Mitigation of estuarine eutrophication by aquatic habitat restoration?

"Getting a start on the basic data needed for oyster nitrogen credits"

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Oyster Recovery Partnership with funding from GenOn Energy Inc.

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HORN POINT LABORATORY

Why This Study?

- From previous work with Roger Newell, it is clear that an important part of the water quality value of oysters, specifically N sequestration/transformation, is related to microbial processes rather than just the N content of harvested tissue
- Most studies, including our own, have either used cores adjacent to reefs or experimental core simulations of reef organic matter loading
- This is the first study investigating reef N cycling that includes the whole reef community!

Nutrient Bioassimilation Capacity of Aquacultured Oysters: Quantification of an Ecosystem Service

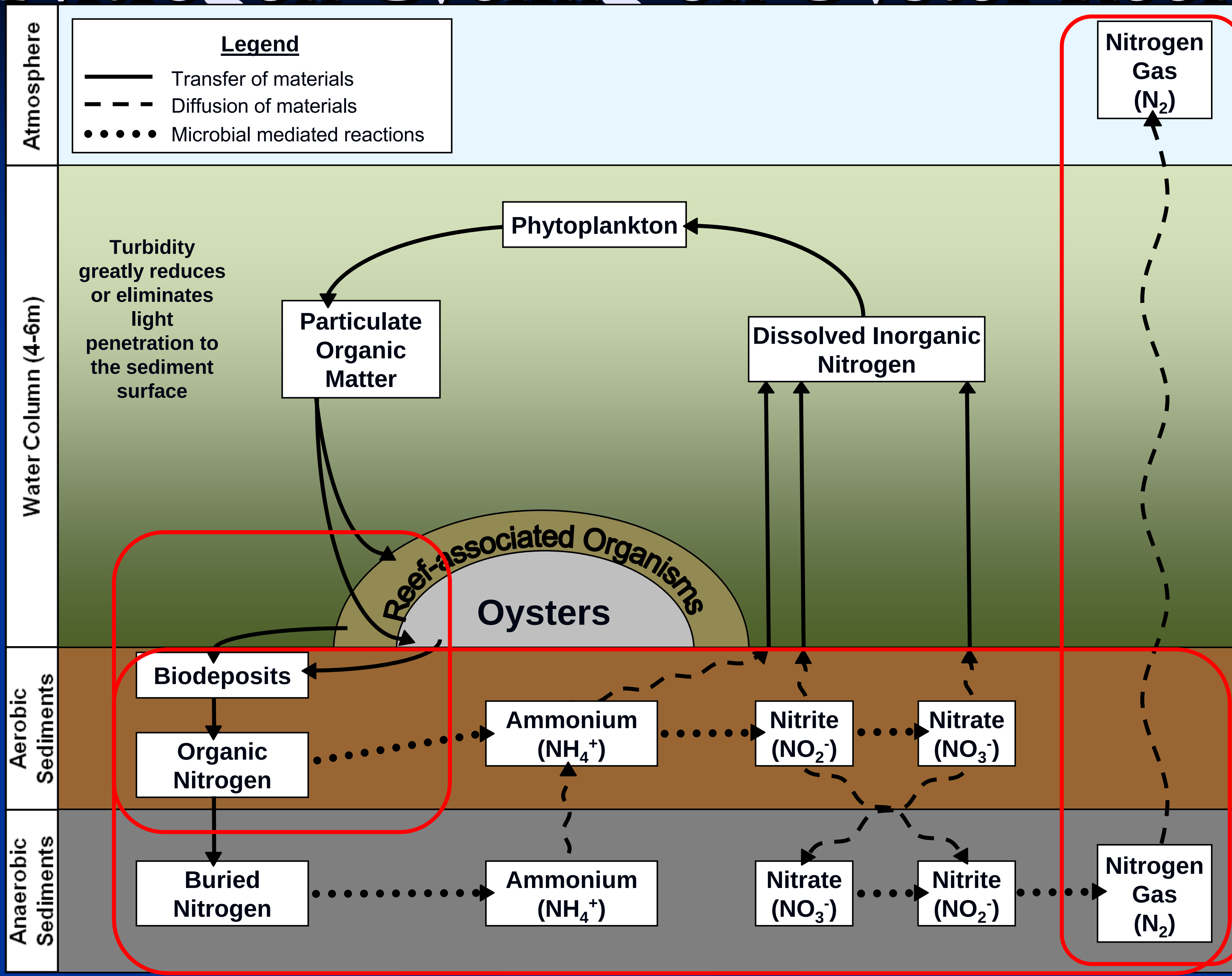
Colleen B. Higgins, Kurt Stephenson, and Bonnie L. Brown*

Table 3. Nutrient mass load predictions for total nitrogen, total phosphorus, and total carbon bioassimilated by 10^6 aquacultured Eastern oysters of various harvest sizes, generated by models for nutrient content of an average aquacultured oyster based on shell total length.

	For 10^6 aquacultured oysters	Nutrient
	mm	kg
TN†	50.8	42
	76.2	132
	101.6	298
TP	50.8	6
	76.2	19
	101.6	41
TC	50.8	1262
	76.2	3823
	101.6	8396

† TC, total carbon; TN, total nitrogen; TP, total phosphorus.

