Microbial C & N Cycling in Estuarine Sediments: A Case Study from Chesapeake Bay

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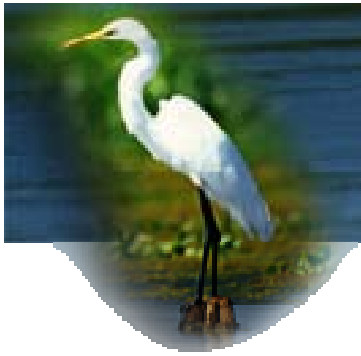
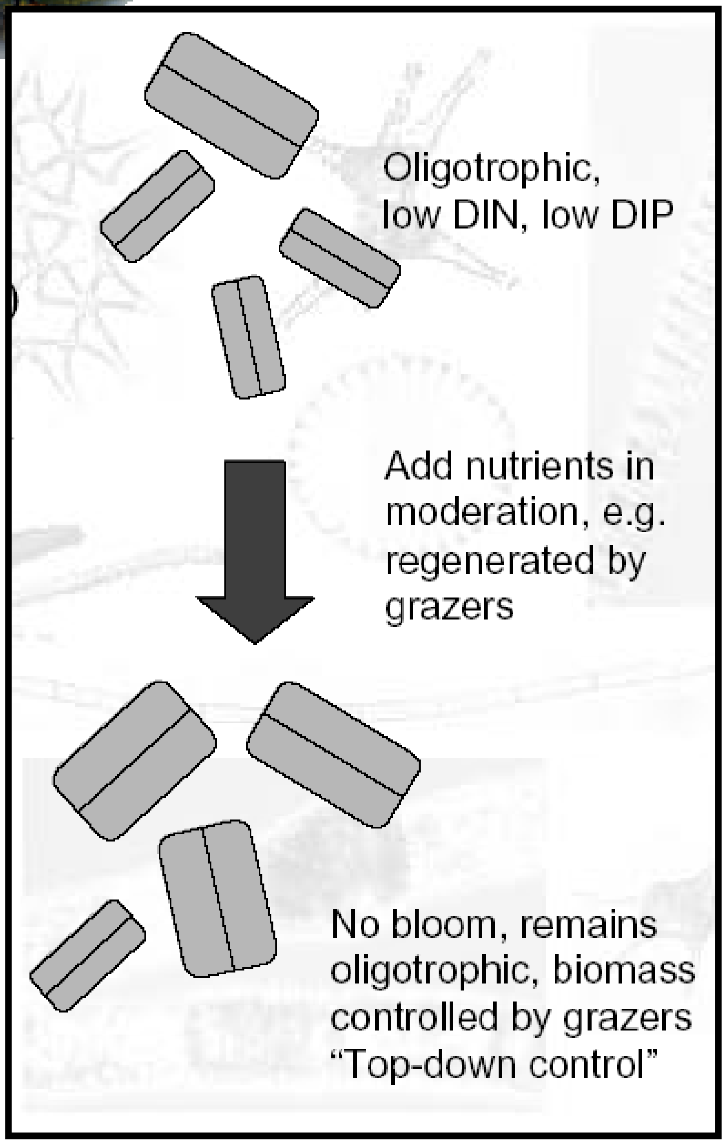
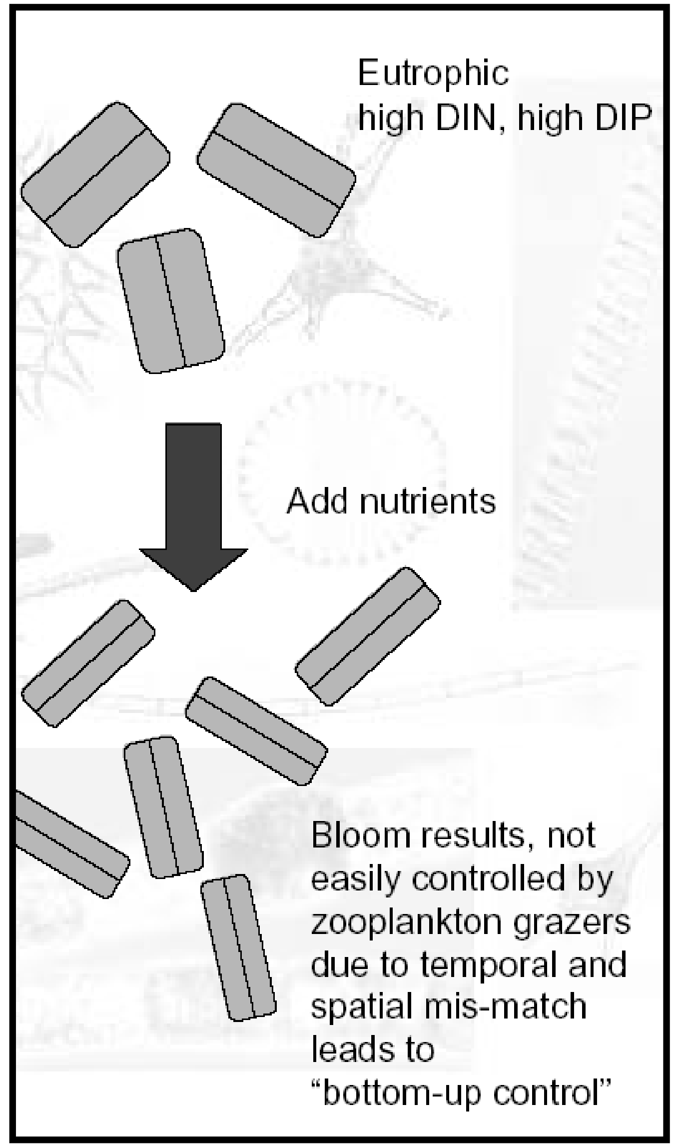


Outline

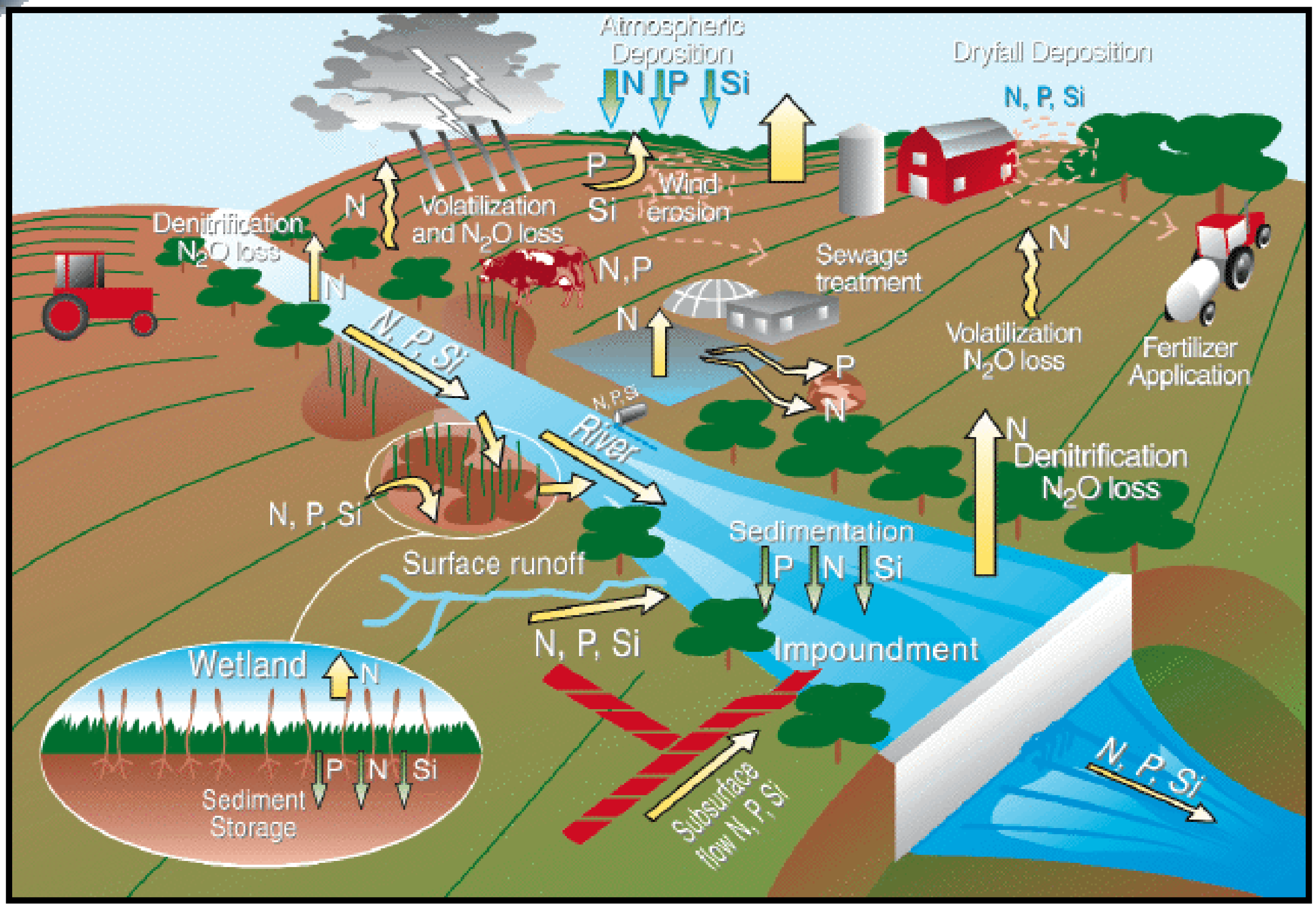
- Background
  - Coastal Eutrophication
  - Benthic Processes
- Objectives & Hypotheses
- Experimental Design
- Results
- Summary & Conclusions
- My Knauss Sea Grant Experience

