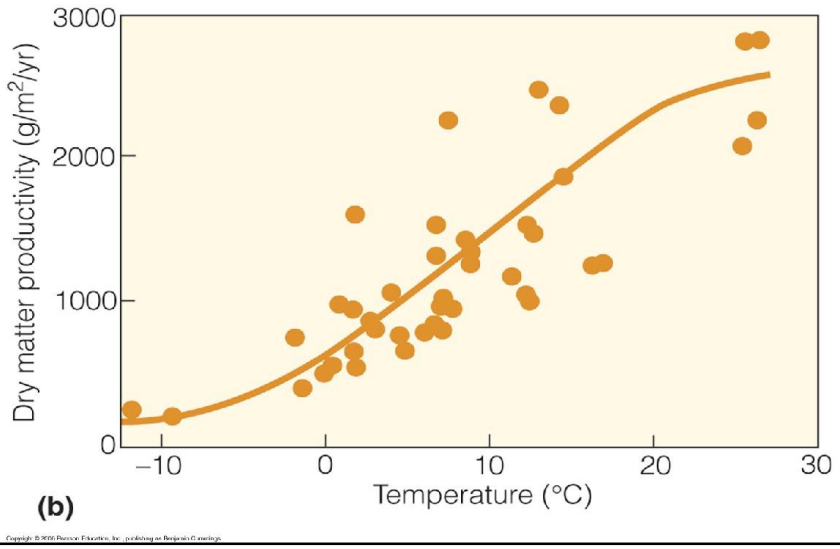
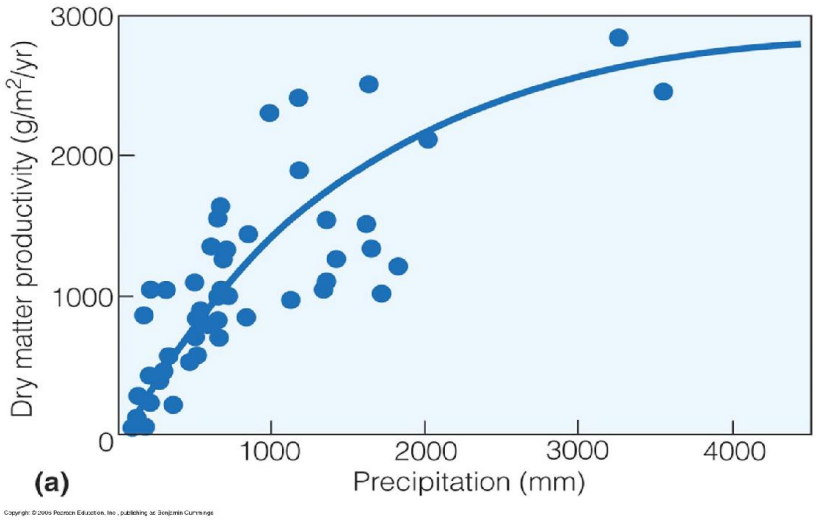
Fattori che limitano la produzione primaria terrestre

- Temperatura
- Precipitazioni
- Luce
- Nutrienti

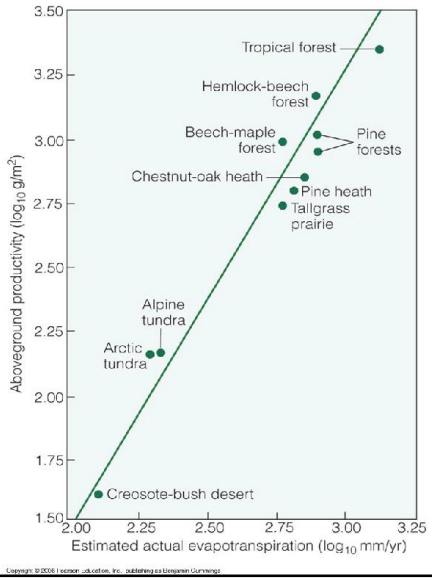
Fattori di controllo in ecosistemi terrestri



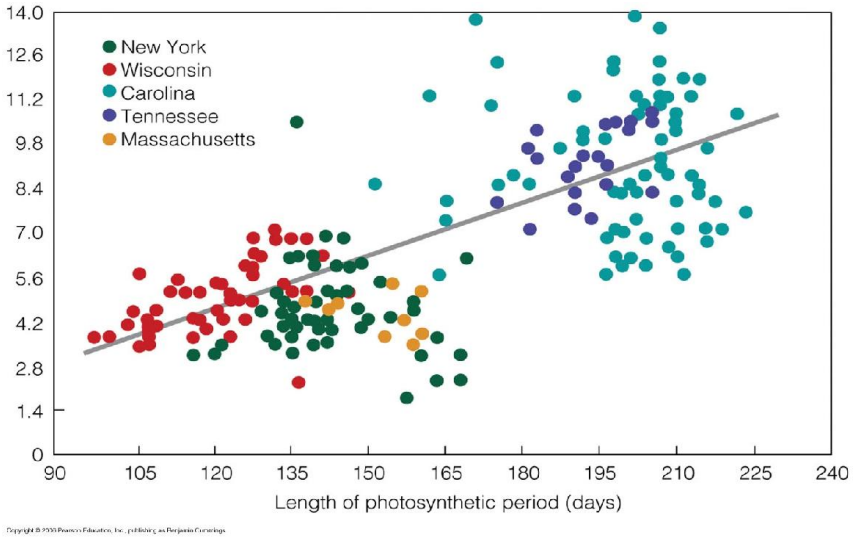
Fattori di controllo in ecosistemi terrestri



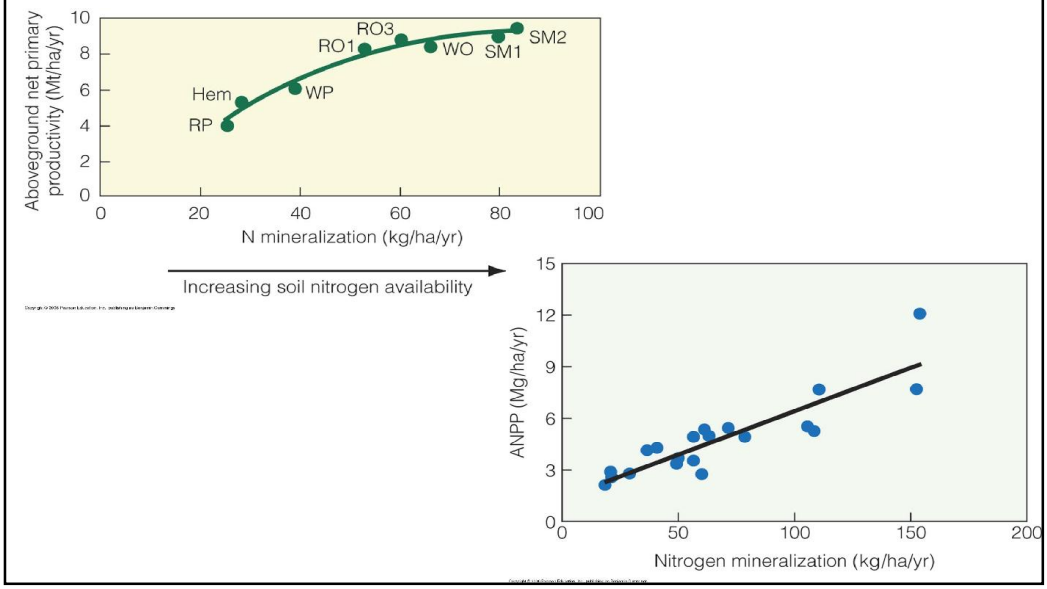
Fattori di controllo in ecosistemi terrestri



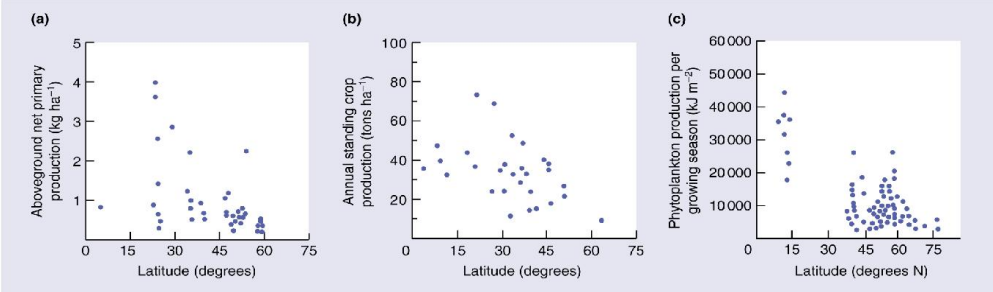
Fattori di controllo in ecosistemi terrestri



Fattori di controllo in ecosistemi terrestri



La latitudine come fattore di controllo



Il trend è ovunque decrescente: a) prateria e tundra; b) Campi coltivati; c) Laghi

Mappa globale di produttività primaria

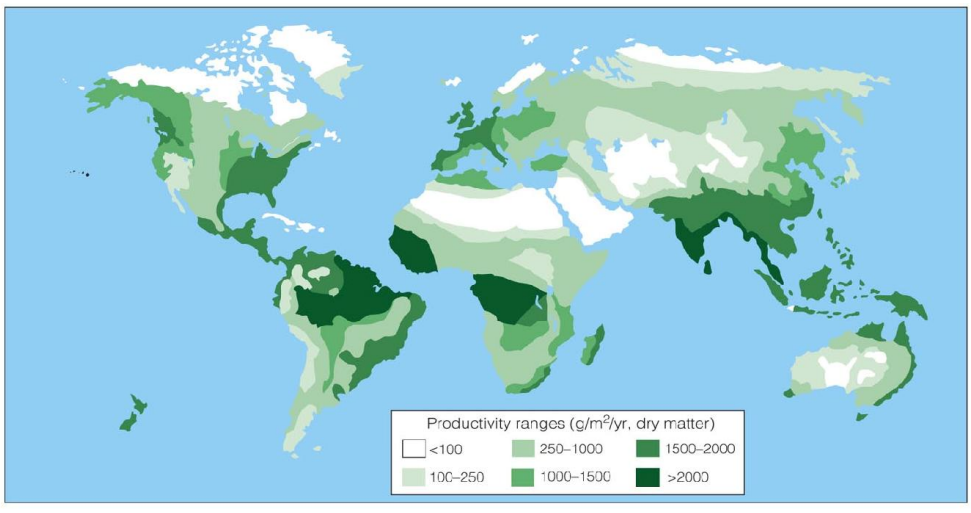
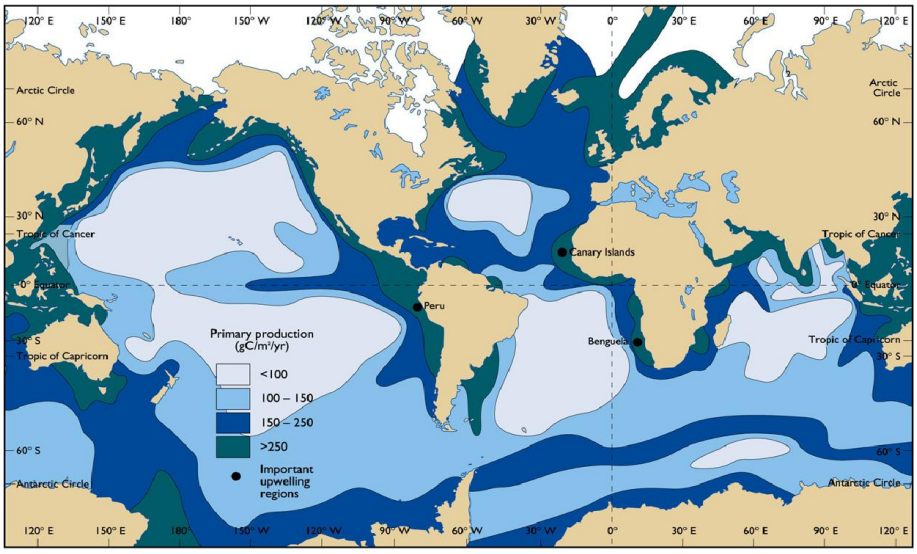
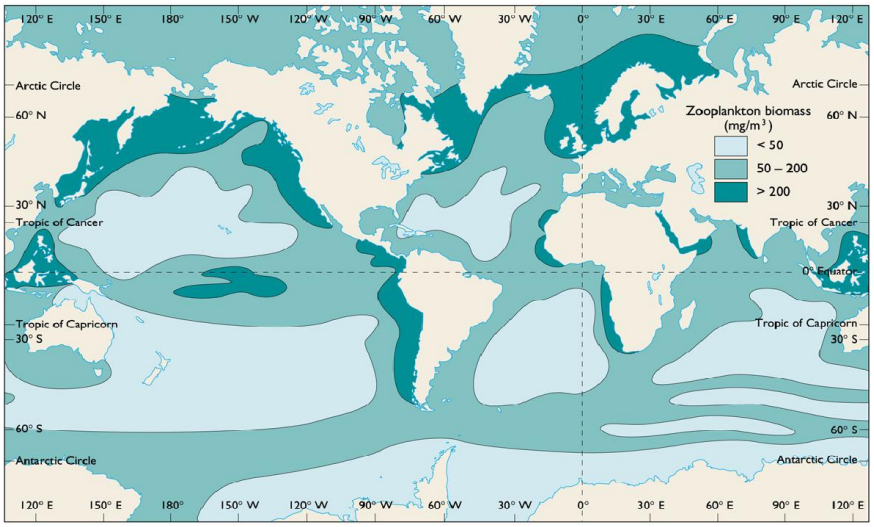


