The influence of eastern oysters on ecological processes in Chesapeake Bay: Insights from modeling studies.

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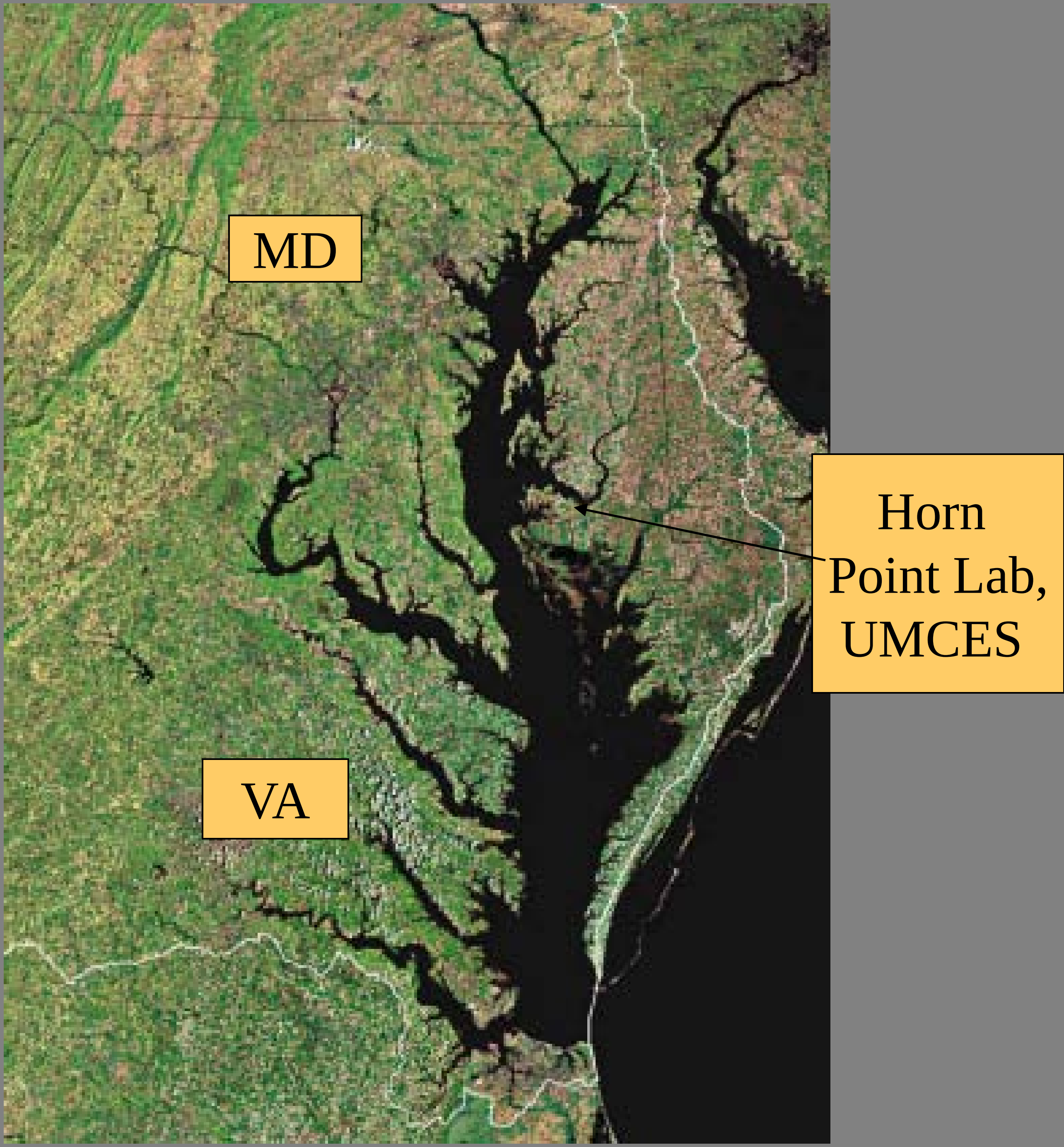
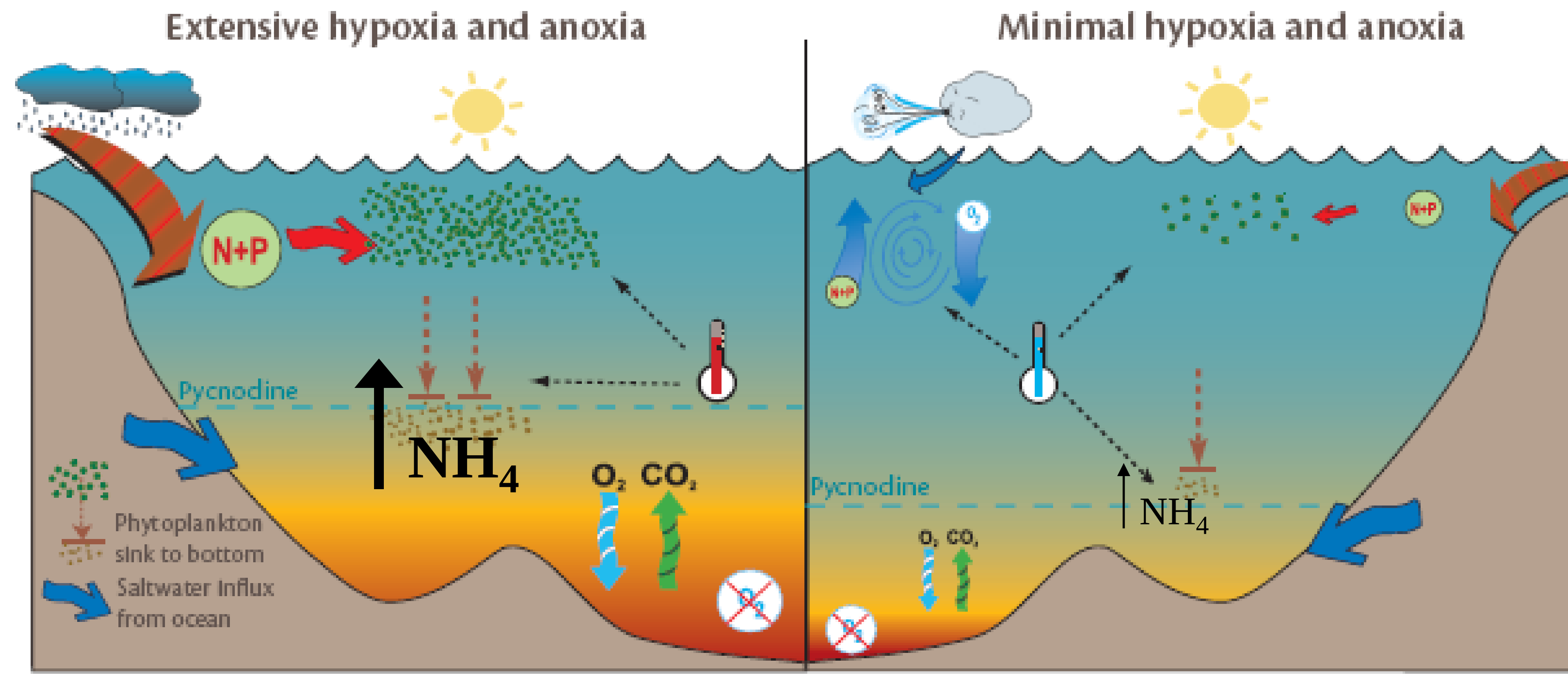
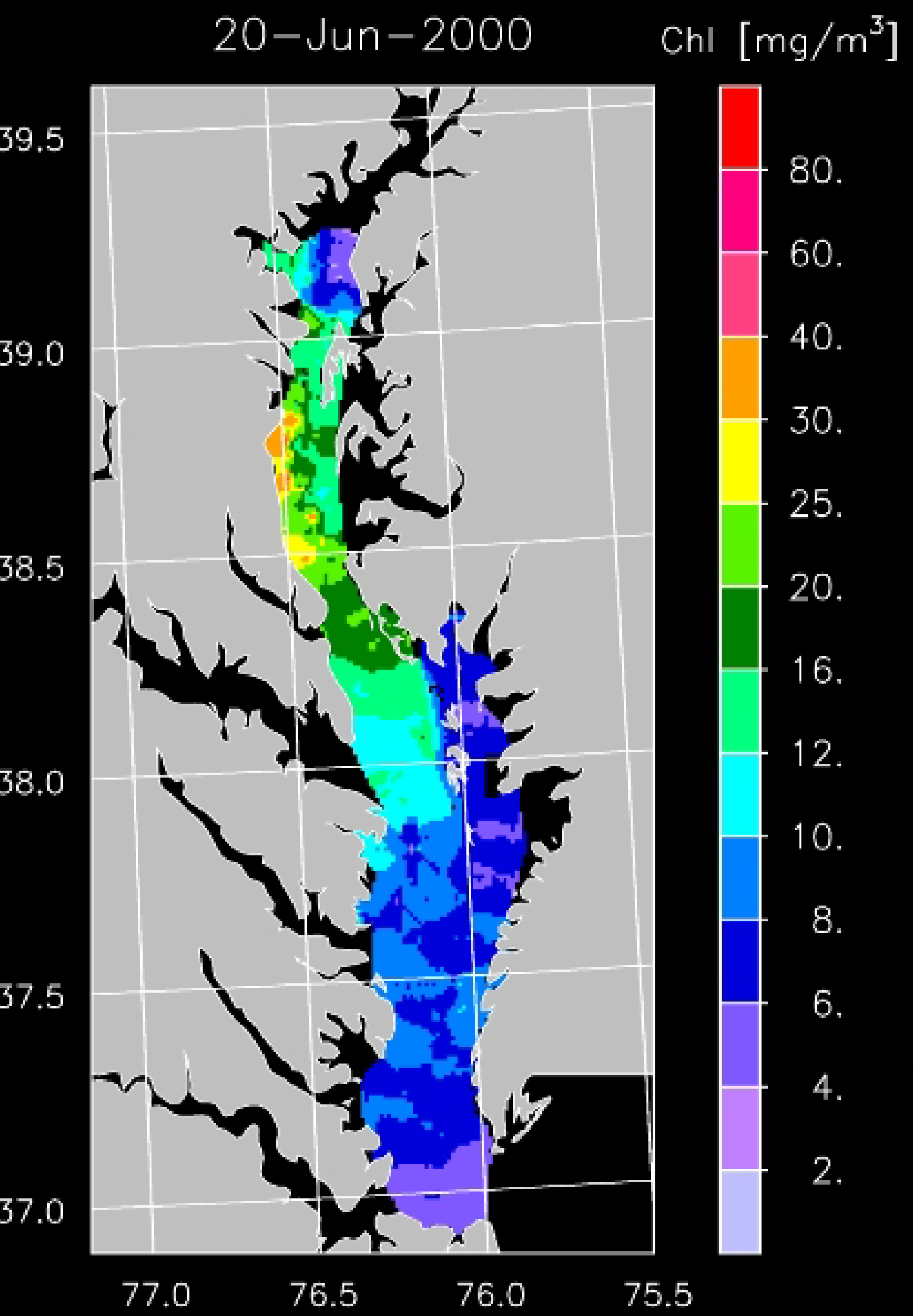
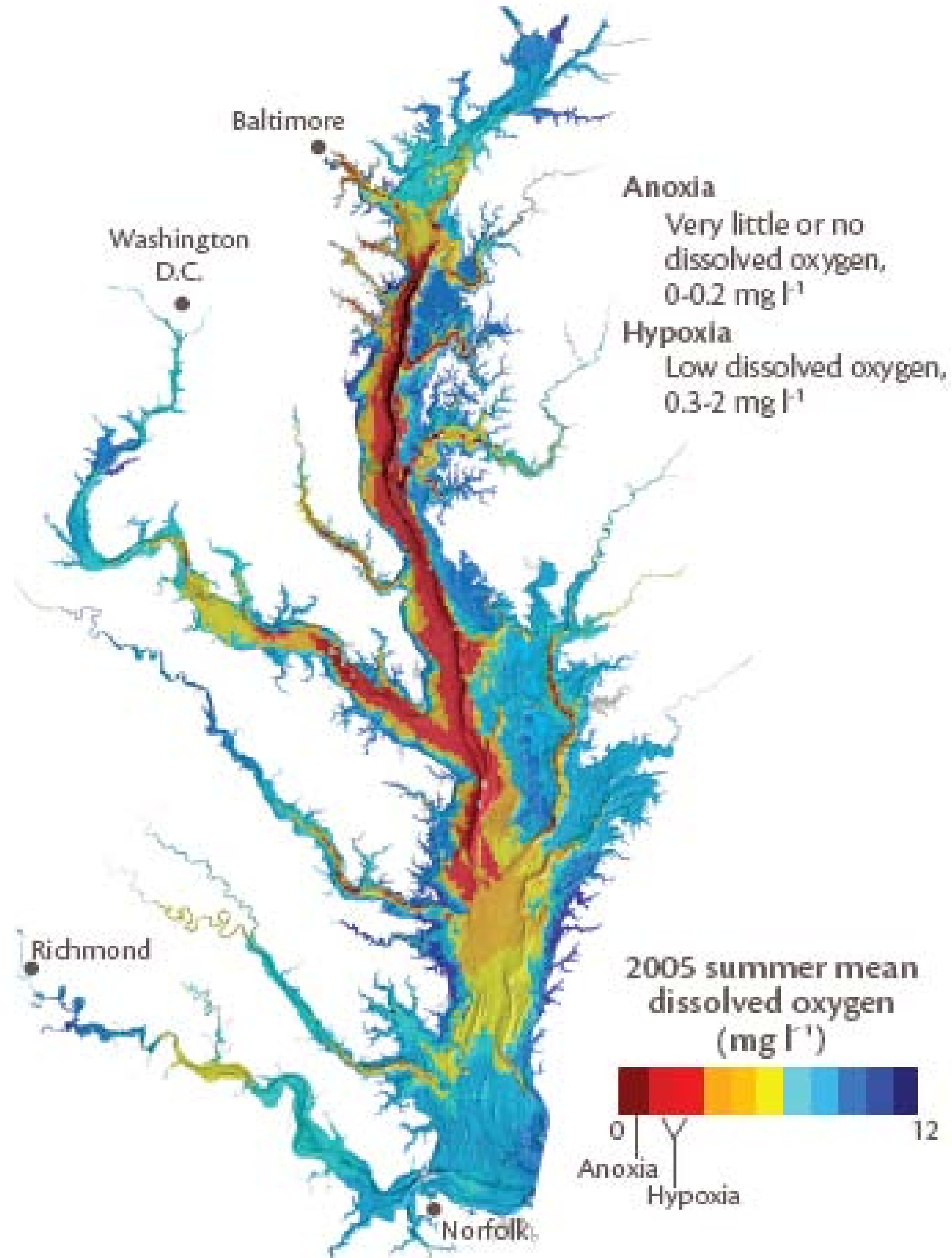
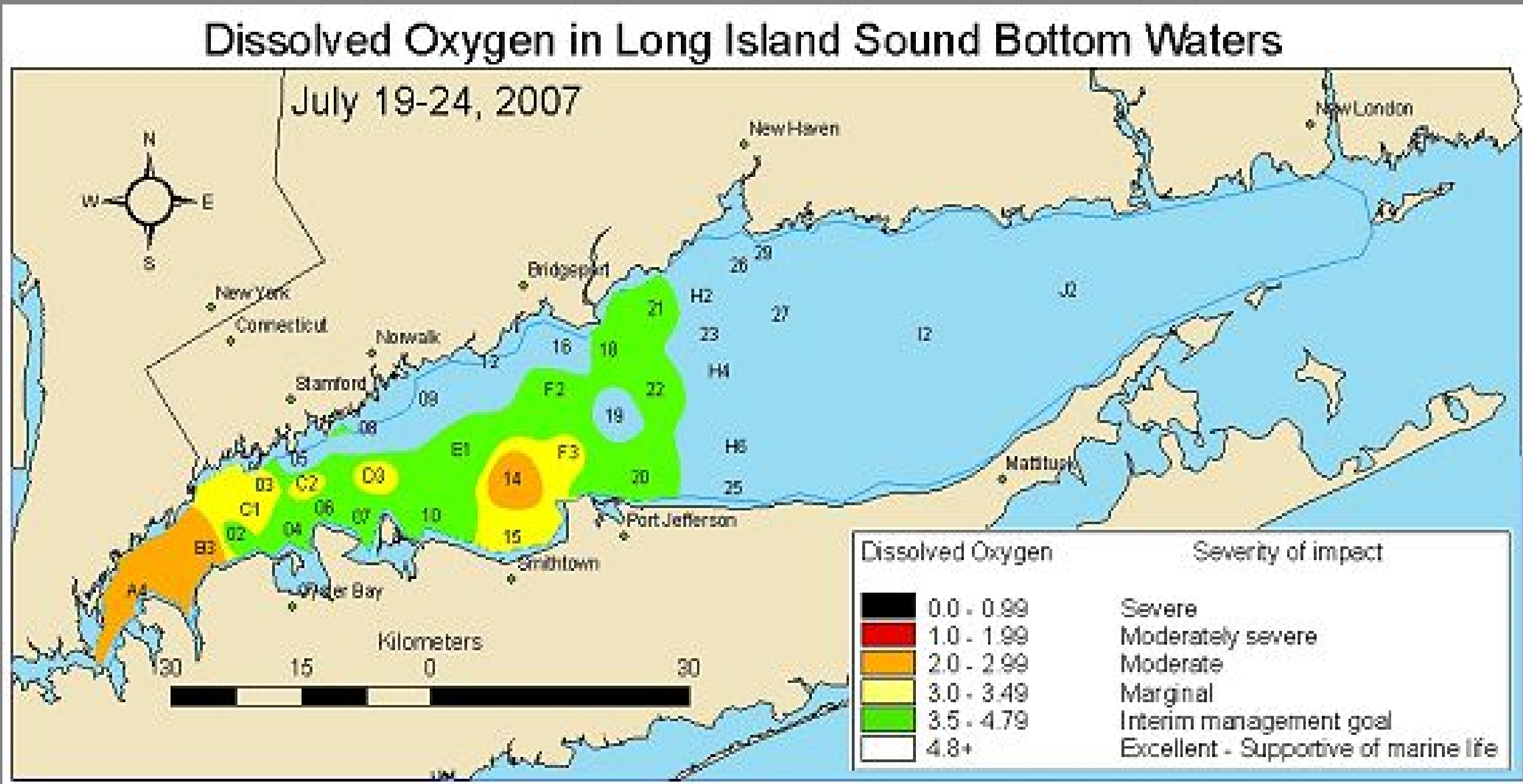
Satellite image of Chesapeake Bay shows a portion of its watershed from which increasing nutrient inputs are delivered. (USGS, www.chesapeakebay.net)




