

Teórica 12:  
Metabolismo ecosistémico 1:  
Productividad primaria

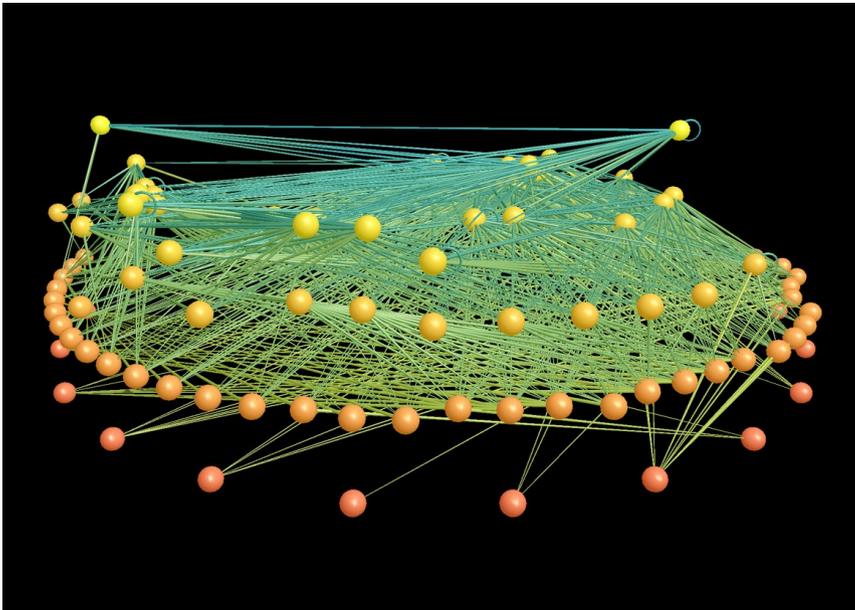
# Teórica 12: Esquema conceptual

- Definiciones
- Variación geográfica en la producción primaria
- Limitantes de la producción primaria en
  - ambientes marinos
  - ambientes acuáticos continentales
  - ambientes terrestres
- Relación entre diversidad y productividad

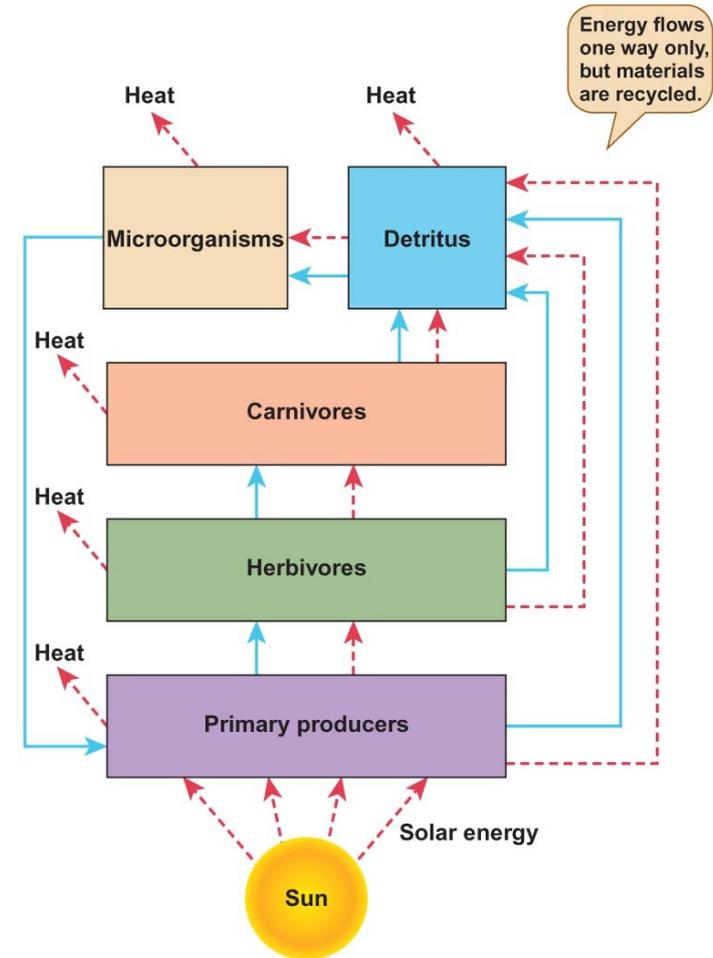
# Enfoques de la ecología de comunidades y ecosistemas

- Poblacional: se centra en las poblaciones y la estructura de las interacciones entre ellas (lo que vimos hasta ahora)
- Ecosistémico: se centra en la física de los ecosistemas, evaluando el flujo de nutrientes y energía

# Enfoques de la ecología de comunidades y ecosistemas



Enfoque poblacional



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Enfoque ecosistémico

# Tipos de productores

- Autótrofos (o productores primarios): organismos que obtienen su energía del sol y de materiales abióticos
- Heterótrofos (o productores secundarios): organismos que obtienen su energía consumiendo otros organismos vivos

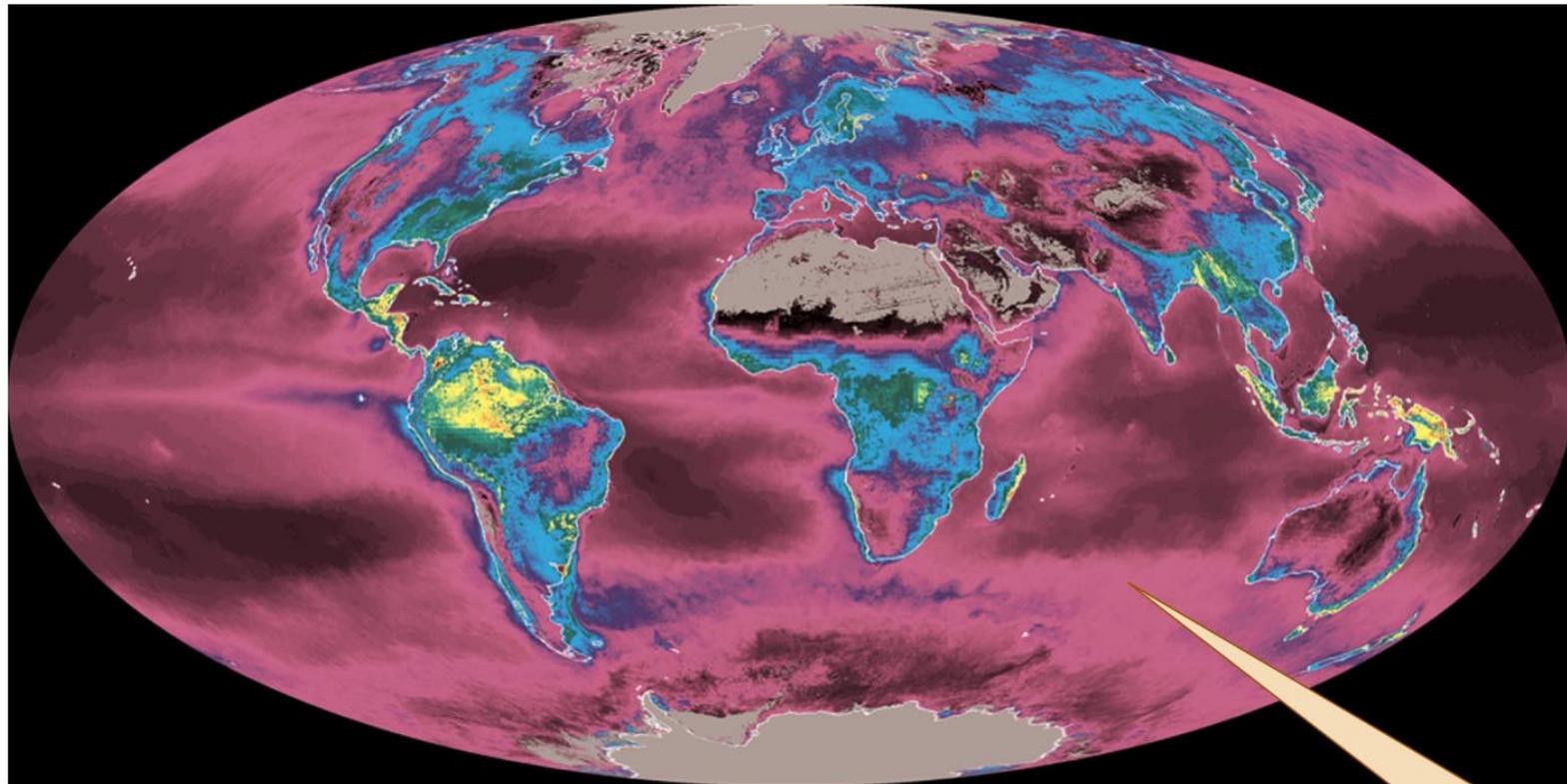
# Producción primaria (PP)

Fotosíntesis:  $6 \text{H}_2\text{O} + 6 \text{CO}_2 + \text{energía solar} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$

Respiración:  $\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \rightarrow 6 \text{H}_2\text{O} + 6 \text{CO}_2 + \text{energía metabólica}$

- Producción primaria bruta: energía (o carbono) fijada mediante fotosíntesis por unidad de tiempo
- Producción primaria neta: energía fijada mediante fotosíntesis – energía perdida en respiración por unidad de tiempo

# Variación geográfica en la producción primaria



Net Primary Productivity (kgC/m<sup>2</sup>/year)



Most of the Oceans have very low net primary production.