Table 20.1 Net Primary Production and Plant Biomass of World Ecosystems

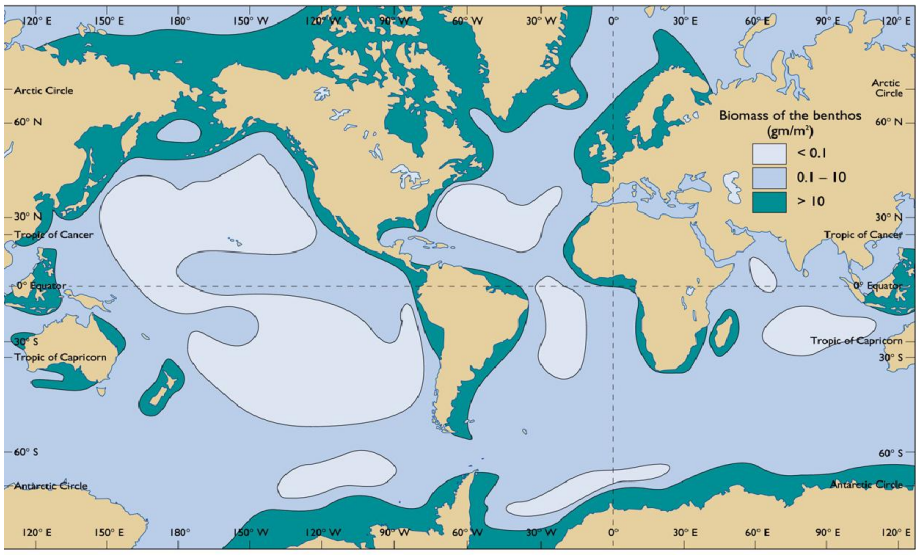
Ecosystems (in Order of Productivity)	Area (10^6 km^2)	Mean Net Primary Production per Unit Area (g/m^2/yr)	World Net Primary Production (10^9 Mt/yr)	Mean Biomass per Unit Area (kg/m^2)
Continental				
Tropical rain forest	17.0	2000.0	34.00	44.00
Tropical seasonal forest	7.5	1500.0	11.30	36.00
Temperate evergreen forest	5.0	1300.0	6.40	36.00
Temperate deciduous forest	7.0	1200.0	8.40	30.00
Boreal forest	12.0	800.0	9.50	20.00
Savanna	15.0	700.0	10.40	4.00
Cultivated land	14.0	644.0	9.10	1.10
Woodland and shrubland	8.0	600.0	4.90	6.80
Temperate grassland	9.0	500.0	4.40	1.60
Tundra and alpine meadow	8.0	144.0	1.10	0.67
Desert shrub	18.0	71.0	1.30	0.67
Rock, ice, sand	24.0	3.3	0.09	0.02
Swamp and marsh	2.0	2500.0	4.90	15.00
Lake and stream	2.5	500.0	1.30	0.02
Total continental	149.0	720.0	107.09	12.30



(a) PRIMARY PRODUCTIVITY



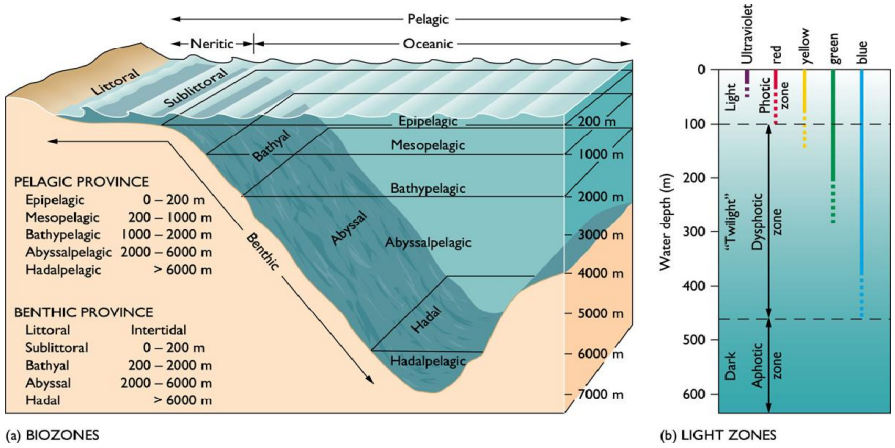
(b) ZOOPLANKTON BIOMASS

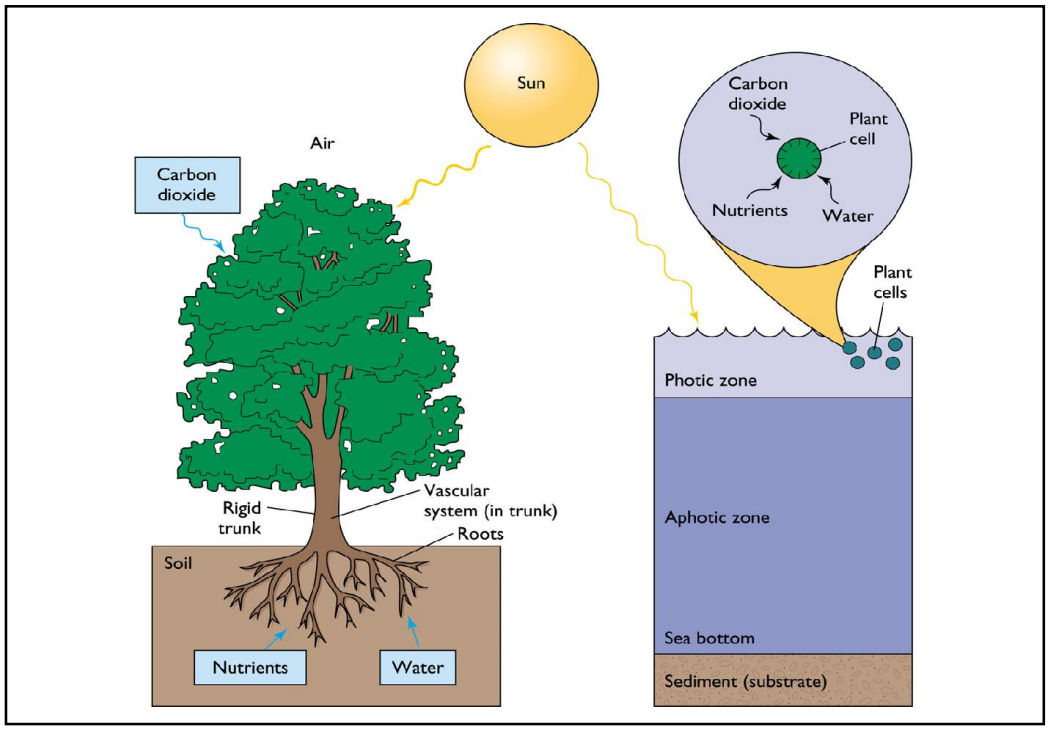


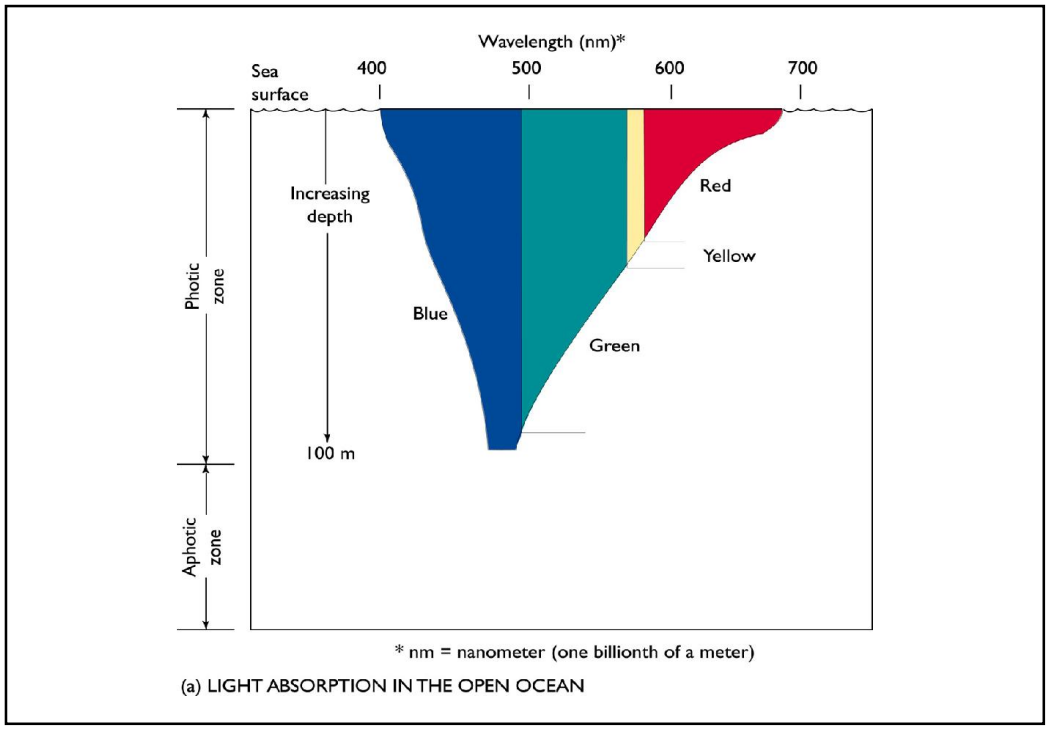
(c) BENTHIC BIOMASS

Fattori che limitano la produzione primaria aquatica

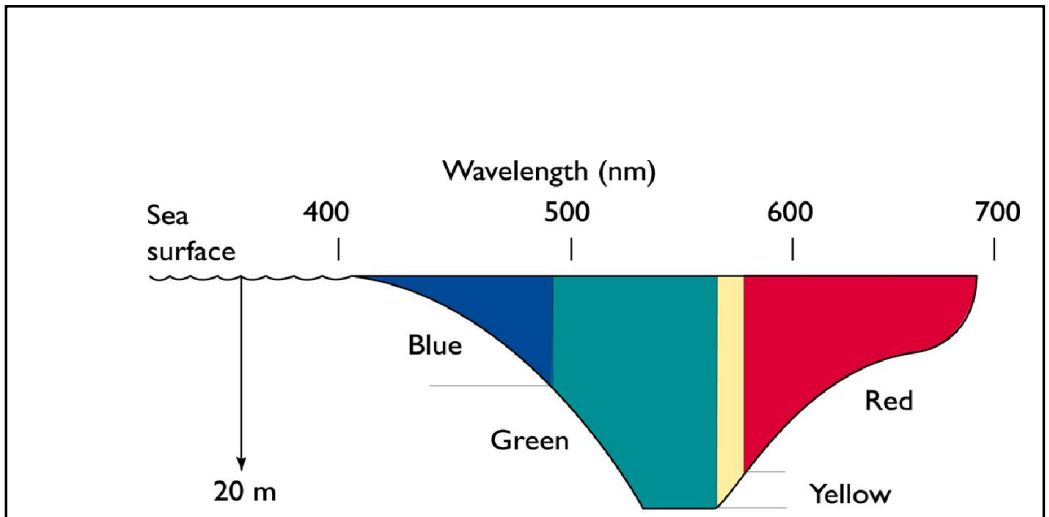
- ~~Temperatura~~
- ~~Precipitazioni~~
- Luce
- Nutrienti



