

Population Growth of Phytoplankton

Pop growth = rate of new cell production - rate of cell loss (sedimentation/sinking + grazing)

- Floating and sinking
- Grazing

Phyto defenses:

- o Increase rates of production
- o Mucilage sheaths
- o Thick walls
- o Hard external coverings
- o Spines are more for buoyancy but could also protect
- o Form colonies (become too large for some zooplankton to handle)
- o Chemical deterrents (toxic species)

Grazers

Herbivores reduce phyto pops by....

- Suspension feeding (filter water)
- Direct feeding
- May remove size specific individuals
- May remove less resistant Phyto species - non-toxic spp
- Results in patchy distributions



Grazers may also ↑ Phyto pops by releasing nutrients through excretion (positive effect)

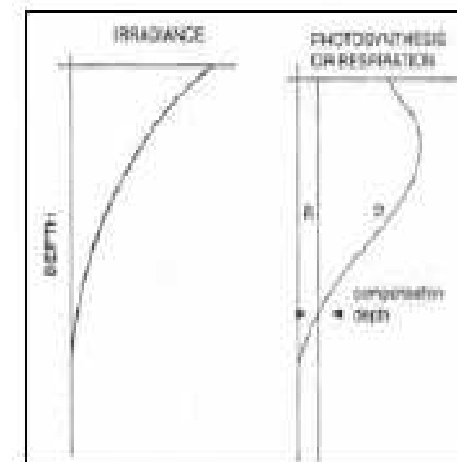


Phytoplankton Production: Distribution and Variability

1. Major bottom-up factors affecting primary production/biomass
 - temperature
 - nutrients
 - light (diel, seasonal, latitude, mixing)
2. Spatial
 - depth, on-off shore (coastal/oligotrophic), mesoscale (ex. eddies), global (meridional)
3. Temporal
 - day (diel)
 - seasonal (annual)
 - inter-annual (ex. El Nino)
 - decadal (ex. PDO)
 - glacial (ex. Milankovitch cycles)
 - epoch



Light



- Compensation depth = depth at which photosynthesis is equal to respiration (net production = 0)

Nutrients

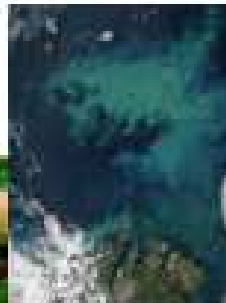
- Major factor limiting new cell production (especially N, Fe)

Nutrient Sources:

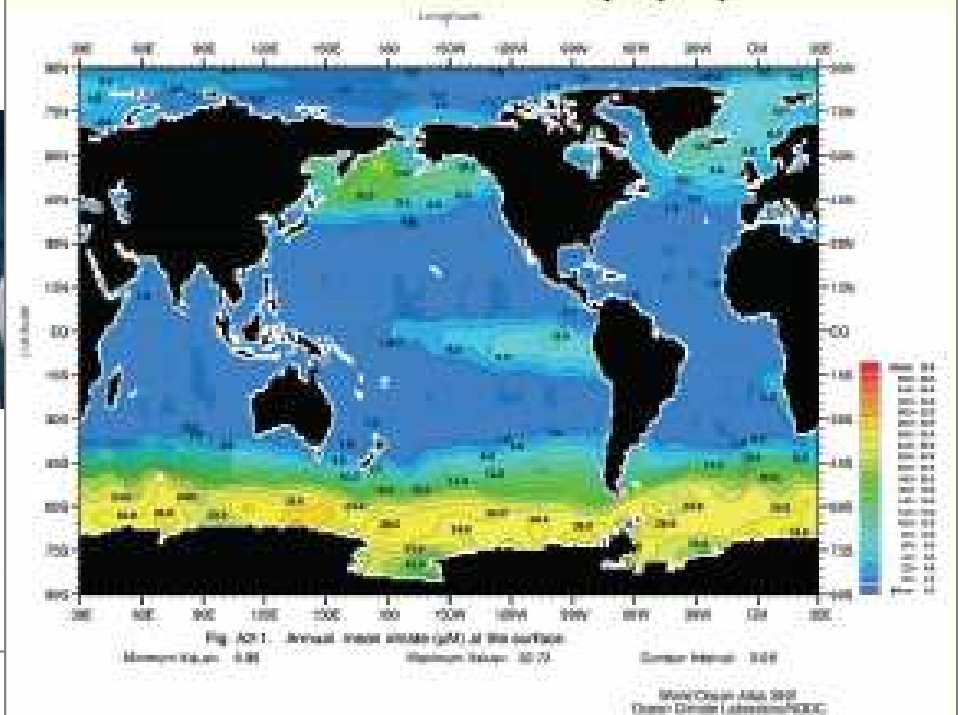
- Rivers, streams, and agriculture (runoff)
- Upwelling
- Recycling (messy eaters)
- Atmosphere (CO_2 , N_2)

Nutrient uptake:

- Advantage of small size
- Simple diffusion to simply nutrients and remove wastes - large SA/V ratio



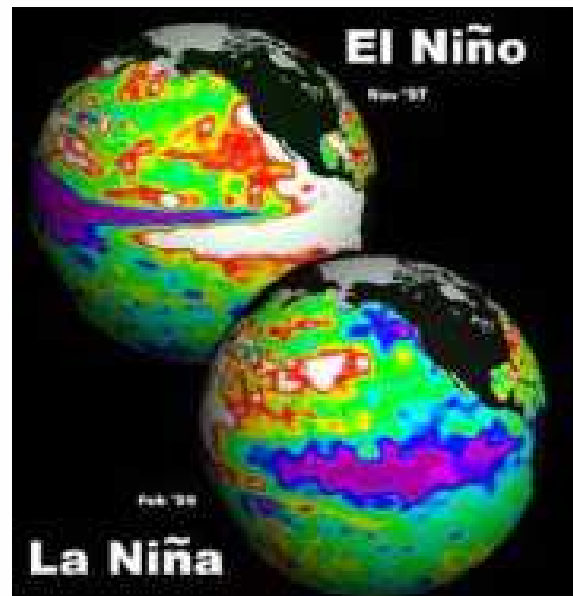
Nutrient limitation of phytoplankton



El Nino / La Nina

El Nino / La Nina influence on nutrients:

- El Nino - Warm water blocks upwelling of nutrient - lowers phytoplankton abundance
- La Nina - surface waters cool, bringing cold nutrient rich water to surface (upwelling) - raises phytoplankton abundance



Size is relevant to

- Nutrient uptake
- Growth rate
- Grazing

Microphytoplankton

Low growth rate

Large dimension

Less affected by mesozooplankton

Nano- and picophytoplankton

High S/V ratio

Growth rate similar to that of grazers

Controlled by microzooplankton

Control:

- bottom-up (nutrients)
- top-down (grazers)

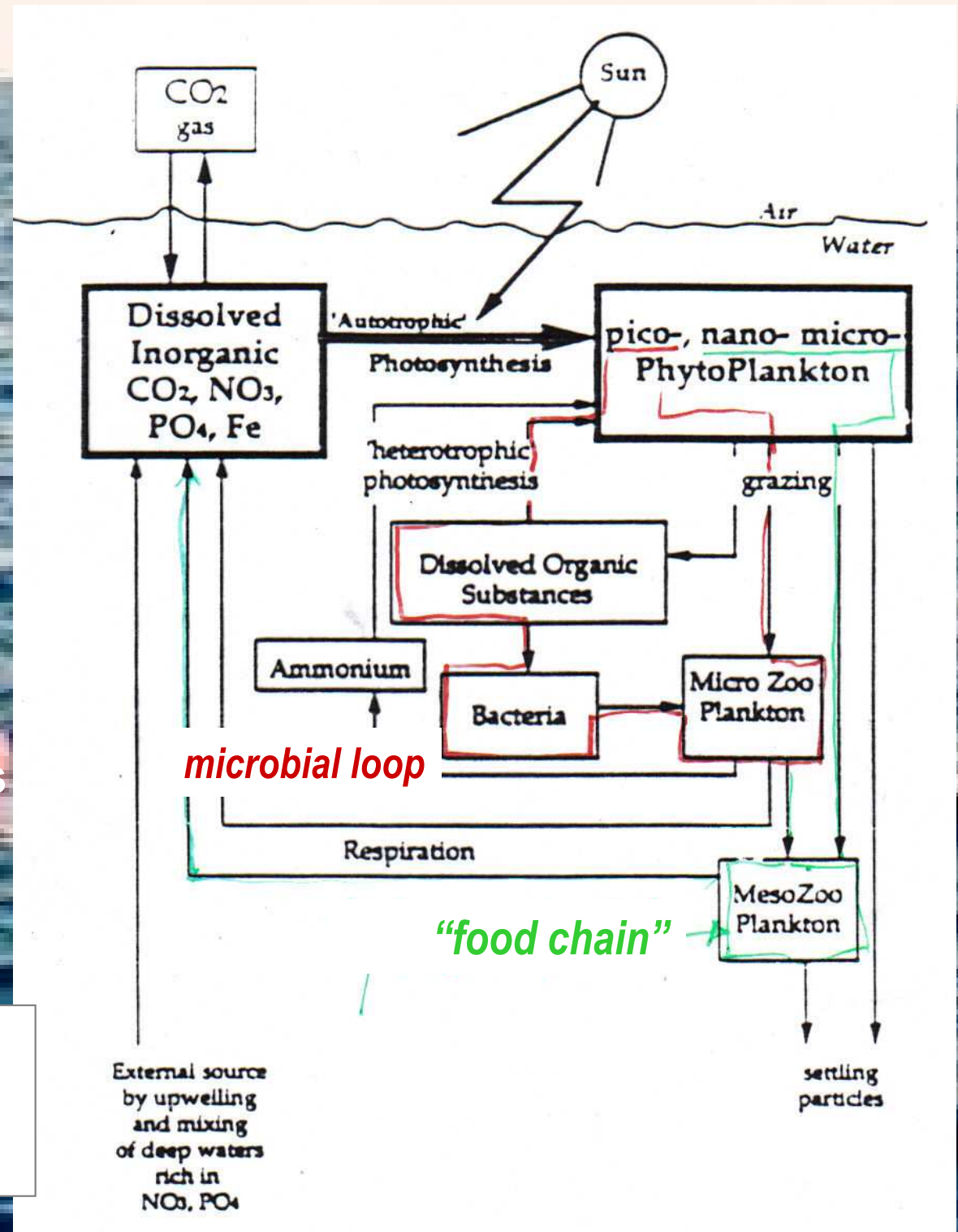
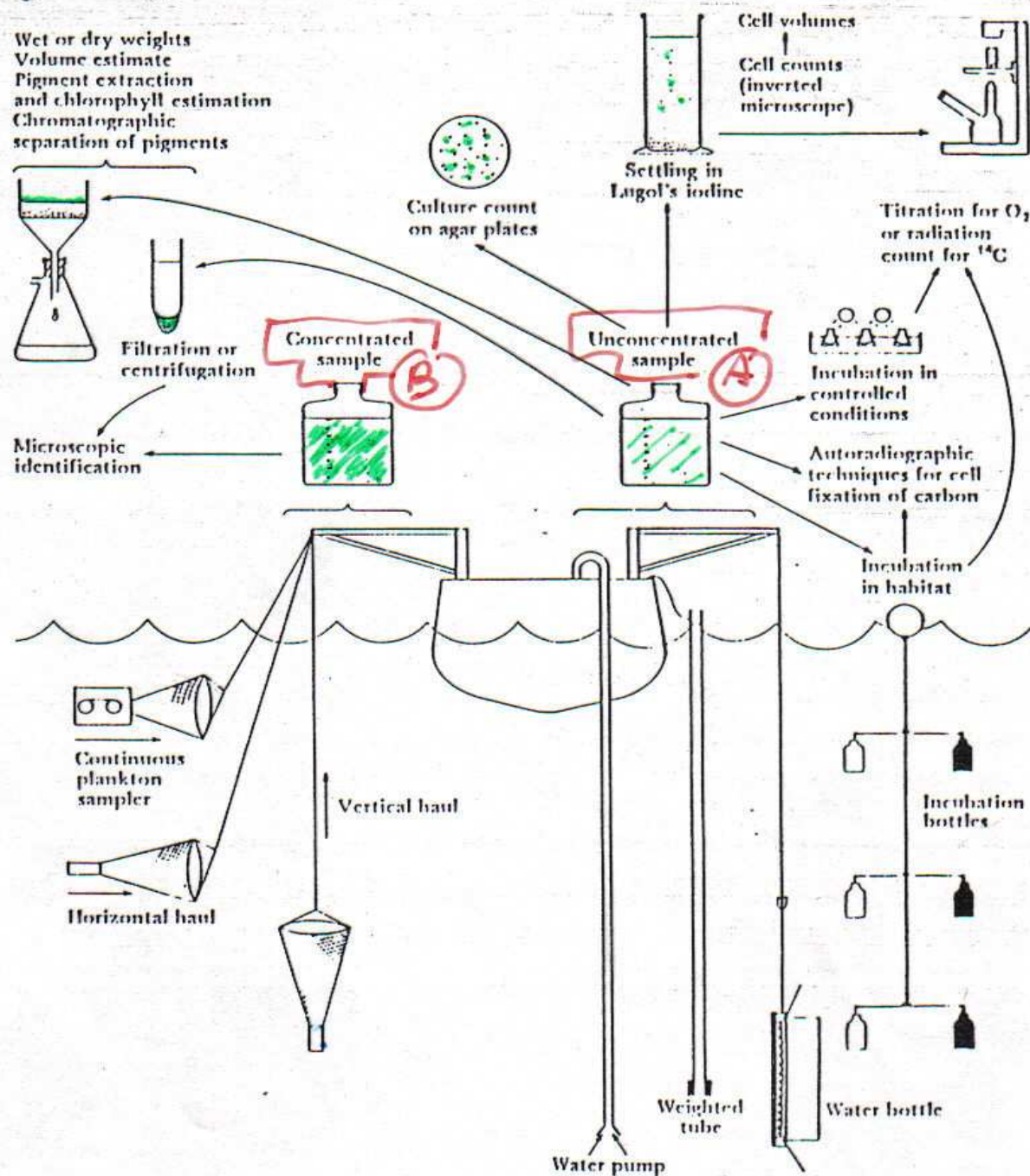


