesapeake Bay, n=4 sites, 3 locations)
- Used the average of the site means outside of Chesapeake Bay (3 studies); values ranged from 0.08-0.32%
- Used site-specific averages within Chesapeake Bay (4 studies); values ranged from 0.15-0.21%

Phosphorus: 0.04% average phosphorus content in oyster shell dry weight

- Based on 3 studies in Chesapeake Bay (n=3 sites, 3 locations)
- Same averaging approach as nitrogen, but only studies in Chesapeake Bay were found; values all equaled 0.04%

Overall, low variance in values from Chesapeake Bay studies





DRAFT Shell Assimilated N and P Compared to Approved Tissue Estimates

Comparison:

- N in shell of oysters grown without gear is equivalent or above N in tissue of diploid oysters.
- P in shell of oysters grown with and without gear is above or near P in tissue of triploid oysters.

Conclusion:

- Amount of N and P assimilated in shell is worthwhile to consider.
- Shell on par with tissue even though it has less % content because total N and P content is driven by weight and shell weighs more than tissue.
- However, harvested shell is temporary sequestration of N and P, since it should be returned to the Bay (oyster practices depend on the availability of shell).

Shell Assimilation: Evaluation of Dissolution Literature to Account for Shell being Returned to the Bay

- **Three types of studies found:**
  - Annual shell loss rates from field studies:
    - Delaware Bay: Average shell loss rate per year ranged from 5-37% (Powell et al. 2007)
    - James River: Shell loss rate >20% per year for reefs (Mann et al. 2009).
  - Instantaneous shell decay rates based on field studies:
    - Rate of 0.5-0.9 per year (Smith et al. 2005)
    - Rate of 0.45 per year for market size oysters (Christmas et al. 1997)
  - Shell dissolution rates based on lab study:
    - Weathered shell degraded from 0.06-0.15% per day depending on pH (Waldbusser et al. 2011)

- **Panel's conclusions:**
  - Studies only evaluated loss of carbonate shell structure and not the loss of N and P; some studies did not differentiate shell loss due to dissolution from burial.
  - Waldbusser et al. 2011 study most relevant, but may not adequately account for what is happening in the field.
  - With existing science, the Panel is not confident in assigning a default deduction to account for N and P that may dissolve back into the water when shells are returned to the Bay.

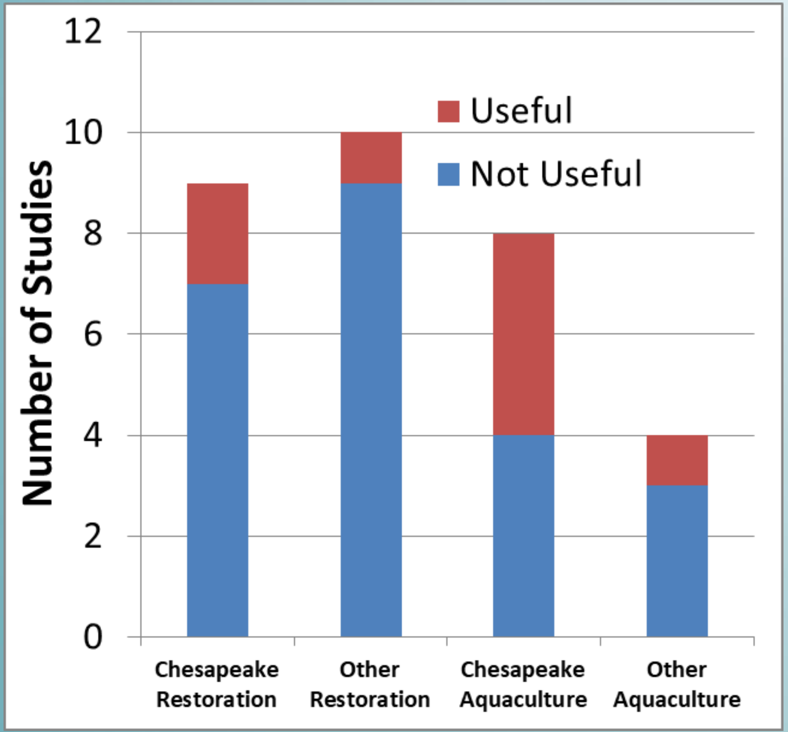
Shell Assimilation: Questions for Feedback Consideration

