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

Open Feedback Meeting

May 22, 2017

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Oyster Recovery Partnership | ORP

Chesapeake Bay Program
Science. Restoration. Partnership.

Requests to the Chesapeake Bay Partnership to Consider Oysters for BMP use to Improve Water Quality in the Chesapeake Bay

Filter Feeders Influence Water Quality

Source: Screenshots from Chesapeake Bay Foundation time-lapsed video

Evaluation of the Use of Shellfish as a Method of Nutrient Reduction in the Chesapeake Bay (2013)

Workshop request to evaluate the science and provide recommendations on the use of oysters to reduce nutrients.

City of Virginia Beach Virginia
A Community for a Lifetime

Request to consider denitrification rates for a "sanctuary oyster reef" BMP

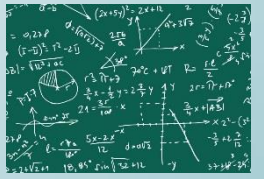
Oyster Company of Virginia

Request for *in situ* nutrient remediation pilot between oyster farm and stormwater permittee

Using science to inform policy: Oyster BMP

Water Quality Assessment
Is there evidence of environmental problems?

TMDL: Environmental modeling
Determine amount/where nutrient reductions are needed to eliminate the problems



Watershed Implementation Plans
States and municipalities come up with plans to achieve the reductions required to fix the problems

Best Management Practices
Practices/technologies are used to reduce nutrients at the state and local level

BMP Expert Panels
Evaluates reduction effectiveness of proposed BMPs following the Chesapeake Bay Program BMP Review Protocol

Proposed Oyster BMPs

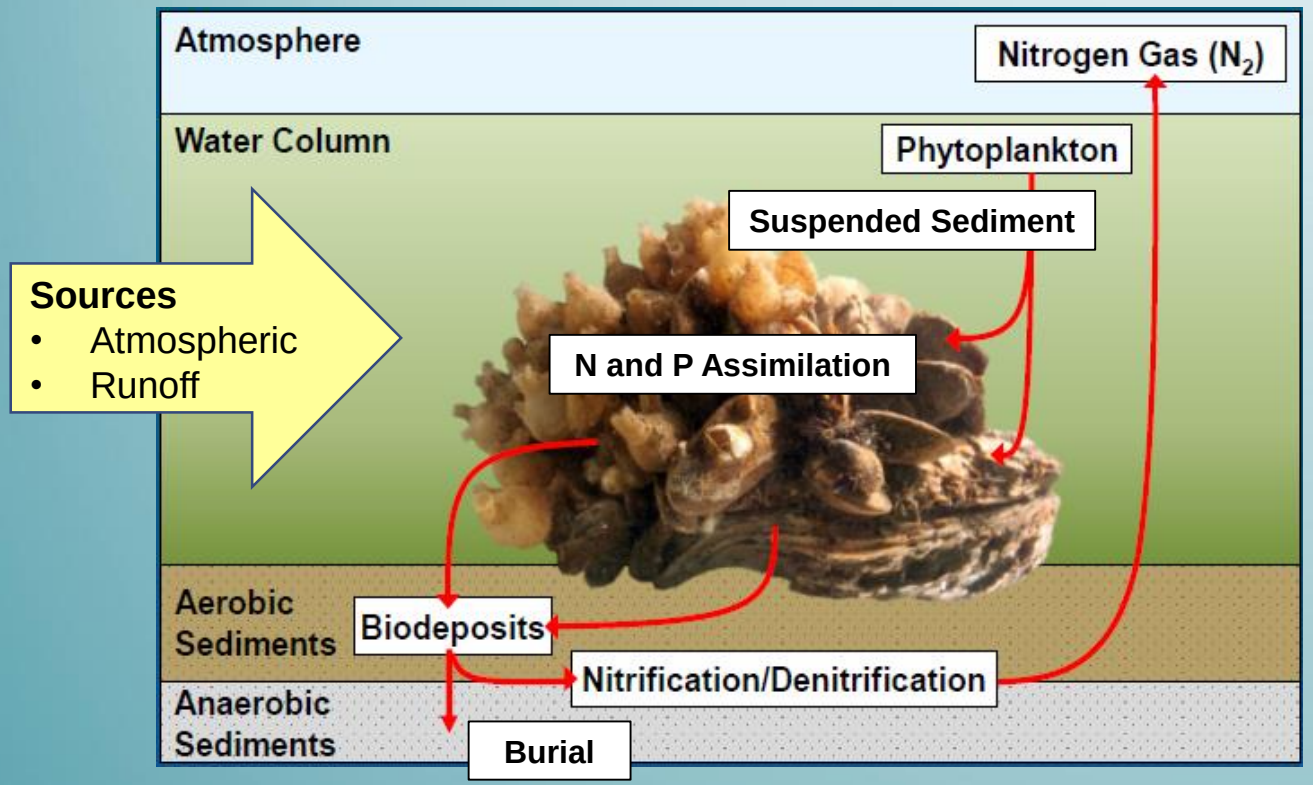
Oyster BMP Expert Panel Charge and Progress

- **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	Definition
Suitable for Consideration	Reduction process occurs with practice; involves enhancement activity producing new oysters
Sufficient Science	Quality and scope of data can generate a reasonably constrained estimate
Verifiable	Practical method exists, or could be created, to track reduction effectiveness
Identified Negative Unintended Consequences Manageable	Potential unexpected effects resulting from the practice; can it be controlled so it doesn't outweigh environmental benefit?