Extensive hypoxia and anoxia
Minimal hypoxia and anoxia
N+P
Pycnocline
NH4
O2 CO2
Phytoplankton sink to bottom
Saltwater influx from ocean
N+P
O2
Pycnocline
NH4
O2 CO2
N+P

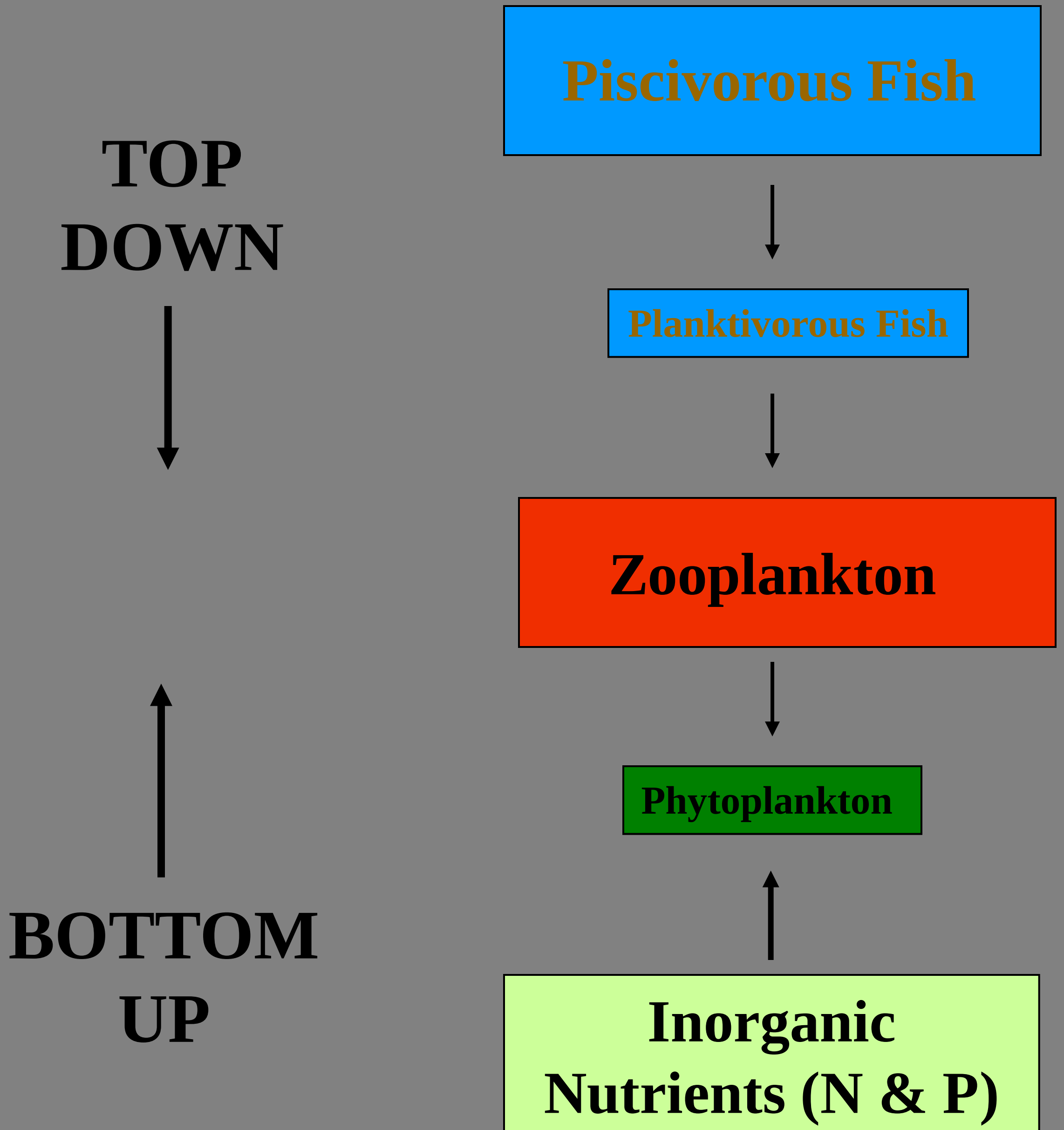

20–Jun–2000
Chl [mg/m^3]
80.
60.
40.
30.
25.
20.
16.
12.
10.
8.
6.
4.
2.
39.5
39.0
38.5
38.0
37.5
37.0
77.0
76.5
76.0
75.5


