CBT Oyster Denitrification –Presentation to Fisheries GIT

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Jeffrey Cornwell

Michael Owens

Larry Sanford

Talk Outline

- New Lander Approach For Denitrification (mostly from summer 2022 GIT meeting)
- Large Substrate Denitrification
- BMP – Future Opportunities

Terms

- Denitrification: the rate of conversion of N in organic matter, nitrate and ammonium to di-nitrogen gas (N_2-N)
  – *recognizing there are other (minor) processes that also may produce N_2-N*
- “Lander”: a lowered chamber that (mostly) seals up the interior of the device so that changes in water column chemistry reflect benthic processes. *Similar in principal to other measures of benthic fluxes.*
- Leakage: the exchange of exterior water with interior water due to an incomplete seal. *Oyster reef topography guarantees a poor seal. Expressed as a proportion per hour (h^{-1})*

Biogeochemical Rate Measurements

- Need to encapsulate part of the environment (water, sediment) to measure the change in water column properties. Most common measurements: bottles for O_2-based production & respiration, sealed cores for O_2/nutrient exchange. Beginning and end chemistry, or a time course
- Such measurements require consideration of level of illumination, temperature, physical regime (mixing, boundary layer), holding time, etc. A complete sequestration of a water mass is a usual requirement.

Published Approaches

Whole Community

- *Ex-situ* approach (Kellogg et al. 2013) Community transferred to trays by divers, recovered a month or so later, sealed up and fluxes measured in lab. Most Chesapeake data from Kellogg and Cornwell.
- *In-situ* approach with embedded rings (Humphries et al. 2016). Ring permanently embedded in bottom, chamber attached by divers and exchange measured over time.

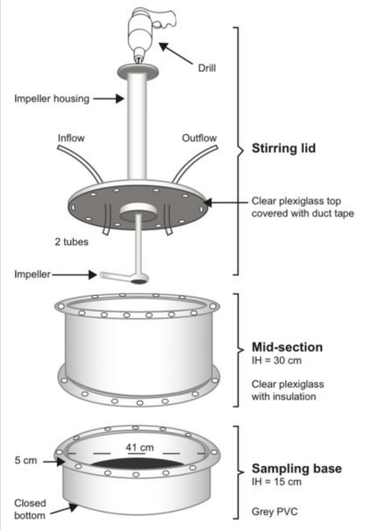


FIGURE 2 | Diagram of incubation chamber used to measure nutrient fluxes *in situ*. See text for full description of setup in the field.

Community Components

- Core incubations, often near but not in reefs (Piehler and Smyth 2011). We believe these give minimum rates.
- Oyster-only incubations. We discovered a majority of denitrification occurred in oyster clumps (Jackson et al 2018). Other studies show single oysters can denitrify.

Project Rationale

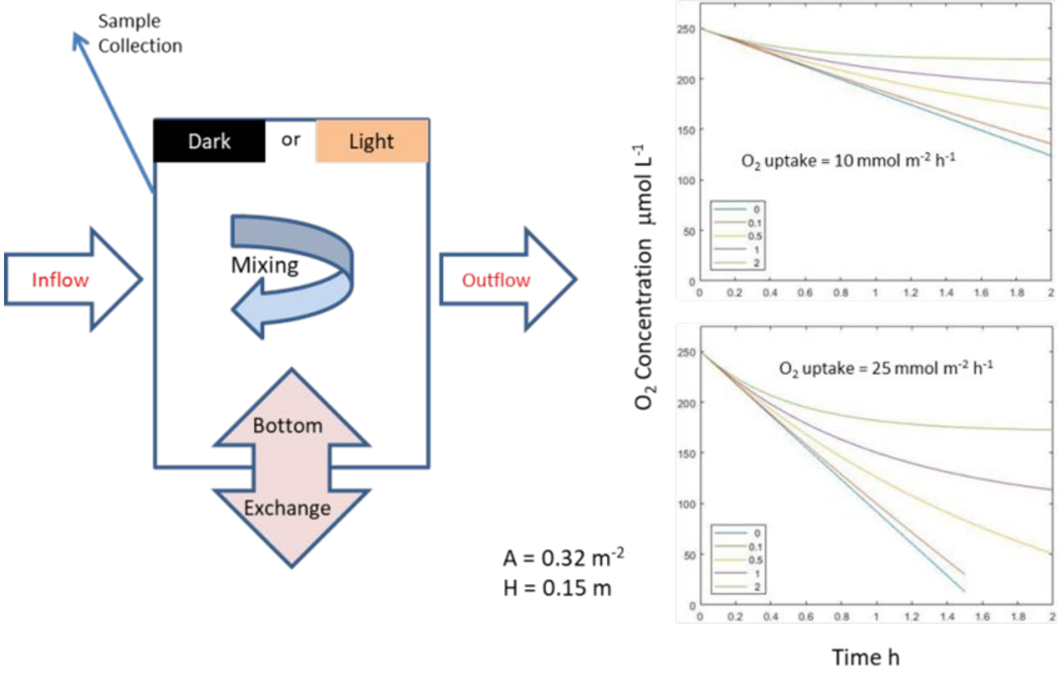
Why Denitrification?