Coastal Eutrophication





Estuarine Nutrient Sources



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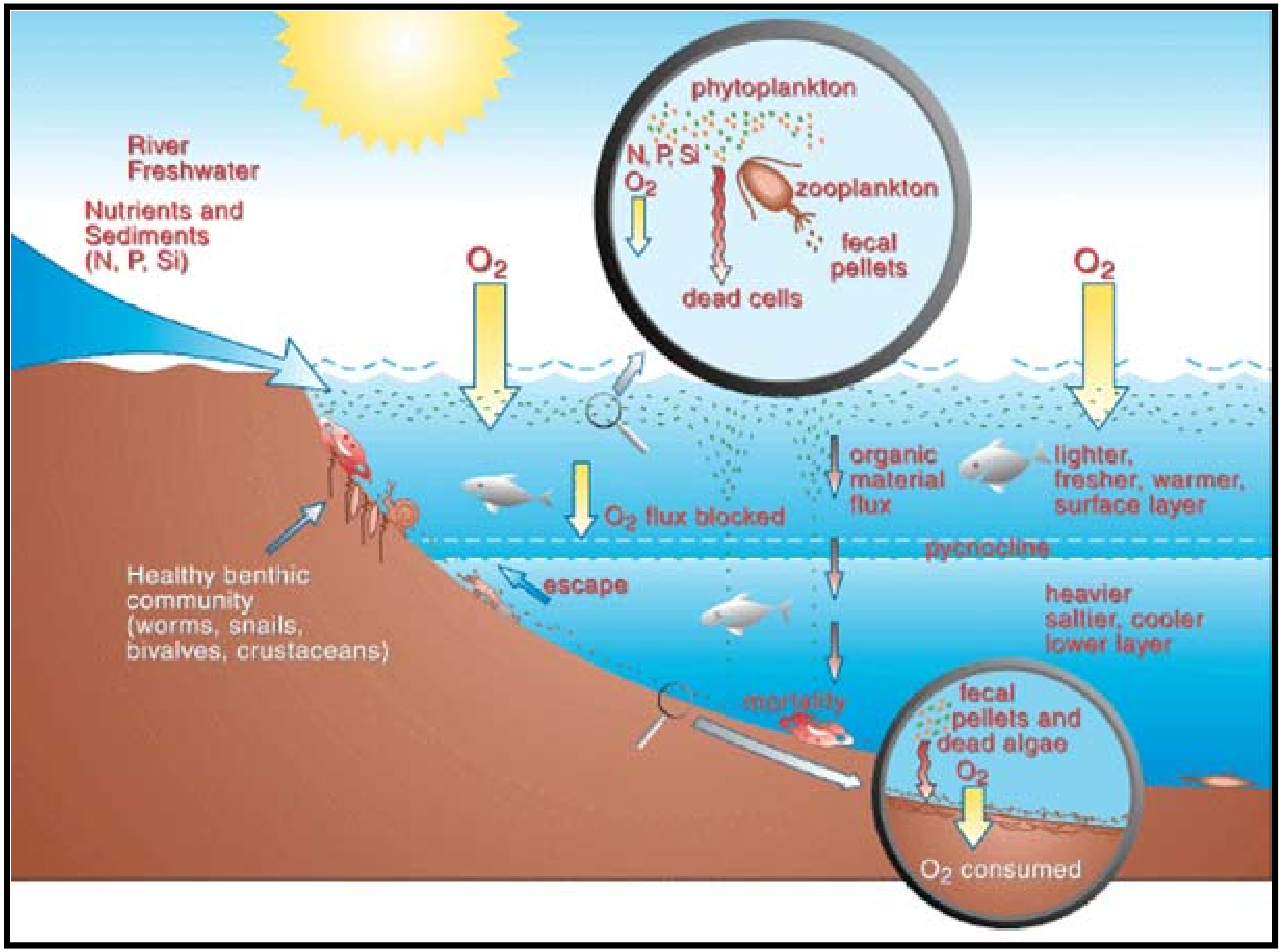
Nutrient Enrichment



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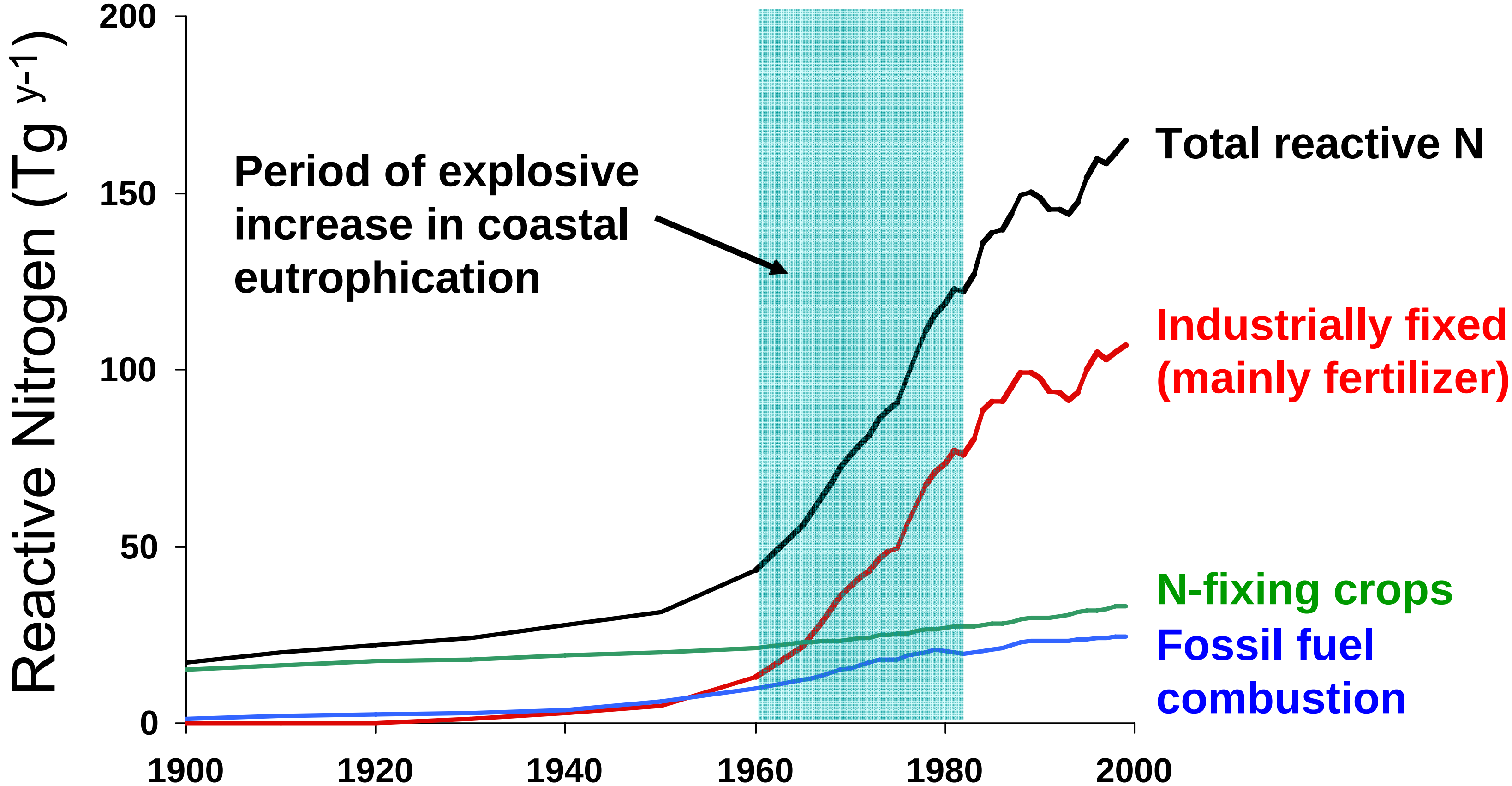
Reactive Nitrogen



Galloway et al. 2003

Sources of N to Chesapeake

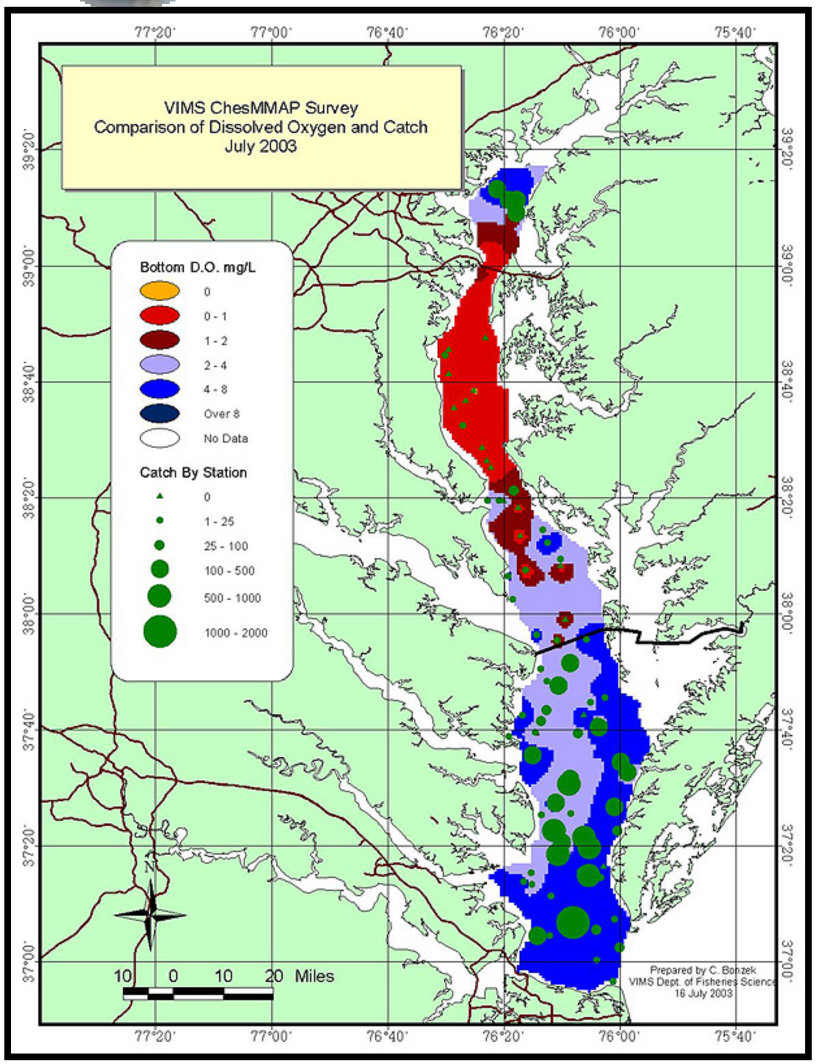
- Point Sources of Pollution: 21 %
  - Sewage Discharge
- Non-point Sources of Pollution
  - atmosphere: 32%
    - vehicles, utilities, industry
  - “other”: 47 %
    - fertilizer, manure, septic, natural

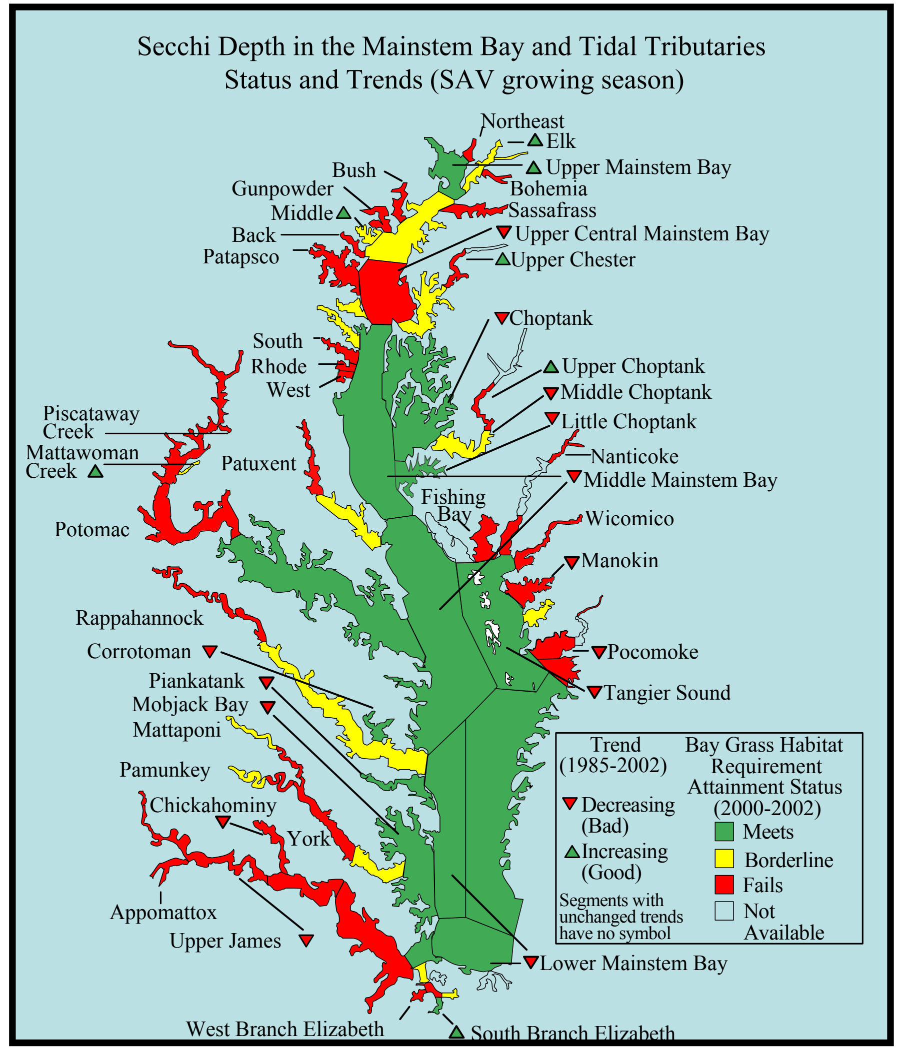
Consequences of Eutrophication

- Nuisance blooms of macroalgae and phytoplankton
- Disappearance of seagrass
- Loss of valuable species
- Hypoxia & Anoxia
- Fisheries collapse
- Stress & disease
- Poor water quality