Baltimore
Washington D.C.
Richmond
Norfolk
Anoxia
Very little or no dissolved oxygen, 0-0.2 mg l^{-1}
Hypoxia
Low dissolved oxygen, 0.3-2 mg l^{-1}
2005 summer mean dissolved oxygen (mg l^{-1})
0
12
Anoxia
Hypoxia

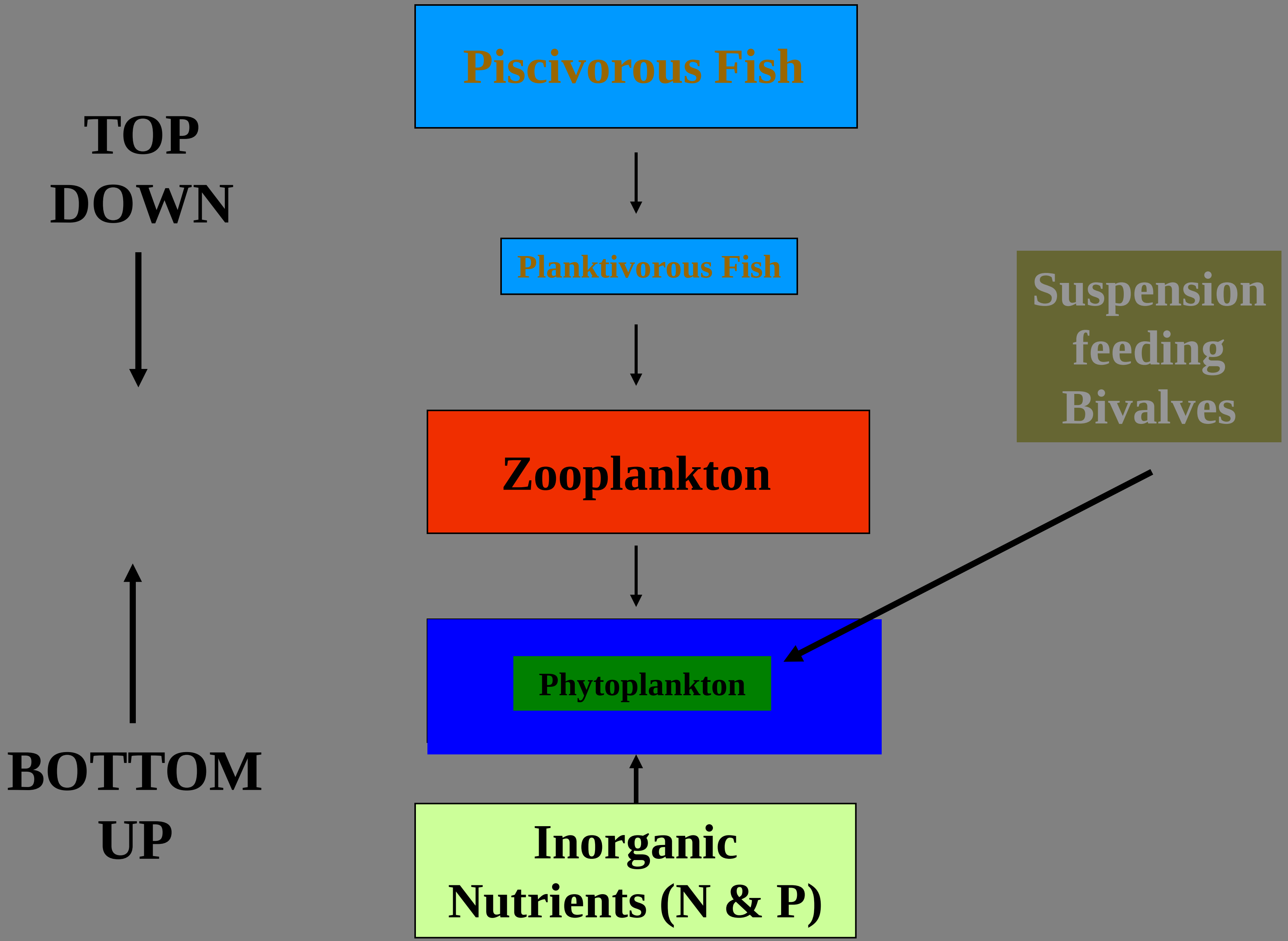


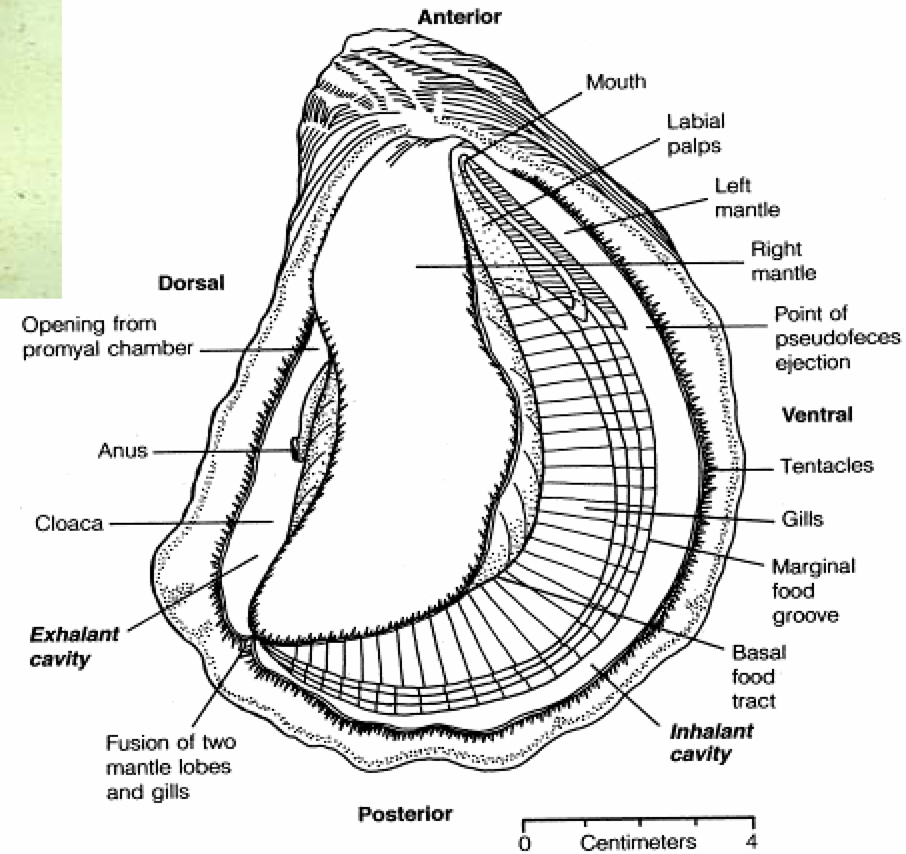
www.longislandsoundstudy.net

Trophic Cascade Hypothesis

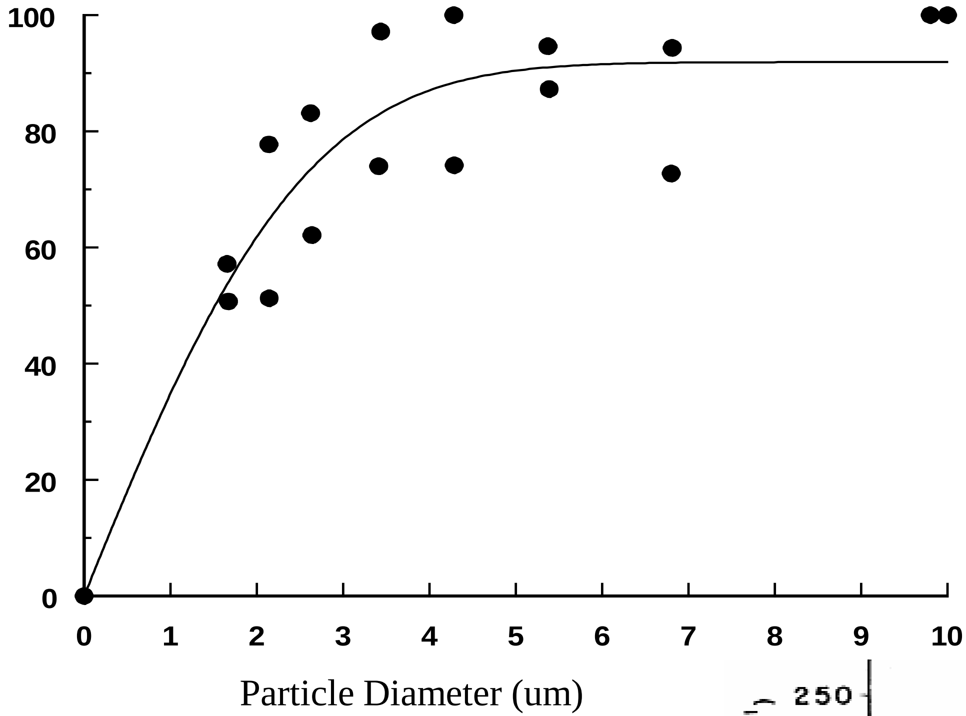


Trophic Cascade Hypothesis



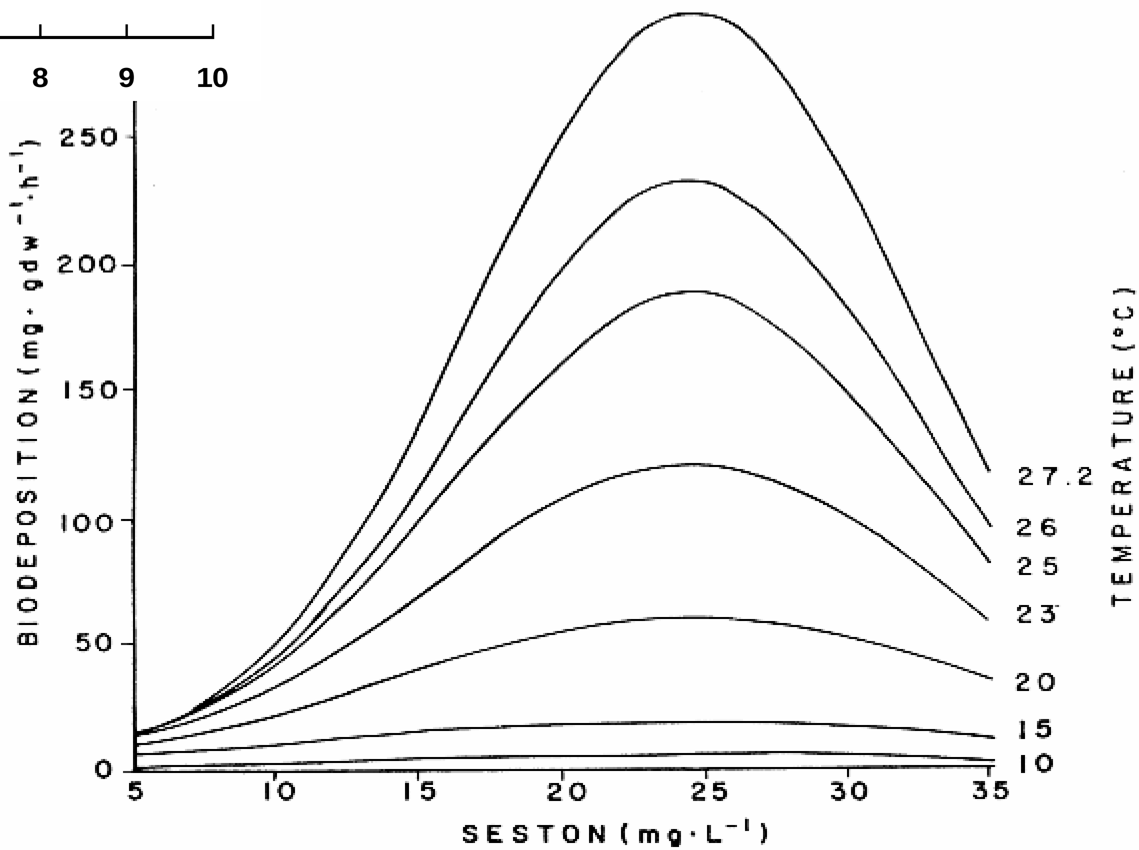


Eastern Oyster
Crassostrea virginica



Particle Size Retention Efficiency

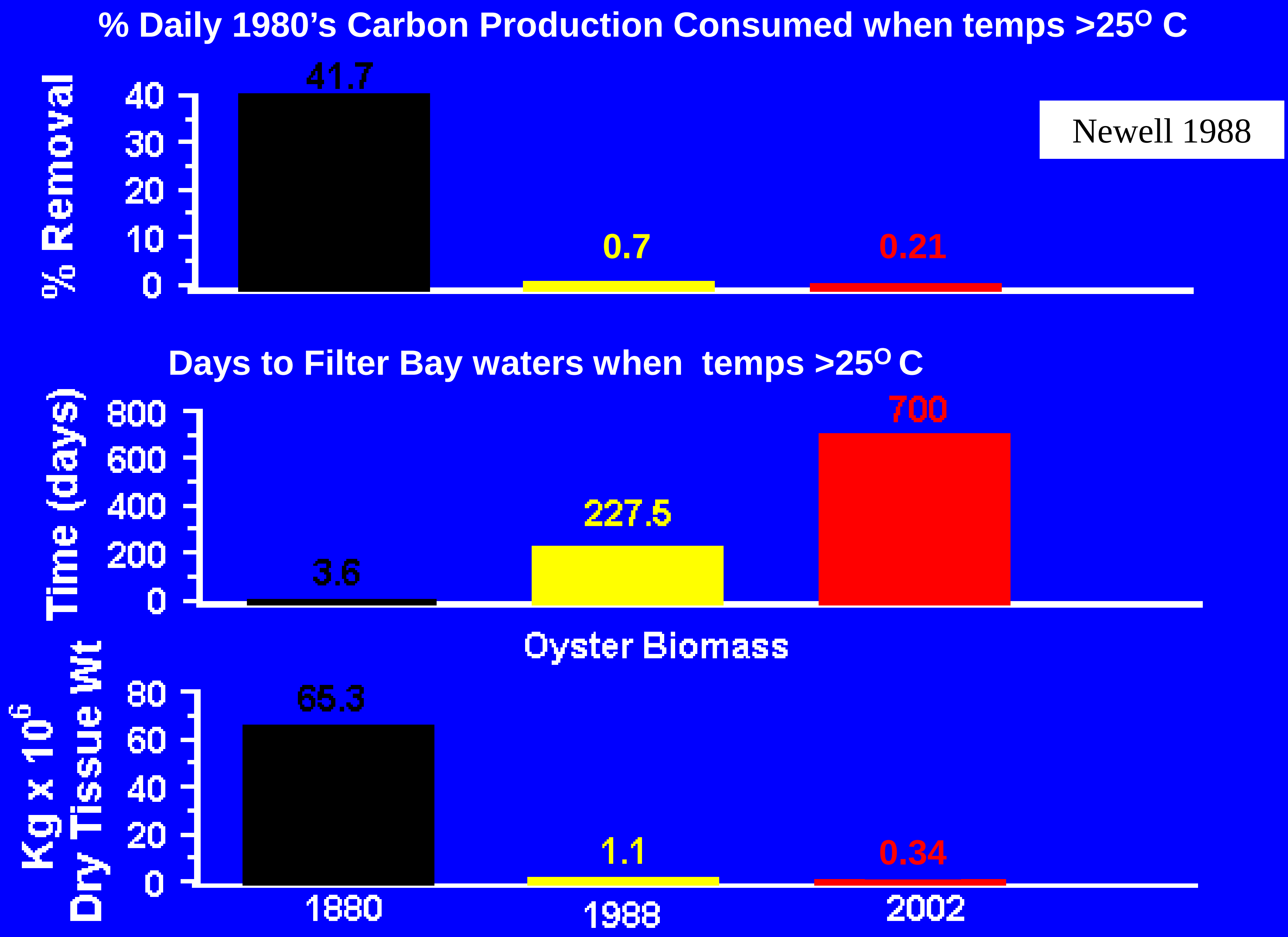
Biodeposition Rates



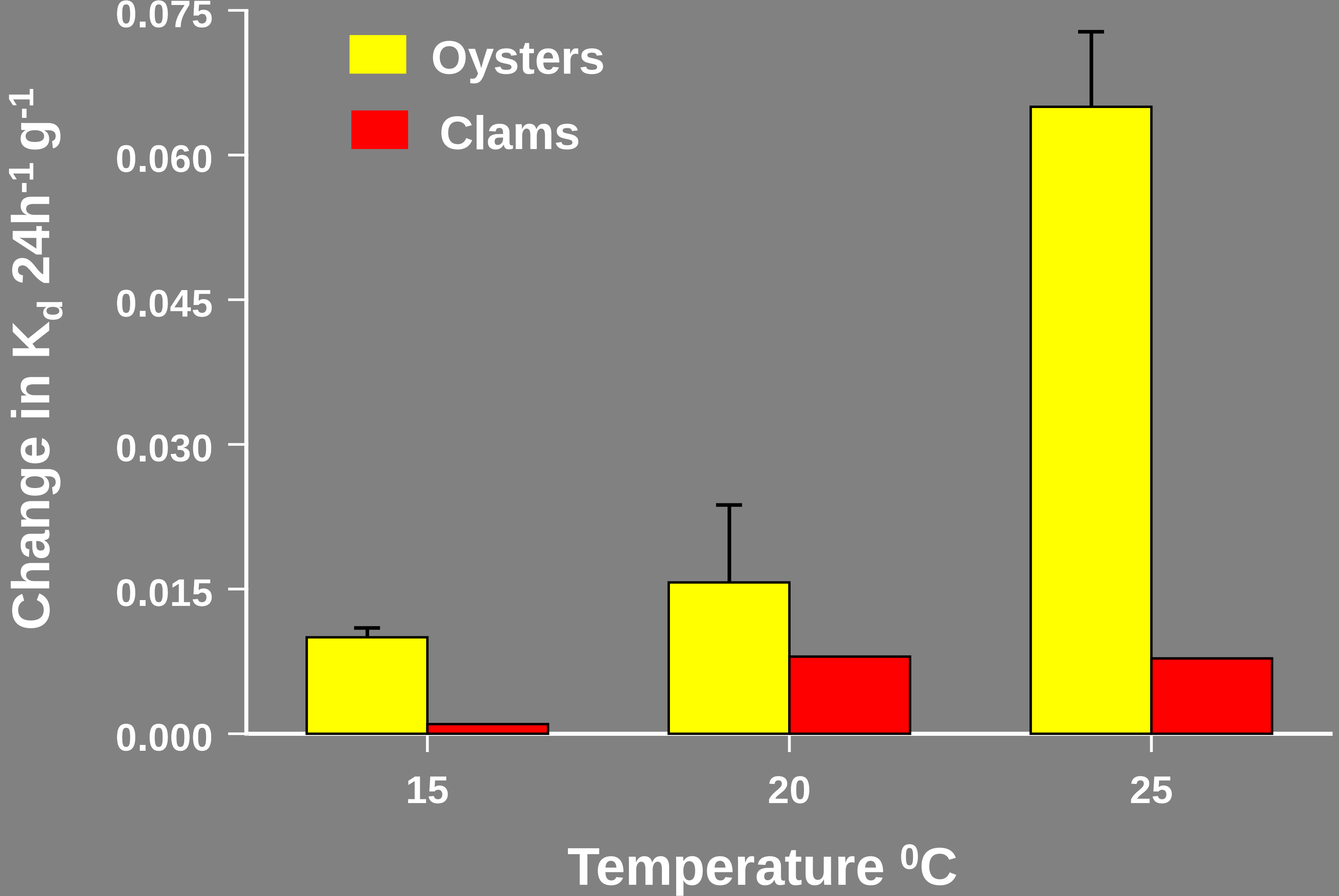
