“Heterotrophy”
(get food from others)
or Secondary Production

Sources are complex and many - how to tell which is going where?

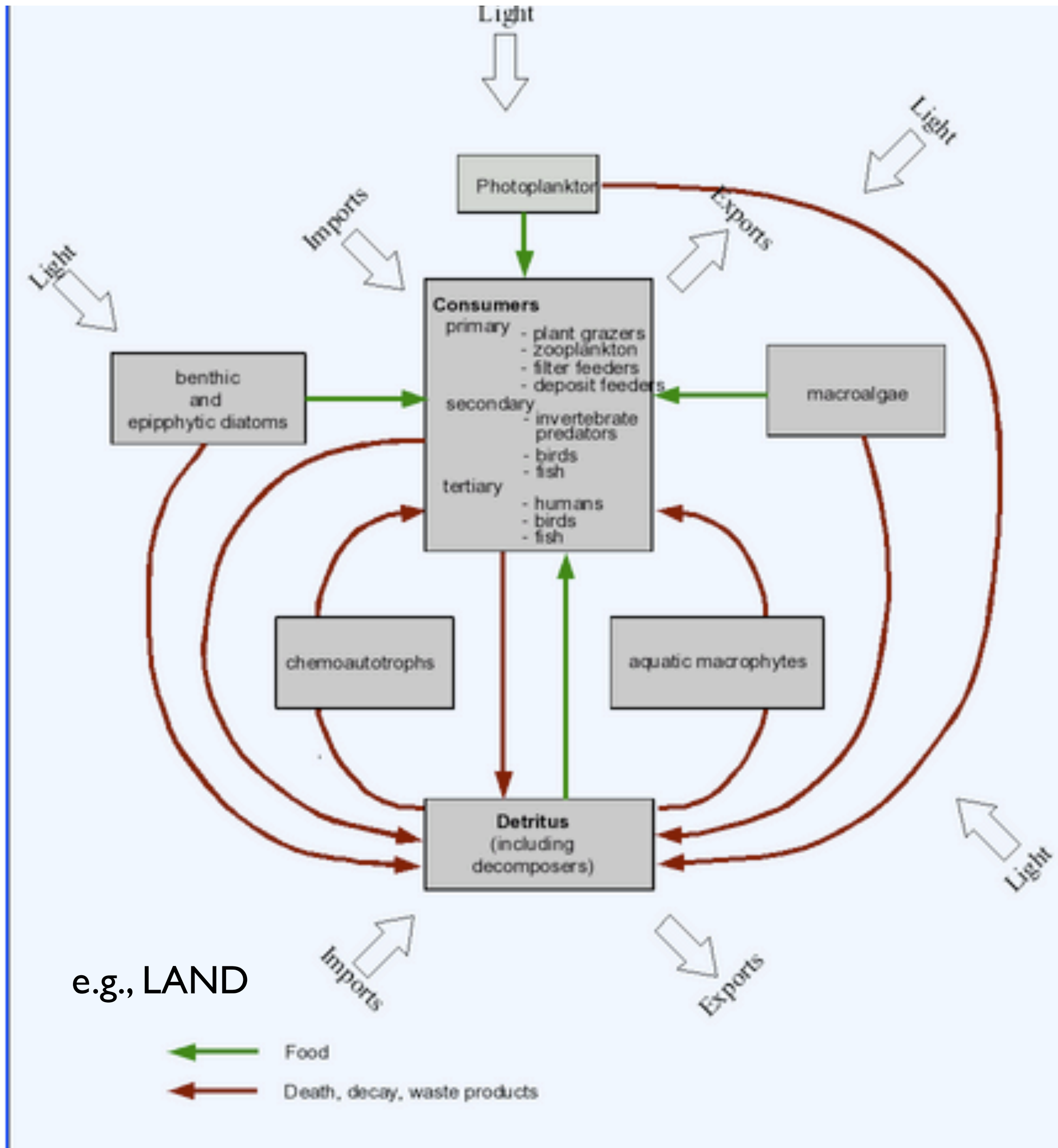
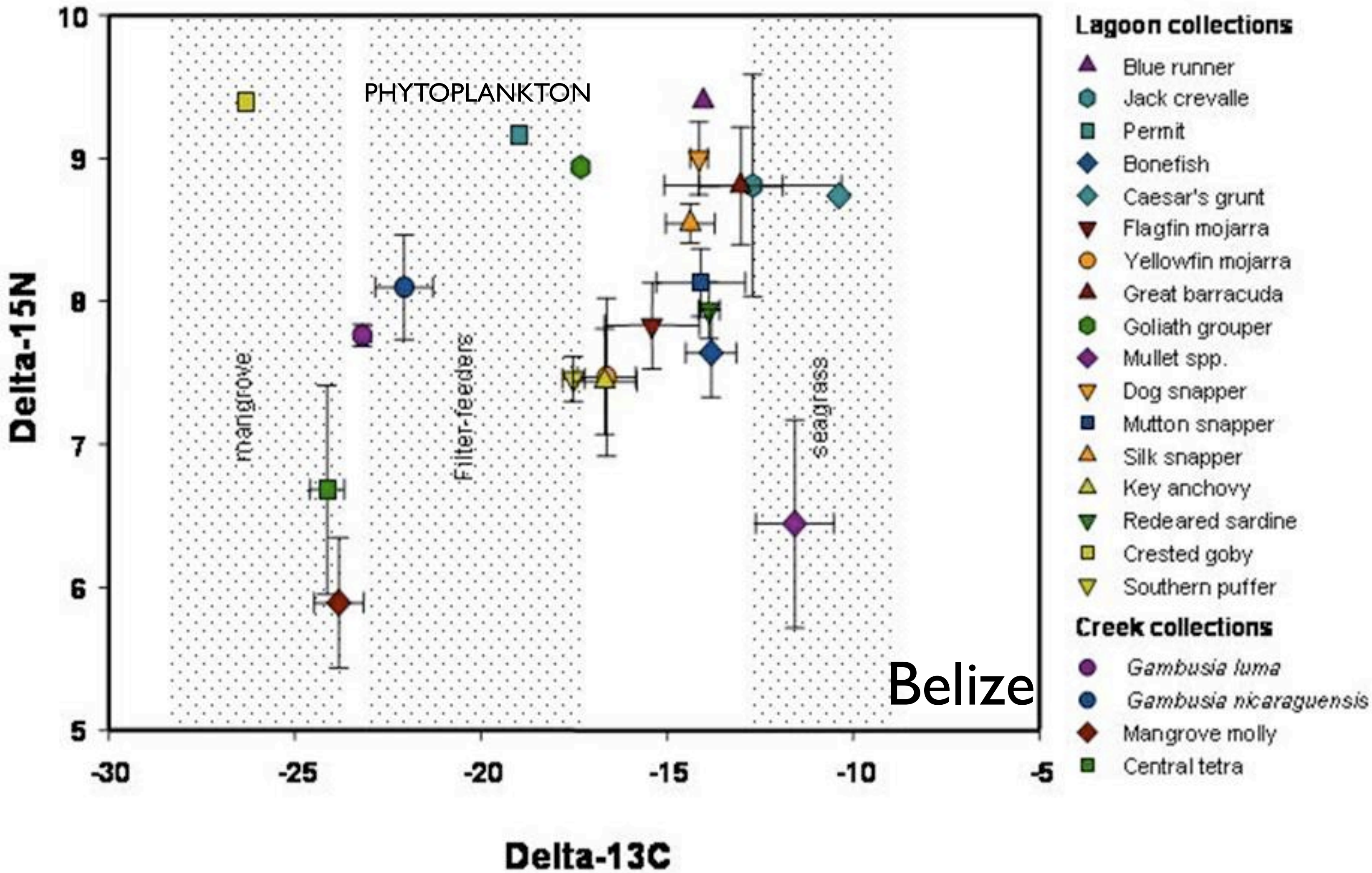


Figure 1 An Estuarine Food Web

One approach - isotopes of elements in organic matter



U R what U eat

3 half-and-half splits to remember

1. What organisms consume organic matter?

At kingdom level,

~ 1/2 to microbes
~ 1/2 to metazoans

II. During heterotrophy, carbon goes roughly

~ 1/2 to respiration (catabolism)
~ 1/2 to biomass production (anabolism)

Physiologists usually keep them apart.