Nitrogen Cycling on Oyster Reefs



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NITROGEN REMOVAL AND SEQUESTRATION CAPACITY OF A RESTORED OYSTER REEF

Final Report to the Oyster Recovery Partnership

with Funding from GenOn Energy, Inc.

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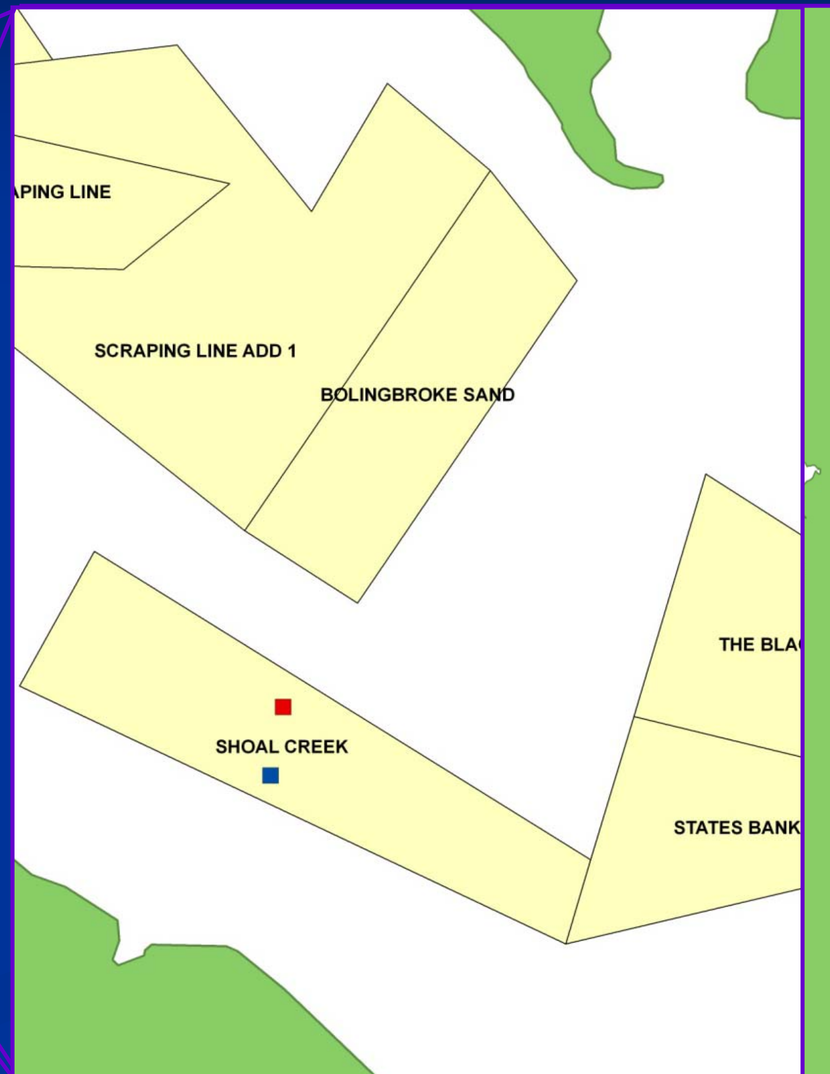
Study Sites

Shoal Creek Oyster Bar,
Choptank River, MD

- Depth: ~4 m
  - Anoxic conditions unlikely
  - Very little light reaches substratum
- Restored oyster reef
  - Hatchery-produced spat on shell planted 3-7 years prior to study
  - Oyster density: ~100 adults m^{-2}
- Non-restored area
  - ~ 200 m from restored reef
  - Suitable for restoration
    - ~5-20 cm of muddy sand and shell hash over oyster shell
  - No oysters



Methods

<u>Design:</u>

- 2 sites: restored and non-restored
- Sampling periods: Nov 2009; Apr, Jun and Aug 2010
- 4 replicate sample trays per site

<u>Deployment and Retrieval:</u>

- Trays (0.1 m^2) filled with material from site and embedded in substratum
- Equilibrate ≥ 2 weeks
- Trays capped underwater
- Brought to surface and transported to Horn Point Laboratory
  - Sample included sediments and a portion of the overlying water column