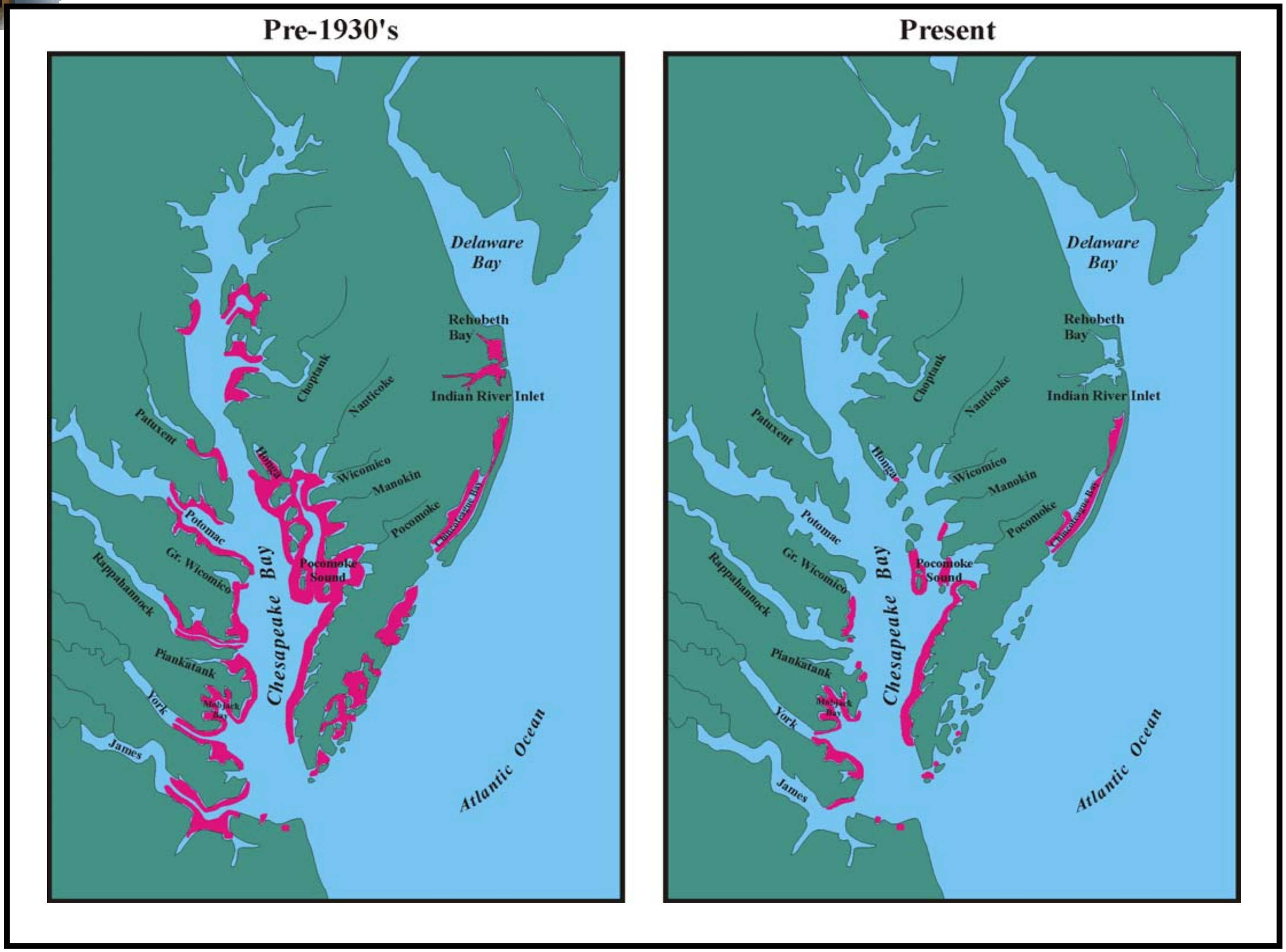
Potential Effects

Coastal Eutrophication





Sea Grass Declines



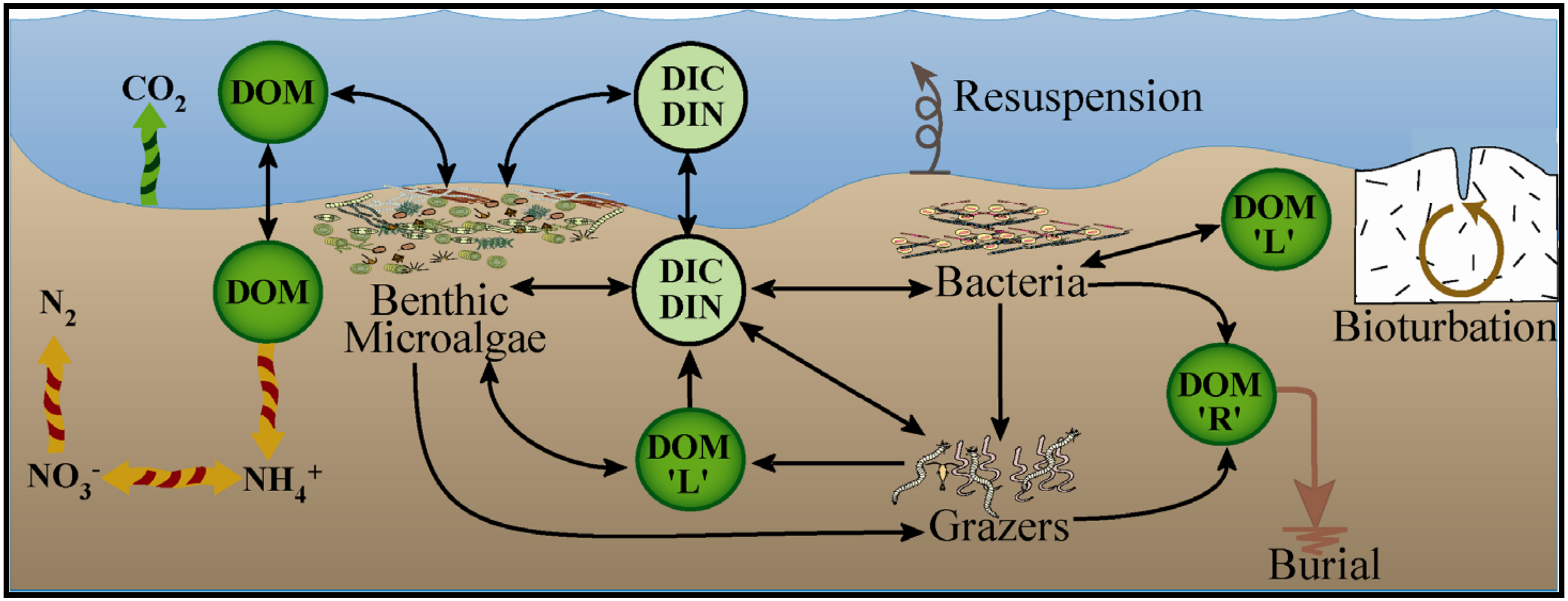
Coastal Population

- By 2025, 75% of the world's population (~ 6.3 billion) could reside in coastal areas
  – 500 million more than the current global population

