“Autotrophy” (grow your own)
Primary Production

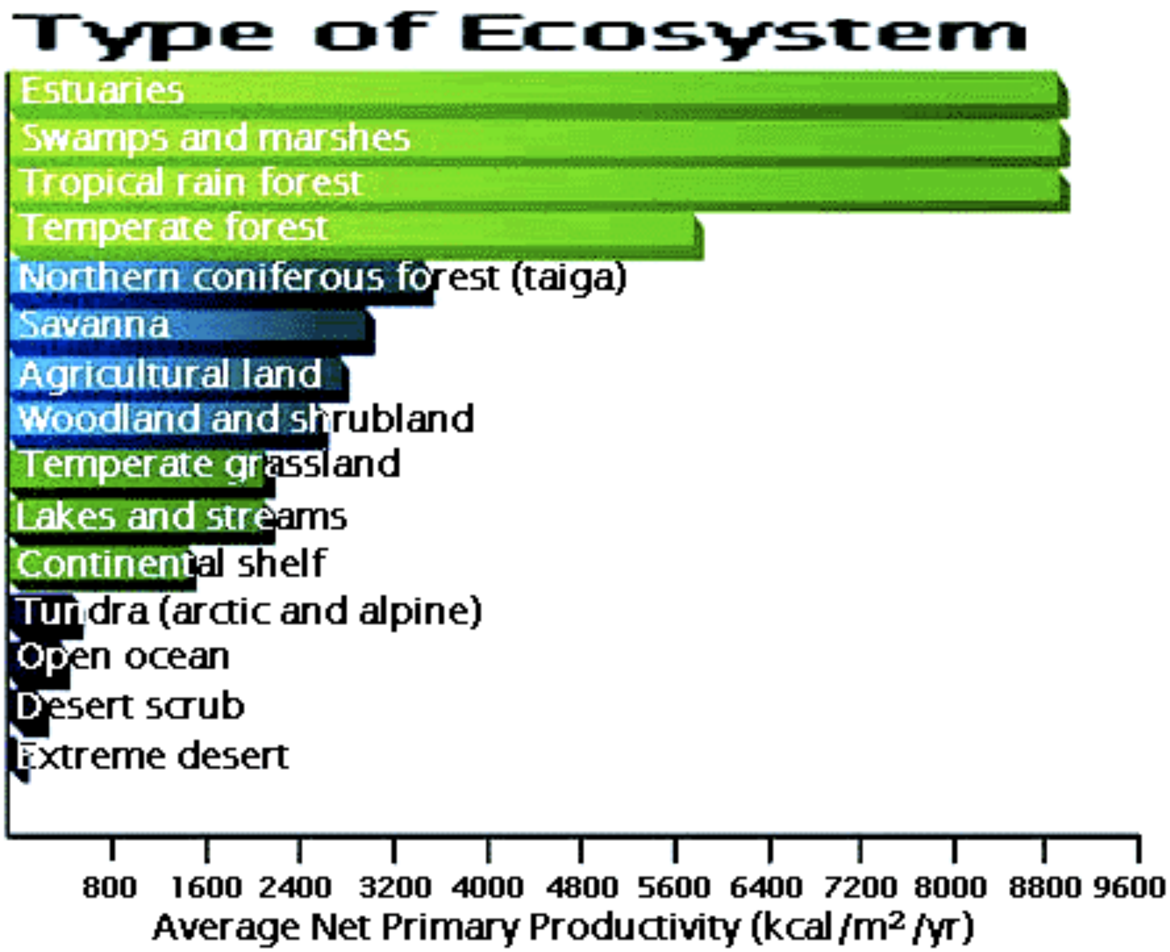


Figure 4. Net Primary Production per unit area of the world's common ecosystems.

WHY?

Planktonic

Benthic (sessile)

What is needed?

Nutrient sources

Rivers (diss/partic)
Groundwater
Ocean
Sediments
Atmosphere

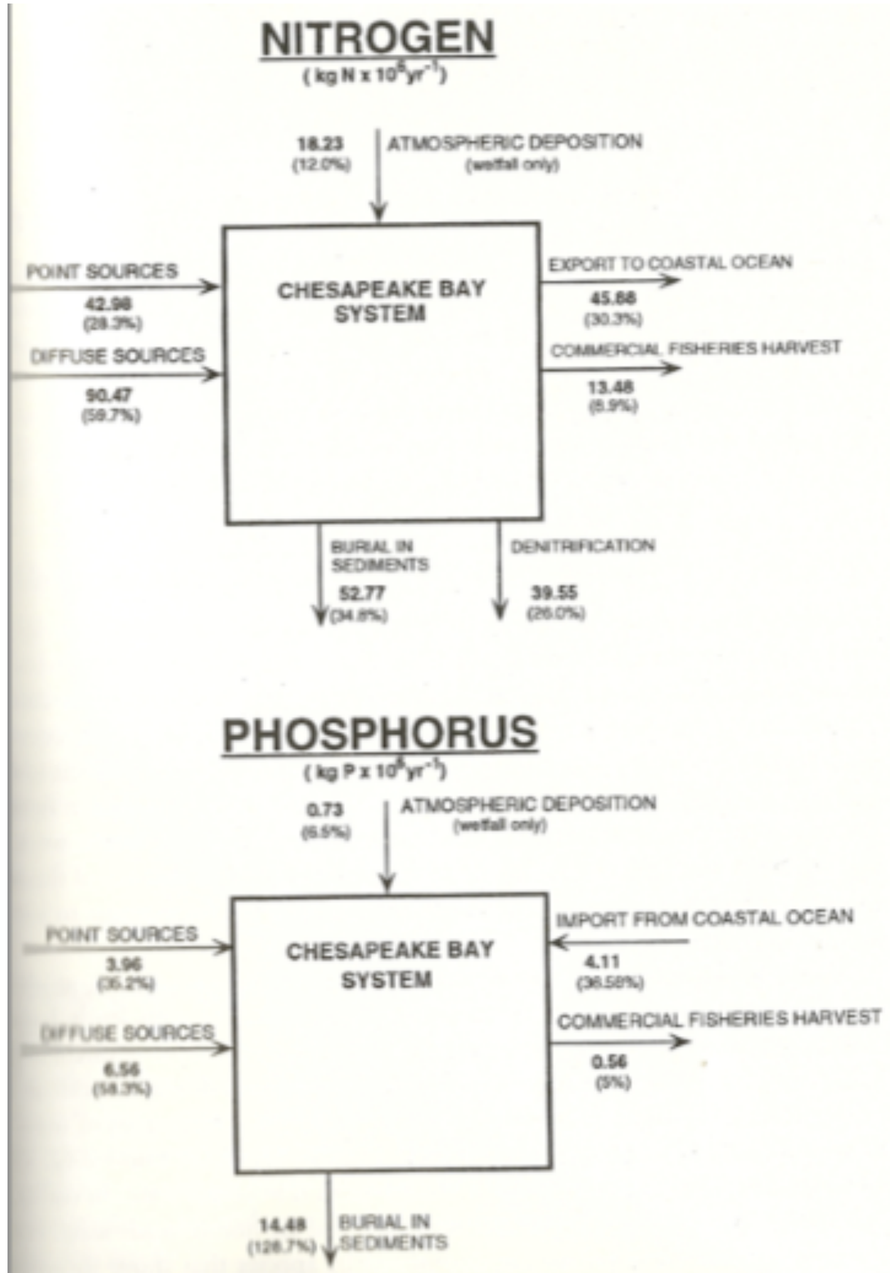


FIGURE 12-7 Nutrient budgets. Nitrogen and phosphorus mass balances for Chesapeake Bay (Boynton et al. 1995, used with permission of the Estuarine Research

Nutrient control of phytoplankton?

934 S. L. Nielsen et al. Estuaries Vol. 25, No. 5, p. 930–937 October 2002

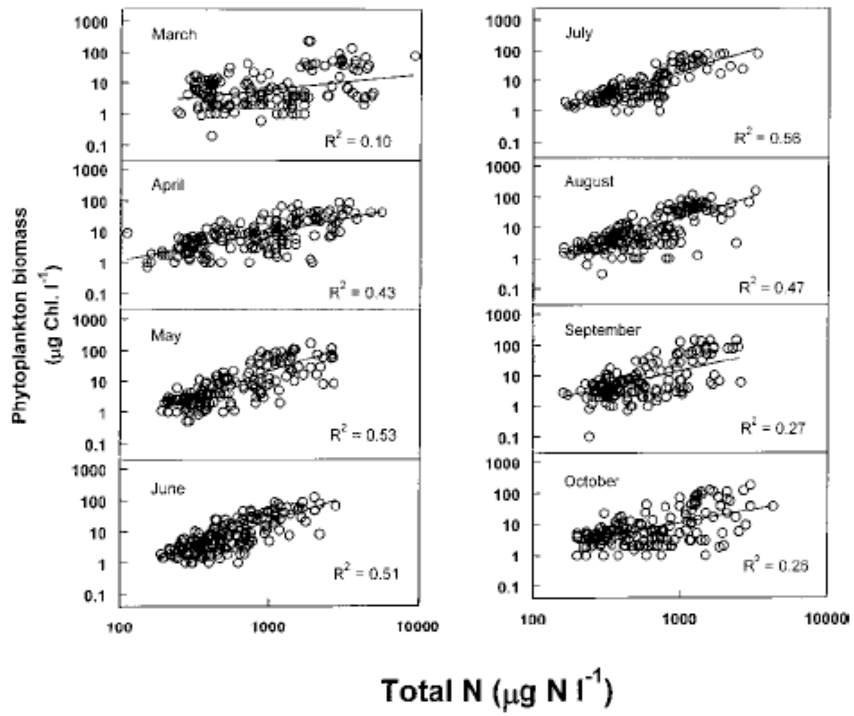


Fig. 2. The relationships between total nitrogen concentration (μg N l^{-1}) and phytoplankton biomass (μg chl *a* l^{-1}) on a monthly basis in the period March–October. The lines represent least squares regression lines fitted on double logarithmically transformed data. The slopes of these lines and the coefficients of determination are given in Fig. 3. The contribution of phytoplankton biomass to total nitrogen has been deducted, as described in the Materials and Methods section.

log-log plot, and for biomass (as chl) not production.

