Effects of benthic community shifts on nitrogen recycling in the hypoxic waters of Chesapeake Bay

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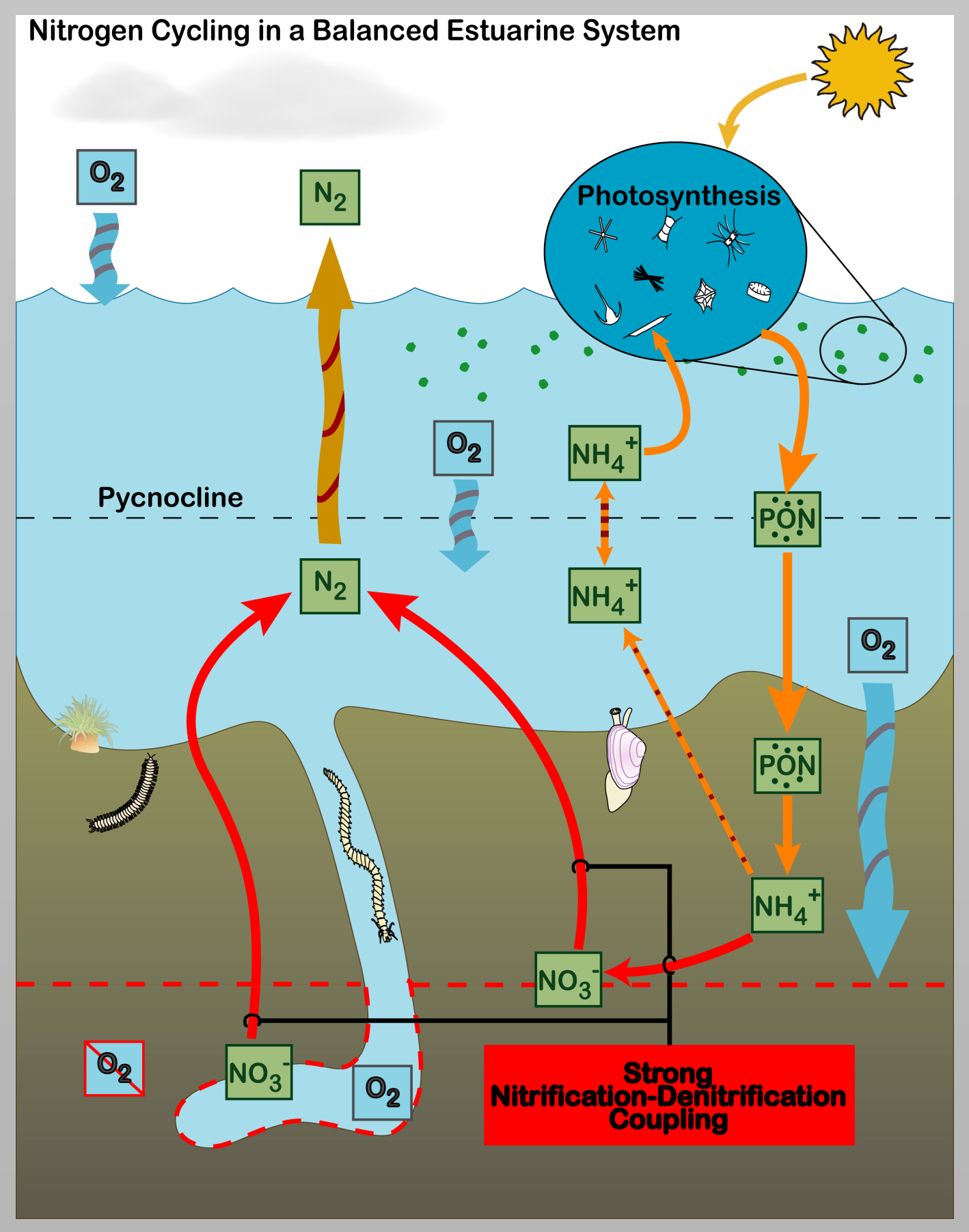
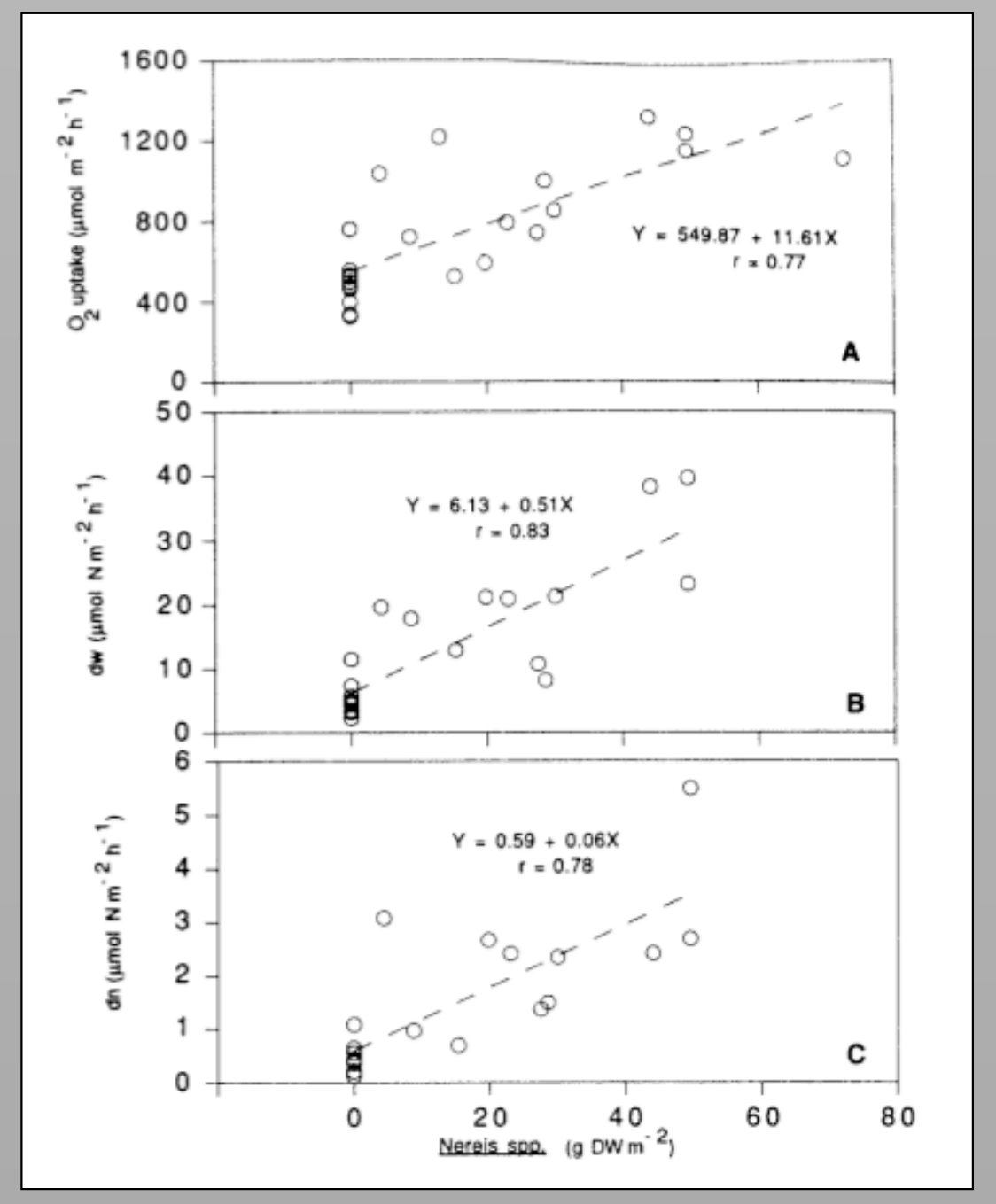
I. Macrofaunal Role in Nitrogen cycling

