

Produção primária - Tópicos

- Tipos de produtores e taxas de produção
- Medição da produção primária
- Mecanismos – Curvas PI e blooms
- Distribuições e tendências
- Variabilidade e erros de determinação
- Aquecimento global



Tipos de produtores

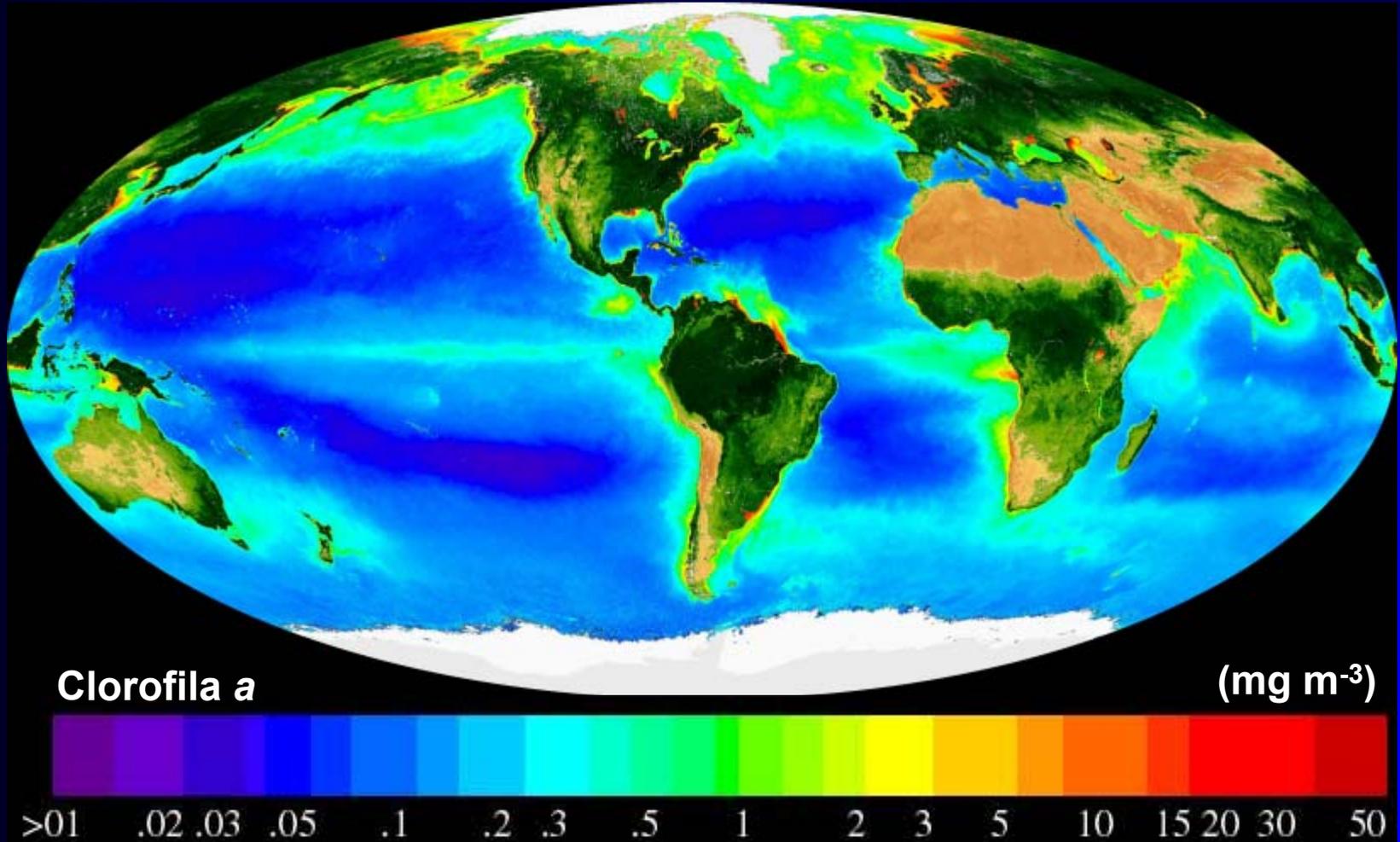
Produtor	Nutrientes	Exemplos
Fitoplâncton	Coluna de água	Diatomáceas
Microfitobentos	Coluna de água	Diatomáceas
Macroalgas (algas macrófitas)	Coluna de água	<i>Fucus</i>
Vegetação de sapal	Sedimento	<i>Spartina</i>
Angiospérmicas (“seagrasses”)	Sedimento e/ou água	<i>Zostera</i>

- Oceano aberto, águas costeiras e estuários
- Unicelulares
- Razão P/B elevada (>50)

- Zonas pouco profundas ($Z_f > Z$) ou intertidais
- Multicelulares
- Razão P/B baixa

Relevância à escala do ecossistema II

Distribuição global de clorofila *a* estimada a partir de dados de satélite



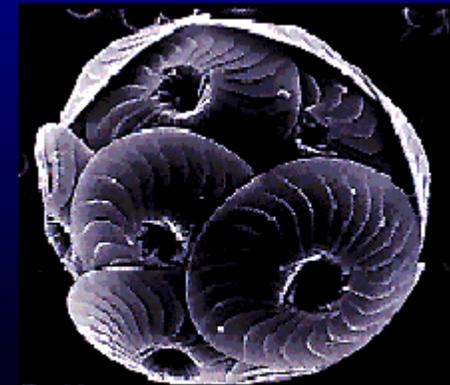
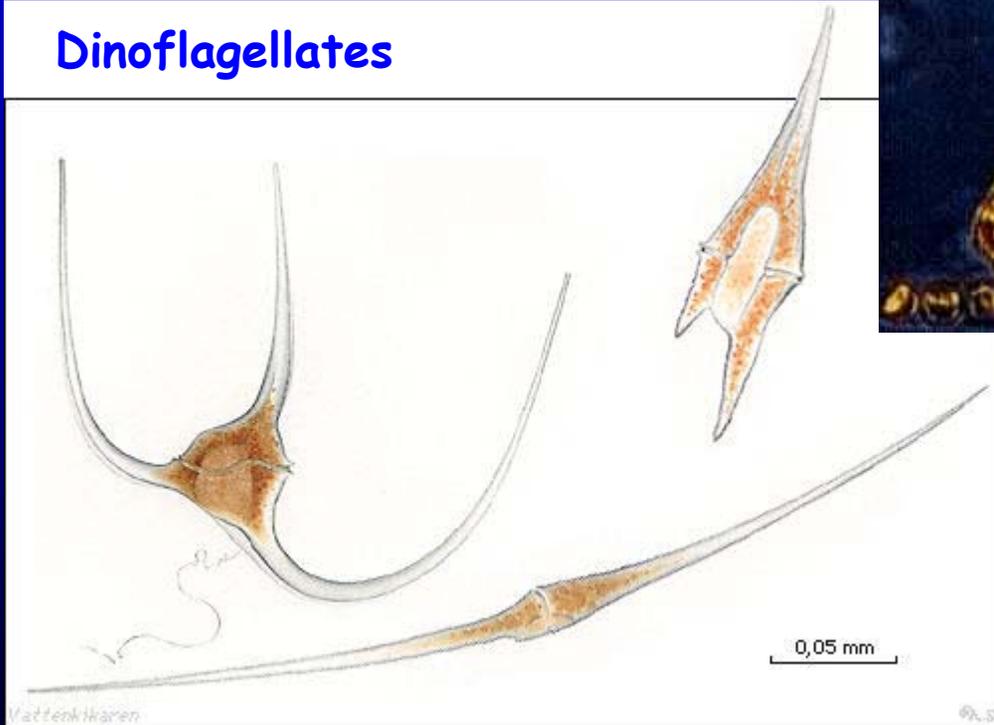
Dados do SEAWIFS, Verão no Hemisfério Norte (1998-2001)

Prod. primária (fitoplâncton) $200-360 \times 10^{14}$ gC ano⁻¹ (98.9%)

Phytoplankton some examples



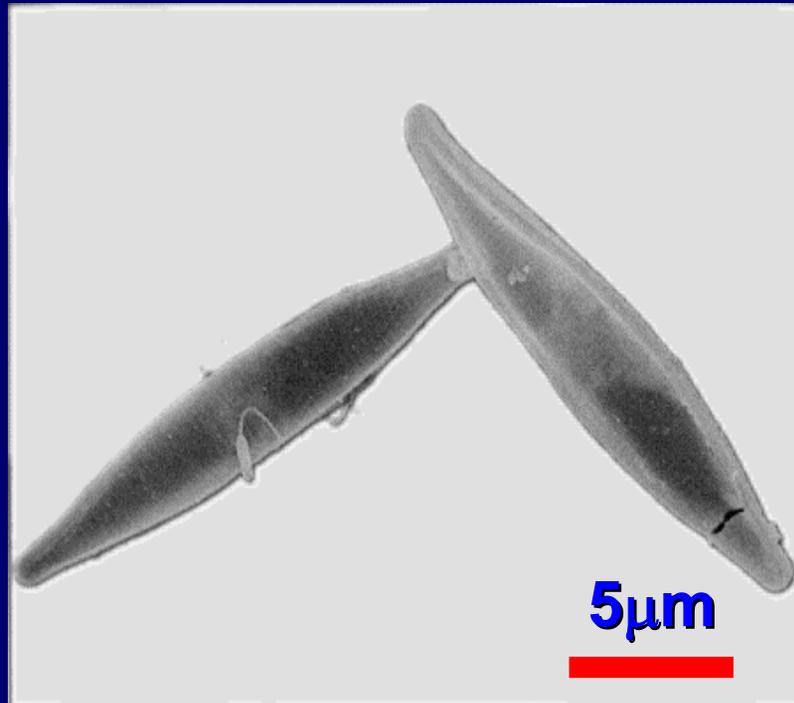
Dinoflagellates



Coccoliths

Phytoplankton - diatoms

Nitzschia bicapitata



Chavez *et al.*, 1991 - Limnol. & Oceanog. 36, p. 1816-33

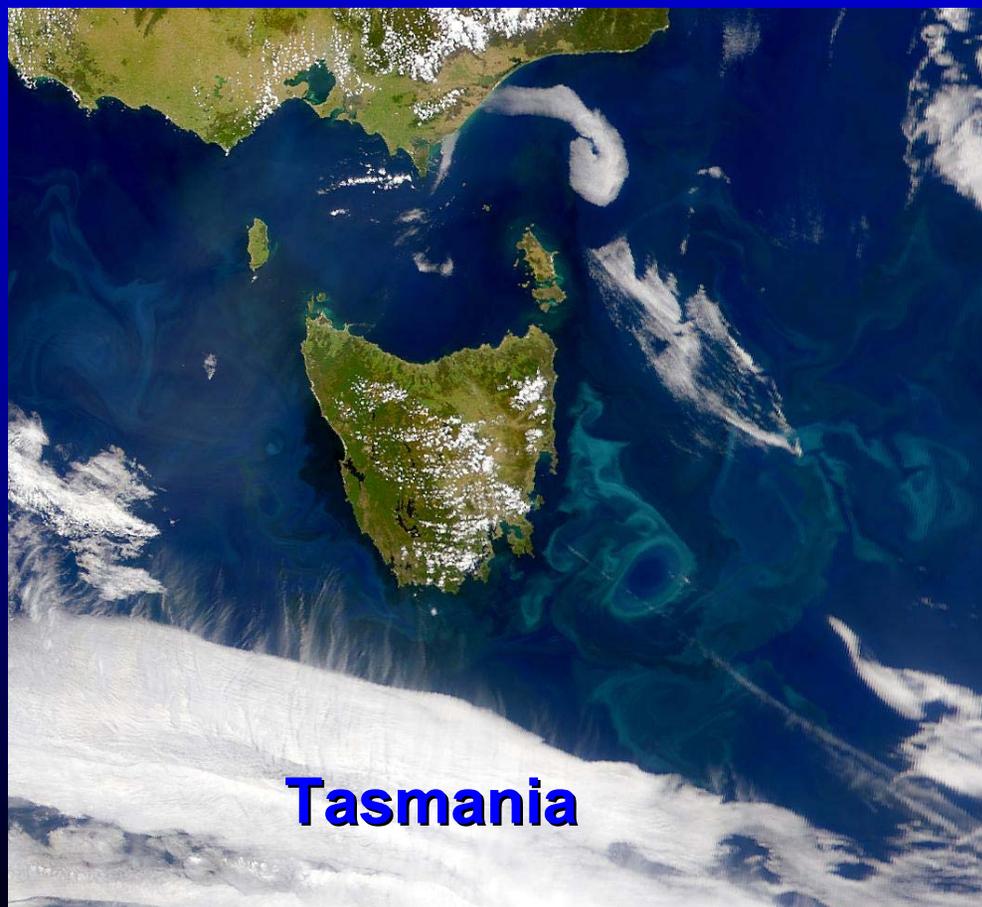
SeaWiFS images of coccolith blooms



Cornwall, U.K.



Tasmania



Relevância para a gestão I “Bloom” de *Noctiluca* – California, E.U.A.



Foto cortesia de P.J.S. Franks, WHOI

Cyanobacteria bloom – Potomac estuary



This dense bloom of cyanobacteria (blue-green algae) occurred in the Potomac River estuary downstream of Washington, D.C. Photo courtesy of W. Bennett USGS.

Relevância para a gestão III

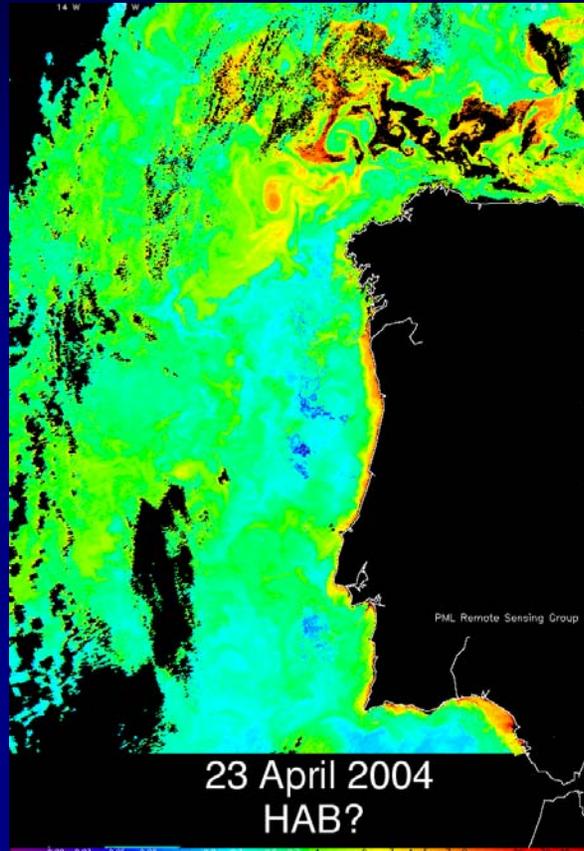
“Bloom” de macroalgas na Florida



Em Florida Bay, este “bloom” de macroalgas colmatou as fanerogâmicas marinhas, provocando o desaparecimento desta vegetação. Foto cortesia de Brian Lapointe, Harbor Branch Oceanographic Institute.

