CBT Oyster Denitrification –Presentation to Fisheries GIT

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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})*

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.

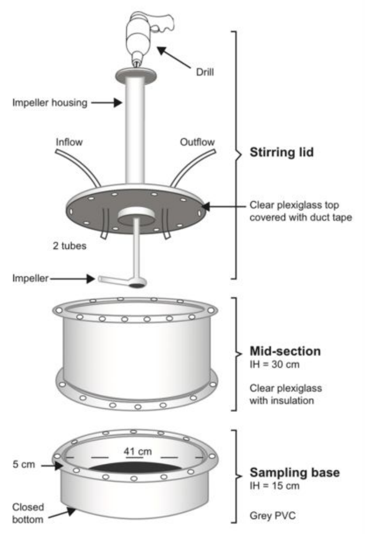


FIGURE 2 | Diagram of incubation chamber used to measure nutrient fluxes *in situ*. See text for full description of setup in the field.

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

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)□
		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)

□ Based on median values

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

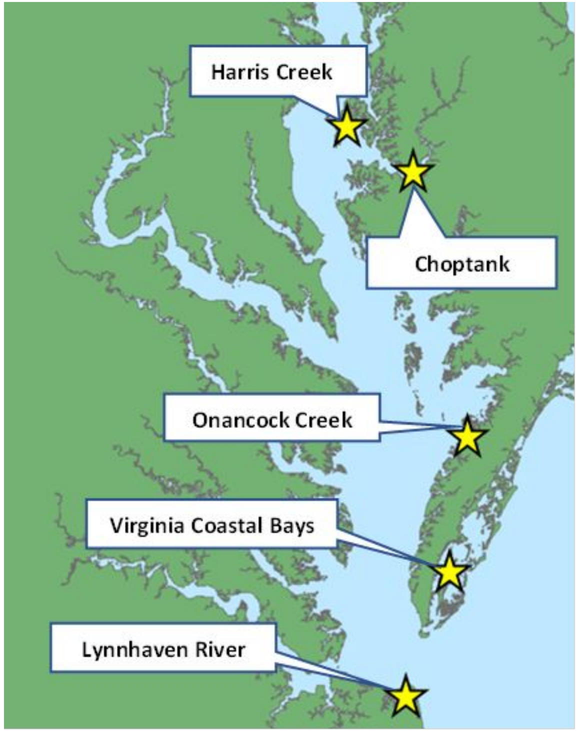
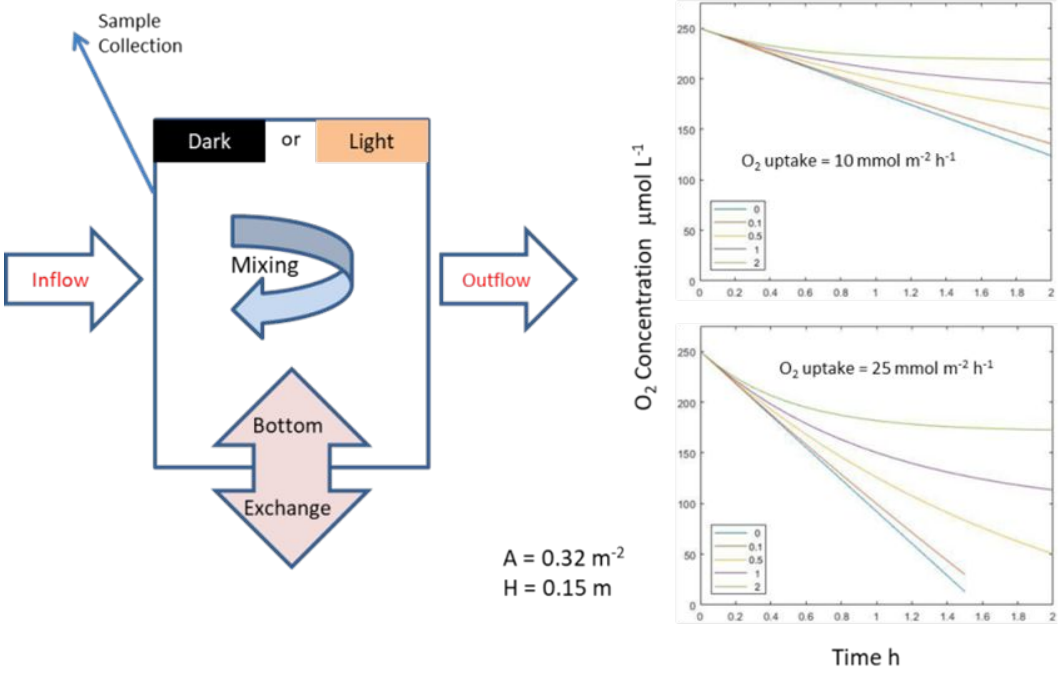
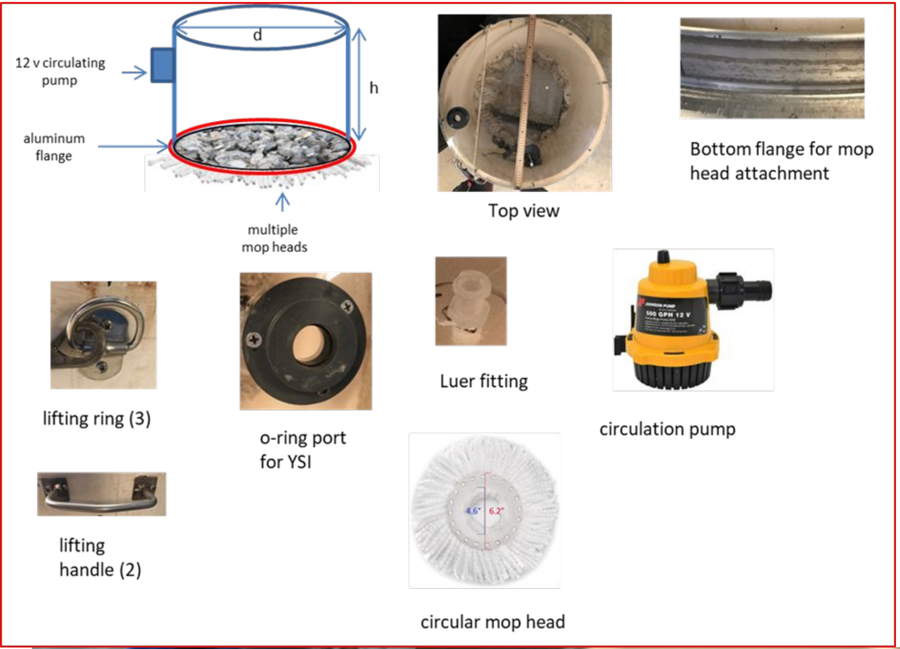
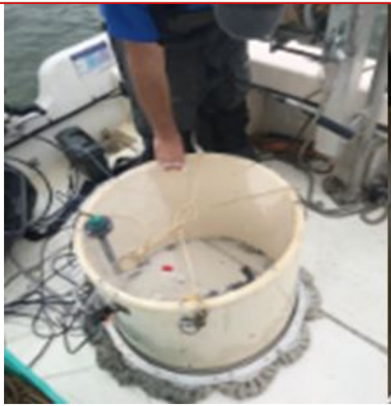