Fig. 9 - Diagrammatic procedures for sampling and subsequent treatment of phytoplankton.



Phytoplankton methods:

- A) quantitative
- B) qualitative

Biomass as:

- Chl a
- cell number L⁻¹
- biovolume
- FW, DW
- Total C (or N or P)
- ATP

Phytoplankton methods

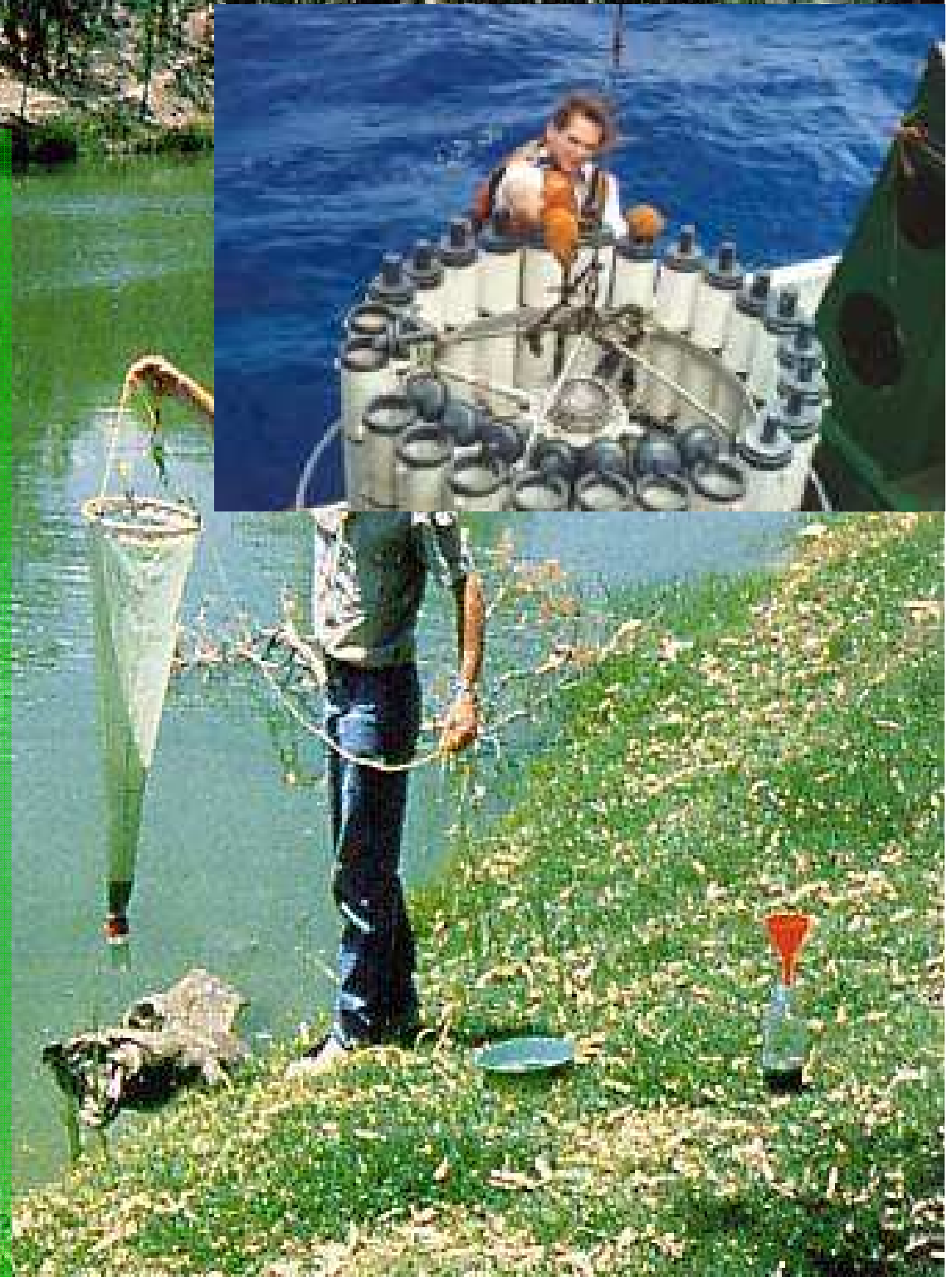
Sampling

- net (100, 50, 20 μm mesh)
- bottle, Niskin bottle, rosette (1-5-12 L)
- continuous sampler

CTD - Multiparametric sensors
(T, O₂, Conductivity, pH, PPFD, ect.)