MD Oyster Harvest

(Bushels Harvested 1870 – 2001)

For Marylands Portion of Chesapeake Bay



Change in Light Attenuation Associated with Bivalve Feeding

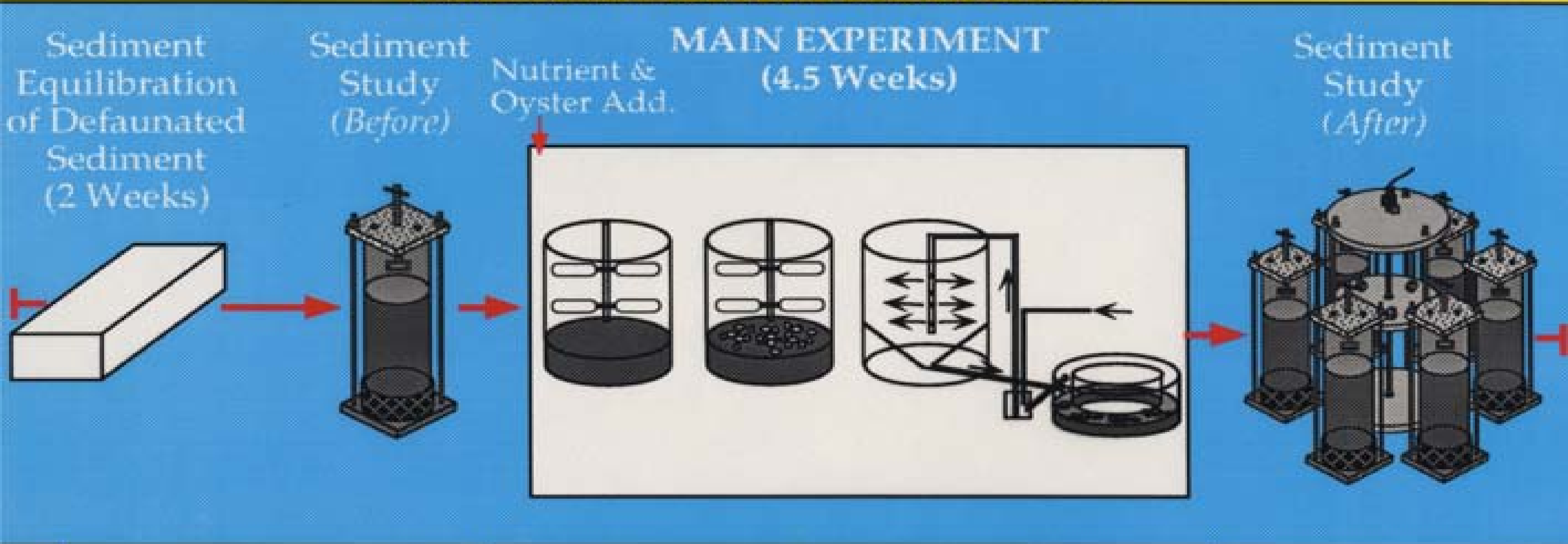


Newell and Koch (2004)

Newell, R.I.E, J.C.Cornwell and M.S.Owens. 2002. Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: a laboratory study. Limnology and Oceanography 47: 1367-1379.

Porter E.T., J.C Cornwell, L.P Sanford, R.I.E. Newell. 2004. Effect of oysters *Crassostrea virginica* and bottom shear velocity on benthic-pelagic coupling and estuarine water quality. Marine Ecology Progress Series. 271:61-75.