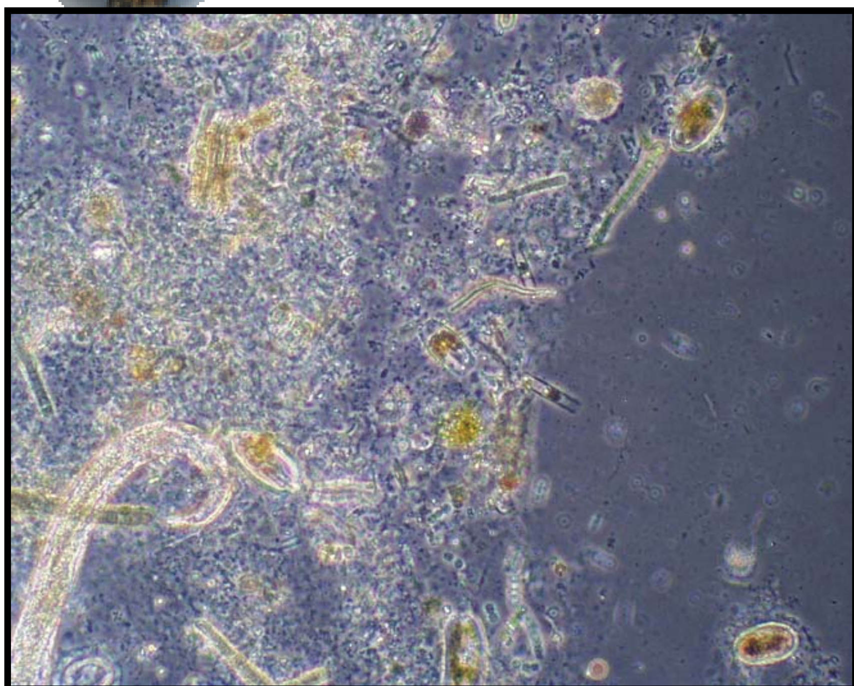
Hinrichsen 1998

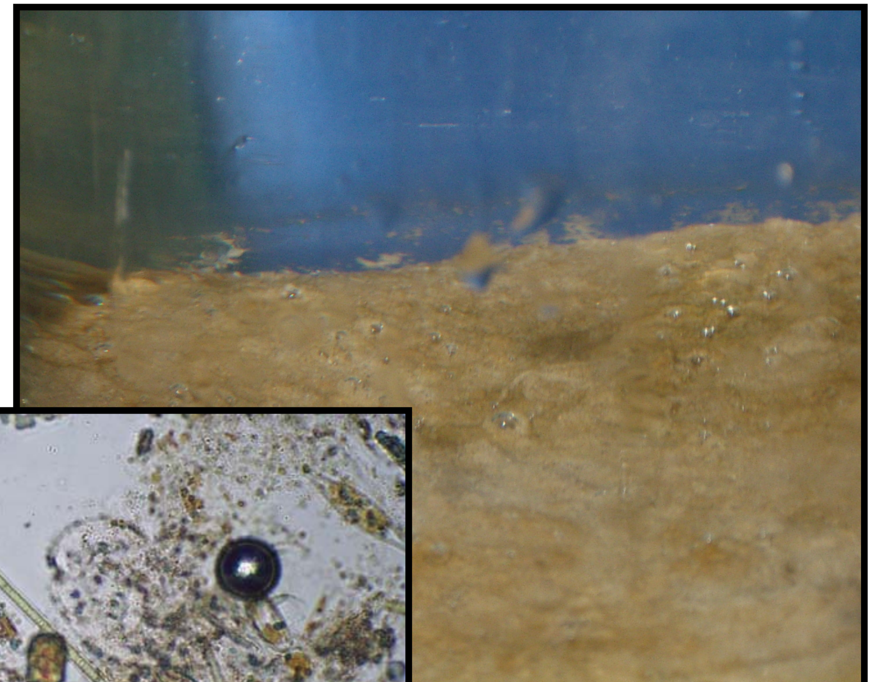
And Now for the Mud…

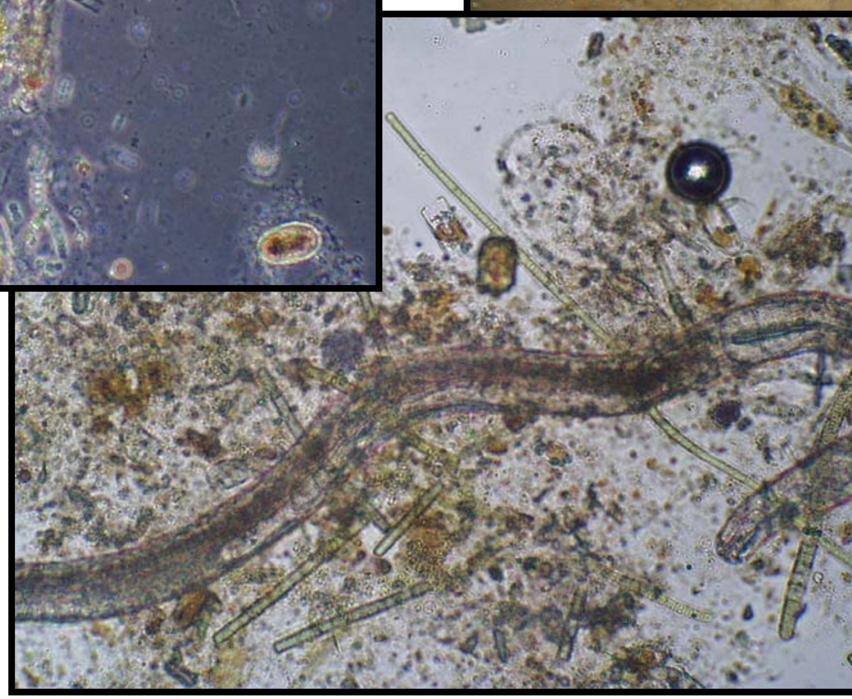
Euphotic Estuarine Sediments



Sediment Complexity…



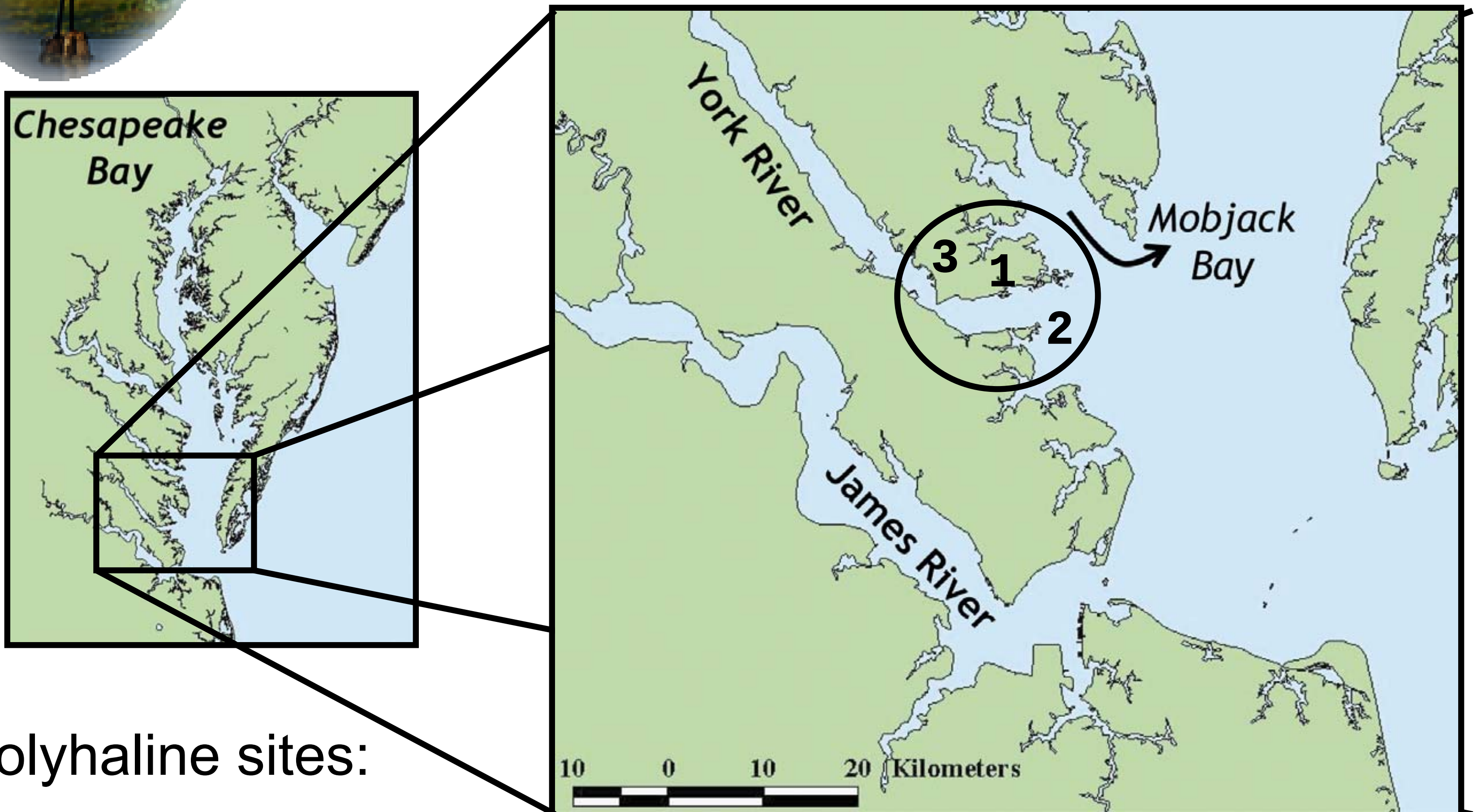




Objectives & Hypotheses

- Hypotheses:
  - BMA dominate microbial N immobilization in surface euphotic sediments
  - Relative uptake of WC & PW DIC & DIN is a function of concentration
- Objectives:
  - Differentiate between BMA & sediment bacteria
  - Examine whether partitioning shifts as a function of water column N availability
  - Compare N mineralization rates to BMA & bulk sediment N immobilization rates

York River, Virginia



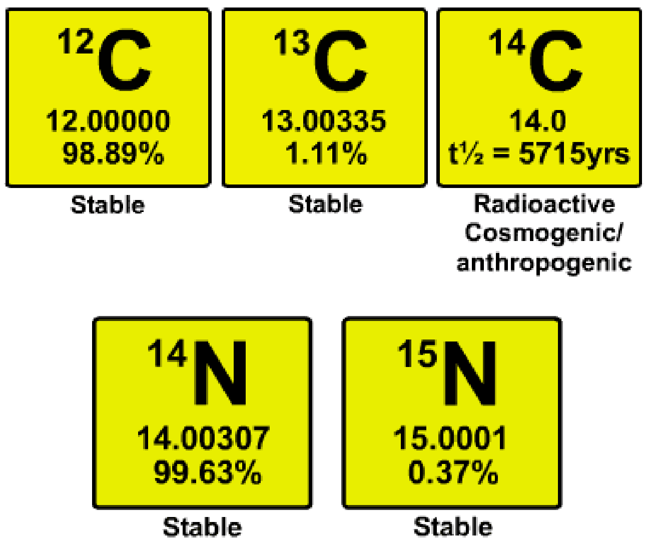
Polyhaline sites:

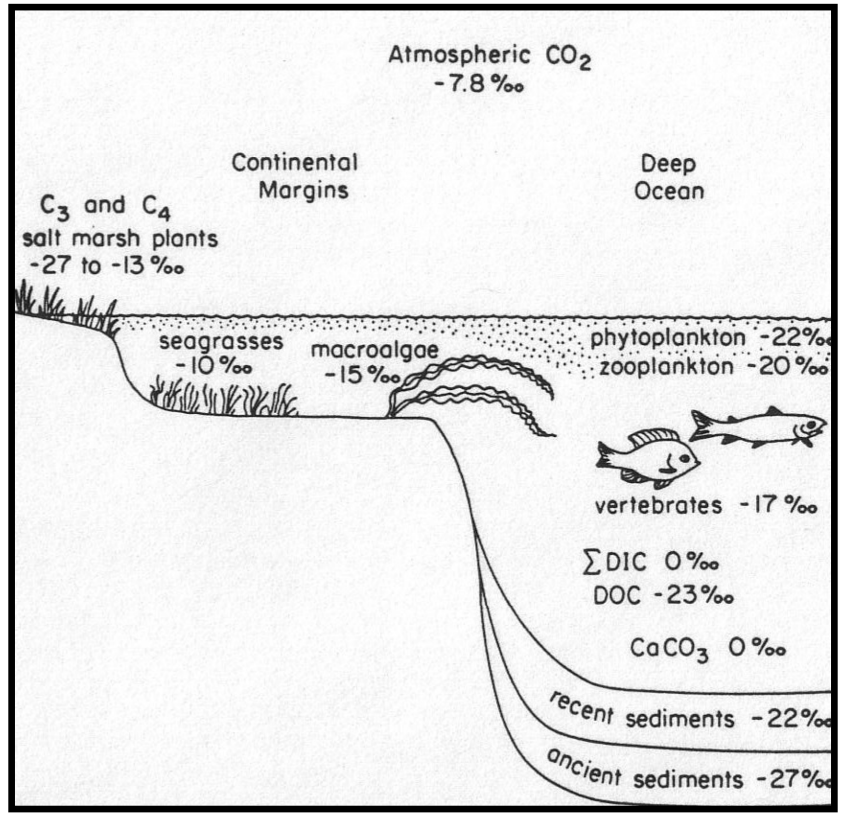
1 = Allen's Island

2 = Goodwin Islands

3 = Mumfort Islands

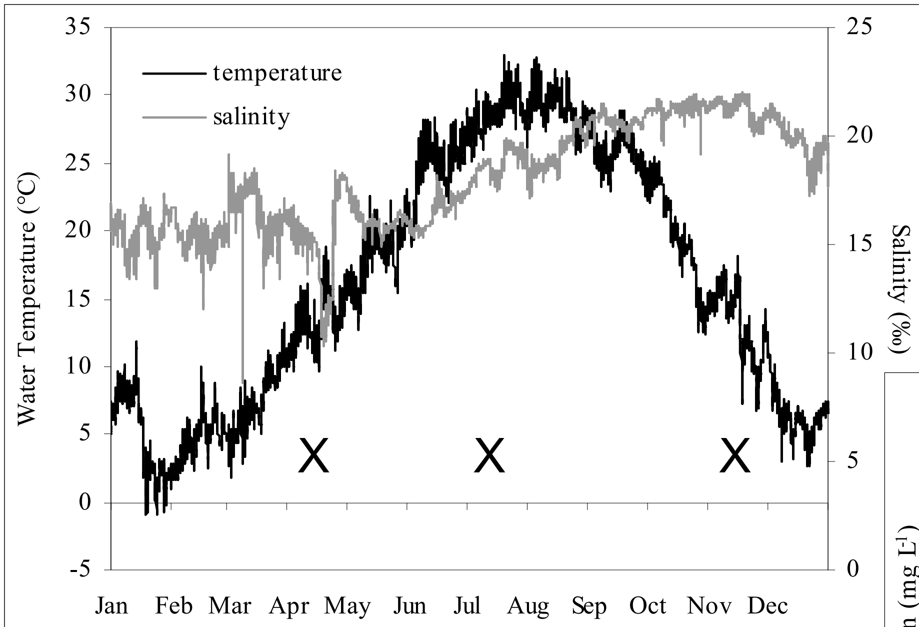
Stable Isotope Primer…

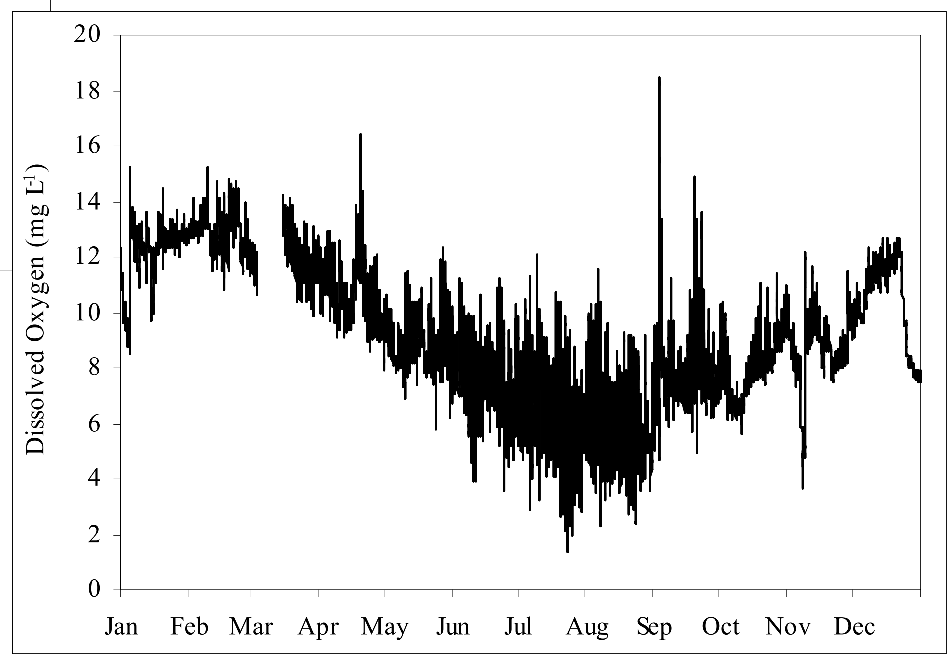




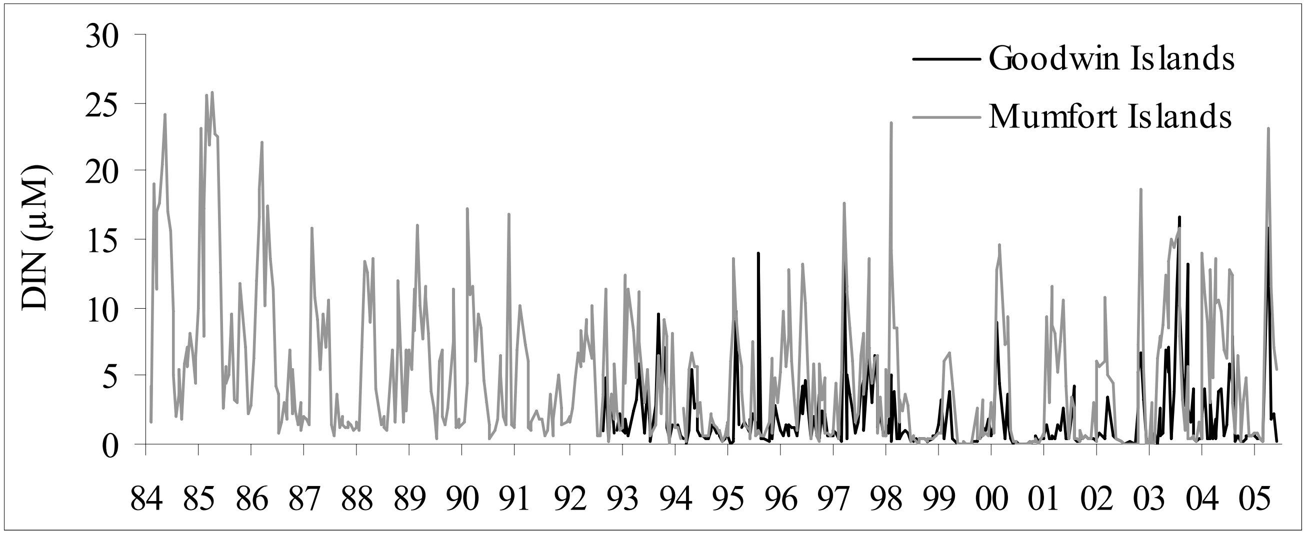
- Isotopes of an element react at different rates due to the slight difference in their atomic masses
  - same number of protons and electrons, so they are chemically identical, but contain different numbers of neutrons