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# Variación geográfica en la producción primaria

**Table 22.1** Net primary production for land and ocean estimated from satellite data, as illustrated in Figure 22.3.

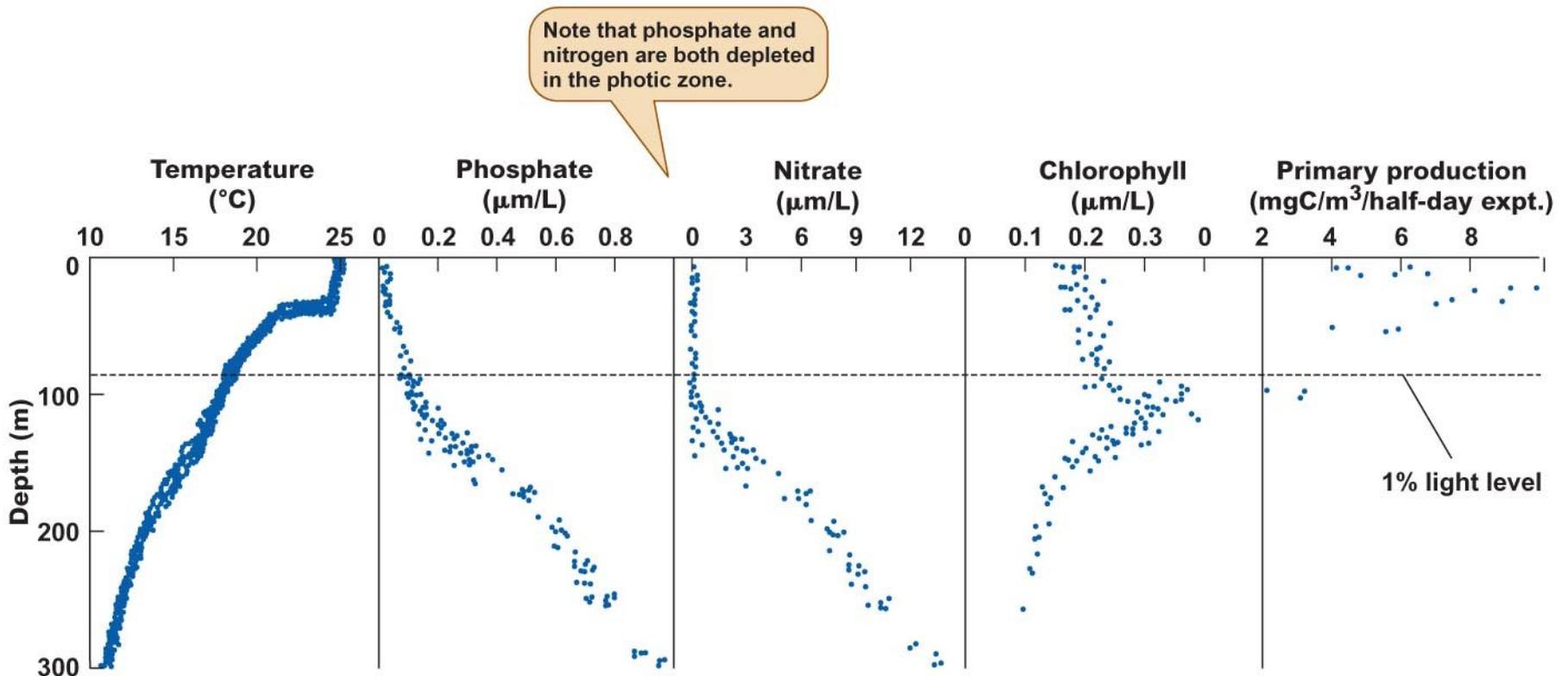
Vegetation type	Annual net primary production
Ocean	48.5
Land	
Tropical rainforests	15.9
Broadleaf deciduous forests	4.4
Broadleaf and needleleaf forests	3.0
Needleleaf evergreen forests	4.5
Needleleaf deciduous forests	1.6
Savannas	12.4
Perennial grasslands	2.8
Broadleaf shrubs	0.2
Tundra	2.3
Desert	1.6
Cultivated areas	8.0
Total for land vegetation	56.7
Total for globe	105.2

All values of net primary production are in petagrams of carbon (1 petagram =  $10^{15}$  grams =  $10^9$  metric tons).

SOURCE: Field et al. (1998) and Ito and Oikawa (2004) estimates.

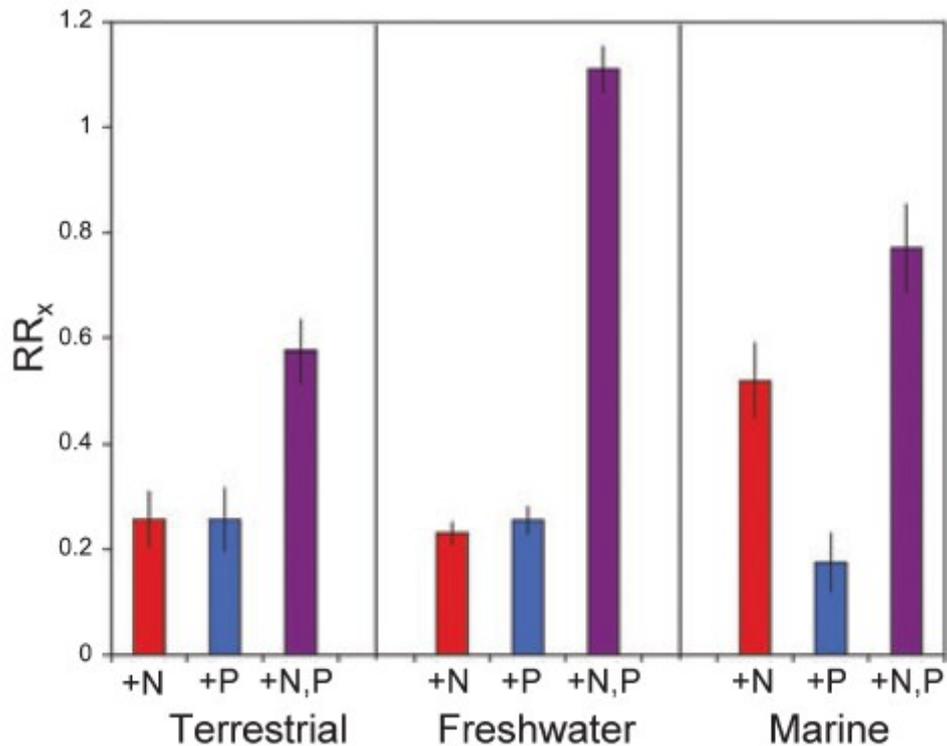
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# Limitantes de la productividad primaria en ambientes marinos