Oyster-Associated Nutrient and Suspended Sediment Reduction Effectiveness Crediting Protocols

From Framework: Identify individual nutrient and suspended sediment reduction effectiveness crediting protocols based on oyster-associated nutrient and sediment reduction processes.



Modified from Kellogg et al. 2013

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

Chesapeake Bay Oyster Practices

From Framework: Establish oyster practice categories that capture individual practices that would have similar nutrient and suspended sediment reduction effectiveness considerations.

Chesapeake Bay Oyster Practices						
Oyster Fate	Oysters removed (harvested) from Bay			Oysters remain in Bay		
Fisheries Management Approach	Private oyster aquaculture (water column and bottom leases)			Oyster reef restoration (sanctuaries)		
Oyster Culture Type	Hatchery-produced oysters		Wild Oysters	Hatchery-produced oysters	Wild oysters	
Activity	Hatchery-produced oysters grown off the bottom using some sort of gear (e.g., floating rafts near the surface or cages near the bottom)	Hatchery-produced oysters grown on the bottom using no gear	Addition of substrate to the bottom to enhance recruitment of wild oyster larvae	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 substrate addition**	**Active oyster reef restoration using hatchery-produced oysters**	**Active oyster reef restoration using wild oysters**	**Passive oyster reef restoration**

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

Looking for Feedback On

Progress on:

- Nitrogen (N) and phosphorus (P) assimilation in oyster shell for private oyster aquaculture practices
- N removal via enhanced denitrification associated with oysters for private oyster aquaculture practices
- N removal via enhanced denitrification associated with oysters for oyster reef restoration practices

Particularly:

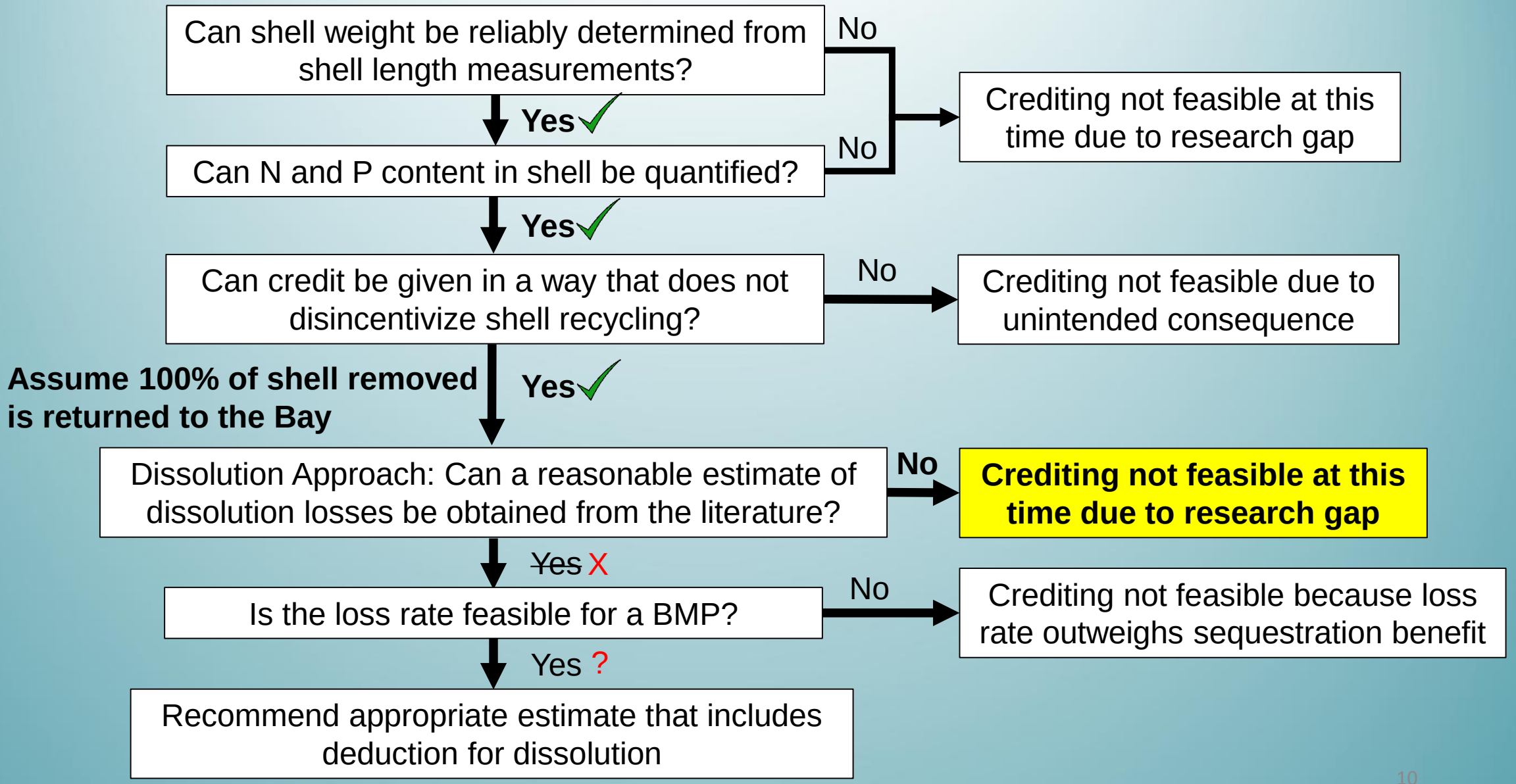
- Approaches used to determine estimates.
- Strategies in addressing concerns related to unintended consequences.
- Thoughts on verification.