- Net loss to ecosystem of "fixed" nitrogen – of great value in a nutrient-stressed ecosystem
- Oyster-related denitrification rates are the highest rates observed in "nature"

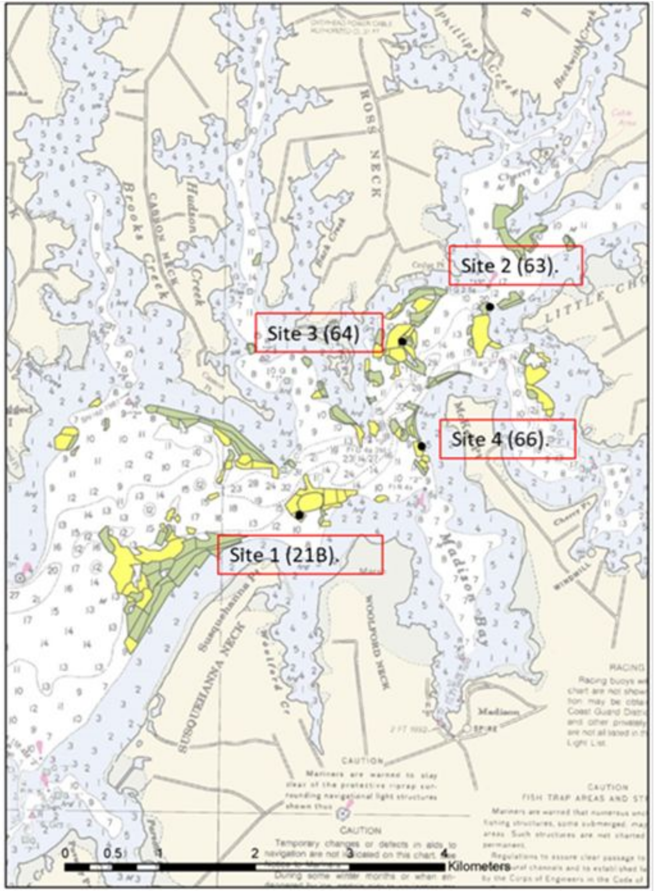
Why a new approach

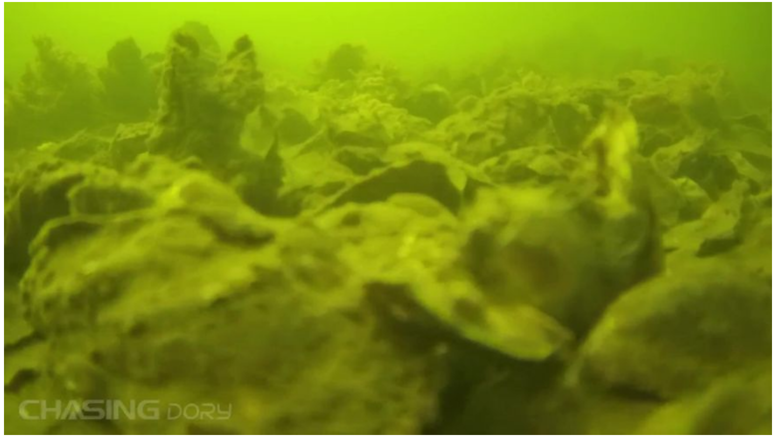
- Faster
- More efficient (manpower, $)
- Less disturbance to the reef community
- Simpler
- Update BMP calculations