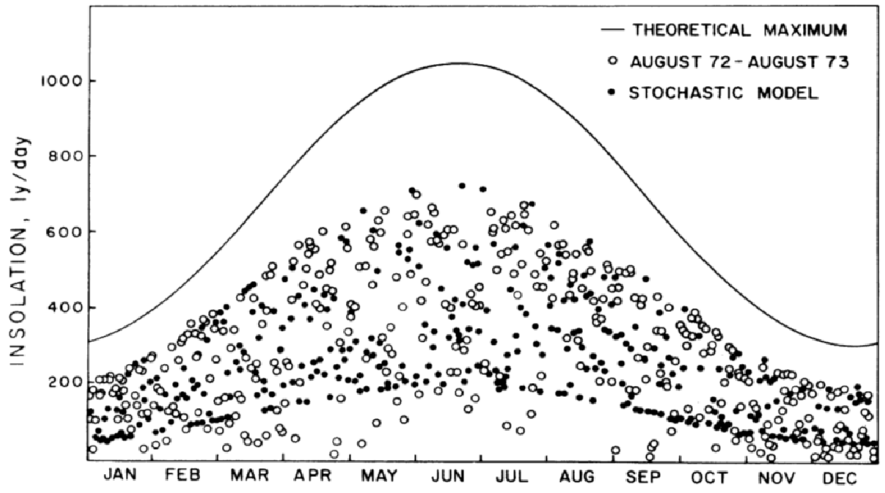


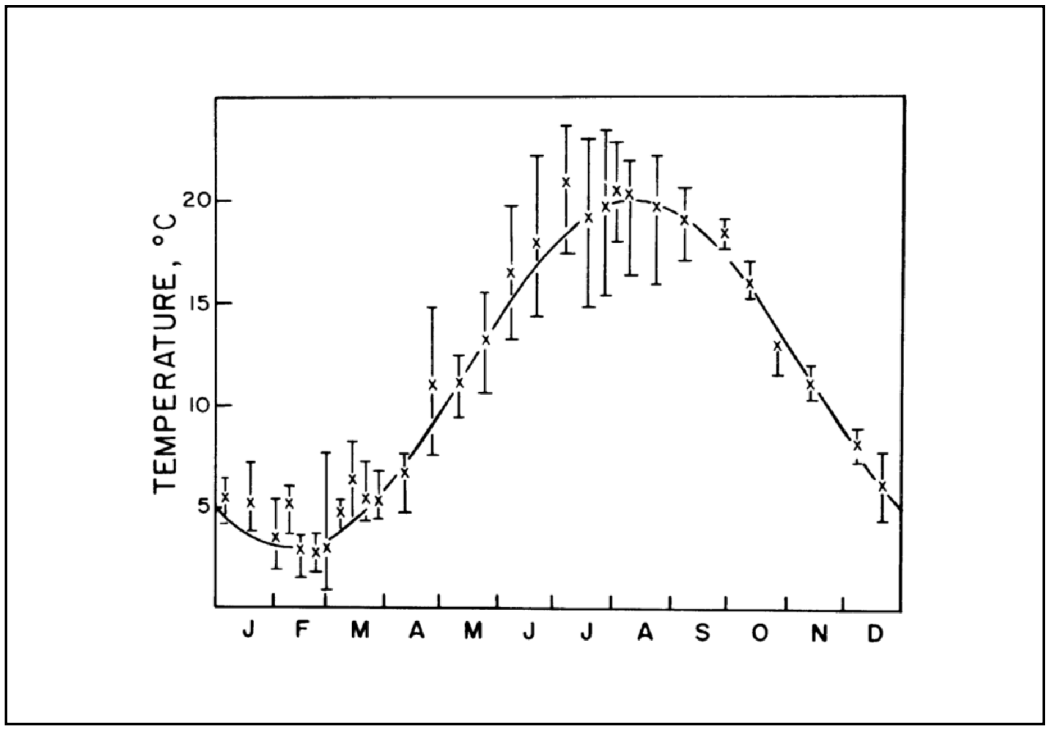


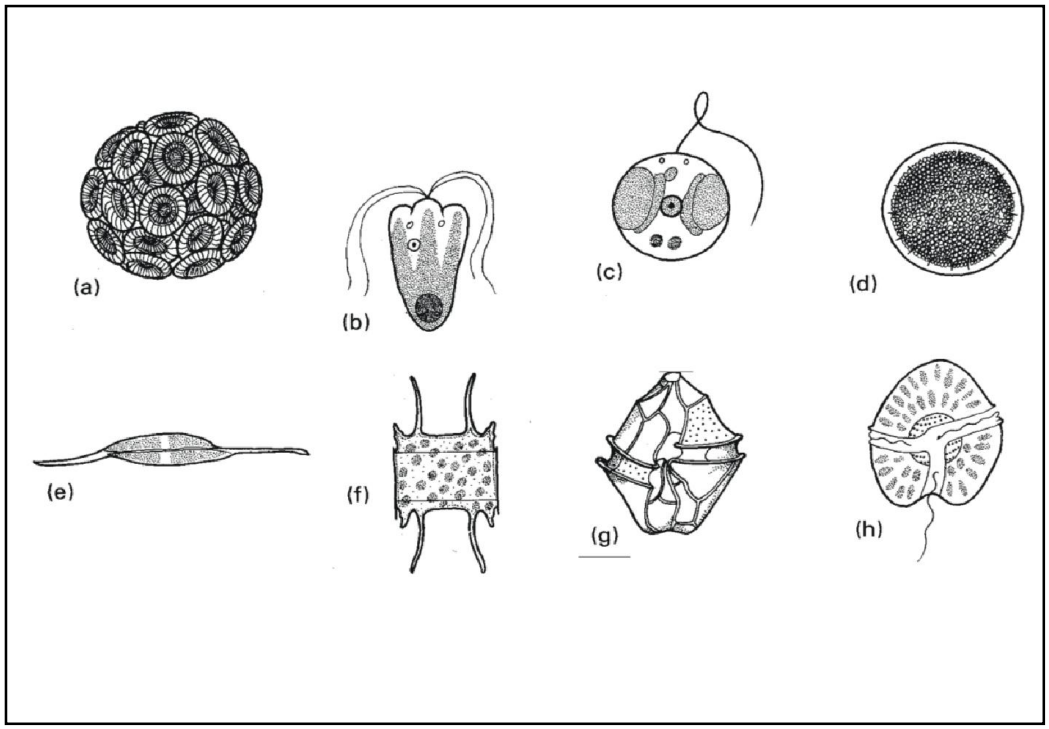
(a) LIGHT ABSORPTION IN THE OPEN OCEAN



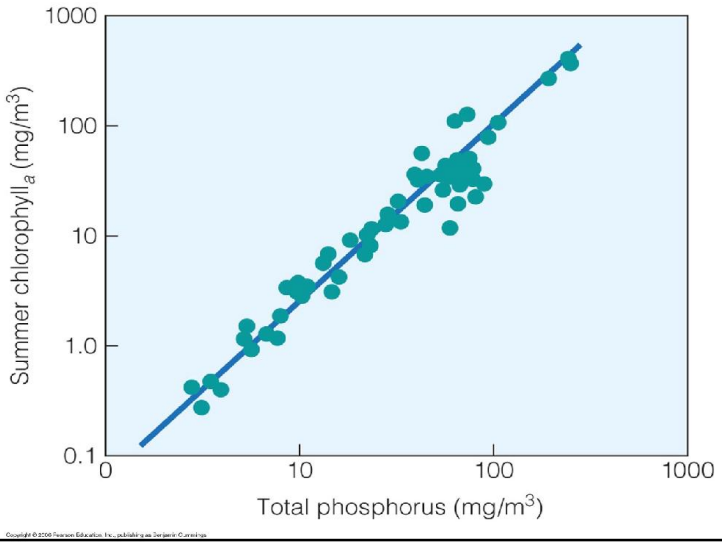
(b) LIGHT ABSORPTION IN NEARSHORE WATERS




TEMPERATURE, °C
20
15
10
5
J F M A M J J A S O N D


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)

Fattori che limitano la produzione primaria aquatica



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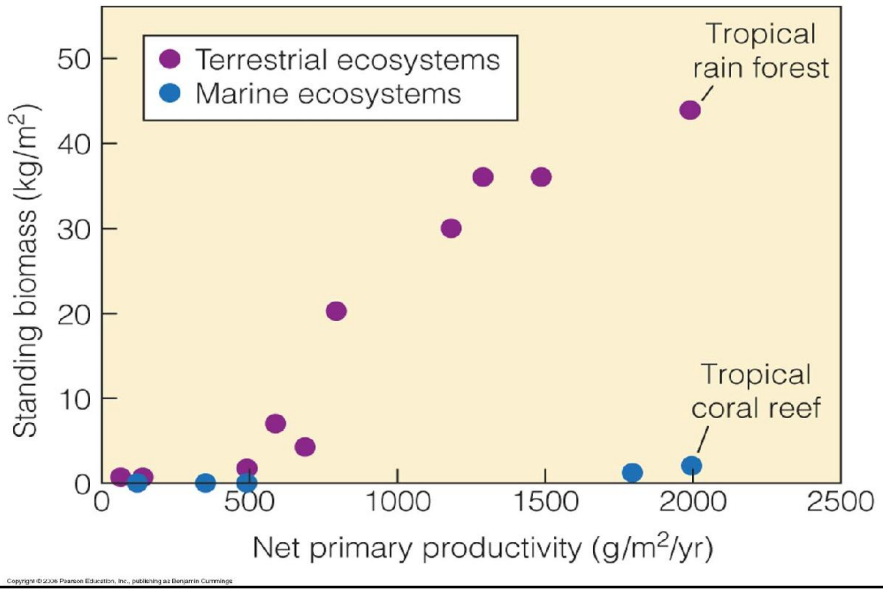
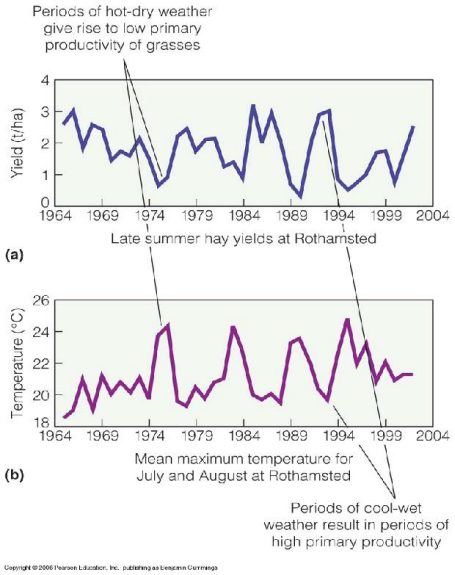
Boreal forest	12.0	800.0	9.50	20.00
Savanna	15.0	700.0	10.40	4.00
Cultivated land	14.0	644.0	9.10	1.10
Woodland and shrubland	8.0	600.0	4.90	6.80
Temperate grassland	9.0	500.0	4.40	1.60
Tundra and alpine meadow	8.0	144.0	1.10	0.67
Desert shrub	18.0	71.0	1.30	0.67
Rock, ice, sand	24.0	3.3	0.09	0.02
Swamp and marsh	2.0	2500.0	4.90	15.00
Lake and stream	2.5	500.0	1.30	0.02
Total continental	149.0	720.0	107.09	12.30
Marine				
Algal beds and reefs	0.6	2000.0	1.10	2.00
Estuaries	1.4	1800.0	2.40	1.00
Upwelling zones	0.4	500.0	0.22	0.02
Continental shelf	26.6	360.0	9.60	0.01
Open ocean	332.0	127.0	42.00	0.003
Total marine	361.0	153.0	55.32	0.01
World total	510.0	320.0	162.41	3.62

Source: Adapted from Whittaker 1975.

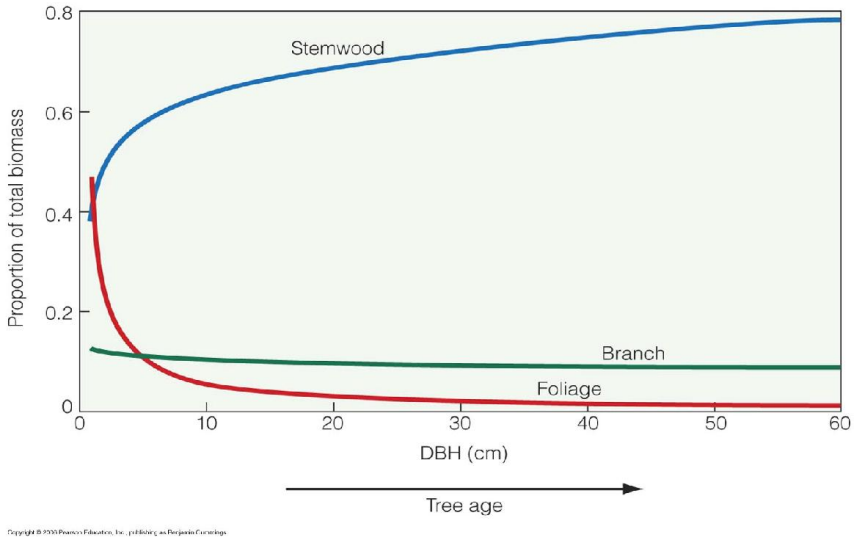
Allocazione dell'energia



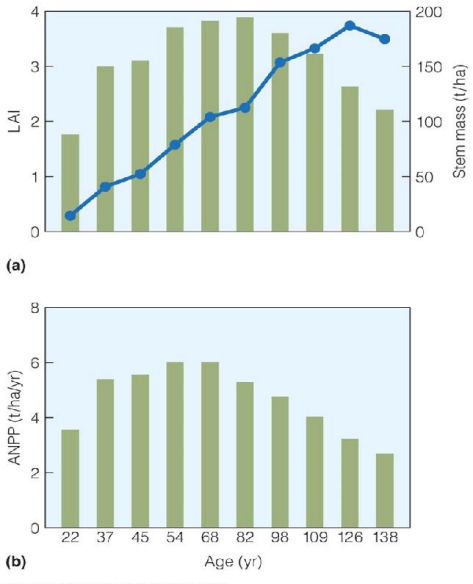
La produzione primaria varia con il tempo