Feedback We've Heard So Far

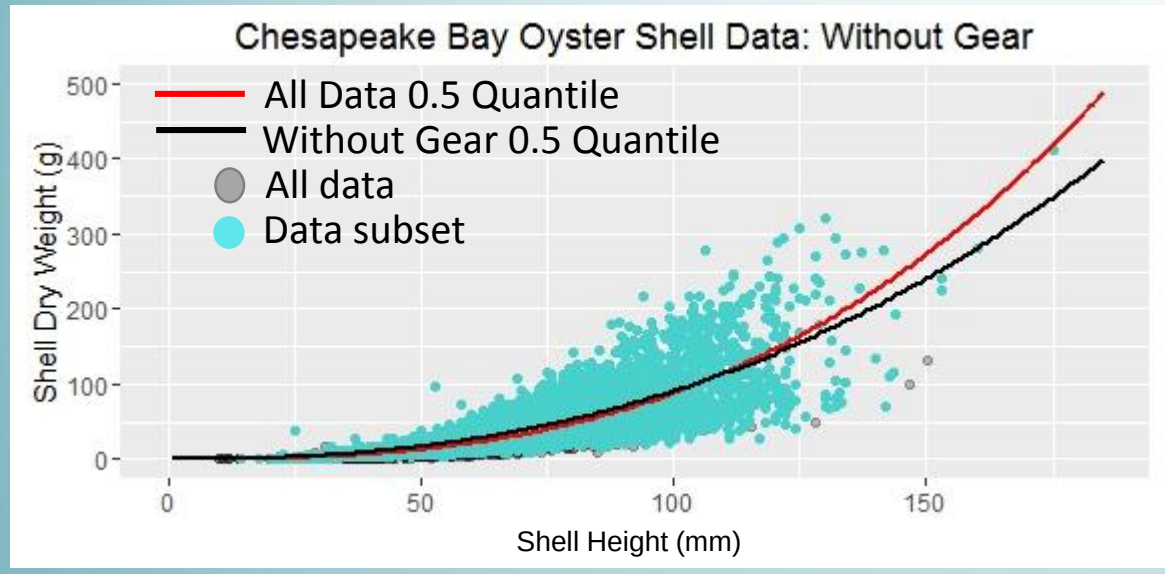
- **N and P Assimilated in Oyster Shell**
  - Consider value of oyster shell being returned to Bay; aquaculture accelerates the production of new shell producing more new oysters (increase in nutrient reduction); overrides concern of N and P being re-released.
  - Sequestering of nutrients should be looked at from a short-term perspective, since the TMDL has short-term goals; need further options that residents will support to meet TMDL goals (such as oysters).
  - Consider shells of cage-grown triploid oysters tend to be thinner.
  - Consider monthly growth differences.
  - Concerned with potential unintended consequence of disincentivizing shell recycling.
  - Concerned that the focus on crediting nutrients stored in oysters will impede efforts to address the source of the problem (improper disposal of poultry litter, manure, and sewage sludge by land applications).