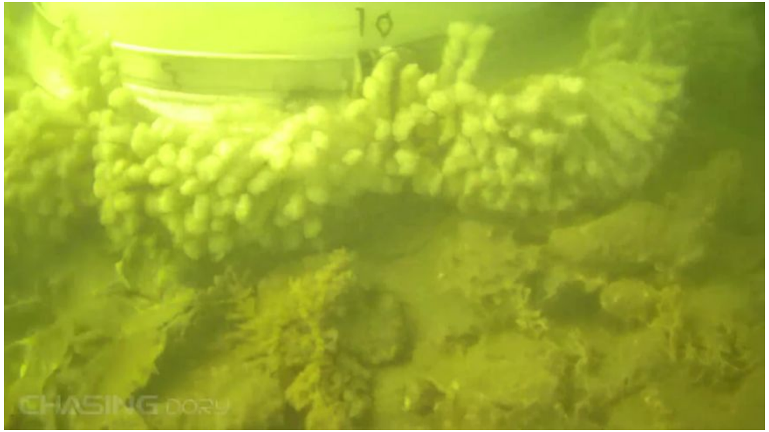
- You can’t drop a lander on the surface of an oyster reef and get a good seal
- If we know how much leakage we encounter, we can solve for the bottom exchange
- A tracer, such as bromide, can be used to determine dilution
- High rates of leakage can be overcome by high rates of nutrient and gas exchange, such as in an oyster reef



Activity #	Description
1	Collect gas sample. Using the always flowing peristaltic pump connected to the chamber, speed up pumping rate and overfill 7 mL glass tubes. Add preservative and store under water. Duplicate samples collected on first run.
2	Collected nutrient sample. Fill 30 mL plastic syringe, filter (0.4 mm, 25 mm diameter), fill 3 sample vials with 5 mL of sample. Vials for soluble reactive P, ammonium, and both bromide and nitrate+nitrite in one vial. Keep samples on ice until frozen at laboratory.
3	Chlorophyll a. Fill a 60 mL syringe from pump, filter 50 ml through a 25 mm diameter glass fiber (GFF) filter, remove and store in aluminum foil, freeze at laboratory


Site 2 (63).
Site 3 (64)
Site 4 (66).
Site 1 (21B).
0 0.5 1 2 3 4 Kilometers

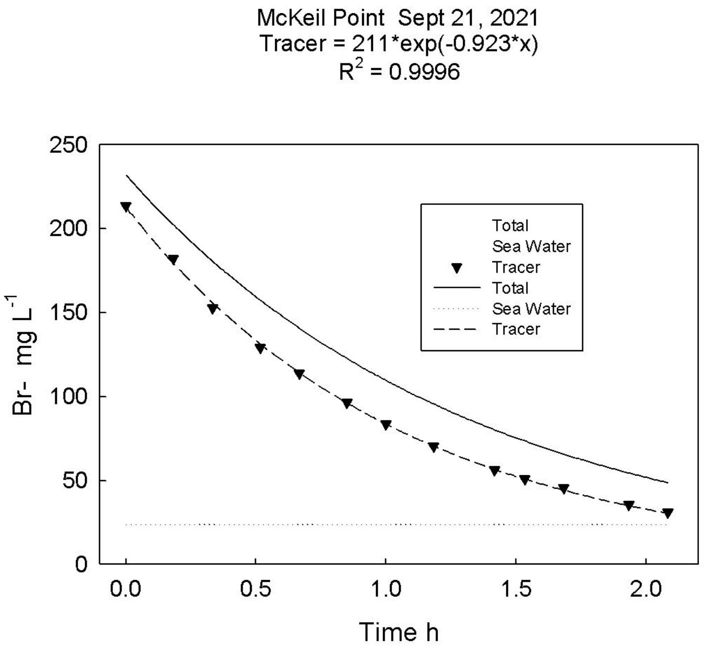




Bromide Works Well As A Tracer

Time course of bromide change in a > 2 hour experiment in the Little Choptank River (9/21/2021), after a spike of > 200 mg L^{-1} Br^- above sea water values. These data suggest a leakage rate of 0.92 h^{-1}; the regression fit is excellent (R^2 = 0.9996)