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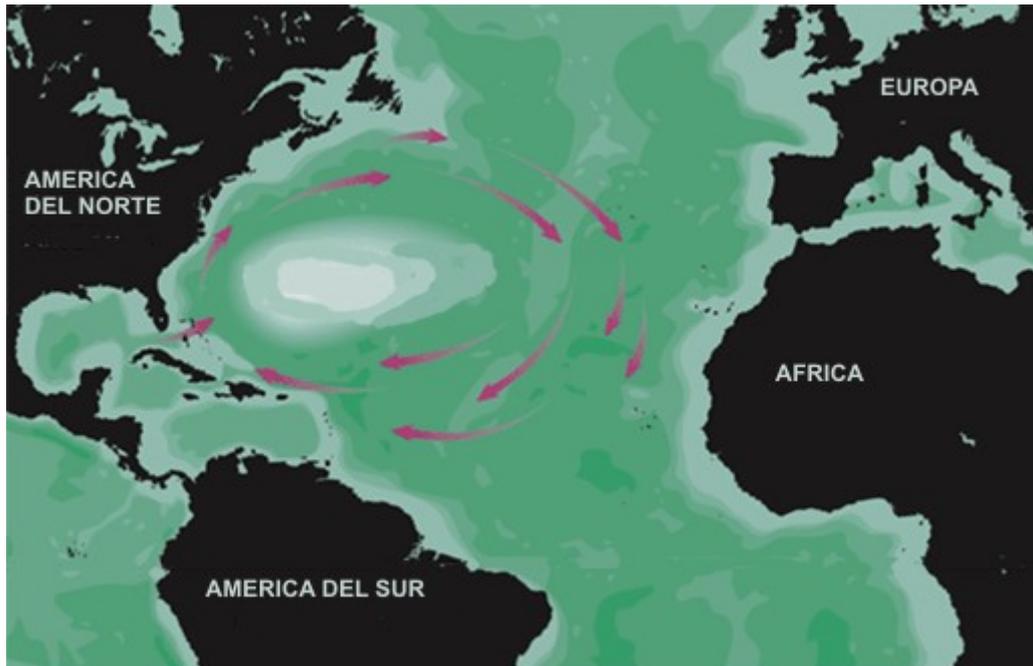
# Limitantes, ambientes marinos



**Figure 1** Responses of autotrophs to single enrichment of N (red) or P (blue) or to combined N + P enrichment (purple) in terrestrial, freshwater and marine ecosystems. Data are given as natural-log transformed response ratios ( $RR_x$ ) in which autotroph biomass or production in the enriched treatment is divided by its value in the control treatment and then ln-transformed (see Methods). Thus, a value of 0.5 indicates a value in the manipulated treatment that is  $\approx$  1.6 times its value in the control, while a value of 1.0 indicates a 2.7-fold increase. Sample sizes +N, +P and +N&P treatments were 112, 107 and 126 for terrestrial studies, 509, 506 and 618 for freshwater studies and 149, 141 and 197 for marine systems, respectively. Error bars indicate plus or minus one standard error.

Fuente: Elser et al. (2007) Ecol. Lett. 10: 1135-1142

# Limitantes, ambientes marinos



Mar de los Sargazos

Experimento de Menzel & Ryther (1961):

Nutrients added to experimental culture	Relative uptake of $^{14}\text{C}$ by cultures
None (controls)	1.00
N + P only	1.10
N + P + metals (excluding iron)	1.08
N + P + metals (including iron)	12.90
N + P + iron	12.00

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Hierro → Cianobacterias → Fijación de nitrógeno → Fitoplancton

# Limitantes, ambientes marinos

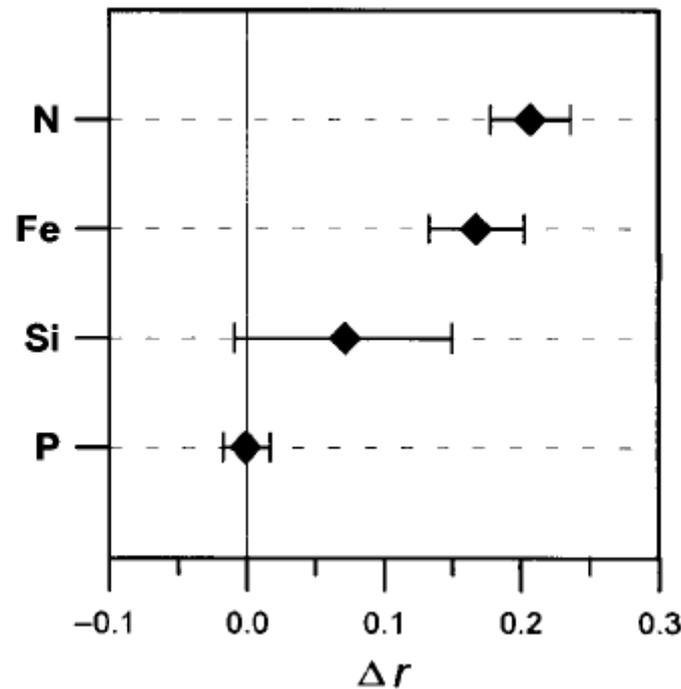
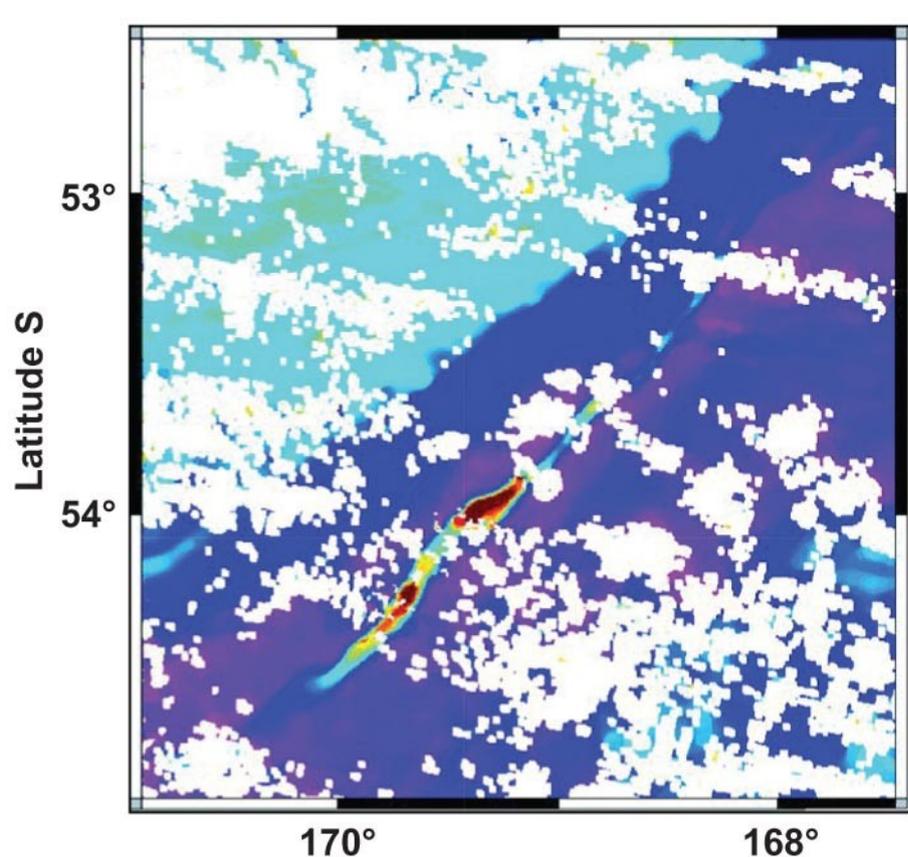


FIG. 2. Effects of nutrient addition on phytoplankton growth, as measured by  $\Delta r$ , the change in per unit (per gram; per unit carbon, or per chlorophyll *a*) growth rate of an algal assemblage following the addition of surplus nutrients. Results give responses for each nutrient added singly to phytoplankton assemblages and show, using an unweighted analysis with resampling procedures, that nutrients varied in their effect on phytoplankton growth ( $P = 0.002$ ). Error bars represent 95% confidence intervals of  $\Delta r$  based on the resampling procedures with 5000 iterations. N denotes experiments enriching with nitrogen, P denotes phosphorus addition, Si denotes silicate addition, and Fe denotes iron addition. The means are based on 148 (N), 114 (P), 35 (Fe), and 6 (Si) experiments.