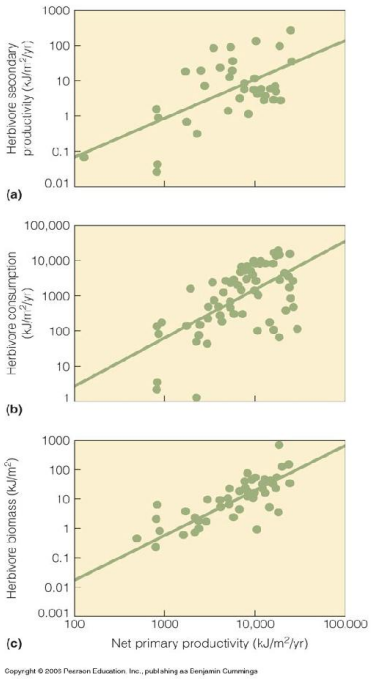
La produzione primaria varia con il tempo



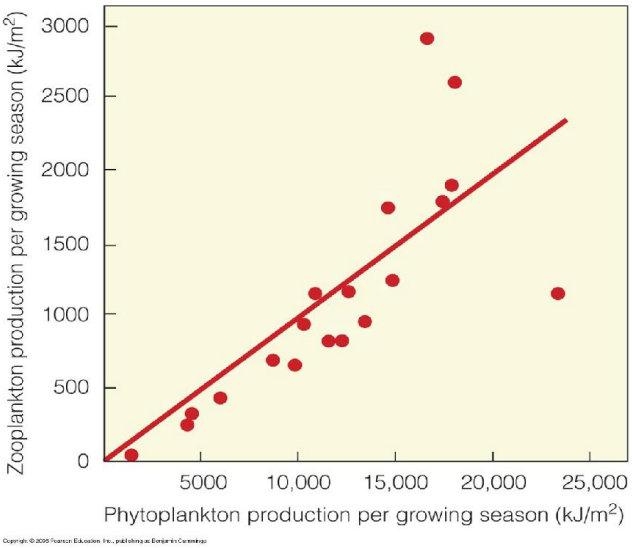
La produzione primaria varia con il tempo

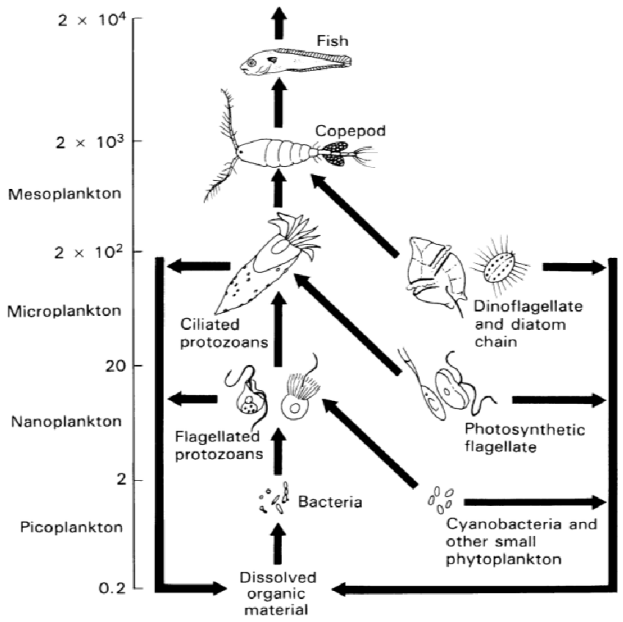


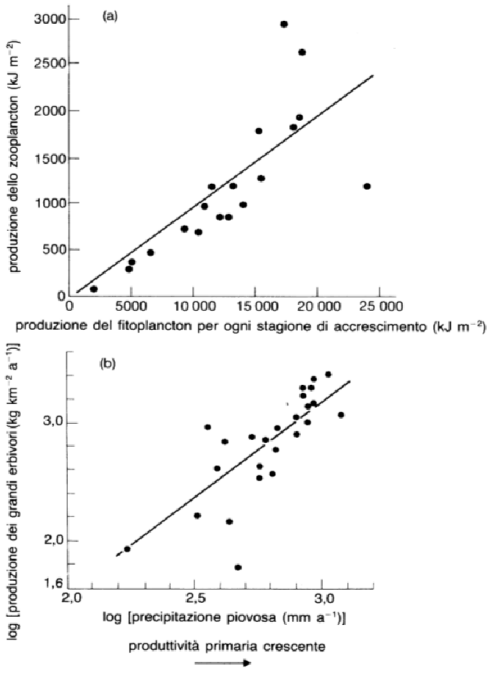
La produzione primaria limita quella secondaria

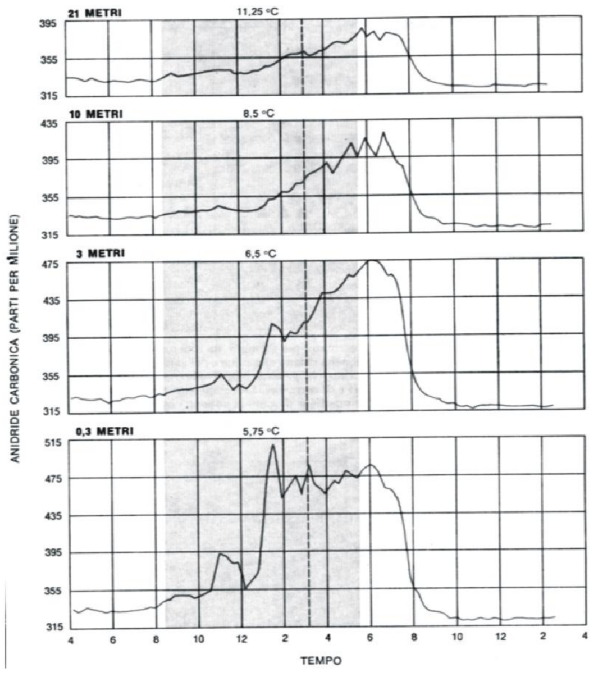


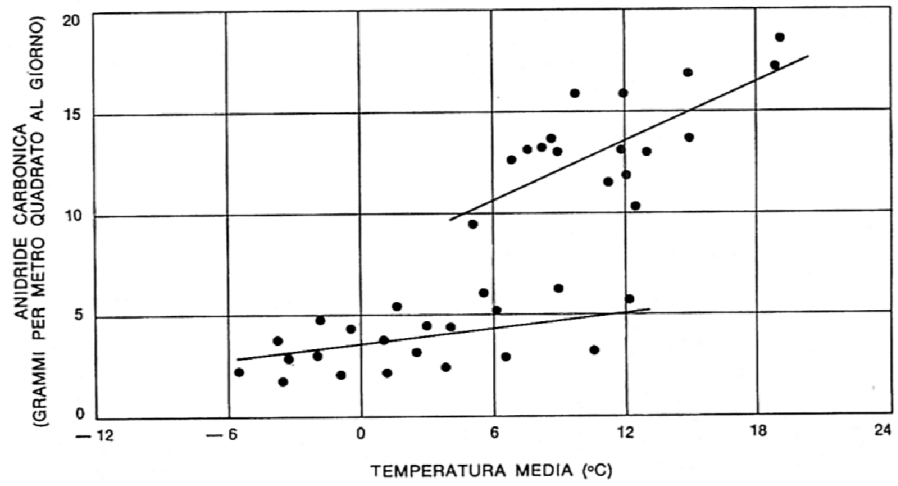
La produzione primaria limita quella secondaria

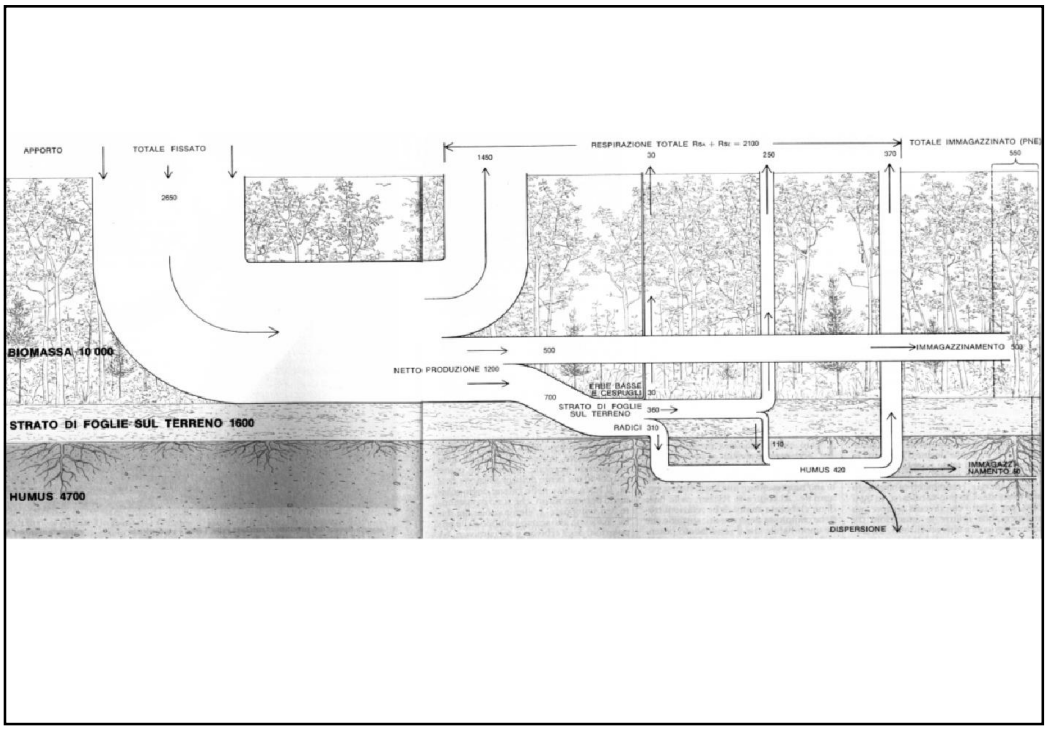


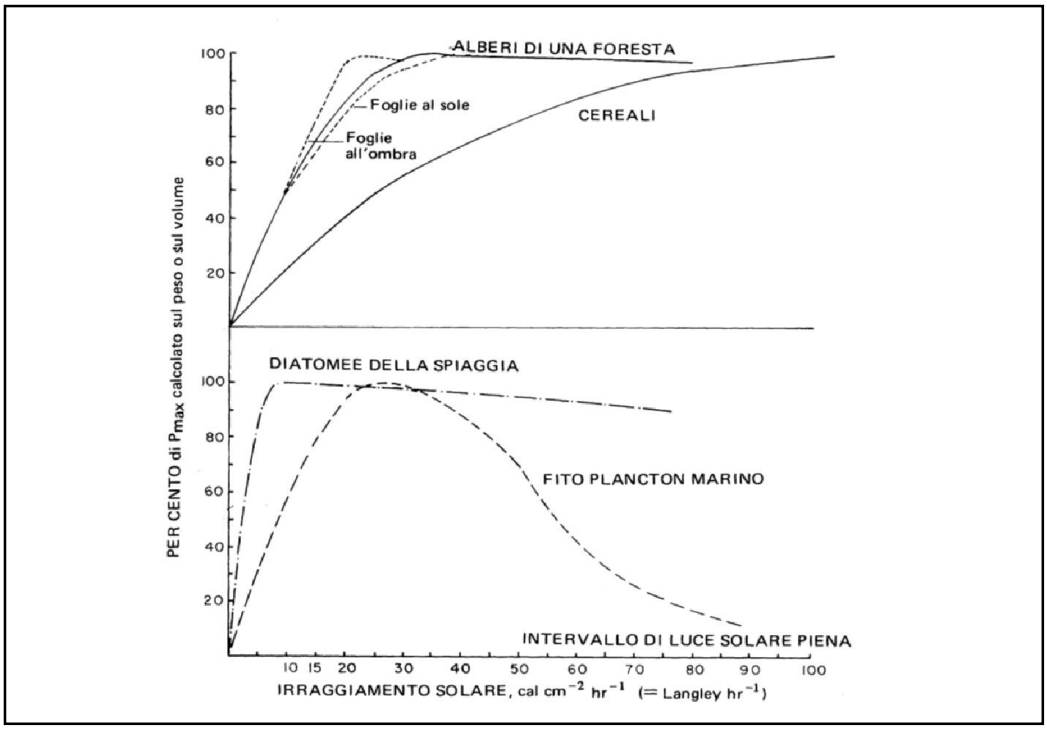

2 × 10⁴
Fish
2 × 10³
Copepod
Mesoplankton
2 × 10²
Microplankton
Ciliated protozoans
Dinoflagellate and diatom chain
20
Nanoplankton
Flagellated protozoans
Photosynthetic flagellate
2
Picoplankton
Bacteria
Cyanobacteria and other small phytoplankton
0.2
Dissolved organic material