Methods

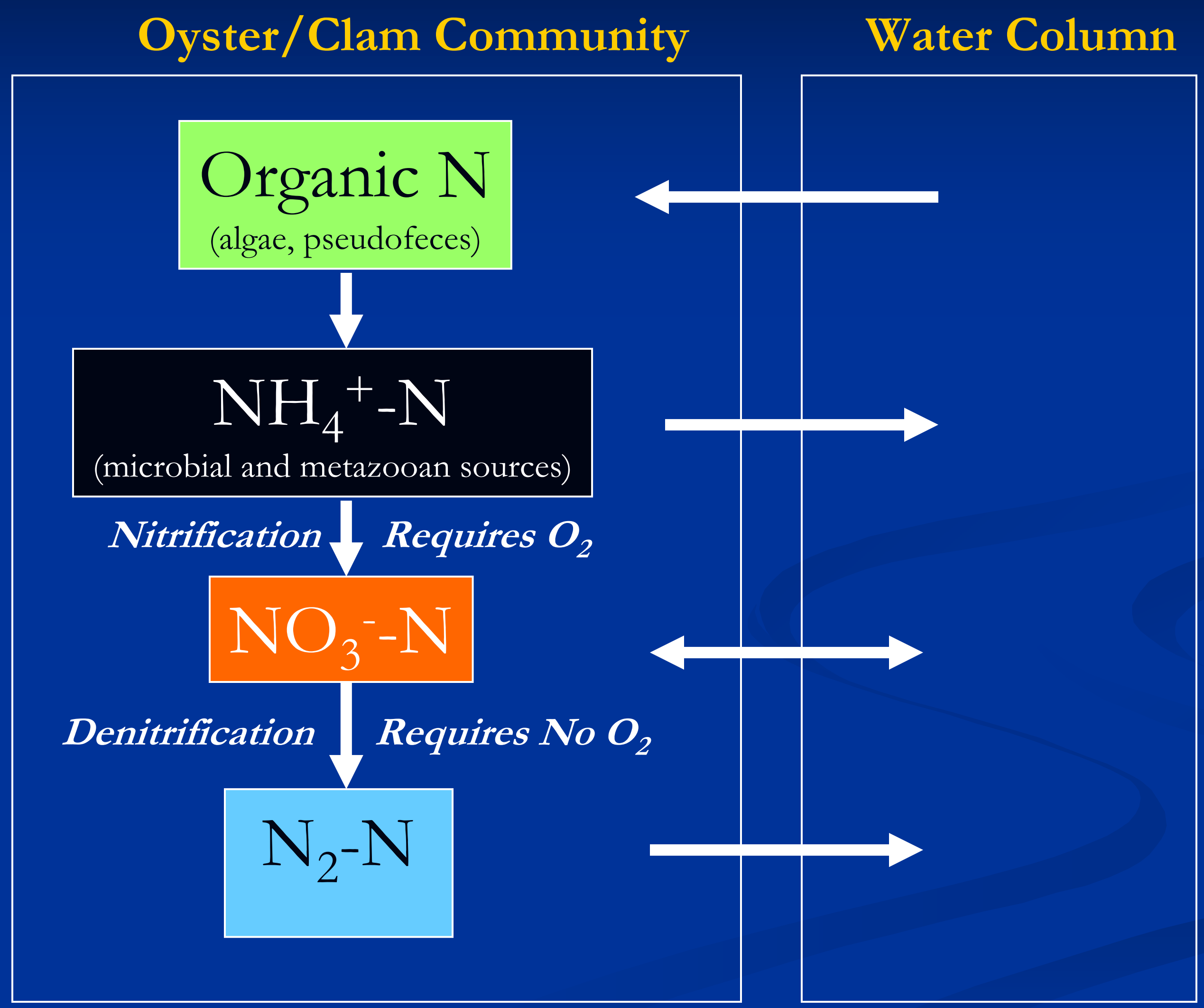
- Placed in waterbath and bubbled with air prior to incubation to bring oxygen levels to saturation
  - 500-μm mesh lid
  - Temperature and salinity matched field conditions and held constant
- Stirring lid added at start of incubation
  - No significant exchange of water or dissolved gases
- All incubations started ≤ 5 hrs after tray was capped in the field