Relevância para a gestão II

Advecção de HAB (?) para a costa a partir de uma frente “offshore”



PML Remote Sensing Group
Cortesia Plymouth Marine Laboratory, UK

<http://pml.ac.uk/>

Multi-sensor discrimination of harmful algal blooms, P. I. Miller, J. D. Shutler, G. F. Moore and S. B. Groom, *Remote Sensing and Photogrammetry Society annual conference RSPSoc 2004*, 7-10 September 2004, Dundee U.K.

Kelp in Sanggou Bay, China



Produtividade de diferentes ecossistemas (kg C m⁻² ano⁻¹)

- **Produtores marinhos**

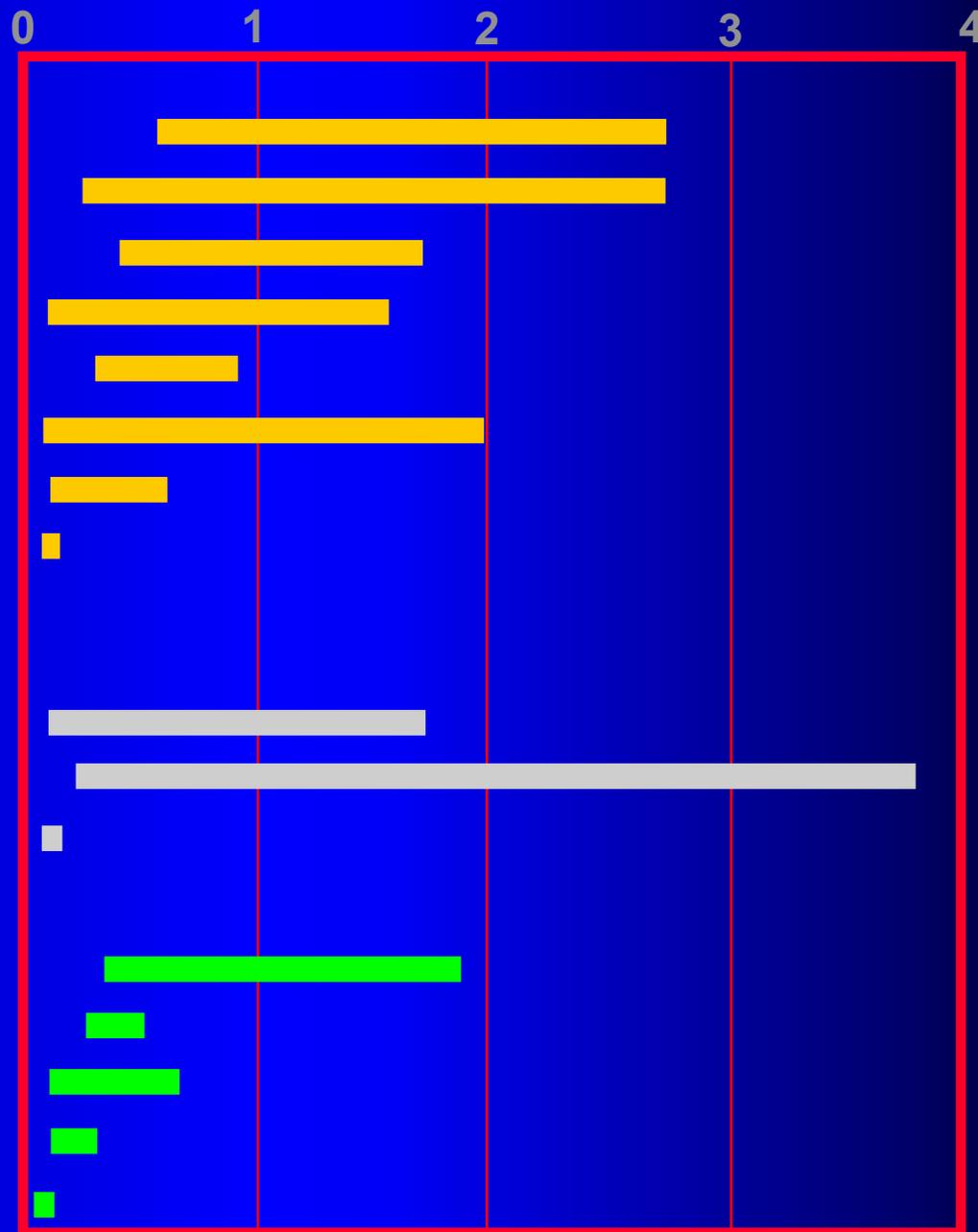
- Corais
- Laminarias
- Plantas de sapal
- Posidonia
- Mangal
- Microalgas bentônicas
- Fitoplâncton costeiro
- Fitoplâncton oceânico

- **Produtores de água doce**

- Macrófitas
- Fitoplâncton (eutrófico)
- Fitoplâncton (oligotrófico)

- **Produtores terrestres**

- Floresta tropical
- Floresta temperada
- Pastagens
- Pradarias
- Desertos, tundra



Produtividade e biomassa média, taxa de renovação e clorofila em diferentes ecossistemas

	Área (10 ⁶ km ²)	Produtividade líquida (gm ⁻² ano ⁻¹)	Biomassa (kg m ⁻²)	Taxa de renovação (P/B, ano ⁻¹)	Clorofila (g m ⁻²)
Oceano aberto	332	125	0.003	42	0.03
Afloramento	0.4	500	0.02	25	0.3
Plataforma	27	300	0.001	300	0.2
Macrófitas/recifes	0.6	2500	2	1.3	2
Estuários	1.4	1500	1	1.5	1
• <i>Total marinho</i>	361	155	0.01		0.05
Ecossistemas terrestres	145	737	12	0.061	1.54
Pântanos	2	3000	15	0.2	3
Lagos e rios	2	400	0.02	20	0.2
• Total continental	149	782	12.2	0.064	1.5

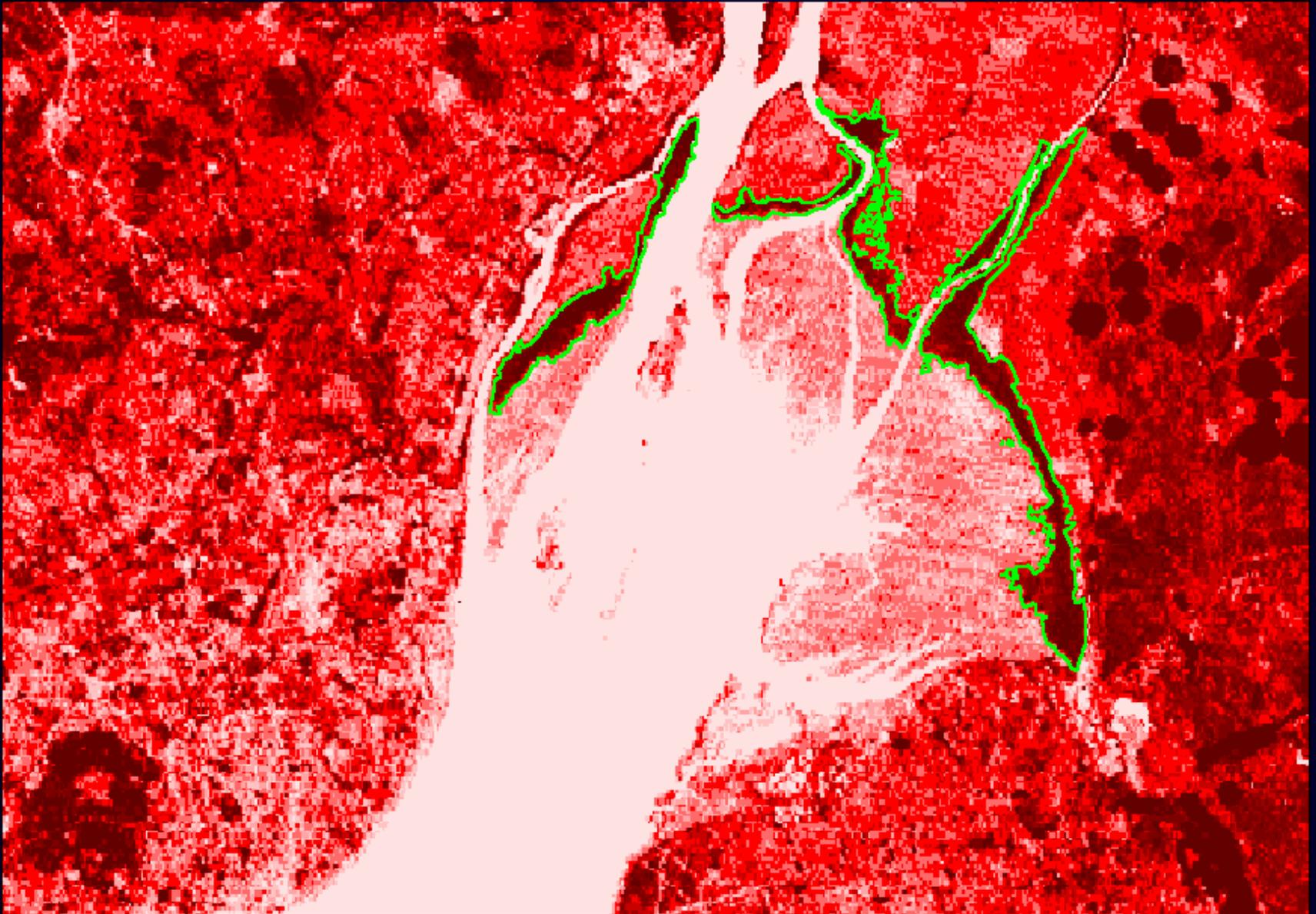
Whittaker & Likens, 1975. The Biosphere and Man. Primary productivity of the biosphere. Springer-Verlag.

Medição da produção primária

Produtor	Medida	Método	Unidades
Fitoplâncton e microfitobentos	Biomassa	Clorofila <i>a</i> (amostra filtrada)	$\mu\text{g L}^{-1}$
	Produção	^{14}C , O_2 (incubação)	d^{-1}
Macroalgas	Biomassa	Cropping	gDW m^{-2}
“Seagrasses”	Produção	O_2 (incubação), cropping	$\text{gC m}^{-2} \text{d}^{-1}$
Sapal	Biomassa	Cropping	gDW m^{-2}
	Produção	O_2 (incubação), cropping	$\text{gC m}^{-2} \text{d}^{-1}$