Fractionation and concentration

- A) Fresh samples for biomass, primary production, cultures
- B) Fixed samples (Lugol's solution) in sedimentation cylinder and chamber for cell counts
- C) Fixed samples (formaldehyde, glutaraldehyde) for cell characterization

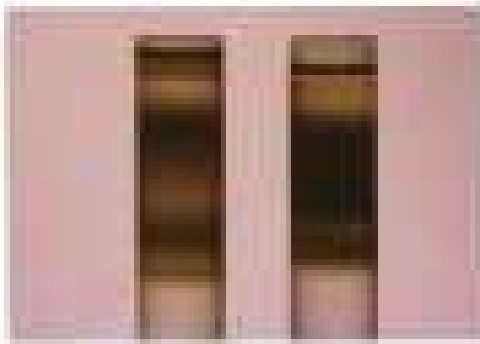


Phytoplankton Biomass

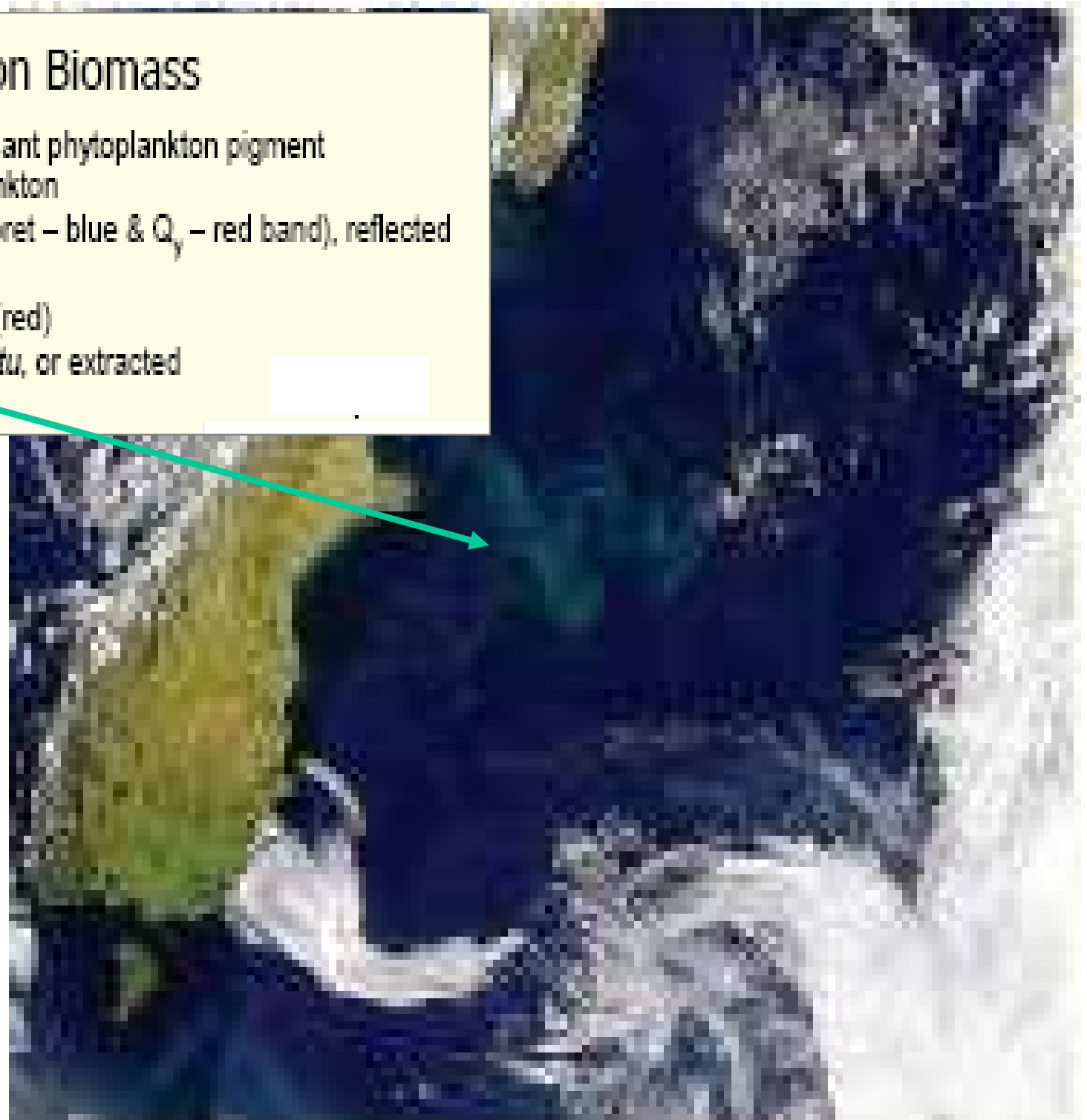
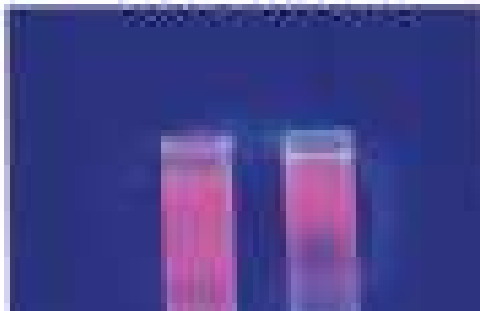
Chlorophyll a – most abundant phytoplankton pigment