EXPERIMENTAL PROTOCOL



MEASUREMENTS

SEDIMENT *Before*:

- **Fluxes of O_2 and NH_4^+, NO_3^-+NO_2^-**
- **N_2 Fluxes**

Others:

- Chl *a*, Sediment C&N
- Porewater Nutrients, H_2S
- Nutrient (PO_4^{---}, Si) Fluxes

WATER COLUMN, Main Expt:

- ***In-situ* Fluorescence, Chl *a* (daily)**

PHYSICAL DATA: -> Light Profiles

Others:

- Nutrients (NH_4^+, NO_3^-+NO_2^-)
- Temp., O_2, Sediment Chl *a*
- Seston Quantity & Quality (POM&PIM)
- Particle Conc., Size, Frequency
- Pigments, Zooplankton, Bacterial Abundance, Bivalve Growth
- Nutrients (PO_4^{---}, Si), CHN, PP

SEDIMENT *After*:

- **Same as Sediment *Before* Main Expt., in Darkness and Light.**

Holyoke, RR., J C.Cornwell, and R.I.E. Newell. Biogeochemical responses of shallow water sediments to small-scale aquaculture of the eastern oyster, *Crassostrea virginica*. Submission to Marine Ecology Progress Series.

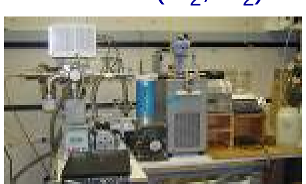
Sediment Core Collection and Incubation

Sediment cores were collected beneath Taylor floats and at Reference sites, located 70-300 m downstream. Cores were incubated in the dark and light at ambient temperature (20-32 C).

Nutrient (and sediment) Analyses

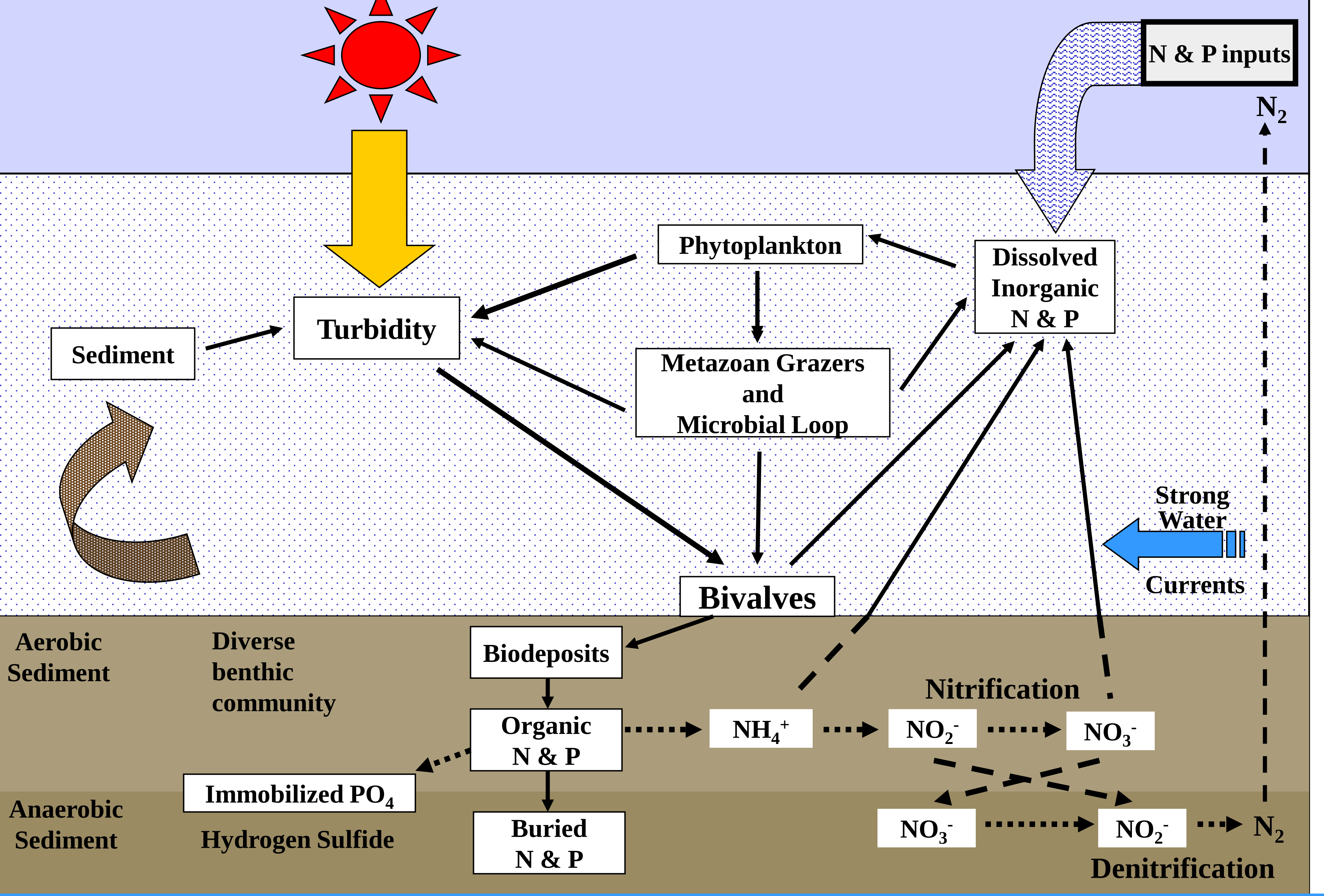
Pore water NH_4^+ and ΣH_2S and surface sediments collected in an N_2 glove bag

MIMS (O_2, N_2)

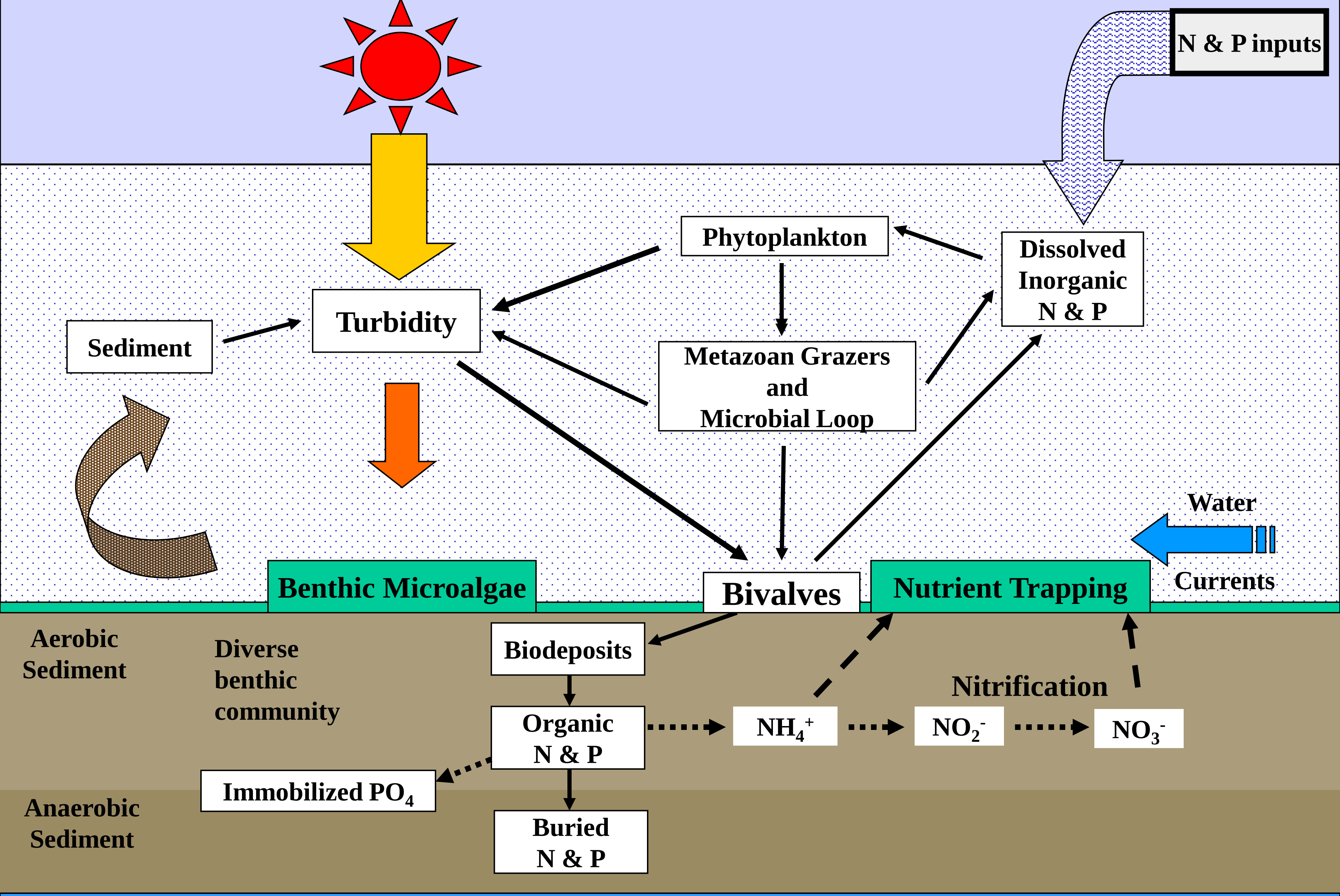


Nutrient fluxes:
NH_4^+, NO_2^- + NO_3^-,
N_2-N, O_2

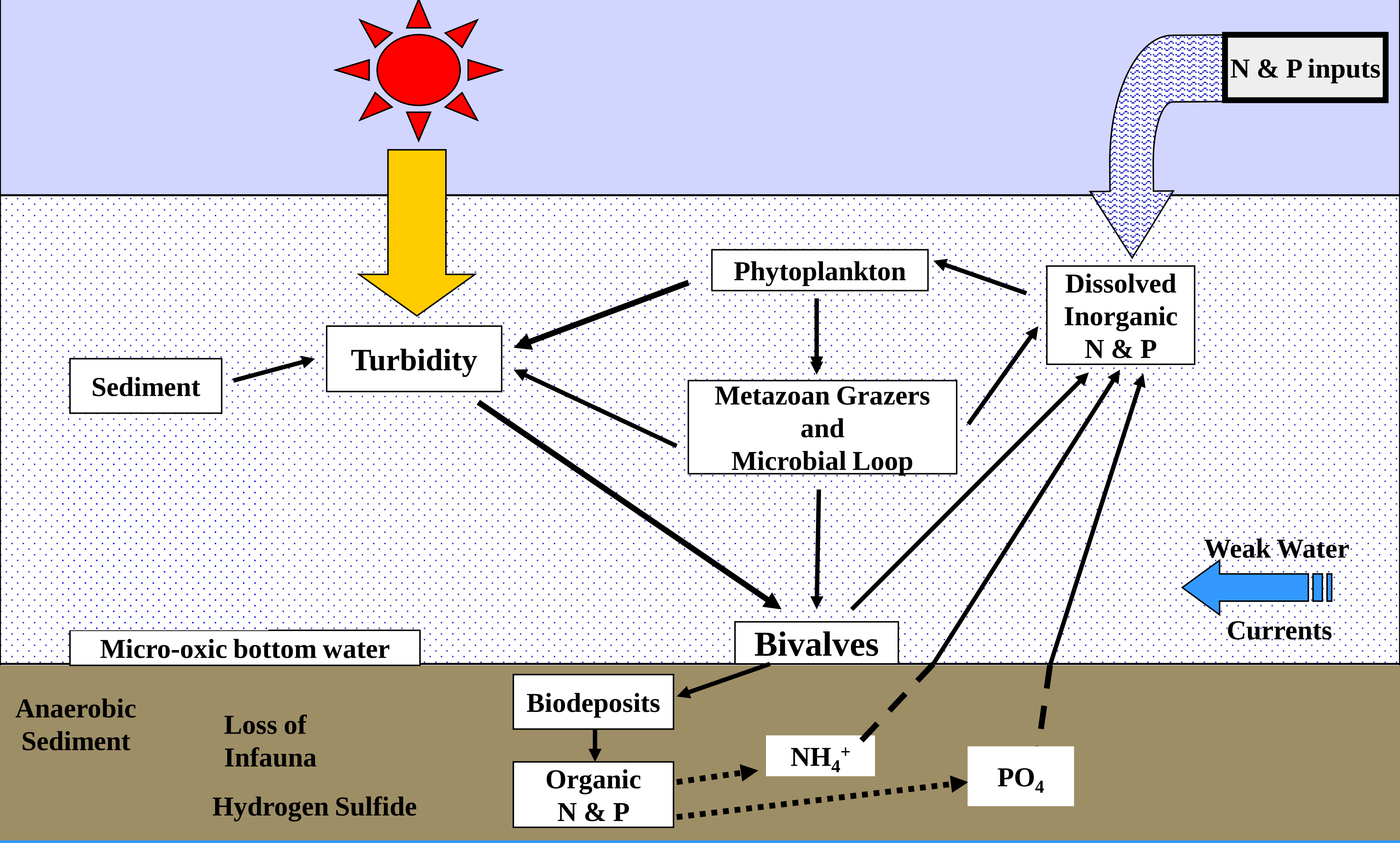
Loss on ignition
Total Nitrogen
Total Carbon