Methods

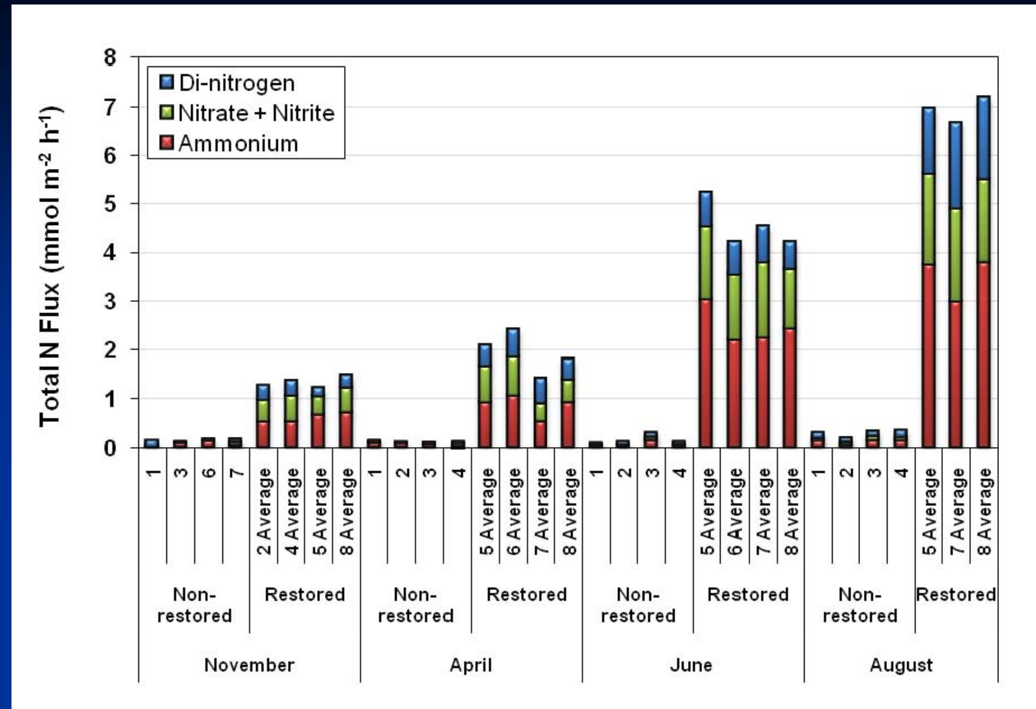
<u>Faunal Analyses:</u>

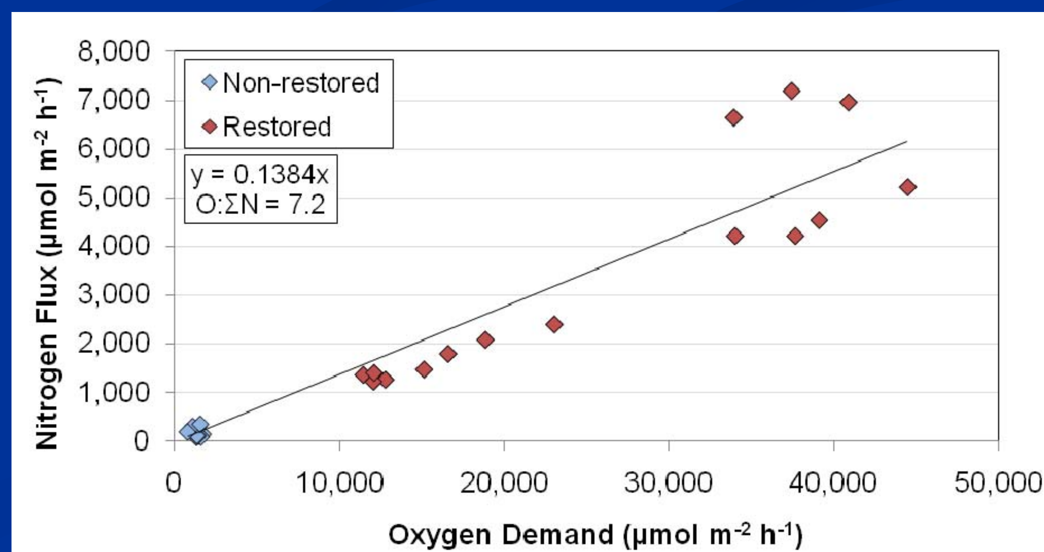
- Tray contents sieved and all organisms retained on 1-mm mesh analyzed
- Data collected for all major faunal groups:
  - Identification to major taxonomic group
  - Abundance
  - Biomass
  - Nitrogen
  - Phosphorus
  - Carbon

Denitrification



- Small tray to tray variability
- O_2:ΣN:P stoichiometry = 115:15:1
- Reef can have 30 x time more metabolic activity than control sediments
- ~ 5000 animals m^{-2} (> 0.5 mm)