- positive relationship evident but not the whole story (months?)

LIGHT

(incident, I_O)

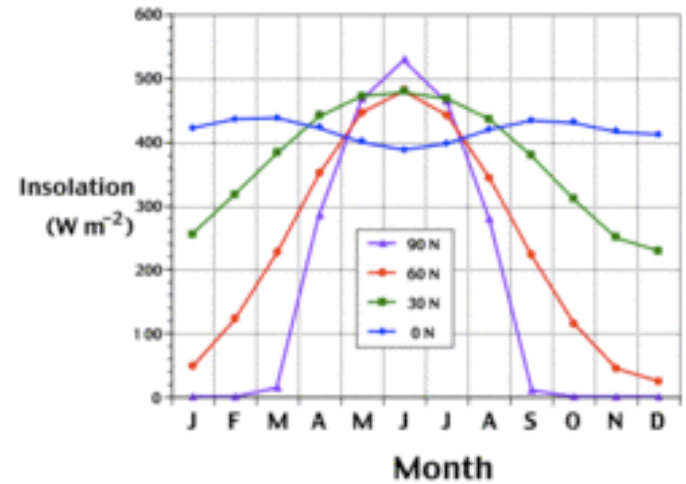
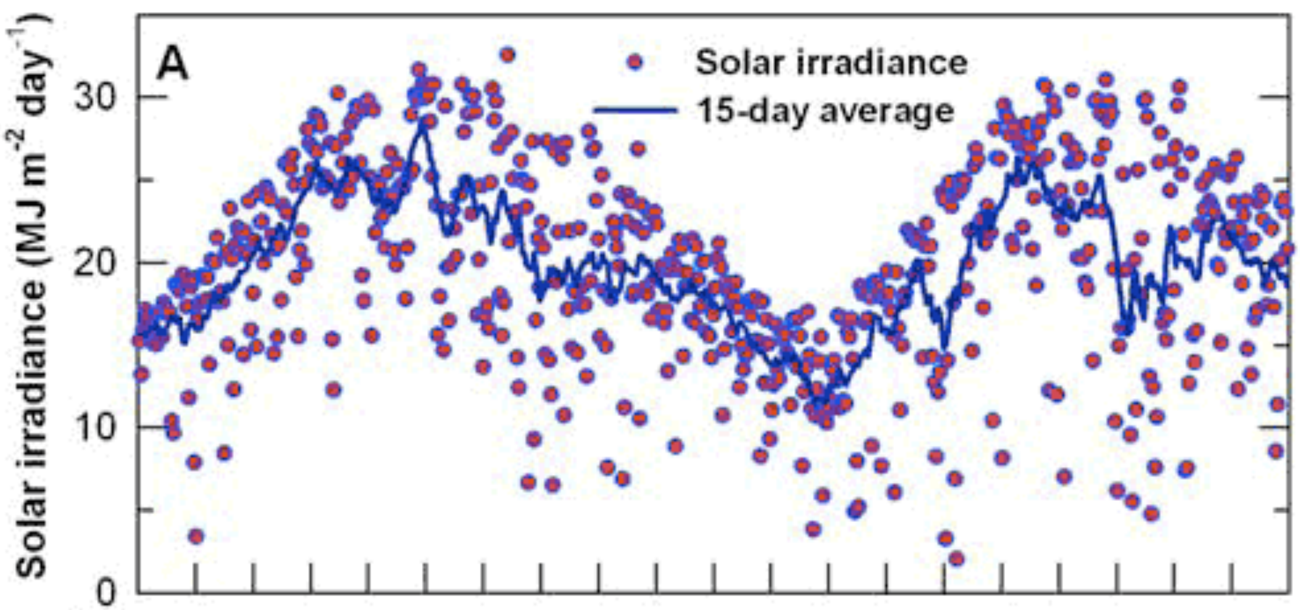
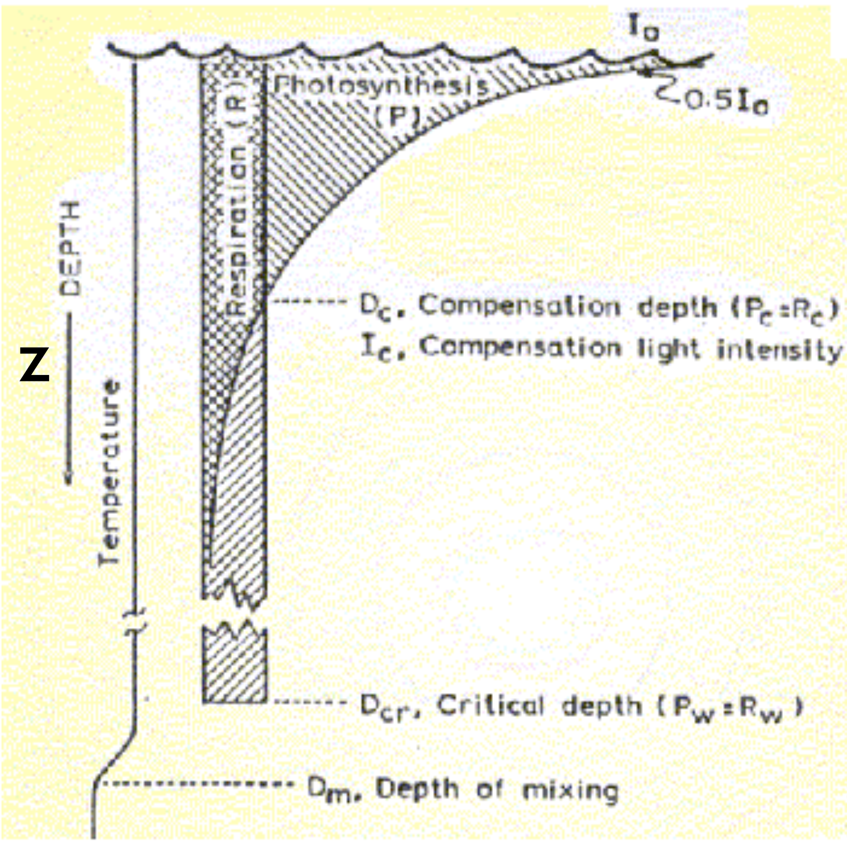


Figure 3: Monthly values of available insolation for the equator, 30, 60, and 90° North. (Source: PhysicalGeography.net)



Everglades

Light: Getting into the water



Sverdrup model

$$I_z = I_o\, e^{-k_T z}$$

make hay while the sun shines

$D_m > D_{cr}$? $D_m < D_{cr}$?

Importance of river nutrients sometimes inferred from flow correlations

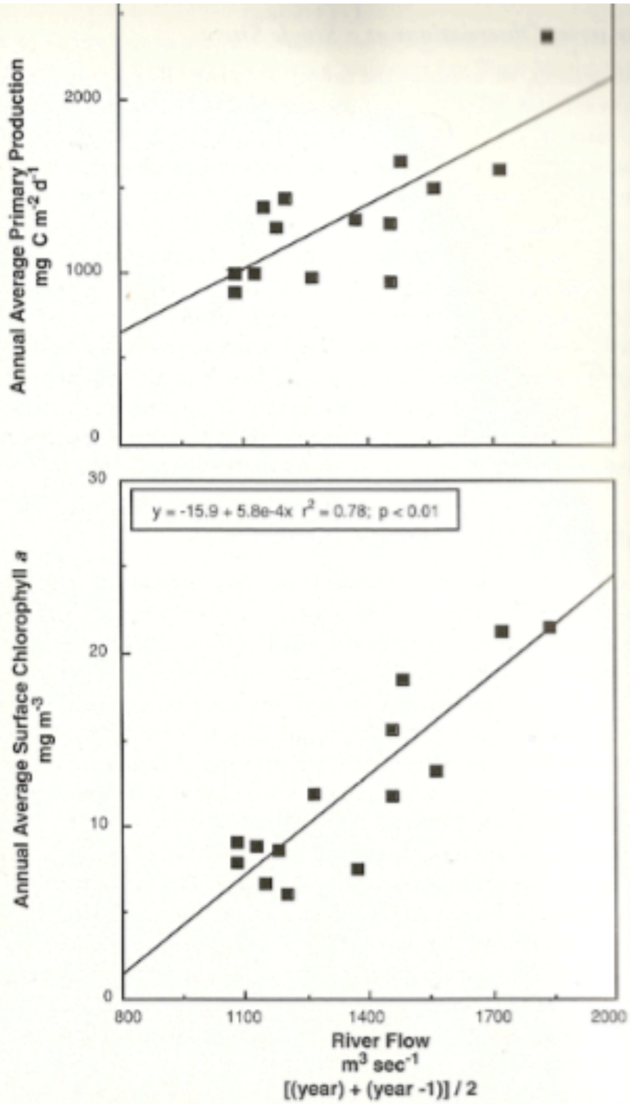


FIGURE 11-4 Results of linear regression models showing relationships betwee annual average phtoplankton primary production and surface chlorophyll *a* concen trations and freshwater flows from the Susquehanna River. River flow was calculat as the average of flow in the present and preceding year. Production and chlorophyll *a* data are from the R-64 site during the periods 1972–1977 and 1985–1993.