$$C = C_0 * e^{-R*t}$$

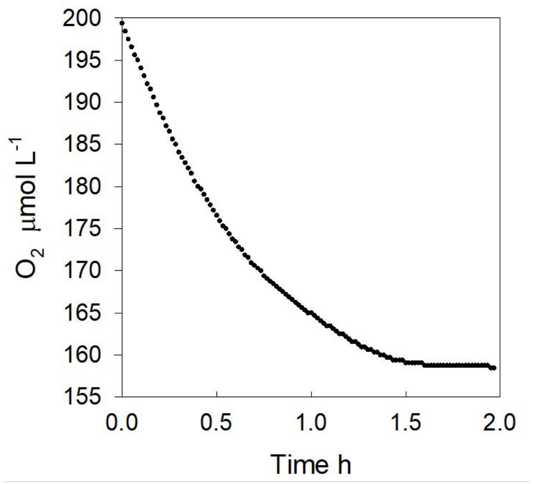


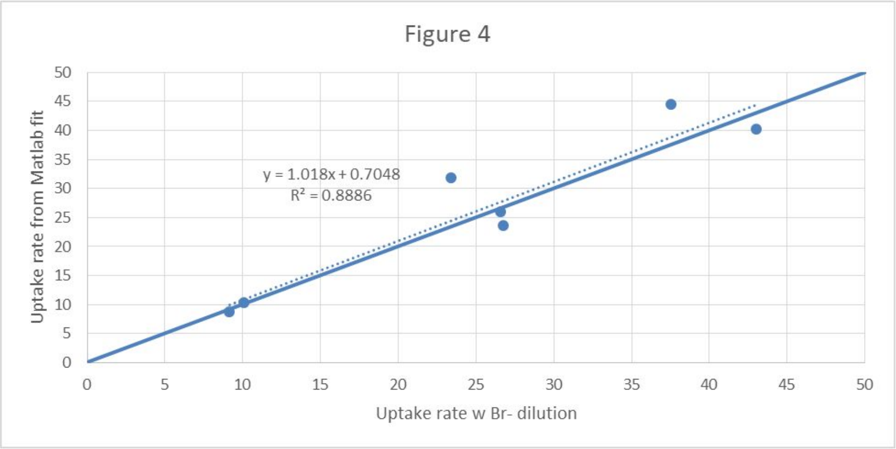
Br^- does not adsorb to particles, rhodamine disappears quickly onto particles (filtered by oysters). Note: varying pumping rate had minimal effect.

- Oxygen fluxes were estimated from YSI continuous data (below)
- The equation presented here can use bromide leakage rates and a point to point look at O_2 data to estimate fluxes
- The oxygen curve can also be fit to the equation and both the flux rate and leakage rate estimated.
- Both approaches yield similar data

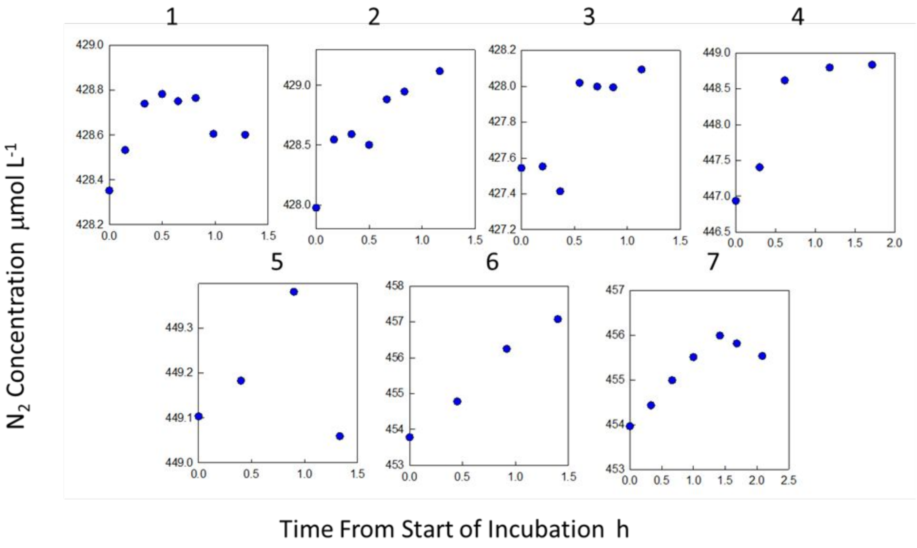
$$R = \frac{h(c_{in}(0) - c_{in}(t))}{\frac{V}{F}\left(1 - e^{-\frac{F}{V}t}\right)}$$

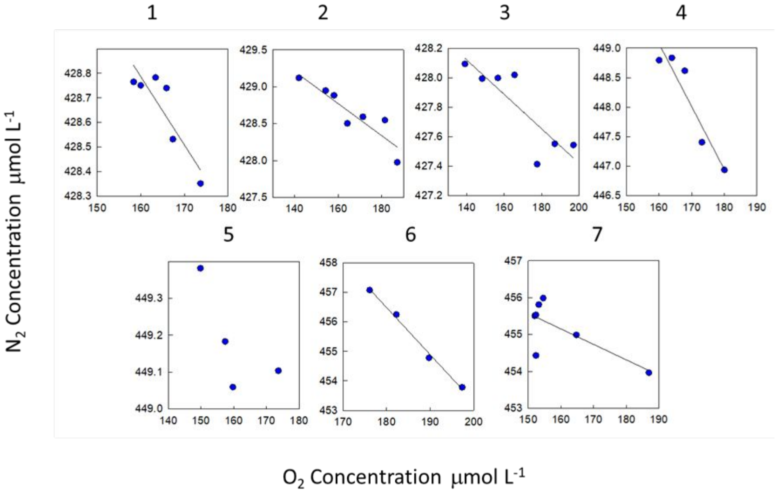
- R = O_2 exchange rate mmol m^{-2} h^{-1}
- h = chamber height m
- c = O_2 concentration mmol L^{-1} at time 0 and time t (h)
- V = volume m^3
- F = leakage rate h^{-1} from Br^-





$$N_2\text{-N Flux} = O_2\text{Flux}_{(YSI)} * \Delta N_2/\Delta O_{2(\text{mass spec})}$$