Fuente: Downing et al. (1999) Ecology 80: 1157-1167

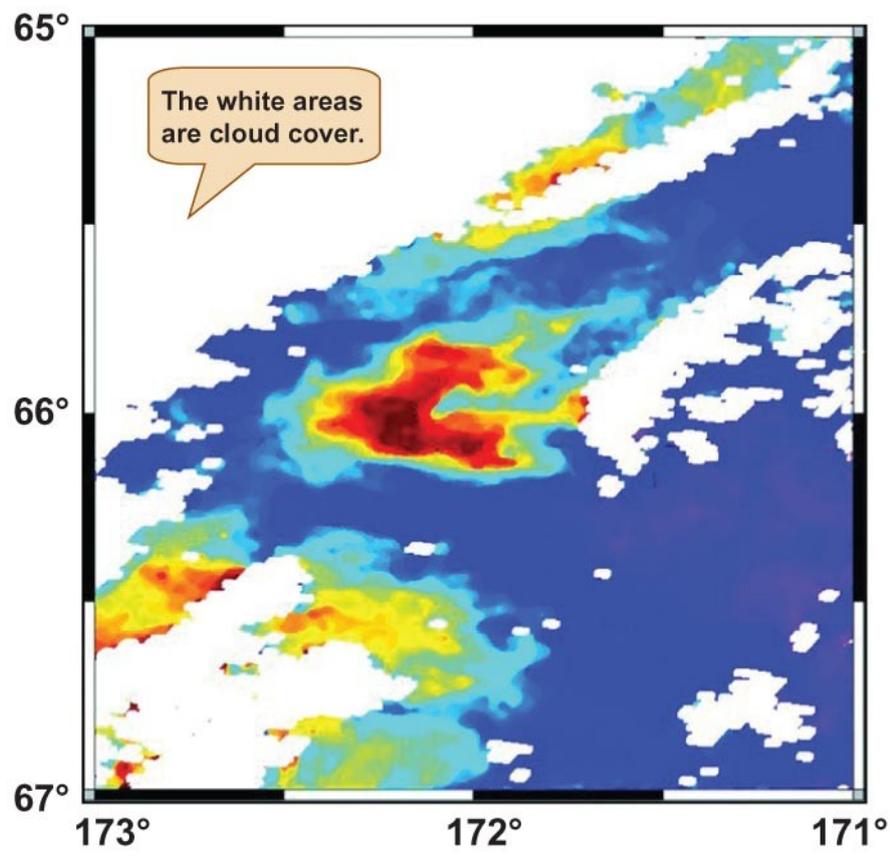
# Limitantes, ambientes marinos

## Hierro: experimento SOFeX



(a) North Patch

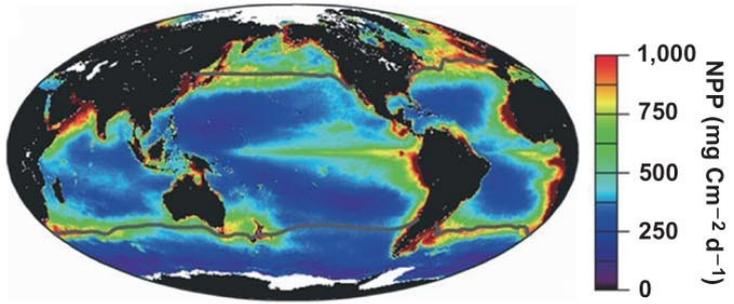
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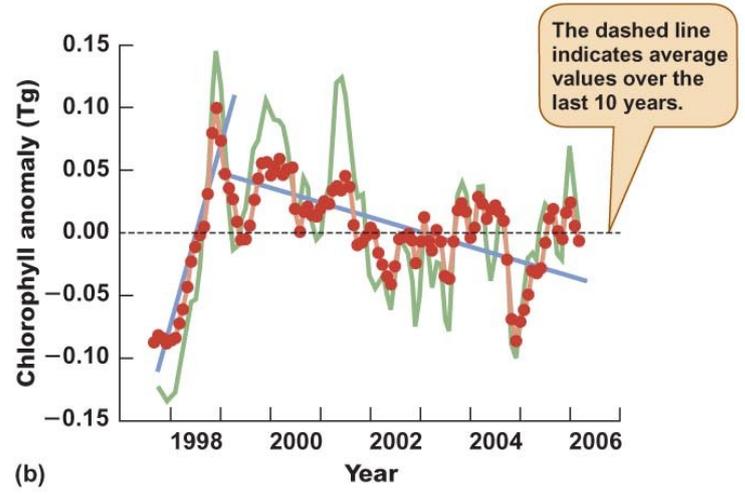
(b) South Patch

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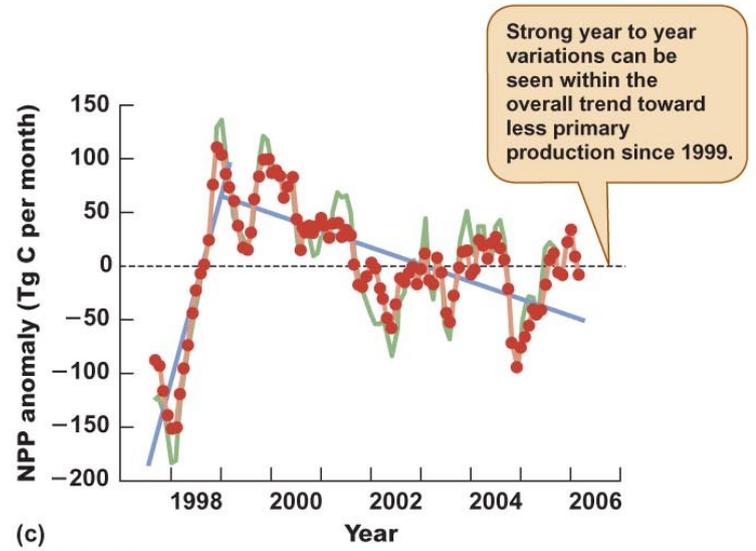
# Limitantes, ambientes marinos



(a)



(b)

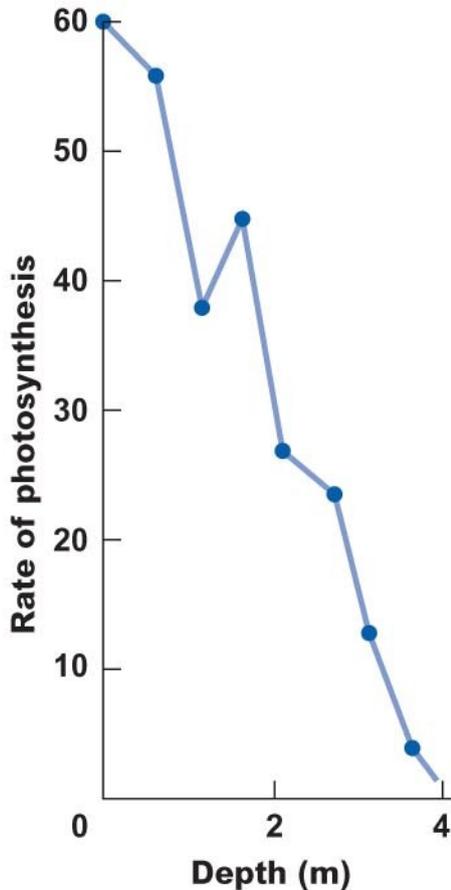


(c)

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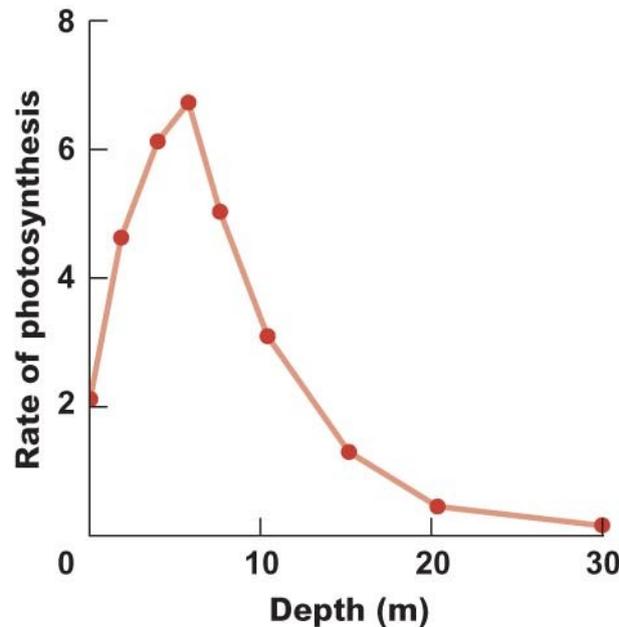
# Limitantes: ambientes dulceacuícolas