BUT...
other ways in which river flow might enhance phytoplankton productivity?

$$I_z = I_o e^{-k_T z}$$

What controls light attenuation?

$$k_T = k_{CDOM} + k_{alg} + k_{SPM}$$

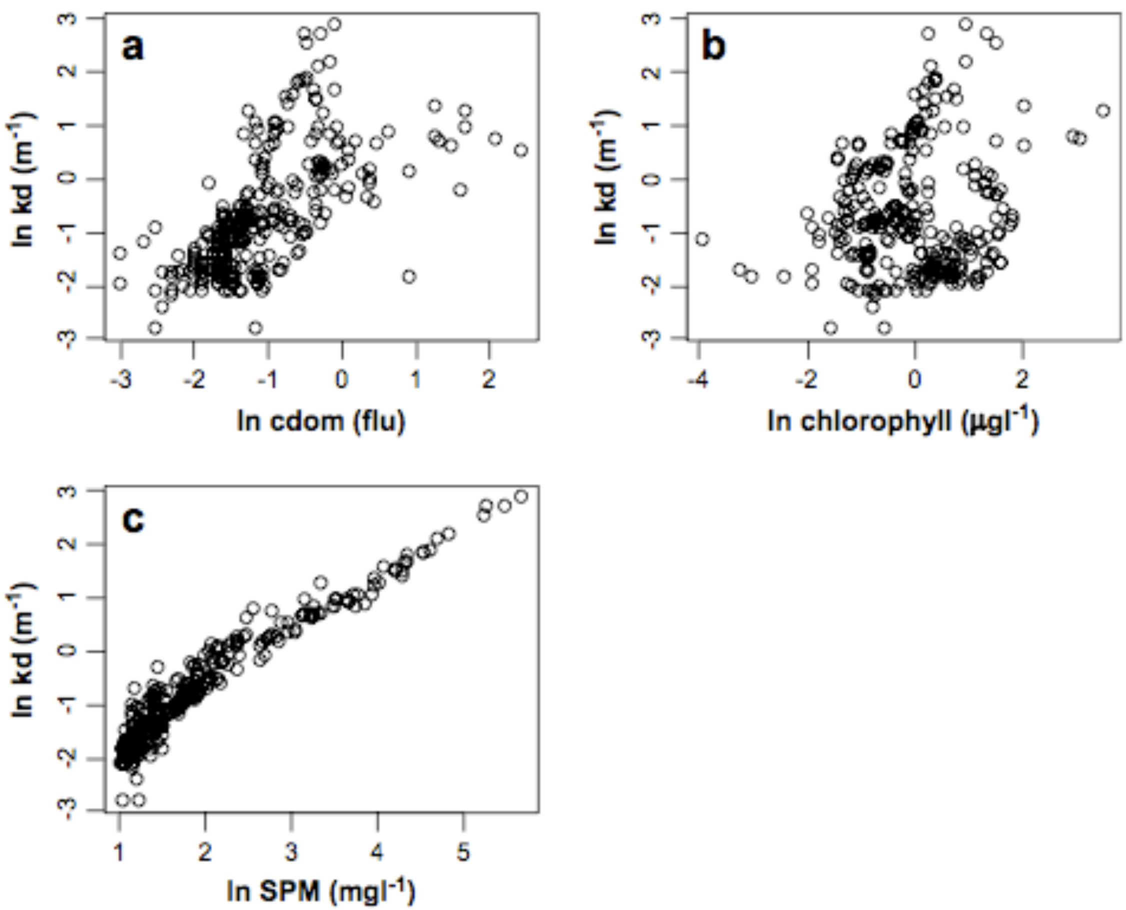


Fig. 1. A map of the British Isles and Republic of Ireland showing the location of sampling sites. Crosses illustrate the stations profiled during the spatial survey. Filled circles denote the site of CEFAS Smart Buoys at the Warp Anchorage in the Thames estuary and in Liverpool Bay. The extent of Water Framework Directive coastal and transitional water types are illustrated in light grey.

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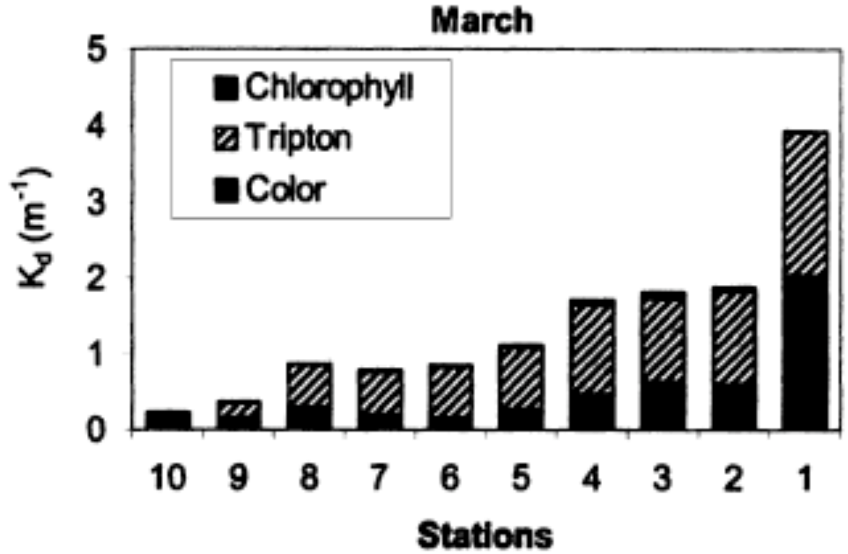

Fig. 3. Light extinction coeficients (K_d) and partial coefficients, K_c (chlorophyll containing particles), K_{ac} (apparent color), and K_t (tripton) for each sampling event.

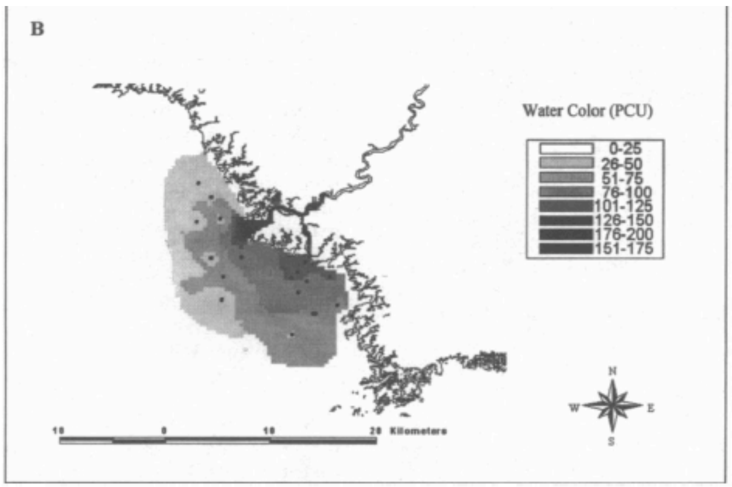

Fig. 2. Mean surface salinity (‰) (A) and mean surface water color (PCU) (B) for 1996–1997. The Suwannee River plume was estimated using salinity and water color during the time period of this study.

Estuaries Vol. 23, No. 4, p. 458–473 August 2000

Relationships Between Phytoplankton Standing Crop and Physical, Chemical, and Biological Gradients in the Suwannee River and Plume Region, U.S.A.

