Benthic Nutrient Cycling in Mid-Atlantic Coastal Systems

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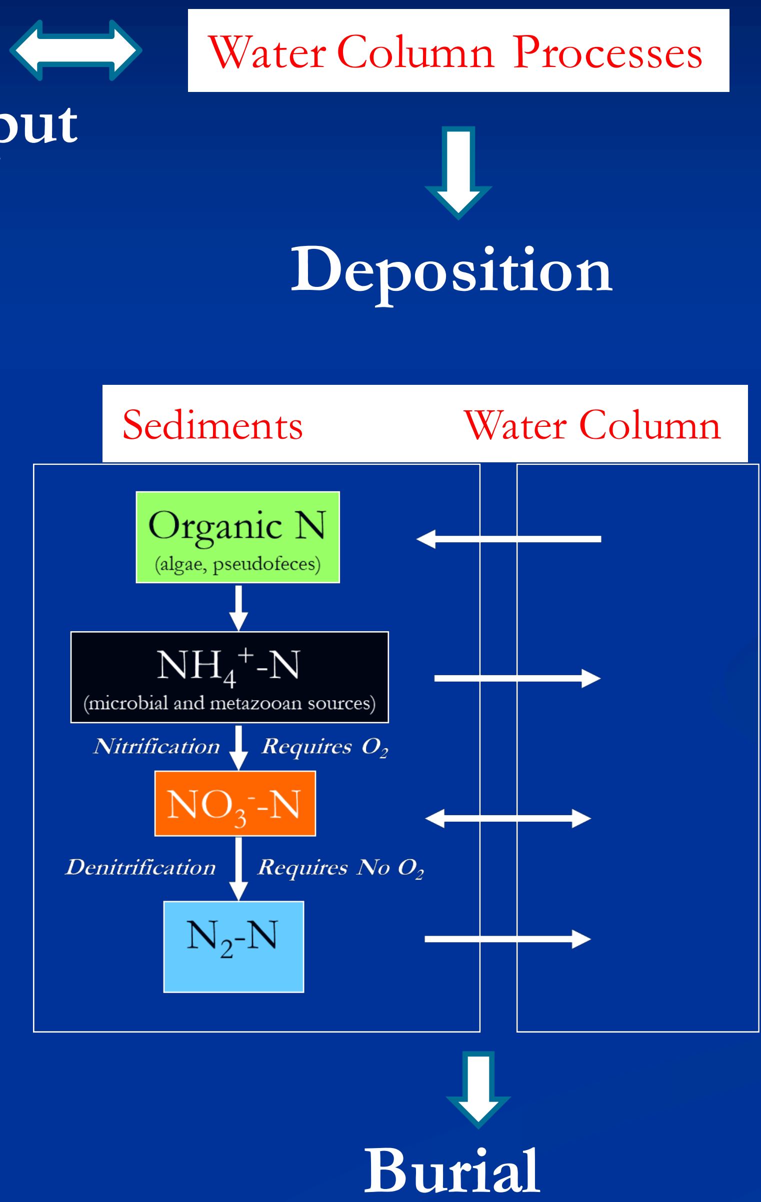
Outline

1. Are shallow bay sediment important to nutrient balances?
2. What features of the environment enhance or hinder the recycling of nutrients?
3. Do sediments respond to changes in inputs – is there “sediment memory?”
4. What does an assessment look like?

Where Have We Worked?