Normal benthic processes when organic particles are remineralized under aerobic conditions beneath the euphotic zone



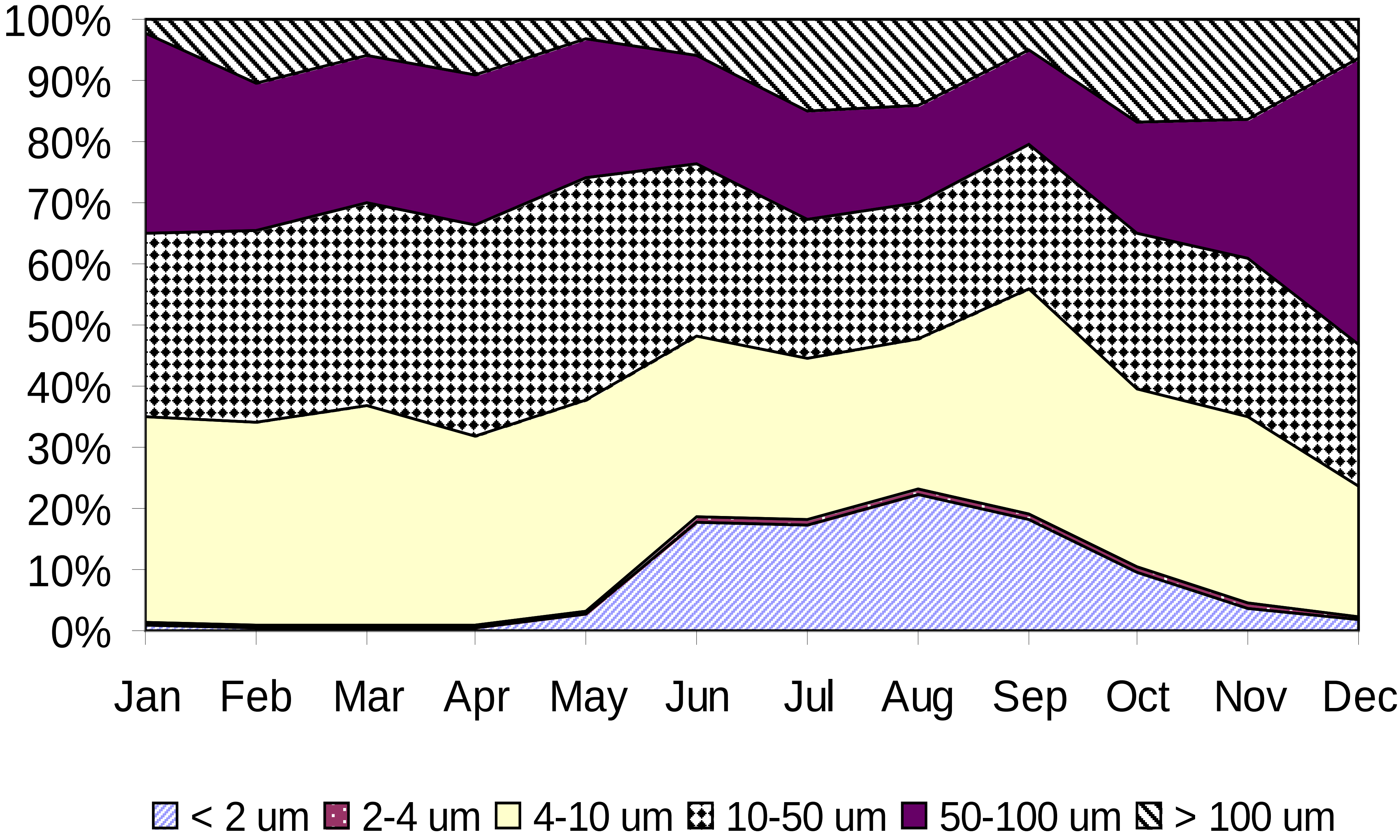
Enhancement of benthic primary production when organic particles are remineralized under aerobic conditions within the euphotic zone



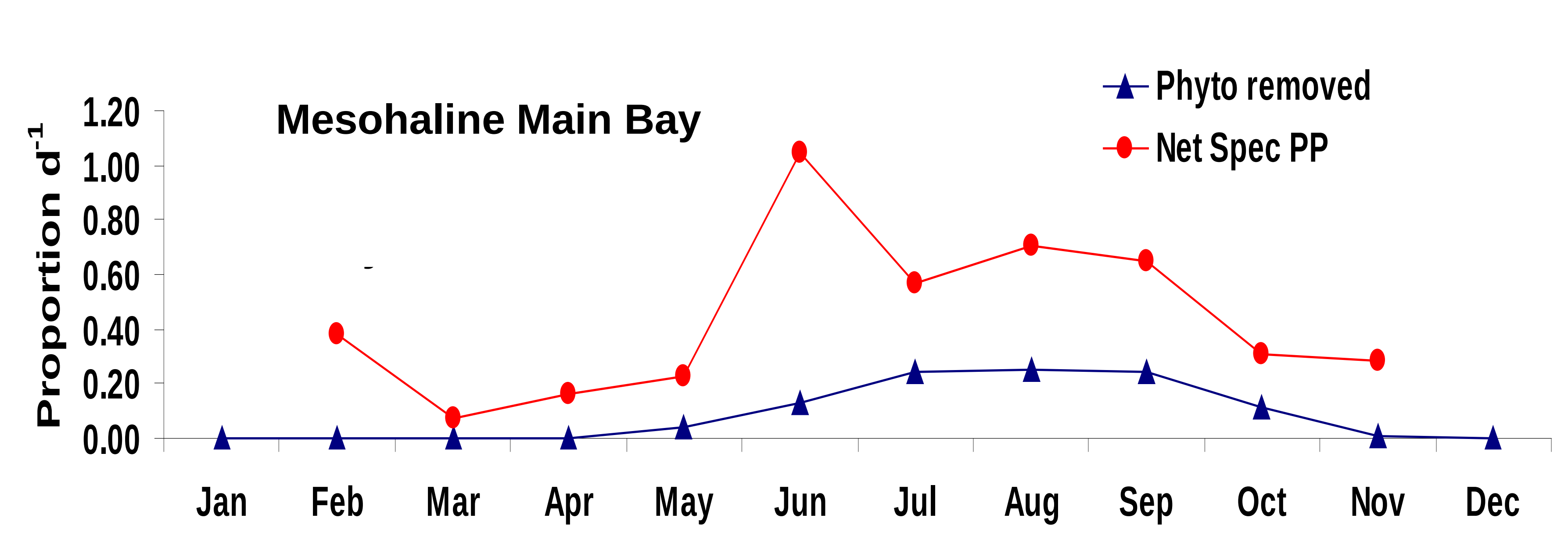
No coupled nitrification-denitrification where organic particles are deposited on anaerobic sediments