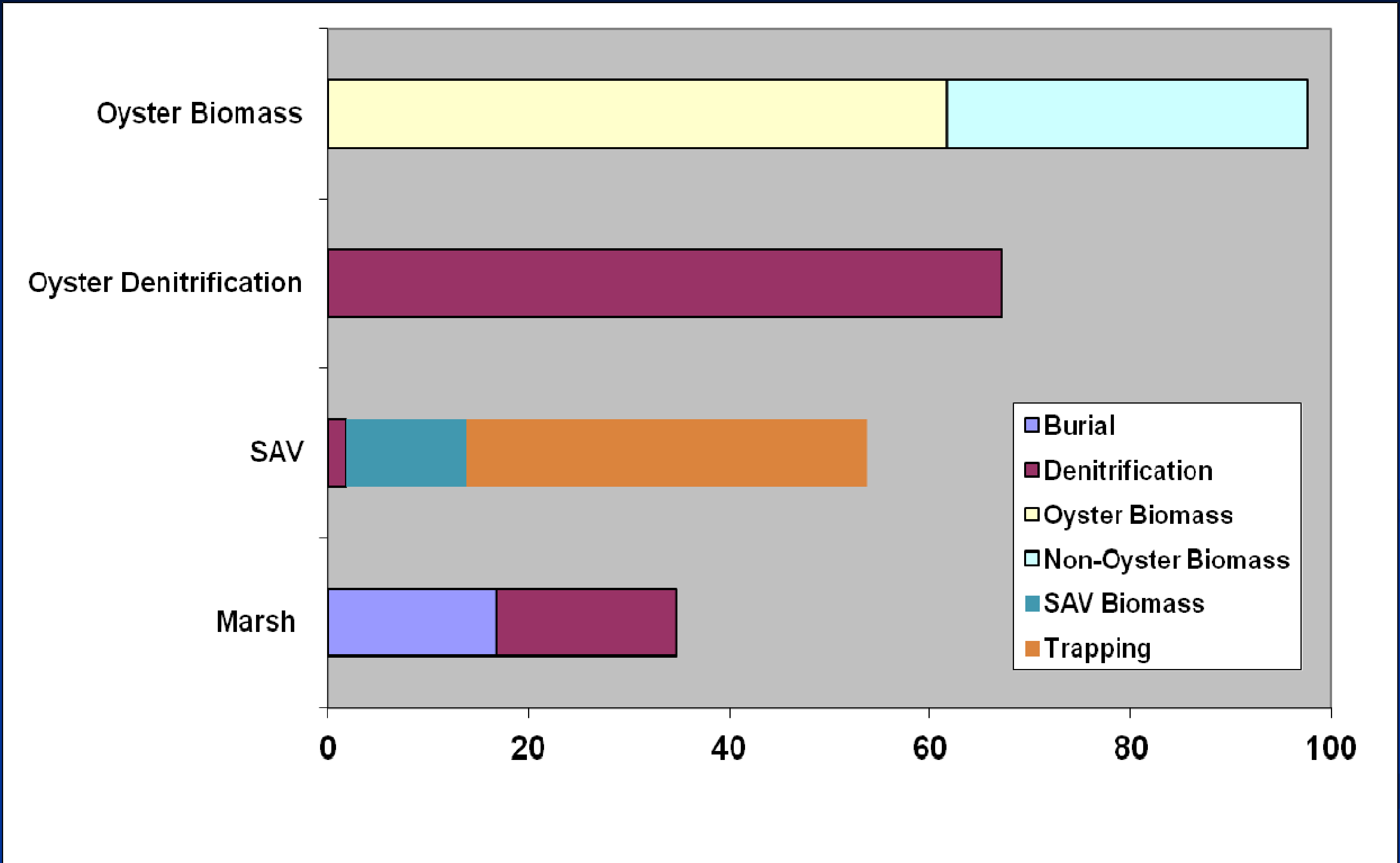




Comparisons to Other Ecosystems

- **Denitrification rates on restored reefs are among highest rates reported**

Ecosystem	Location	Denitrification Rate (µmol N m⁻² h⁻¹)	Source
Present Study			
Oyster Reef - Restored - Subtidal	Choptank River, MD	253 – 1,592	Present Study
Oyster-related Studies			
Oyster Reef - Natural – Intertidal	Bogue Sound, NC	~31 – 136	Piehler and Smyth (2011)
Oyster Aquaculture - Underlying sediments	Chesapeake Bay, MD	4 – 130	Holyoke (2008)
Simulated oyster biodeposition	UMCES - HPL	24 – 51	Newell et al. (2002)
Choptank River and/or Chesapeake Bay			
Soft sediments - Fine grained	Choptank River, MD	0 – 160	Owens (2009)
Soft sediments - Fine grained	Chesapeake Bay	0 – 26	Kemp et al. (1990)
Mid-Atlantic			
Marsh	Patuxent River, MD	38 – 110	Boynton et al. (2008)
Submerged Aquatic Vegetation	Bogue Sound, NC	~67 – 156	Piehler and Smyth (2011)
Marsh	Bogue Sound, NC	~50 – 108	Piehler and Smyth (2011)
Intertidal Flat	Bogue Sound, NC	~12 – 91	Piehler and Smyth (2011)
Subtidal Flat	Bogue Sound, NC	~1 – 30	Piehler and Smyth (2011)
Wetland - 1 year post-construction	South River, NC	50 – 278	Poe et al. (2003)
Wetland - 2 years post-construction	South River, NC	50 – 657	Poe et al. (2003)
Global – Rates During Warmest Month			
River	24 published studies	0 – 3,400	Pina-Ochoa and Alvarez-Cobelas (2006)
Estuary	24 published studies	1 – 596	Pina-Ochoa and Alvarez-Cobelas (2006)
Lake	21 published studies	1 – 312	Pina-Ochoa and Alvarez-Cobelas (2006)
Coastal Ecosystem	25 published studies	0.05 – 141	Pina-Ochoa and Alvarez-Cobelas (2006)
Ocean	13 published studies	1 – 60	Pina-Ochoa and Alvarez-Cobelas (2006)



Rate/Biomass g N m^{-2} y^{-1} or g N m^{-2}

- Historic oyster bars dominated Chesapeake shoals
- They often were found adjacent to deeper water (which is now hypoxic or anoxic)
- If they still existed, they would focus remineralization into zones with higher O_2, meaning more coupled nitrification-denitrification.