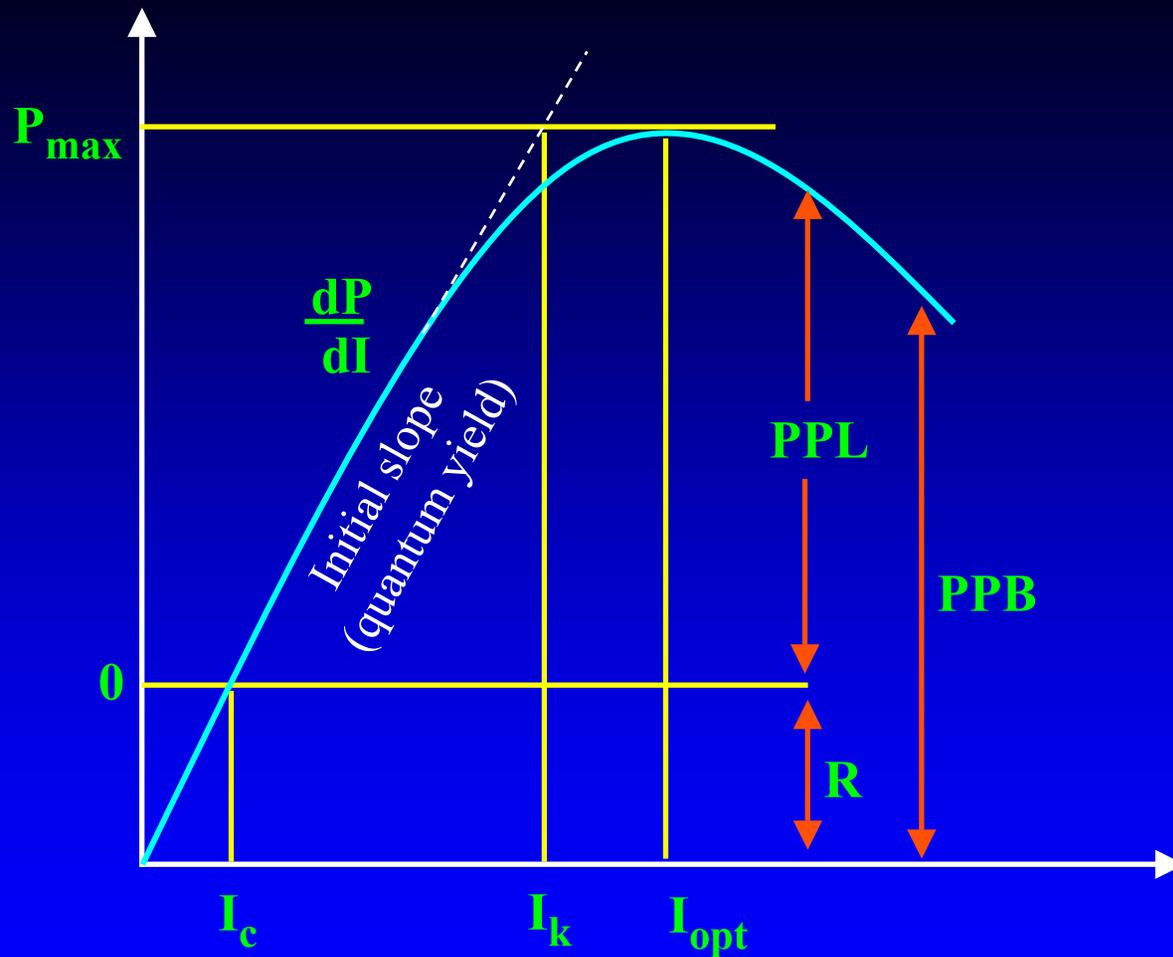
- Upscaling: SIG, modelação

Saltmarsh definition – NDVI and bathymetry

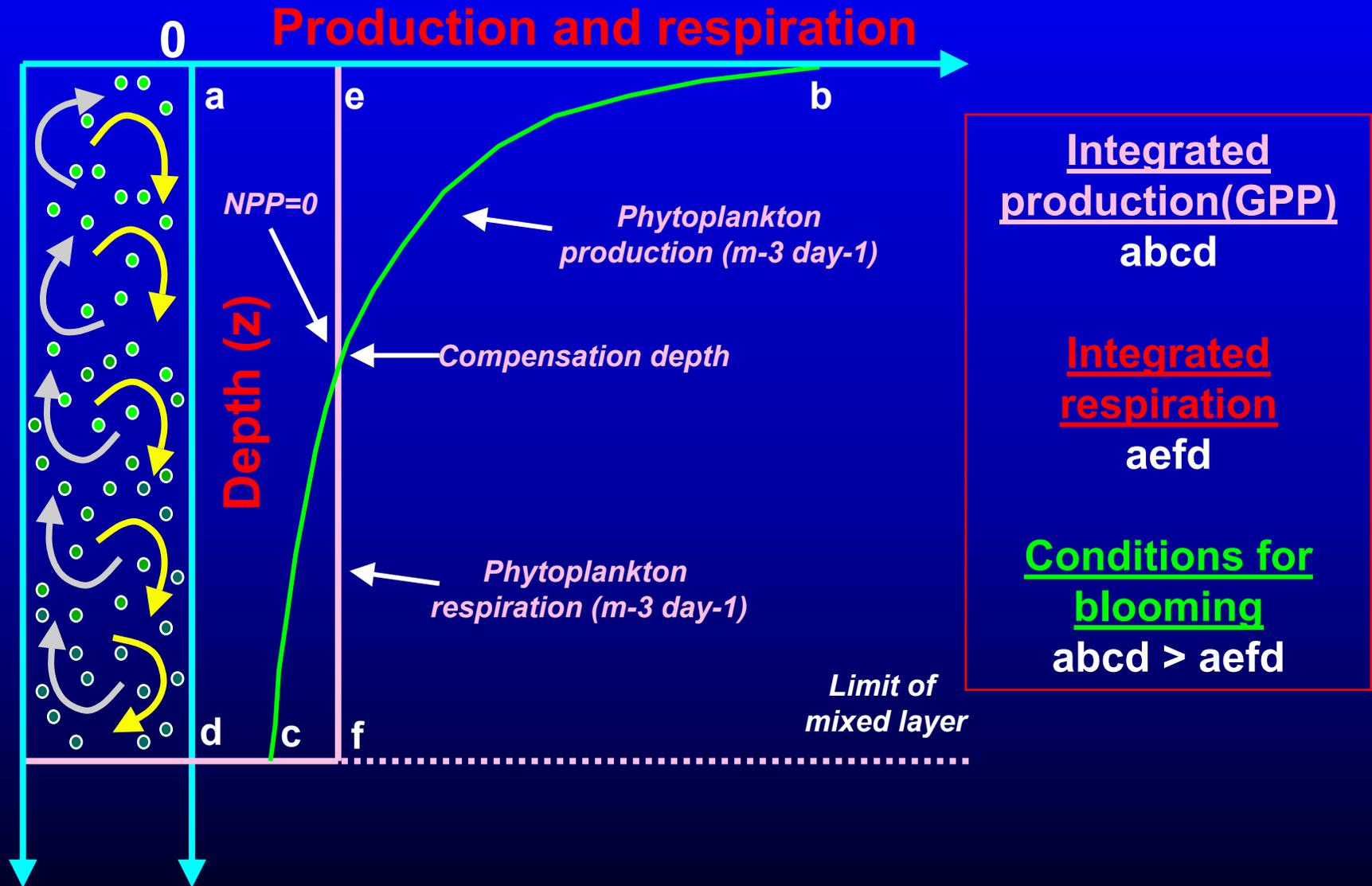


$NDVI = (Near_Infrared - Red) / (Near_Infrared + Red)$ Near_Infrared e Red são duas bandas da imagem de satélite. O NDVI situa-se entre -1 e 1. Os pigmentos absorvem grandes quantidades de energia no vermelho (R), e poucas no infravermelho próximo (NIR), ao contrário dos objectos inertes que absorvem todos os espectros da mesma forma.

Relação entre a taxa de fotosíntese (P) e a intensidade luminosa (I)



Phytoplankton blooms and vertical mixing



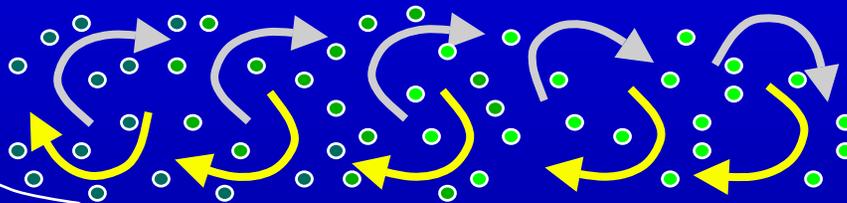
Sverdrup, H.U., 1953. On conditions for the vernal blooming of phytoplankton. J. Cons. Perm. Int. Exp. Mer, 18: 287-295

Phytoplankton blooms in estuaries

Phytoplankton growth: P_0 = initial population, P_t = population at time t

$$P_t = P_0 e^{kt}$$

Freshwater inflow Q (m^3s^{-1})



Tidal exchange with the ocean



Phytoplankton flushing: P_0 = initial population, P_m = population after m tidal cycles, r = exchange ratio (proportion of estuary water which does not return each tidal cycle)

$$P_m = P_0 (1-r)^m$$

Ketchum (1954) Relation between circulation and planktonic populations in estuaries. Ecology 35: 191-200

Phytoplankton blooms in estuaries

*Combining the two equations
(and expressing t in terms of m):*

Growth

$$P_t = P_0 e^{kt}$$

Flushing

$$P_m = P_0 (1-r)^m$$

$$P_m = P_0 e^{mk(1-r)^m}$$

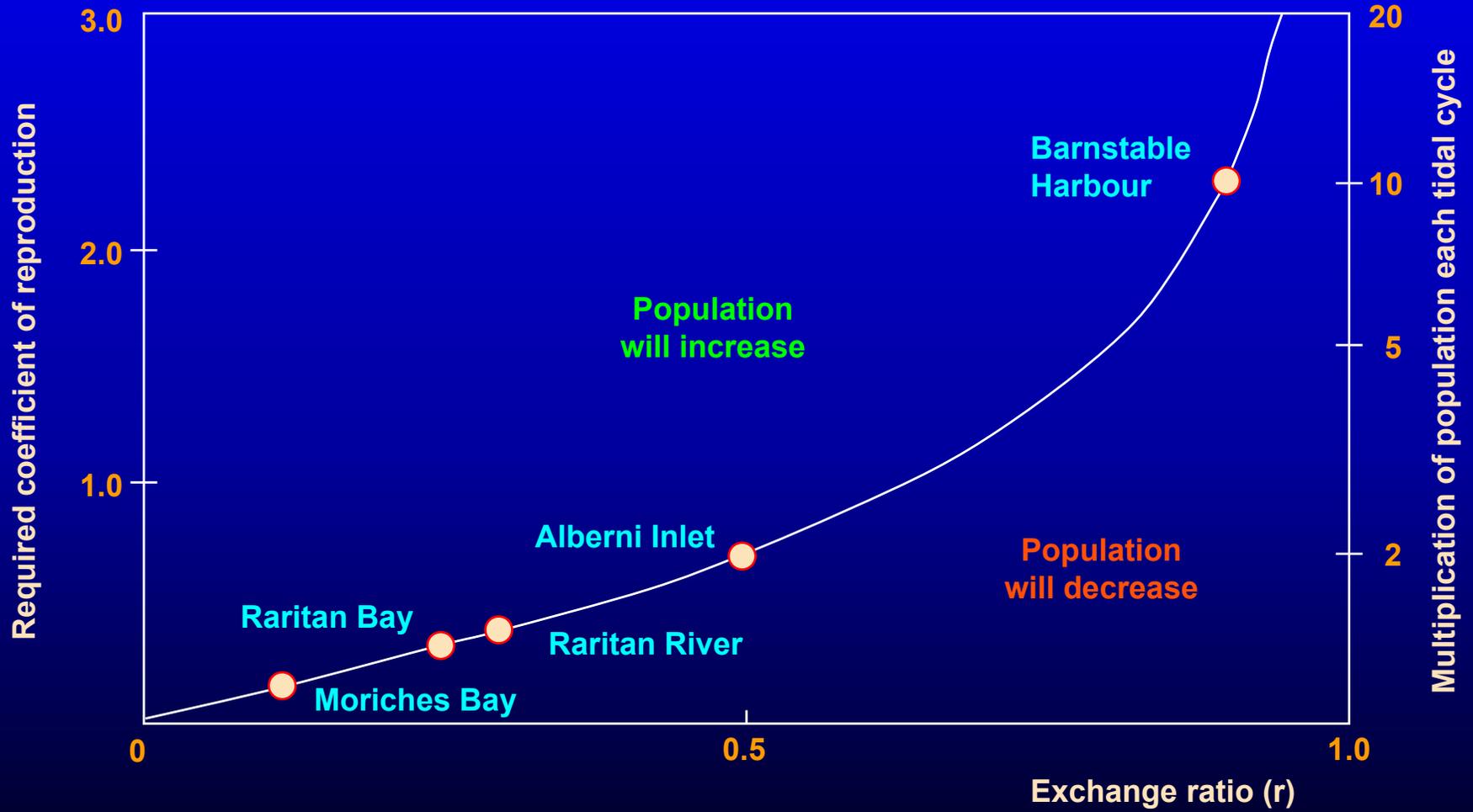
For a steady-state population, $P_m = P_0$:

$$k = -\ln(1-r)$$

$$\frac{1}{(1-r)^m} = e^{mk}$$

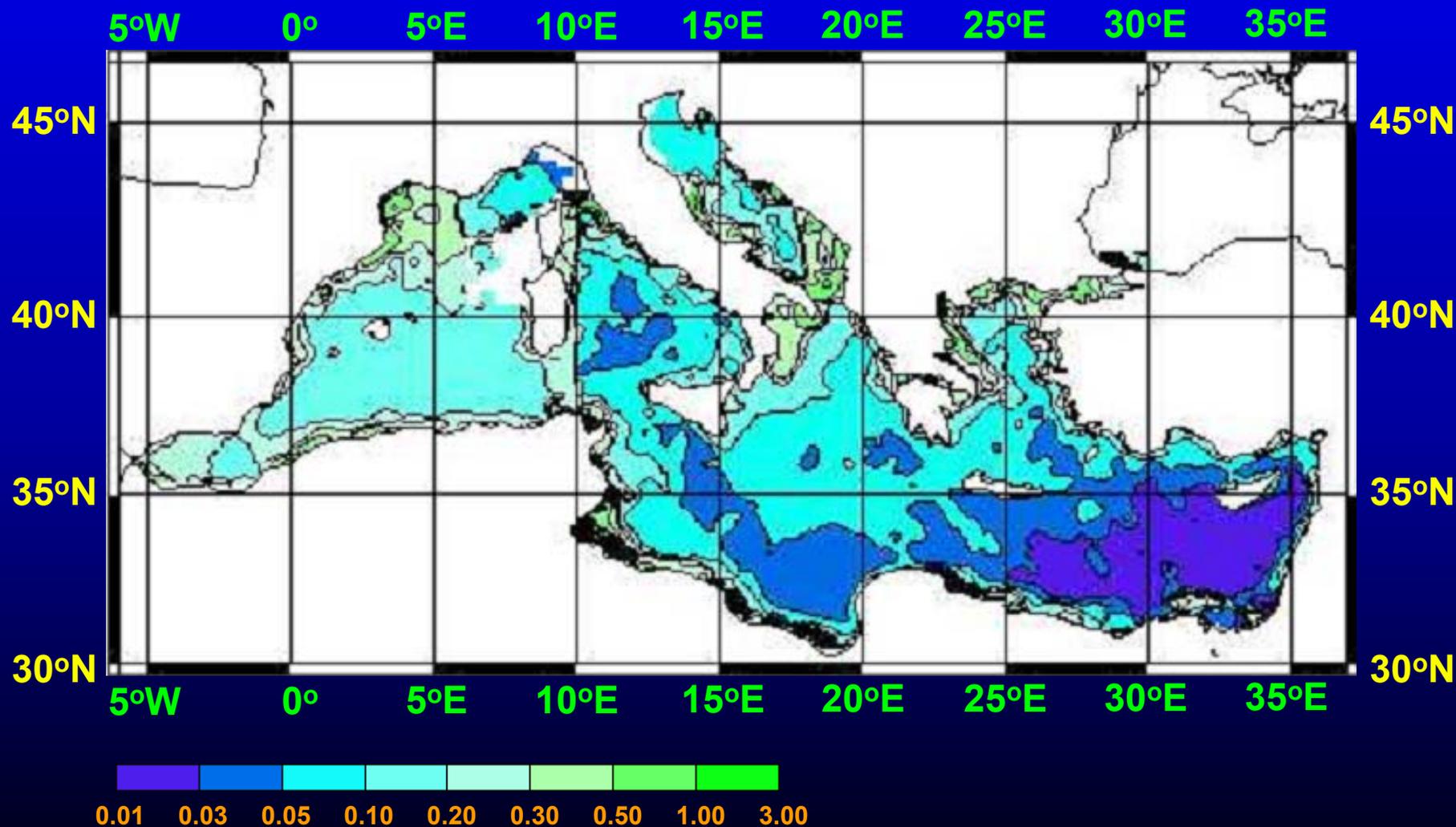
For phytoplankton to exist and potentially bloom in an estuary, growth must balance flushing, i.e. $k \geq -\ln(1-r)$