Current oyster BMP plans would credit the biomass of 112-123 g dw m^{-2} at Harris Creek and other sites for ~250 umol m^{-2} h^{-1} of N_2-N efflux, minus background (maybe 50-75, so ~200 umol m^{-2} h^{-1}.

Our Little Choptank data from McKeil Point averaged 2,100 ± 600 μmol m^{-2} h^{-1}

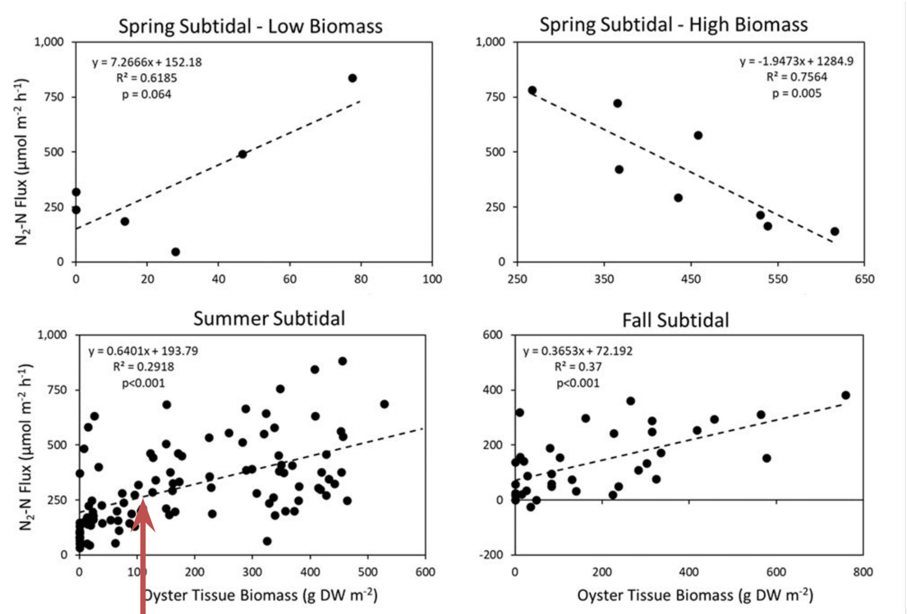


Figure 8.3. Final linear regressions of spring, summer and fall data oyster reef denitrification rates plotted as a function of oyster tissue biomass.

Table 3. Denitrification cost comparison, lander versus tray approach. This is an estimate for each individual rate measurement, including oxygen and nutrients.

Cost Category	Lander – This Study	Tray Approach Kellogg et al. 2013
Personnel	812	1,832
Boats & Logistics	79	164
Analytical	671	407
Gear (amortized - 25 deployments)	54	75
Per Measurement	1,615	2,477
With 26% overhead (State of MD)	2,035	3,121
With 55 % overhead (Federal)	2,503	3,839