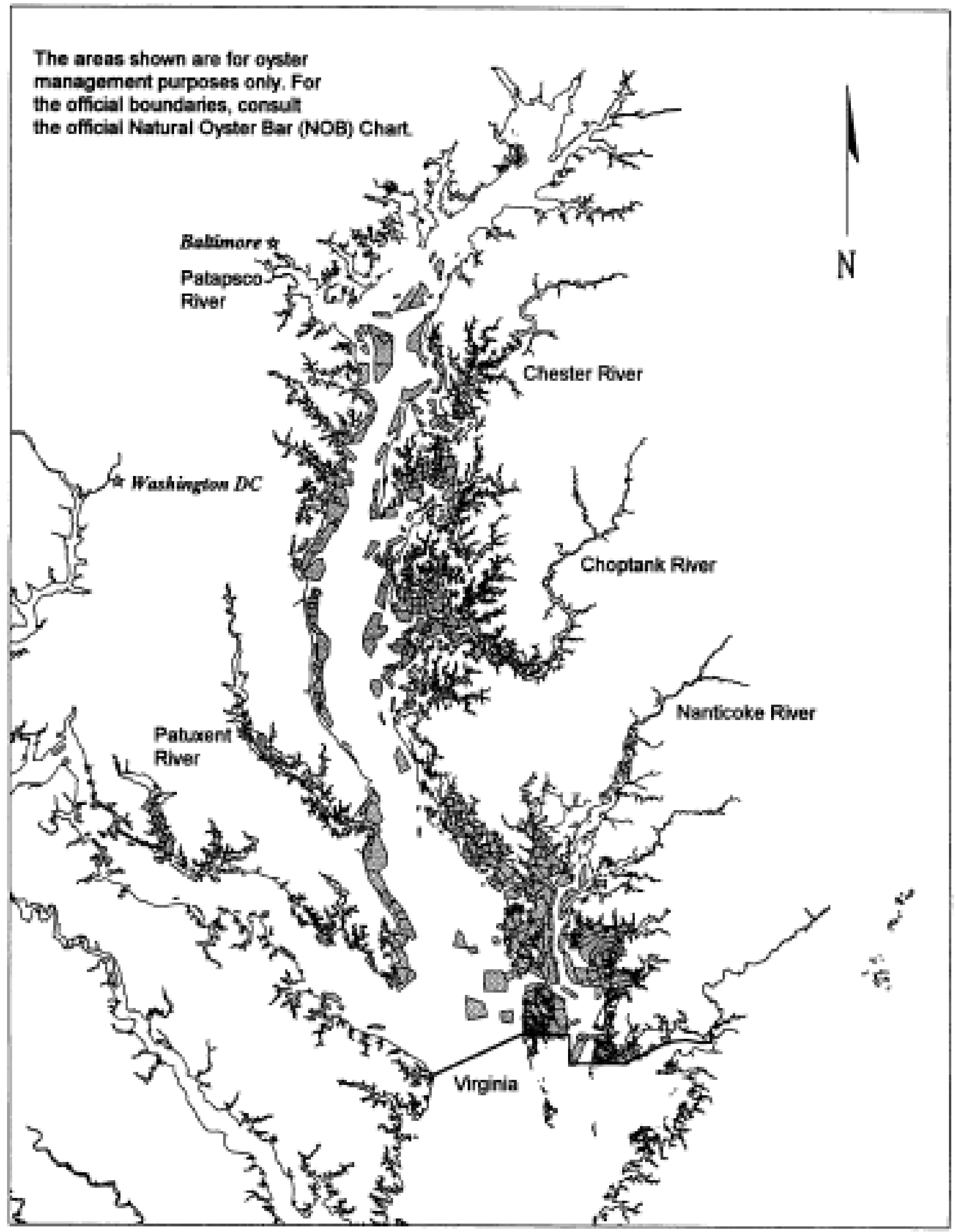
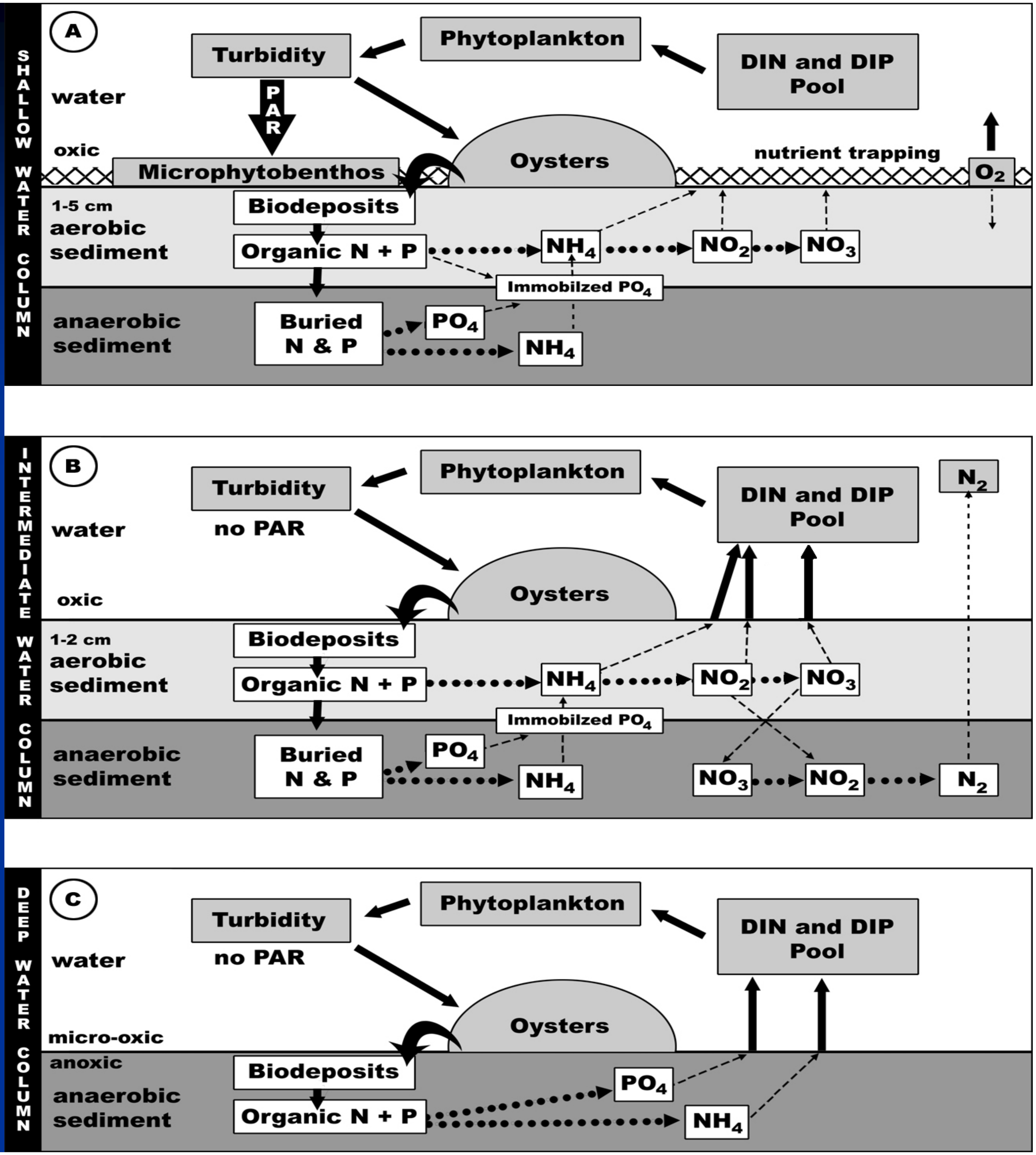