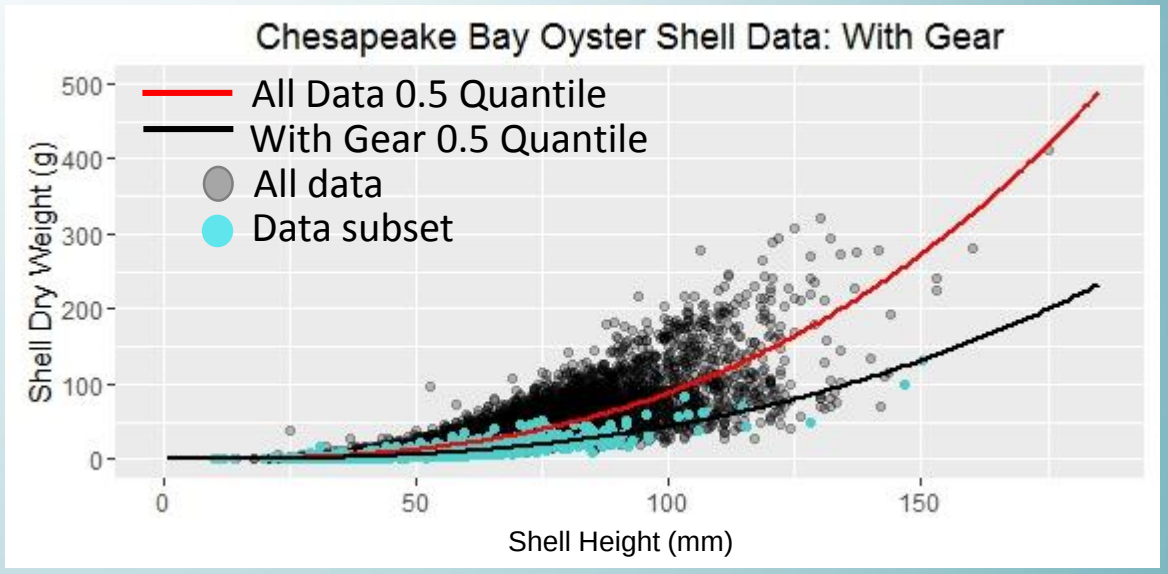
- **Enhanced Denitrification Associated with Oysters**
  - For baseline, consider denitrification that would occur in the absence of oysters.
  - Support for crediting protocols for sanctuary oyster reef nutrient removal.
  - Data availability; is there adequate data to account for variability in oyster growth?
  - How to handle accumulation of nutrient heavy biodeposits in systems with heavy oyster aquaculture?
  - Crediting should be accompanied with verification guidelines due to variability among sites.
  - Concerned that studies don't document denitrification above background in aquaculture settings.
  - Concept is very premature; not enough reliable, reproducible data.

N and P Assimilation in Oyster Shell: Strategy to Determine Reduction Effectiveness for Private Oyster Aquaculture Practices



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





Step 1: Use quantile regression to determine shell height (SH) to shell dry weight (DW) relationship

Step 2: Identify typical industry size classes and use midpoint shell height to calculate shell weight with regression equation

Step 3: Convert dry weight to N & P assimilated using average N & P content of oyster tissue from East Coast estuaries

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.
- Still evaluating seasonal and ploidy differences, but appears that culture method is driving the weight differences (potentially ploidy too).
- Literature review showed that **average N content in shell = 0.20% and P = 0.04%**

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

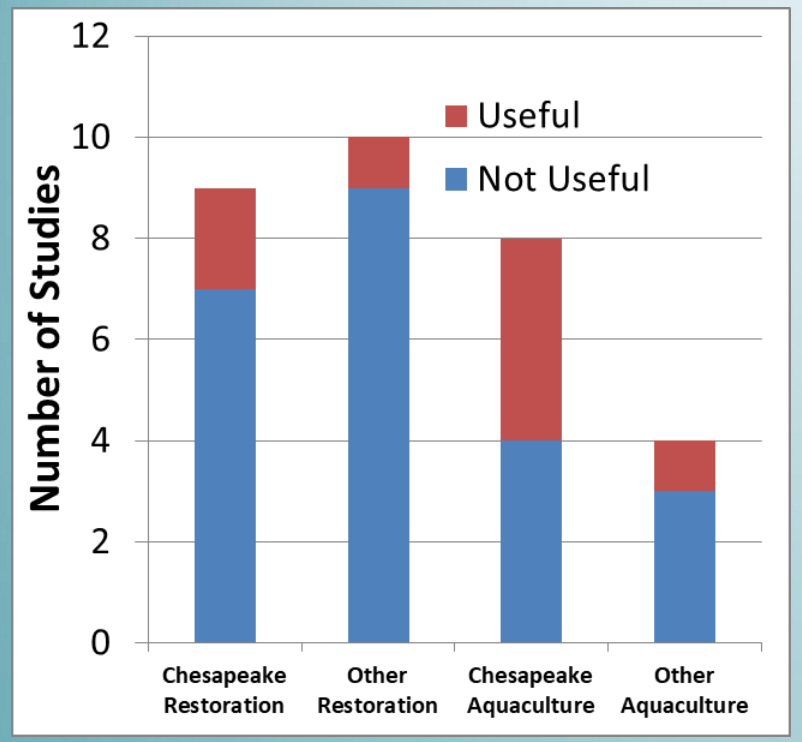
- **Three types of studies found:**
  - Annual shell loss rates from field studies:
    - Delaware Bay: Average shell loss rate per year ranged from 5-37% (Powell et al. 2007)
    - James River: Shell loss rate >20% per year for reefs (Mann et al. 2009).
  - Instantaneous shell decay rates based on field 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.