Large Substrate Denitrification

BMP has site-specific nature

Oyster Castles –
Shoreline Protection

Reef Balls –
Fish Habitat

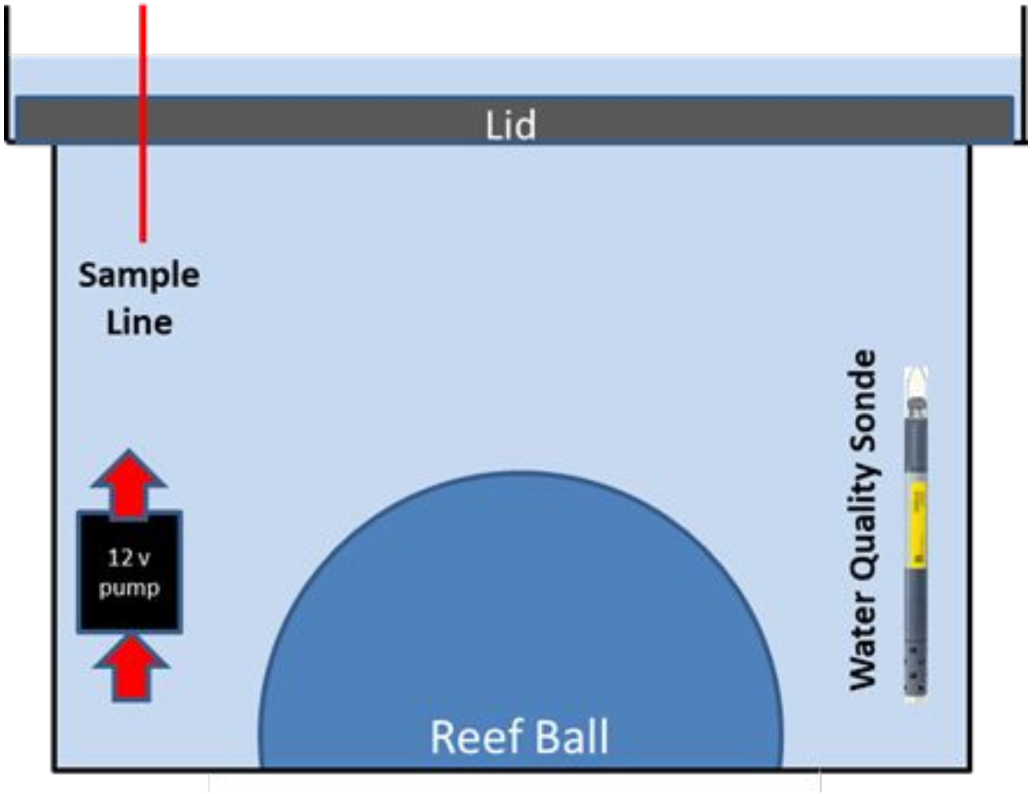
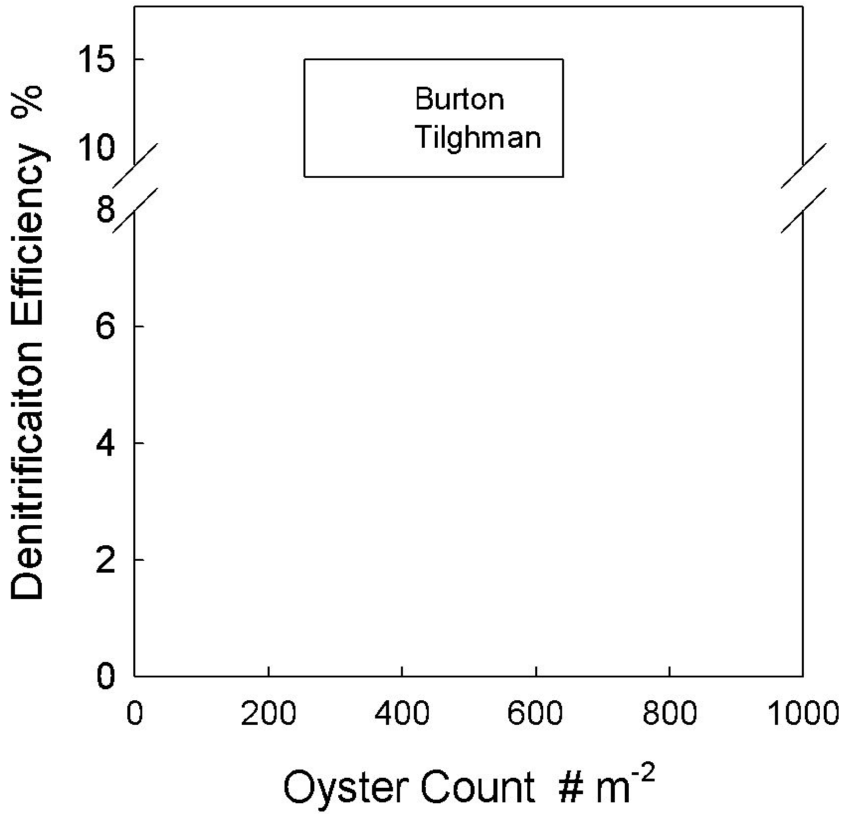

Lid
Sample Line
12 v pump
Reef Ball
Water Quality Sonde

Photo of two of the four castle segments incubated. The circulating pump in the upper right corner keeps the water homogenous during incubation.

Incubation tank for oyster castle incubations. All bubbles are excluded during incubation under the while lid which is clamped down. We have used this setup for incubations of reef balls with the Chesapeake Bay Foundation.