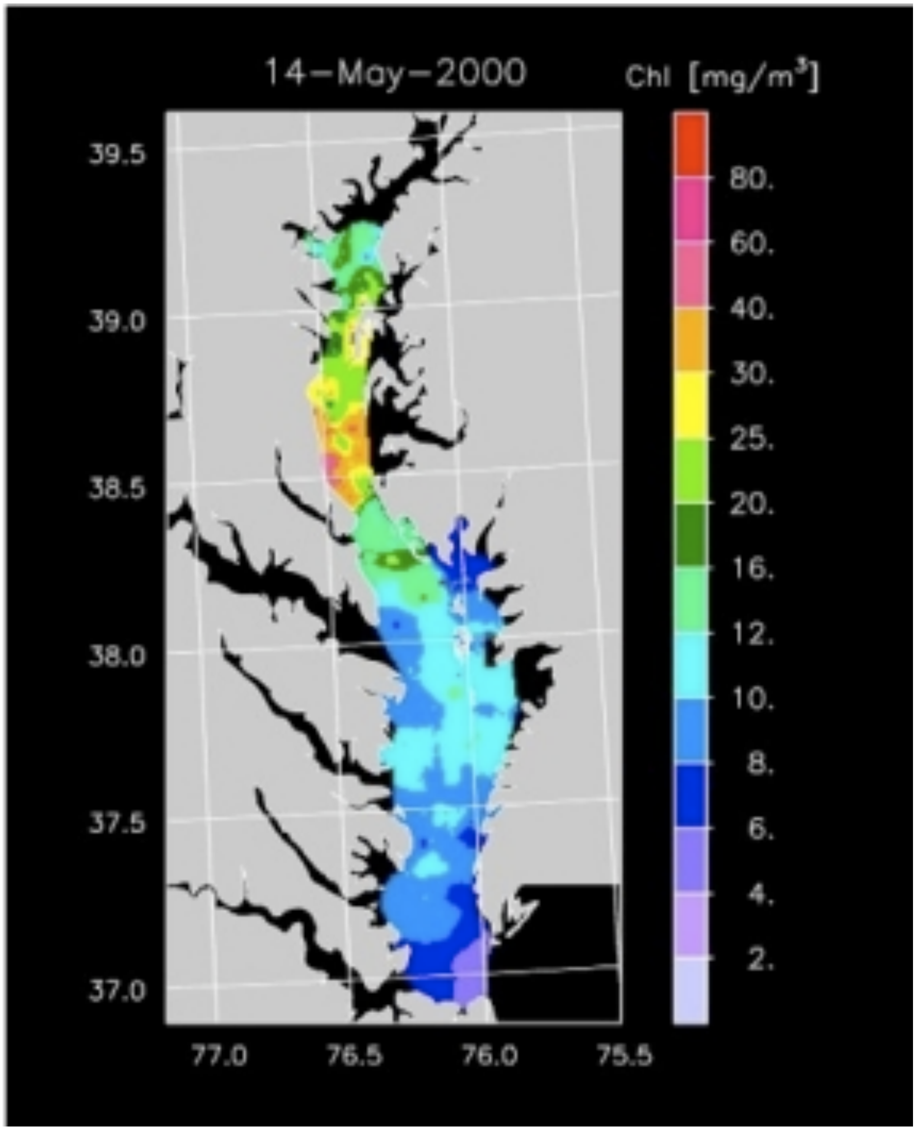
Oceanographers, ecologists, fisheries folk <u>often</u> assess secondary production as respiration for microbes and biomass accumulation for animals.

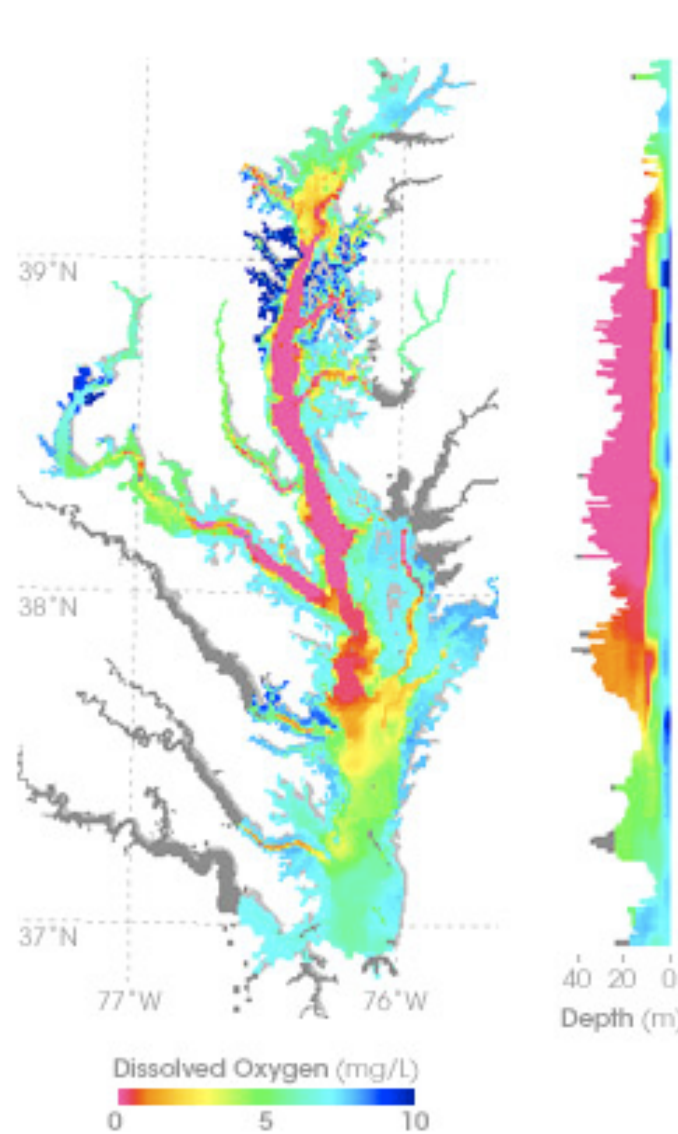
III. Where does the consumption take place?

~ 1/2 in the water column
~ 1/2 in the benthos

true for phytoplankton production alone;
hence probably even more goes to benthos
with benthic primary production taken into account

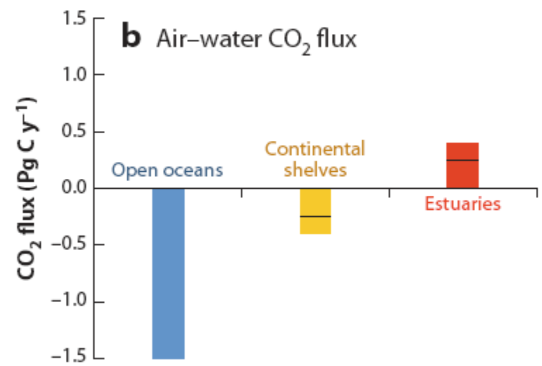
Oxygen consumption as measure - $CO_2 + H_2O \leftrightarrow CH_2O + O_2$

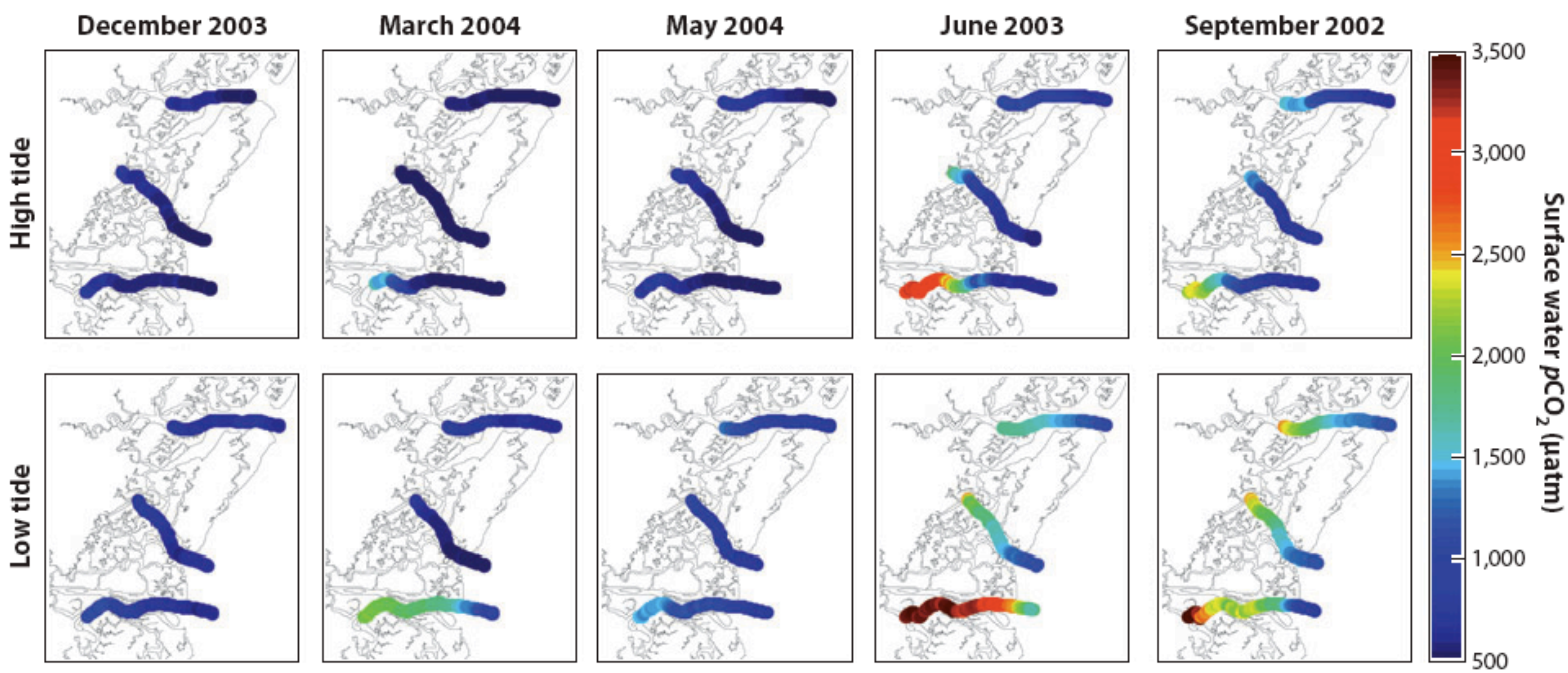




Heterotrophy > Autotrophy in many (most?) estuarine systems

$CO_2 + H_2O \leftrightarrow CH_2O + O_2$





Annu. Rev. Mar. Sci. 2011. 3:123–45

Figure 5

Surface water pCO_2 distribution at in situ temperature in three Georgia estuaries. See **Figure 4** for details of the sites; see also Jiang et al. 2008a for other relevant information.