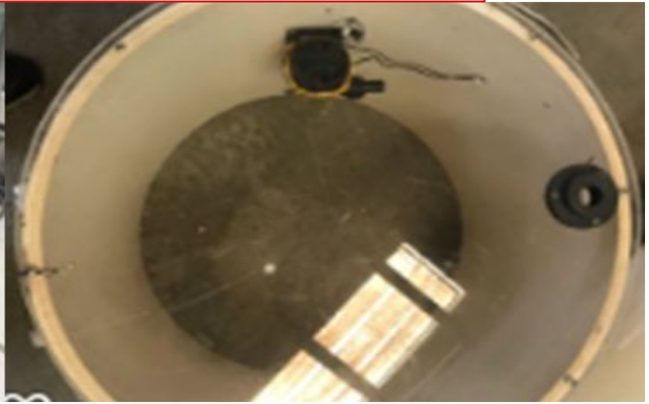
Figure 8.2. Map of Chesapeake Bay showing locations (yellow stars) where oyster reef denitrification rates included in the Panel's meta-analysis were measured. Some of the stars represent multiple sites in close proximity.

- 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





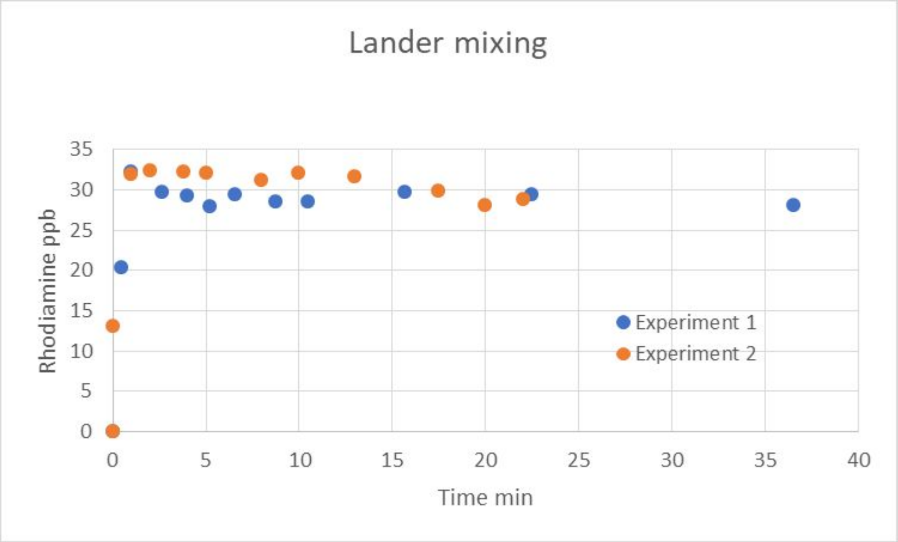




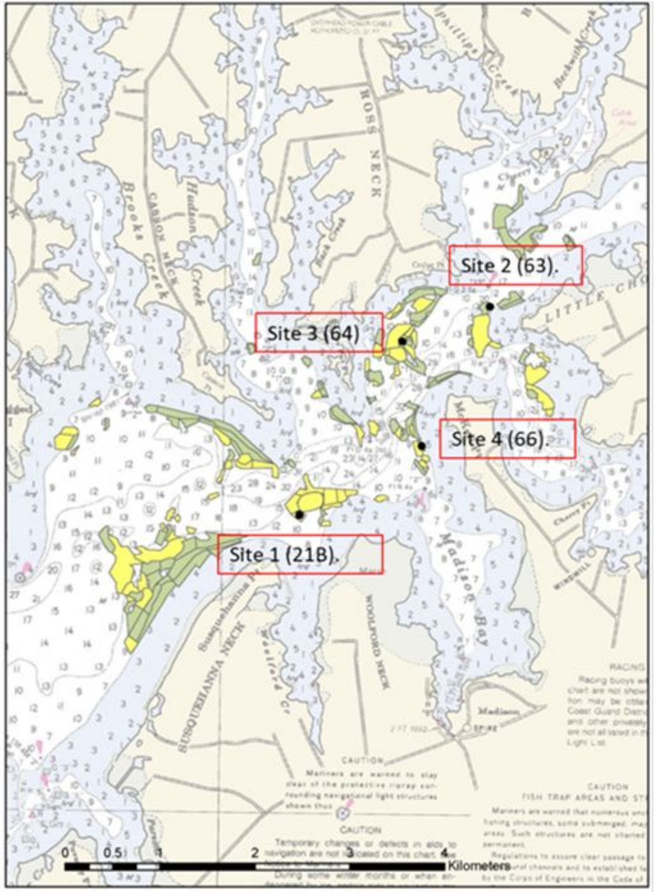
Best Estimate Oct 2021 - single deployable chamber		Unit cost	Sum	$7,225.23
CHAMBER CONSTRUCTION				
mop replacement head	Amazon spin micro fiber mop	$3.17	9	$28.53
bilge pump for water circulation	Amazon: Johnson pump 500 gph	$37.64	1	$37.64
24" White PVC Schedule 40 pipe	We bought 14' for $100 per foot from our hatchery. US plastics current cost is $205.64 per foot, 20' minimum.	$100.00	2	$200.00
Acrylic top				
Aluminum angle for oyster tub		$12.40	1	$12.40
battery for bilge pump circulator	Amazon: Dakota lithium 12v 18 ah	$179.99	1	$179.99
Luer bulkhead fitting		$1.00	2	$2.00
lifting rings, handles, rope		$100.00	1	$100.00
battery for circulation pump	Amazon, Dakota lithium	$179.99	1	$179.99
acrylic sheet for top	Material was on hand, costo fo 12 mm 24" x 24" US Plastics	$69.91	1	$69.91
low voltage wire		$10.00	1	$10.00