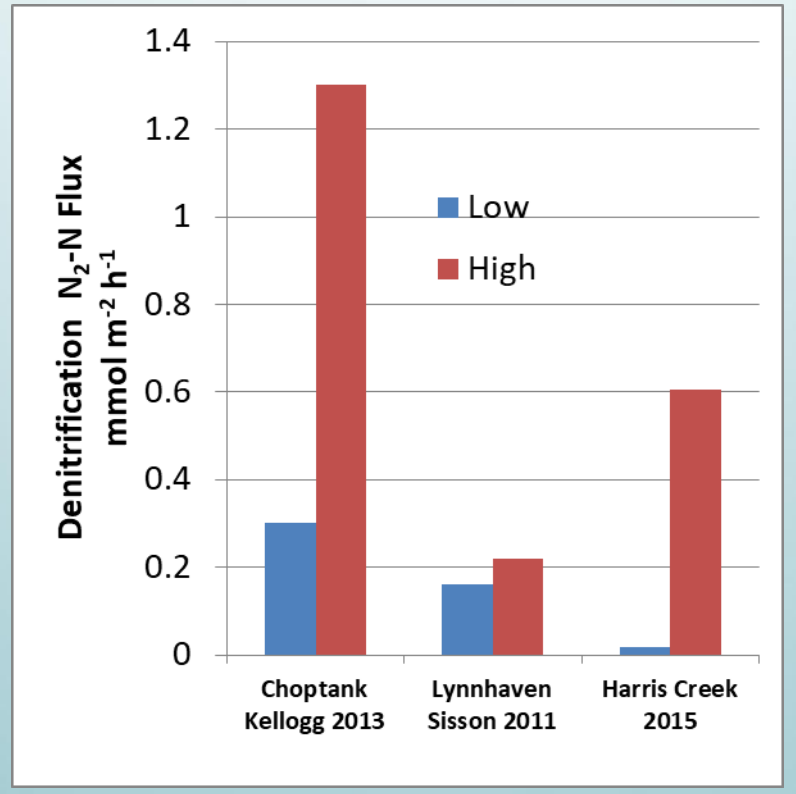
Enhanced Denitrification as an Oyster BMP – Data, Data Analysis, and Challenges

- 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.