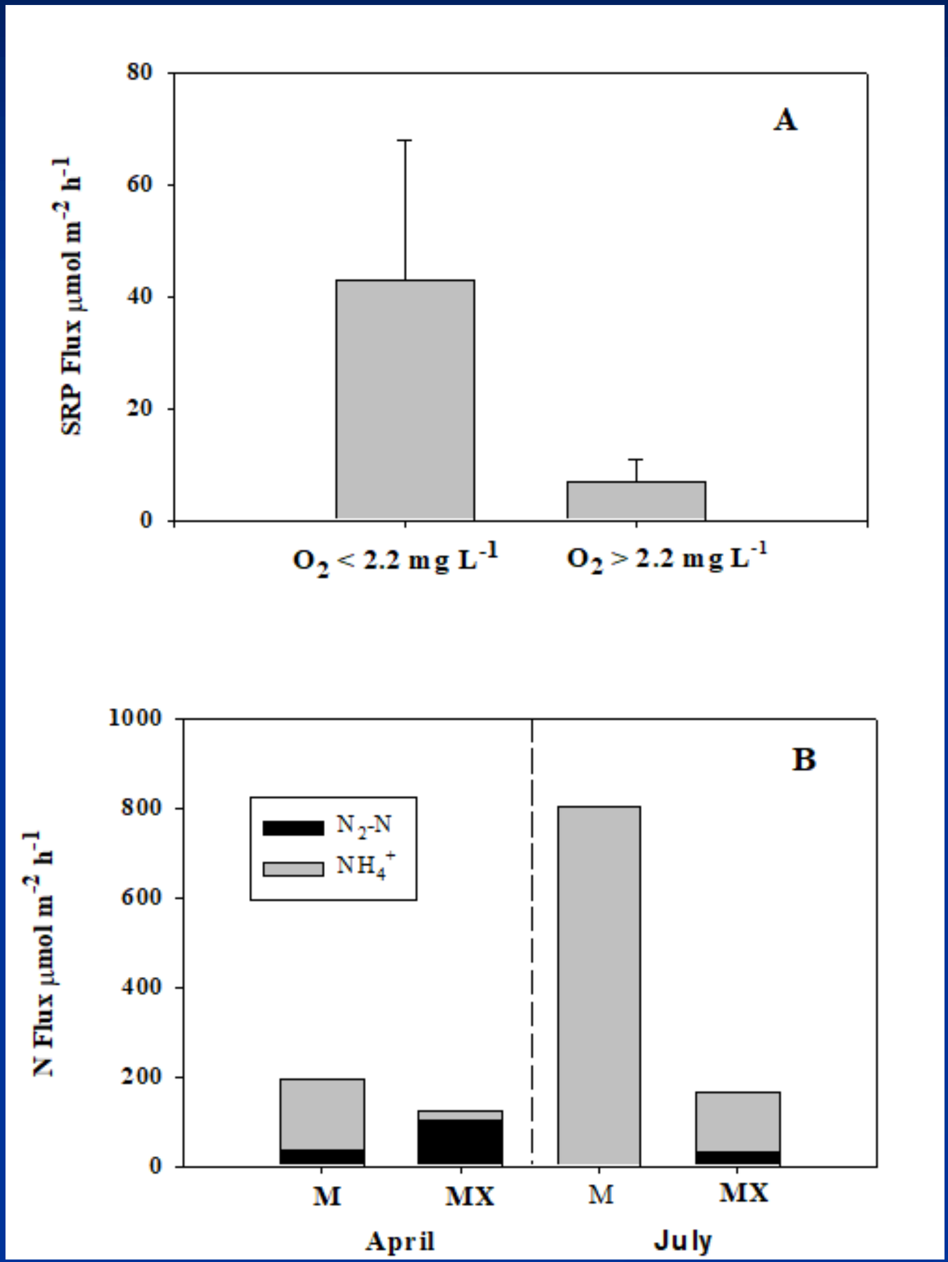
- Impacted coastal ecosystems – nutrient and oxygen flux measurements in New York/Jamaica Bay, Delaware River (PWD), San Francisco Bay, Delaware (St. Jones, Assawoman, Indian River)
- Shallow photic systems – Chincoteague Bay, Tampa Bay, Florida Bay estuary and wetland, Long Island bays, Choptank River
- Oyster restoration and bivalve aquaculture environments – Maryland and Washington State
- Wetlands – Murderkill River, Poplar Island, Tributaries (Patuxent, Choptank, Nanticoke)
- Lakes, Reservoirs – Lake Champlain, Spokane Lake (WA), Byllesby Reservoir (MN), Conowingo Reservoir (MD)