Erin L. Bledsoe
Edward J. Philips[1]

Muddy Estuaries

"Photic Depth" = $z_{1\%}$

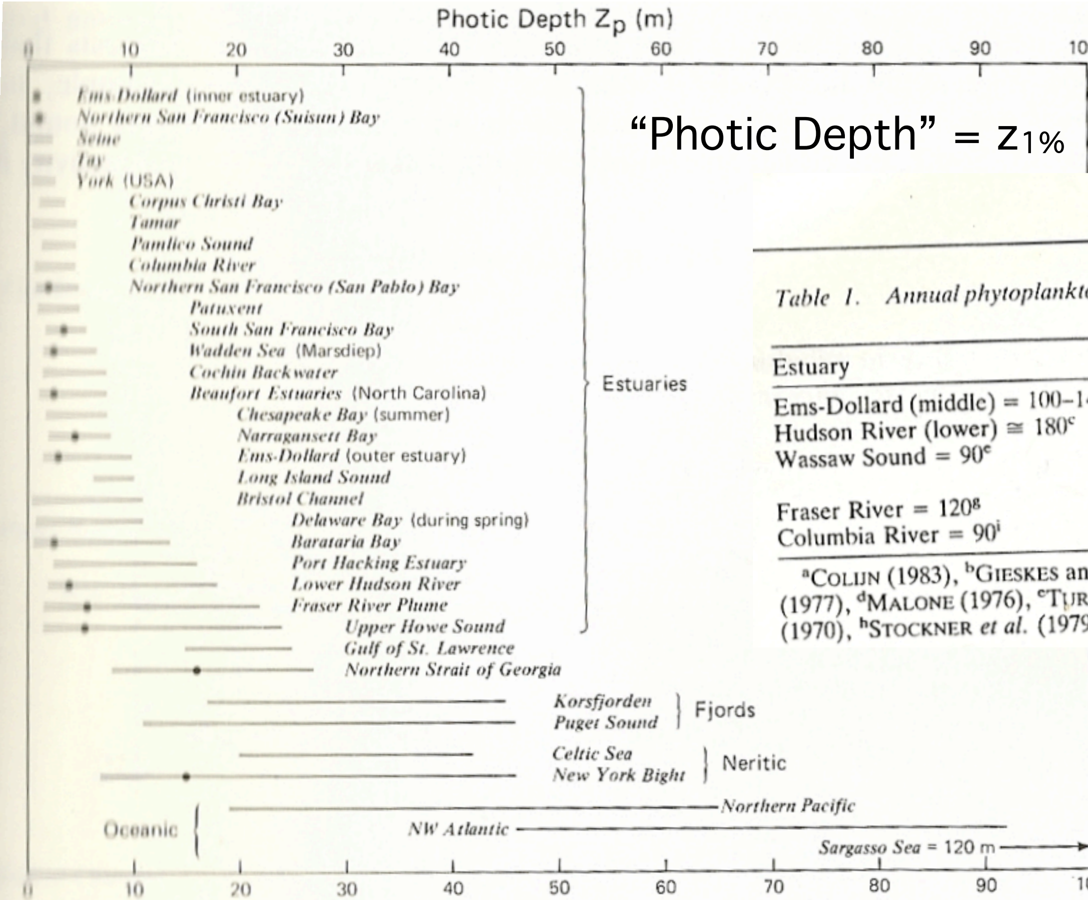

Fig. 3. Photic depths (means shown as circles and ranges shown as horizontal lines) in a variety of estuaries, compared to other marine waters. Photic depths were calculated as $4.61/k_T$ where k_T was either (1) measured directly, (2) estimated as 1.7/Secchi depth, or (3) estimated as 0.06 × SPM where SPM was measured. Data are from the following: Ems-Dollard (COLIJN, 1982), San Francisco Bay (CLOERN *et al.*, 1985), Seine (ROMANA, 1979), Tay (SHOLKOVITZ, 1979), York (MEADE, 1972), Corpus Christi Bay (FLINT, 1984), Tamar (OWENS, 1985), Pamlico (KUENZLER *et al.*, 1979), Columbia River (SMALL and FREY, 1984), Patuxent (STROSS and STOTTLEMEYER, 1965), Wadden Sea (CADÉE and HEGEMAN, 1979), Cochin Backwater (QASIM, 1979), Beaufort estuaries (THAYER, 1971), Chesapeake Bay (CHAMP *et al.*, 1980), Narragansett Bay (OVIATT *et al.*, 1981), Long Island Sound and northwest Atlantic (reported by RYTHER and YENTSCH, 1957), Bristol Channel (JOINT and POMROY, 1981), Delaware Bay (PENNOCK, 1985), Barataria Bay (SKLAR and TURNER, 1981), Port Hacking Estuary (SCOTT, 1978), Hudson River and New York Bight (MALONE, 1980), Fraser River and Strait of Georgia (STOCKNER *et al.*, 1979), Howe Sound (STOCKNER *et al.*, 1977), Gulf of St. Lawrence (SEVIGNY *et al.*, 1979), Korsfjorden (ERGA and HEIMDAL, 1984), Puget Sound (WINTER *et al.*, 1975), Celtic Sea

J. E. CLOERN

Table 1. Annual phytoplankton production (g C m^{-2}) *in five estuaries and in the adjacent coastal ocean*

Estuary	Coastal ocean
Ems-Dollard (middle) = 100–140[a]	North Sea coastal zone = 160–240[b]
Hudson River (lower) ≅ 180[c]	New York Bight = 370[d]
Wassaw Sound = 90[e]	Shelf waters off Georgia = 285[f]
	Altmaha River plume = 600[f]
Fraser River = 120[g]	Strait of Georgia = 300[h]
Columbia River = 90[i]	Columbia River plume = 125[j]

[a]COLIJN (1983), [b]GIESKES and KRAAY (1975), [c]COLIJN's (1983) estimate from data of MALONE (1977), [d]MALONE (1976), [e]TURNER *et al.* (1979), [f]reported in YODER *et al.* (1983), [g]PARSONS *et al.* (1970), [h]STOCKNER *et al.* (1979), [i]SMALL and FREY (1984), [j]ANDERSON (1972).

Cloern J.E. (1987) Contin.ShelfRes 7:1367

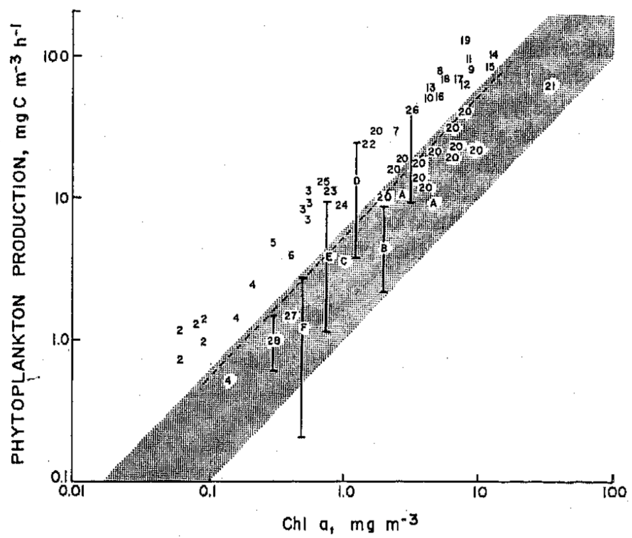

Figure 15

Assimilation efficiency of the phytoplankton in a variety of lagoons around the world (numbered points) compared with the annual range observed in other types of coastal waters (placed arbitrarily on abscissa), a regression developed from observations on 11 marine phytoplankton species during exponential growth in the laboratory (broken line ; Glover, 1980), and a variety of offshore and open ocean measurements reviewed by Parsons and Takahashi (1973). Data from : 1 (Tiahura Lagoon, Moorea Island, French Polynesia, assuming 12 h light, Sournia and Ricard, 1976) ; 2 (Vairao Lagoon, Tahiti, same as 1) ; 3 (Fanning Island, Gilbert Islands, Gordon et al., *1971) ; 4 (Kavaratti Lagoon, Laccadive Islands, Arabian Sea, Quasim* et al., *1972) ; 5-19 (Eastern Gulf of California Lagoons, Mexico, Gilmartin and Revelante, 1978) ; 20 (Inshore North Carolina Sounds, USA, monthly values over an annual cycle, Thayer, 1971) ; 21 (Manguio Lagoon, French Mediterranean, annual mean assuming 12 h day, 50 % active Chl* a *— Vaulot, pers. comm., Frisoni and Vaulot, 1981) ; 22 (Biguglia Lagoon, Corsica, same as 21) ; 23 (Thau Lagoon, French Mediterranean, same as 21) ; 24, 25 (Diana and Urbino Lagoons Corsica, same as 21) ; 26 (San Quentin Lagoon, Pacific Coast, Baja California, Mexico, June-July max-min, Lara-Lara* et al., *1980 ; 27, 28 (Western and Eastern Wadden Sea, annual range, Cadée and Hegeman 1974* a *and* b*) ; A (San Francisco Bay, CA, USA, assuming 6 m depth, 9 and 14 h days, November and August data, Cloern, 1979) ; B (Port Valdeze, Alaska, USA, annual range, Goering* et al., *1973) ; C (Narragansett Bay, R.I., USA, annual range Durbin* et al., *1975) ; D (Surface water, nearshore, Louisiana, USA, annual range, Fucik 1974) ; E (Bedford Basin, N.S., Canada, annual range, Harrison and Platt, 1980) ; Saanich Inlet, B.C., Canada, annual range, Hobson, 1981).*

We usually measure chlorophyll
We usually want production
Any relation?

Units, mg m^{-3} =

N uptake?

Work through Redfield eqn.

How productive can phytoplankton be?

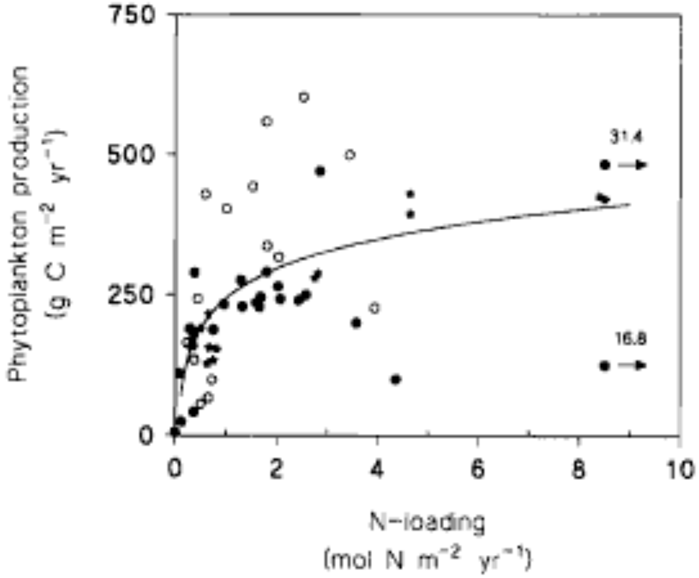

Fig. 1. Annual phytoplankton production as a function of nitrogen loading rate from land of different temperate coastal ecosystems or nutrient enriched mesocosms. Data from (○): Boynton et al. (1982), (*): the MERL mesocosmos experiments (Nixon et al. 1986), and from (●) Danish coastal areas and the literature (see Table 1). Arrows with figures are off-scale data. Regression: $y = 244 + 175 \log(x)$, $r = 0.599$, $n = 51$, $p < 0.001$.