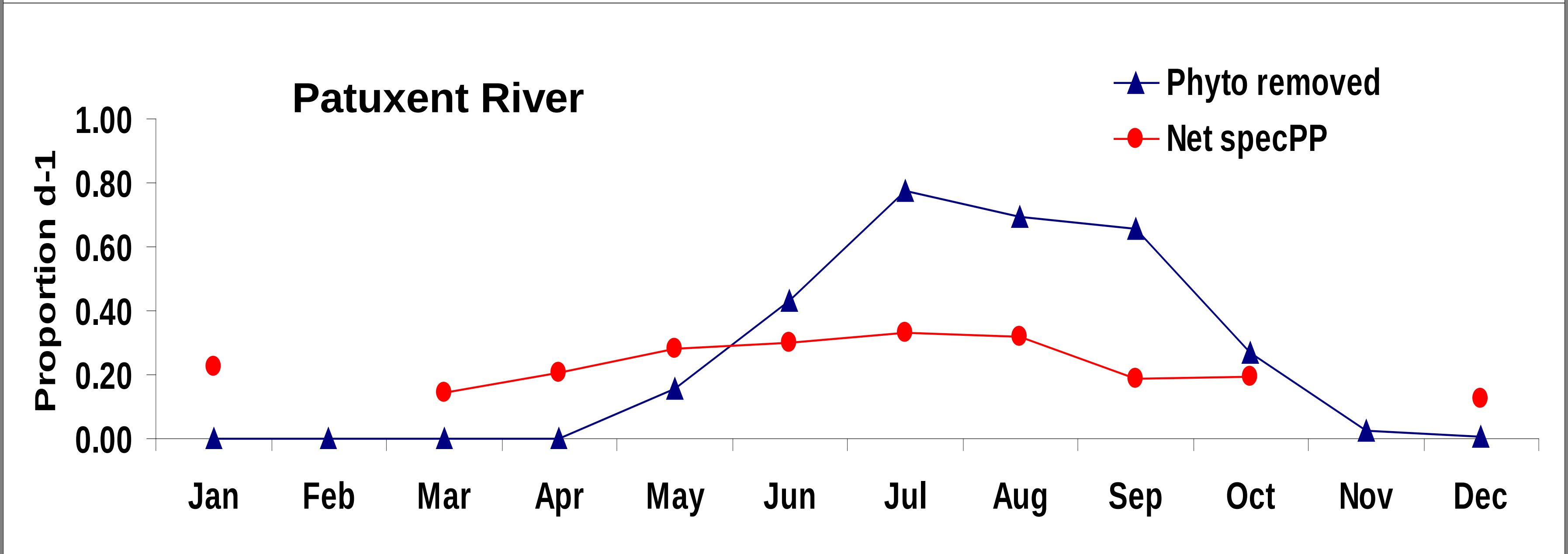
Phytoplankton Size Distribution

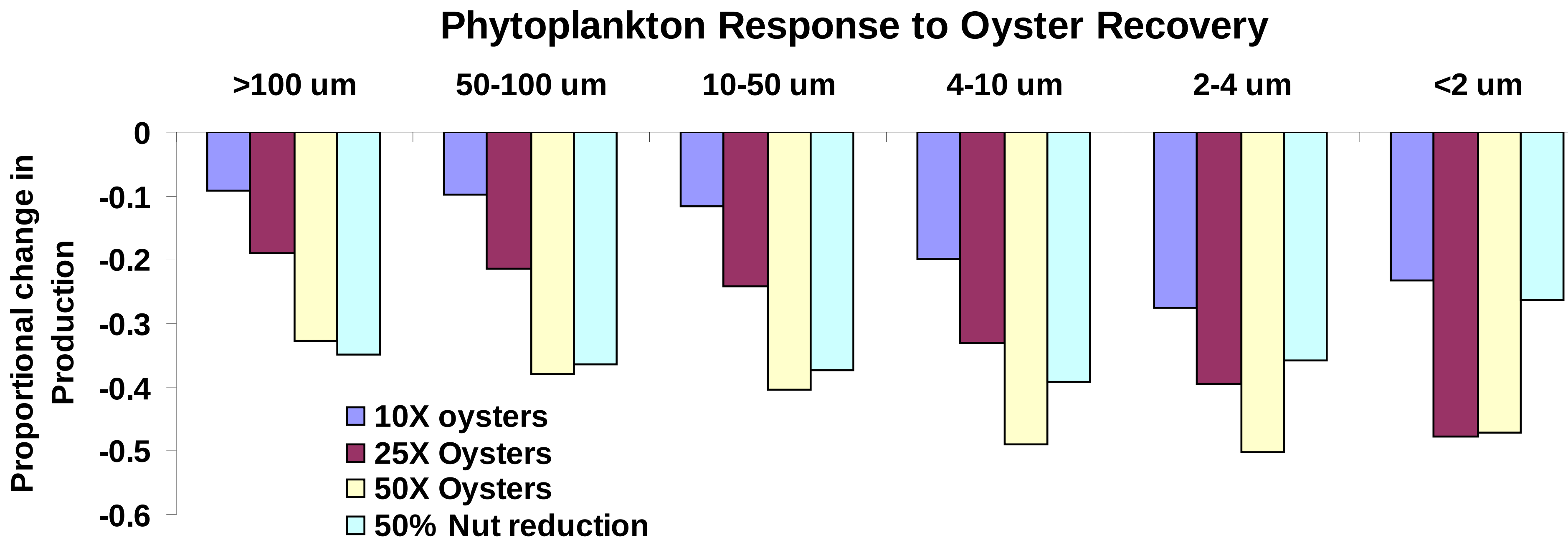
Chesapeake Bay Program Data

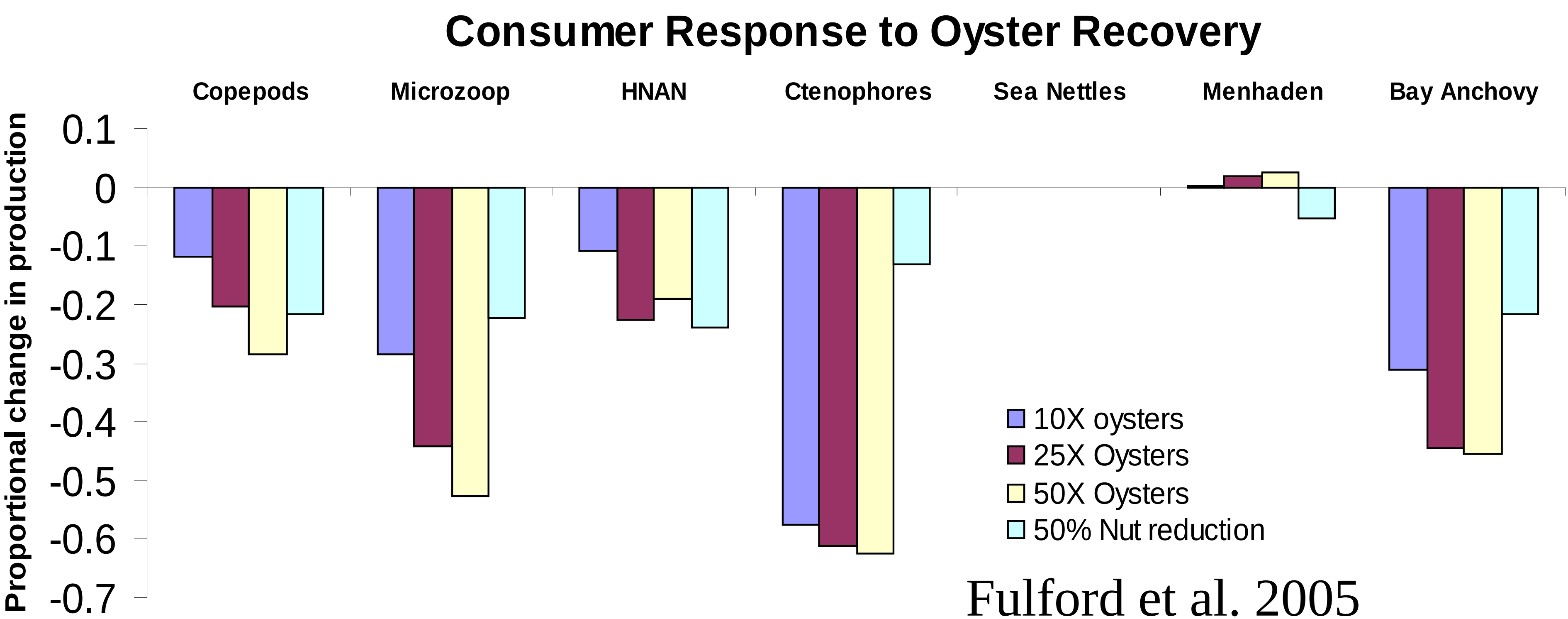


Phytoplankton consumption at 100 times current oyster densities relative to phytoplankton daily production (g C g^{-1} C d^{-1}). Fulford et al. 2005

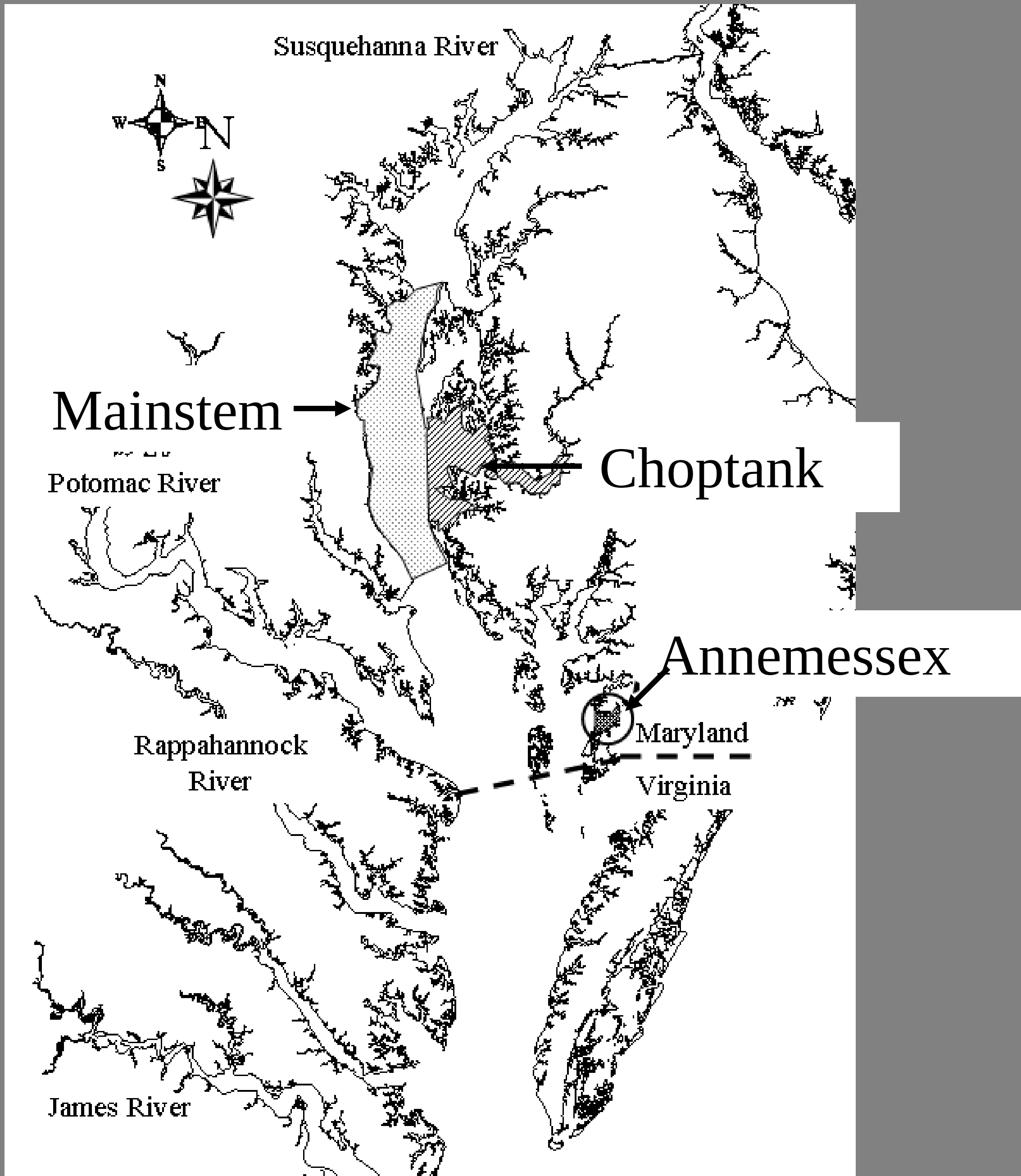








Fulford et al. 2005



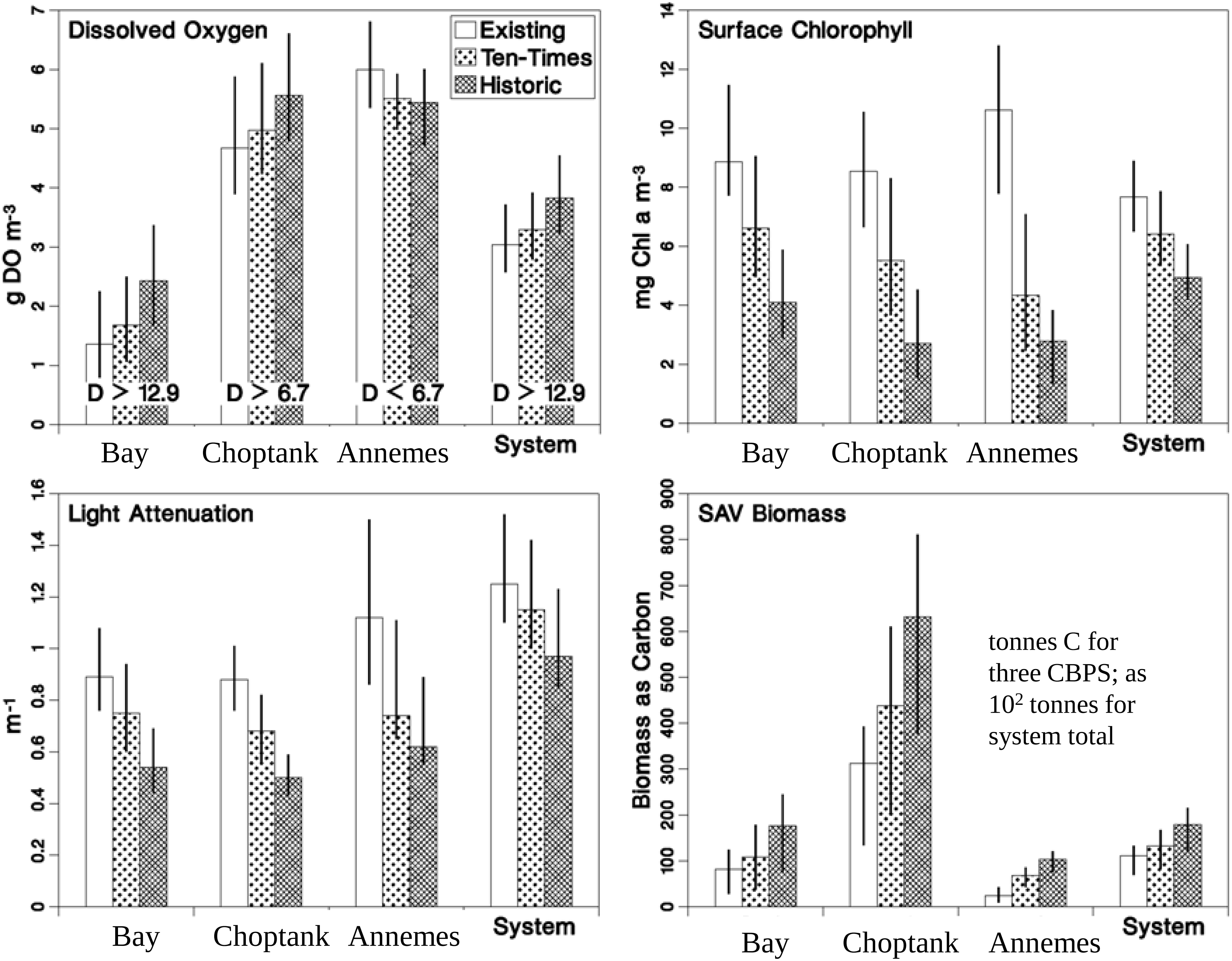
Chesapeake Bay, illustrating segments selected for analysis of regional effects.