Nitrogen Input/Output



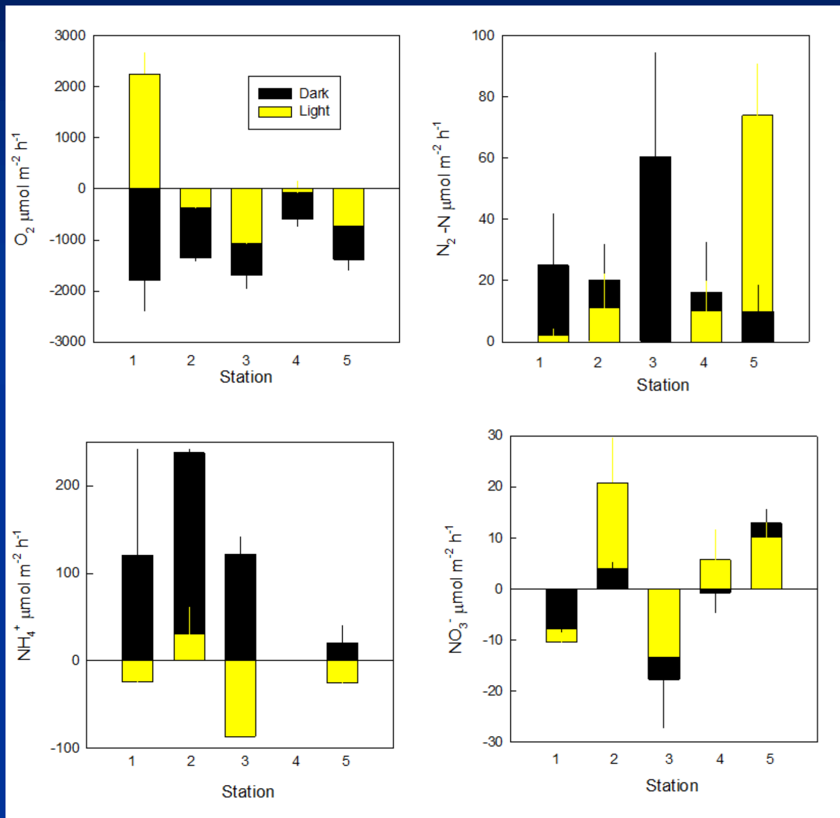
- In deep systems, most nutrient remineralization is in the water column
- In shallow systems, both the water column and sediments are sites for nutrient remineralization
- In shallow systems, both water column and sediments are sites for photosynthesis (benthic algae, macroalgae, macrophytes)

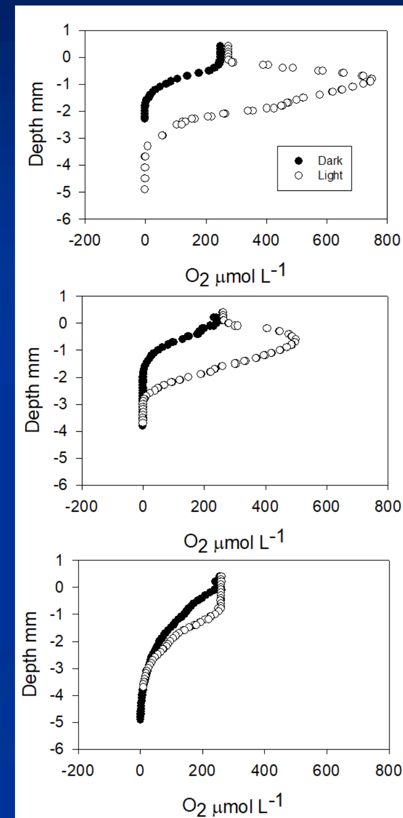
Overlying Water Oxygen is a Major Control



- Low oxygen leads to high P fluxes from sediments, mainly due to lack of inorganic P binding after conversion of iron oxides to iron sulfides
- Low oxygen limits nitrification and can result in low rates of denitrification and high ammonium effluxes
- Low oxygen can also cause the loss of key macrofauna species that irrigate the sediment and promote denitrification.
- This classic example is form the main stem of the Chesapeake Bay.