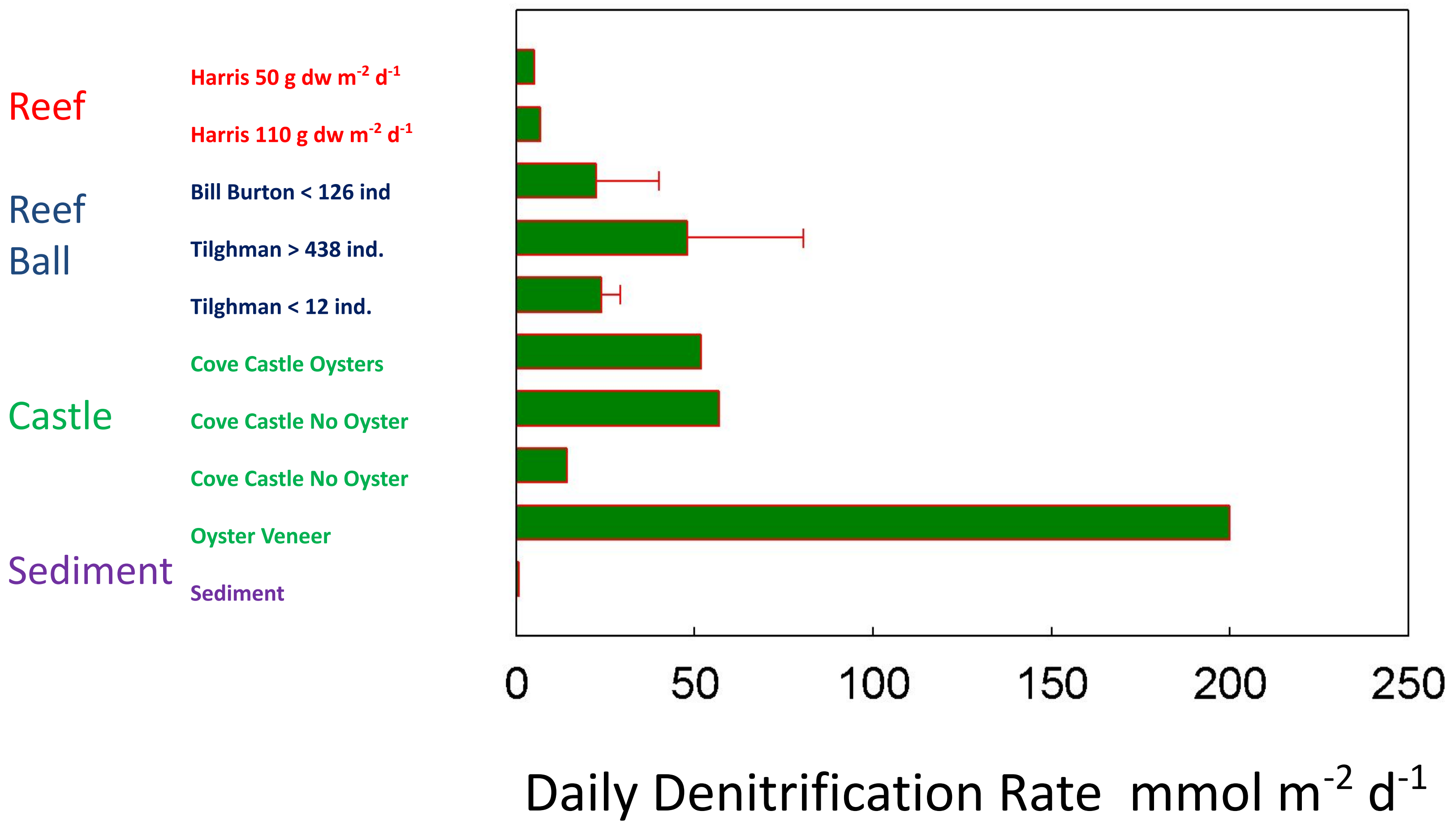


Cornwell et al., *in prep*

Denitrification efficiency is the % of remineralized N that is denitrified (N_2-N)

Denitrification rates are high, but production of N_2-N is an inefficient pathway

Trapping of biodeposits within the reef ball may result in low O_2 and low N_2-N. The “bottom” of the reef ball often is very sulfidic (H_2S, iron sulfide minerals)