- Is a deduction approach (based on dissolution) acceptable for a BMP estimate (assumption is that 100% of removed shell is returned to the Bay)? Does this approach adequately address concerns that shell won't be returned to the Bay? Are there any concerns with this approach?
- Are there any suggestions for another approach to accommodate shell crediting with shell being returned to the Bay that the Panel could consider?

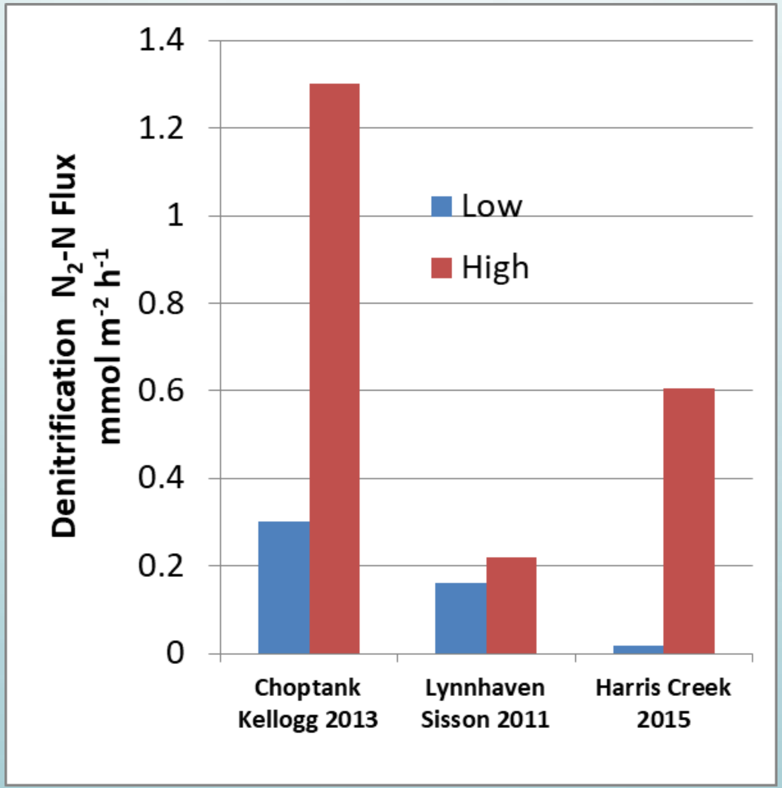
Denitrification as a BMP – Data, Data Analysis, and Challenges

- In the Chesapeake Bay, we have more (valid) data on denitrification - associated with oyster restoration and aquaculture than any other region.
- There are still a relatively few number of studies.
- There may be substantive issues with the "simple" approach used in previous studies.
- From Panel evaluation thus far, current estimates of nitrogen removal via denitrification data may overestimate the benefit for restoration and underestimate it for aquaculture.
- Robust estimates will rely on site-specific information about the fate of biodeposits, a parameter for which few data exist.