OIKOS 76:2 (1996)

Why the plateau?
Why the noise?

Is Total Primary Production in Shallow Coastal Marine Waters Stimulated by Nitrogen Loading?
Jens Borum and Kaj Sand-Jensen
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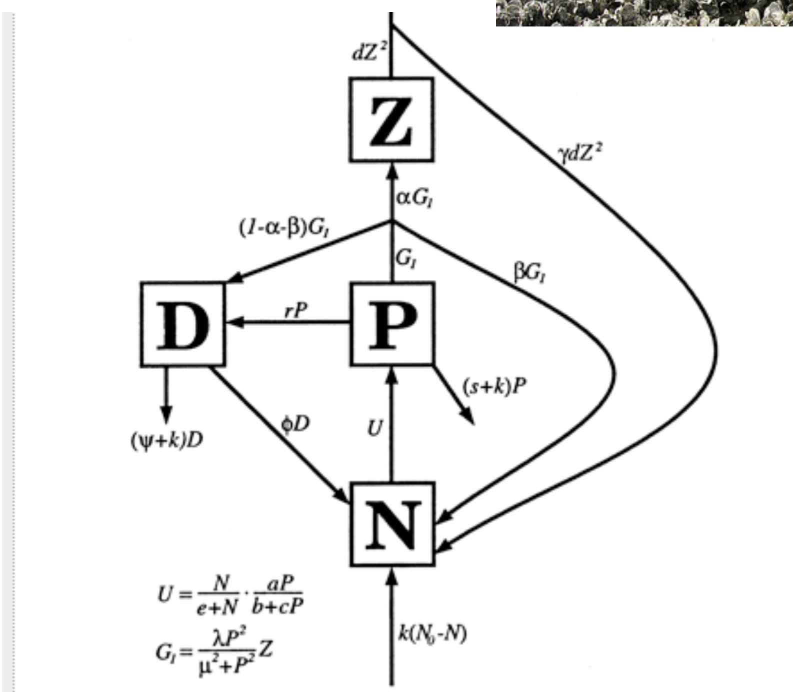
Grazing control?

JGOFS



J. Plankton Res. (2001) 23 (4): 389-413.
doi: 10.1093/plankt/23.4.389

Fig. 1.
Interactions between nutrients (*N*), phytoplankton (*P*), zooplankton (*Z*) and detritus (*D*) for Model 1. Arrows indicate flows of matter

Phytoplankton success: 1st order controls

- nutrients: positive but plateau upon self-shading

- light: positive but complex
    - ratio of photic depth to mixing depth
    - incident light (e.g., season, clouds)
    - competitors for photons (sediment, CDOM)

- mortality (e.g., grazing by zooplankton, benthic FF)

RESIDENCE TIME

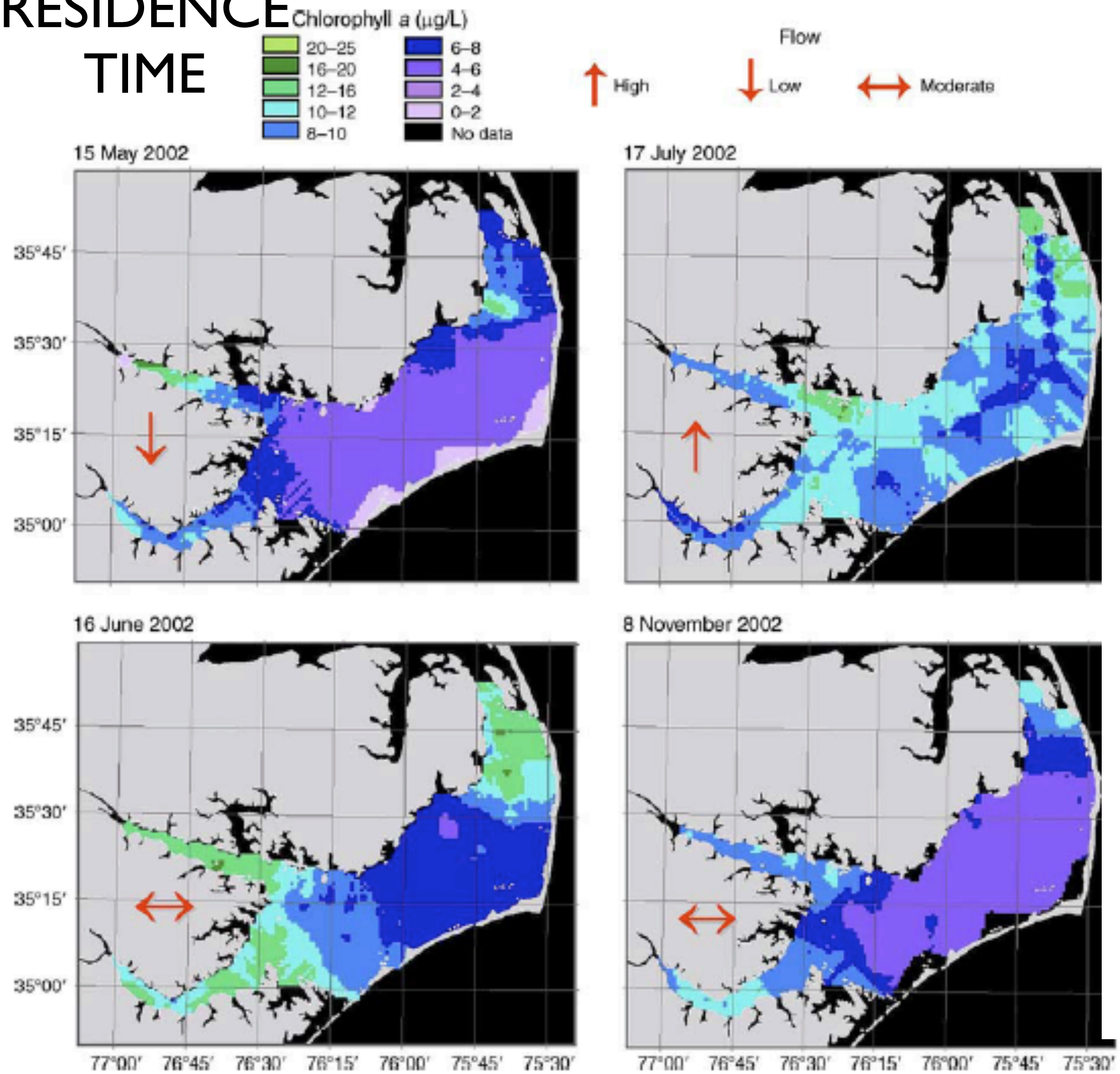


FIG. 8. Spatial relationships between remote-sensed phytoplankton biomass, as chlorophyll *a*, and freshwater discharge (flow arrows) to the Pamlico Sound system. Surface water chlorophyll *a* concentrations were estimated using an aircraft-based sea-viewing wide field-of-view sensor (SeaWiFS) remote sensing system, calibrated by FerryMon-based chlorophyll *a* data. Under relatively low-flow, long residence time conditions, phytoplankton biomass is concentrated in the upstream reaches of the estuarie (i.e., Neuse and Pamlico River Estuaries). Under moderate flow, phytoplankton biomass maxima extend farther downstream

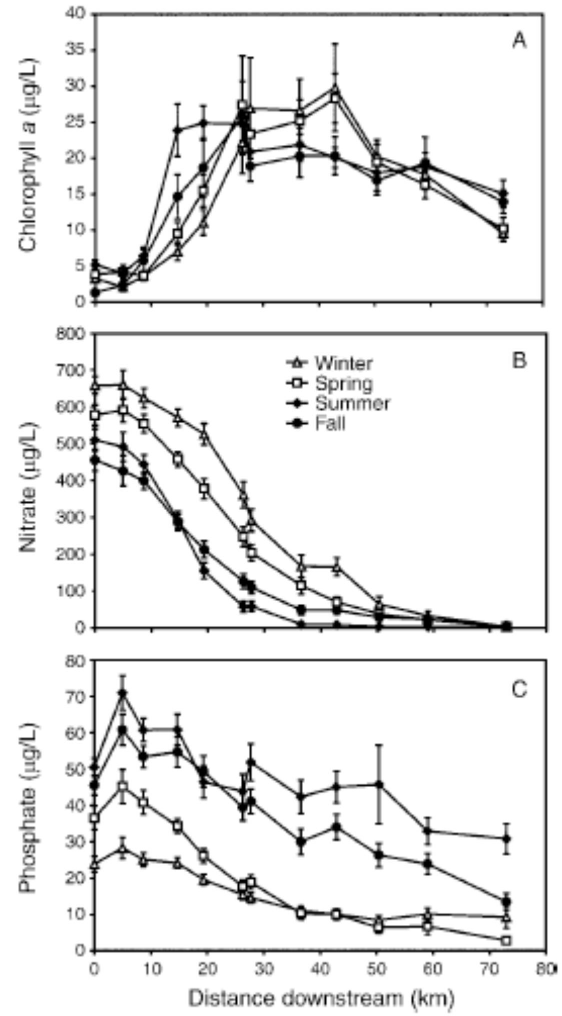


FIG. 4. Seasonal means (±SE) of (A) chlorophyll *a*, (B) nitrate, and (C) phosphate concentrations measured at each sampling station along the length of the Neuse River Estuary for all years from 1994 to 2003. Distance downstream refers to the distance in kilometers of the sampling station from the most upstream sampling location at Streets Ferry Bridge.