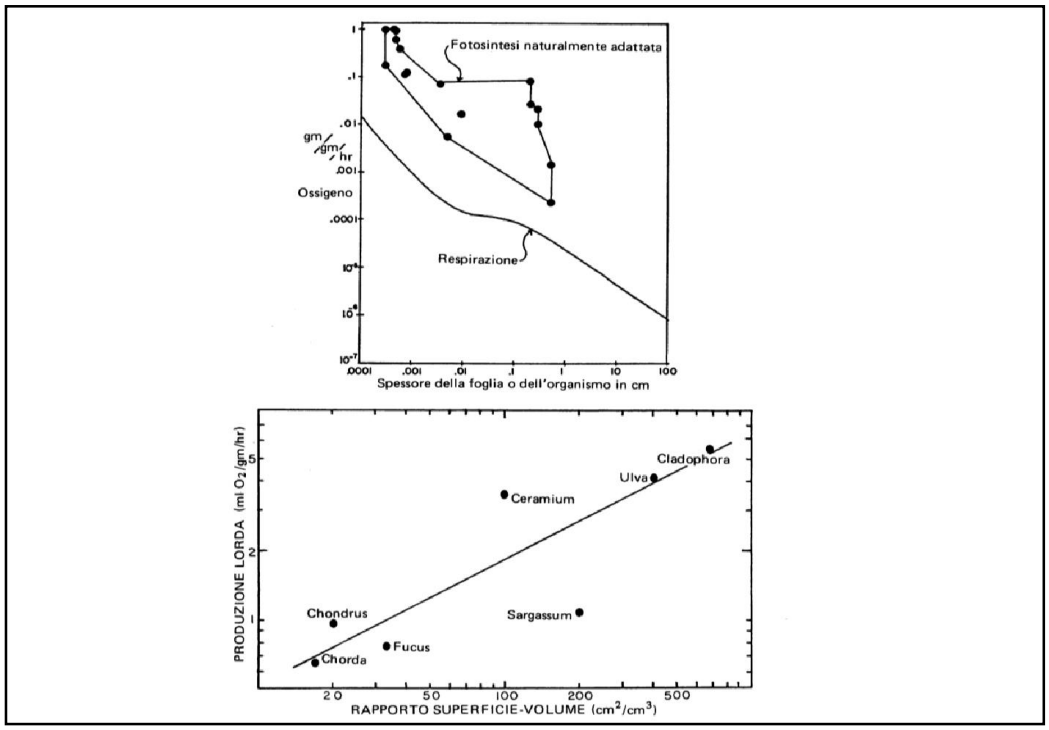

(a)
produzione dello zooplancton (kJ m⁻²)
3000
2500
2000
1500
1000
500
0
0
5000
10 000
15 000
20 000
25 000
produzione del fitoplancton per ogni stagione di accrescimento (kJ m⁻²)
(b)
log [produzione dei grandi erbivori (kg km⁻² a⁻¹)]
3,0
2,0
1,6
2,0
2,5
3,0
log [precipitazione piovosa (mm a⁻¹)]
produttività primaria crescente

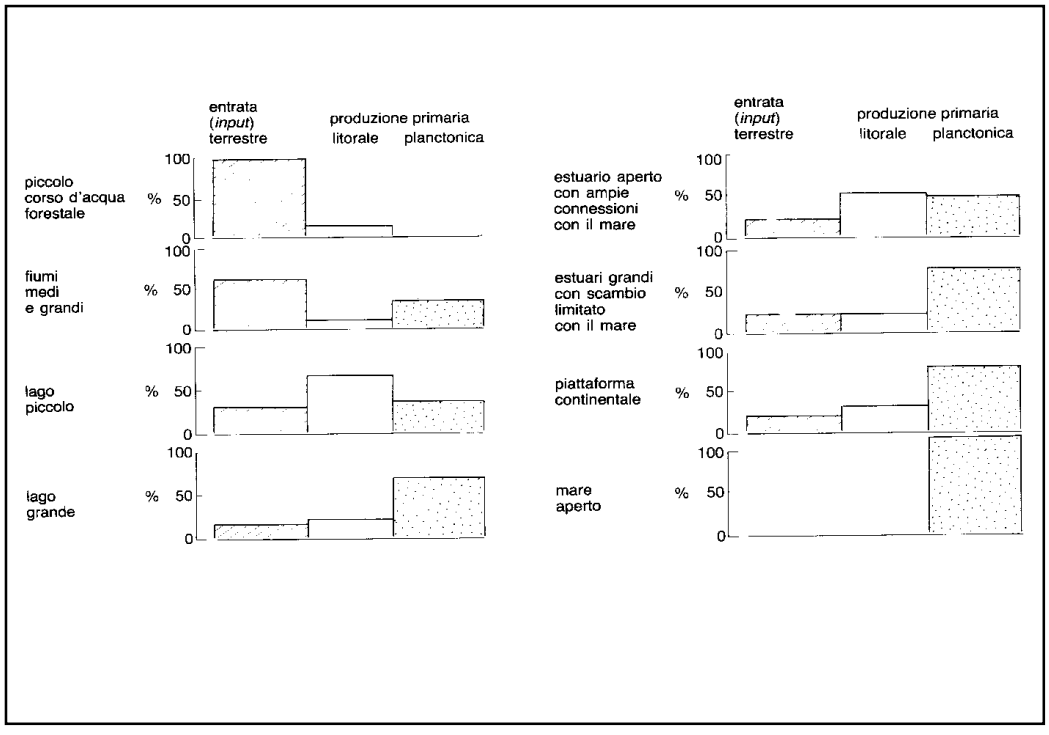

21 METRI
11,25 °C
10 METRI
8,5 °C
3 METRI
6,5 °C
0,3 METRI
5,75 °C
ANIDRIDE CARBONICA (PARTI PER MILIONE)
TEMPO

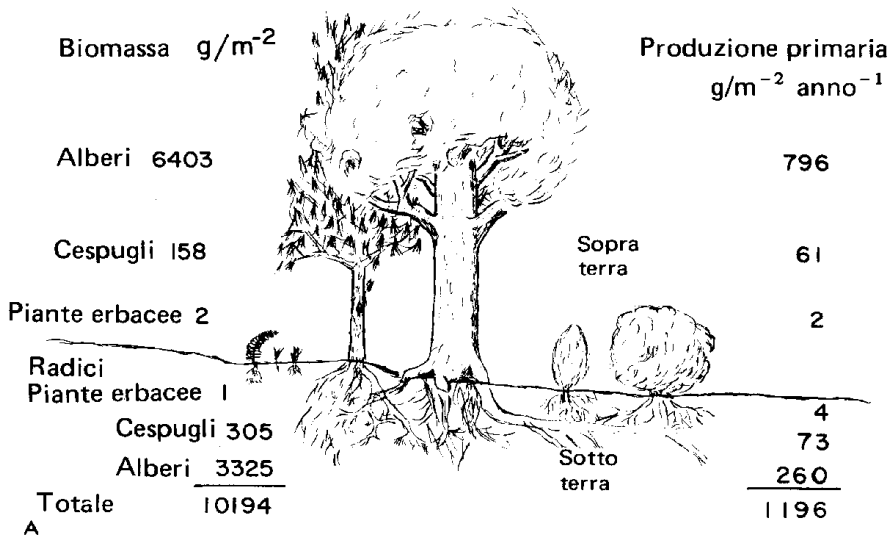

ANIDRIDE CARBONICA
(GRAMMI PER METRO QUADRATO AL GIORNO)
TEMPERATURA MEDIA (°C)

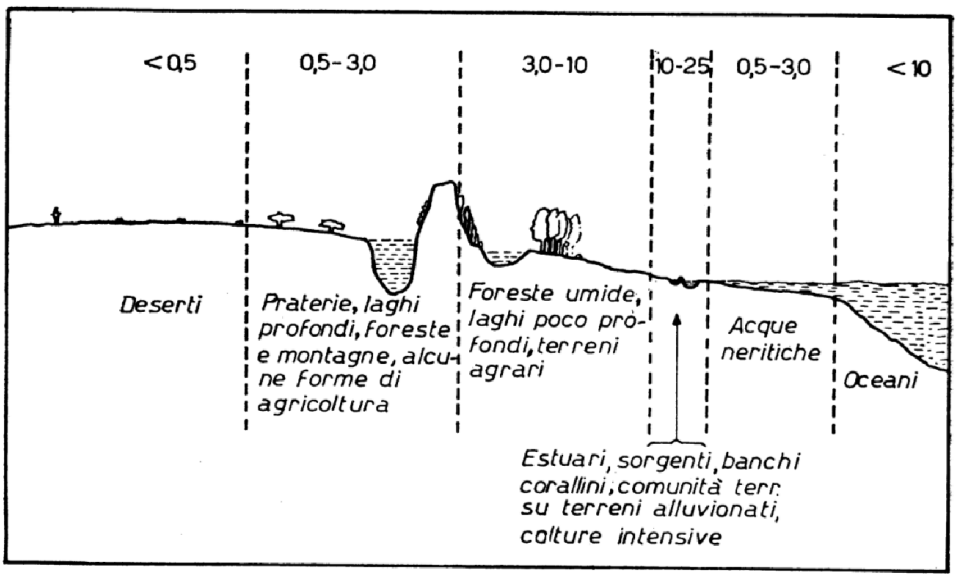

APPORTO
TOTALE FISSATO
2650
RESPIRAZIONE TOTALE Rs + Rs = 2100
1450
30
250
370
TOTALE IMMAGAZZINATO (PNE)
550
BIOMASSA 10 000
NETTO PRODUZIONE 1200
500
IMMAGAZZINAMENTO 530
ERBE BASSE E CESPUGLI 30
700
STRATO DI FOGLIE SUL TERRENO 360
STRATO DI FOGLIE SUL TERRENO 1600
RADICI 310
110
HUMUS 420
IMMAGAZZINAMENTO 80
HUMUS 4700
DISPERSIONE


ALBERI DI UNA FORESTA
Foglie al sole
Foglie all'ombra
CEREALI
DIATOMEE DELLA SPIAGGIA
FITO PLANCTON MARINO
INTERVALLO DI LUCE SOLARE PIENA
PER CENTO di Pmax calcolato sul peso o sul volume
IRRAGGIAMENTO SOLARE, cal cm⁻² hr⁻¹ (= Langley hr⁻¹)
100
80
60
40
20
10 15 20 30 40 50 60 70 80 90 100

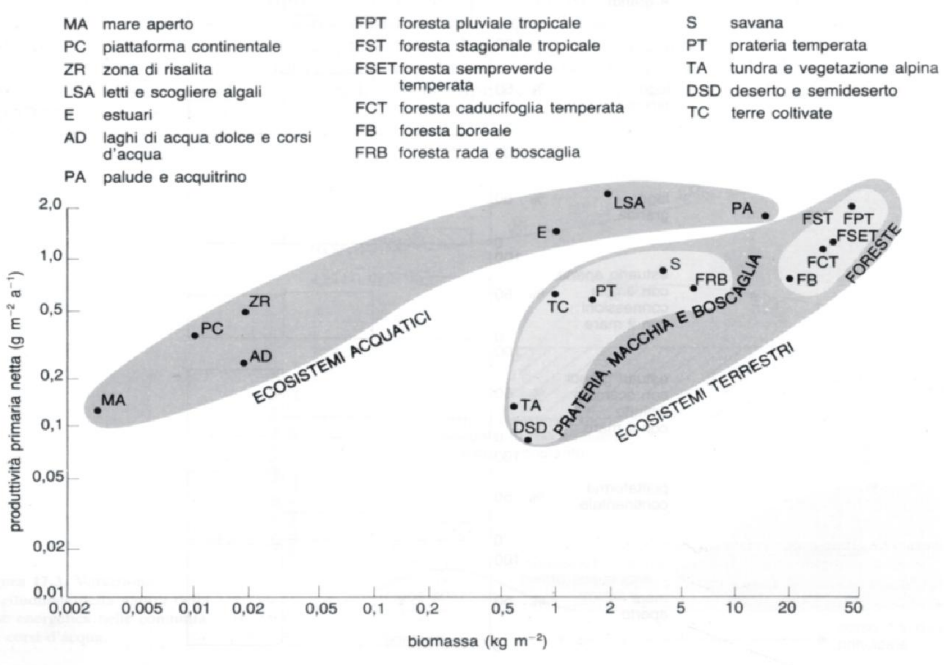

Fotosintesi naturalmente adattata
Respirazione
Ossigeno
gm/gm/hr
Spessore della foglia o dell'organismo in cm
PRODUZIONE LORDA (ml O2/gm/hr)
RAPPORTO SUPERFICIE-VOLUME (cm2/cm3)
Cladophora
Ulva
Ceramium
Chondrus
Sargassum
Fucus
Chorda

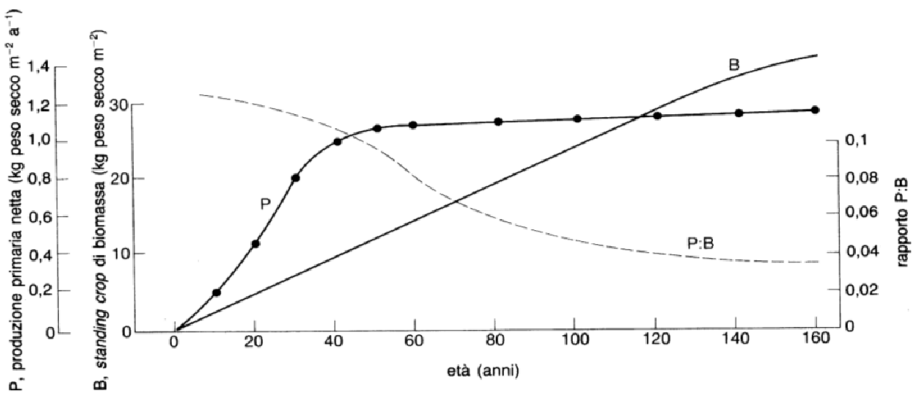

entrata (input) terrestre
produzione primaria litorale
produzione primaria planctonica
piccolo corso d'acqua forestale
fiumi medi e grandi
lago piccolo
lago grande
estuario aperto con ampie connessioni con il mare
estuari grandi con scambio limitato con il mare
piattaforma continentale
mare aperto
%
100
50
0