Heterotrophy at the ecosystem level - how could that be?

Remember this plot? Shows the same thing

Heterotrophy inside, autotrophy outside

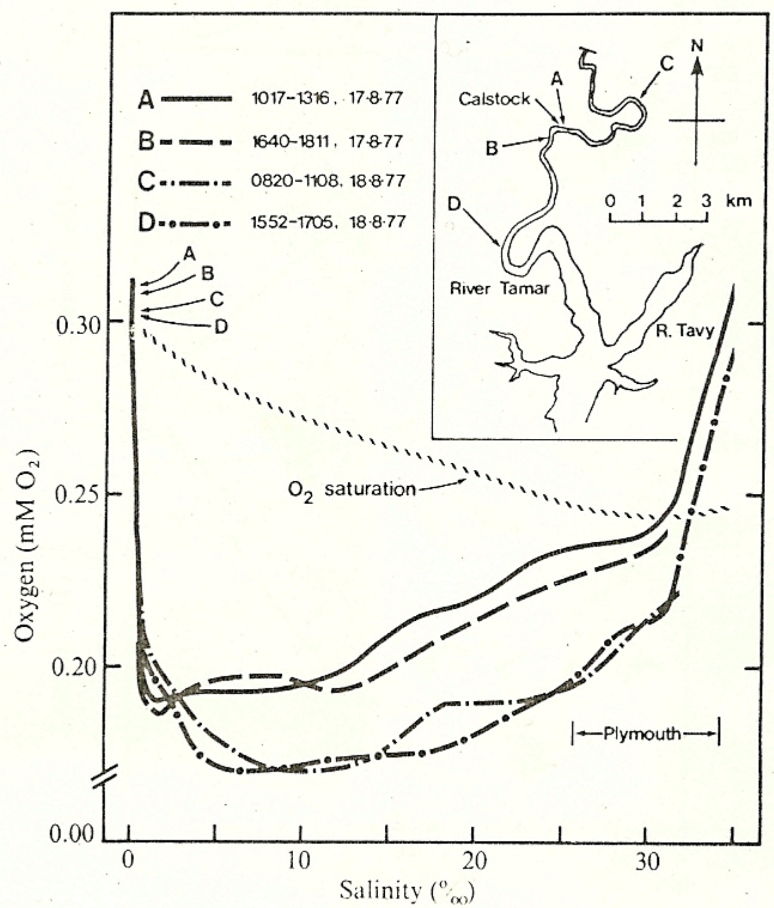


Fig. 1 Inset map of the upper reaches of the Tamar Estuary and the positions of the 1.0‰ isohalines during four traverses on 17 and 18 August 1977 (Plymouth City is located ~25 km downstream from Calstock). The corresponding dissolved O_2 concentrations as well as the 100% O_2-saturation profile are plotted against salinity.

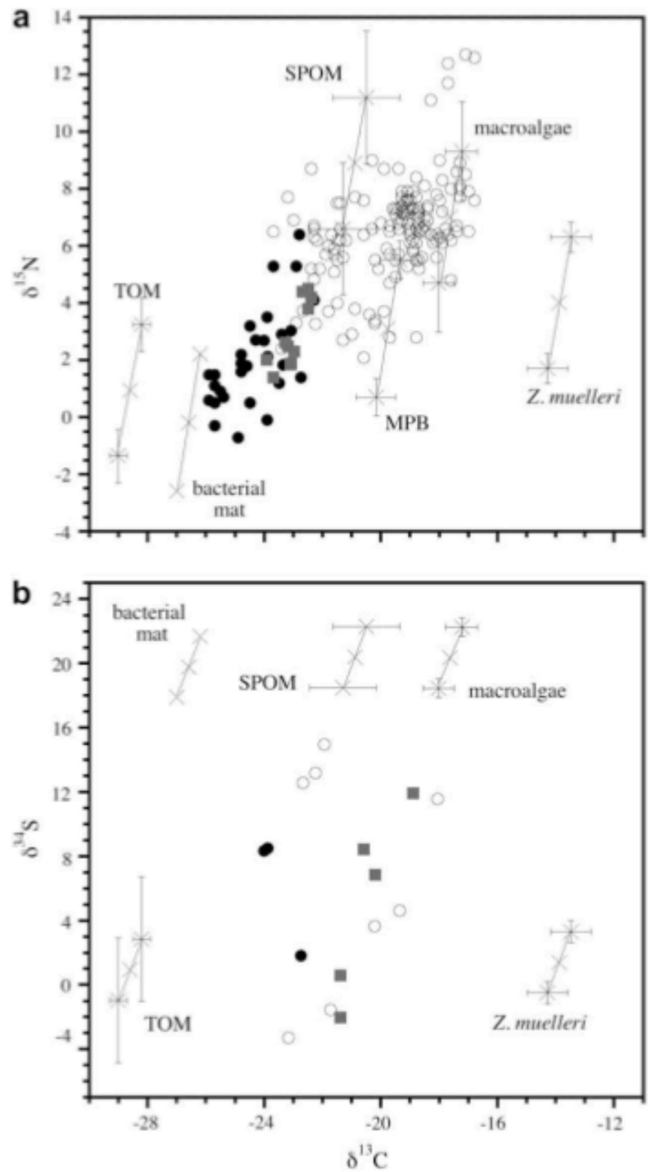


Fig. 3. Values of (a) $\delta^{13}C$ and $\delta^{15}N$, and (b) $\delta^{13}C$ and $\delta^{34}S$ (‰) of invertebrates collected from inner Doubtful and Bradshaw Sounds. Points represent individual taxa, or multiple individuals of the same taxon. The sub-surface deposit feeders *Echinocardium cordatum* are represented by closed circles, and *Pectinaria australis* by closed squares. Remaining invertebrates are represented by open circles. Mean values of potential organic sources (±1 SE) are plotted (crosses) with estimated amounts of fractionation per trophic level ($\delta^{15}N$ +2.3‰, $\delta^{13}C$ +0.4‰, $\delta^{34}S$ +1.9‰; McCutchan et al., 2003).

Terrestrial subsidies

explain heterotrophy > autotrophy

Table 2

Distribution of feasible solutions from the IsoSource mixing model (Phillips and Gregg, 2003) of contributions of organic matter sources to the diet of *Echinocardium cordatum* and *Pectinaria australis*, based on values of $\delta^{15}N$ and $\delta^{13}C$. The 1st and 99th percentiles are given, with the median in parentheses. TOM: terrestrially derived organic matter, SPOM: suspended particulate organic matter, MPB: microphytobenthos.

	TOM	*Zostera muelleri*	SPOM	macroalgae	MPB
E. cordatum	52–70 (62)	0–27 (14)	0–4 (1)	0–7 (2)	0–46 (20)
P. australis	37–57 (48)	0–30 (14)	0–12 (6)	0–21 (9)	0–52 (23)

R.J. McLeod, S.R. Wing / Estuarine, Coastal and Shelf Science 82 (2009) 645–653

Also, CO_2 released in estuarine sediments often shows partial terrestrial origin

open system

Algae decay more quickly than vascular plant detritus

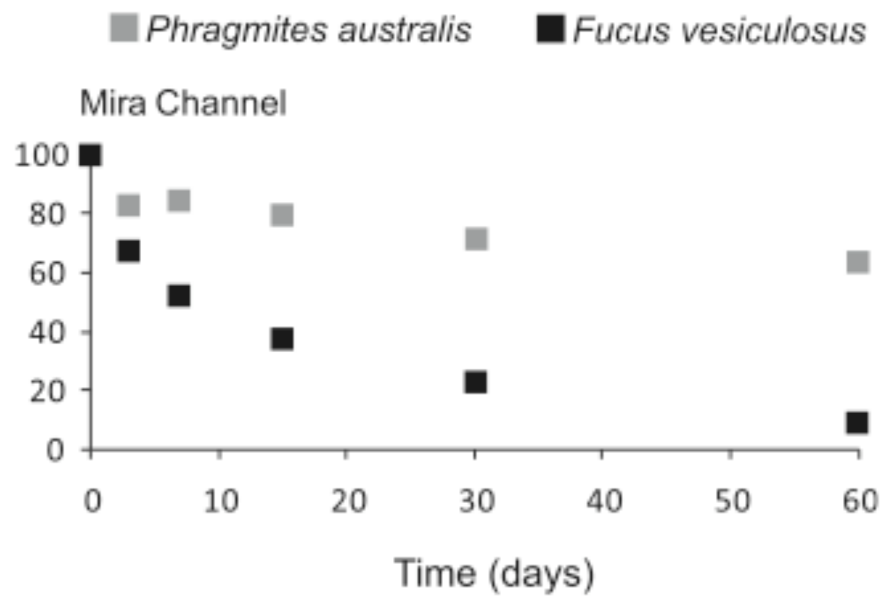


Fig. 3. Evolution of the remaining biomass of *Phragmites australis* and *Fucus vesiculosus* during the 60-day decay period in areas 1 to 5, Mira Channel, Ria de Aveiro. The data obtained for each species are plotted in separate graphs, in order to better compare the results obtained in the 5 areas. The bottom summary graph shows the evolution of the mean values for the whole Mira Channel, for each species.