- present in all oxygenic phytoplankton
- two strong absorption bands (Soret – blue & Q_y – red band), reflected light is green
- strong fluorescence at ~680nm (red)
- can be measured remotely, *in situ*, or extracted
- sensitive, simple, rapid

absorption



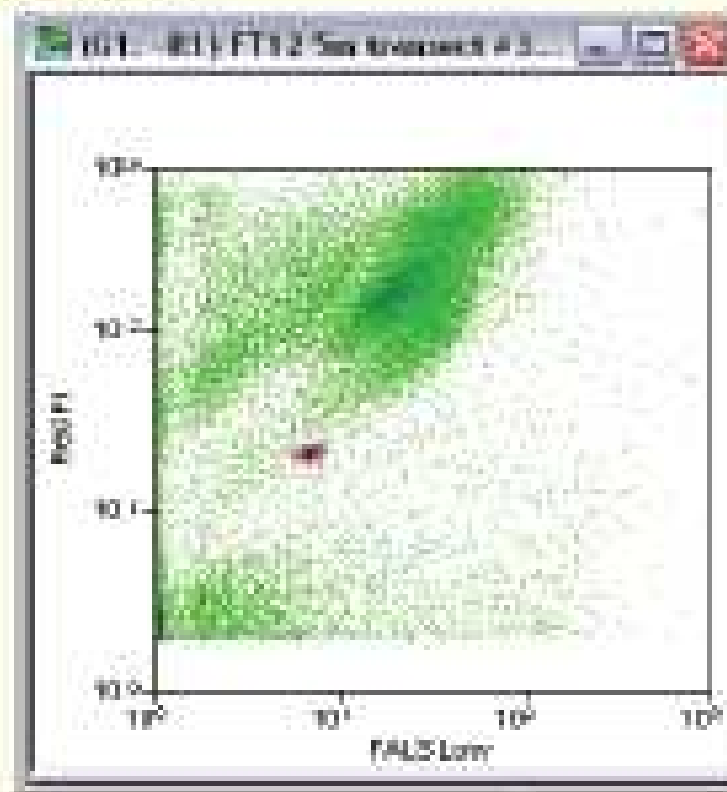
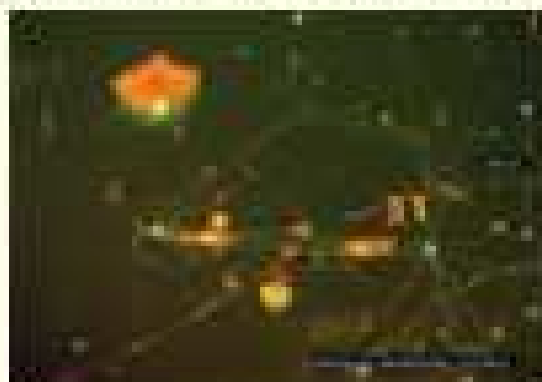
fluorescence



Phytoplankton Biomass

1: Quantifying Phytoplankton Biomass

- a. carbon (nitrogen, phosphorous, etc.)
 - "dead" carbon > live carbon
 - what fraction is phytoplankton specific?
- b. counting cells (microscope, flow cytometry)



2: Identifying species

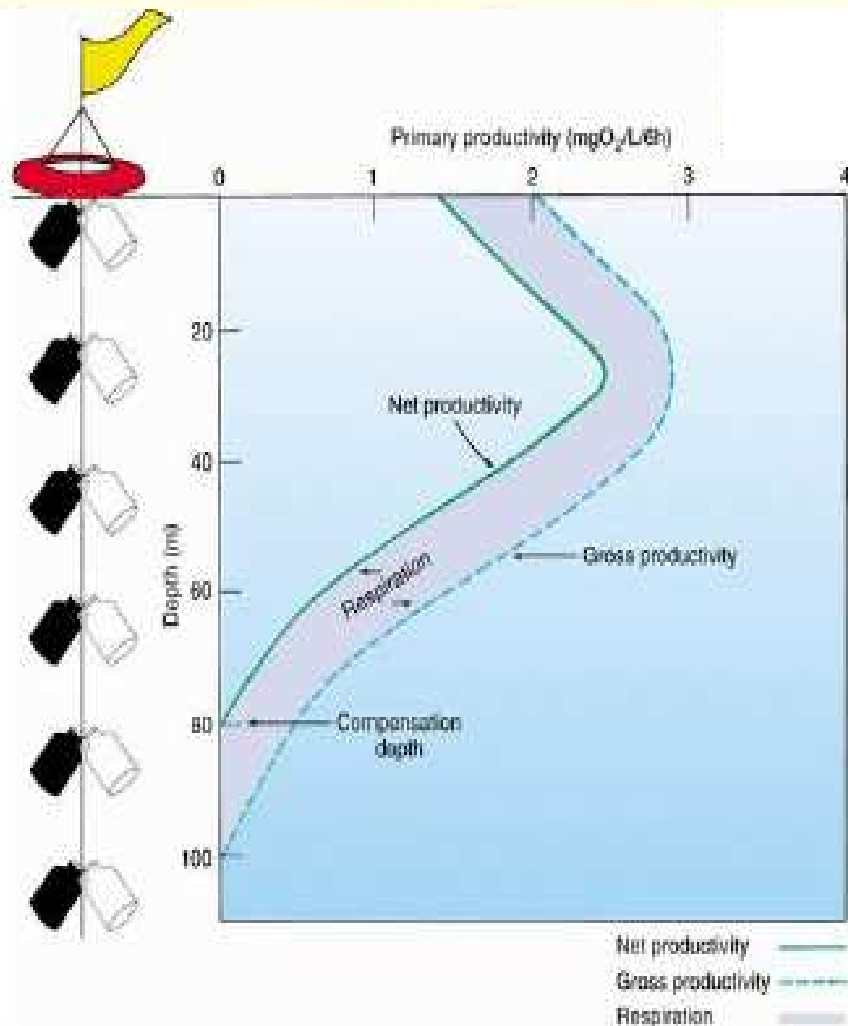
- LM microscopy (bright field, phase contrast, fluorescence)
- electron microscopy (SEM and TEM)