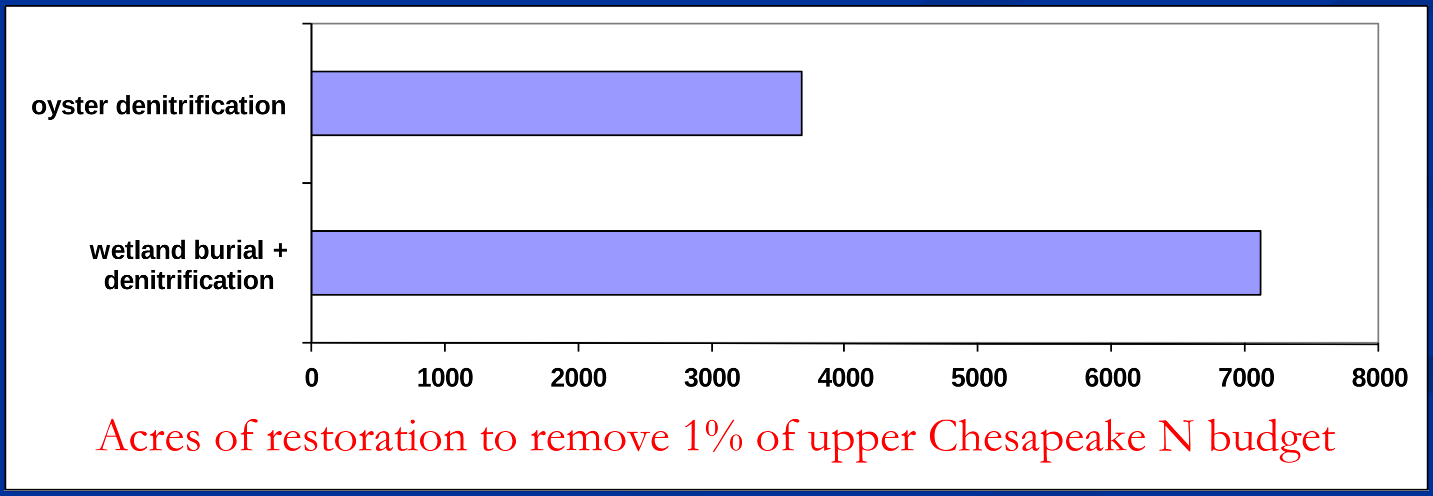
Figure 1. Maryland Historic Oyster Bottom. Depiction based on the MDNR spatial data file - MDOYSBRS. Shaded regions are named oyster bottom.

Newell, RIE, TR Fisher, RR Holyoke and JC Cornwell, 2004. In: *The comparative Roles of Suspension Feeders in Ecosystems* (eds. Richard Dame and Sergej Olenin), NATO Science Series: IV - Earth and Environmental Sciences. Kluwer Academic Publishers, Dordrecht, The Netherlands.