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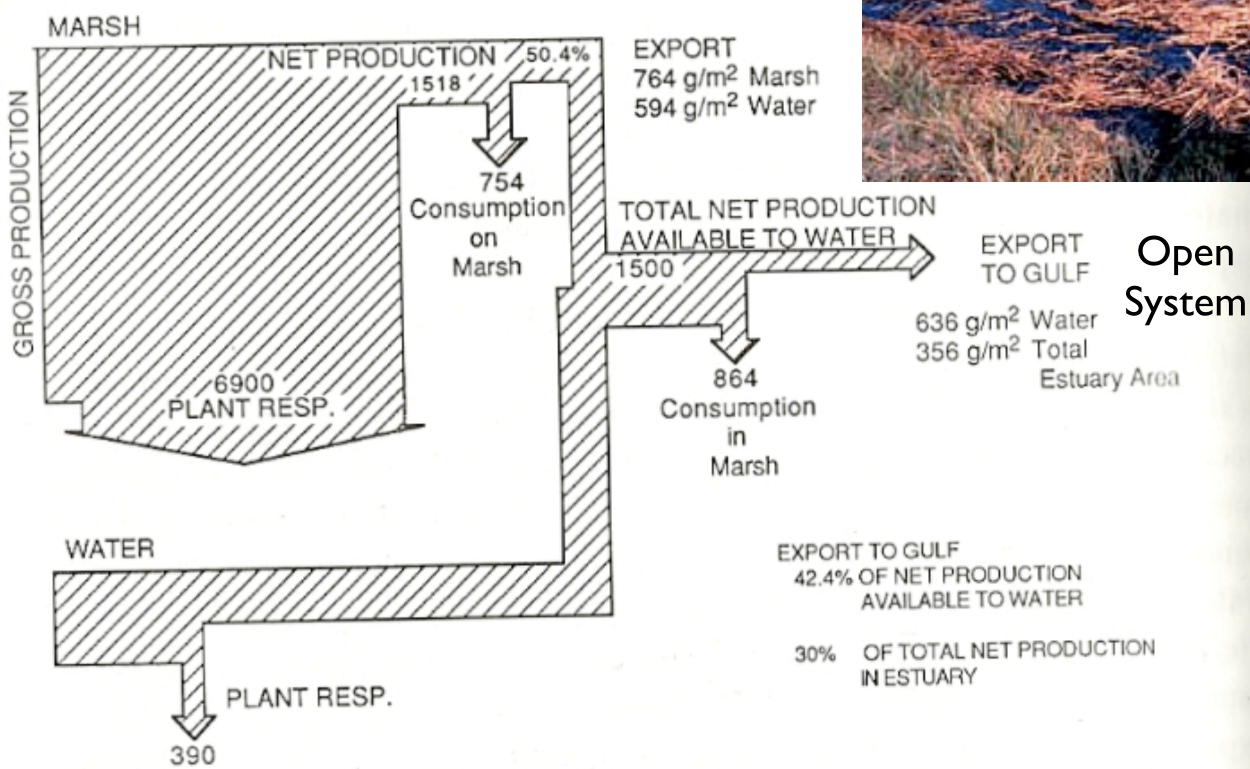
In situ experimental decomposition studies in estuaries: A comparison of _Phragmites australis_ and _Fucus vesiculosus_

Marta Lobão Lopes[a], Patrícia Martins[a], Fernando Ricardo[a], Ana Maria Rodrigues[a] and Victor Quintino[a]

Expose slowly decaying estuarine, vascular detritus
to estuarine circulation -
what will happen?

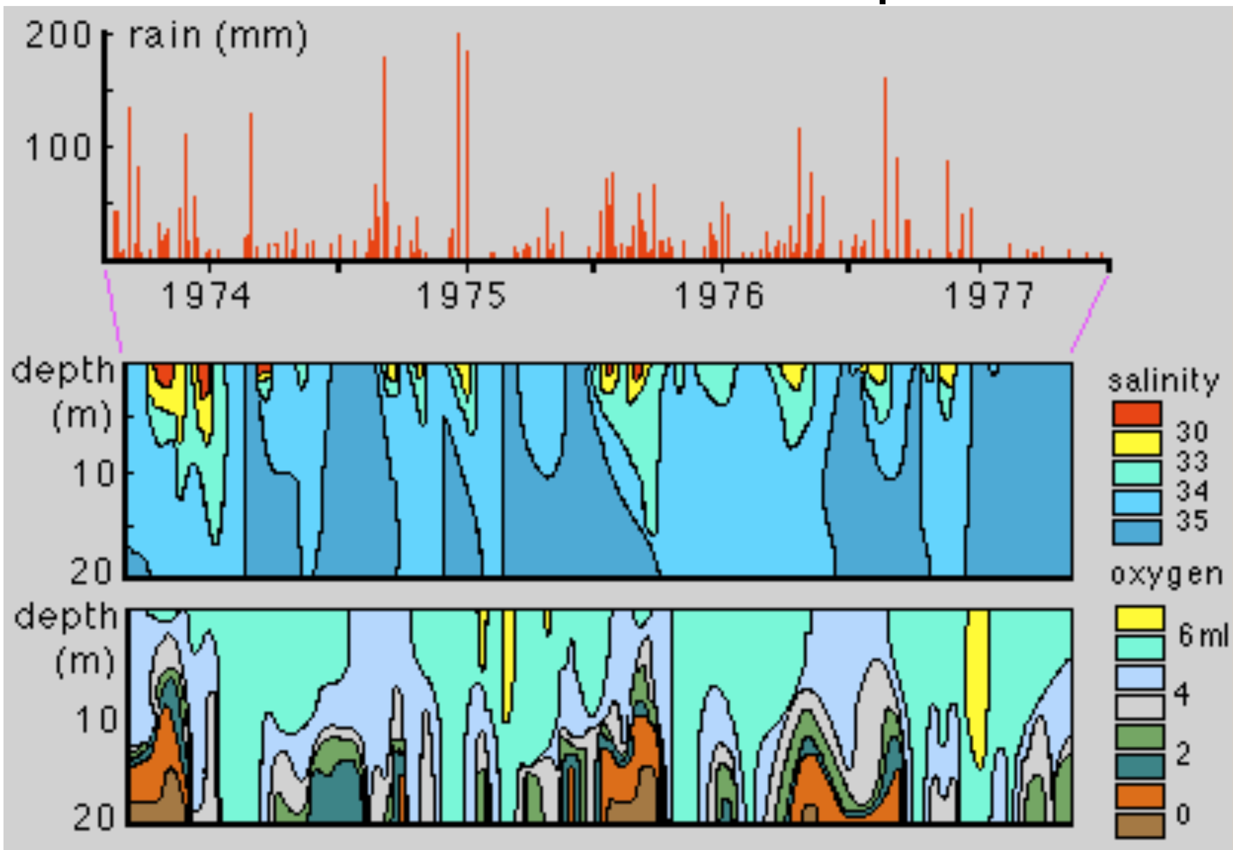


Open
System

Figure 7.12 Organic budget of Barataria Bay, Louisiana (Day et al. 1973). Values in
organic matter/m²/yr.

Importance is controversial

Hypoxia/Anoxia - often driven by microbial and stratification processes



Salinity and oxygen in central South West Arm of Port Hacking, Sydney, during 1974 - 1977. The top figure shows rainfall at a meteorological station close to the catchment area of South West Arm creek. The salinity of the lower layer remains close to 35 throughout the entire period. The upper layer responds quickly to freshwater input from rain, when the salinity can drop to less than 30. During these periods the estuary develops a sharp interface between the two layers and displays the structure of a salt wedge or highly stratified estuary.

f(loading, stratification, sill at mouth)

http://www.es.flinders.edu.au/~mattom/ShelfCoast/chapter13.html

After O2 is gone, complex microbial communities appear. So goes the "half" of primary production in sediments.

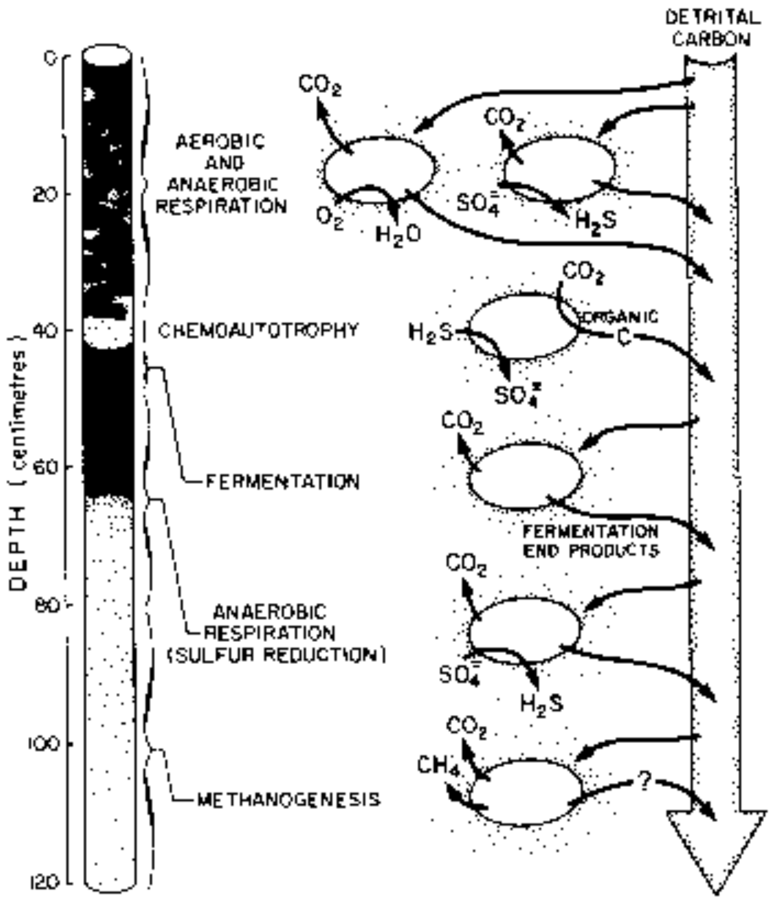


FIG. 97. Vertical stratification of aerobic and anaerobic metabolic processes carried out by bacteria in sediments (redrawn from Kepkay and Novitsky, 1980).