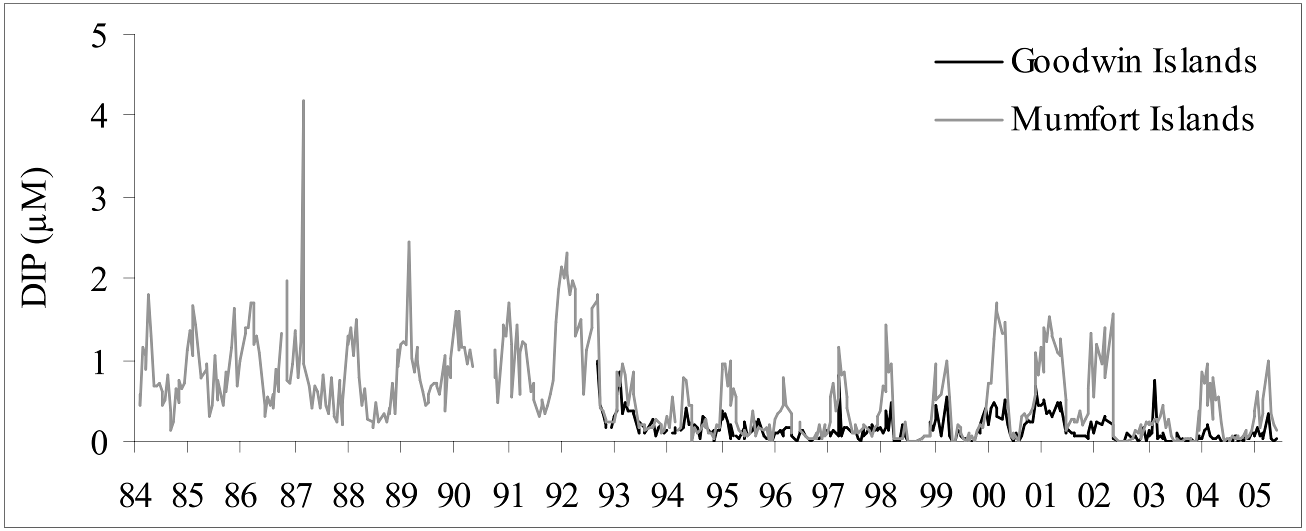
CBNERRS Long-term Data



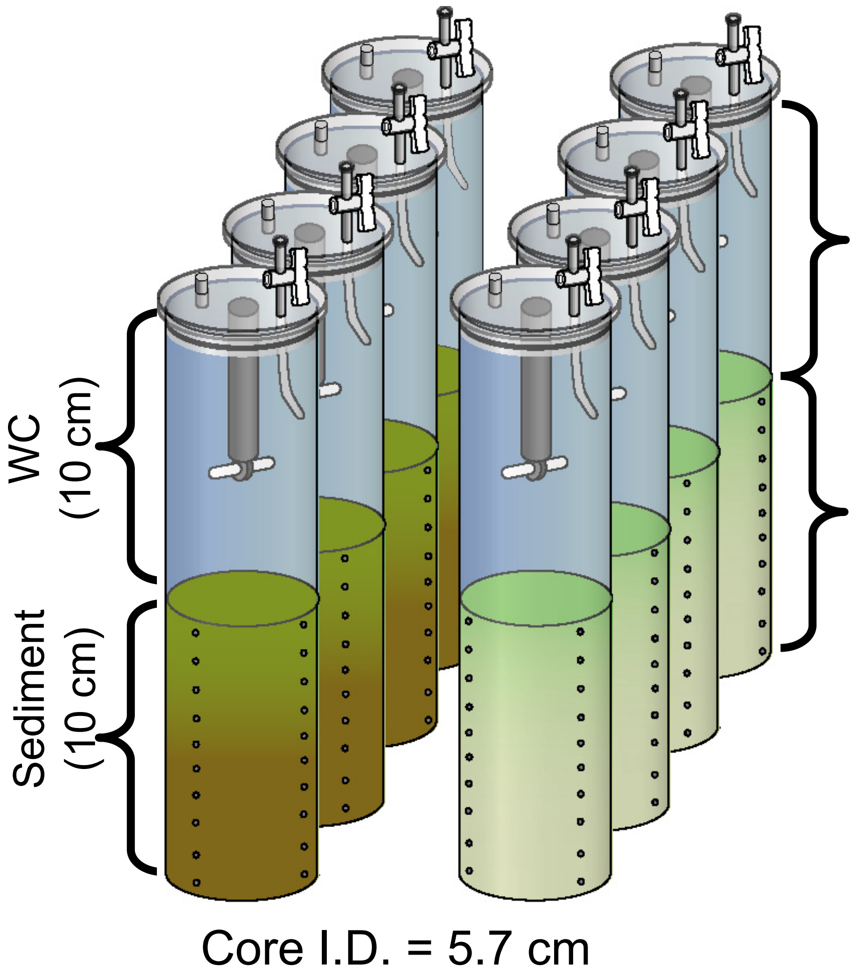


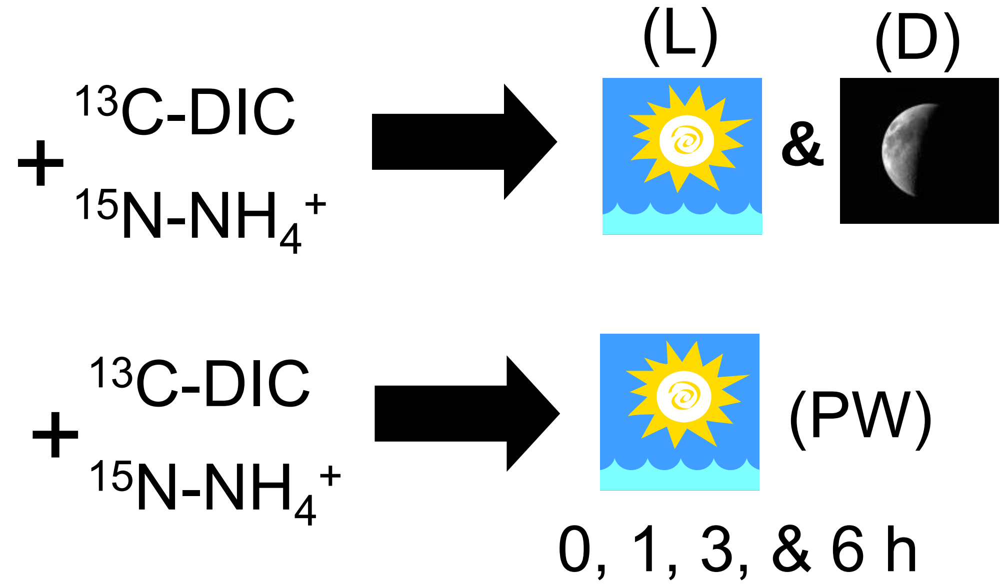
CBNERRS Long-term Data





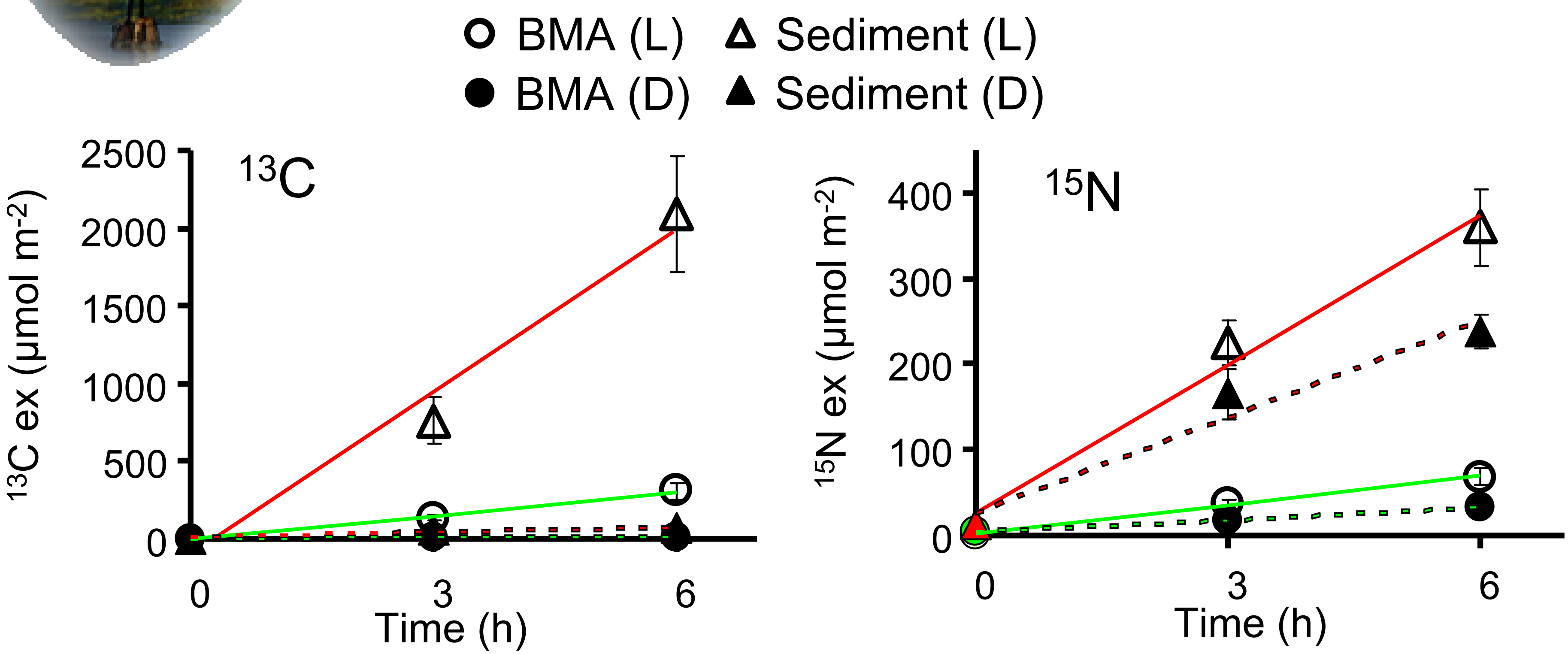
Incubation Experiments





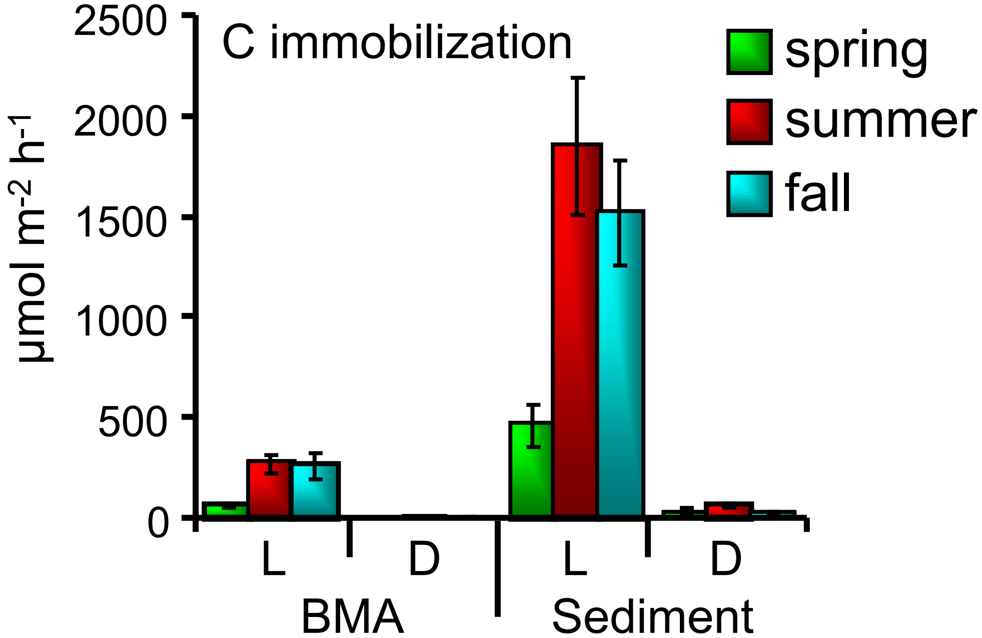
- C & N immobilization rates by sediments & BMA determined from time-series of isotopic enrichments

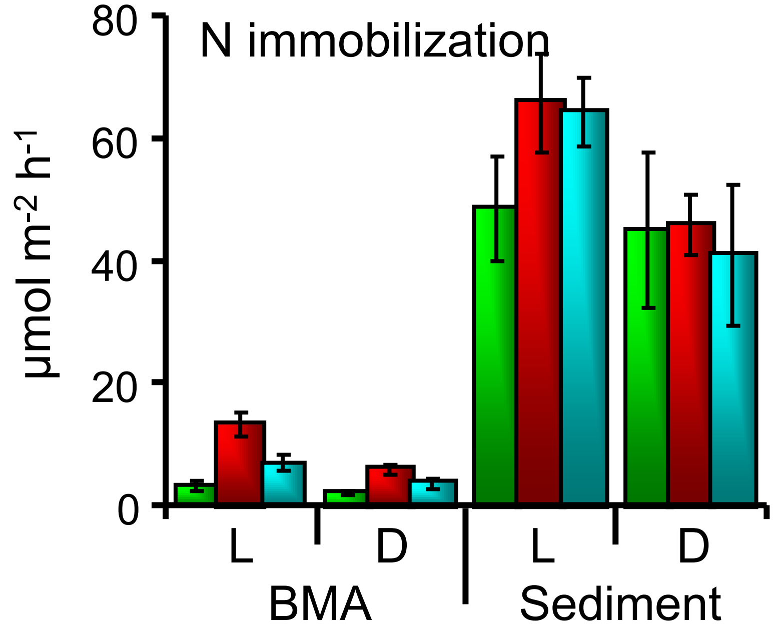
^{13}C & ^{15}N WC Immobilization



- ***Light:*** ^{13}C & ^{15}N immobilization by BMA & Sediments was linear
- ***Dark:*** ^{15}N immobilization was linear, however ^{13}C uptake was close to zero in both bulk sediment & BMA pools

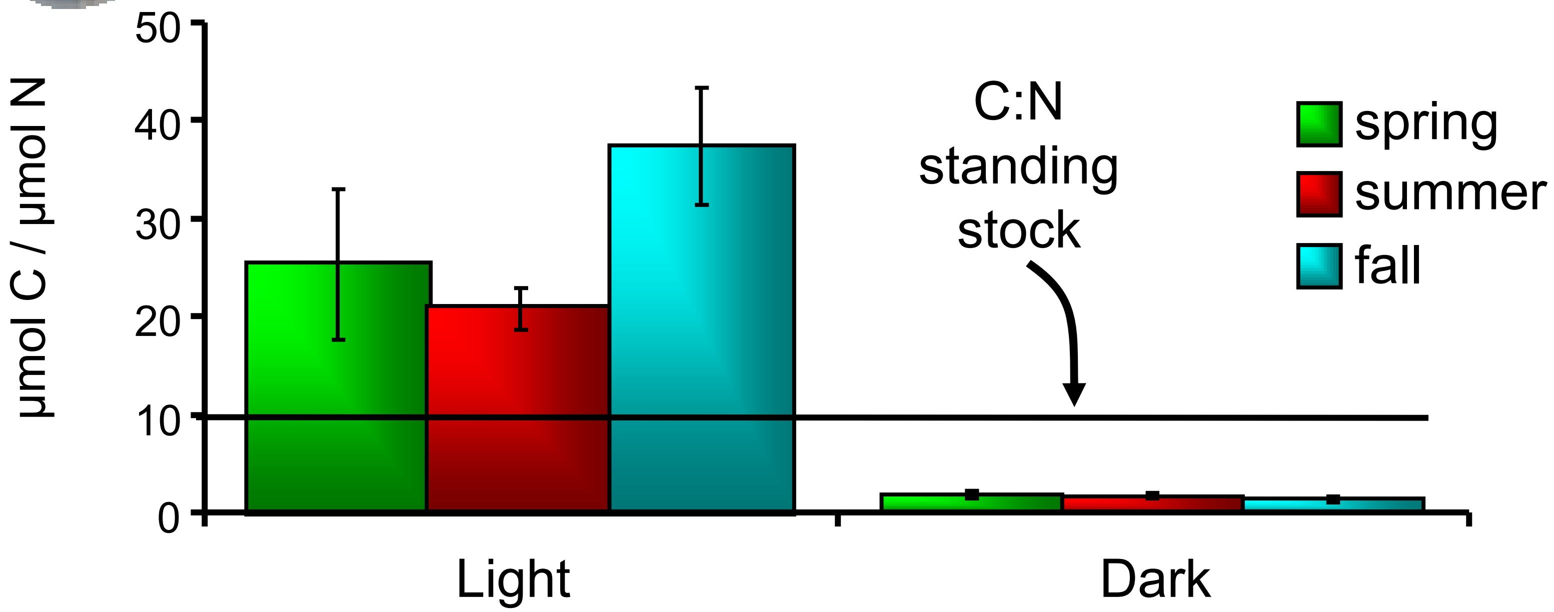
Light vs. Dark Immobilization





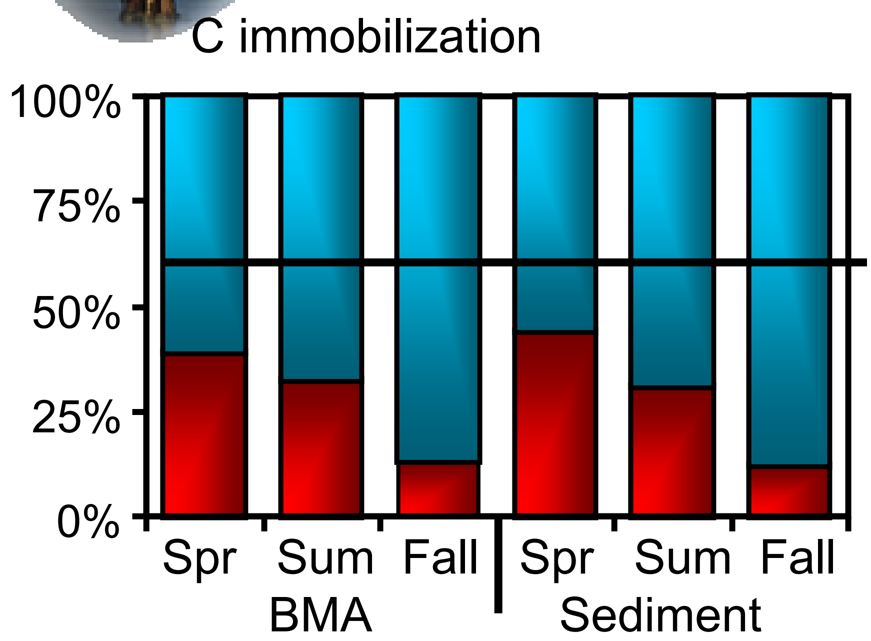
- C incorporation into bulk sediment OM must pass through BMA
  - Indicates BMA are releasing a large fraction (70 - 80 %) of fixed C
- Dark immobilization of N by BMA was approximately half the rate in the light
- Sediment N uptake >> BMA N