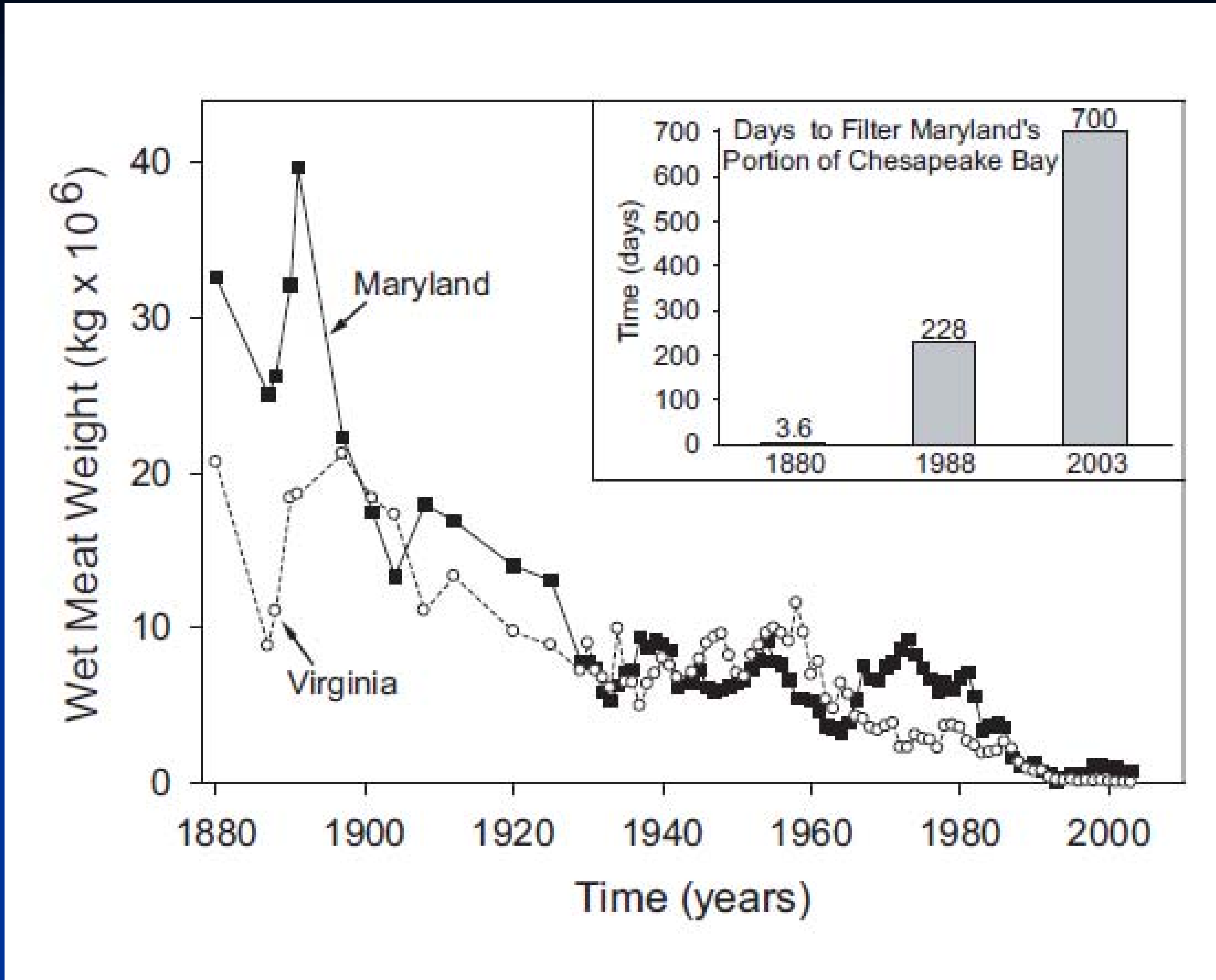


This all assumes…..

- Restored marshes = natural marshes
- 100 oysters m^{-2}
- We have oyster and wetland denitrification seasonality correct
- That denitrification would not occur without oysters: i.e. algal sedimentation into deeper hypoxic bay environments
- Similar restoration at in Choptank River



MD historic oyster acreage ~ 200,000-300,000 acres



Kemp et al. MEPS 2005

The acreage is both intimidating and encouraging!

- Although you need a lot of acreage, there is a clear water quality benefit with each acre
- Historically, oysters could have been a dominant biogeochemical control!

- Thanks to Oyster Recovery Program, MD Sea Grant, NOAA NERRS, Mirant Energy Corporation
- Roger Newell for sharing ideas and getting me involved in this!

Ongoing Activities

- VIMS Wachapreague – Lynnhaven intertidal oyster fluxes – Kellogg
- VIMS Wachapreague – TNC-funded. Fluxes in beds of different density – Kellogg, VA Coastal Reserve
- VIMS Wachapreague – NOAA-funded. Fluxes in beds of different density, mouth of Onancock Creek – Kellogg,
- Horn Point – Newell, Cornwell, Sanford. Nutrient cycling, physics in Marinetics aquaculture site. Similar work in Maine 2012