tubing		$0.27	40	$10.80
Total chamber Cost				$820.46
SAMPLING APPARATUS				
peristaltic sampling pump	Dyrabrest 0-140 mL	$119.00	1	$119.00
case for pump storage	Amazon: Sheffield 12626 field box	$14.99	1	$14.99
ammeter to determine if pump is worl	Amazon: Bediffer	$24.58	1	$24.58
battery pack for peristaltic sampling pı	Amazon: Progeny 350 w	$199.99	1	$199.99
Sampling gear cost				$358.56
Essential Water Quality Gear				
YSI Prosolo meter, ODO probe, case, sl	Xylem, university price. We have used 1, now will use 2 for outside measurements	$1,995.60	2	$3,991.20
BOAT GEAR				
davit with block		$400.00	1	$400.00
winch		$65.00	1	$65.00
anchors	for 3 point anchoring - 3 needed, 1 assumed with boat - 13 lb fluke anchor from Amazon	$99.99	2	$199.98
Boat gear total				$664.98
EXTRA GEAR (optional)				
Go Pro Black 7		$228.04	1	$228.04
Underwater light	Amazon, Suptig dive light 84 LED	$36.99	1	$36.99
Extras Total				$265.03
Labor				
		Per hour		
Machine Shop	Per hour, billing in progress, best estimate	$75.00	15	$1,125.00

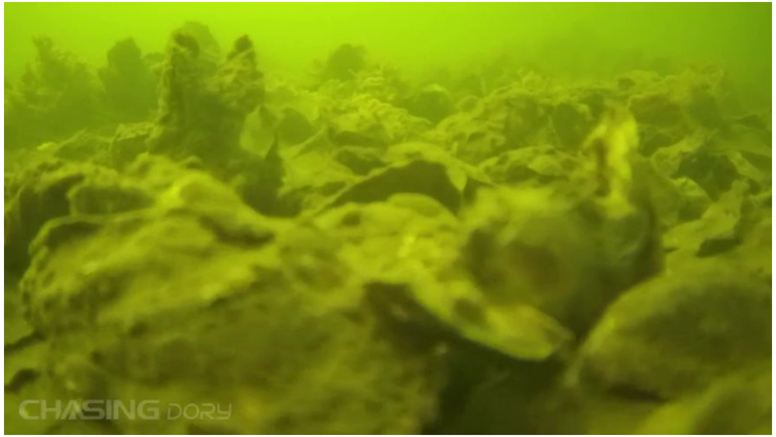
Mixing Is Fast

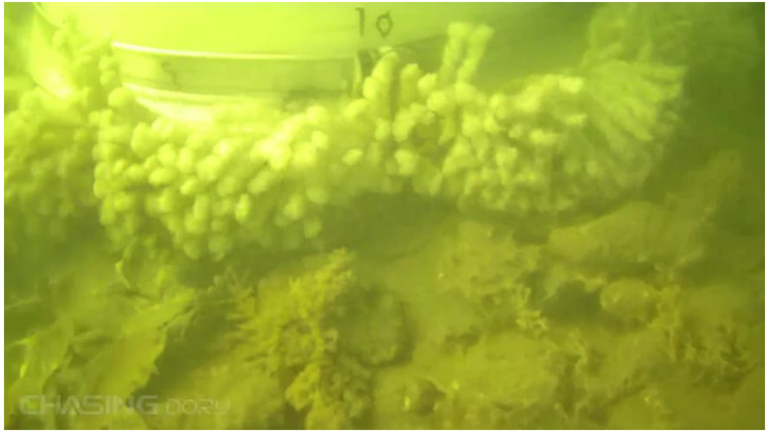
- Rhodamine dye added to filtered sea water in tank
- Mixing complete in << 2 minutes