- In estuaries, nitrogen is a limiting nutrient in phytoplankton production

- The processes of nitrification and denitrification in bottom sediments play an important role in the recycling and mineralization of nitrogen in an aquatic system.

- Macro faunal irrigation increases the rate of nitrogen cycling by increasing the volume of sediment exposed to oxygen in turn facilitating bacterial driven nitrification-denitrification coupling.





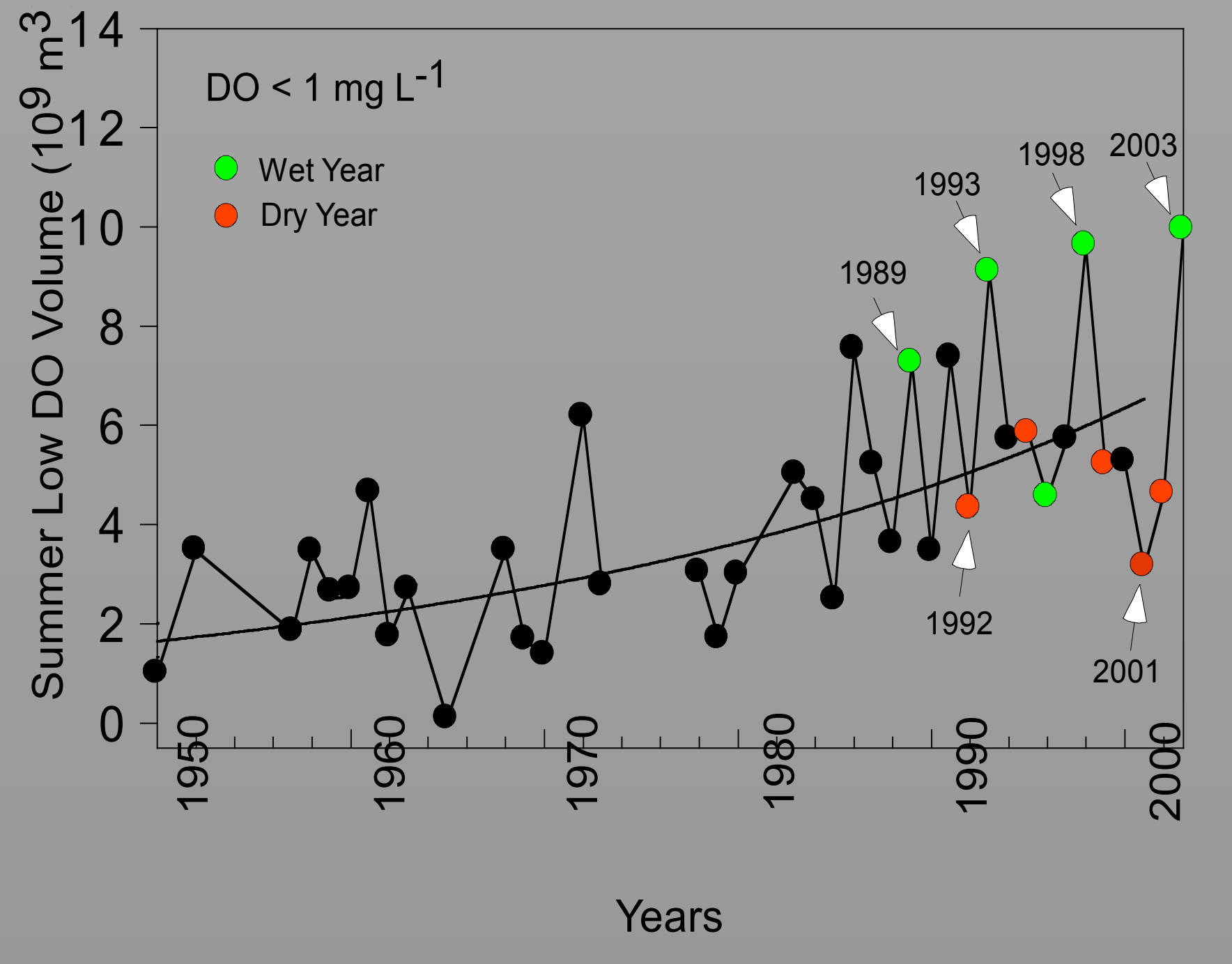
Pelegri and Blackburn (1995)

- Greater biomass of burrowing macro fauna like *Nereis* spp. leads to higher denitrification rates of both water and sediment derived nitrate. (see left figure)

- Here we examine the possible role of benthic macro fauna in nutrient (specifically nitrogen) cycling in Chesapeake Bay, a highly eutrophic system with seasonal hypoxia.

II. History of Chesapeake Bay Hypoxia

- Recent analyses suggest that hypoxia has increased in the bay over the last 50 years



- This increase is clear, despite the strong effect of interannual variations in river flow on hypoxia (Hagy et al. 2004)

III. What are the effects of hypoxia on a benthic community?

- In a balanced estuarine system a stable, mature benthic faunal community undergoes annual variation. However few species are conditioned to withstand extended periods of low dissolved oxygen.