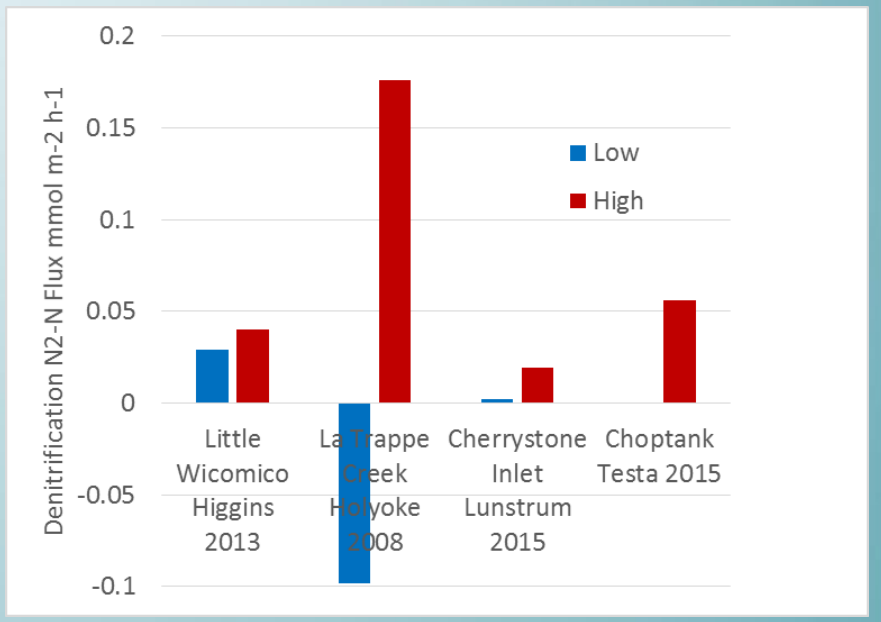
Denitrification Literature Review



Chesapeake Bay, Restoration-Related



Chesapeake Bay, Aquaculture-Related

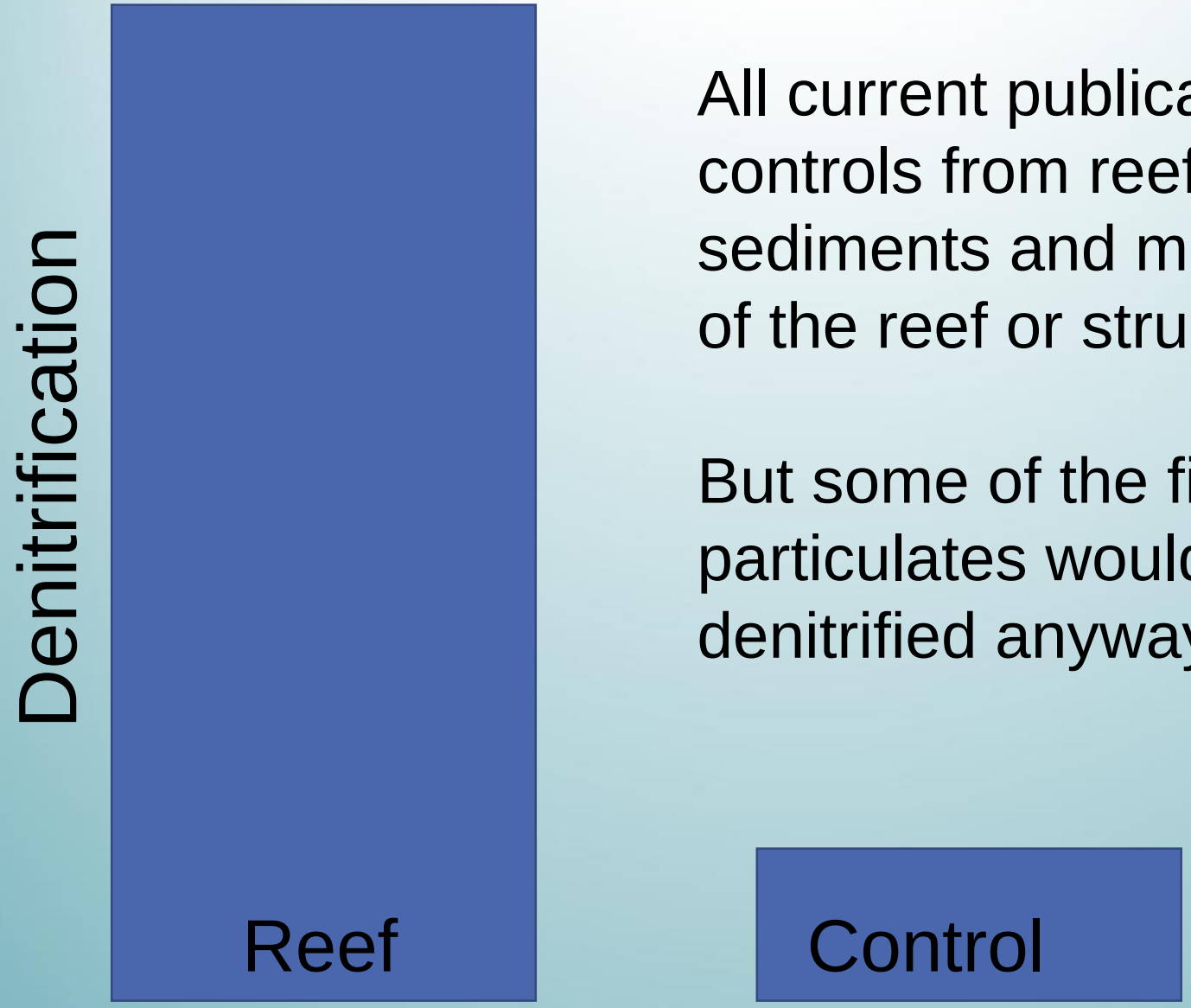


"Useful" determination based on whether a modern technique was used to measure denitrification rates and Panel's best professional judgement