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


CHASING DORY

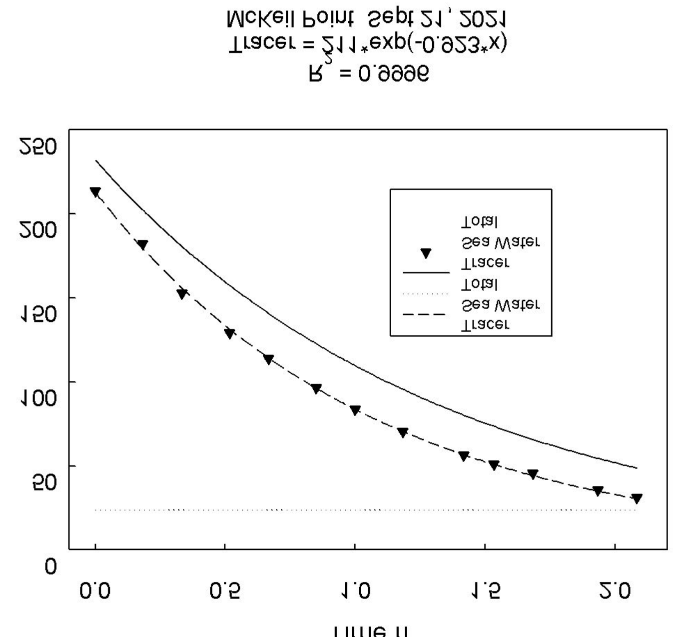


Run Video?

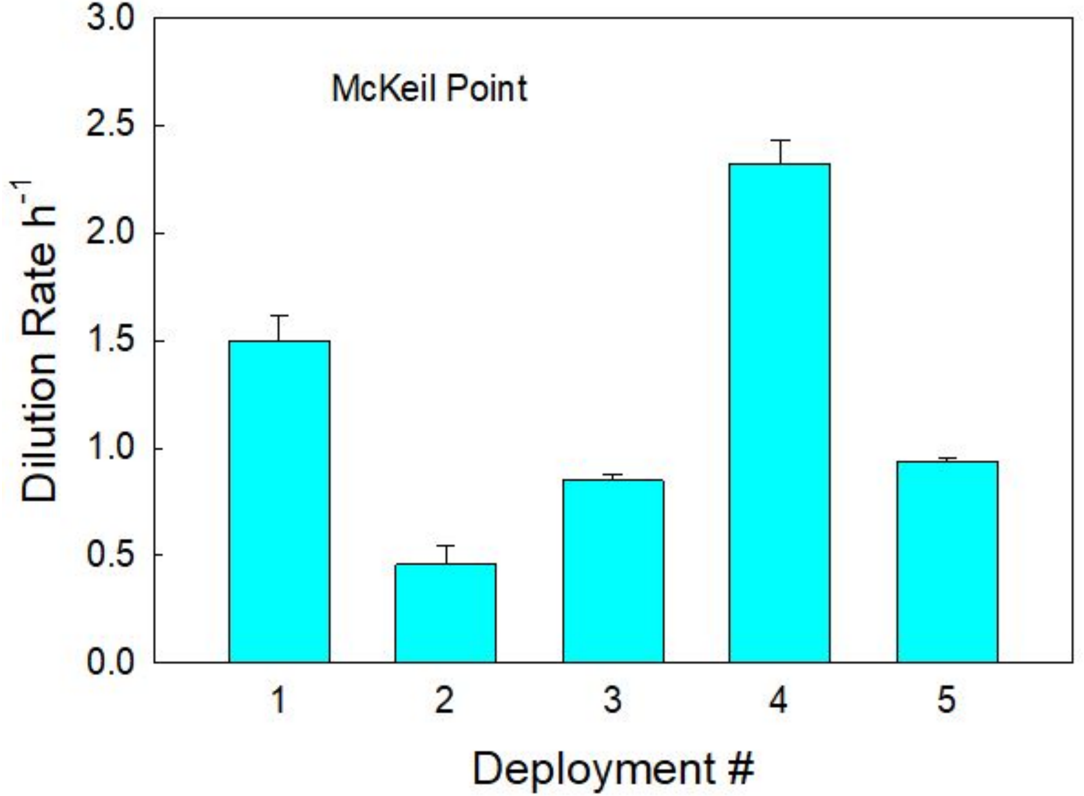
Bromide Works Well As A Tracer

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.