Light (PAR) is an Important Control



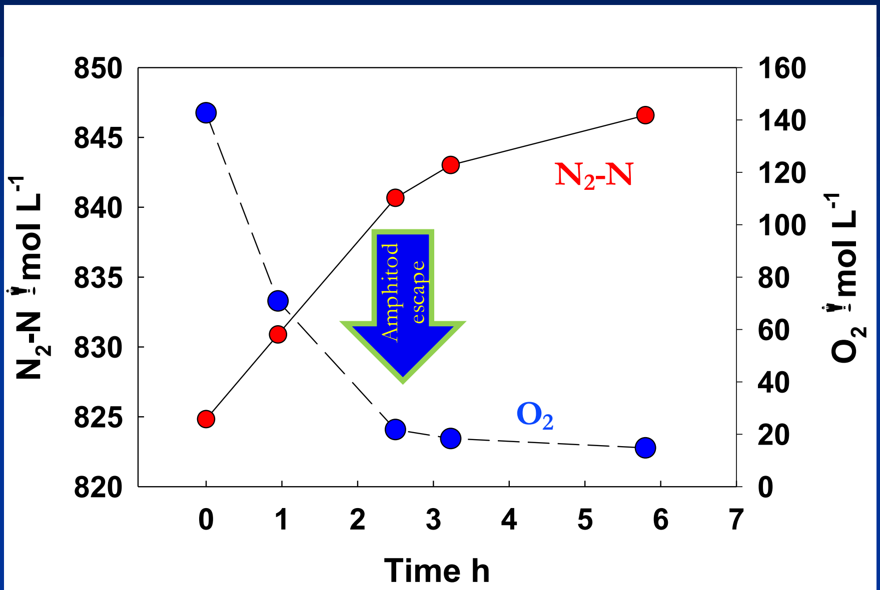


Maryland Coastal Bays

San Francisco Bay

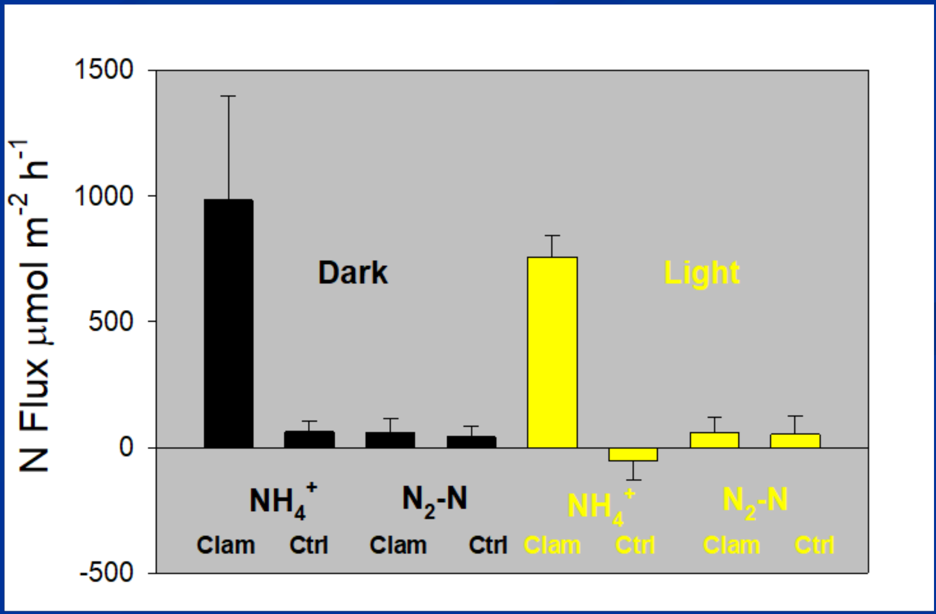
Wazniak, C. E. and others 2009. Chapter 13. Water quality responses to nutrients, p. 249-291. *In W. C. Dennison et al. [eds.], Shifting Sands. Environmental and cultural change in Maryland's Coastal Bays. UMCES.*