Phytoplankton blooms in estuaries



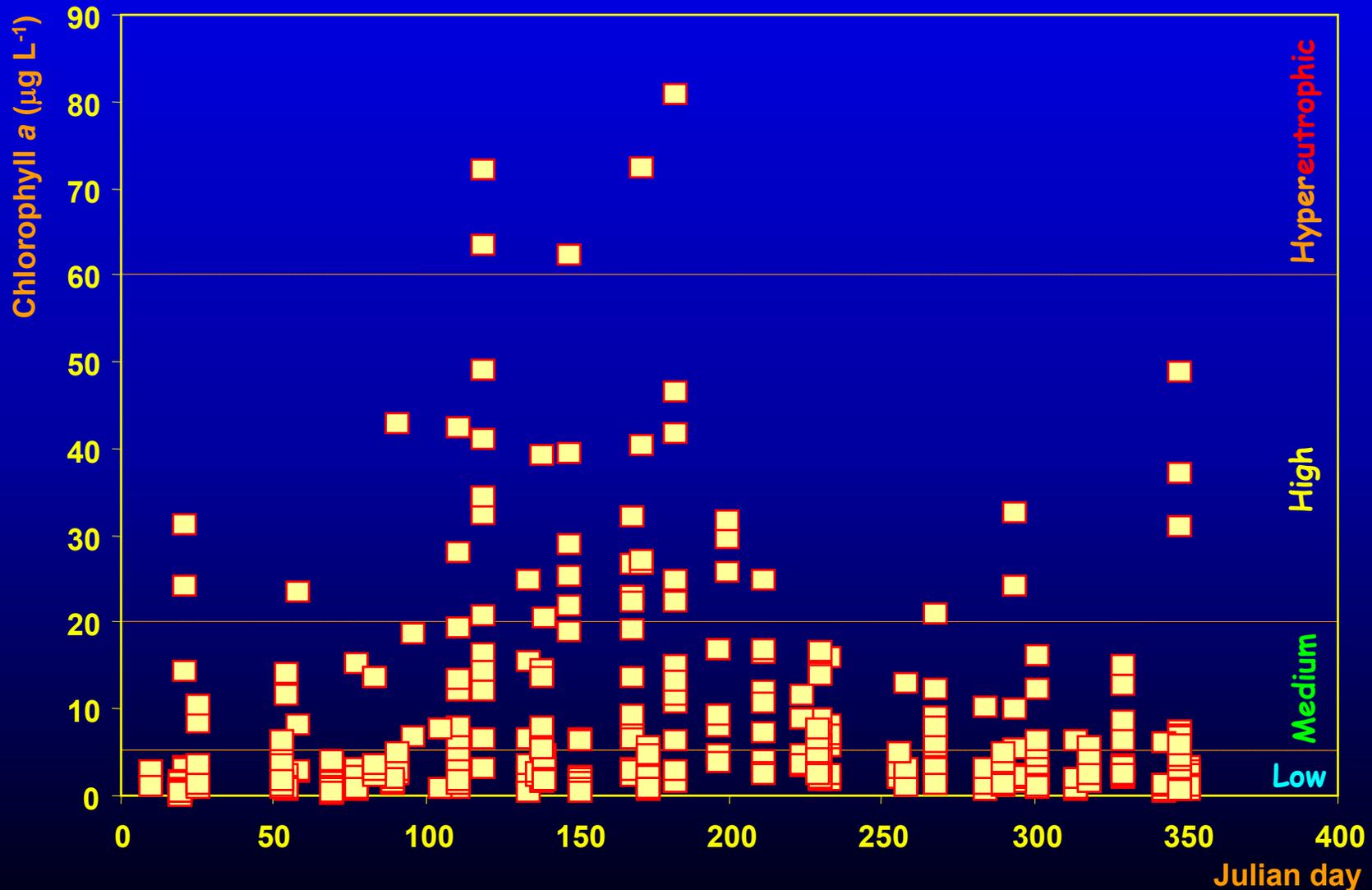
Redrawn from Ketchum (1954)

CZCS derived sea-surface pigments Mediterranean Sea



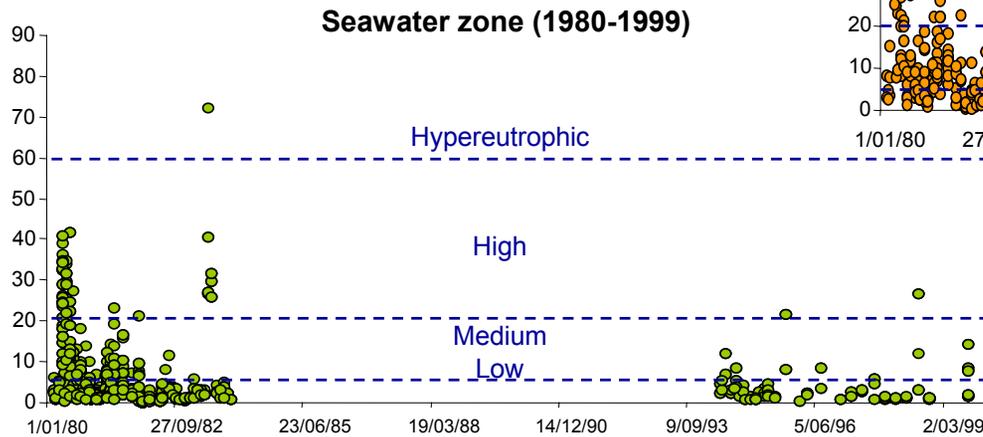
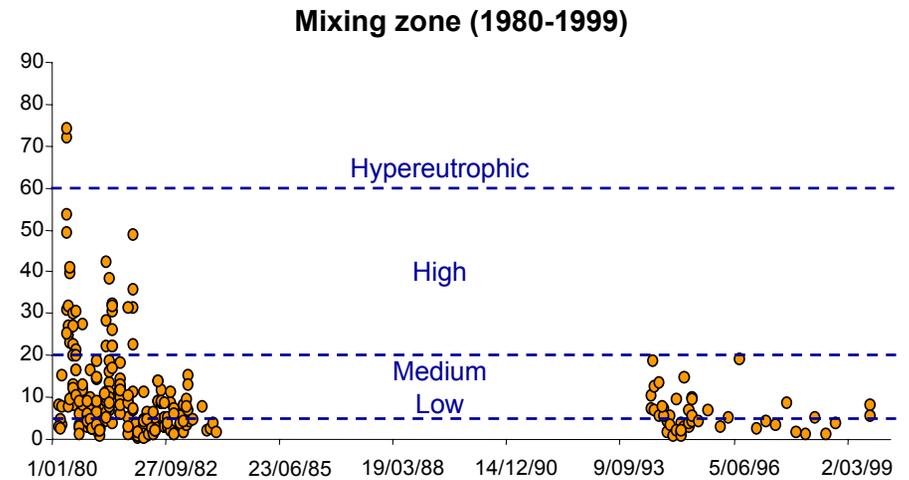
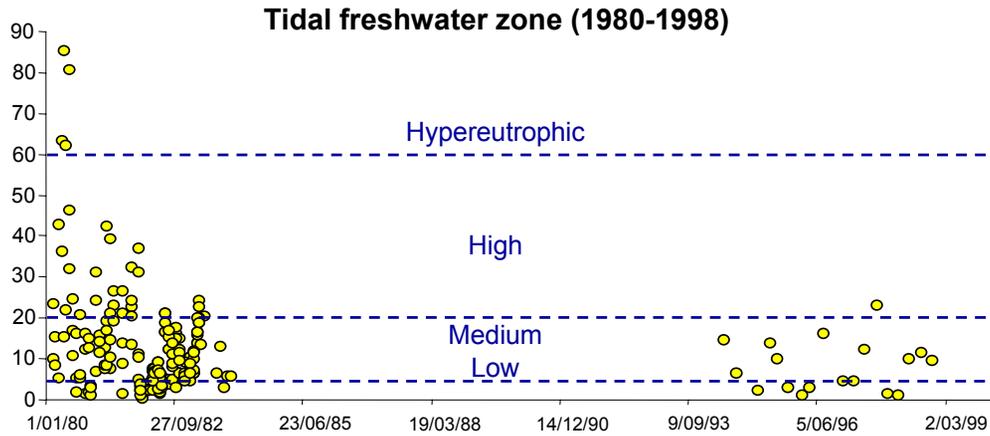
Chlorophyll a in the Tagus estuary

Surface values on a longitudinal section



Data from BarcaWin2000 - Stations #1.0, #2.0, #3.9, #4.0, #5.0 and #8.0 – 385 values

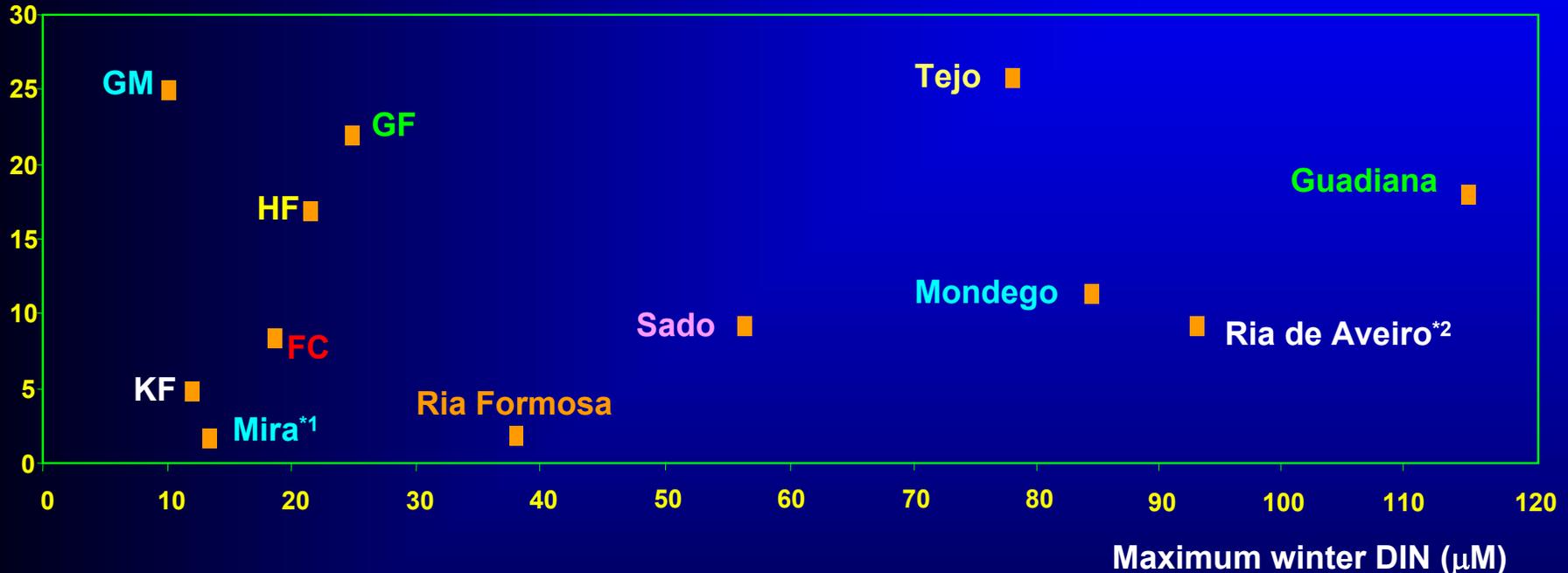
Chlorophyll *a* trends in the Tagus estuary



OAERRE data + TICOR data

Chlorophyll a and nutrients

Maximum spring phytoplankton (chl a $\mu\text{g L}^{-1}$)



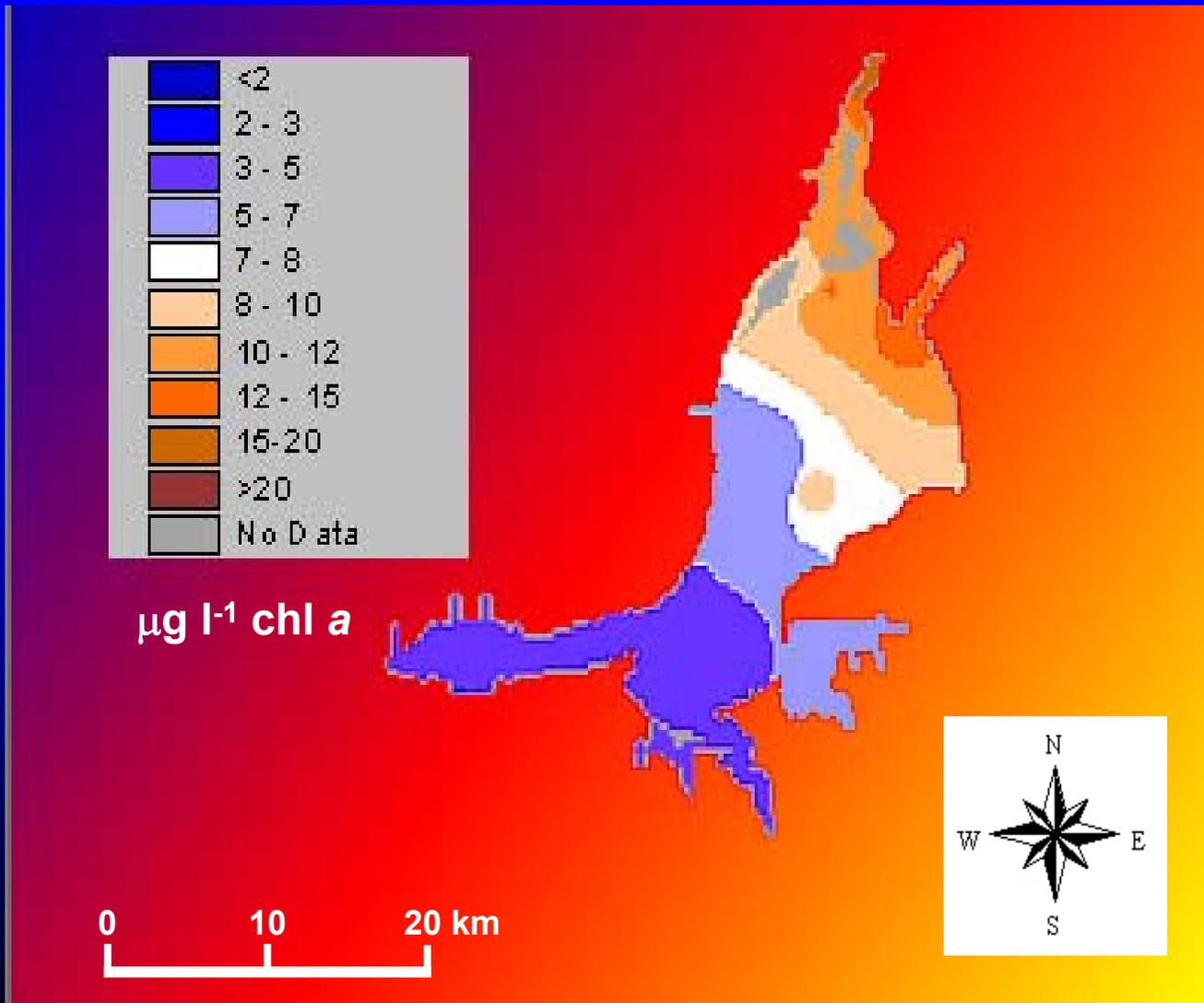
Tett, P., Gilpin, L., Svendsen, H., Erlandsson, C.P., Larsson, U., Kratzer, S., Fouilland, E., Janzen, C., Lee, J., Grenz, C., Newton, A., Ferreira, J.G., Fernandes, T., Scory, S., 2002. Eutrophication and some European waters of restricted exchange. Submitted to Coastal and Nearshore Oceanography, NEEA, and unpublished work from TICOR.