Ecological Applications, 17(5) Supplement, 2007, pp. S88–S101

How important are phytoplankton in overall primary production?

Table 1. Estimates of annual benthic, pelagic and total primary production (g C m^{-2} yr^{-1}) in various temperate coastal marine ecosystems. Areas for which annual nitrogen loading from land have been estimated are marked with an asterisk. Conversion factors from dry weight or oxygen to carbon mass were 0.30 and 0.37, respectively.

	Annual primary production			
area	pelagic	benthic	total	reference
*Rottnest Island	6	516	522	Walker et al. (1988)
*St. Margaret's Bay	190	603	793	Mann (1972)
*Chesapeake Bay, Upper	250	144	394	Kemp et al. (1984)
Great South Bay	450	80	530	Lively et al. (1983)
Grays Harbour Estuary	9	303	312	Thom (1984)
Padilla Bay	0	351	351	Thom (1990)
*Bothnian Bay	25	3	28	Elmgren (1984)
*Bothnian Sea	110	3	113	Elmgren (1984)
*Baltic Proper	160	5	165	Elmgren (1984)
*Roskilde Vig	470	0	470	Jensen et al. (1990)
*Roskilde Bredning	233	138	371	Borum et al. (1991)
*Frederiksværk Bredning	188	218	406	Borum et al. (1991)
Puget Sound	465	0	465	Winter et al. (1975)
*Lake Grevelingen	190	130	320	Nienhuis (1992)
*Ems-Dollard	100	60	160	Nienhuis (1992)*
Wadden Sea	200	110	310	Nienhuis (1992)
*Veerse Meer	240	210	450	Nienhuis (1992)
*Oosterschelde	180	60	240	Nienhuis (1992)
*Westerschelde	125	150	275	Nienhuis (1992)
Bissel Cove	56	764	820	Welsh et al. (1982)
Flax Pond	60	359	419	Welsh et al. (1982)
Alewife Cove	162	186	348	Welsh et al. (1982)
Jordan Cove	66	259	325	Welsh et al. (1982)
Niantic River	72	212	284	Welsh et al. (1982)*
Charlestown River	42	274	316	Welsh et al. (1982)
Hempstead Bay	177	104	281	Welsh et al. (1982)*
Narraganset Bay	242	106	348	Welsh et al. (1982)
Tomales Bay	263	66	329	Smith et al. (1991)
San Fransisco Bay SB	76	36	110	Jassby et al. (1993)
San Fransisco Bay NB	45	19	64	Jassby et al. (1993)*
Lower New York Bay	483	0	483	O'Reilly et al. (1976)
Barataria Bay	195	165	360	Day et al. (1973)
Marsdiep Basin	303	10	313	Hoppema (1991)
*Kattegat	290	1	291	Richardson and Christoffersen (1991), Granéli and Sundbäck (1986)
*Ringkøbing Fjord 1987–91	229–291			Ringkøbing County (pers. comm.)
*Various areas	56–603			Boynton et al. (1982)
*MERL mesocosmos	128–430			Nixon et al. (1986)

varies....

Sessile 1°P: Microphytobenthos (intertidal and subtidal)

generally light or grazing, not nutrient, limited

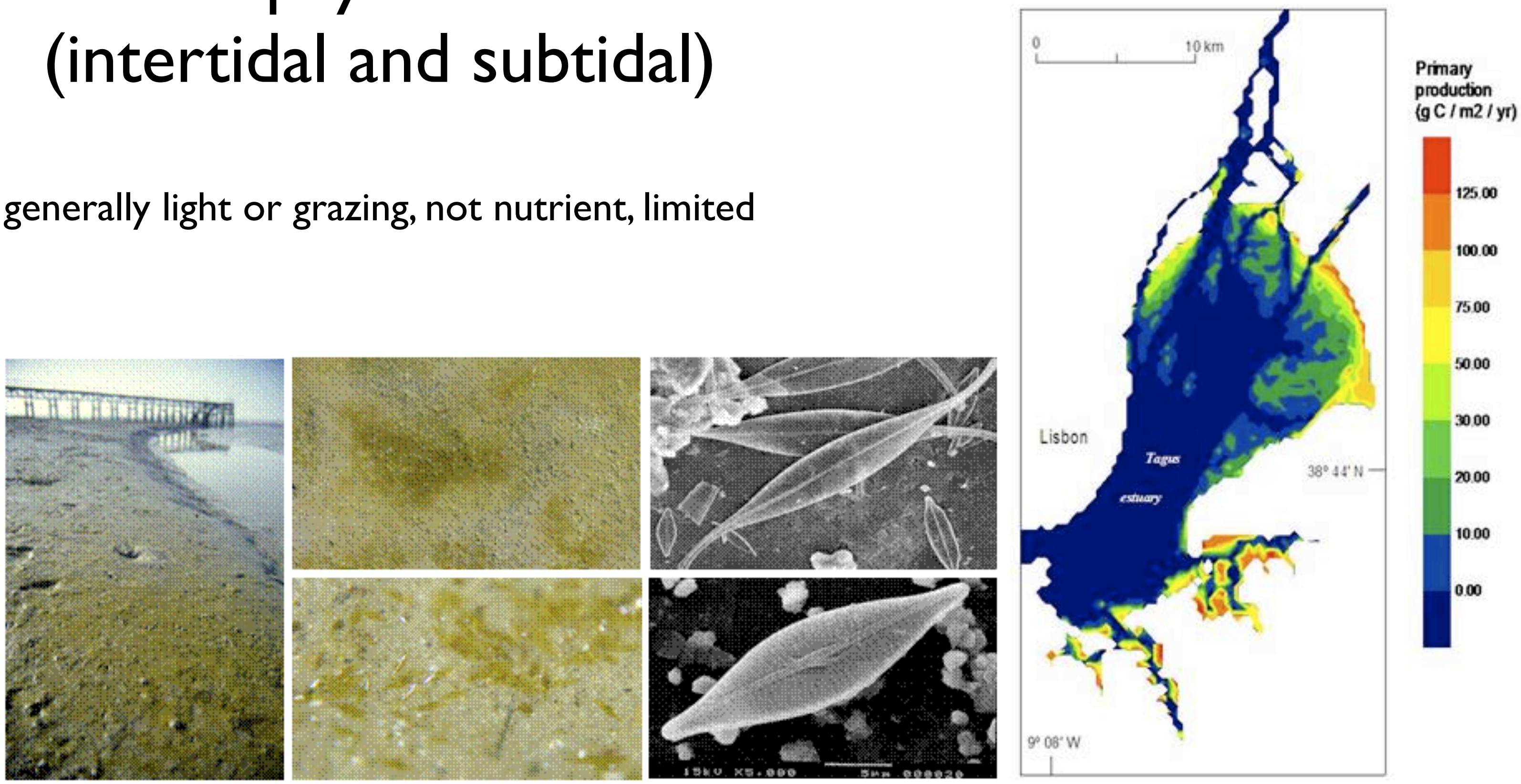


Figure 1. Biofilms of benthic microalgae, or microphytobenthos (MPB) growing on the surface estuarine intertidal flats, detectable by an intense golden-brown colour. The high photosynthetic rates carried out by MPB biofilms contribute to up to 50% of ecosystem-level carbon fixation. For example, for the Tagus estuary, primary productivity by MPB has been estimated to reach over 160 g C m^{-2} d^{-1}, or 4300 ton C yr^{-1}, for the whole intertidal area.