Animal Activity is an Important Control

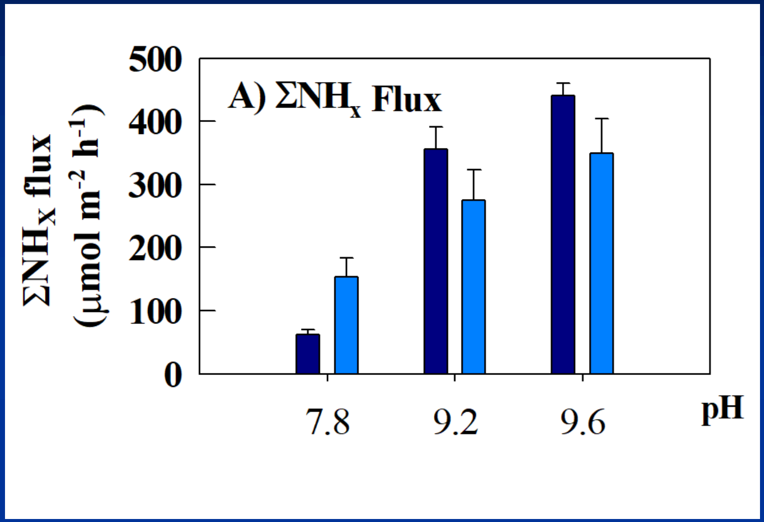


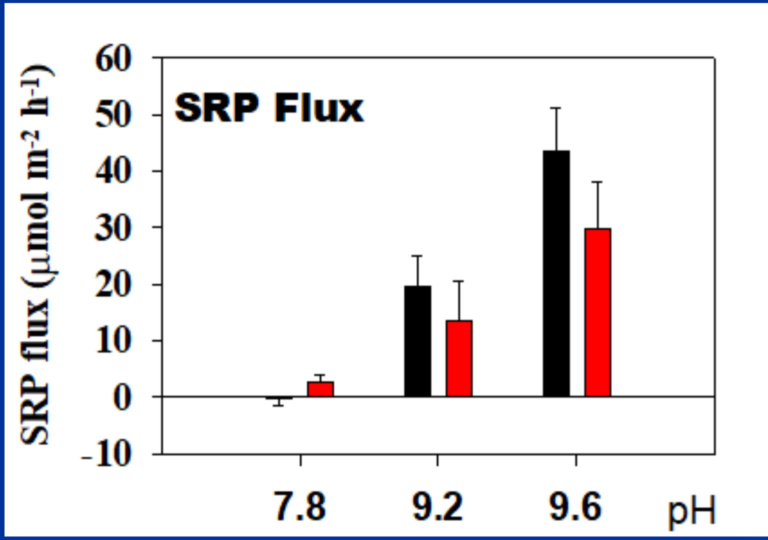
- In Jamaica Bay, NYC, we see that when oxygen decreases during incubation, the rate of denitrification decreases, and tube-dwelling amphipods swim into the water column
- Worms and amphipods tend to increase denitrification

- In Maryland’s coastal bays, clam aquaculture results in much bigger sediment effluxes of ammonium, with little change to denitrification
- Oysters in bottom culture tend to increase denitrification



pH is an Important Control





- Cyanobacterial blooms tend to increase water column pH (up to > 10); in shallow systems the sediments see large pH increases
- In the Sassafras River, elevated pH results in elevated fluxes of soluble reactive P and ammonium; coupled nitrification/denitrification is inhibited

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www.biogeosciences.net/9/2697/2012/
doi:10.5194/bg-9-2697-2012

Biogeosciences

Effects of cyanobacterial-driven pH increases on sediment nutrient fluxes and coupled nitrification-denitrification in a shallow fresh water estuary