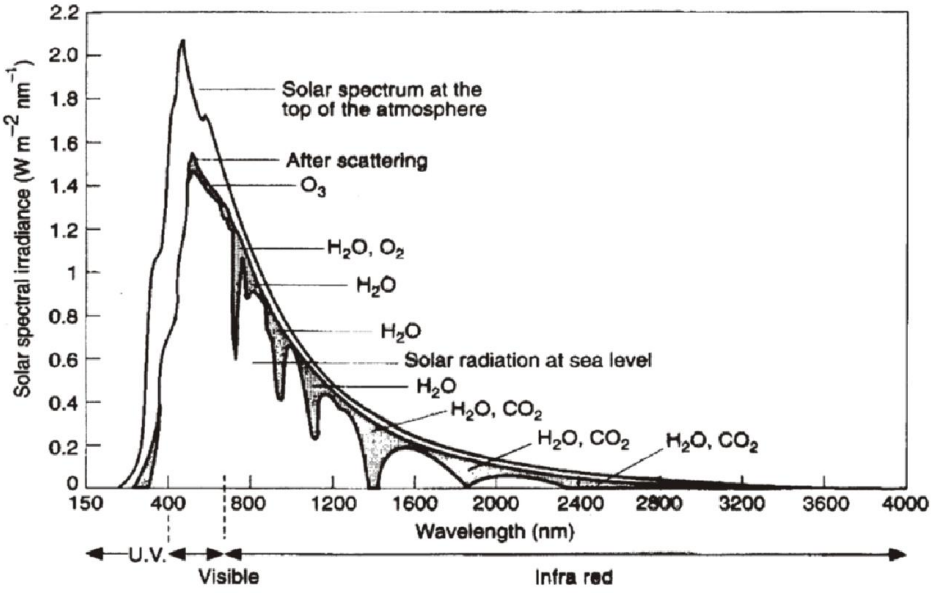

Biomassa g/m-2
Produzione primaria netta
g/m-2 anno-1
Alberi 6403
796
Cespugli 158
Sopra terra
61
Piante erbacee 2
2
Radici
Piante erbacee 1
4
Cespugli 305
73
Alberi 3325
Sotto terra
260
Totale 10194
1196
A

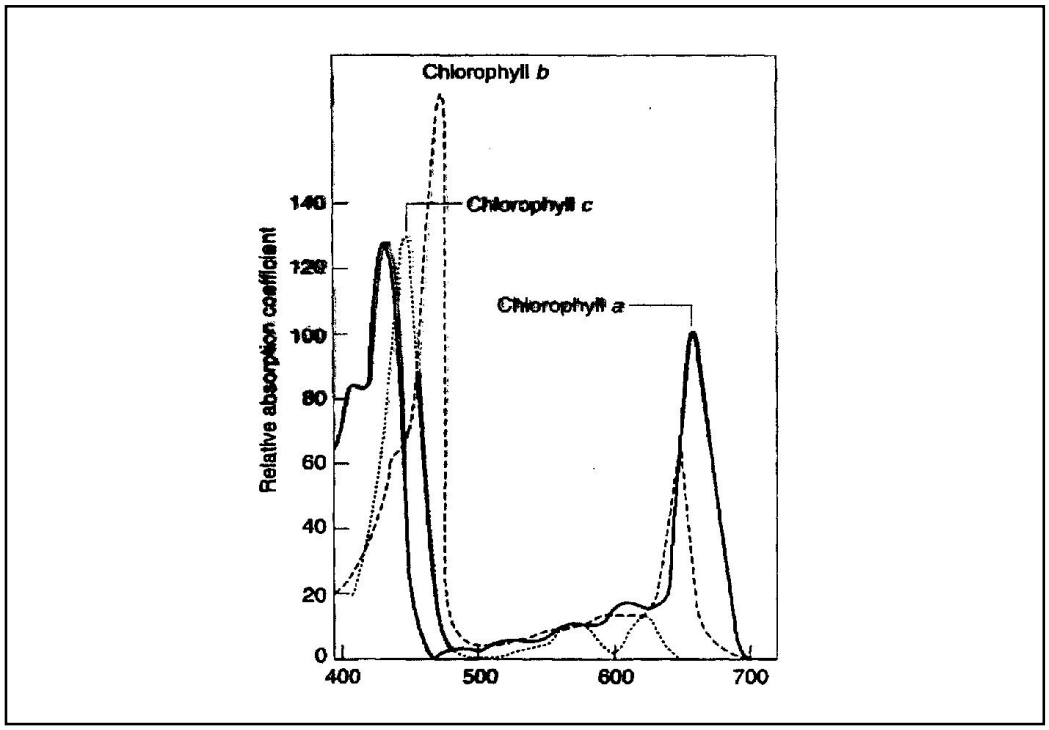

<0,5
0,5-3,0
3,0-10
10-25
0,5-3,0
<10
Deserti
Praterie, laghi profondi, foreste e montagne, alcune forme di agricoltura
Foreste umide, laghi poco profondi, terreni agrari
Acque neritiche
Oceani
Estuari, sorgenti, banchi corallini, comunità terr
su terreni alluvionati,
colture intensive

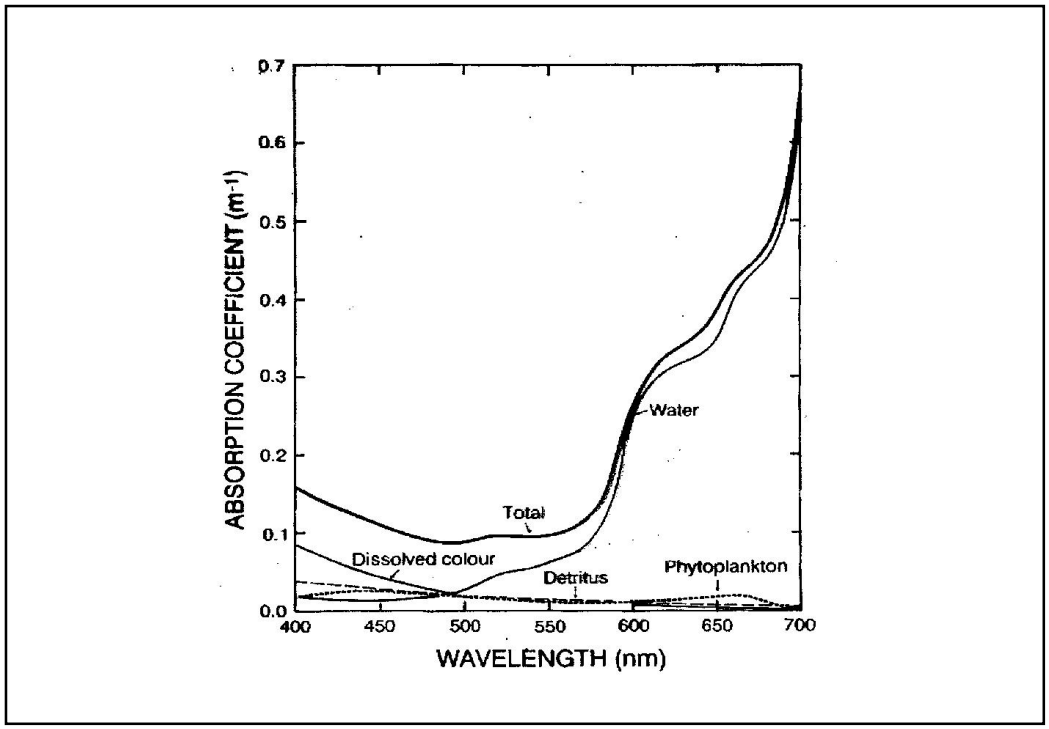
Tipo di ecosistema	Area (10^6 km^2)	Produttività primaria netta riferita all'unità di area (g m^{-2} *o* t km^{-2})		Produttività primaria netta mondiale (10^6 t)	Biomassa riferita all'unità di area (kg m^{-2})		Biomassa mondiale (10^9 t)
		intervallo normale	valore medio		intervallo normale	valore medio	
foresta pluviale tropicale	17,0	1000÷3500	2200	37,4	6÷80	45	765
foresta stagionale tropicale	7,5	1000÷250	1600	12,0	6÷60	35	260
foresta sempreverde temperata	5,0	600÷2500	1300	6,5	6÷200	35	175
foresta caducifoglia temperata	7,0	600÷2500	1200	8,4	6÷60	30	210
foresta boreale	12,0	400÷2000	800	9,6	6÷40	20	240
foresta rada e boscaglia	8,5	250÷1200	700	6,0	2÷20	6	50
savana	15,0	200÷2000	900	13,5	0,2÷15	4	60
prateria temperata	9,0	200÷1500	600	5,4	0,2÷5	1,6	14
tundra ed ecosistema alpino	8,0	10÷400	140	1,1	0,1÷3	0,6	5
boscaglia deserticola e semideserticola	18,0	10÷250	90	1,6	0,1÷4	0,7	13
deserto estremo, roccia, sabbia e ghiaccio	24,0	0÷10	3	0,07	0÷0,2	0,02	0,5
terre coltivate	14,0	100÷3500	650	9,1	0,4÷12	1	14
palude e acquitrino	2,0	800÷3500	2000	4,0	3÷50	15	30
lago e corso d'acqua	2,0	100÷150	250	0,5	0÷0,1	0,02	0,05
totale continentale	149		773	115		12,3	1837
mare aperto	332,0	2÷400	125	41,5	0÷0,005	0,003	1,0
zone di risalita (*upwelling*)	0,4	400÷1000	500	0,2	0,005÷0,1	0,02	0,008
piattaforma continentale	26,6	200÷600	360	9,6	0,001÷0,04	0,01	0,27
letti e scogliere algali	0,6	500÷4000	2500	1,6	0,04÷4	2	1,2
estuari	1,4	200÷3500	1500	2,1	0,001÷6	1	1,4
totale marino	361		152	55,0		0,01	3,9
totale generale	510		333	170		3,6	1841