- As a system experiences periodic hypoxic events, low oxygen stress eliminates the larger and more long-lived equilibrium species.

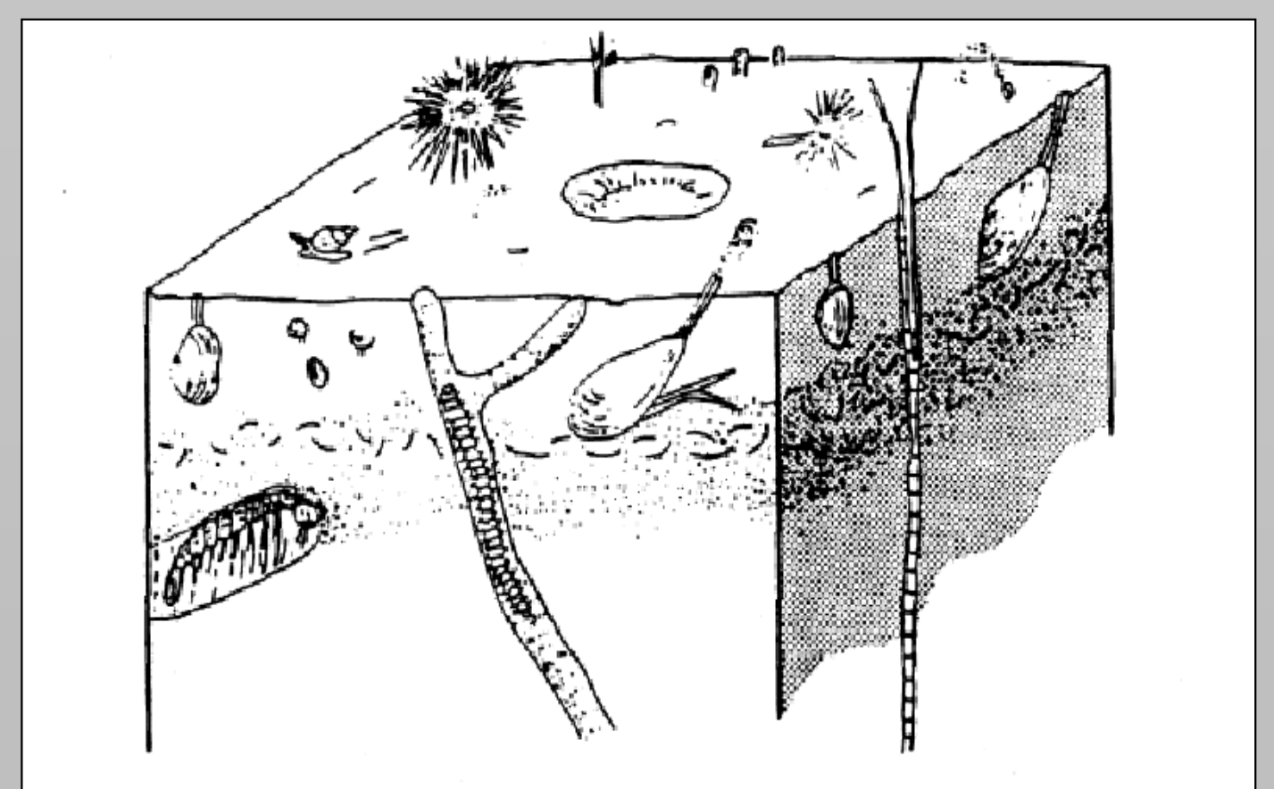
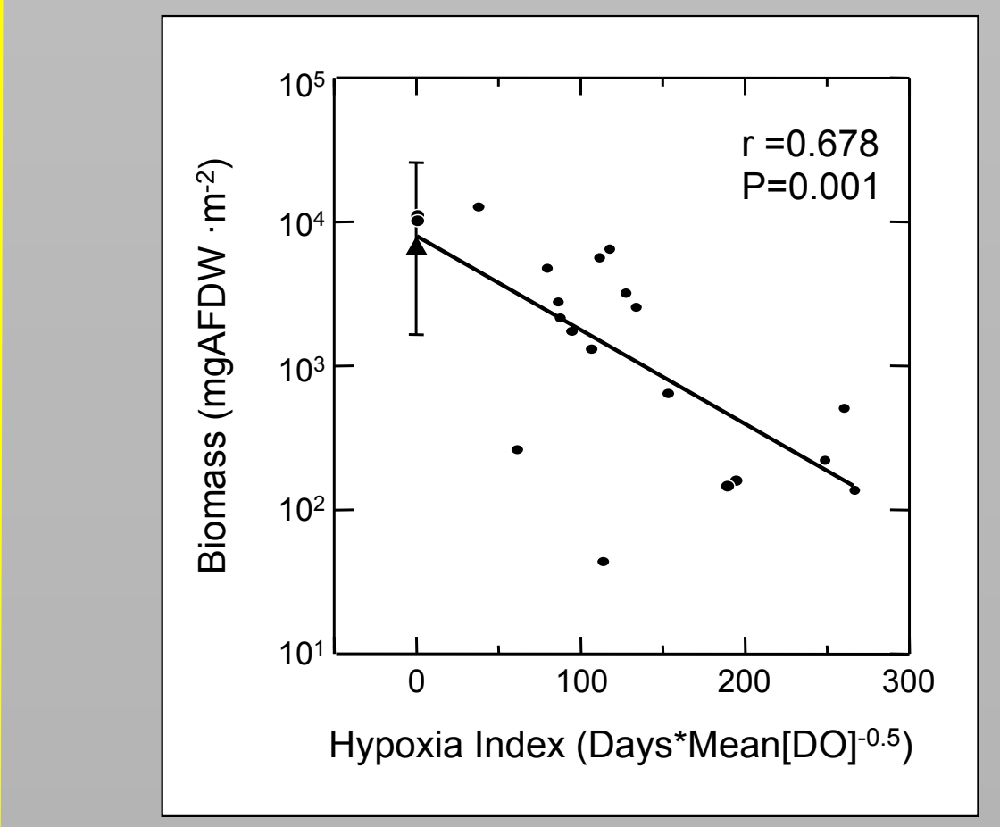