## Luz

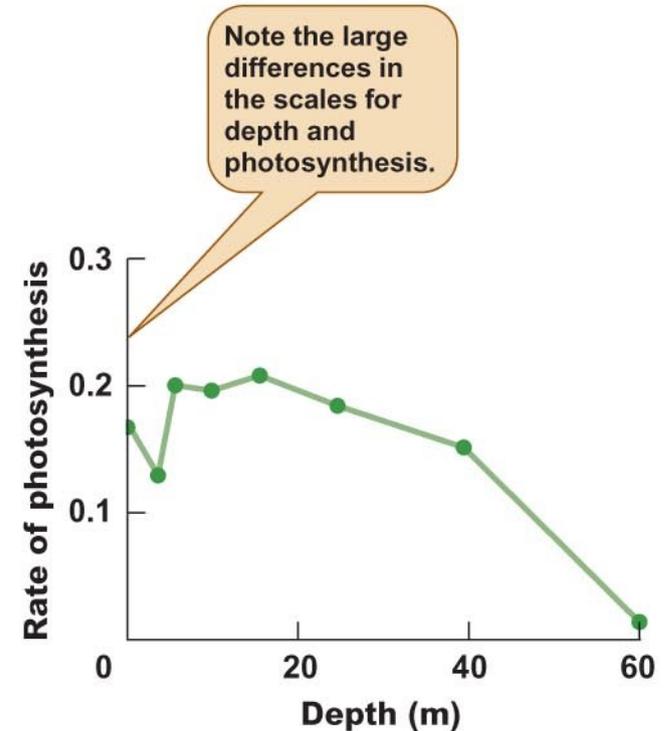


(a) Clear Lake

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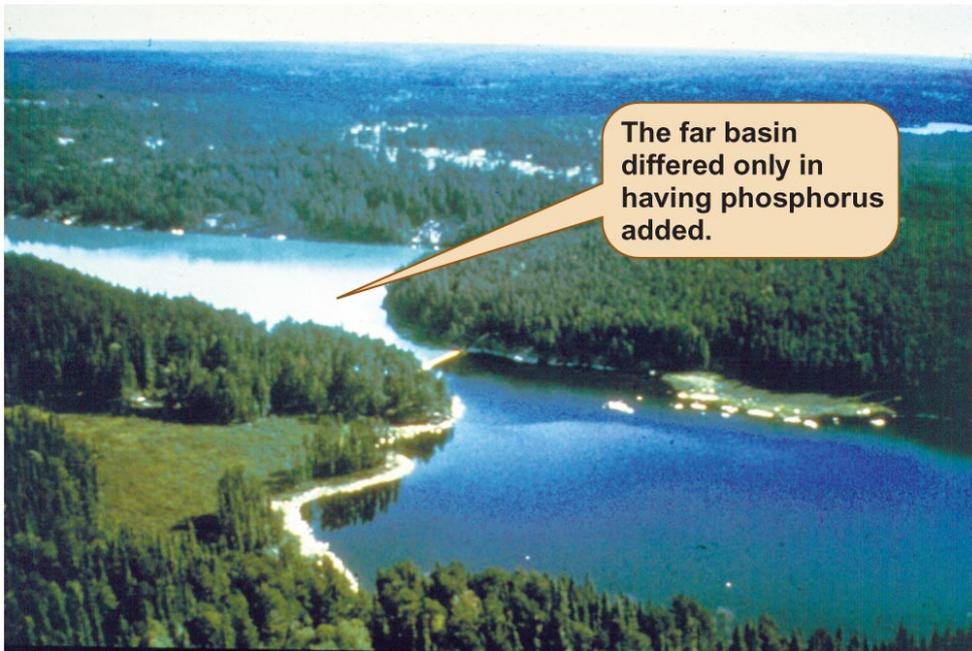
(b) Castle Lake