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

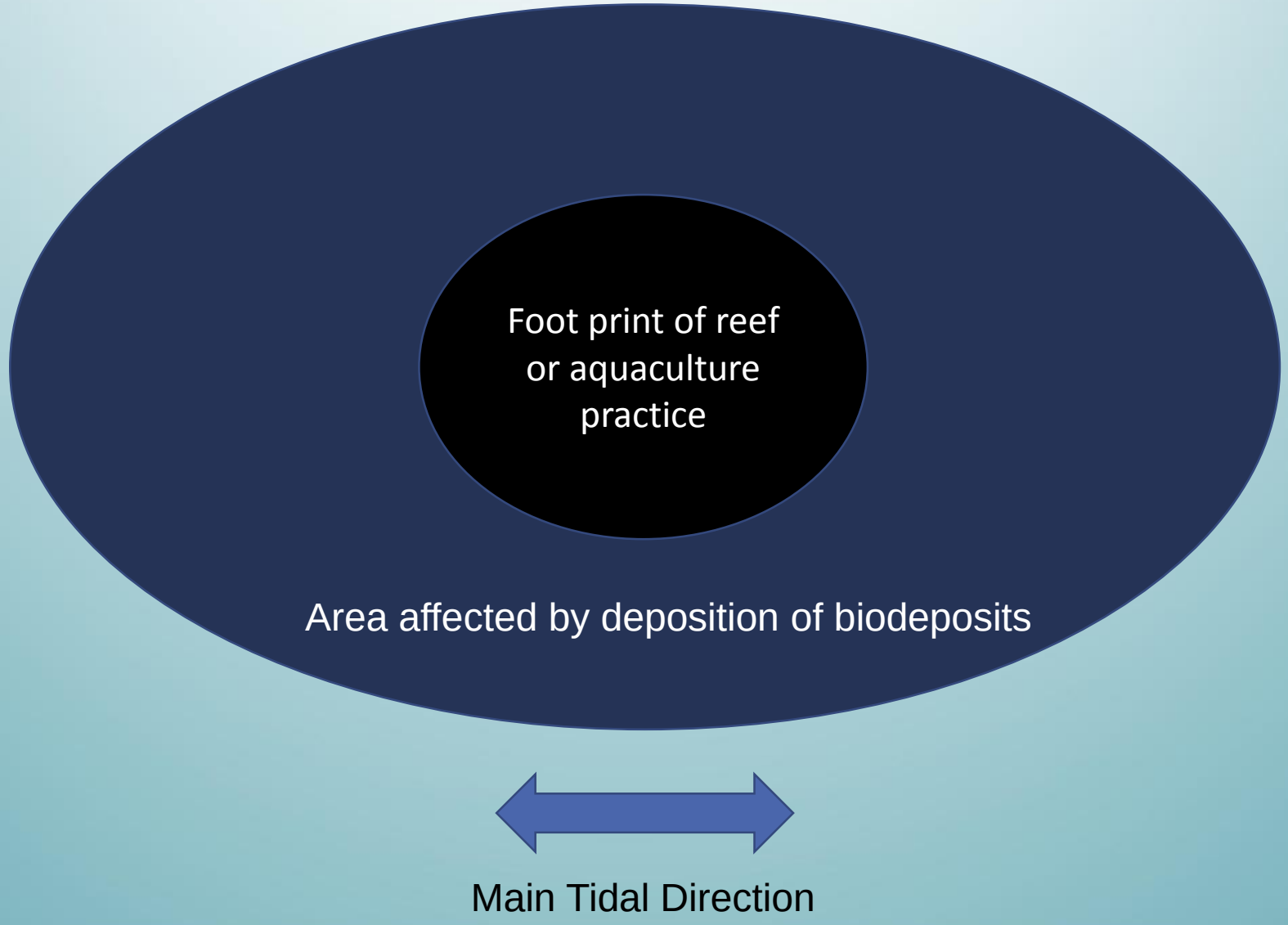
Before Oysters

- 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



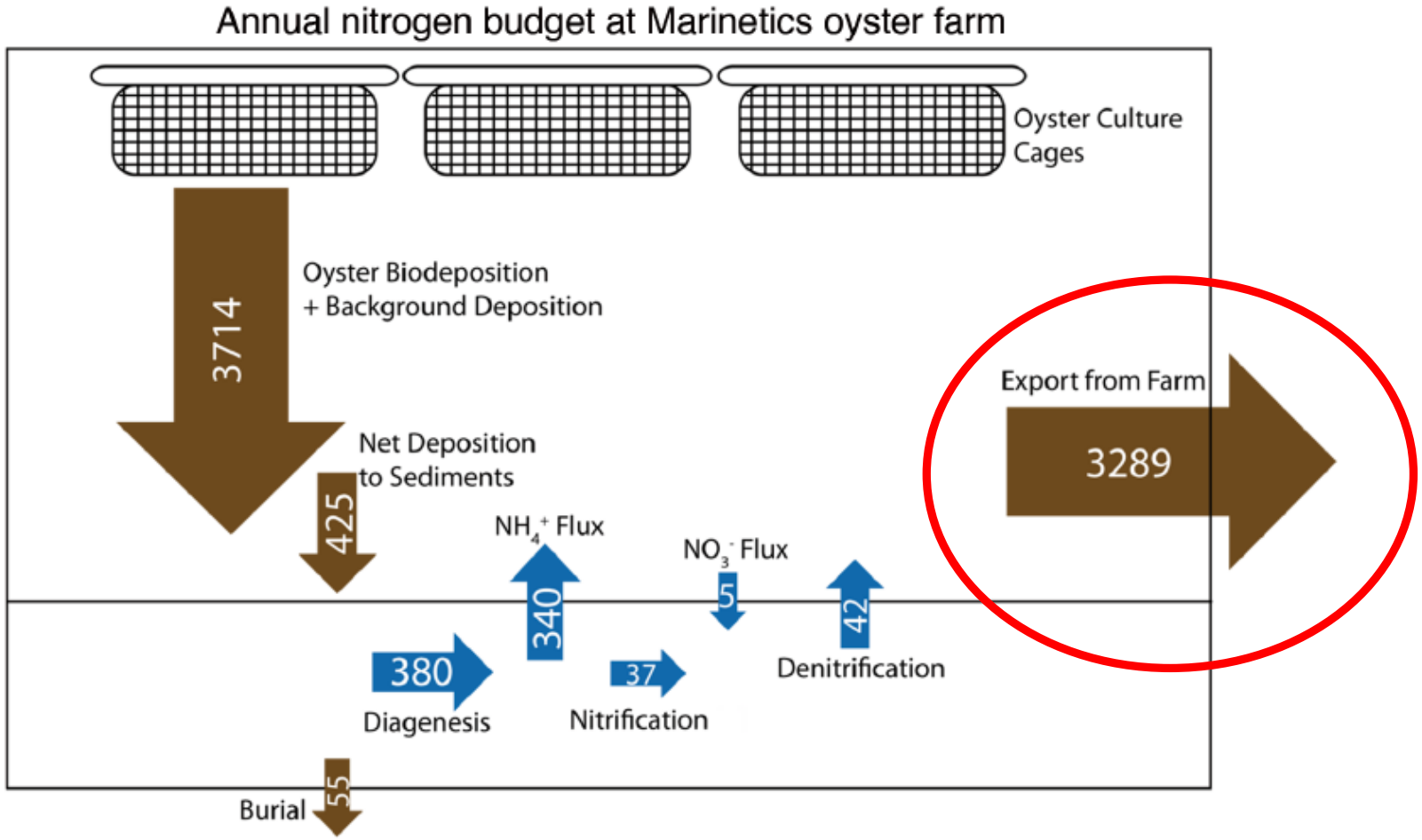


Fig 11. Annual nitrogen budget for the Marinetics oyster farm. Brown arrows represent physical transport, while blue arrows represent biogeochemical fluxes. Clearly, the majority of the material that could potentially be integrated into the sediments is exported from the site before biogeochemical transformation could occur. NH_4^+ fluxes dominate the sediment–water exchanges. All units in μmol 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!

How to Keep Informed of Panel Efforts

ORP webpage summarizing Panel progress available at

oysterrecovery.org/water-quality-improvement

First report available at

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

Contact Information: jreichert@oysterrecovery.org

QUESTIONS

Looking for Feedback On

Progress on:

- Nitrogen (N) and phosphorus (P) assimilation in oyster shell for private oyster aquaculture practices
- N removal via enhanced denitrification associated with oysters for private oyster aquaculture practices
- N removal via enhanced denitrification associated with oysters for oyster reef restoration practices

Particularly:

- Approaches used to determine estimates.
- Strategies in addressing concerns related to unintended consequences.
- Thoughts on verification.

Group 1: Nitrogen and Phosphorus Assimilation in Oyster Shell for Private Oyster Aquaculture Practices

1. Do you have any specific thoughts or concerns that you would like the Panel to consider related to the proposed approach that could be used to assign reduction estimates for the nitrogen and phosphorus shell assimilation crediting protocols?
2. What do you think of using a deduction approach based on dissolution for the BMP estimate (assumption is that 100% of removed shell is returned to the Bay) to address concerns related to the potential unintended consequence that shell won't be returned to the Bay? Are there any concerns with this approach?