*1 – Chlorophyll determined from graphical data

*2 – Nitrate, not DIN

GIS - Chlorophyll a

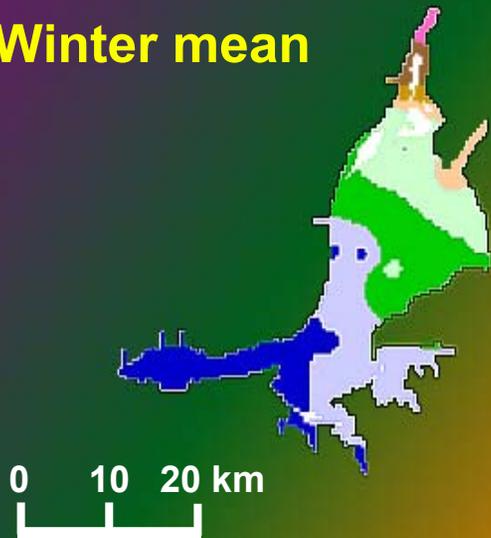
Composite annual mean



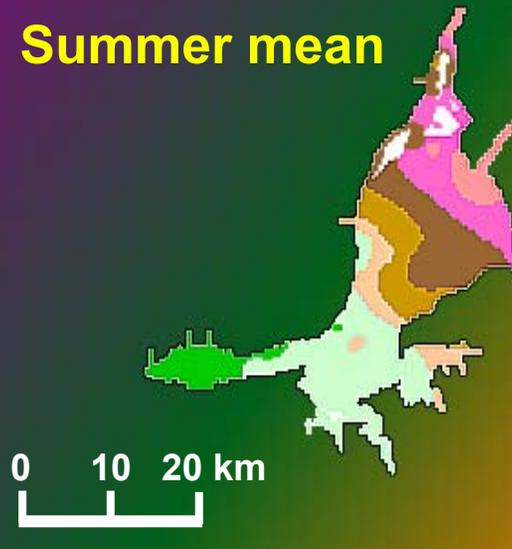
GIS - Mean chlorophyll a

Winter, summer and global

Winter mean

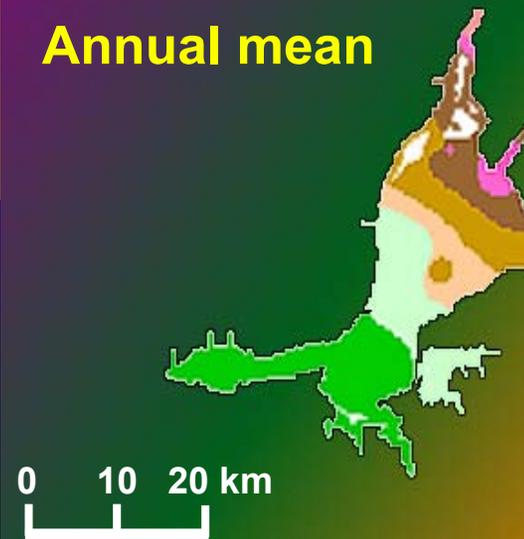


Summer mean

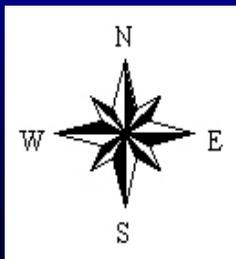
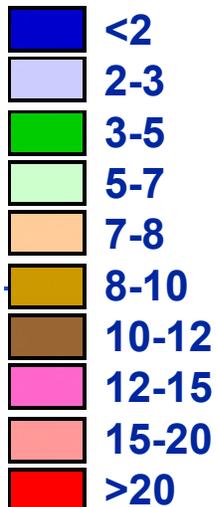


Data from 1980-1983, Tagus estuary, Portugal

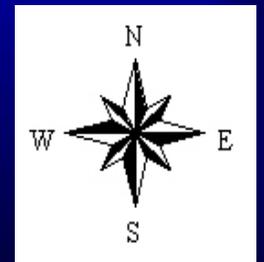
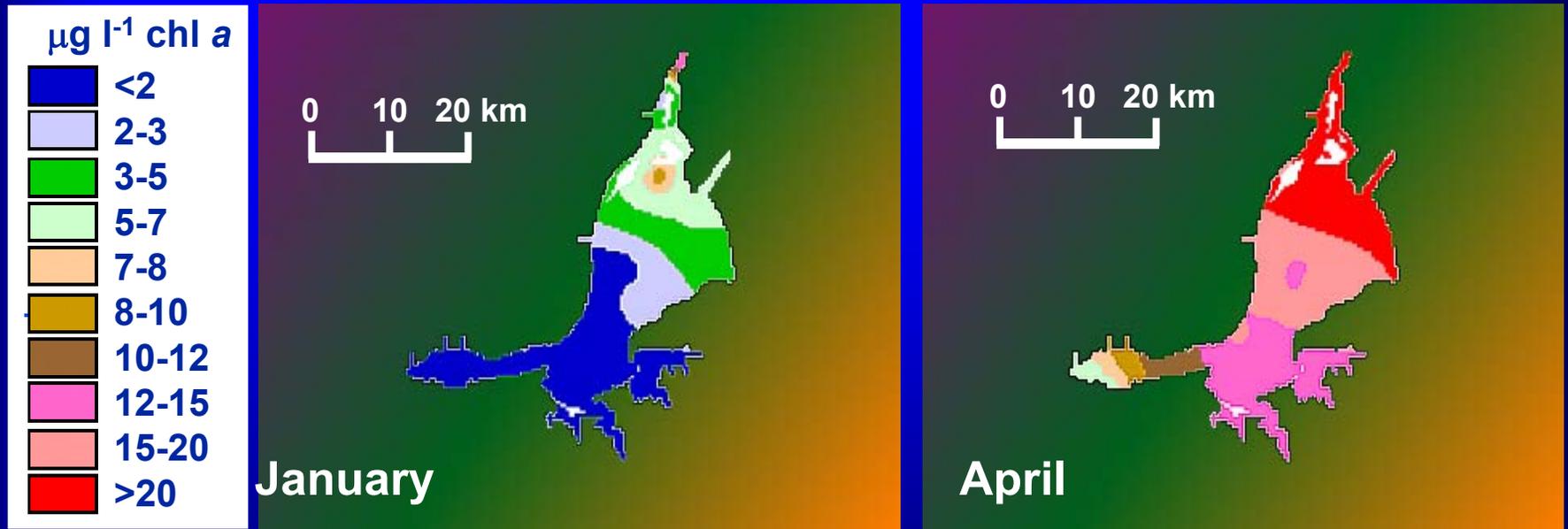
Annual mean



$\mu\text{g l}^{-1}$ chl a



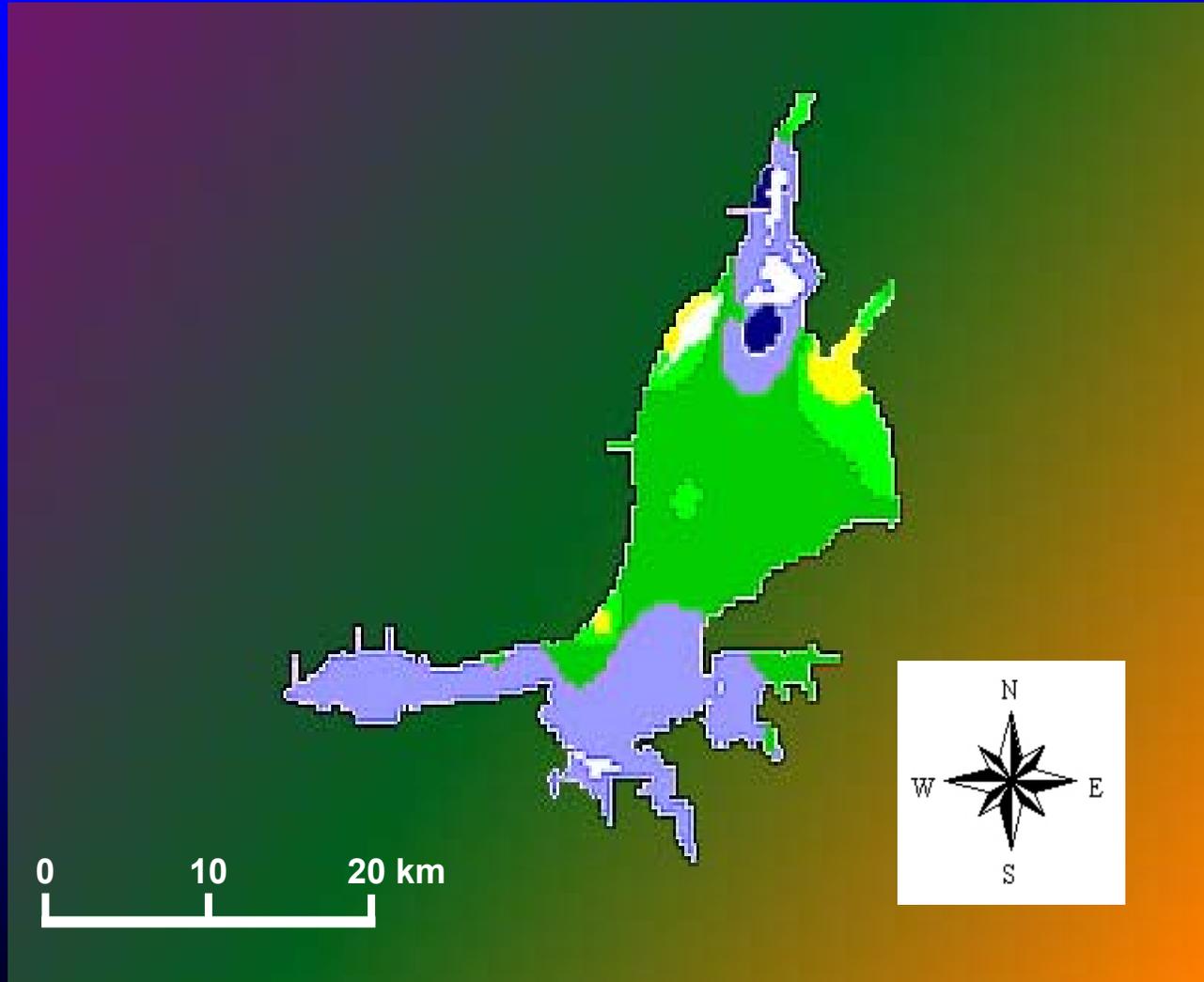
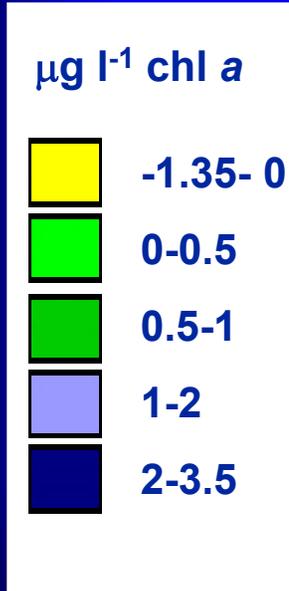
GIS - Comparison between January and April chlorophyll a



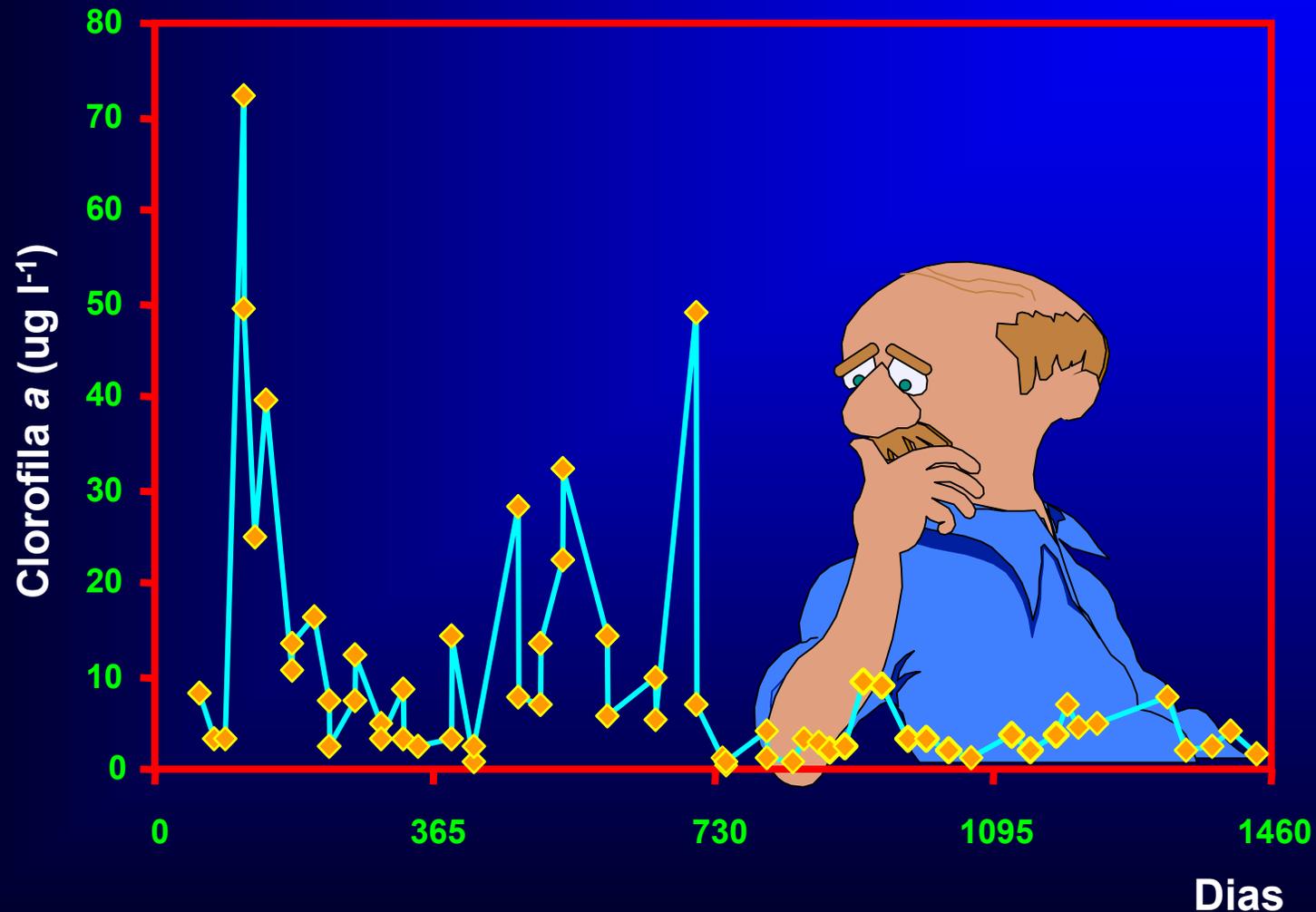
Data from 1980-1983, Tagus estuary, Portugal

GIS - Chlorophyll a

Surface minus bottom



Variação interanual de clorofila a no estuário do Tejo, durante 4 anos



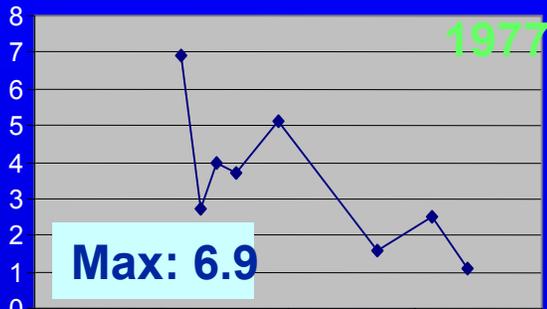
Dados para a estação #2.0, amostras de superfície colhidas ao longo de 4 anos

Baía de S. Francisco – E.U.A.