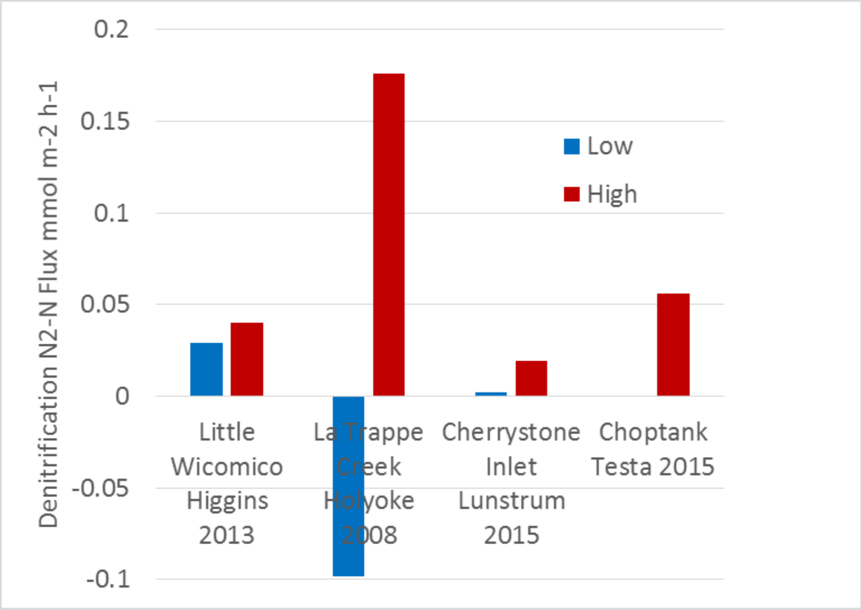
Denitrification Literature Review



Chesapeake Bay, Restoration-Related



Chesapeake Bay, Aquaculture-Related

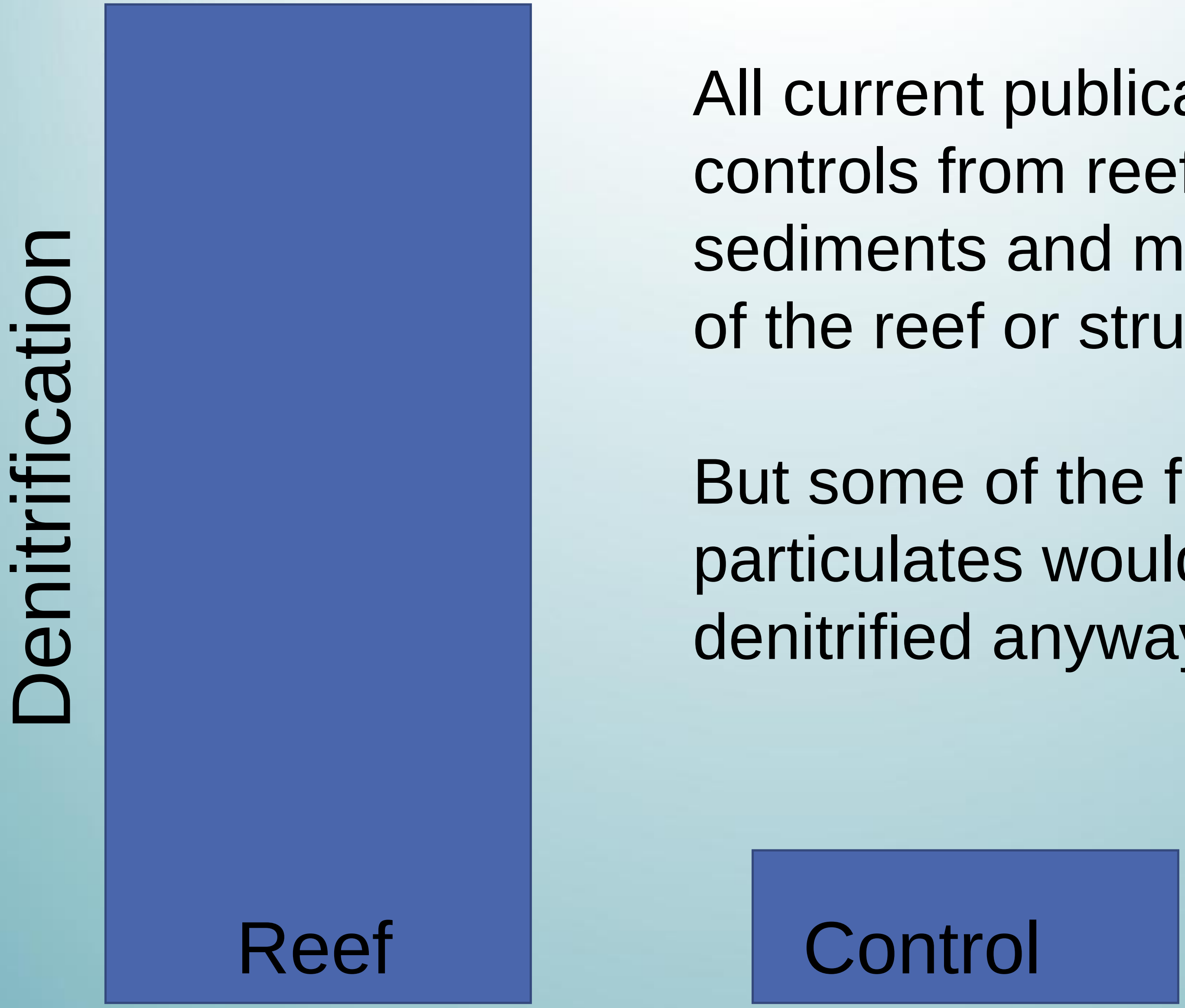


"Useful" determination based on whether a modern technique was used to measure denitrification rates and Panel's best professional judgement

Low = minimum rate observed
High = maximum rate observed

From These Data We Can….

- Consider what we mean by enhancement of denitrification. Denitrification occurs in all of the systems prior to the addition of oysters, but how much more is added at the ecosystem level?
- Identify where we need to go to make a BMP recommendation.
- Identify assessment need to quantify enhanced denitrification.



All current publications subtract controls from reef or aquaculture sediments and multiply by the area of the reef or structures.

But some of the filtered particulates would have been denitrified anyway!