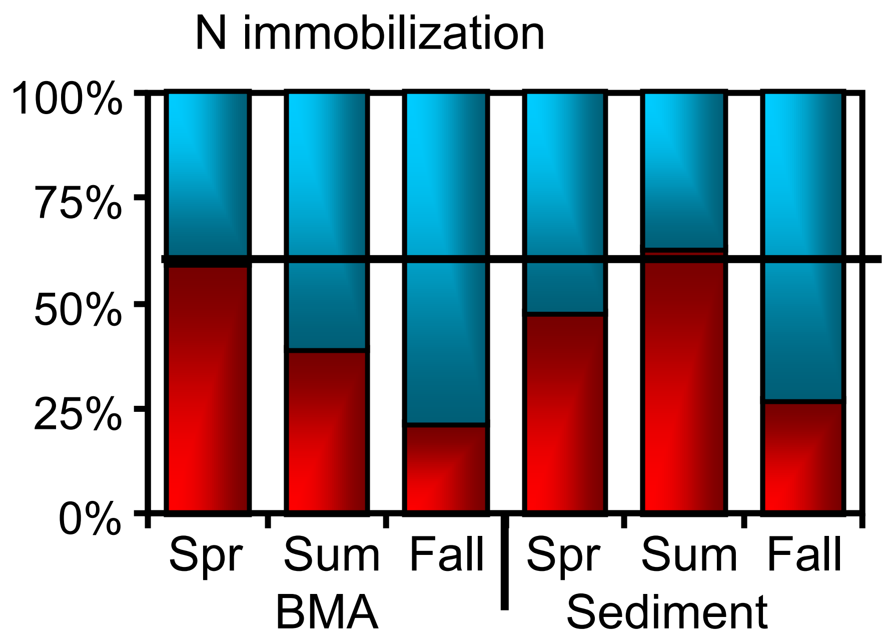
BMA C:N Immobilization



- BMA C:N standing stock ≈ 10
- Average daily BMA C:N immobilization rate was 16:1
- Bulk sediment C:N = 8

WC vs. PW Immobilization

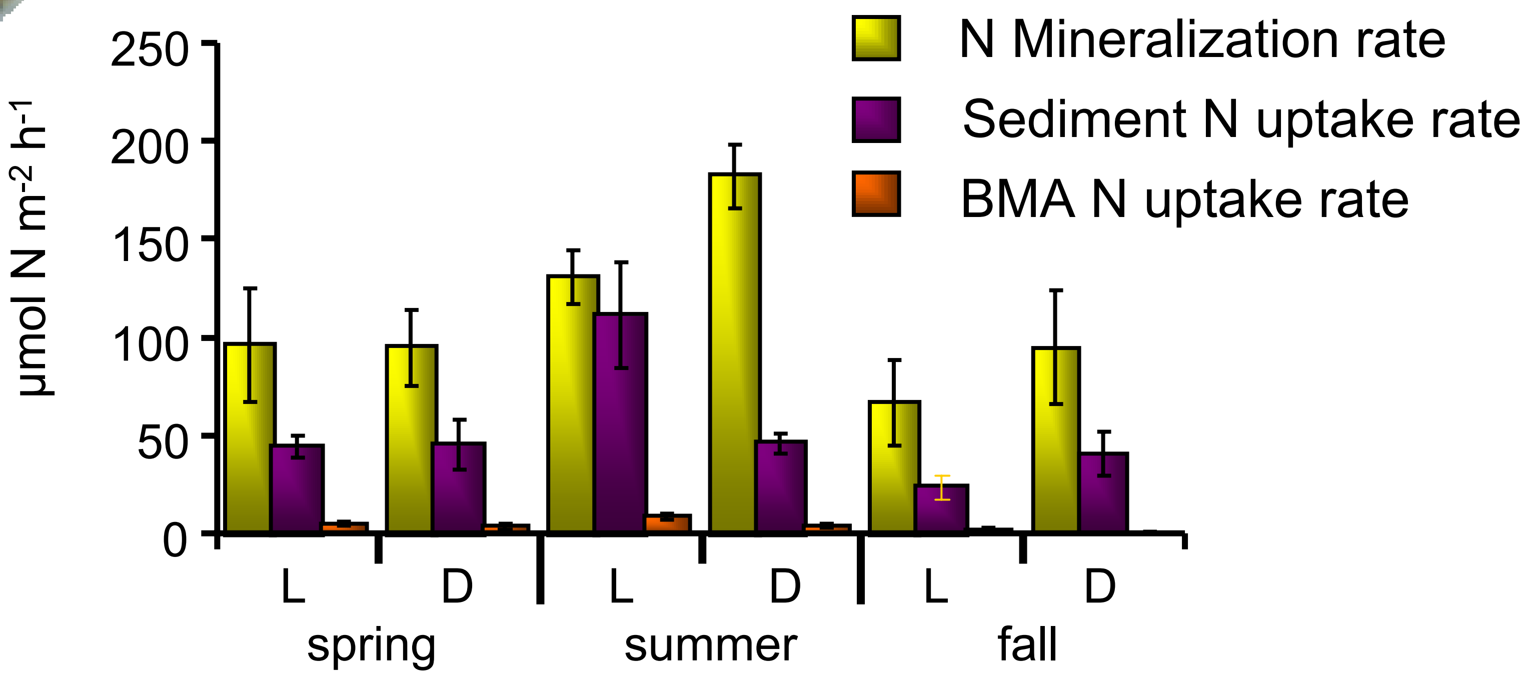




Water column   Porewater

- BMA & bulk sediments have a greater affinity for WC DIC than PW DIC in all seasons (~70 % from the WC)
- For NH_4^+, uptake between WC & PW sources varied greatly between seasons

Mineralization vs. Immobilization



- Previous work suggests that BMA N demand estimated from GPP accounts for a large percentage of N mineralization
- BMA N immobilization rate = 3.8 ± 1.3 % of MIN rate
- Sediment N immobilization rate = 42 ± 11 % of MIN rate

Summary

1. Euphotic sediment microbes are an important link in estuarine benthic-pelagic coupling

2. BMA play a critical role in supporting the euphotic sediment microbial loop

    - BMA fix excess C, most of which originates from the water column
    - The excess organic C is rapidly metabolized by sediment bacteria
    - Sediment bacteria require additional sources of inorganic N in order to build biomass

3. Benthic bacteria are the dominant microbial pool for C & N immobilization into biomass

Acknowledgements

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William & Mary VIMS Virginia Institute of Marine Science School of Marine Science

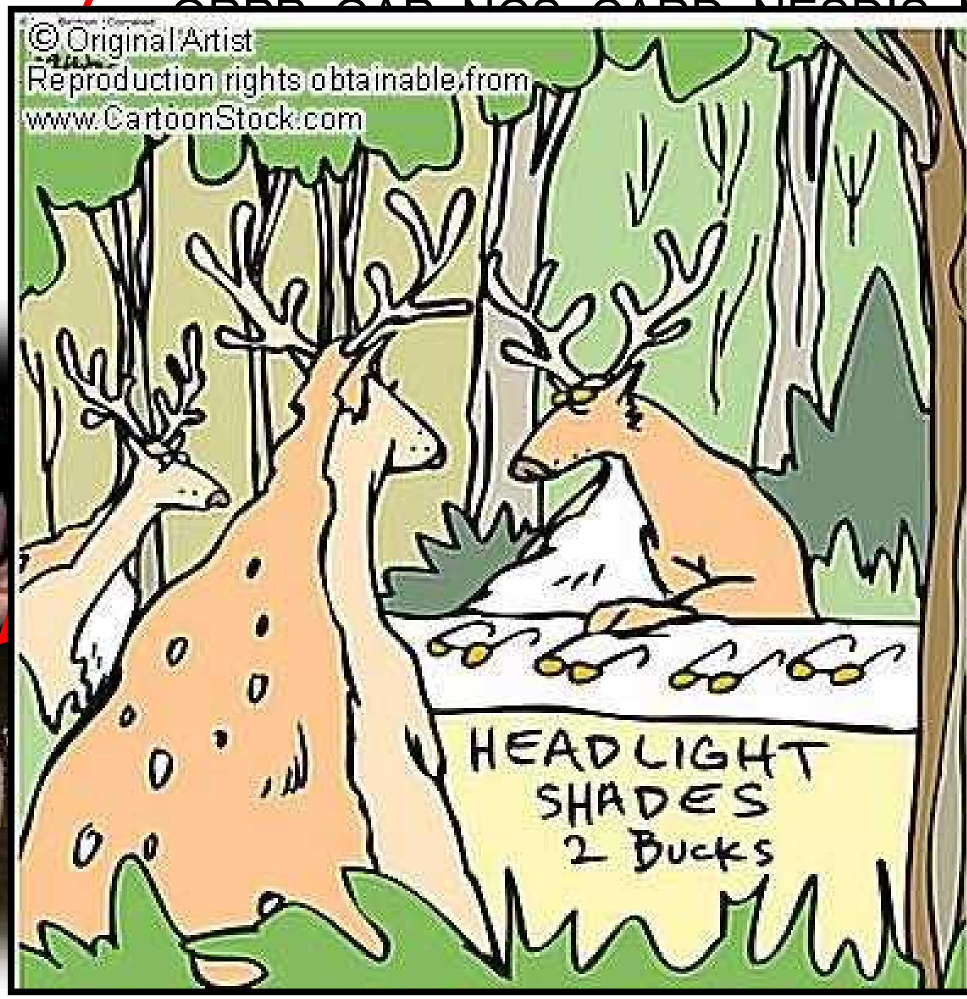
SERDP Strategic Environmental Research and Development Program

Knauss: In the beginning…

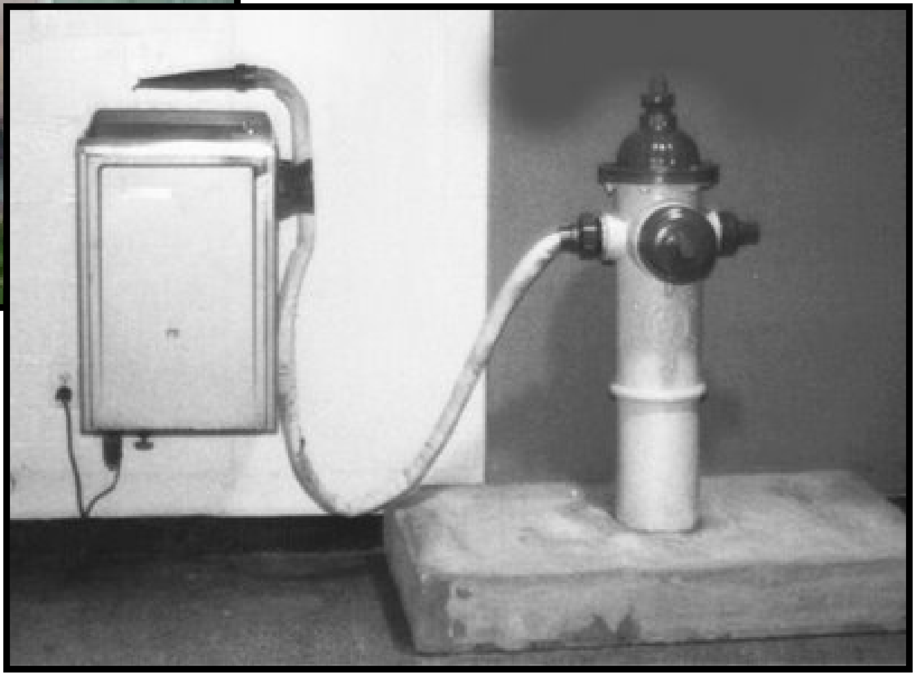
PPE, NOC, NEC, NEP, ICOSRMI, STIP, OSTP, NRC, ORPP, OAP, NCS, CARD, NESDIS, NOPP, IWG-OP, IWG-GOO, IOOS, PPI, PPBES, NWS, NOS, CRCP, CRW, NERRS, NMSP, NMFS, NMSF, SAB, OEAWG, NFWF, DOI, EPA, POTUS, FLOTUS, HOB, OMB, CPO, PCO, OER, NURP, OE, OkE, NASA, ESRL, AOML, PMEL, NSSL, GFDL, GLERL, GMD, PSD, LMNOP, VADM DUS, AA, DAA, CFO, CIO, PA, IA, DOE, DoD, DOC, OGC, IG, NSF, POES, GOES-R, GCOS, GOESS, MPA, NEOS, NGDC, NGO, NCDDC, IPA, JHT, JSOST, GUIRR, GAO, WRF, HAB, PATT, OHRM, RISA, PRC, PDM, PA&E, CSCOR, MOD, POP, SPA, IEA, TAO, WFO, UCAR, UAS, …ABCDEFGHIJ…