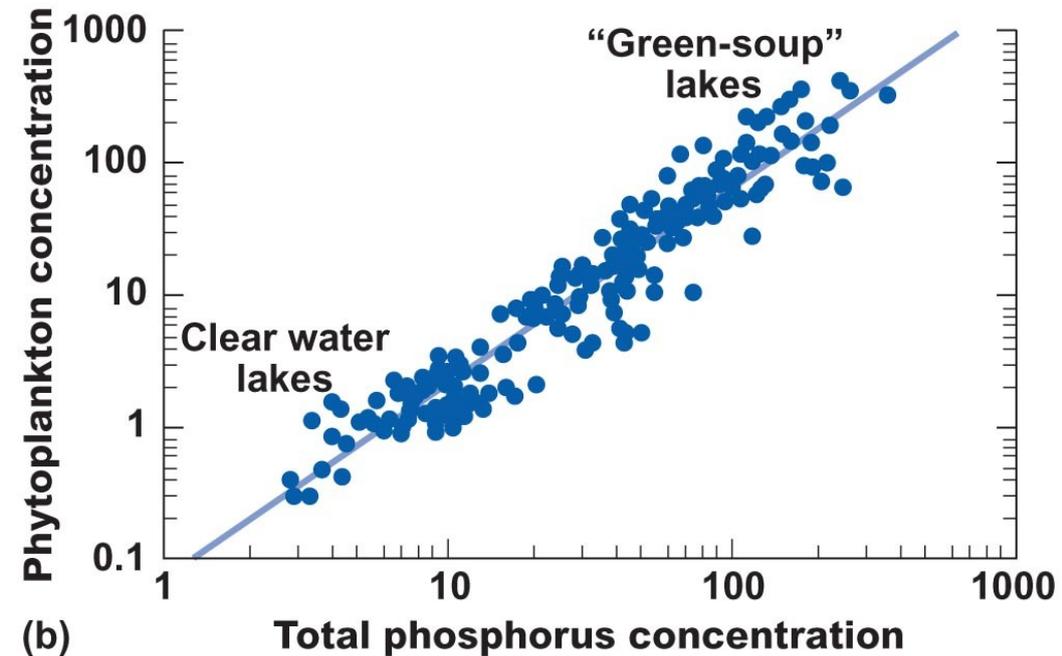
(c) Lake Tahoe

# Limitantes: ambientes dulceacuícolas

## Fósforo



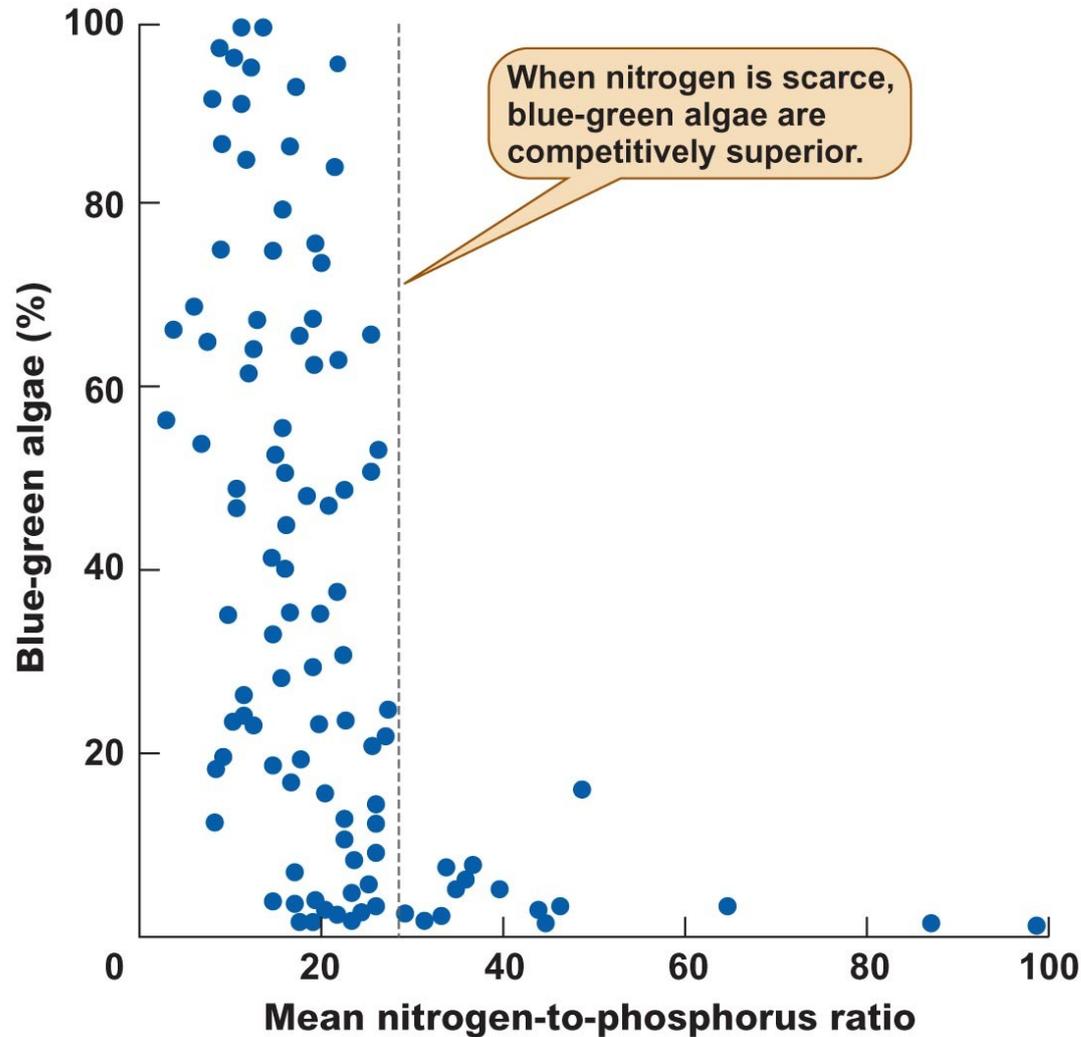
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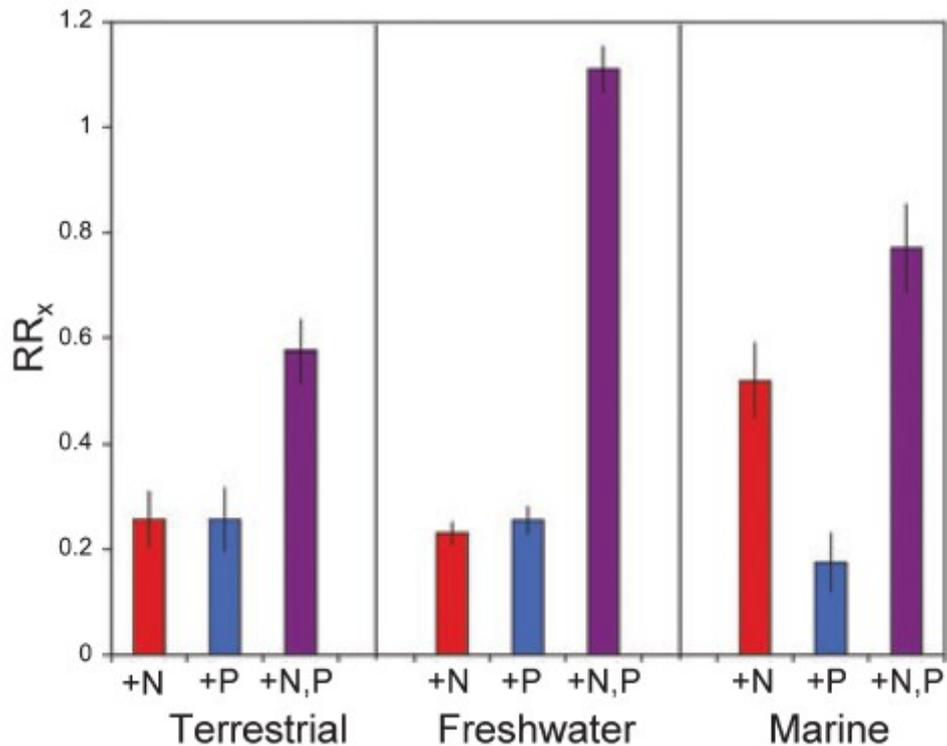
# Limitantes: ambientes dulceacuícolas

## Fósforo y relación N:P



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# Limitantes, ambientes dulceacuícolas

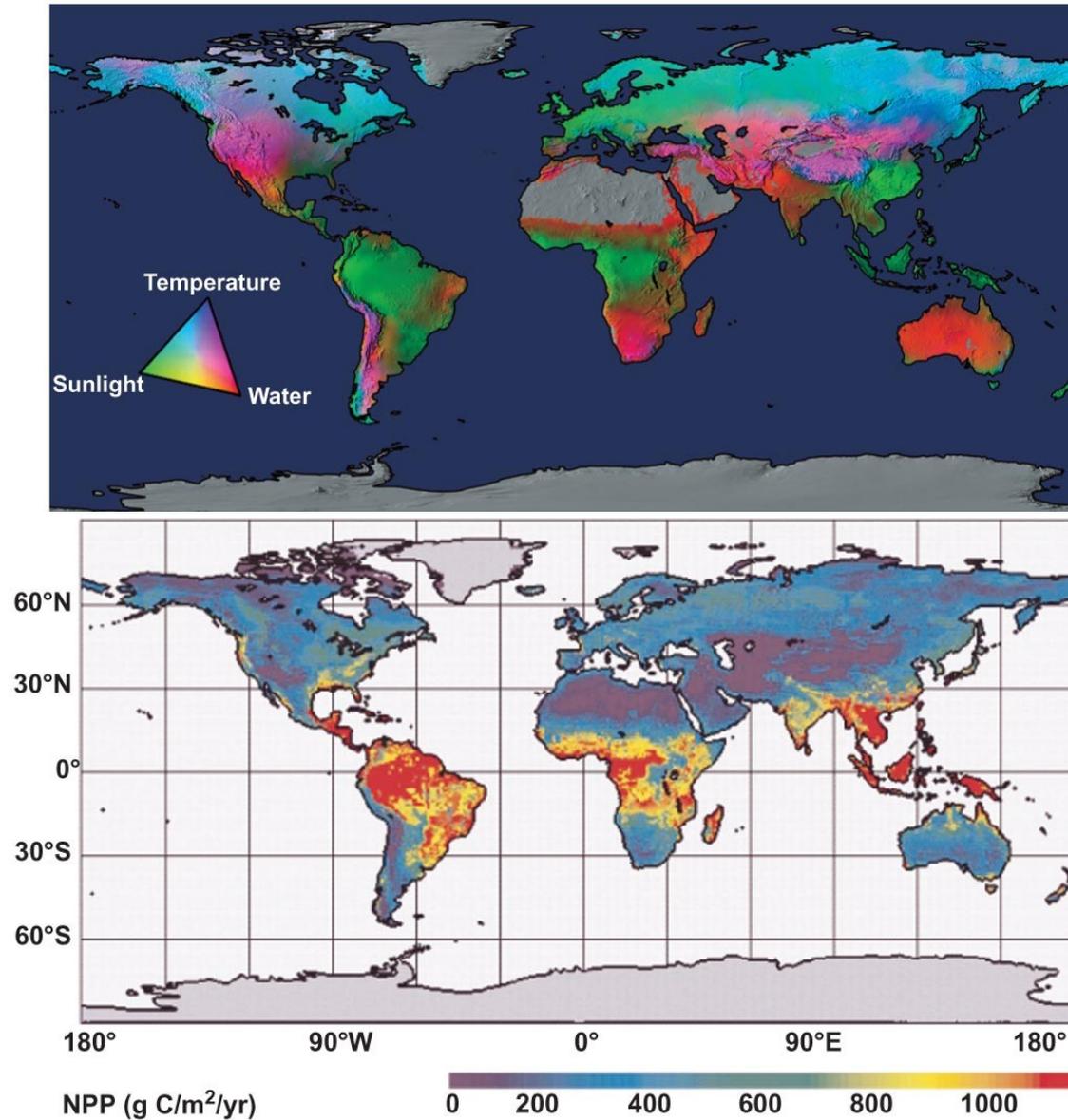


**Figure 1** Responses of autotrophs to single enrichment of N (red) or P (blue) or to combined N + P enrichment (purple) in terrestrial, freshwater and marine ecosystems. Data are given as natural-log transformed response ratios ( $RR_x$ ) in which autotroph biomass or production in the enriched treatment is divided by its value in the control treatment and then ln-transformed (see Methods). Thus, a value of 0.5 indicates a value in the manipulated treatment that is  $\approx$  1.6 times its value in the control, while a value of 1.0 indicates a 2.7-fold increase. Sample sizes +N, +P and +N&P treatments were 112, 107 and 126 for terrestrial studies, 509, 506 and 618 for freshwater studies and 149, 141 and 197 for marine systems, respectively. Error bars indicate plus or minus one standard error.