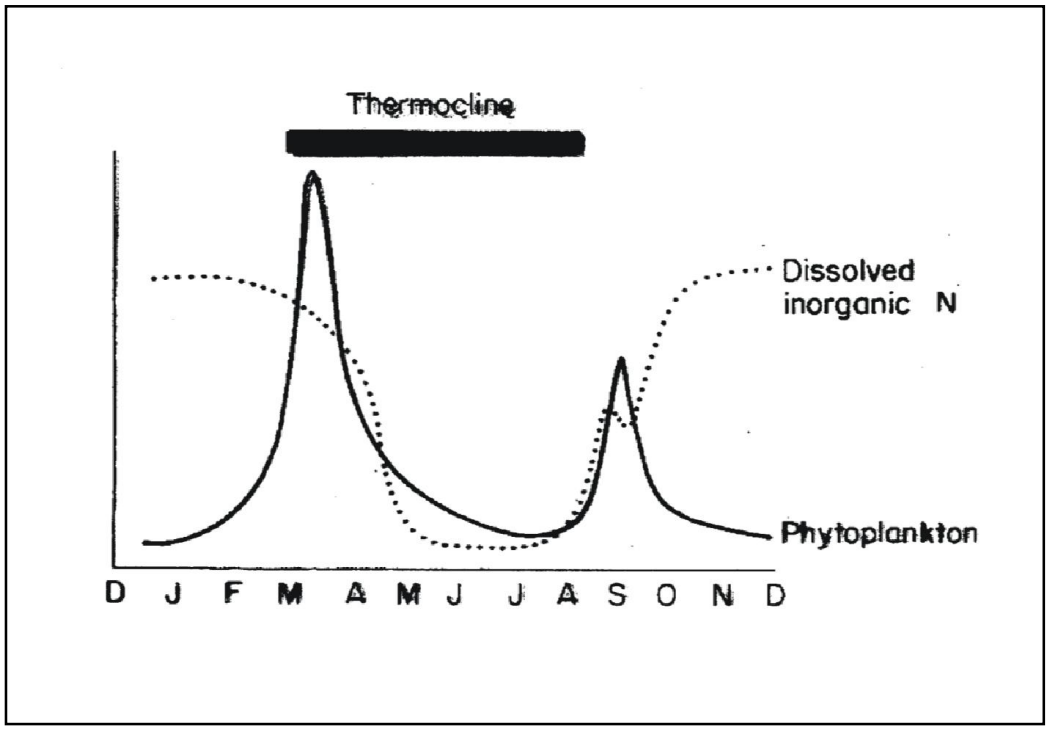


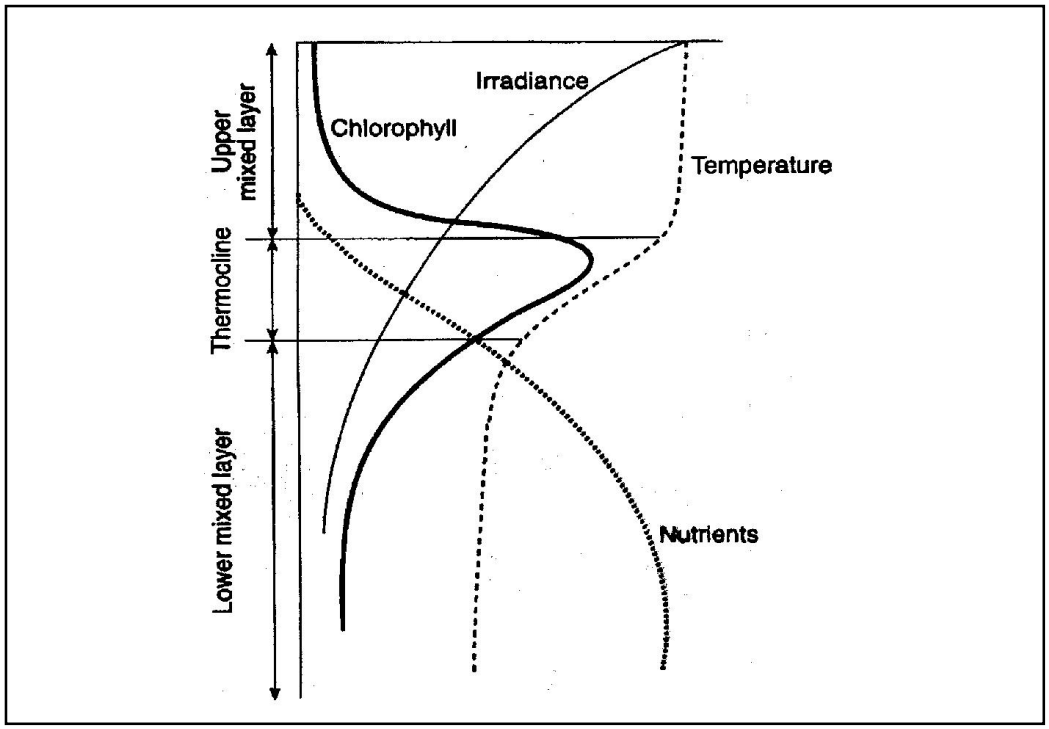

P, produzione primaria netta (kg peso secco m⁻² a⁻¹)
B, standing crop di biomassa (kg peso secco m⁻²)
rapporto P:B
età (anni)
P
B
P:B
0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
10
20
30
0,02
0,04
0,06
0,08
0,1
0
20
40
60
80
100
120
140
160

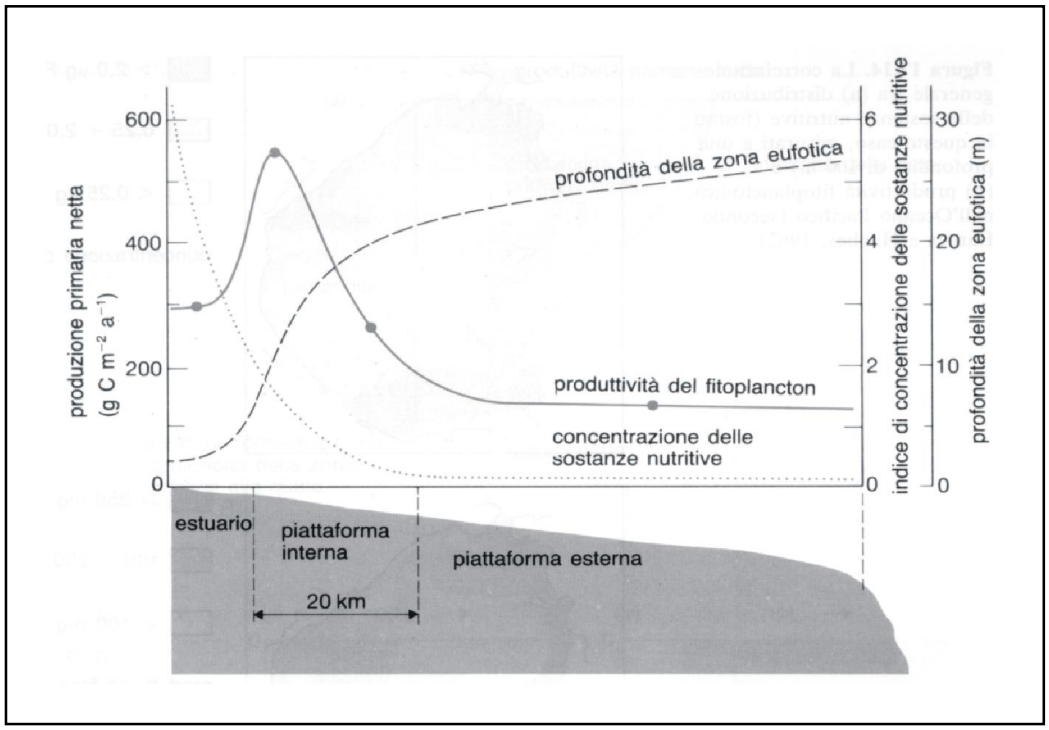

Solar spectral irradiance (W m⁻² nm⁻¹)
Solar spectrum at the top of the atmosphere
After scattering
O3
H2O, O2
H2O
H2O
Solar radiation at sea level
H2O
H2O, CO2
H2O, CO2
H2O, CO2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2.0
2.2
150
400
800
1200
1600
2000
2400
2800
3200
3600
4000
Wavelength (nm)
U.V.
Visible
Infra red

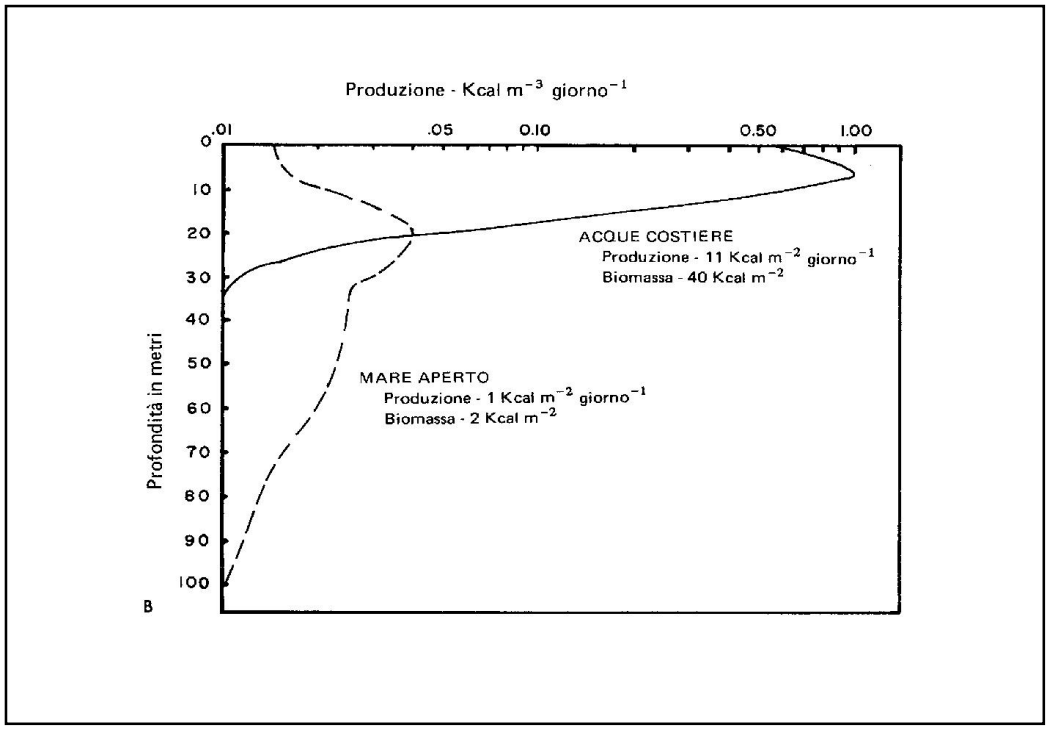

Chlorophyll b
Chlorophyll c
Chlorophyll a
Relative absorption coefficient
140
120
100
80
60
40
20
0
400
500
600
700

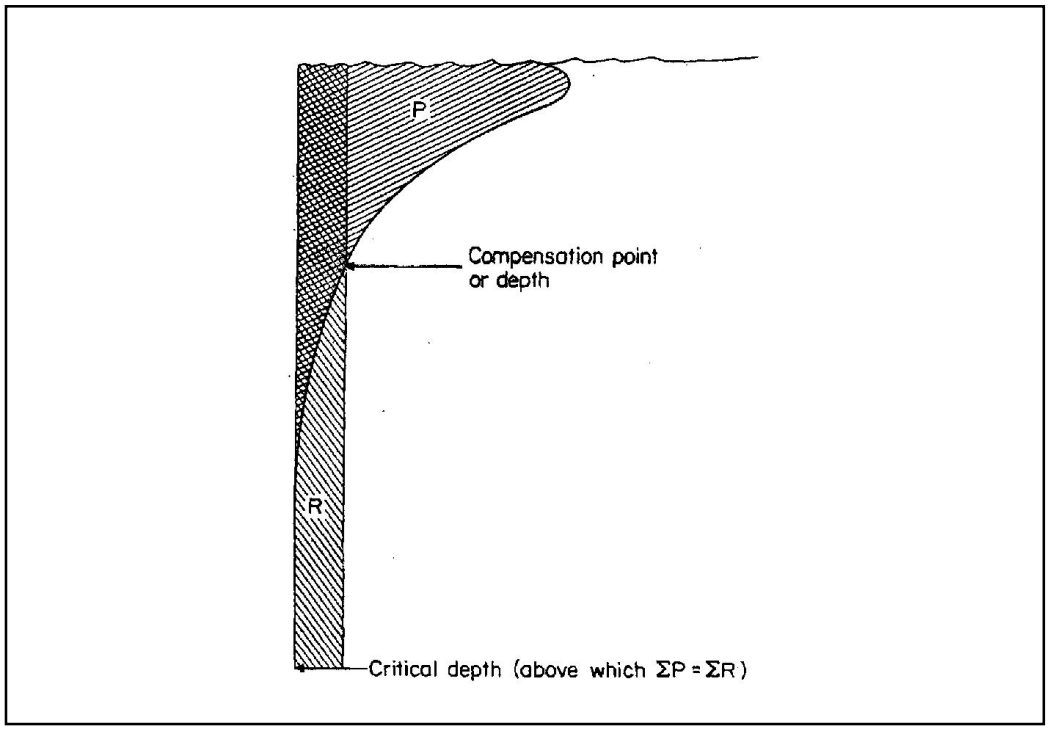

ABSORPTION COEFFICIENT (m-1)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Water
Total
Dissolved colour
Detritus
Phytoplankton
400
450
500
550
600
650
700
WAVELENGTH (nm)

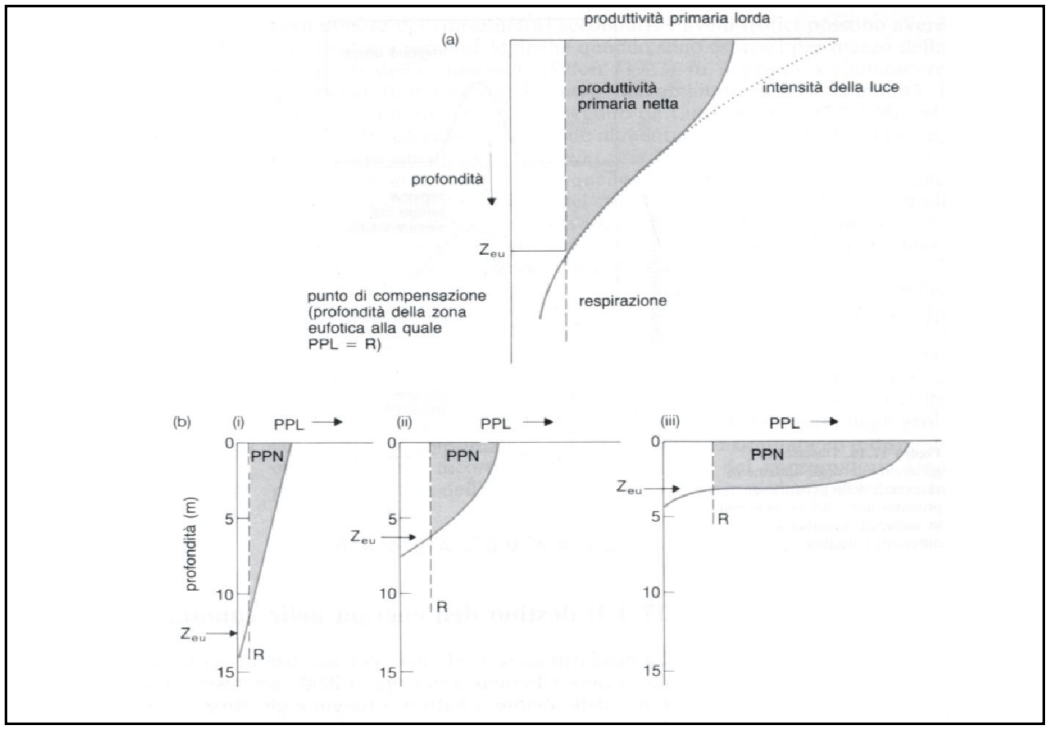

Thermocline
Dissolved inorganic N
Phytoplankton
D J F M A M J J A S O N D


Irradiance
Chlorophyll
Temperature
Upper mixed layer
Thermocline
Lower mixed layer
Nutrients


produzione primaria netta
(g C m⁻² a⁻¹)
600
400
200
0
6
4
2
0
30
20
10
0
indice di concentrazione delle sostanze nutritive
profondità della zona eufotica (m)
profondità della zona eufotica
produttività del fitoplancton
concentrazione delle
sostanze nutritive
estuario
piattaforma
interna
piattaforma esterna
20 km