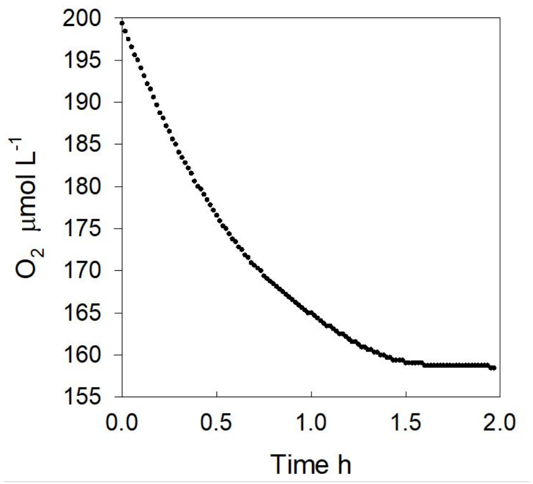


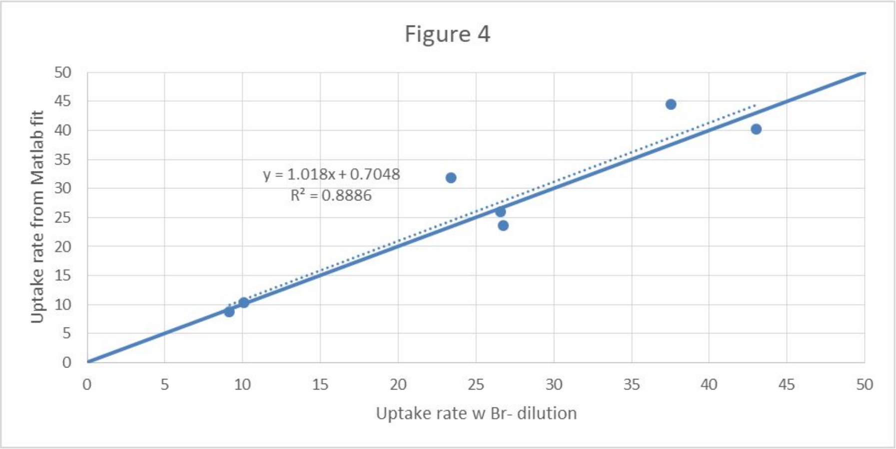
As expected, each deployment can have a different seal to the bottom and a different leakage rate

- 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

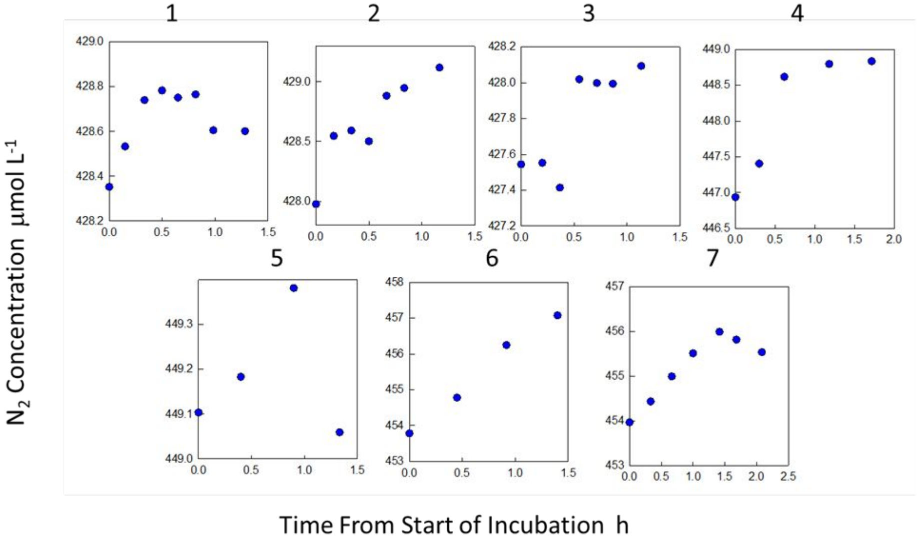
$$R = \frac{h(c_{in}(0) - c_{in}(t))}{\frac{V}{F}\left(1 - e^{-\frac{F}{V}t}\right)}$$

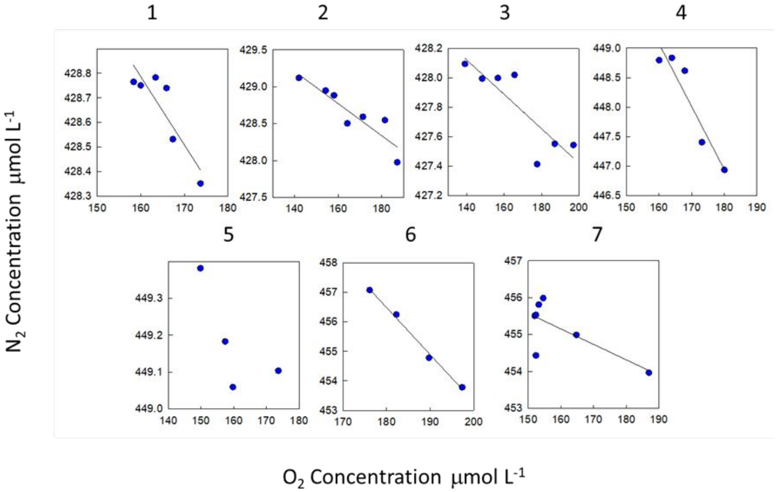
- R = O_2 exchange rate mmol m^{-2} h^{-1}
- h = chamber height m
- c = O_2 concentration mmol L^{-1} at time 0 and time t (h)
- V = volume m^3
- F = leakage rate h^{-1} from Br^-