Figure 3.5a Schematic representation of major burrowing fauna from a sediment locality in Long Island Sound indicating the degree to which animals can alter the sediment structure (from Aller 1980, Berner 1980).



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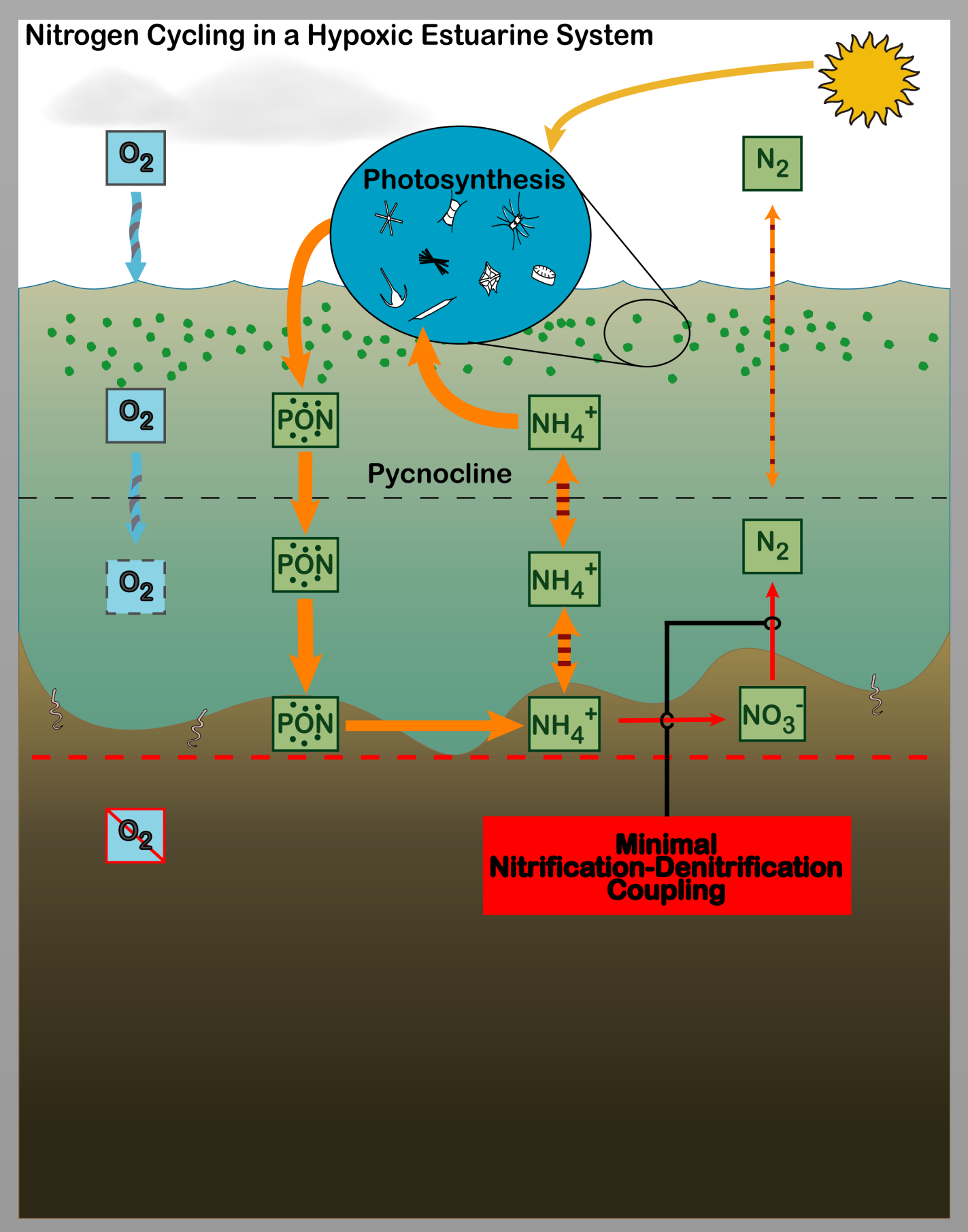
- A hypoxic tolerant community develops consisting of smaller, shorter-lived, opportunistic species; however, overall biomass of macro fauna decreases (see left figure).

IV. What are the impacts of an altered benthic community on nutrient recycling?



- Eutrophic surface water leads to large phytoplankton blooms that contribute a large quantity of particulate organic nitrogen (PON) that sinks to the bottom.

- This PON is decomposed to ammonia through bacterial respiration.

- That respiration consumes much of the oxygen in the surrounding water creating hypoxic conditions.

- Without bioturbating and tube dwelling macro fauna the volume of reduced sediment exposed to oxygen is minimal resulting in minimal nitrification and denitrification.