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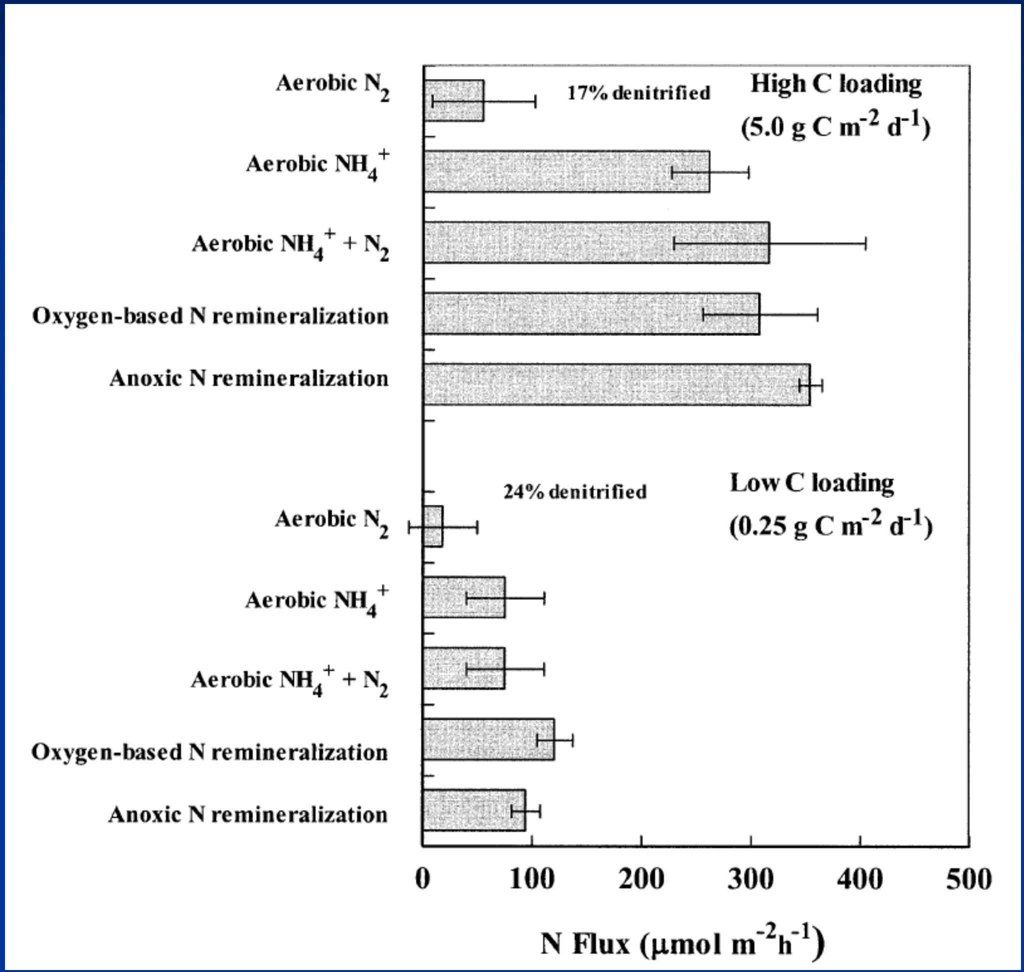
Organic Matter Loading is a Key Control



Limnol. Oceanogr., 47(5), 2002, 1367–1379

Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: A laboratory study

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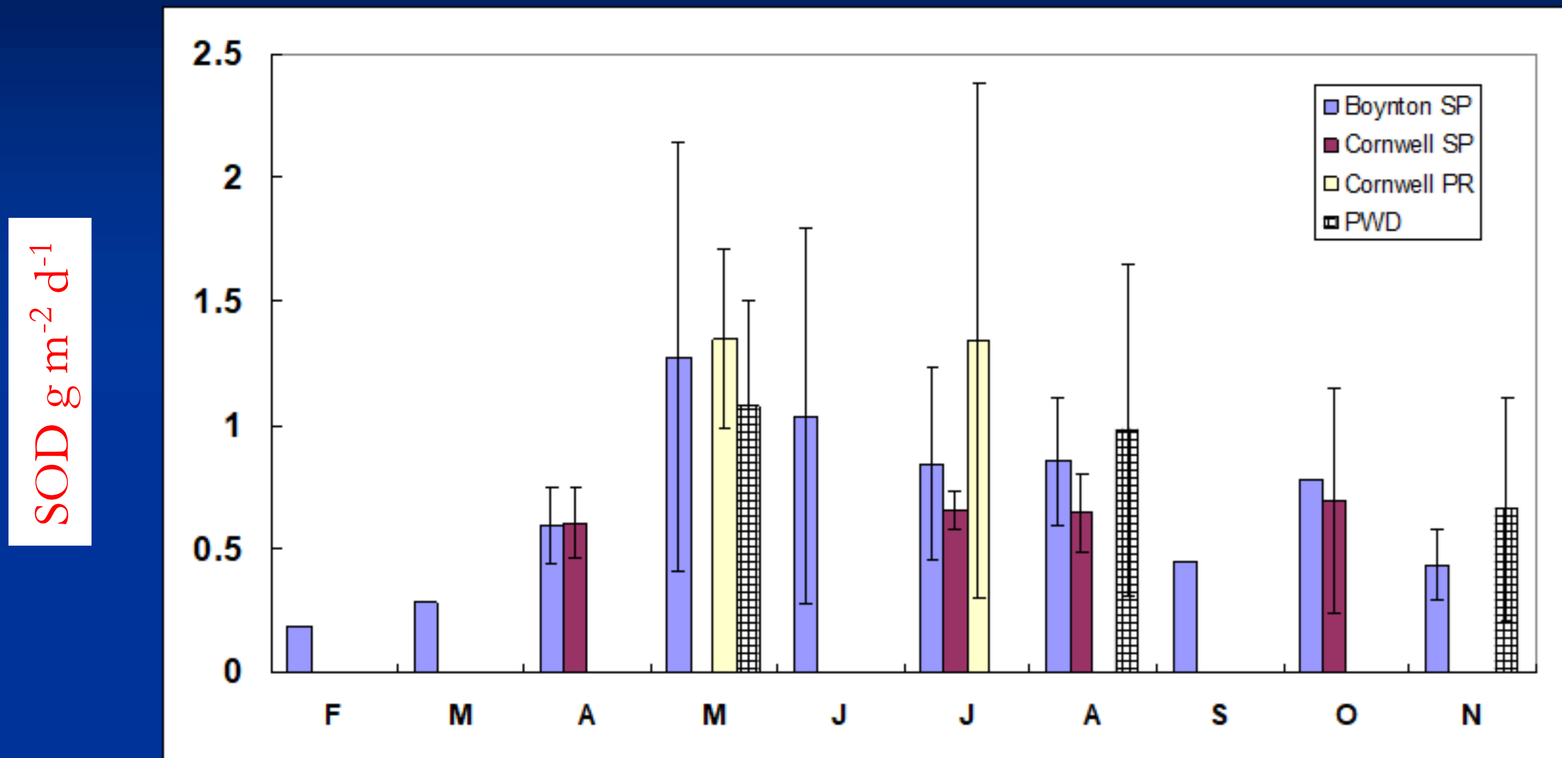
Season/Temperature is a Key Control