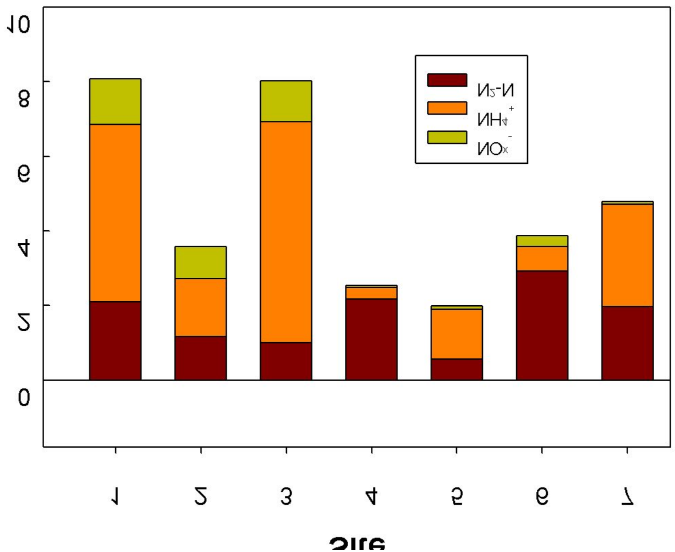




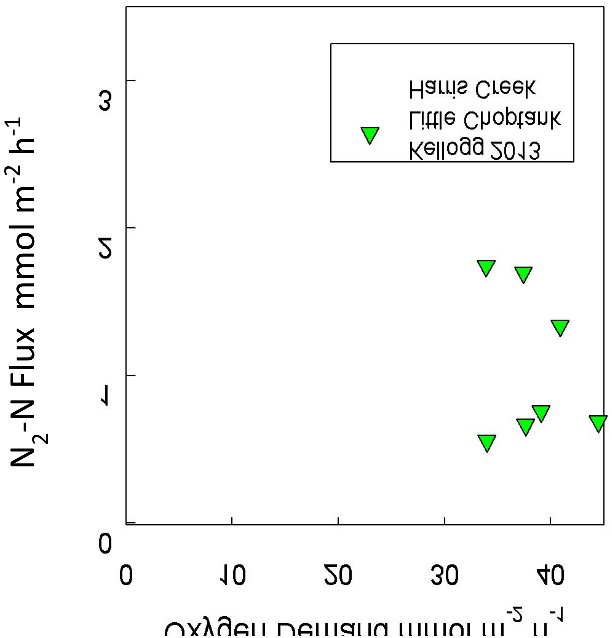
$$N_2\text{-N Flux} = O_2\text{Flux}_{(YSI)} * \Delta N_2/\Delta O_{2(\text{mass spec})}$$

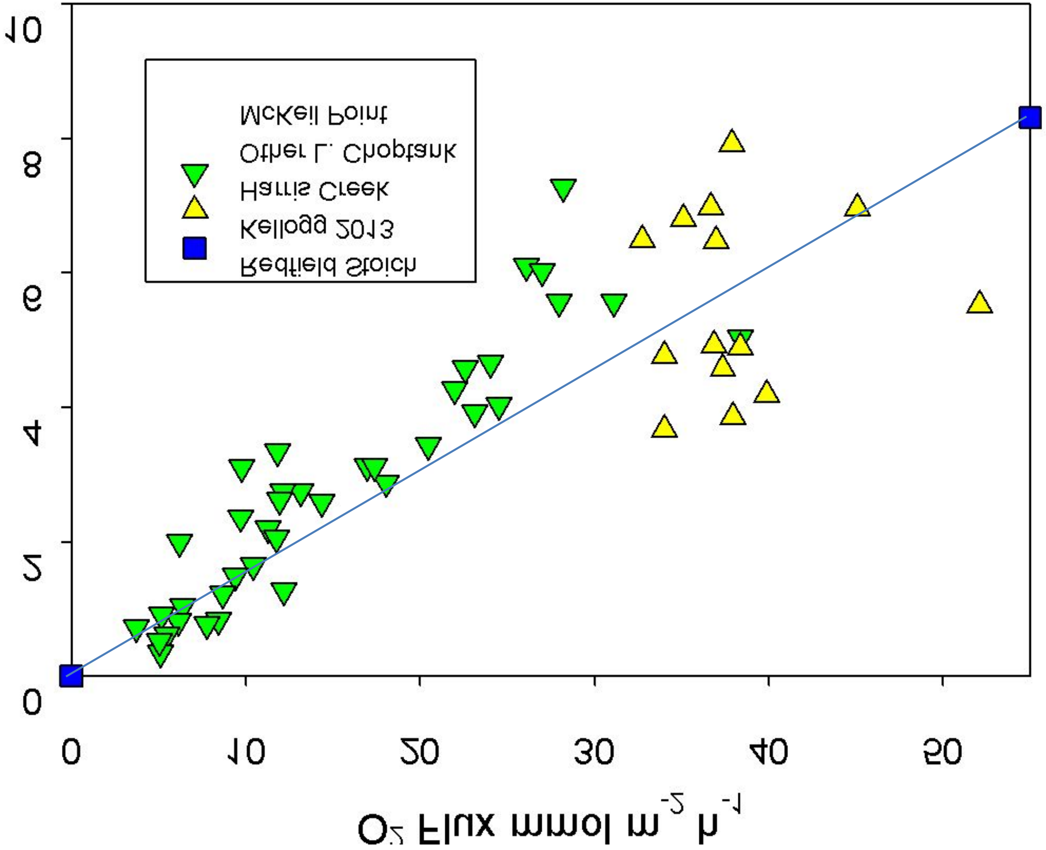






1	McKeil 8 20
2	McKeil 8 25
3	McKeil 8 25
4	Susquehanna 9 17
5	Susquehanna 9 17
6	Town Pt 9 21
7	McKeil 9 21





McNeil Point
Other L. Choptank
Harris Creek
Kellogg 2013
Redfield Stoich
0
2
4
6
8
10
0
10
20
30
40
50
O2 Flux mmol m-2 h-1