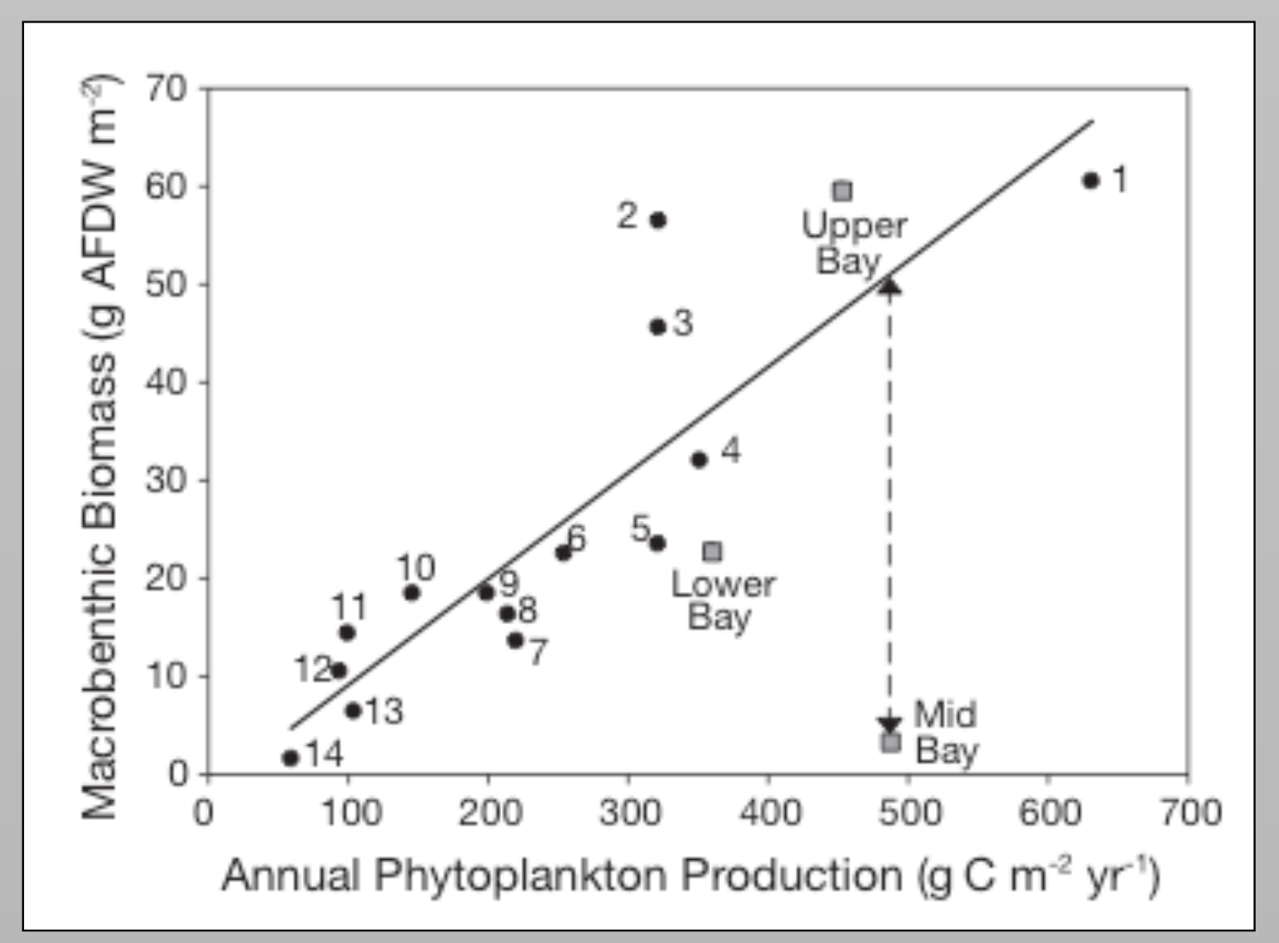
- Consequently, ammonia diffuses back into the water column fueling more algal production in the surface water.

V. Hypothesis: Loss of benthic macro fauna leads to a significant increase in bottom respiration.

- Data presented by Hagy (2002) suggest a hypoxia-driven deficiency of ~ 45g AFDW m^{-2} of macro benthic biomass with respect to annual phytoplankton production for the Mid Bay region (see right figure).

- Based on the work of Pelegri and Blackburn (1995) this amount of biomass would result in a denitrification loss of ~ 30 µmol N m^{-2} h^{-1}.

- This loss of denitrification would result in an increase of 57.0 mg C m^{-2} d^{-1} that could be produced from the nitrogen that was not denitrified due to the lack of macro fauna in hypoxic sediments.



Kemp et al (2005)

- Assuming the seasonal nature of hypoxia in the Chesapeake and a respiratory quotient of 1, the resulting increase in bottom respiration is calculated to be 0.61 g O m^{-2} d^{-1} .

- Assuming the average bottom respiration for an estuary is ~ 2 O g m^{-2} d^{-1} , the loss of benthic macro fauna to a system leads to ~ 30% increase in daily bottom respiration.

VI. Initial Questions

- What are the spatial and temporal shifts in the benthic community over the last 30 years with respect to increased hypoxia?

- What are the dominant species of deposit and suspension feeders lost from this Mid Bay region?

- What is the role of these dominant species in denitrification and other nutrient cycling processes?

- What is the calculated bottom respiration with and without these dominant species in the environment?

VII. References

Hagy, J.D. (2002) *Eutrophication, hypoxia and trophic transfer efficiency in Chesapeake Bay*. PH.D. Dissertation, University of Maryland at College Park, College Park, Maryland.

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Pelegri, S.P., and T.H. Blackburn (1995) *Effect of Bioturbation by Nereis sp., Mya Arenaria and Cerastodermsp. on Nitrification and Denitrification in Estruarine Sediments.* OPHELIA 42:289-299.