Phytoplankton Production

2: Quantifying Primary Production: incubations with tracers



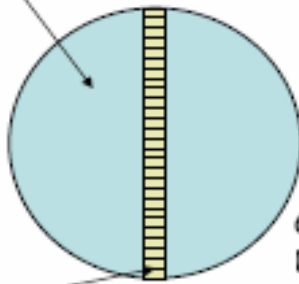
^{14}C or O_2 evolution: dark bottle / light bottle technique



- **Gross Primary Production:** The rate of organic carbon production *via* the reduction of CO_2 due to photosynthesis.
- **Net Primary Production:** Gross primary production, less photoautotrophic respiration, integrated over time and depth.
- **Net Community Production:** Gross primary production, less autotrophic and heterotrophic losses due to respiration.
- Units for all measures of production: $\text{mgC m}^{-2} \text{d}^{-1}$

Calcolo del numero di organismi fitoplanctonici

Cella di sedimentazione



Campi esplorati

Numero campi = area cella/area campo proiettato

$$\text{Area cella (mm}^2\text{)} = (25/2)^2 \times 3,14$$

$$\text{Area campo proiettato (mm}^2\text{)} = \text{altezza} \times \text{larghezza}$$

$$\text{Altezza} = \text{diametro cella} / \text{n.campi per diametro verticale}$$

$$\text{Larghezza campo} = \text{altezza campo} \times 3/2$$

CALCOLO DEL NUMERO
DI ORGANISMI PER CAMPO

Numero di organismi contati/numero
di campi in cui sono stati contati

NUMERO CAMPI
IN UNA CELLA

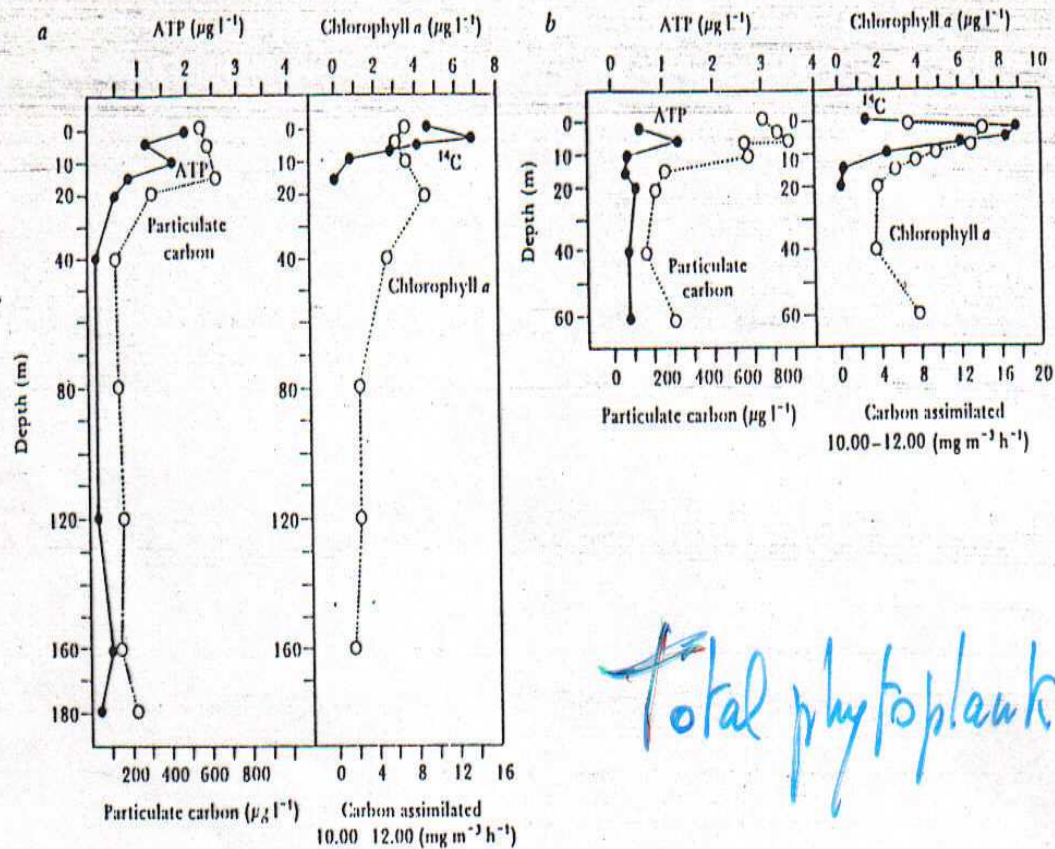
Organismi	Numero organismi contati	Numero organismi/campo	Numero organismi nella cella	Numero organismi/ml	Numero organismi/ m ³	Altezza strato fetico	Numero organismi/ m ²
Tipo A	Totale organismi contati nei vari campi esplorati	/n° campi in cui sono stati contati	x N° campi nella cella	/ aliquota prelevata (ml)	Numero organismi/ml x 10 ⁶	m	N° organismi/ m ³ x altezza strato fetico (m)

Biovolume

Calcolo delle dimensioni degli organismi in μm^3

Organismi	Unità considerata	Formula	Lunghezza μm	Larghezza μm	Altezza μm	Diametro μm	Volume unitario μm^3
Specie A	Colonia	$Lu \cdot La \cdot h$					
Specie B	Singola Cellula di colonia	$r^2 \cdot \pi \cdot h$					
Specie C	Organism o non coloniale	$4/3 \cdot \pi \cdot r^3$					

Fig. 3. The vertical distribution of ATP, particulate carbon, chlorophyll *a* and carbon assimilation, *a*, at an offshore station and, *b*, at an inshore station in Lake Ontario. From Stadelmann & Munawar, 1974.