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 2.1±0.6 mmol m^{-2} h^{-1}

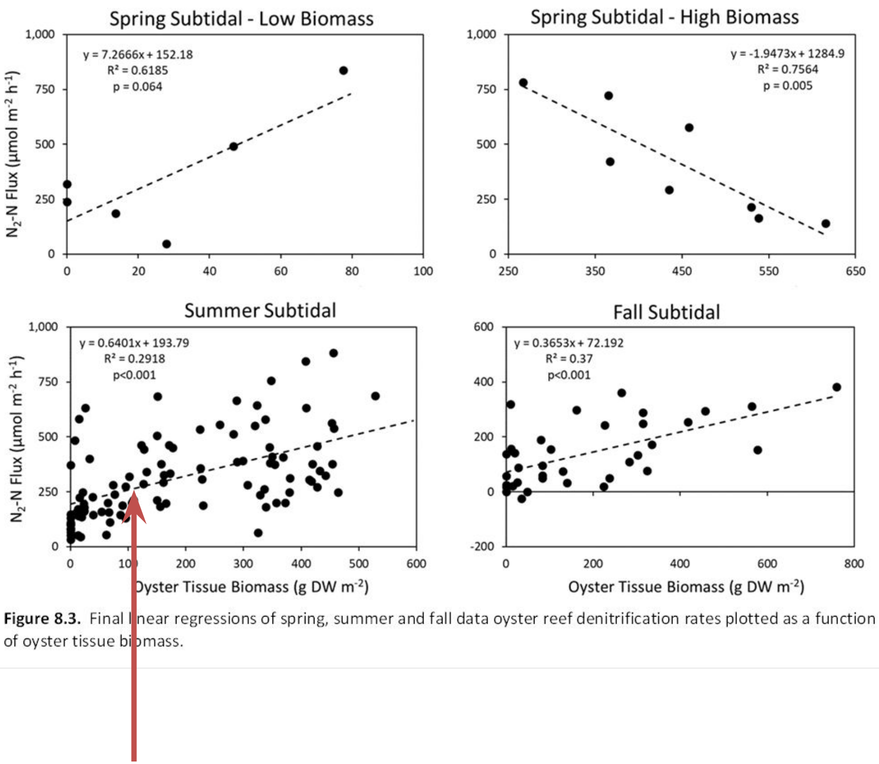


Figure 8.3. Final linear regressions of spring, summer and fall data oyster reef denitrification rates plotted as a function of oyster tissue biomass.

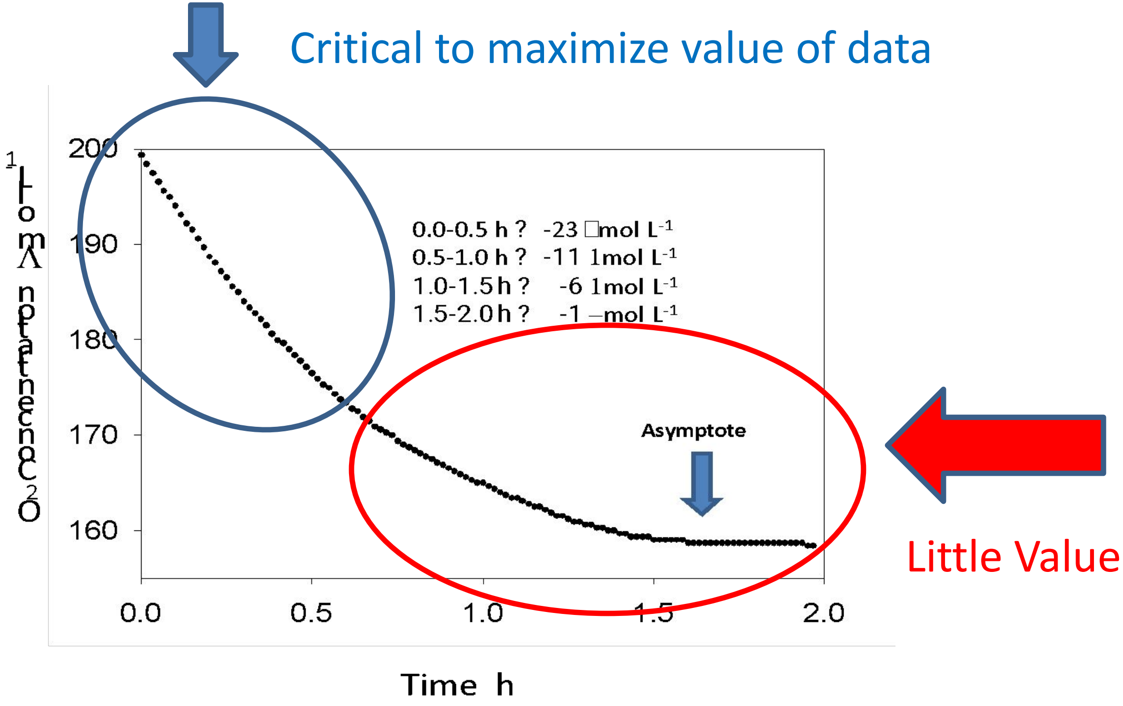
Lander-Tray Comparison

- Tray
  - Known oyster biomass in tray, but may differ from actual biomass
  - Disruption of sediment layers
  - Require divers
  - May take 4-5 hours after sampling before incubation
  - Need rapid sampling
  - Requires temperature control, supply of water at appropriate salinity
  - Great for manipulations