Measured Denitrification ≠ Enhanced Denitrification

Controls on Denitrification Rates

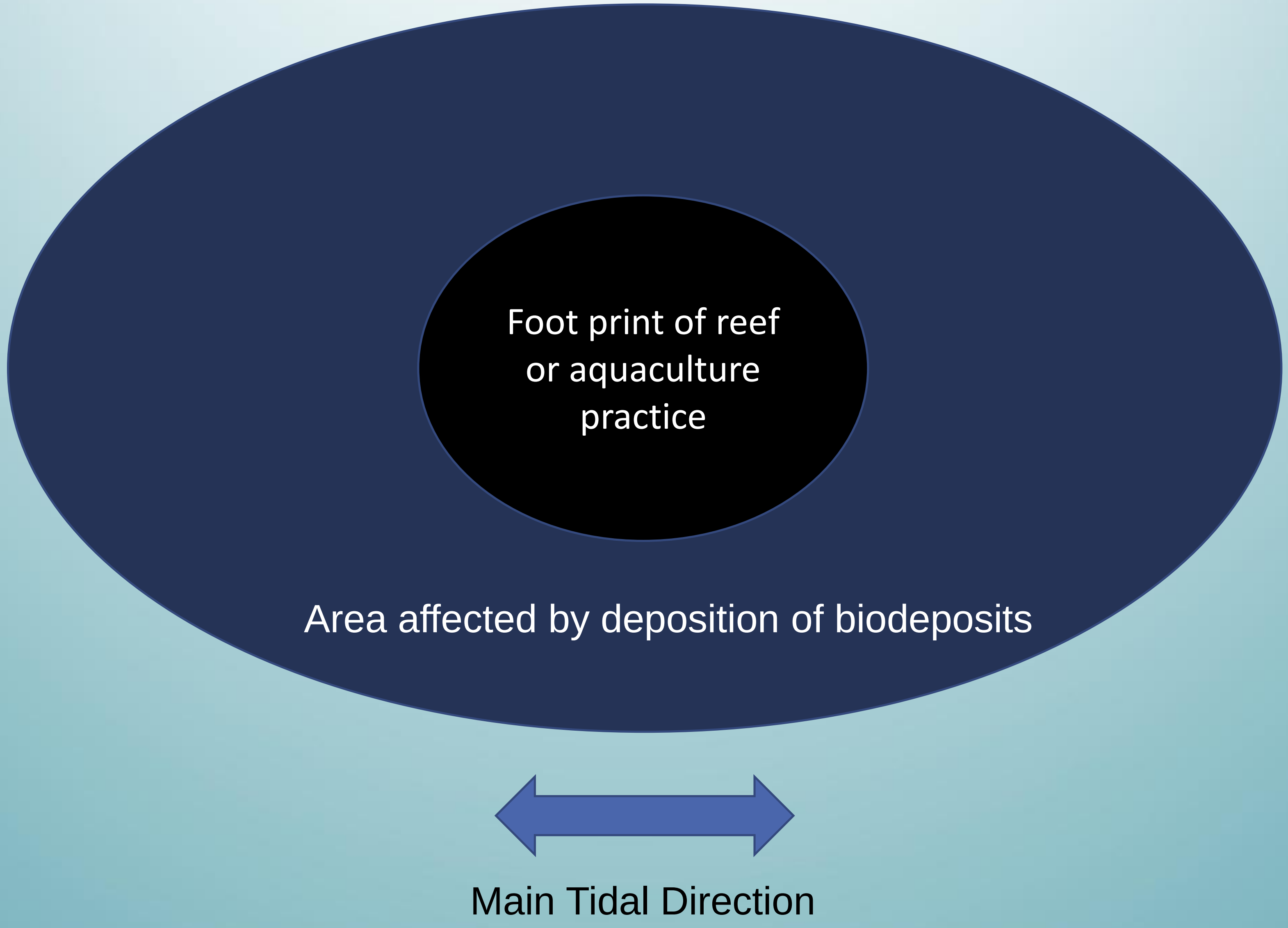
Before Oysters

- Particulate nitrogen remineralized in water column and in sediments
- Only in sediments is there denitrification from remineralized nitrogen
- The efficiency of transforming this remineralized nitrogen to N_2 gas is the "denitrification efficiency"

After Oysters

- Oysters filter that same particulate nitrogen, assimilate some, and package the rest as biodeposits
- The only "new" denitrification is the denitrification coming from what would have been water column remineralization
- The denitrification efficiency of the reef versus the original sediment fate has a large impact on enhanced denitrification rates