Plots of sediment oxygen demand from upper Chesapeake Bay (SP), Potomac River (PR) and the Delaware River (PWD)

Making Measurements

Fluxes

- Core collection into 7-10 cm id core tubes – intact interfaces essential
- Time course incubation for gas ratios (N_2:Ar; O_2:Ar), ammonium, nitrate, soluble reactive phosphorus
- Sequential dark/light incubation conditions
- Regression analysis for rates

Other Parameters

- Grain size
- Sediment C, N, P, Fe, S solid phase analyses
- Pore water chemistry
- Surficial sediment chlorophyll a

Owens, M. S., and J. C. Cornwell. 2016. The Benthic Exchange of O-2, N-2 and Dissolved Nutrients Using Small Core Incubations. Jove-Journal of Visualized Experiments.

http://www.jove.com/video/54098/the-benthic-exchange-o2-n2-dissolved-nutrients-using-small-core

Methods

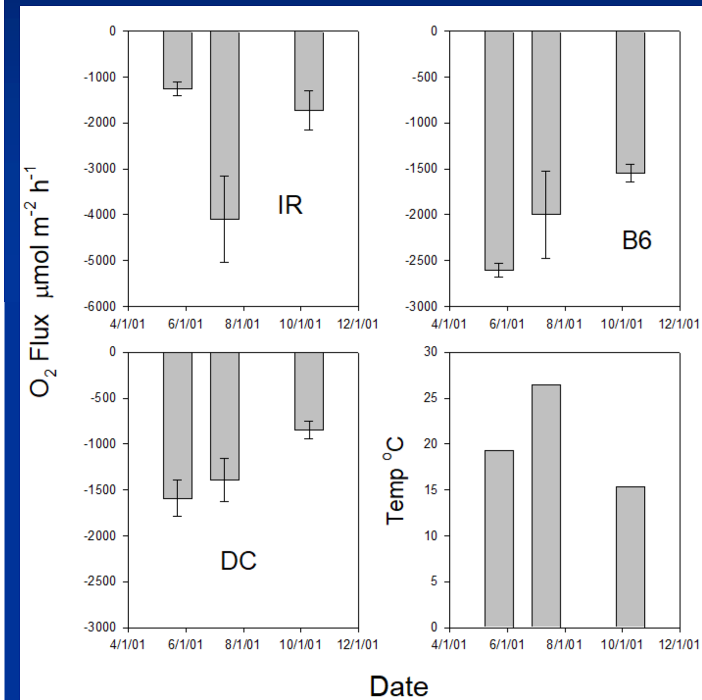
Replicate core incubations in stirred microcosms