Total phytoplankton

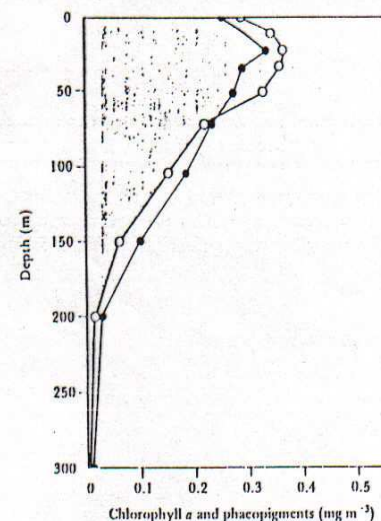
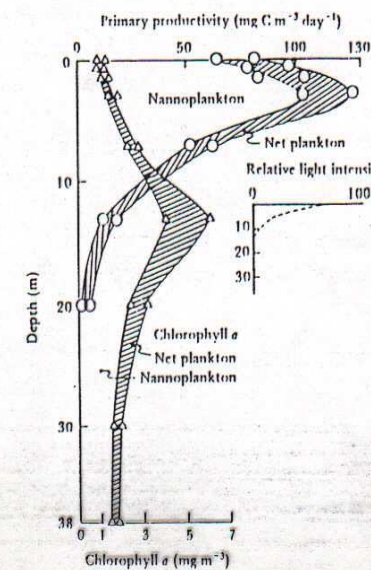


Fig. 4. The vertical distribution of chlorophyll *a* (stippled area) and phaeopigments (filled circles) based on average values from all stations during a cruise from Australia to Antarctica. From El-Sayed & Jitts, 1973.

Fig. 5. The vertical distribution of primary productivity ($\circ$) and chlorophyll *a* (Δ) in the water column in Lake Biwa. Each curve shows the larger contribution by the nanoplankton relative to the net plankton down the whole profile. From Tanaka *et al.*, 1974.



Fraction

Fig. 6. Chromatographic 'map' of major photosynthetic pigments separated from coastal phytoplankton on thin layers of cellulose. Solvent system: first dimension, 25% chloroform in light petroleum (60-80 °C); second dimension, 2% *n*-propanol in light petroleum (60-80 °C). Pigment fractions: 1: carotene (orange); 2: chlorophyll *a* (blue-green); 3: diadinoxanthin (yellow); 4: fucoxanthin (orange); 5: neofucoxanthin (orange); 6: chlorophyll *c* (light green); 7: pheophytin *a* (grey); 8: chlorophyllide

a (blue-green); 9: pheophorbide *a* (grey); 10: astaxanthin (pink); 11: chlorophyll *b* (olive green); 12: neoxanthin (yellow); 13: peridinin (red); 14: neoperidinin (red).
b. Chromatograms of photosynthetic pigments through the water column, 8 miles off Sydney, Australia, Station 1, 1 October 1970. Cross-hatched areas, chlorophyll *a*; stippled areas, breakdown products of chlorophyll *a*. From Jeffrey, 1974.

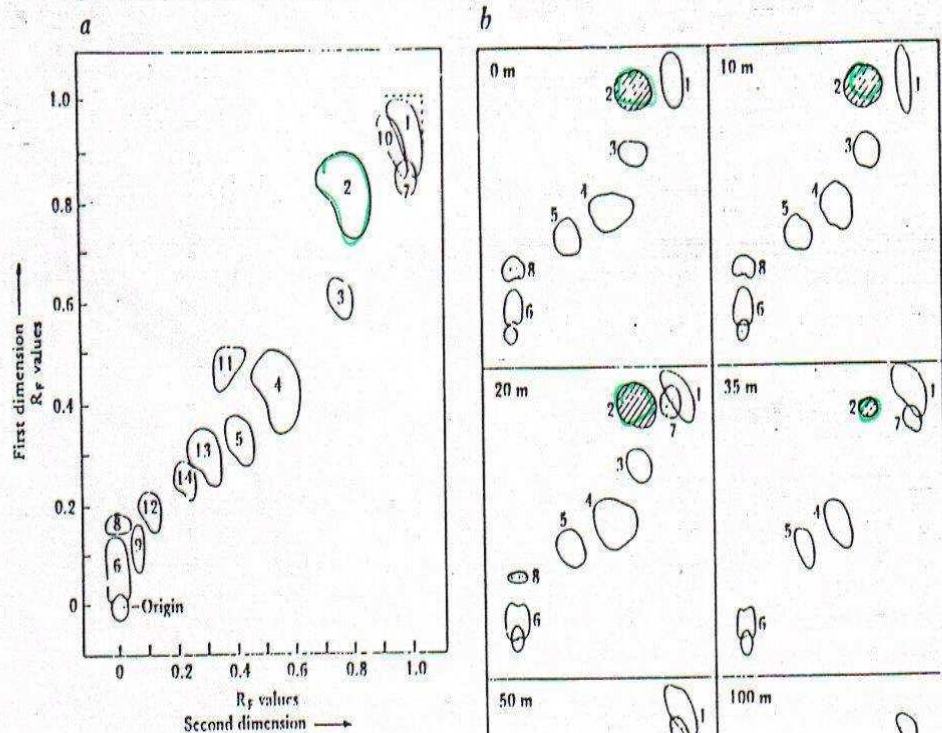


Fig. 7. The distribution of algal pigments at different depth at a station off Sydney. Cross hatched columns, pigments from living cells. Black bars, degraded pigments. From Jeffrey, 1974.