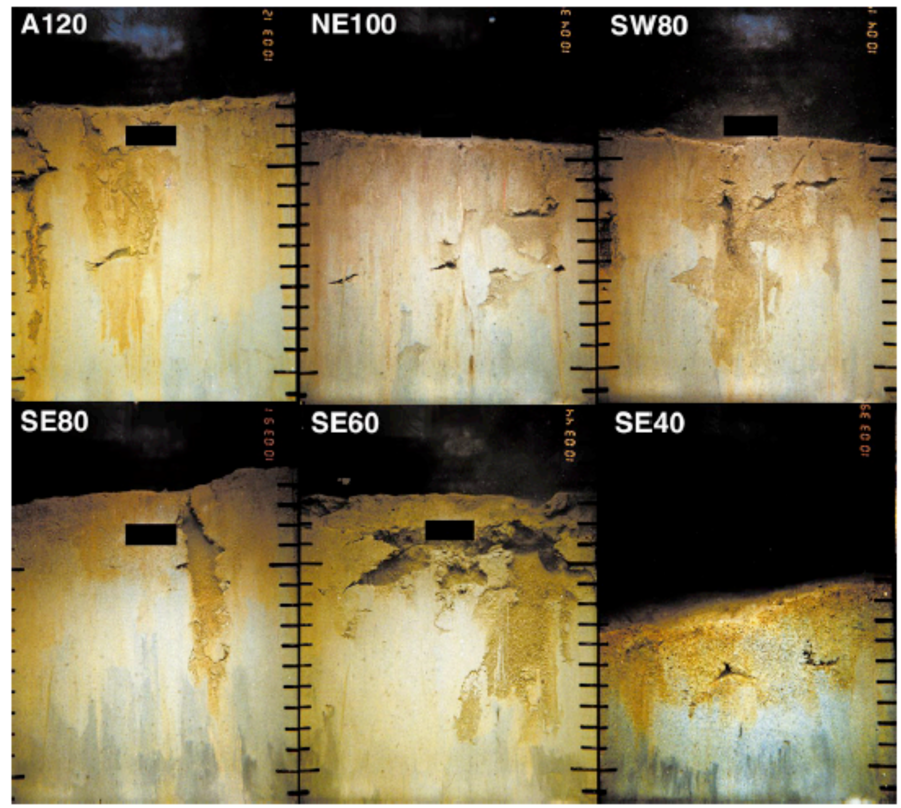
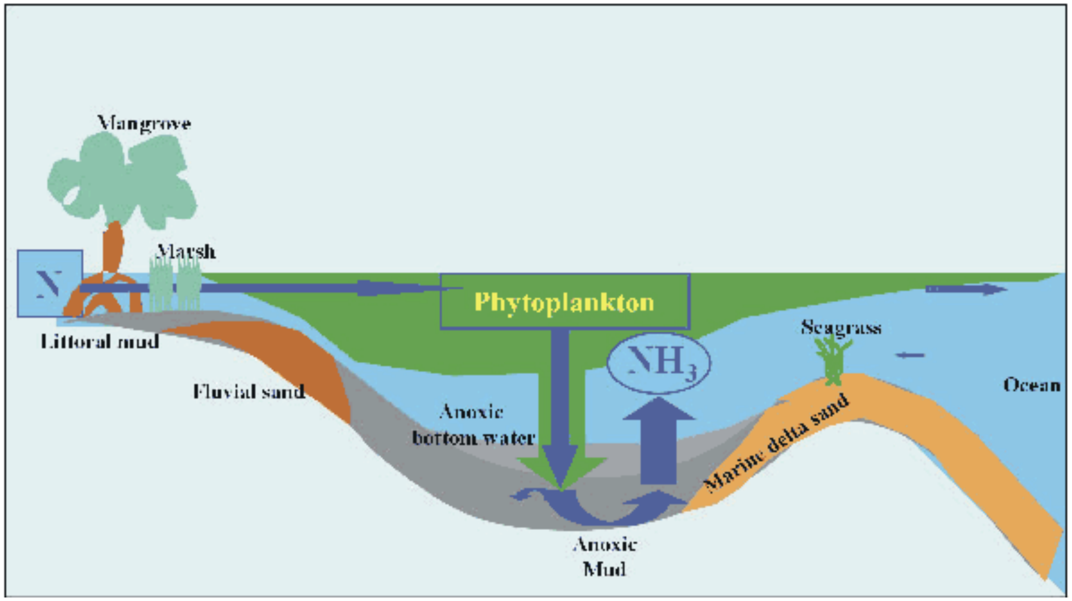
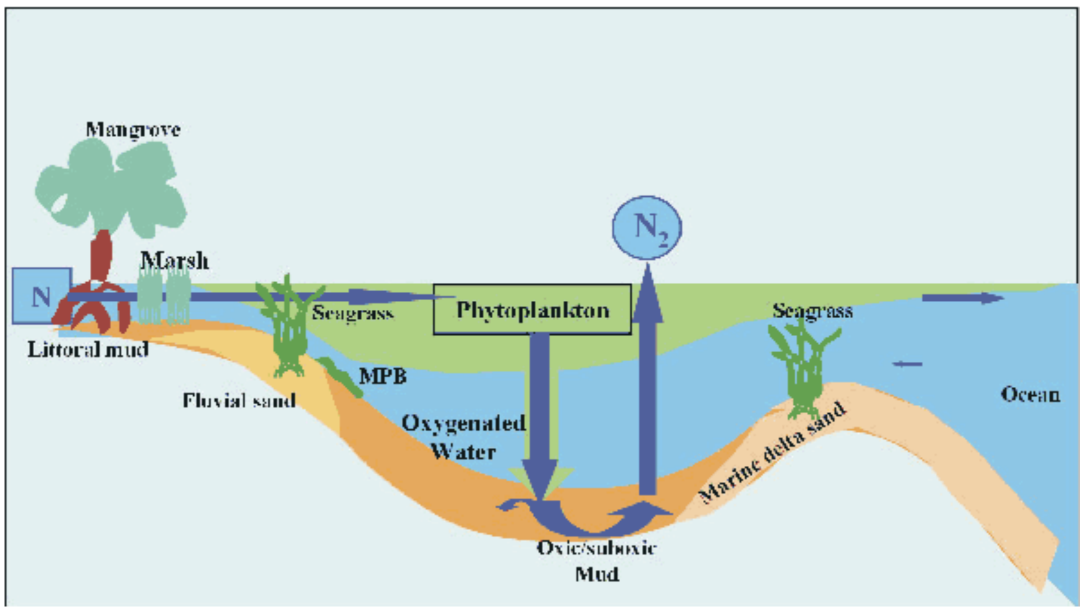


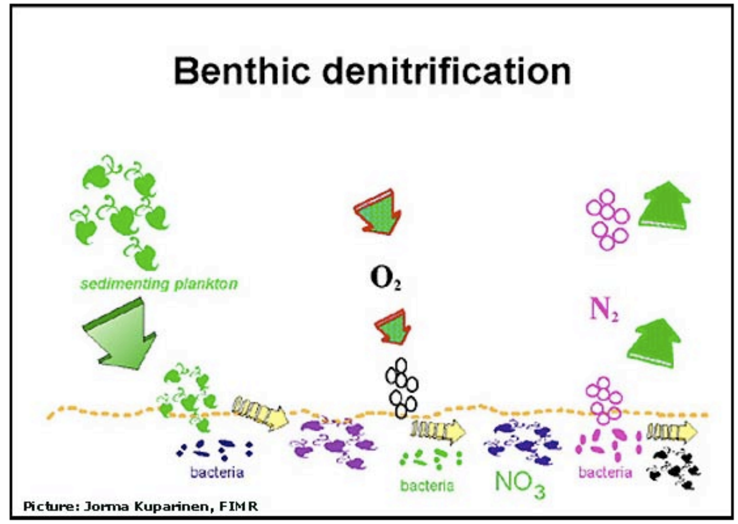
FIG. 6. – Sediment profile images from depths between 40 and 120 m in the Kattegat (West Sweden). The yellow colour indicates the oxidised sub-oxic zone and the darker zone is reduced sediment (colours are digitally enhanced). The large burrows at 60 to 120 m depth are probably made by the crustaceans *Calocaris macandreae* and *Maera loveni*. Several polychaetes are seen in the image from 100 m and appear to be *Heteromastus filiformis*. The vertical scale is centimetres, and the black rectangle masks reflections of the flash (from Rosenberg *et al.*, 2000)