Fuente: Elser et al. (2007) Ecol. Lett. 10: 1135-1142

# Limitantes: ambientes terrestres

## Evapotranspiración real (AET)

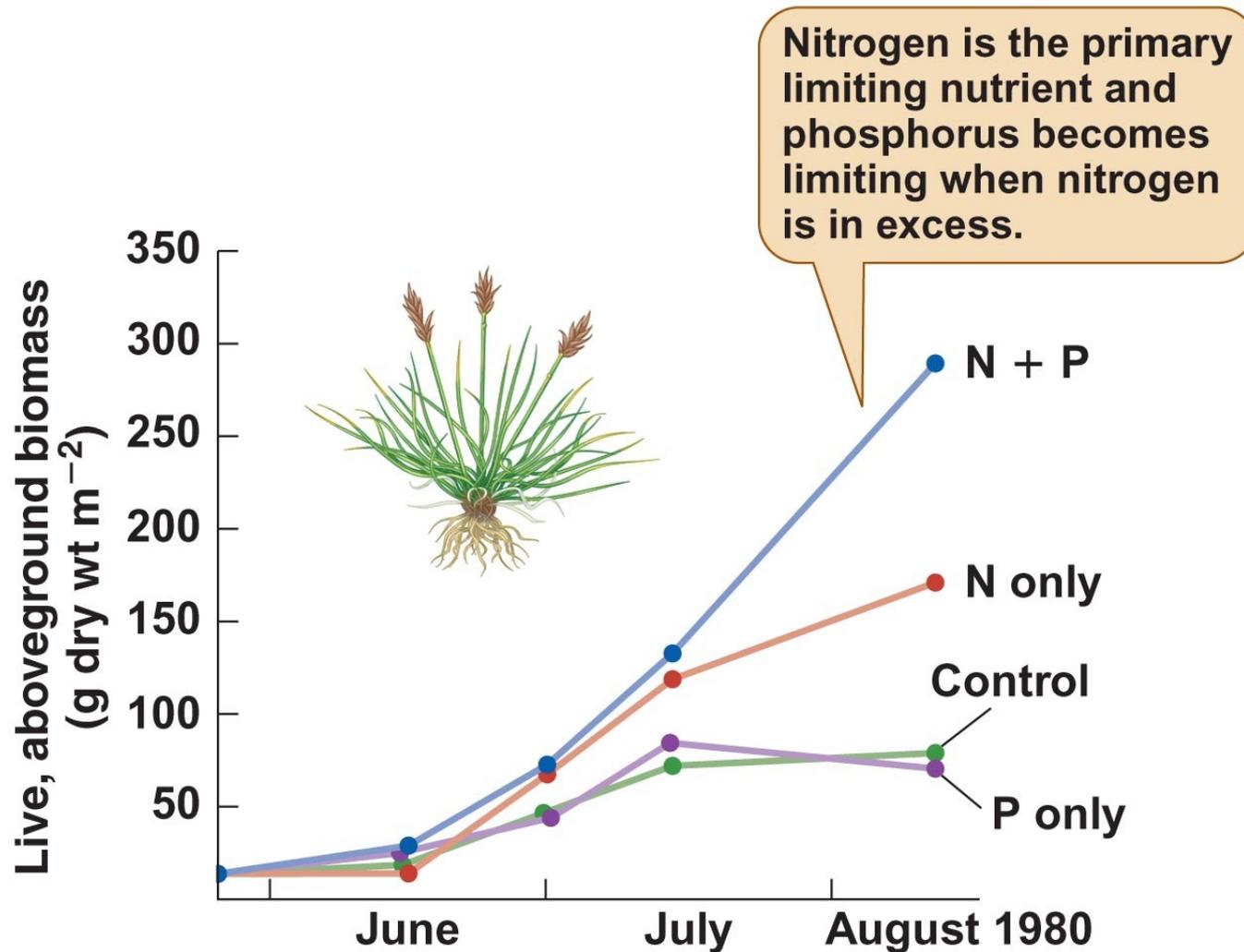


(b)

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# Limitantes: ambientes terrestres

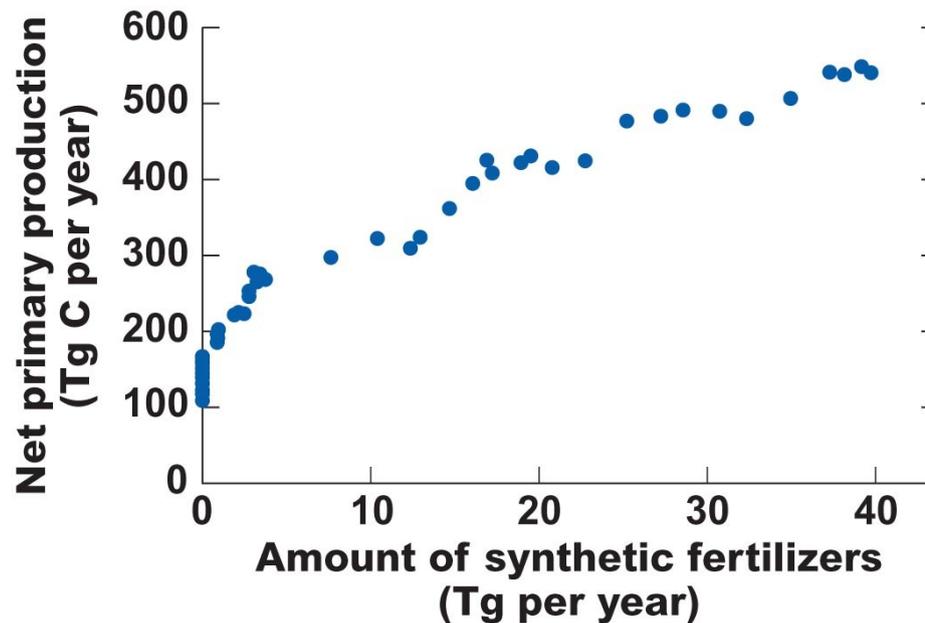
## Nitrógeno y fósforo



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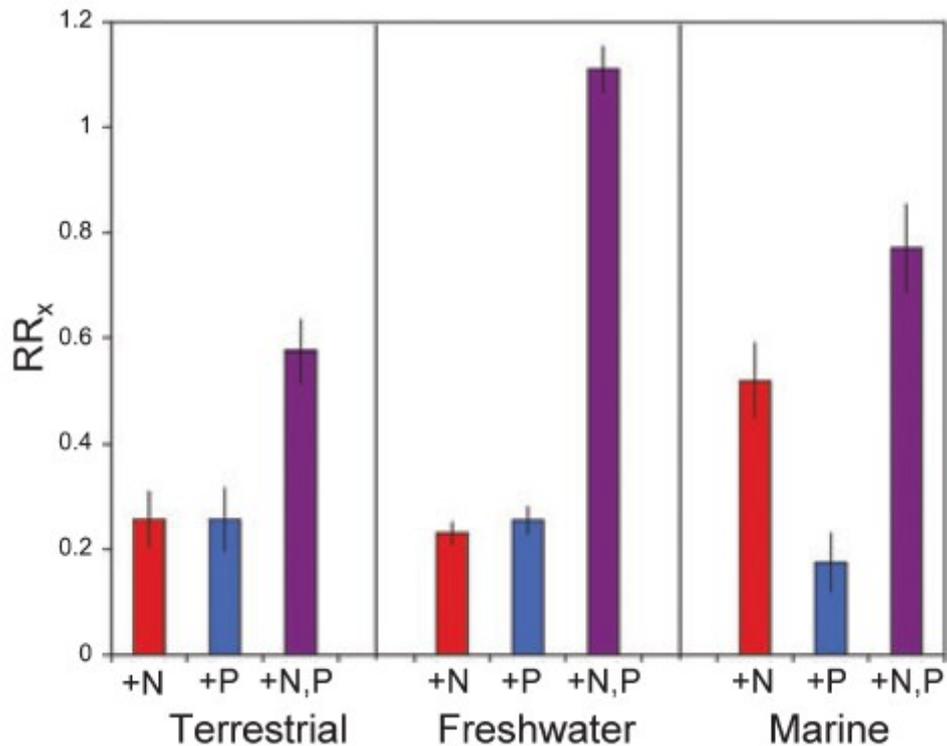
# Limitantes: ambientes terrestres