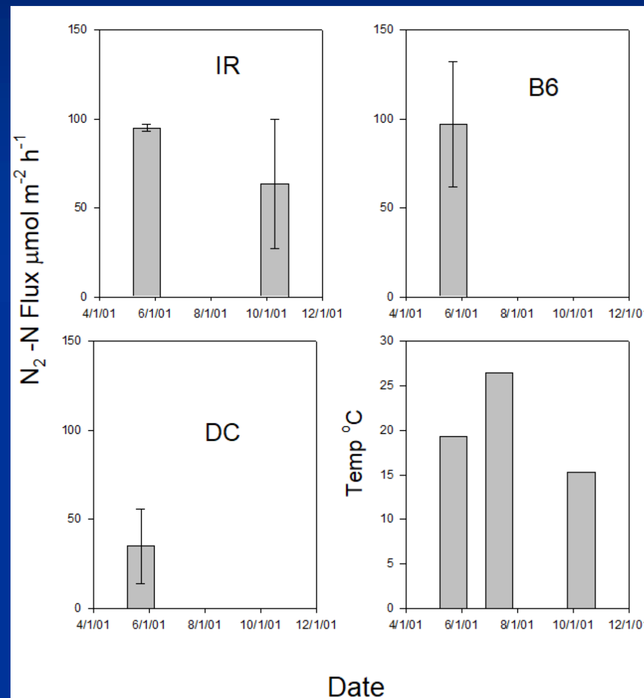
Flux rates corrected for changes in water column blank

Time course sampling of dissolved gases and nutrients

Direct measurements of N_2 production using Membrane Inlet Mass Spectrometry

Delaware Coastal Bays





Sediment-Water Exchange in DE Coastal Bays ($\mu mol\ m^{-2}\ h^{-1}$)					
Station	Mean	S.D.	Median	Min	Max
			Oxygen		
IR	-1815	621	-1570	-2685	-1095
Buoy 6	-2497	1399	-1895	-5429	-1071
DC	-1374	488	-1413	-2306	-739
			N_2-N		
IR	76	37	93	12	125
Buoy 6	0	0	0	0	0
DC	25	38	0	0	113
			Ammonium		
IR	224	100	227	54	368
Buoy 6	91	150	0	0	439
DC	52	81	0	0	189
			Nitrate		
IR	-39	44	-24	-113	16
Buoy 6	0	0	0	0	0
DC	-1	25	0	-55	26
			Phosphate		
IR	0	0	0	0	0
Buoy 6	0	0	0	0	0
DC	2	6	0	-5.1	10.5

- Data from DNREC-funded assessment – Robin Tyler with logistics
- Indian River, Buoy 6, Dirickson Creek

Site ID	Location	Date	T	O_2	Salinity	NH_4^+	NO_3^-	SRP
		(2001)	°C	mg L^{-1}	PSU	µmol L^{-1}		
Indian River	38° 35' 20.0" N 75° 13' 19.0" W	May 16	20.8	6.5	19	20.7	50.9	0.24
		July 12	26.9	6.0	20	1.1	0.60	0.34
		Oct 10	14.3	7.2	17	3.2	50.6	0.35
Buoy 6	38° 28' 33.8" N ***75° 03' 49.4" W***	May 16	19.5	8.9	24	2.1	0.81	0.08
		July 12	25.7	5.3	18	1.5	0.69	0.46
		Oct 10	13.3	8.0	27	1.0	1.2	0.10
Dirickson Creek	38° 29' 03.9" N 75° 05' 51.1" W	May 16	20.4	7.6	16	1.7	1.94	0.11
		July 12	25.6	5.6	25	1.7	0.81	0.17
		Oct 10	13.5	8.7	22	0.5	2.8	0.13

A Note On Sediment Memory

- The most labile components of algal organic matter (including organic C, N and P) are remineralized in weeks, a second pool in << 1 year, and a residual pool over a longer period. Year to year carryover of labile organic matter is relatively small.
- Sediment inorganic P can be a somewhat of a legacy in come circumstances, especially colonization of macrophytes and with increasing anoxia.

Delaware Coastal Bays – Sampling Design

- Seasonality need to be accounted for (3 time minimum, preferably 4)
- Spatial: 8 sites seasonally with duplicate cores, another 16 sites with single cores on at least one occasion
- Modeling needs: grain size, pore water chemistry, solid phase analyses
- Location choices: representative of different regimes – dead end canals with low oxygen, wide-open "clean" environments, shallow, deep