Denitrification

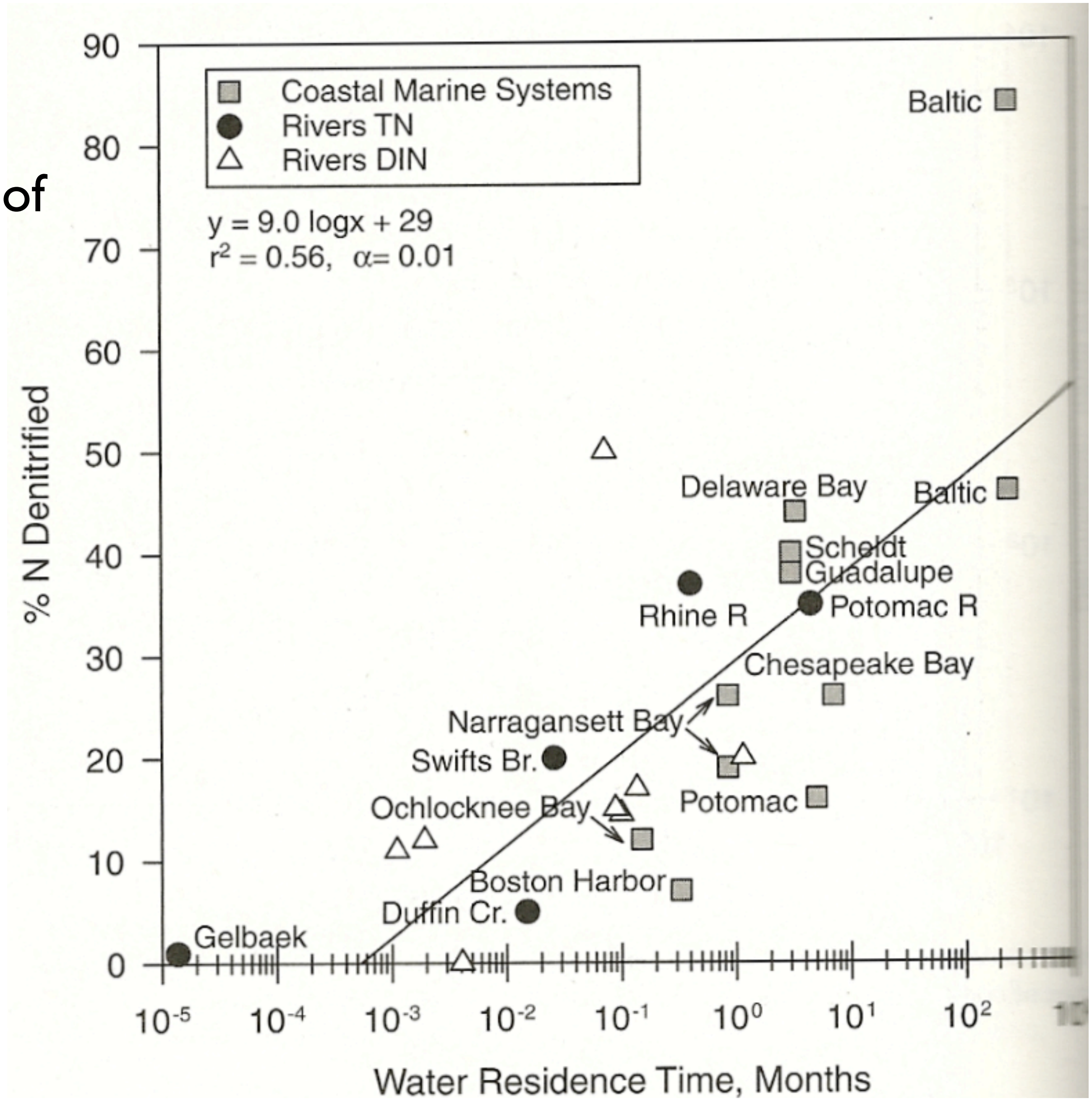
an especially important microbial form of respiration in estuaries using NO_3 instead of O_2



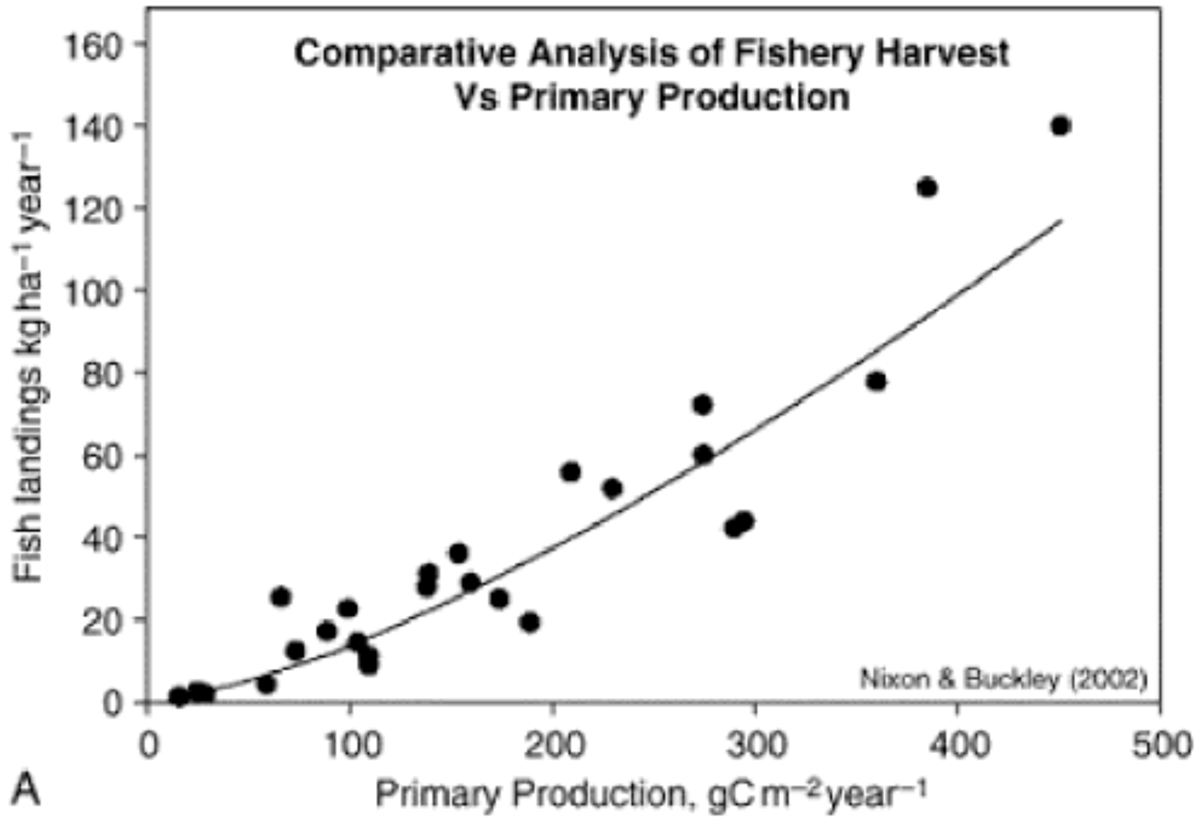




Denitrification can inactivate (--> N_2) significant fractions of nitrate in estuaries