## Fertilizantes artificiales y producción agrícola



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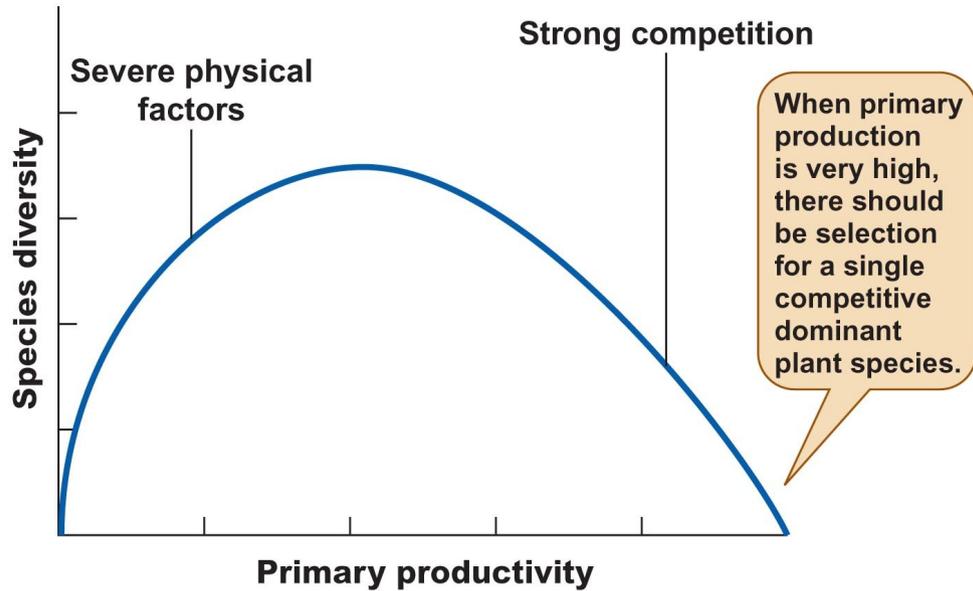
# Efecto combinado del nitrógeno y el fósforo en todos los ambientes



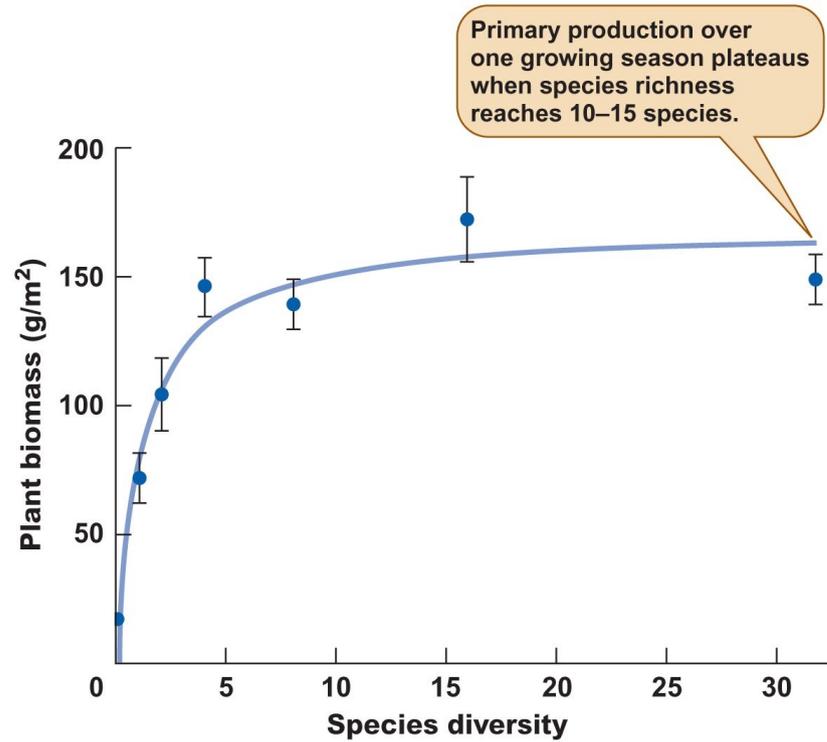
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Fuente: Elser et al. (2007) Ecol. Lett. 10: 1135-1142

# Diversidad de especies y productividad

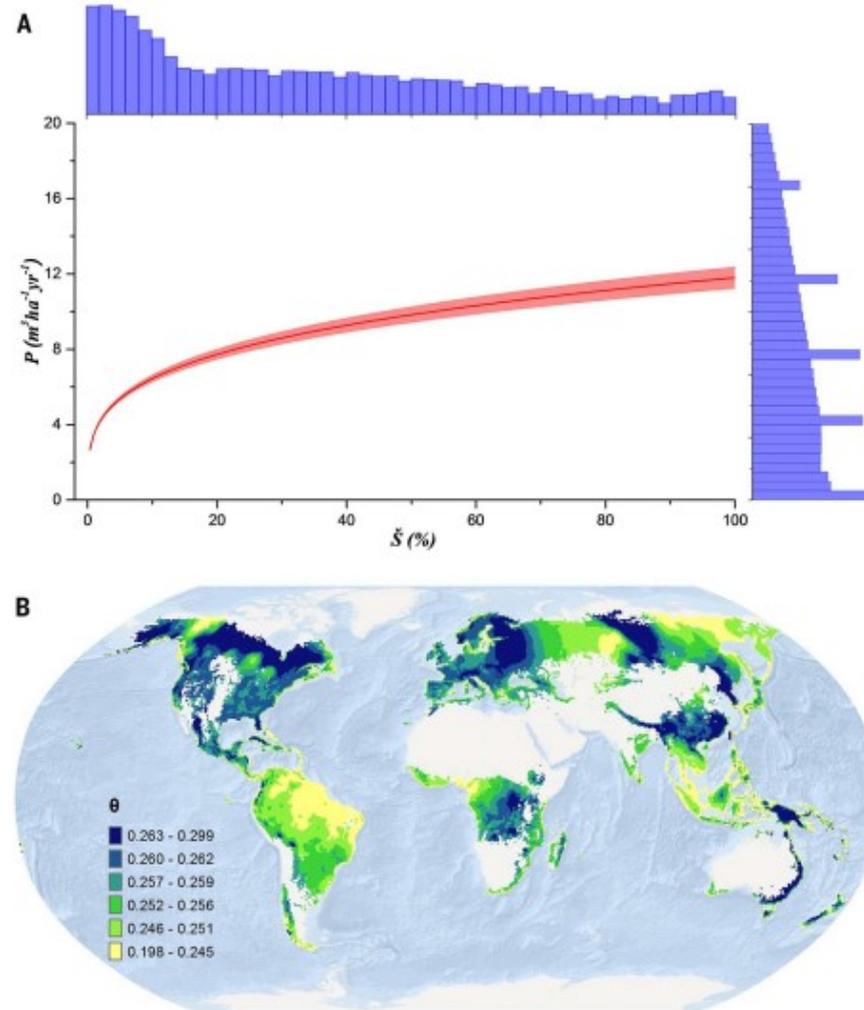


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# Diversidad de especies y productividad



Fuente: Liang et al. (2016) Science 354

**Fig. 3. The estimated global effect of biodiversity on forest productivity was positive and concave-down, and revealed considerable geospatial variation across forest ecosystems worldwide. (A)** Global effect of biodiversity on forest productivity (red line with pink bands representing 95% confidence interval) corresponds to a global average elasticity of substitution ( $\theta$ ) value of 0.26, with climatic, soil, and other plot covariates being accounted for and kept constant at sample mean.

Relative species richness ( $\bar{S}$ ) is in the horizontal axis, and productivity ( $P$ ,  $\text{m}^3 \text{ha}^{-1} \text{year}^{-1}$ ) is in the vertical axis (histograms of the two variables on top and right in the logarithm scale). **(B)**  $\theta$  represents the strength of the effect of tree diversity on forest productivity. Spatially explicit values of  $\theta$  were estimated by using universal kriging (Materials and methods) across the current global forest extent (effect sizes of the estimates are shown in Fig. 5), whereas blank terrestrial areas were nonforested.

# Teórica 12: Recapitulación

- Las plantas capturan energía mediante fotosíntesis, sosteniendo a todos los niveles tróficos
- La productividad primaria (PP) varía geográficamente
- Principales limitantes de PP:
  - Mar: N y Fe, y P en menor medida. Luz y temp. no suelen limitar.
  - Agua dulce: luz y temp., junto con P y N.
  - Tierra: luz (radiación), temp., humedad, N y P.
- La diversidad de especies y la productividad primarias están íntimamente relacionadas