- Lander
  - Dependent on ORP biomass from a hopefully recent assessment
  - Minimal disruption
  - Can be done by 2 personnel in boat
  - Requires good weather for anchoring
  - Need rapid sampling
  - May not be as sensitive to low rates

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



After looking at the data, it is clear we need higher frequency data, but don't need to go to the asymptote. Many incubation could be 0.5-0.75 hours, with O_2 monitoring informing the time course.

Now For Something Entirely Different

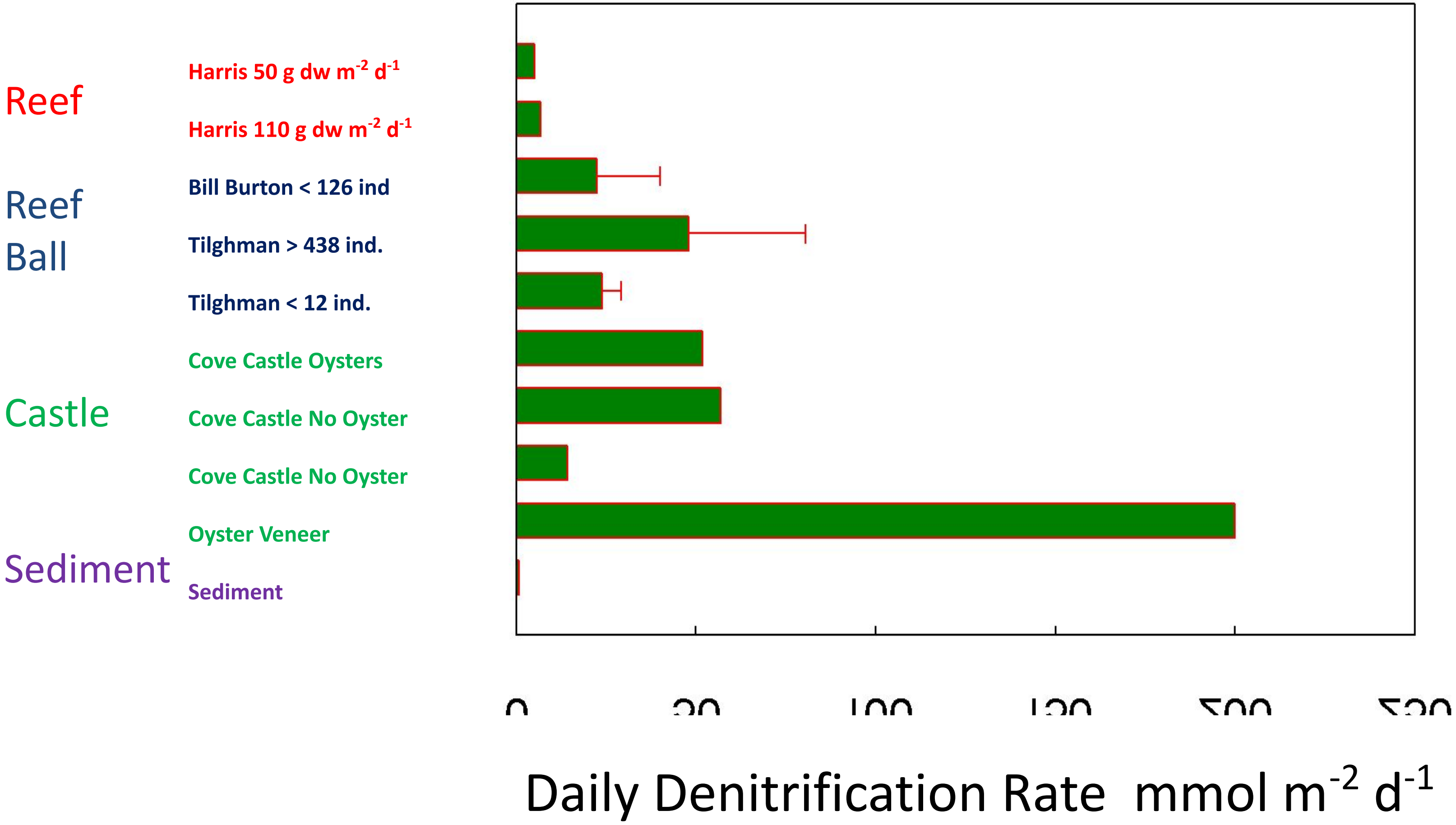
Large, Very Large Substrate

Oyster Castles –
Shoreline Protection

Reef Balls –
Fish Habitat

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.



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
Daily Denitrification Rate mmol m-2 d-1

As we move towards adding/improving infrastructure to enhance coastal resilience, there may be a place, or better yet an opportunity, to increase bivalve populations.

The highest areal rate of denitrification we have observed is the fouling community (bryozoans, barnacles, mussels) in Baltimore Harbor.

Areal rates of denitrification on structures are very high – the question is how much area can there be?