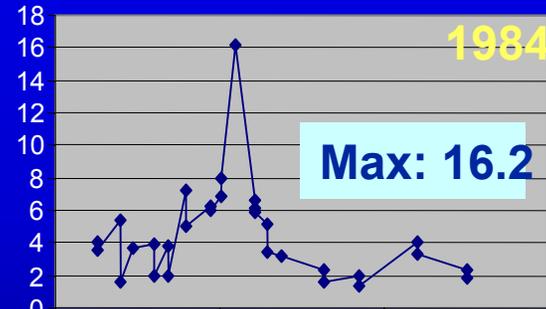
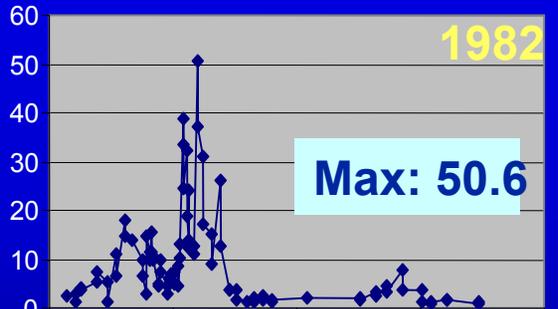
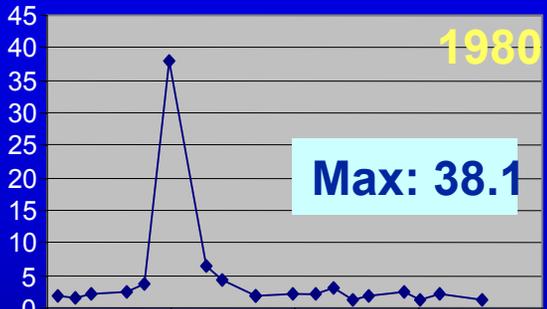


Baía de S. Francisco (South Bay) - Clorofila a

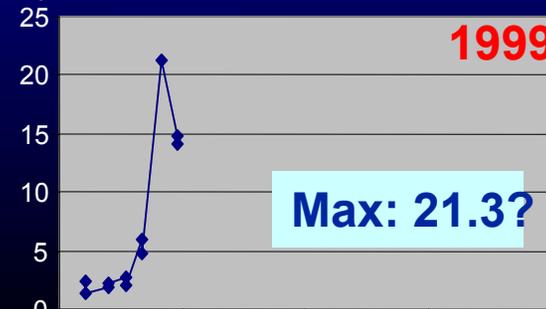
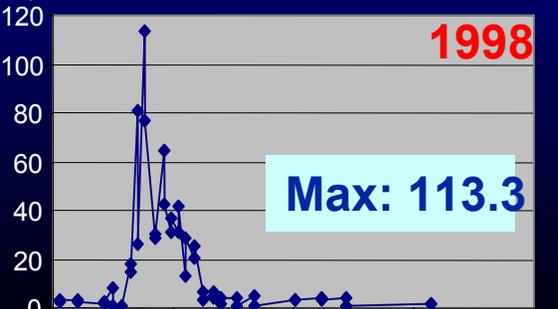
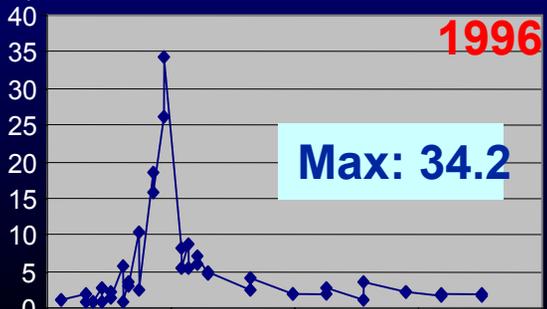
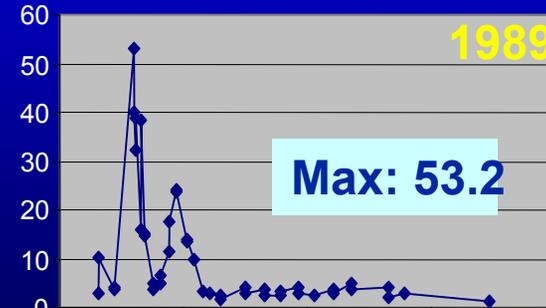
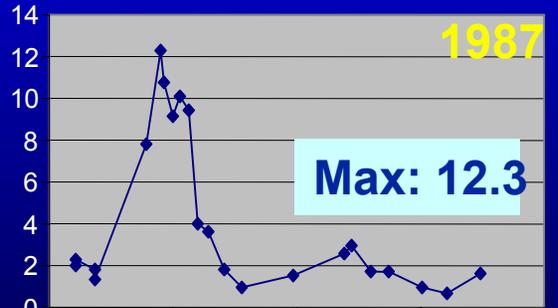
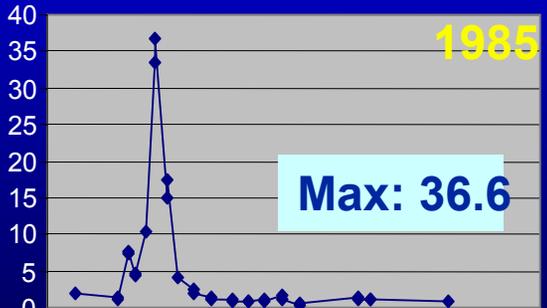
Anos 70



Década de oitenta



Anos 90



30 - Redwood Creek, 37°33.3'N, 122°11.4'W, z = 12.8m

Baía de S. Francisco (South Bay)

Máximo de clorofila *a* ($\mu\text{g chl } a \text{ l}^{-1}$)



Estação 30 - Redwood Creek, 37°33.3'N, 122°11.4'W, z= 12.8m

Baía de S. Francisco (South Bay)

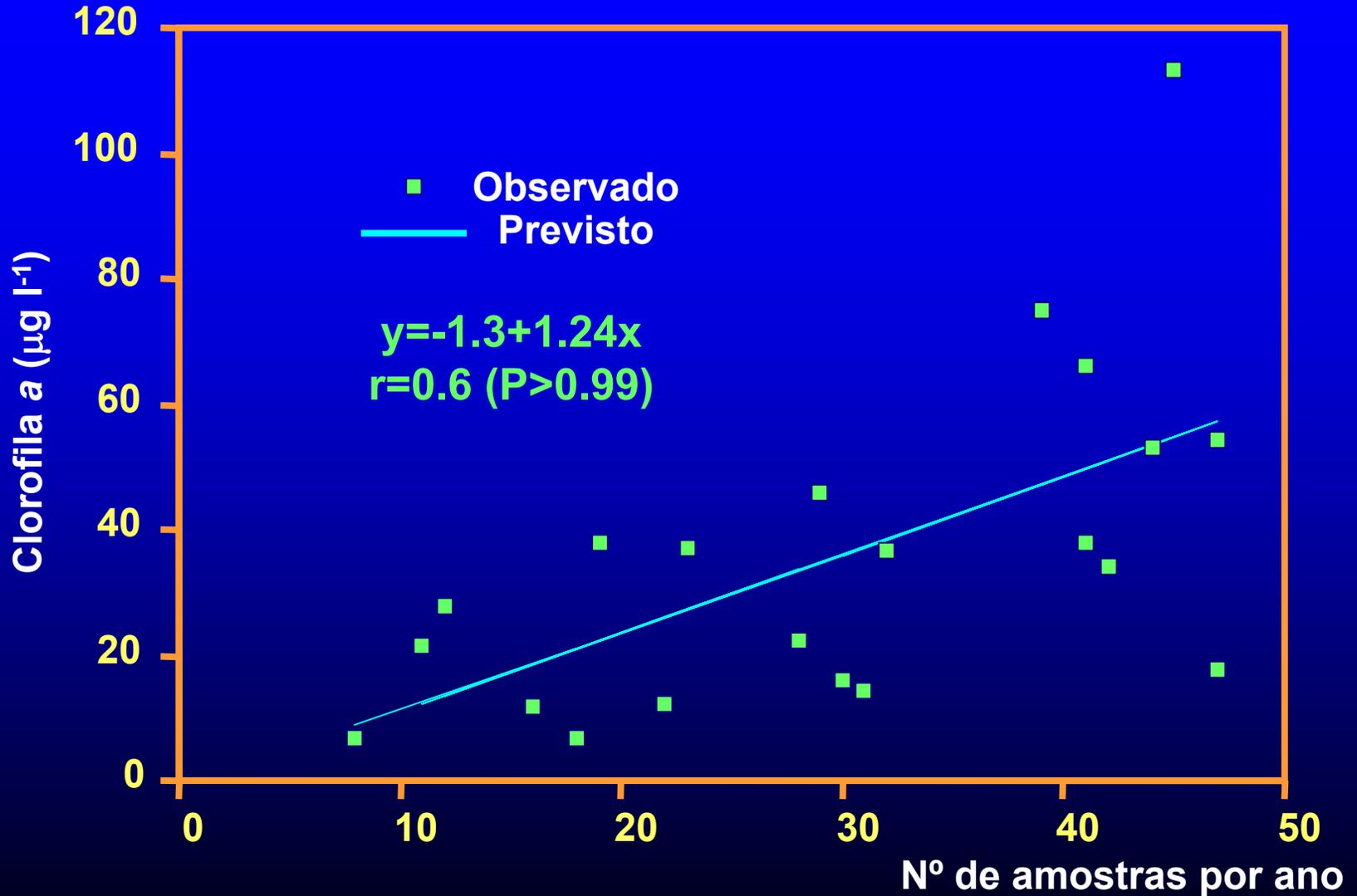
Máximo de clorofila *a* ($\mu\text{g chl } a \text{ l}^{-1}$)



Estação 30 - Redwood Creek, 37°33.3'N, 122°11.4'W, z= 12.8m

Baía de S. Francisco (South Bay)

Máximo de clorofila *a* em função do número de amostras



Estação 30 - Redwood Creek, 37°33.3'N, 122°11.4'W, z = 12.8m

Primary production budget Tagus estuary (t C y⁻¹)

Pelagic producers

Phytoplankton*¹ 41160 (62%)

Benthic producers

Microphytobenthos*² 4265 (6%)

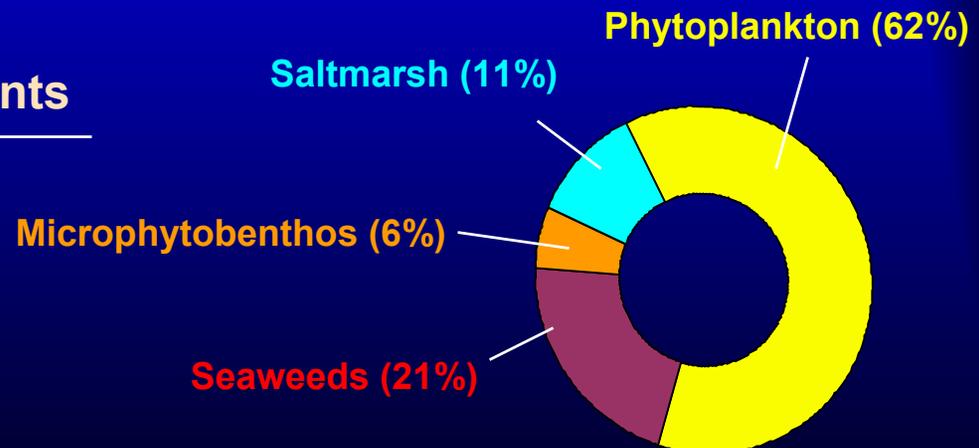
Seaweeds 13770 (21%)

Saltmarsh vegetation*⁴ 7700 (11%)

Sub-total pelagic 41160 (62%)

Sub-total benthic 25735 (38%)

Total GPP 66895 t C y⁻¹
N removal ~10500 t N y⁻¹
Pop. equivalent 2.3 X 10⁶ inhabitants



*¹ – EcoWin2000 ecological model, Ferreira (2000)

*² – Modelling and field measurements, Serôdio & Catarino (2000)

*³ – Modelling and field measurements, Alvera-Azcárate et al, (2002)

*⁴ – Modelling and field measurements, Simas *et al.* (2001)