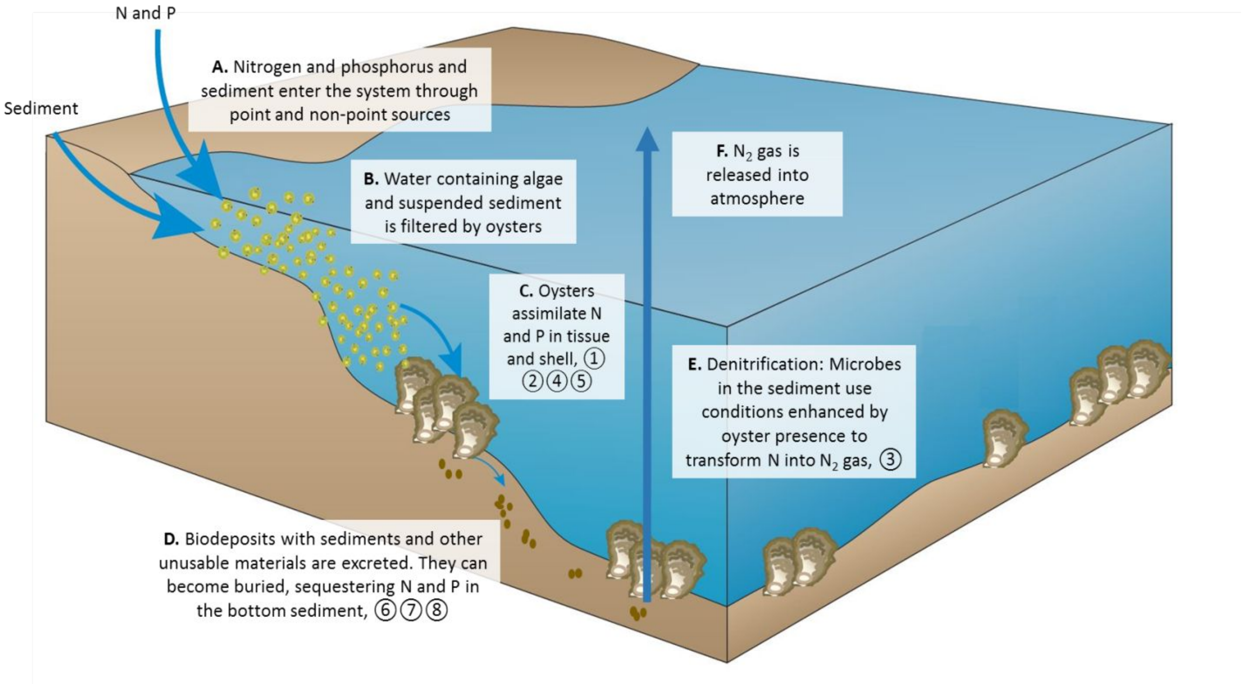


Reef
Harris 50 g dw m-2 d-1
Harris 110 g dw m-2 d-1
Reef Ball
Bill Burton < 126 ind
Tilghman > 438 ind.
Tilghman < 12 ind.
Castle
Cove Castle Oysters
Cove Castle No Oyster
Cove Castle No Oyster
Oyster Veneer
Sediment
Sediment
0
50
100
150
200
250
Daily Denitrification Rate mmol m-2 d-1

Limitations

- Biodeposits may slough off of structures, what are the effects on local sediment biogeochemistry?
- Removal of structures difficult in some cases, possible artifacts.
- Can we devise a way to make measurements on-bottom? Maybe our leaky lander approach.

Oysters and Water Quality

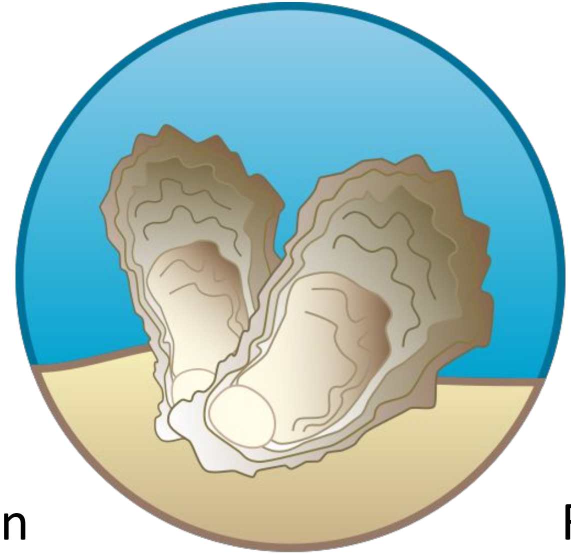


Through filtration, oysters contribute to biogeochemical cycling in estuaries

Elements of the Oyster BMP Toolset

Aquaculture-Assimilation
Approved

Harvest-Assimilation
Under Review



Restoration-Denitrification
Under Review

Restoration-Assimilation
Under Review

Graphic: UMCES Integrated Application Network

Future Assessments to Inform Bivalve BMP's

- Revisit default denitrification rates, more measurements in variable salinity, temperature, oyster density
- On-bottom aquaculture $\neq$ restoration: size/age, density, post-harvest data for denitrification
- Water column aquaculture denitrification: some + effects, some – effects on sediments. What about transformation in the cage? Off-site biodeposits?
- Could freshwater mussels be useful for N removal via denitrification? (see STAC meeting on topic)