3. Are there any suggestions for another approach that could be used that would accommodate shell crediting with shell being returned to the Bay that the Panel could consider?
4. Are there any other unintended consequences the Panel should consider?
5. Are there any ancillary benefits (positive consequences) the Panel should consider?
6. Do you have any specific thoughts or concerns related to verification of the shell crediting protocols?
7. What are the concerns of users and managers regarding how we proceed?

Group 2: Enhanced Denitrification for Private Oyster Aquaculture Practices

1. Do you have any specific thoughts or concerns that you would like the Panel to consider related to the proposed approach (consideration of the transport of biodeposits) that could be used to assign reduction estimates for enhanced denitrification pertaining to private oyster aquaculture practices?
2. 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?
3. Are there any other studies/ongoing work that anyone is aware of?
4. Are there any unintended consequences the Panel should consider?
5. Are there any ancillary benefits the Panel should consider?
6. Do you have any specific thoughts or concerns related to verification of a default denitrification estimate for private oyster aquaculture practices?
7. What are the concerns of users and managers regarding how we proceed?

Group 3: Enhanced Denitrification for Oyster Reef Restoration Practices

1. Do you have any specific thoughts or concerns that you would like the Panel to consider related to the proposed approach (consideration of the transport of biodeposits) that could be used to assign reduction estimates for enhanced denitrification pertaining to oyster reef restoration practices?
2. 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?
3. Are there any other studies/ongoing work that anyone is aware of?
4. Are there any unintended consequences the Panel should consider?
5. Are there any ancillary benefits the Panel should consider?
6. Do you have any specific thoughts or concerns related to verification of a default denitrification estimate for oyster reef restoration practices?
7. What are the concerns of users and managers regarding how we proceed?