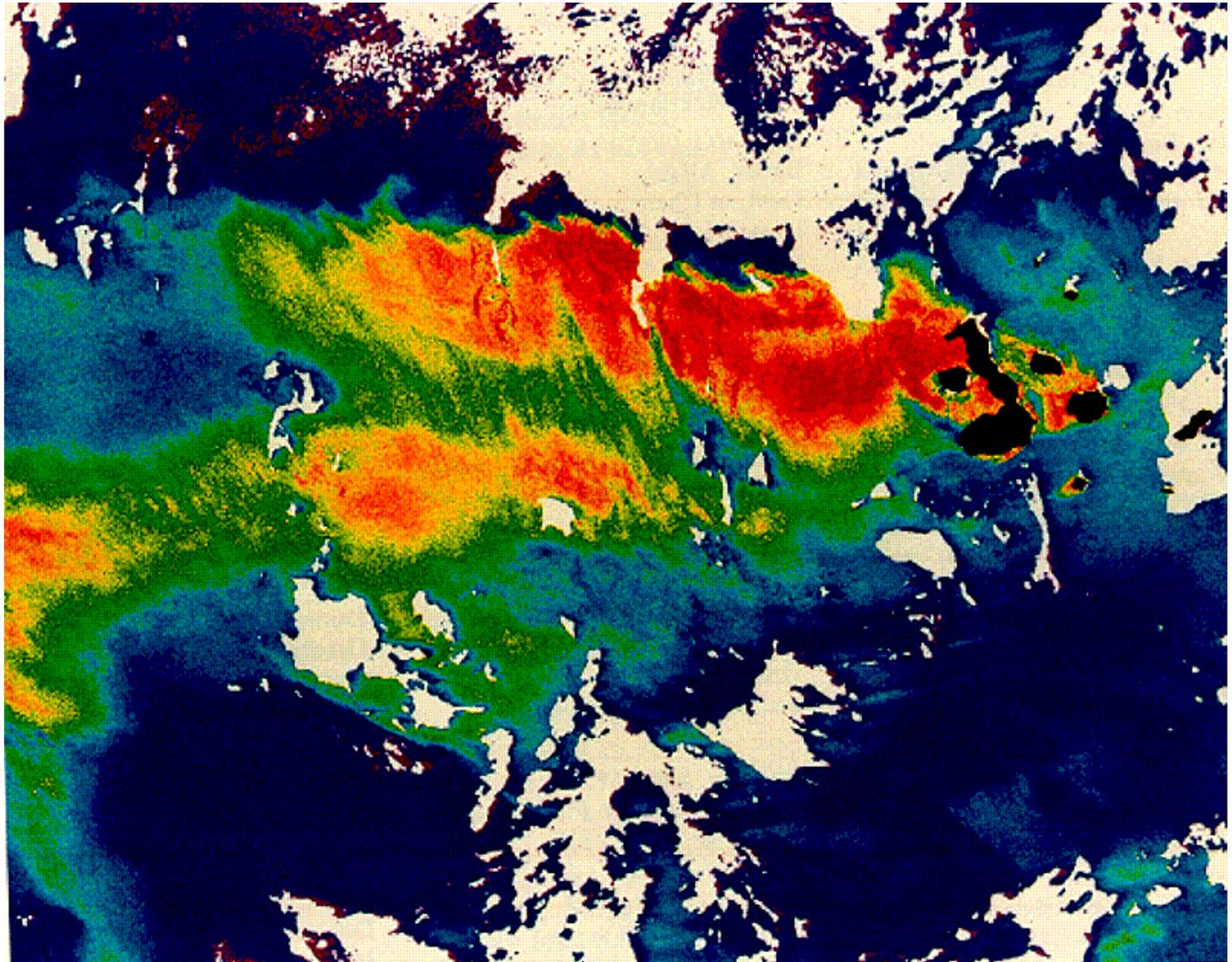
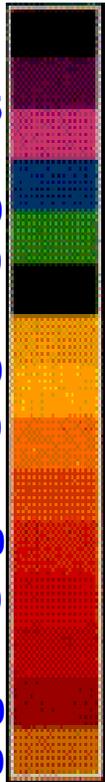
Global warming



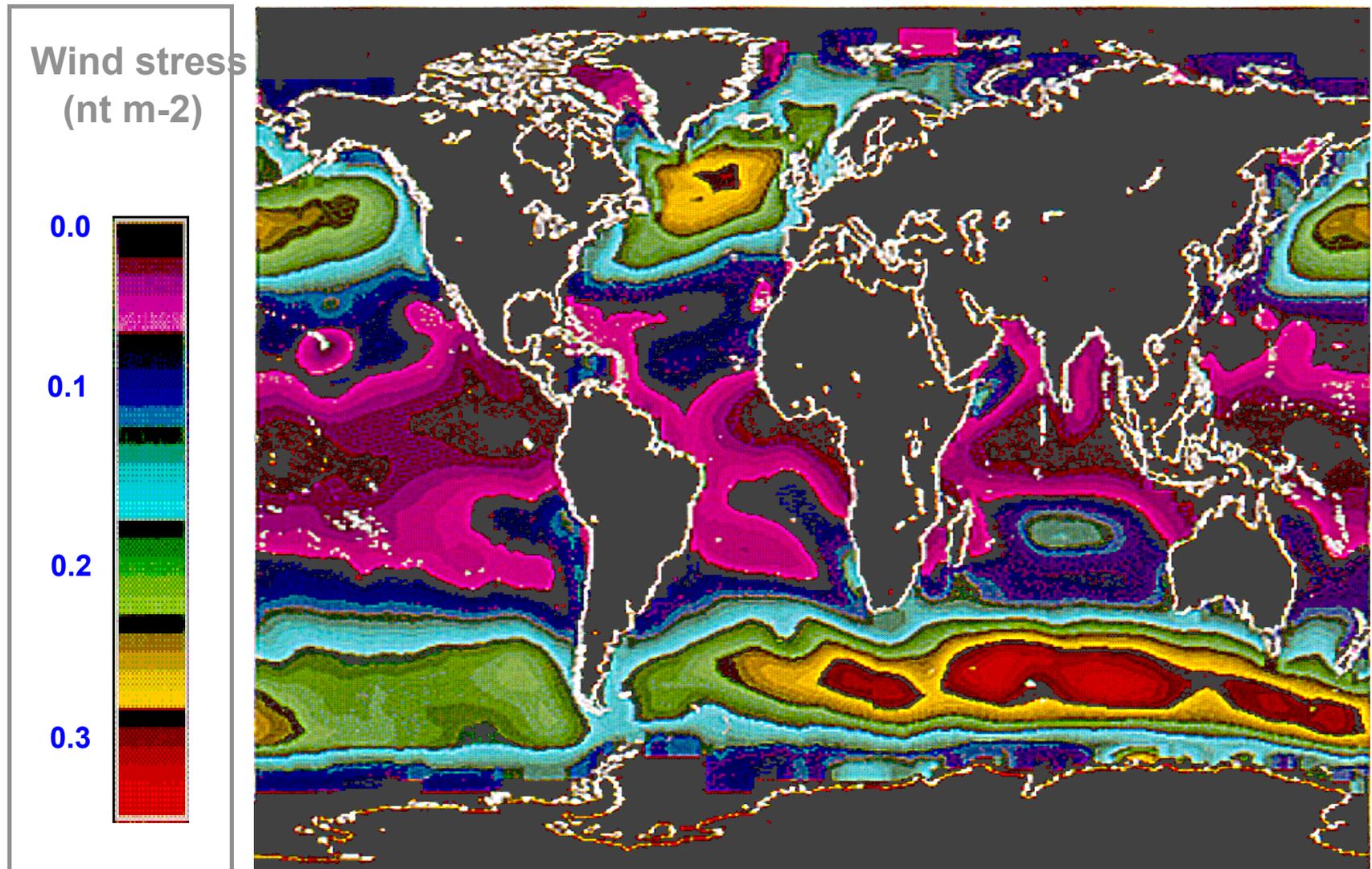
High nutrient - Low chlorophyll paradox

Pigments
(mg m⁻³)

0.05
0.10
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
5.00

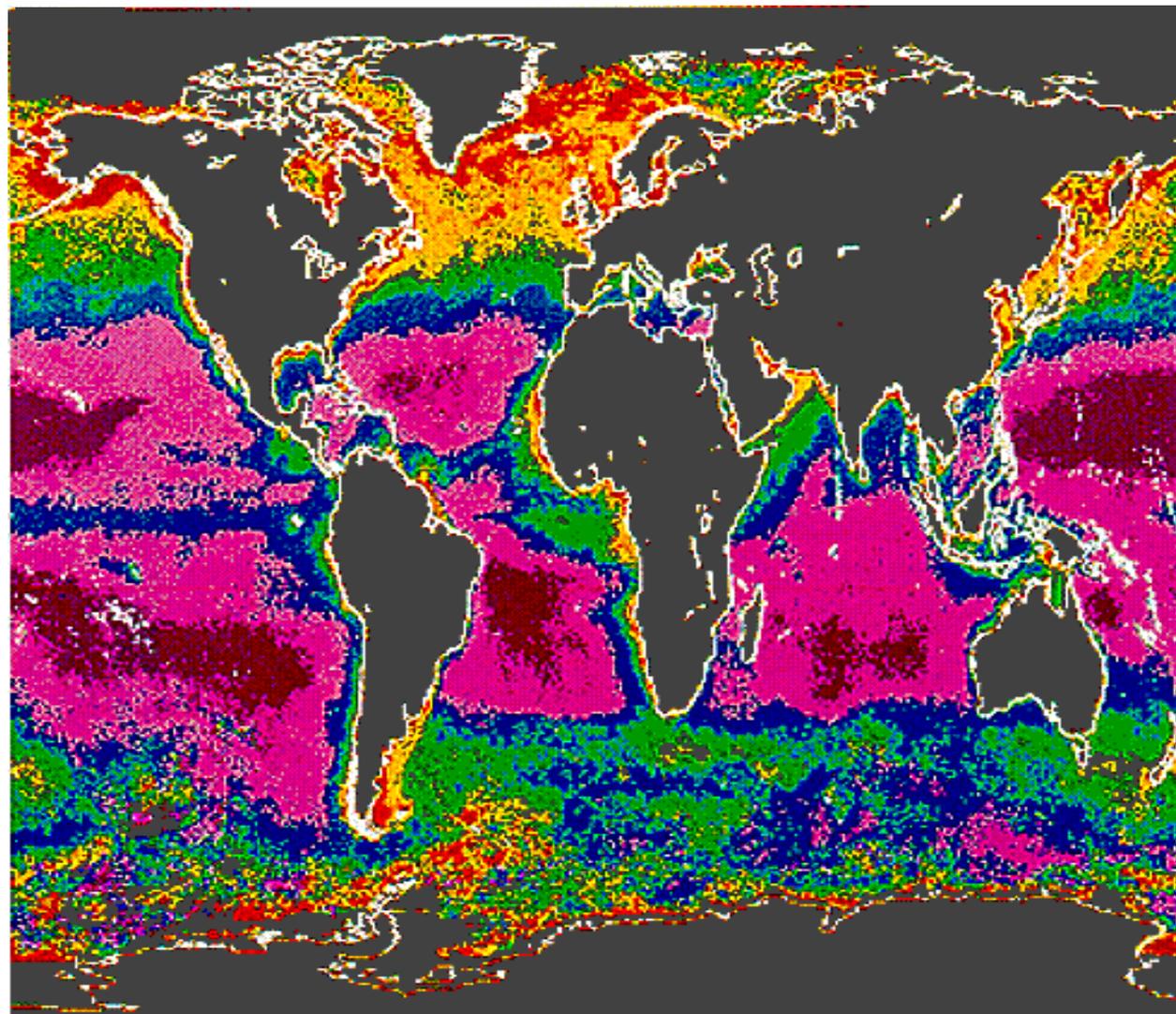
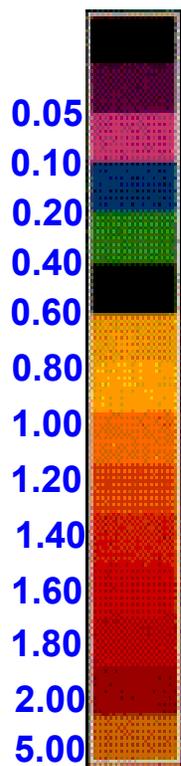


Global climatology of annual mean wind stress

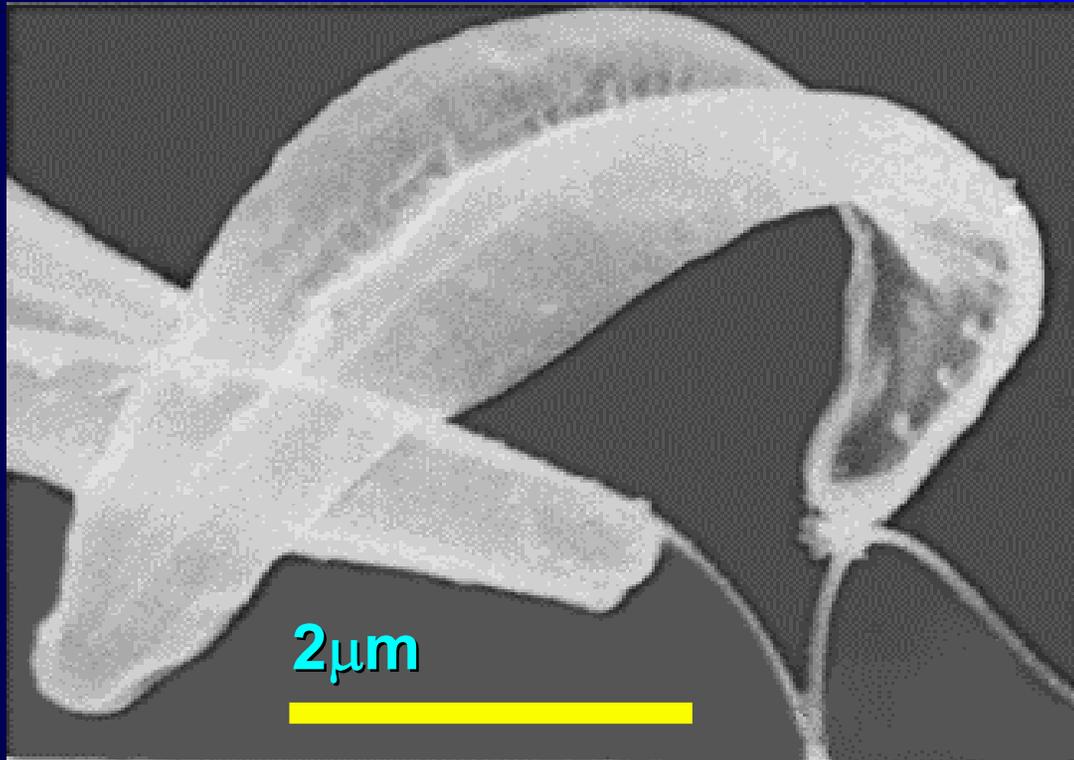


Global seven-year mean pigment fields

Pigments
(mg m⁻³)