Biomass production



note upward curvature -
more productive systems are more efficient

Estuaries are (relatively) efficient at producing fish

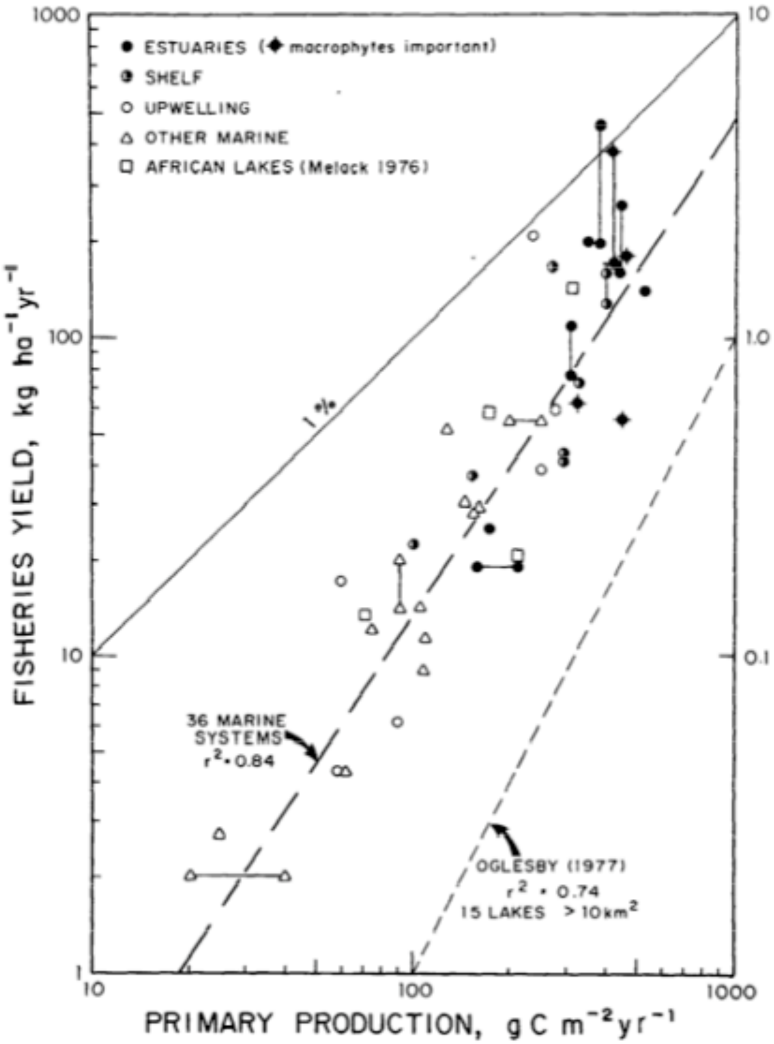
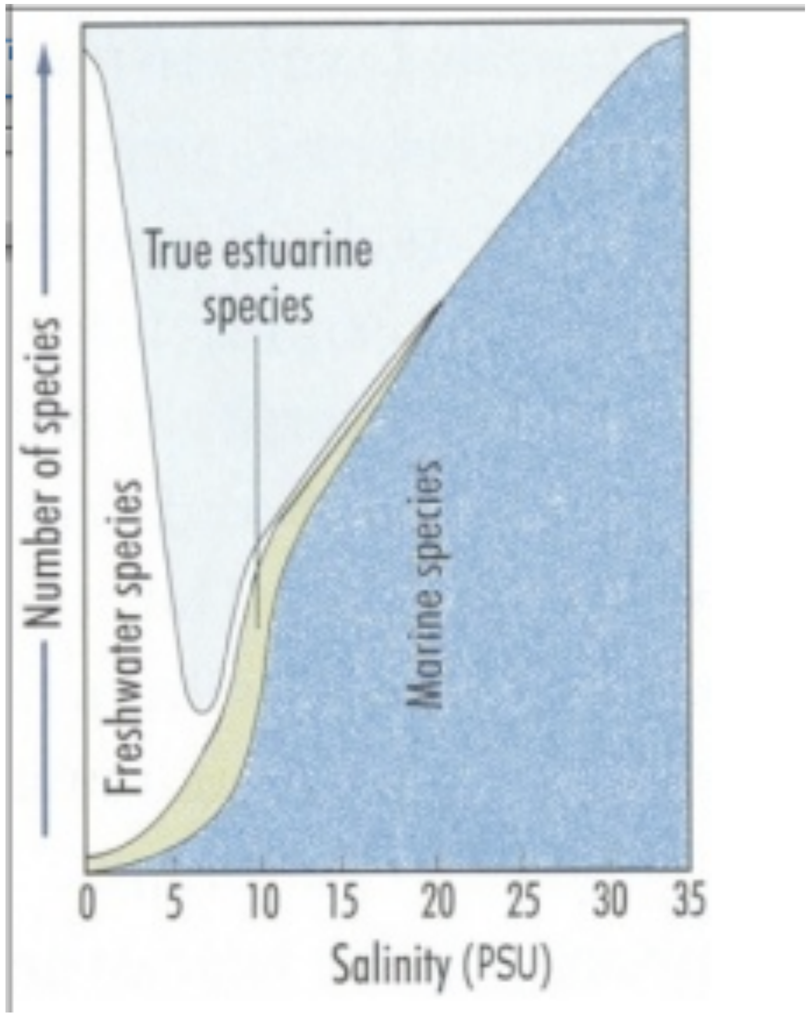


Fig. 6. Fisheries yield (FY) per unit area as a function of primary production (PP) per unit area in a variety of estuarine and marine systems compared with the regression obtained by Oglesby (1977) for large lakes. Regression line for the marine systems is ln FY = 1.55 ln PP − 4.49. A summary of regressions relating gross plankton production from O_2 changes to fish harvests from various intensively managed ponds is given by Liang et al. (1981). The fisheries landings have been converted to carbon assuming C is 10% of fresh weight (Gulland 1970). Data sources for marine systems given by Nixon (1982) and Nixon et al. (1986*b*).

Nixon SW (1988) Limnol. Oceanogr. 33:1005

Support for high levels of the food chain
goes even higher than fish,
and across ecosystems in both directions

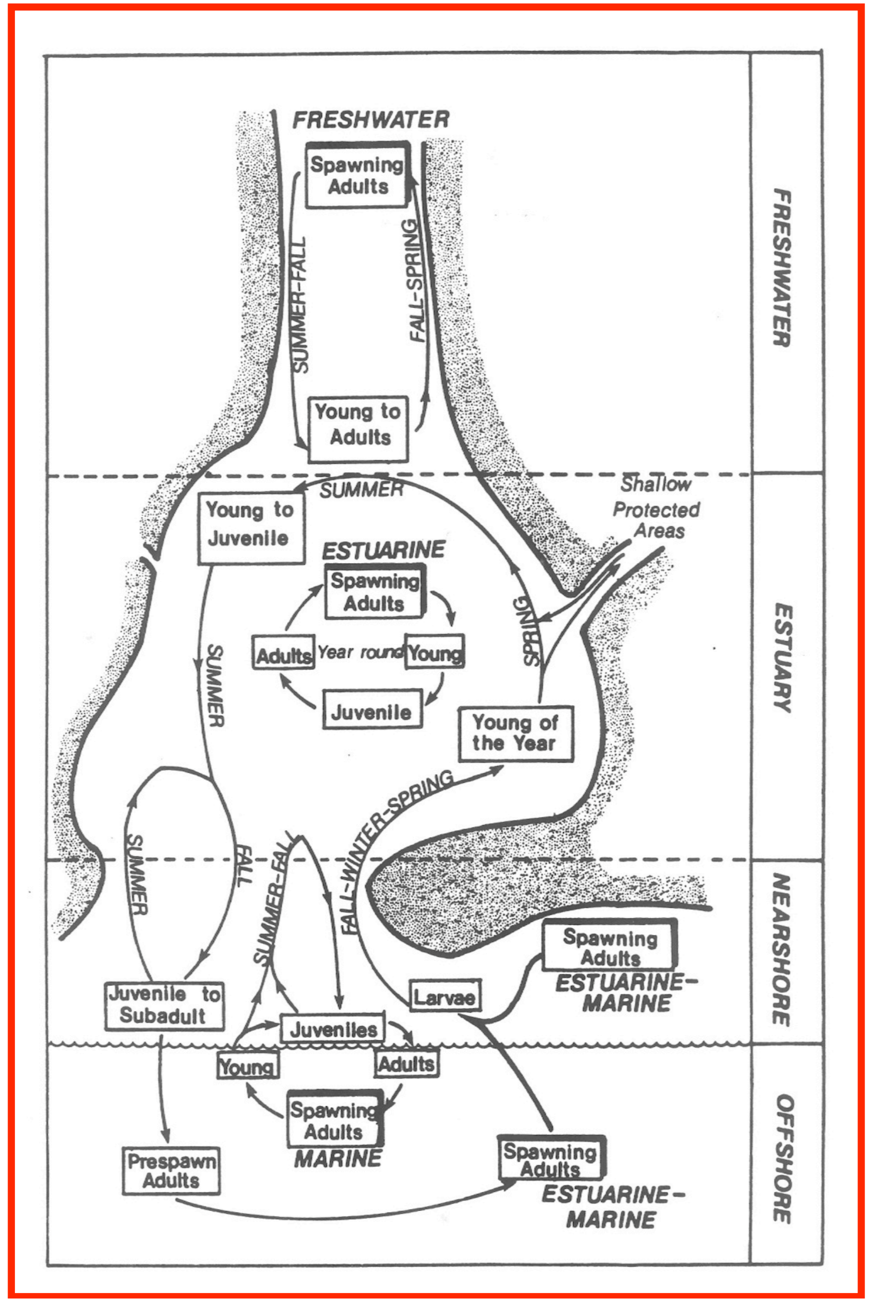
Physiologically, estuaries are a tough neighborhood (for any single organism)



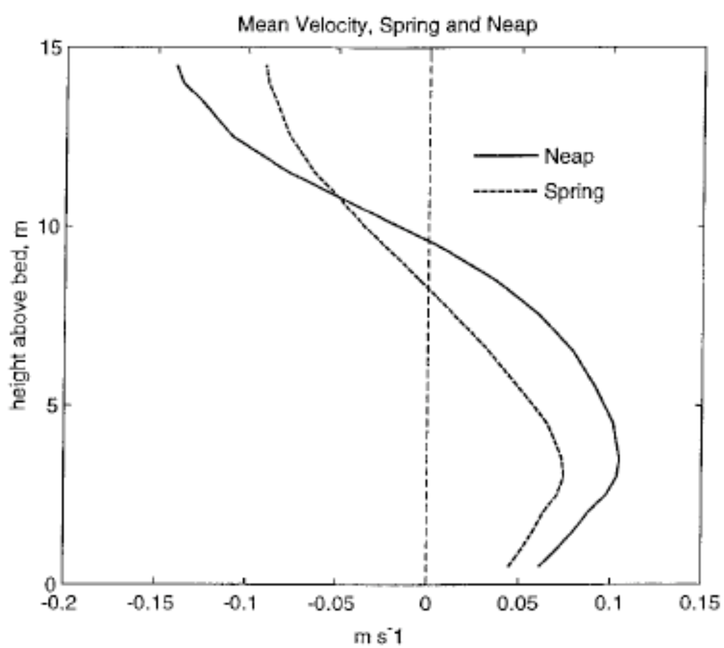
Benthic fauna

Estuaries thus serve as temporary life habitats for many species.