Produzione - Kcal m⁻³ giorno⁻¹
.01
.05
0.10
0.50
1.00
0
10
20
30
40
50
60
70
80
90
100
Profondità in metri
ACQUE COSTIERE
Produzione - 11 Kcal m⁻² giorno⁻¹
Biomassa - 40 Kcal m⁻²
MARE APERTO
Produzione - 1 Kcal m⁻² giorno⁻¹
Biomassa - 2 Kcal m⁻²
B

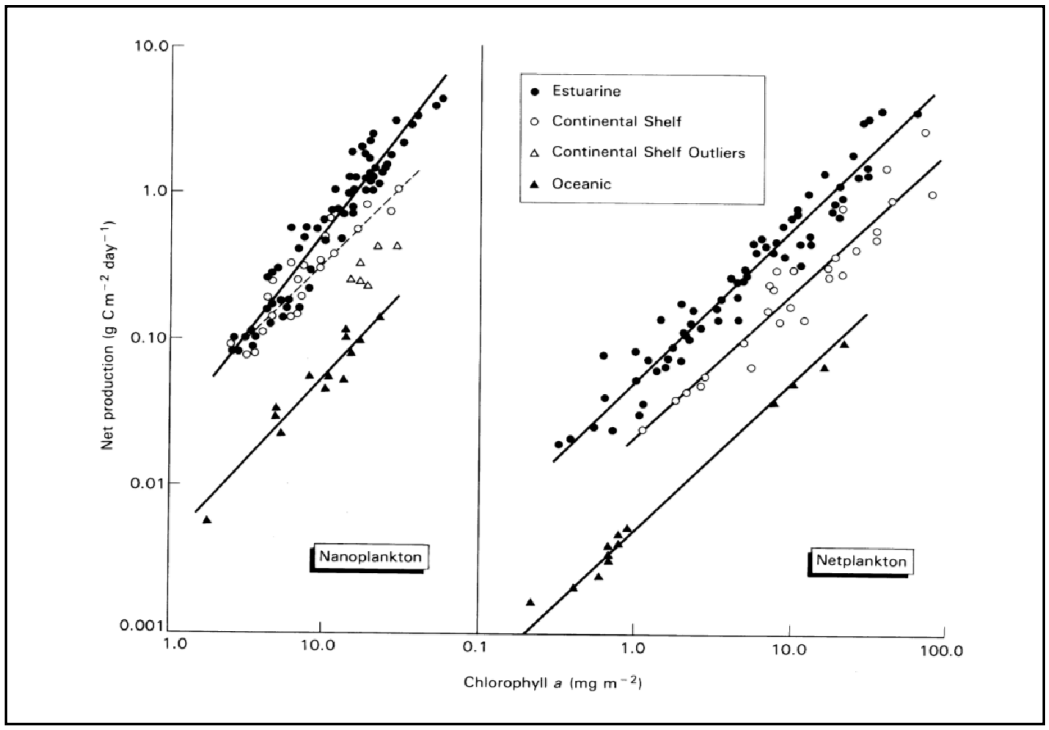

P
Compensation point
or depth
R
Critical depth (above which ΣP = ΣR)

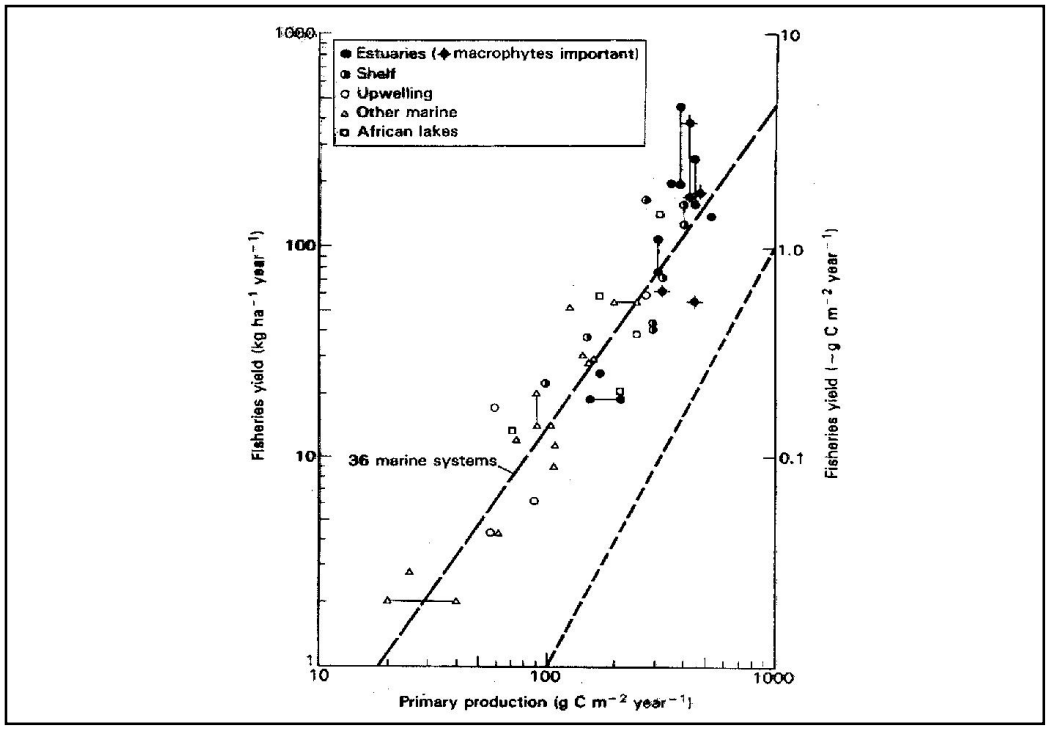

produttività primaria lorda
(a)
produttività
primaria netta
intensità della luce
profondità
Z_{eu}
punto di compensazione
(profondità della zona
eufotica alla quale
PPL = R)
respirazione
(b)
(i)
PPL
PPN
profondità (m)
0
5
10
15
Z_{eu}
R
(ii)
PPL
PPN
Z_{eu}
R
(iii)
PPL
PPN
Z_{eu}
R

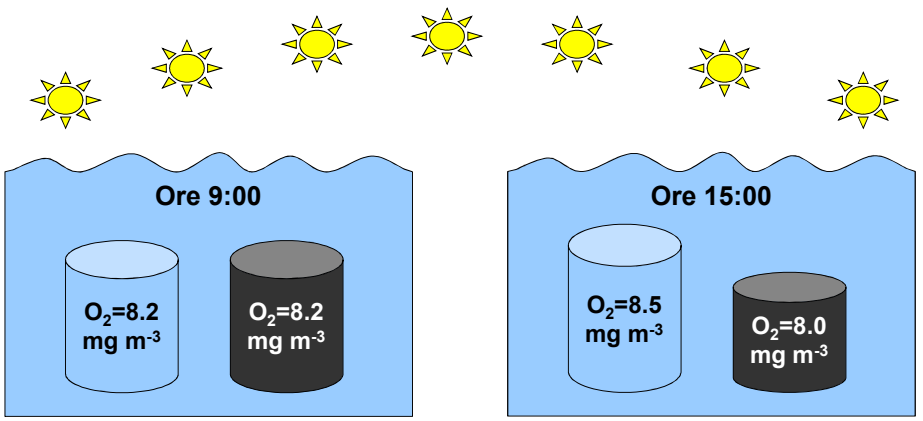
	Surface area (10^6 km^2)	Approx. volume of biosphere* (10^6 km^3)	Net plant production (10^9 tonnes year^{-1})	Animal production (10^6 tonnes year^{-1})
Terrestrial	145	14.5	110.5	867
Aquatic	365	1445	59.5	3067
Ratio	1 : 2.5	1 : 99	1 : 0.54	3.54 : 1

Group (size)	Biomass (g m^{-2})	Organic carbon concentration (mg m^{-2})	*P/B*	*P/B**	Annual production (mg C m^{-2})
Bacteria (1–3 μm)	0.2–2	20–210	100–250	10–25	200–5250
Meiofauna (>40 μm)	0.05–0.5	2–20	2–15	1–7	2–40
Macrofauna (>250 μm)	0.01–10	4–400	0.8–5	0.4–3	2–1000
Megafauna (>1 cm)	0.02–1	0.8–40	0.4–3	0.2–1	2–40
Fish (>10 cm)	0.02–1(?)	1–40	0.2–1.3	0.1–0.7	0.1–28
Abyssopelagic plankton (up to 50 m above bottom)	0.01–0.1	0.4–0.5	0.3–2	0.2–1	0.8–5
Total	0.31–14.6	28–695			207–6463

	Net production (g dry wt m^{-2} year^{-1})	Biomass (kg dry wt m^{-2})	Annual *P/B*	Chlorophyll (g m^{-2})
Marine water				
Open ocean	125	0.003	42	0.03
Upwellings	500	0.02	25	0.3
Continental shelf	300	0.001	300	0.2
Near-shore reefs	2500	2	1.3	2
Estuaries	1500	1	1.5	1
Fresh water				
Wetlands	3000	15	0.2	3
Lakes and streams	20–8000	0.02	20	0.2

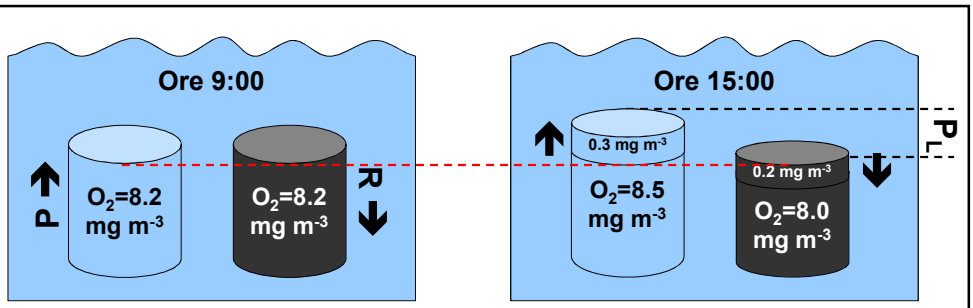

Estuarine
Continental Shelf
Continental Shelf Outliers
Oceanic
Nanoplankton
Netplankton
Net production (g C m⁻² day⁻¹)
Chlorophyll a (mg m⁻²)
10.0
1.0
0.10
0.01
0.001
1.0
10.0
0.1
1.0
10.0
100.0


Estuaries (✦ macrophytes important)
Shelf
Upwelling
Other marine
African lakes
36 marine systems
Fisheries yield (kg ha⁻¹ year⁻¹)
Fisheries yield (~g C m⁻² year⁻¹)
Primary production (g C m⁻² year⁻¹)
1000
100
10
1
10
1.0
0.1
10
100
1000



Bottiglia chiara: $\Delta O_2 = O_2(15:00) - O_2(9:00) = 8.5 - 8.2 = 0.3$ mg m^{-3}

Bottiglia scura: $\Delta O_2 = O_2(15:00) - O_2(9:00) = 8.0 - 8.2 = -0.2$ mg m^{-3}



$P_N \propto \Delta O_2 =$ 0.3 mg m^{-3} $\quad R \propto \Delta O_2 =$ 0.2 mg m^{-3}

$P_L = (P_N + R) \propto$ (0.3 mg m^{-3} + 0.2 mg m^{-3}) $\rightarrow P_L \propto$ 0.2 mg m^{-3} + 0.3 mg m^{-3}

$P_L \propto 0.3 + 0.2 = 0.5$ mg O_2 m^{-3}

P_L $ora^{-1} \propto (0.3 + 0.2)/6 = 0.083$ mg O_2 m^{-3} ora^{-1}

P_L ora^{-1} $\propto$ (0.3 + 0.2)/6 = 0.083 mg O_2 m^{-3} ora^{-1}

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

C → 12 g / mole

O → 16 g / mole

fissando 6 x 12 g C

si liberano 6 x 2 x 16 g O

$$\frac{72 \text{ g C}}{192 \text{ g O}} = 0.375$$

1 mg O_2 m^{-3} ora^{-1} = 0.375 mg C m^{-3} ora^{-1}

P_L = 0.083 mg O_2 m^{-3} ora^{-1} x 0.375 = 0.031 mg C m^{-3} ora^{-1}