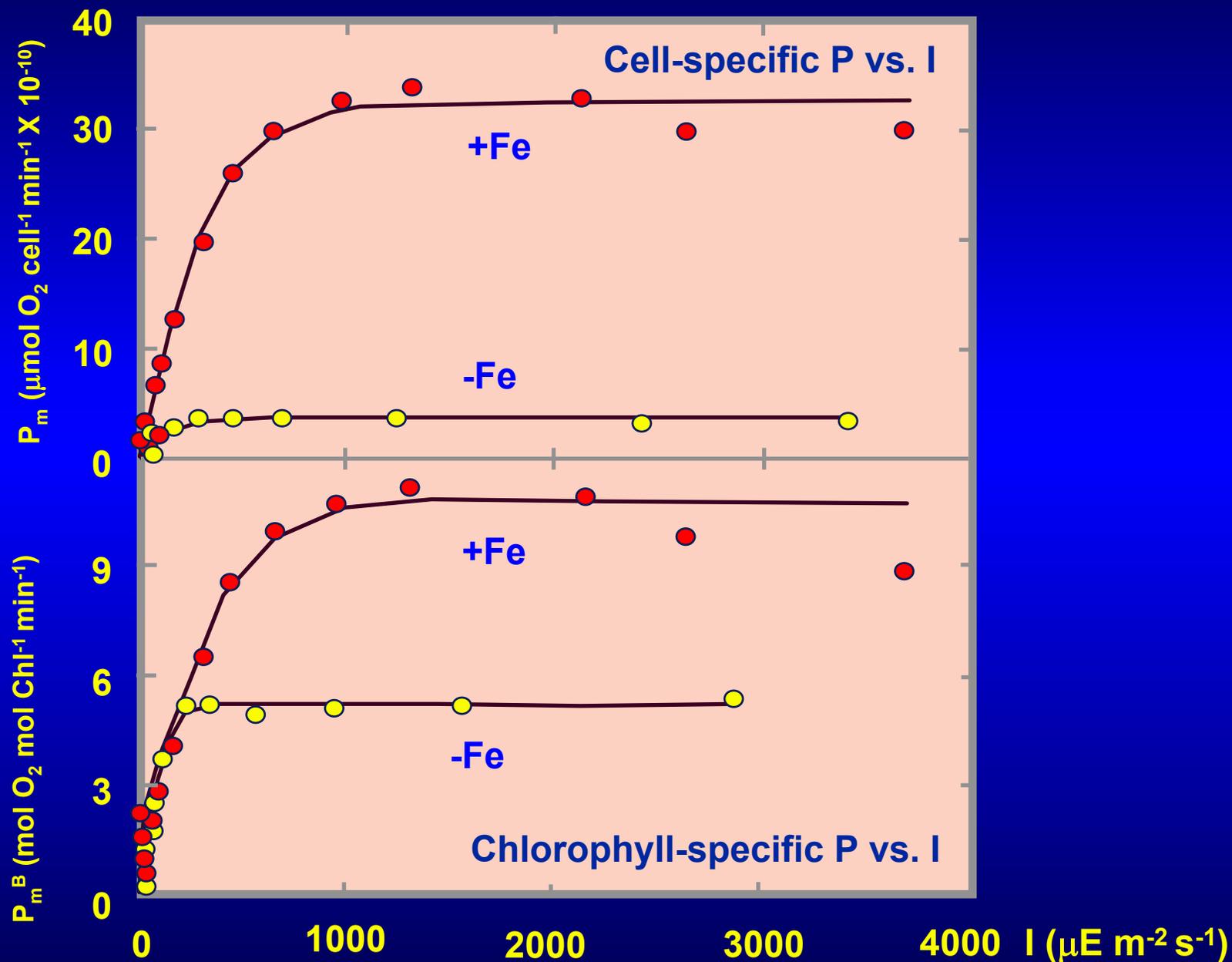


Phytoplankton from 40m Fe enrichment incubations
Nitzschia sp.



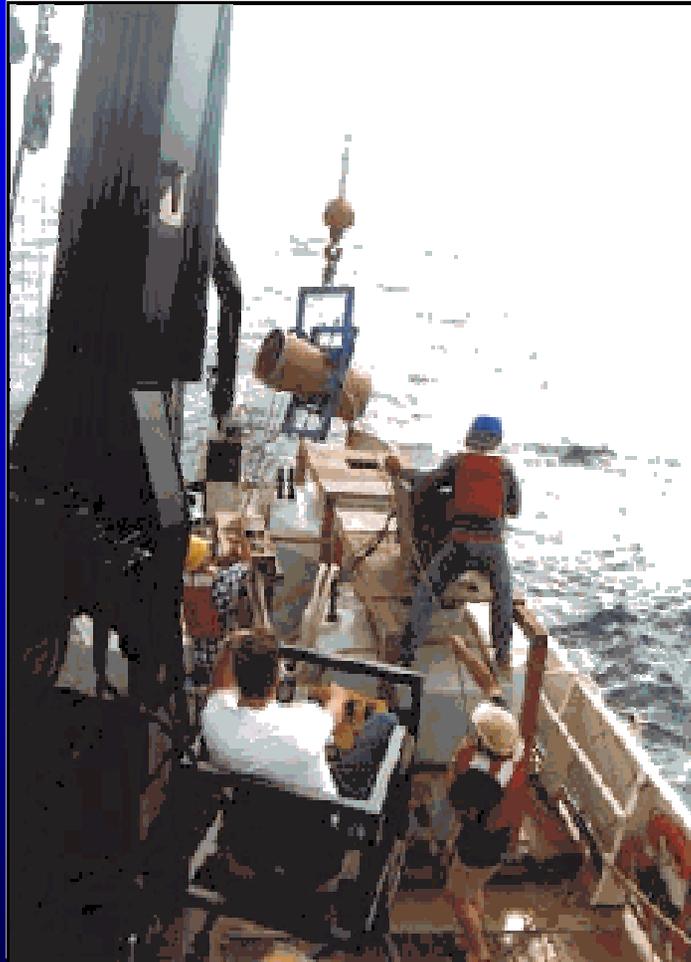
Chavez *et al.*, 1991 - *Limnol. & Oceanog.* 36, p. 1816-33

Efeito de Fe em curvas P-I para *Phaeodactylum tricornutum*



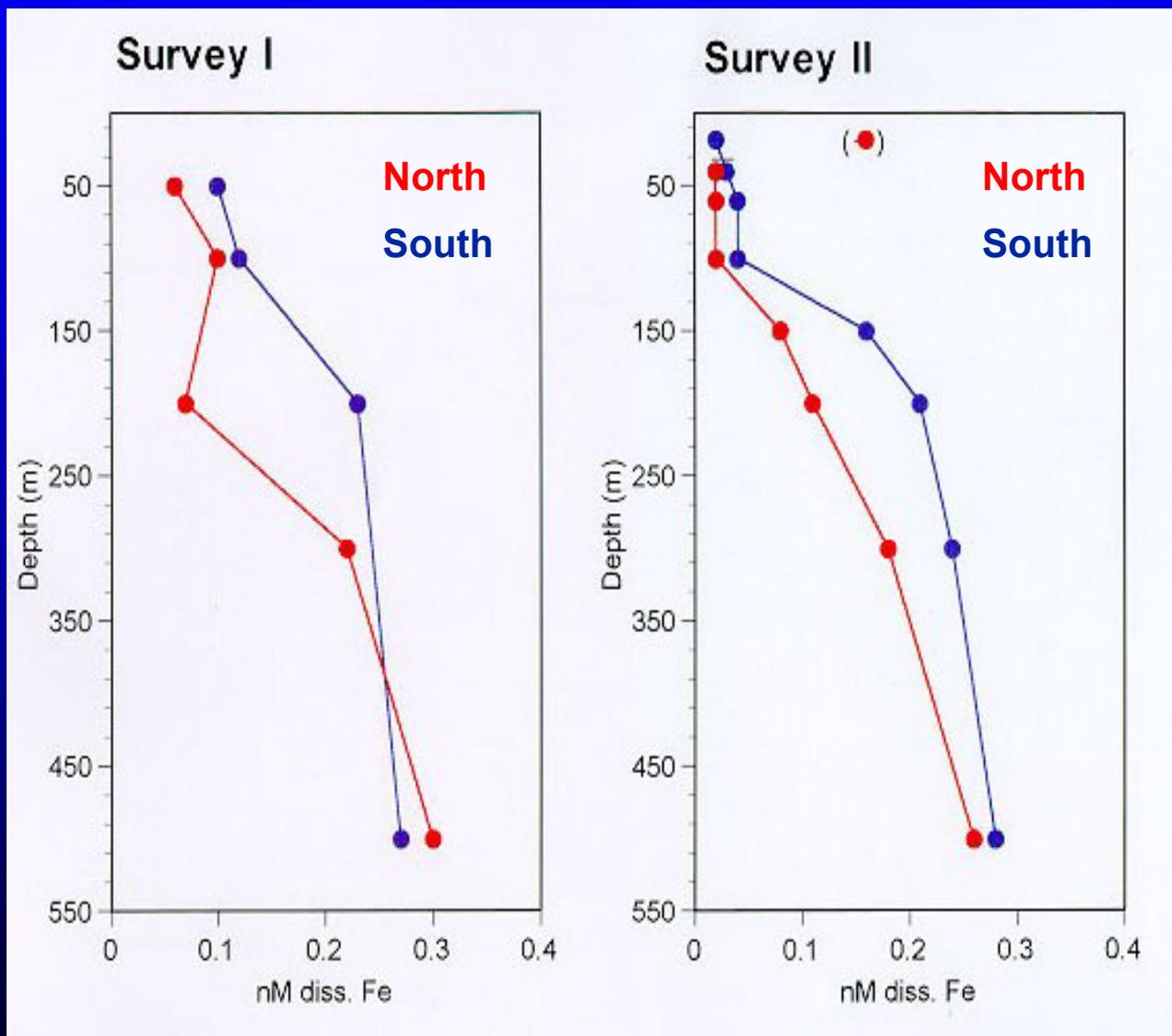
Greene et al., 1991. Limnol. & Oceanog. 36, 8, 1772-1782

IronEx I - Large-scale patch experiment in 193



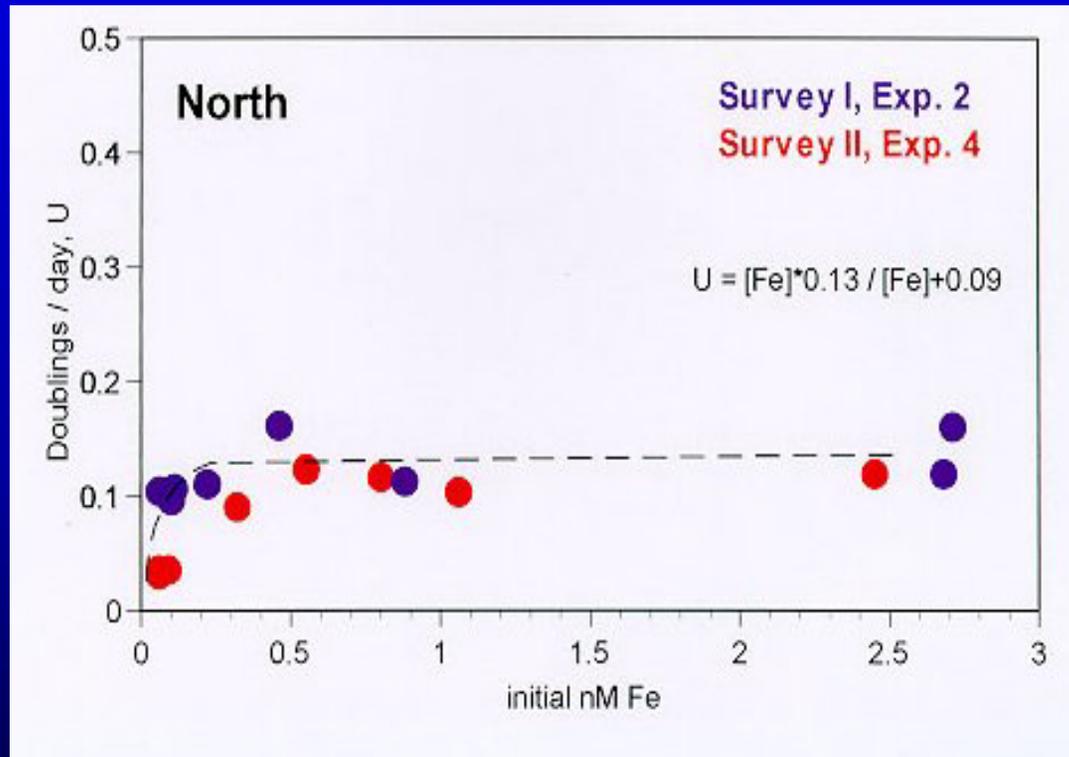
Mixing Fe and SF₆ (artificial tracer) in the equatorial Pacific Ocean.
IronEx I was followed by IronEx II in 1995, which showed conclusively that phytoplankton production may be limited by Fe.

Dissolved Fe profiles - Antarctic Polar Front



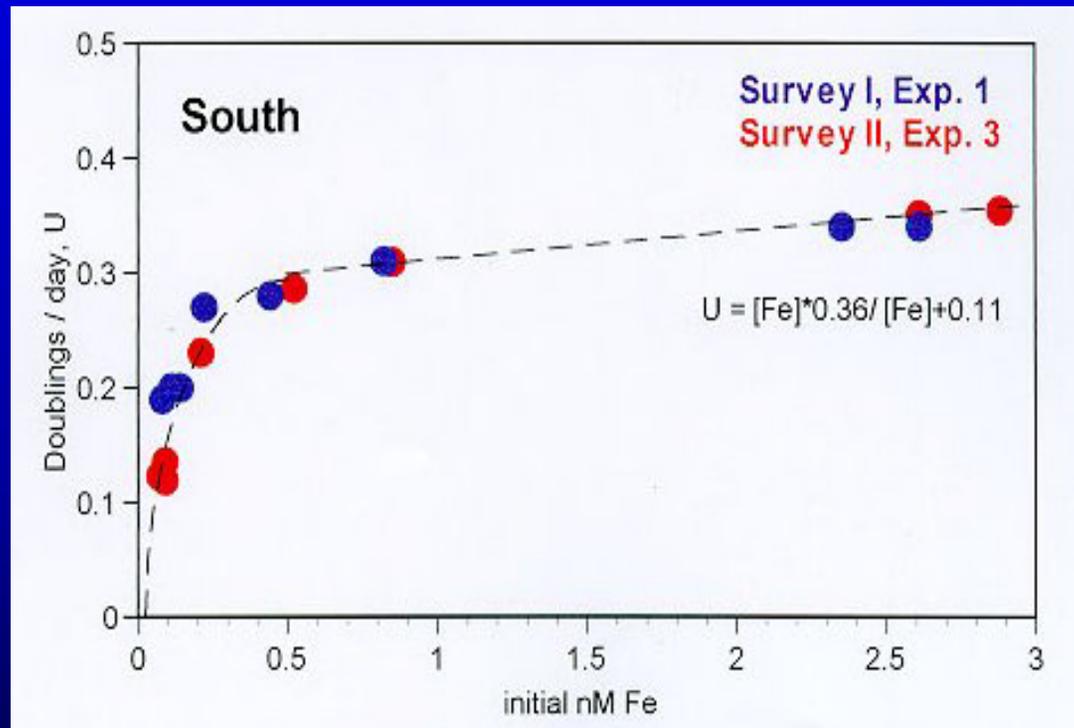
Dissolved Fe profiles North (red) and South (blue) of the Polar Front during JGOFS experiment in the late 1990's

Phytoplankton growth rates versus initial Fe concentration



Phytoplankton incubation experiments North and South of Polar Front during Survey I (blue) and Survey II (red)

Phytoplankton growth rates versus initial Fe concentration



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Comparison between North and South results

“The pseudo-Michaelis Menten response to added iron in deckboard enrichment experiments differs north of the APFZ relative to south of the APFZ, indicating:

- All dissolved iron concentrations are below half saturation constants, indicating limiting conditions persist throughout the entire Southern Ocean.
- Waters to the North may be limited by something in addition to iron (silicate).
- Similar saturation values are consistent with other observations from other oceans.”

High nutrient - Low chlorophyll paradox