For nutritional and refugium reasons



Animal movement in estuarine flow



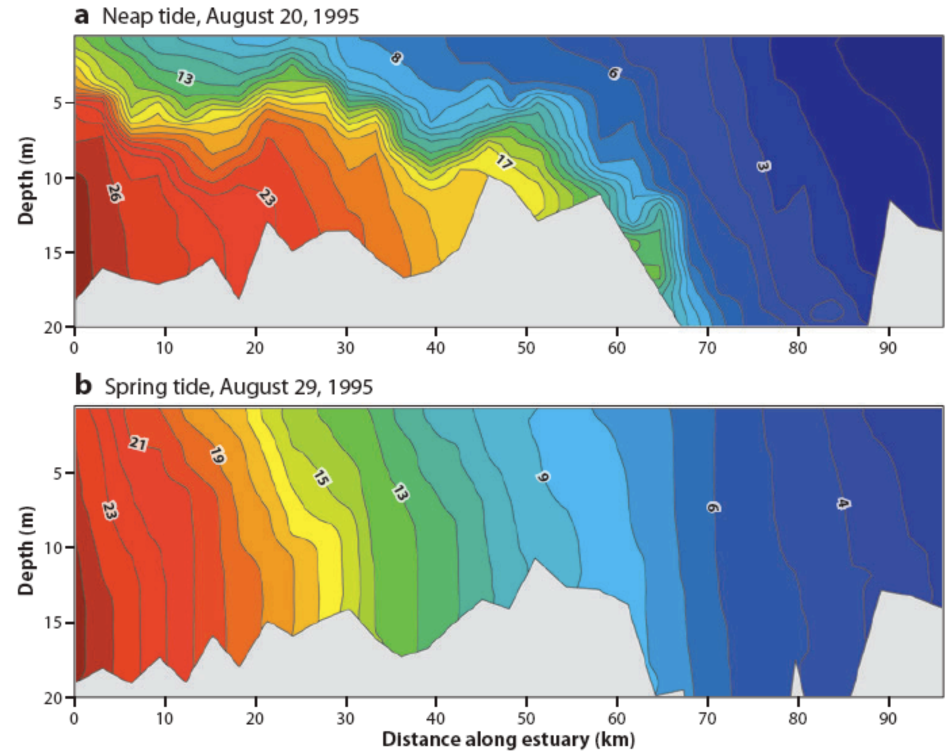


Figure 10

Along-estuary salinity contours in the Hudson River estuary during neap and spring tides, showing the strong spring-neap variation in stratification. The vertically averaged along-estuary salinity distribution changes only slightly, whereas the strength of the stratification changes by an order of magnitude.

52 *MacCready • Geyer*

Tidal Stream Transport interacts with tide, light, and stratification

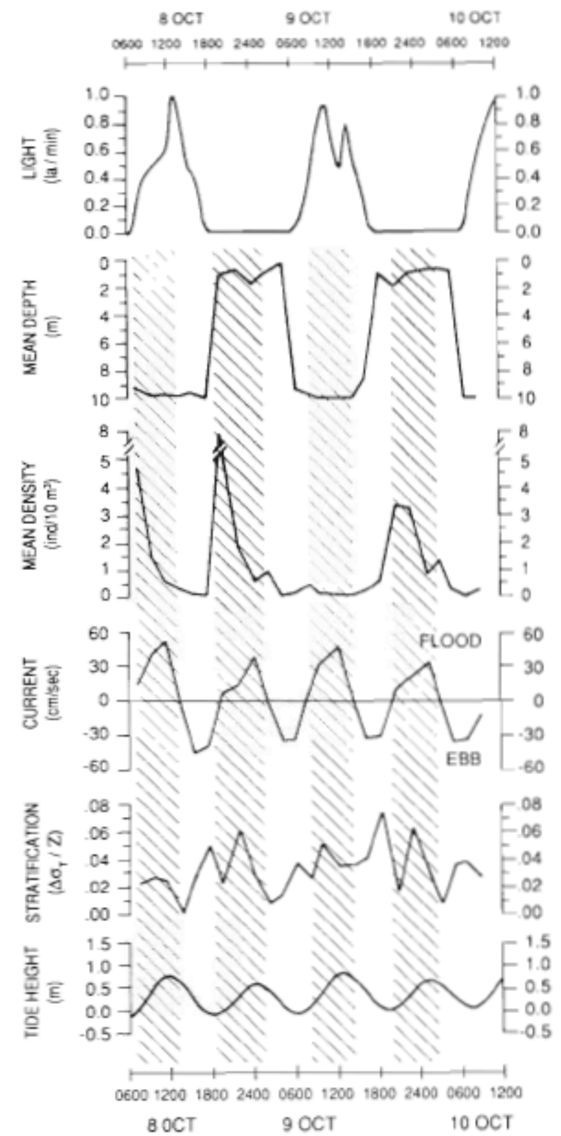


Fig. 5. *Callinectes sapidus*. Mean density and mean depth of megalopae with light, depth-averaged current speed, stratification index, and tidal height during 8–10 October 1990. Shading represents night and hatching indicates times of flood current

Mar. Ecol. Prog. Ser. 113: 39–54, 1994

Clearance time = (estuarine water volume)/(# of filter feeders/water filtration rate per filter feeder)
Residence time = overall water residence time

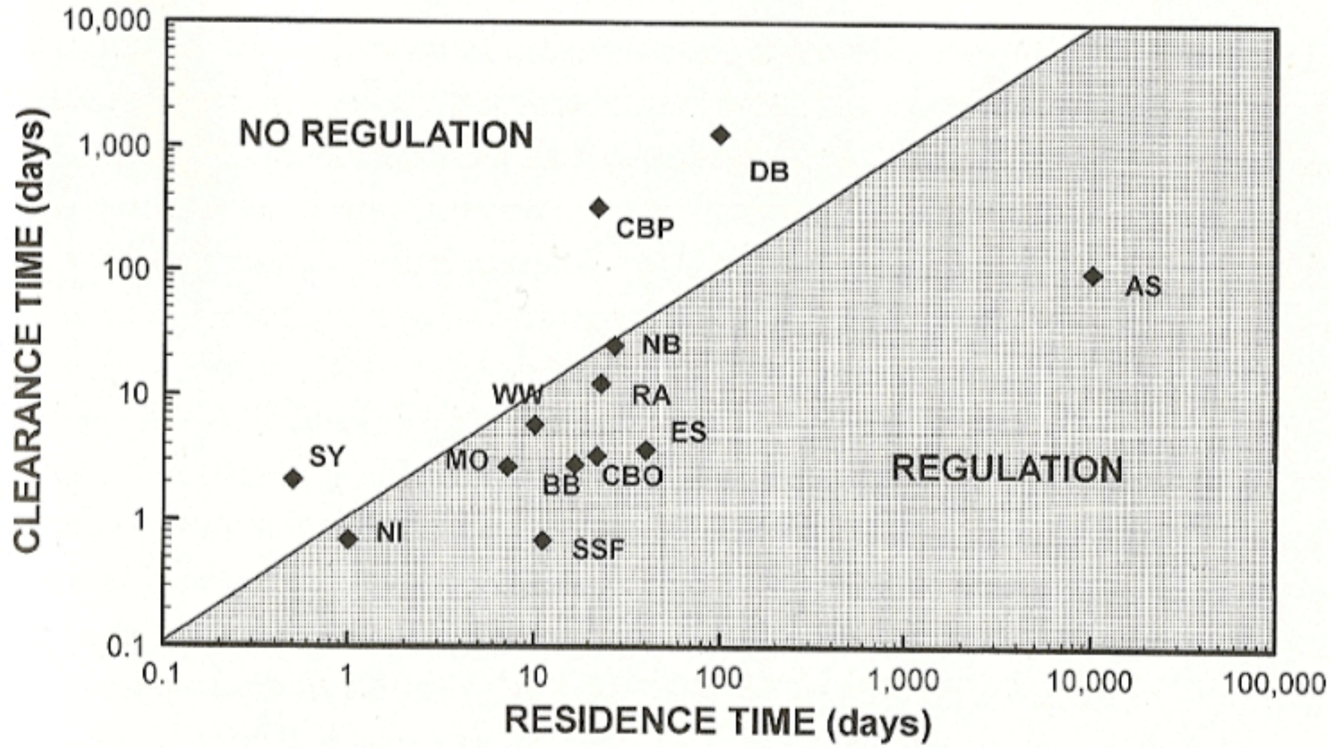


FIGURE 16-5 Relationship between bivalve clearance time and residence time, and potential for suspension feeding to dominate trophic structure, in a number of estuaries (from Dame 1996, used with permission from CRC Press); AS = Asko, Baltic Sea; BB = Bay of Brest; CBO = Chesapeake Bay, past; CBP = Chesapeake Bay, present; DB = Delaware Bay; ES = Eastern Scheldt; NB = Narragansett Bay; NI = North Inlet; MO = Marennes-Oleron Bay; RA = Ria de Arosa; SSF = South San Francisco Bay; SY = Sylt; WW = Western Wadden Sea.