Cerco and Noel 2007

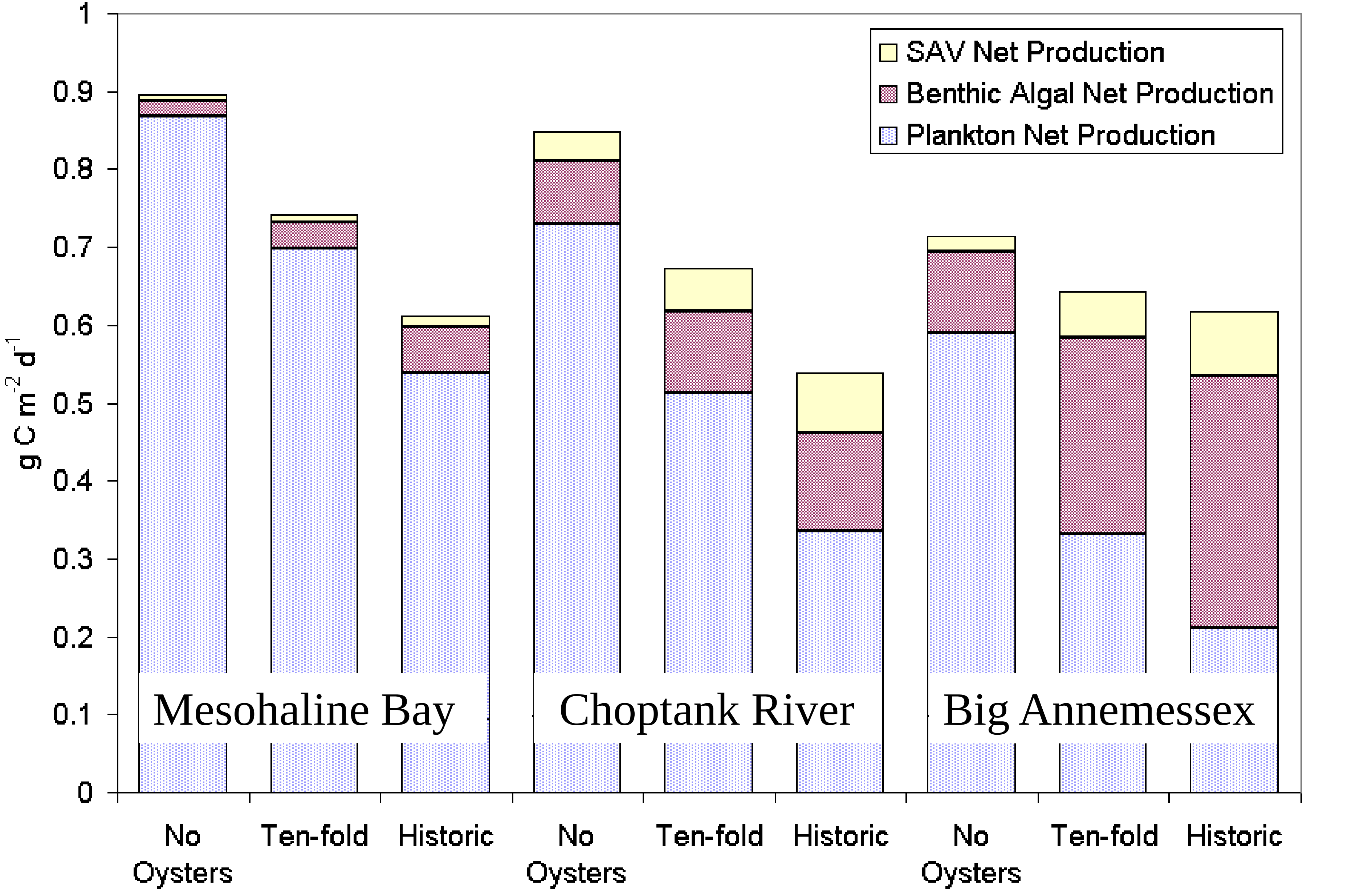
Estimates of Existing and Historical Oyster Biomass (Cerco and Noel 2007)

Source	Maryland (kg C)	Virginia (kg C)	Total (kg C)
Existing, this study	287,000	1,170,000	1,457,000
Existing, Newell (1988)	550,000	400,000	950,000
Existing, Uphoff (2002)	570,000[a]		
Tenfold increase, model	14,100,000	4,375,000	18,475,000
19th century, Newell (1988)			94,000,000
Historic, model	69,750,000	17,200,000	86,950,000

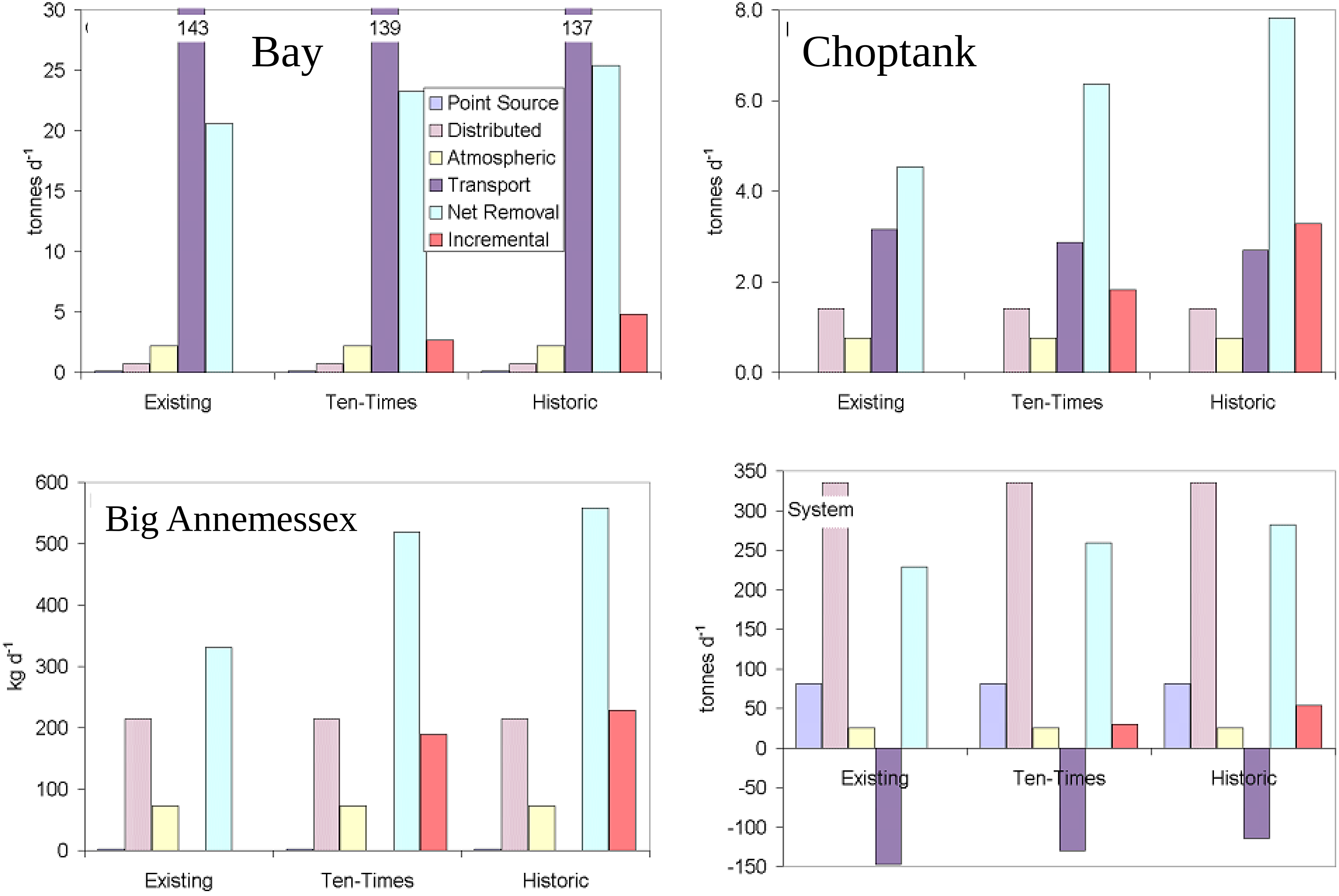
In the southern portion, high densities (mean = 6.2 g DW m^{-2}) are concentrated in limited areas (377 km^2), primarily in the lower James and Rappahannock Rivers.
In the northern portion, lower densities (0.43 g DW m^{-2}) are distributed over a wide area (1330 km^2).



Ten-year means (solid bars) and inter-annual range (vertical lines) (Cerco and Noel 2007)



Effects of oysters on ten-year annual-average net primary production of phytoplankton, benthic microalgae, and submerged aquatic vegetation (Cerco and Noel 2007)



Effects of oysters on ten-year annual-average nitrogen budgets (Cerco and Noel 2007)

SUMMARY:

Strong seasonality in bivalve activity alters rates of phytoplankton consumption.

Bivalves graze on phytoplankton growing on ambient inorganic nutrients; hence no additional nutrients are introduced as occurs when caged fish are fed food pellets.

Bivalves enhance deposition in shallower waters and hence reduce microbial respiration of POM beneath the pycnocline, thereby reducing the severity of summer bottom water hypoxia

Makes particulate nutrients available to other benthic organisms.

Biodeposits enrich sediments and alter their geochemistry.

Where water flow and oxygen are adequate, N may be lost as gaseous N_2 and N and P buried.

When biodeposition is high and either water flow or oxygen are low, sediments may become anoxic, leading to mortality of benthic organisms, release of bound P,and inhibition of nitrification/denitrification.

Bivalve feeding reduces turbidity thereby permitting growth of benthic plants. Beneficial if benthic microalgae and seagrass grow but possible adverse if macroalgal (e.g.,*Ulva* spp) colonize.

Benthic microalgae, an important food source for many invertebrates, can take up large amounts of N & P regenerated from bivalve biodeposits.

Natural populations of suspension-feeding benthic bivalves can exert the most profound ecosystem effects in regions with relatively shallow water (i.e., where clearance rate in relation to water volume is high)

By culturing bivalves off—bottom in aquaculture floats it will be possible to extend their influence to deeper waters.

Because of the magnitude of bivalves required to effect near total water quality improvements and uncontrollable factors (disease, storms, etc) the use of bivalves as a mechanism for nutrient remediation should complement but never substitute for curbing nutrient inputs to the estuary.