Enhanced Denitrification Consideration: Fate of Biodeposits



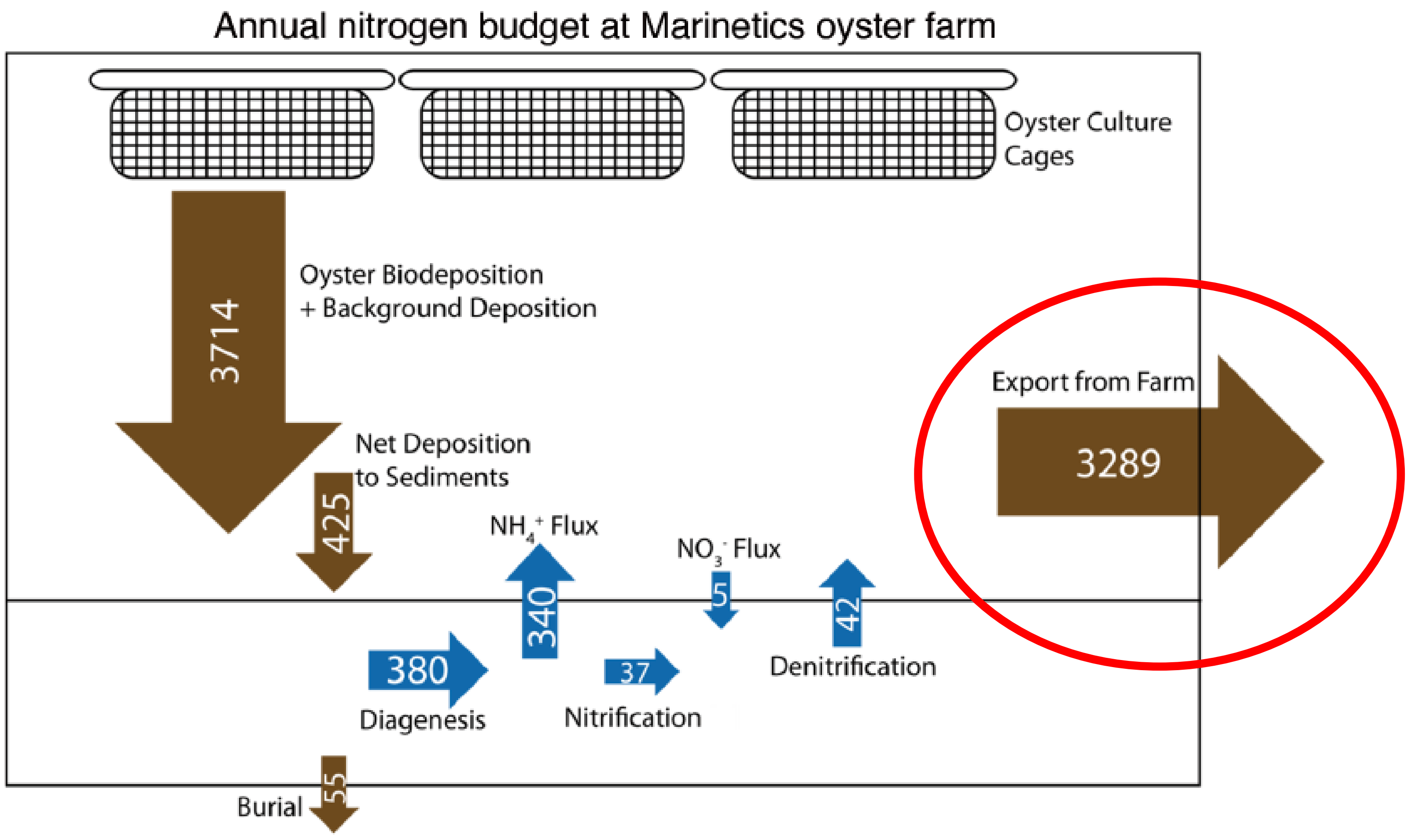


Fig 11. Annual nitrogen budget for the Marinetics oyster farm. Brown arrows represent physical transport, while blue arrows represent biogeochemical fluxes. Clearly, the majority of the material that could potentially be integrated into the sediments is exported from the site before biogeochemical transformation could occur. NH_4^+ fluxes dominate the sediment–water exchanges. All units in $\mu mol\ m^{-2}\ h^{-1}$

BUT THE 3289 IS THE MOST INTERESTING PART REGARDING ECOSYSTEM SERVICES!

Conclusions I.

- We don't really know all of the parameters of biodeposit production and redistribution in many places
- But we know a lot in some places
- A simple comparison of control and reef may overestimate denitrification. Except that it does not account for enhanced denitrification in surrounding areas.
- In aquaculture, the *footprint* looks grim in many cases. But with redistribution of biodeposits to surrounding sediments, near and far, denitrification may be enhanced.
- In the same way, enhanced ammonium flux may be much less of a problem (in a system sense).

Conclusions II. What, in the end, do oysters really do?

- They take away remineralization, i.e. production of inorganic N, from the water column and transfer the process to the sediments. In the water column, 100% of remineralized N is available for algae. In sediments, denitrification intercepts some of this remineralized N.
- So for enhanced denitrification, we need to consider the whole system.
- We may not be able to use 100% of on bottom oyster additions for enhanced denitrification. But we also know that aquaculture, if we only consider the structural footprint, is shorted in our current calculations!

Denitrification: Questions for Feedback Consideration

- Would an average or minimum default value be acceptable to use now until we have a larger observational data set to consider fate of biodeposits for the different practices under various types of environmental conditions?
- Are there any other studies/ongoing work that anyone is aware of?
- What are the concerns of users and managers regarding how we proceed?

How to Keep Informed of Panel Efforts

ORP webpage summarizing Panel progress and registration for open meeting on May 22, 2017 available at

oysterrecovery.org/water-quality-improvement

First report available at

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

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QUESTIONS