http://la.cesam.ua.pt/highlights/2007/EMM_v1_JoaoSerdio.htm

Salt Marsh

1 g ~ 0.5 g-C

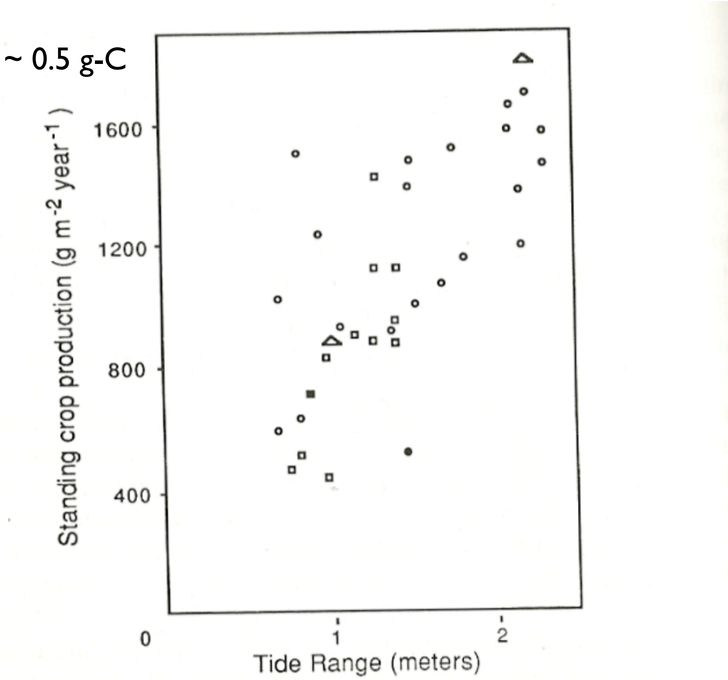
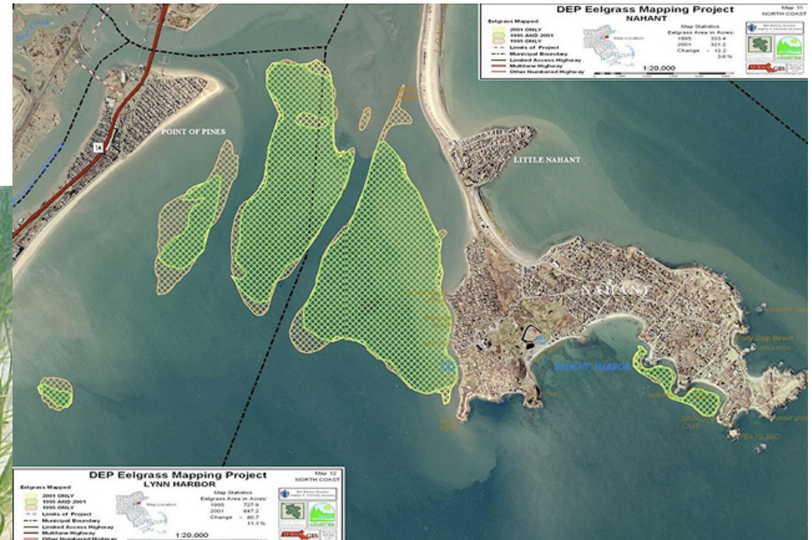


Figure 5.14 Production of intertidal *S. alterniflora* vs. mean tide range for various lantic coastal marshes: o, Long Island Sound; □, Narragansett Bay; ●, North Caroli ■, New Jersey; △ Sapelo Island, Georgia (from Steever et al. 1976).

Salt marsh system in Hampton Harbor (photo by Ben Kimball)



Zostera marina (eelgrass)

“Seagrasses”
(*aka* SAV)

generally need more light than phytoplankton

Ruppia maritima (widgeongrass)

Mangrove

Figure 2. World Distribution of Mangroves

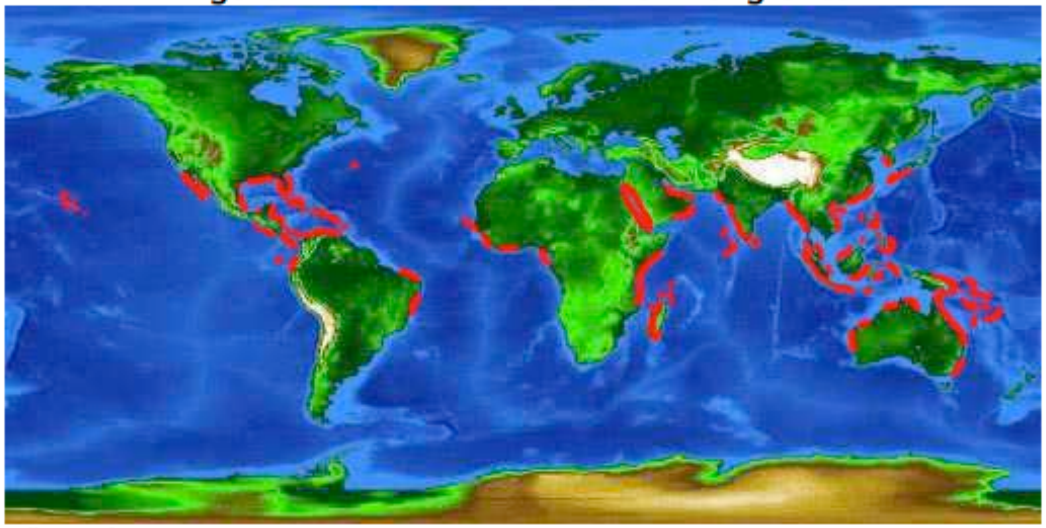


Photo from (SFAE "Distribution", 2006)

Seagrass and Mangrove System Productivity

M. A. Mateo, J. Cebrián, K. Dunton, and T. Mutchler

Table 1. Comparison between average seagrass and other marine and terrestrial ecosystems. NPP (net primary production). Simplified and modified from Margalef, 1986 and Duarte and Cebrián, 1996.

System	Area covered (10^6 km^2)	NPP (gC m^{-2} year^{-1})	Total NPP (PgC year^{-1})
Marine phytoplankton			
Oceanic waters	332	130	43
Coastal waters	27	167	4.5
Coastal macrophytes			
Mangroves	1.1	1000	1.1
Seagrasses	0.6	817	0.49
Macroalgae	6.8	375	2.55
Microphytobenthos	6.8	50	0.34
Terrestrial ecosystems			
Forests	41	400	16.4
Crops	15	350	5.25
Deserts	40	50	2
Terrestrial ecosystems	148	200	29.6
Continental waters	1.9	100	0.19
Oceans	359	132	47.5

NET vs GROSS

SEAGRASSES: BIOLOGY, ECOLOGYAND CONSERVATION

ANTHONY W.D. LARKUM, ROBERT J. ORTH and CARLOS M. DUARTE

Revisit Planktonic vs. Benthic (sessile)

f(nutrients, depth,...)

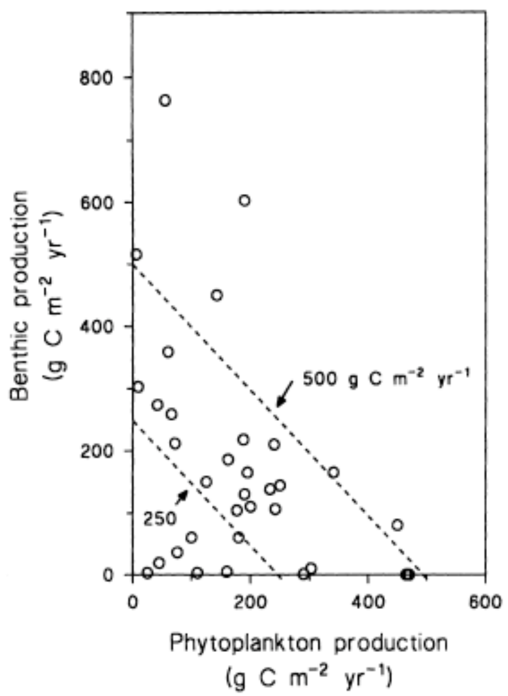


Fig. 2. Annual production of benthic plant communities compared with the annual phytoplankton production of different temperate coastal areas (see Table 1). The stippled lines indicate where the combined production of phytoplankton and benthic plants is 250 and 500 g C m^{-2} yr^{-1}.