Knauss: In the beginning…

PPE, NOC, NEC, NEP, ICOSRMI, STIP, OSTP, NRC,
NOPP, IWG-OP,
S, NOS, CRCP,
, SAB, OEAWG,
S, HOB, OMB,
NASA, ESRL,
L, GMD, PSD,
D, CIO, PA, IA,
DES, GOES-R,
, NGO, NCDDC,
RF, HAB, PATT,
COR, MOD, POP,
R, UAS,



Drink up!



Tranquility Realized…

- Platte River: "It's a mile wide and an inch deep."

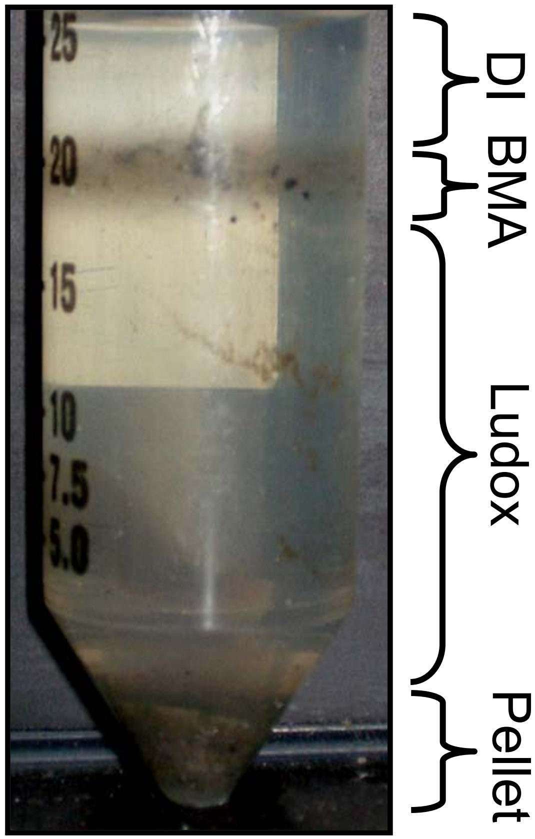
Questions?

BACK-UP SLIDES

- BACK-UPS

Benthic Microalgal Elutriation

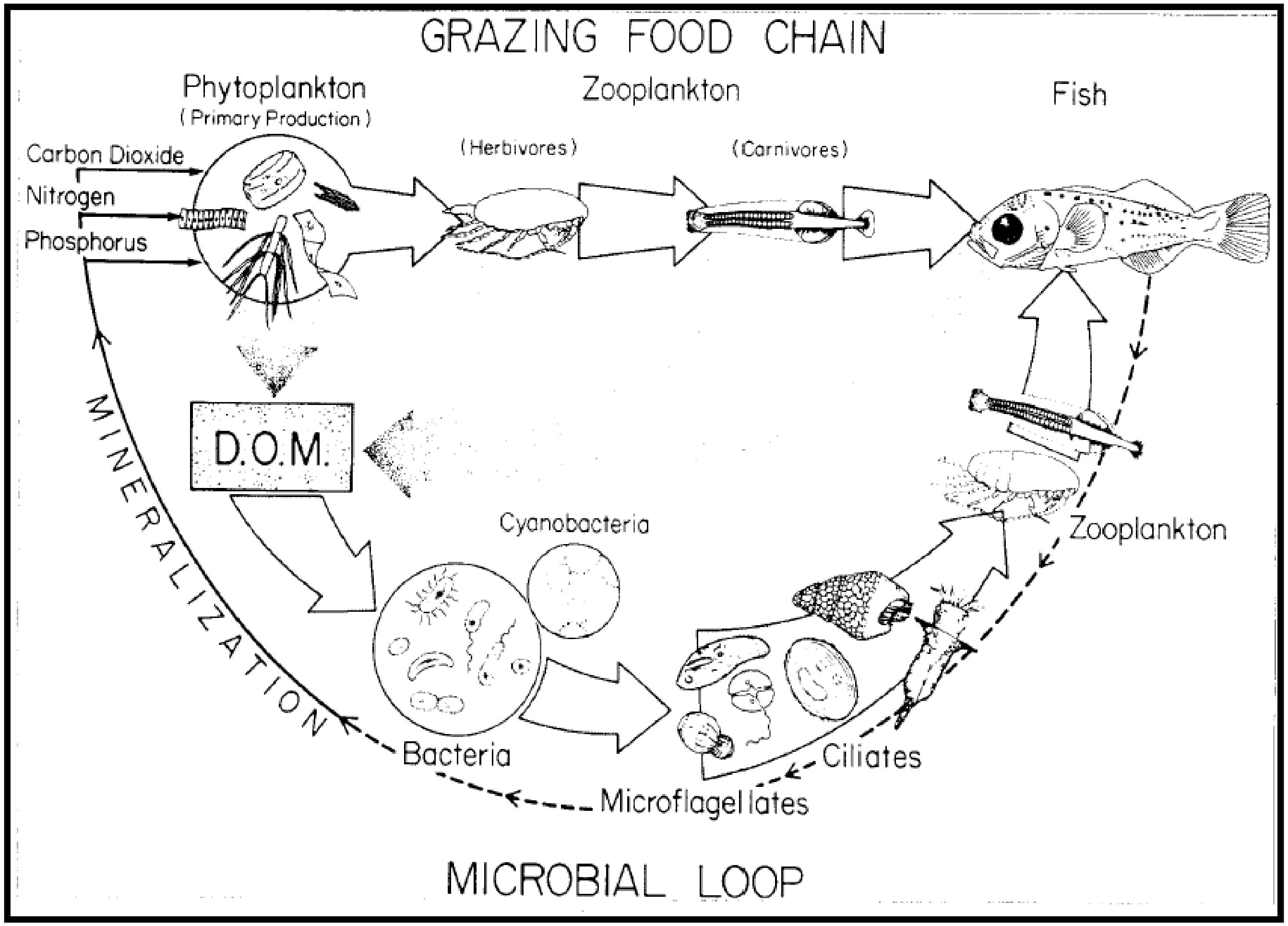
0.6 mL surface sediment
↓
20 mL Silica gel Ludox HS 40 (1.3 g cm^{-3})
↓
Vortex (1 min); add 5 mL DI water
↓
Centrifuge 15 min, 4500 rpm
↓
Decant liquid phase through Nitex (63 µm)
↓
AH filter (1.5 µm, 47 mm) → dry & acidify → Mass spec ($^{12:13}C$ & $^{14:15}N$)



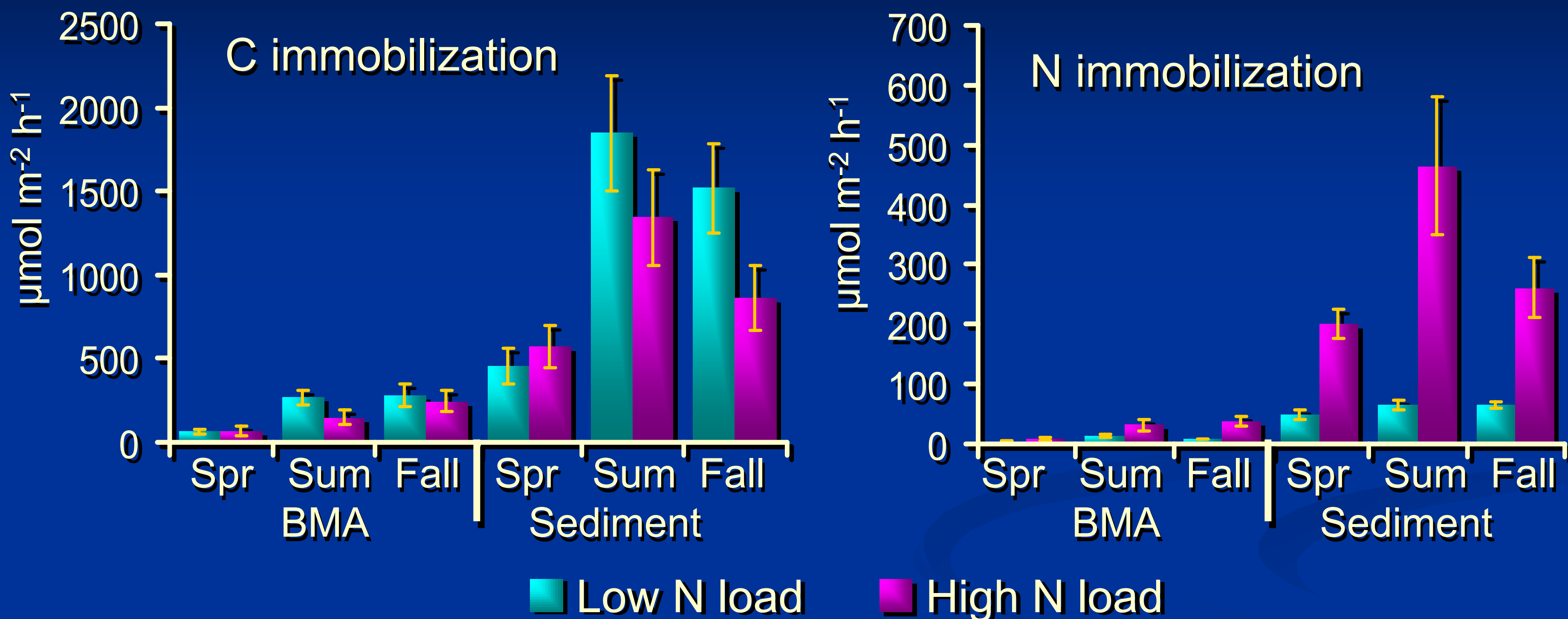
- BMA C : benthic chl-*a* = 35 ± 11
  - de Jonge (1980) reported ratios of 40 – 60
  - Sundbäck *et al* (2000) reported ratios from 18 – 40
  - de Jonge (1979) recovered 83 % of benthic chl-*a* in elutriated samples
- BMA C:N = 10.1 ± 2.2
- Sediment OM content < 2.5 %

de Jonge (1979), Blanchard et al. (1990)

Grazing & Microbial Loop



Low vs. High Water Column N Load



- Increased N load did not increase C immobilization
- Increased N load did increase N immobilization