Is Total Primary Production in Shallow Coastal Marine Waters Stimulated by Nitrogen Loading?
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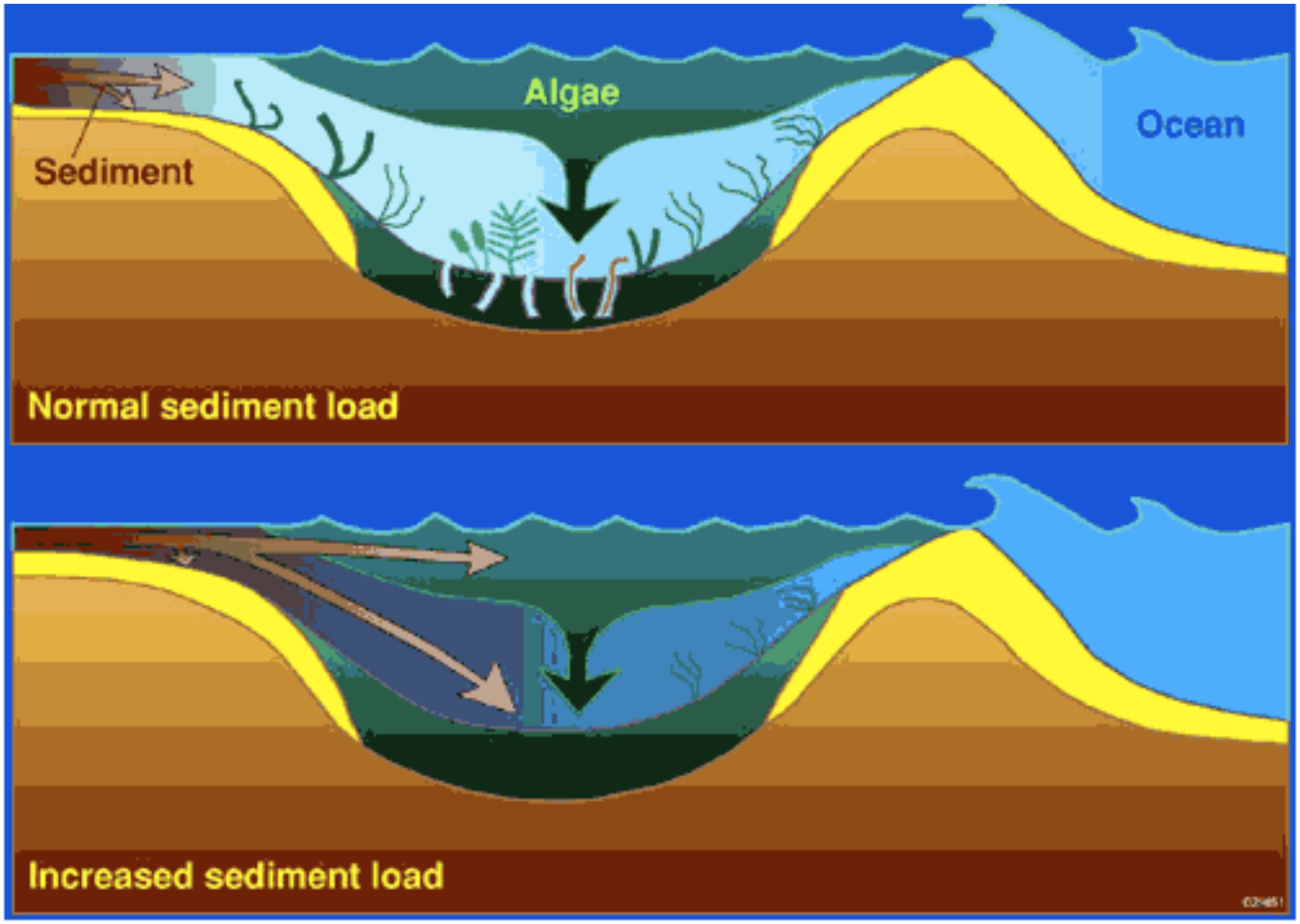
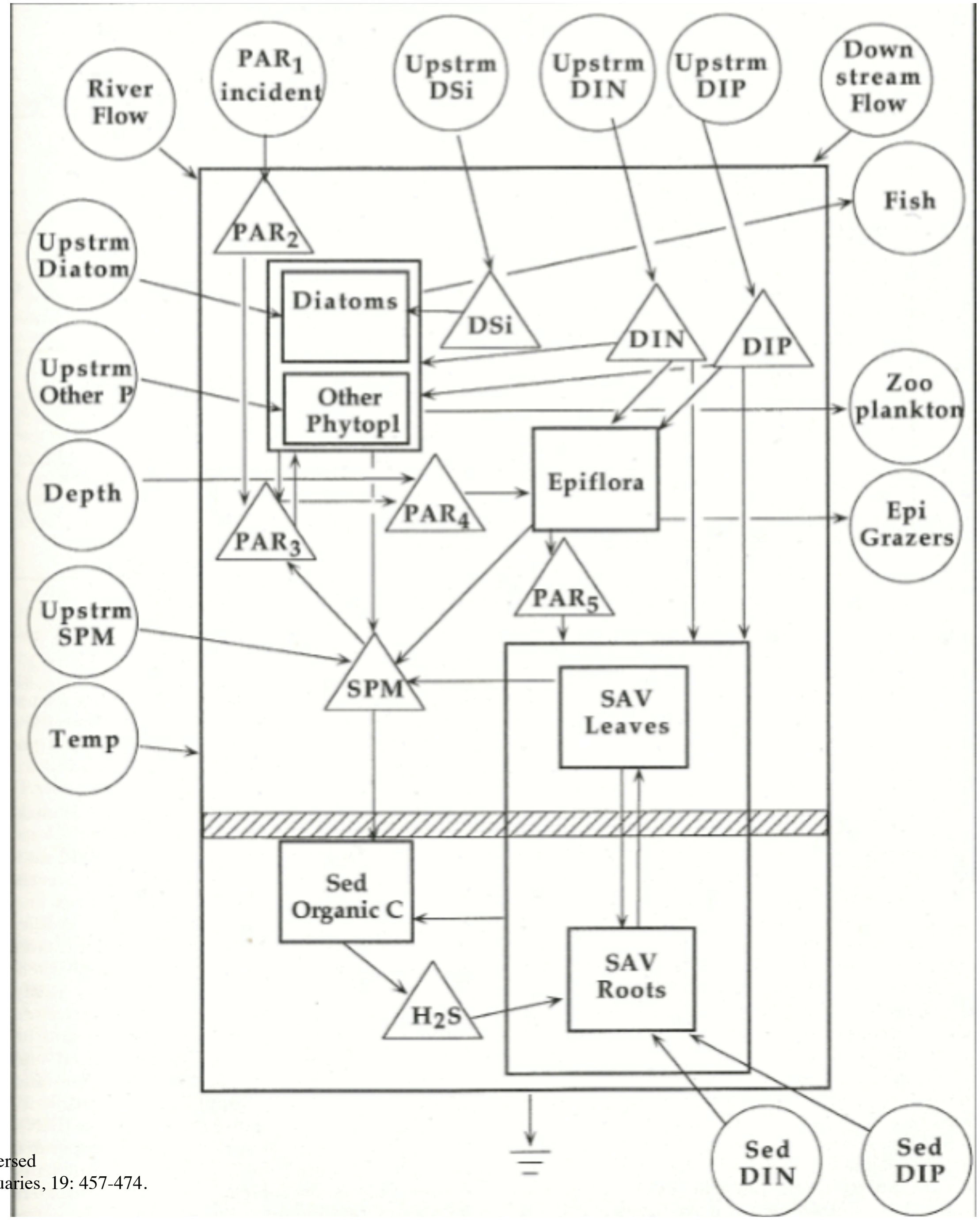
Modulating via light - via sediment or nutrients

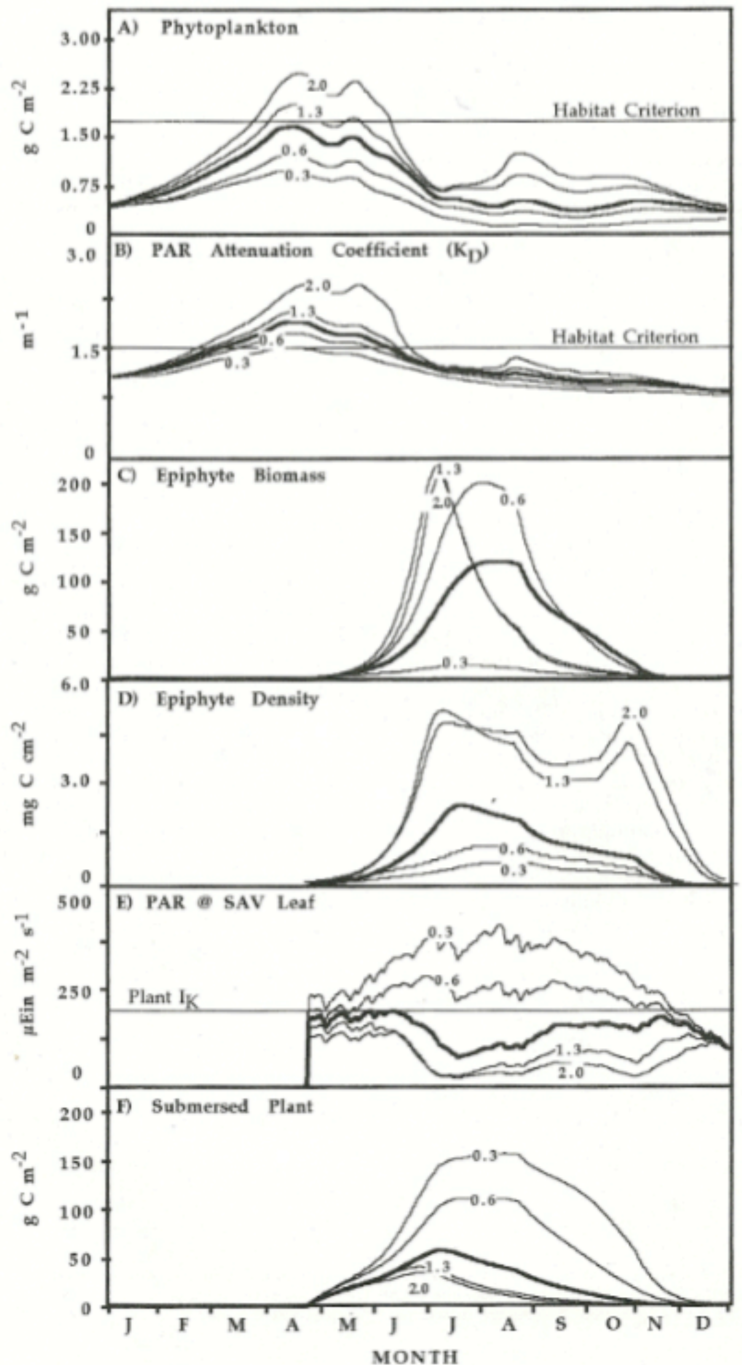


Concept map for this competition



Madden, C.J. and Kemp, W.M. 1996. Ecosystem model of an estuarine submersed plant community calibration and simulation of eutrophication responses. Estuaries, 19: 457-474.

Model output under various nutrient loading conditions



Madden, C.J. and Kemp, W.M. 1996. Ecosystem model of an estuarine submersed plant community calibration and simulation of eutrophication responses. Estuaries, 19: 457-474.