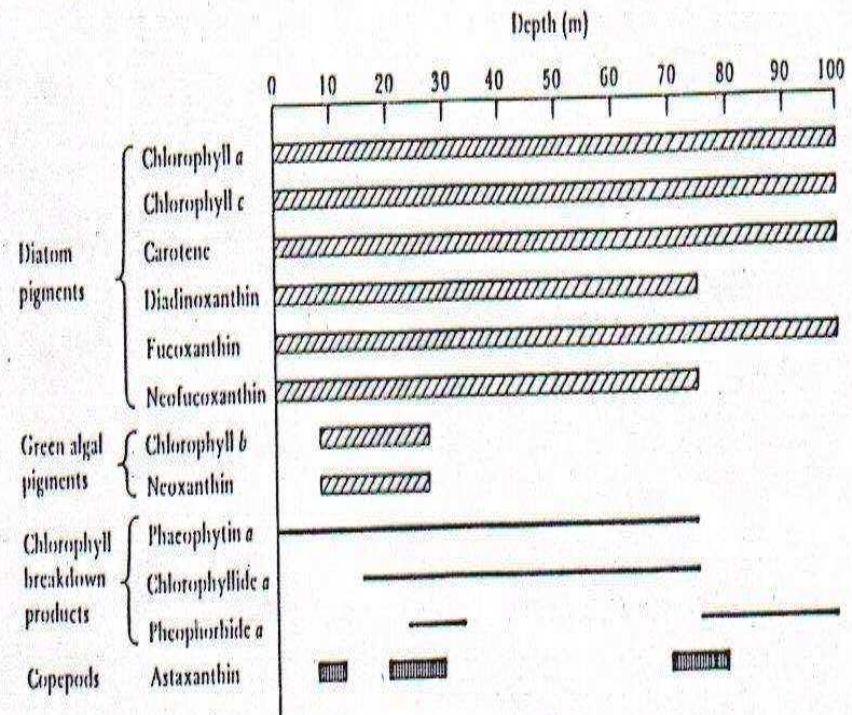
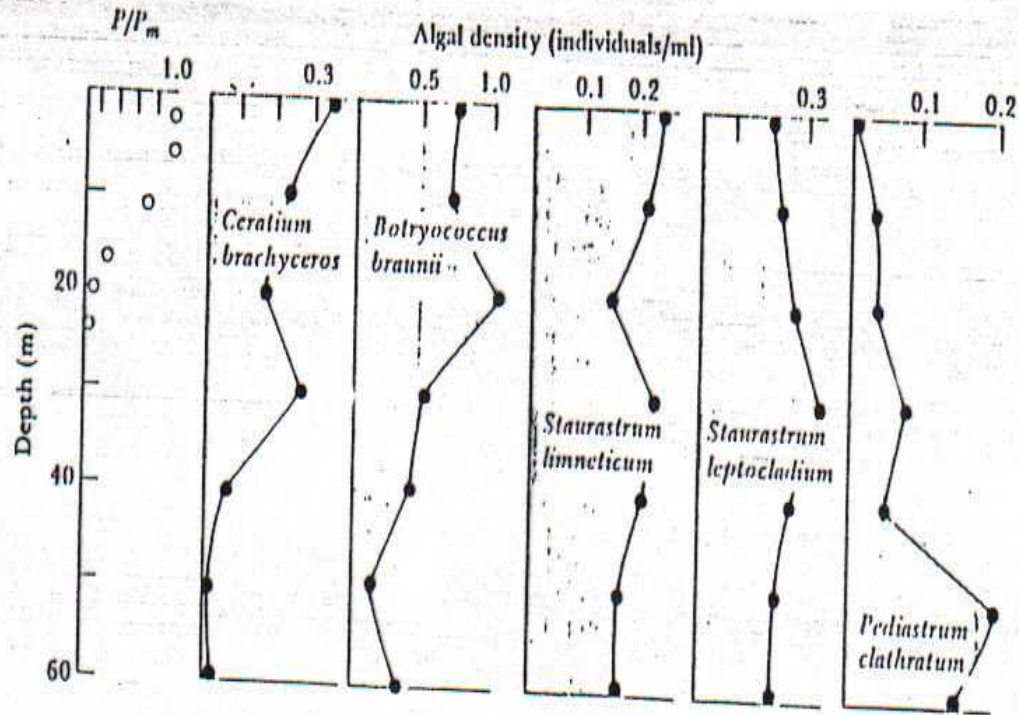
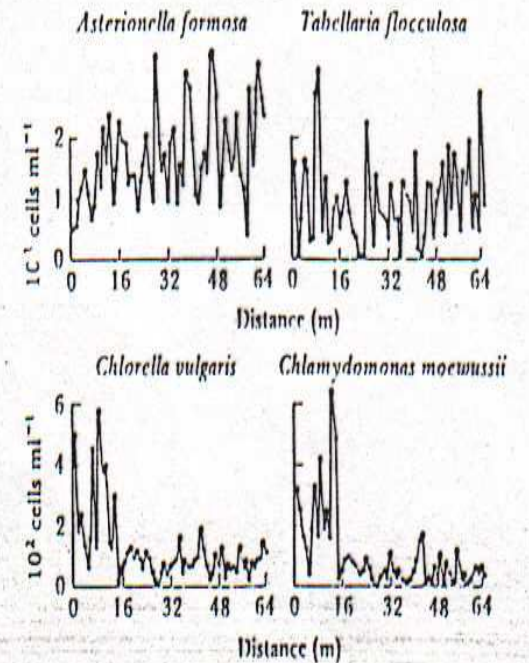


Fig 1. The vertical distribution of some phytoplankton species down the water column in Lake Victoria. 'Individuals' are cells except for *Botryococcus* and *Pediastrum* which are colonies. The photosynthetic rate is shown as a fraction (P/P_m) of the maximum rate (P_m).



Individual species

Fig. 17. The horizontal distribution of population density expressed as cells ml^{-1} , along 64 m transect in surface water, for four species of algae.



Individual species

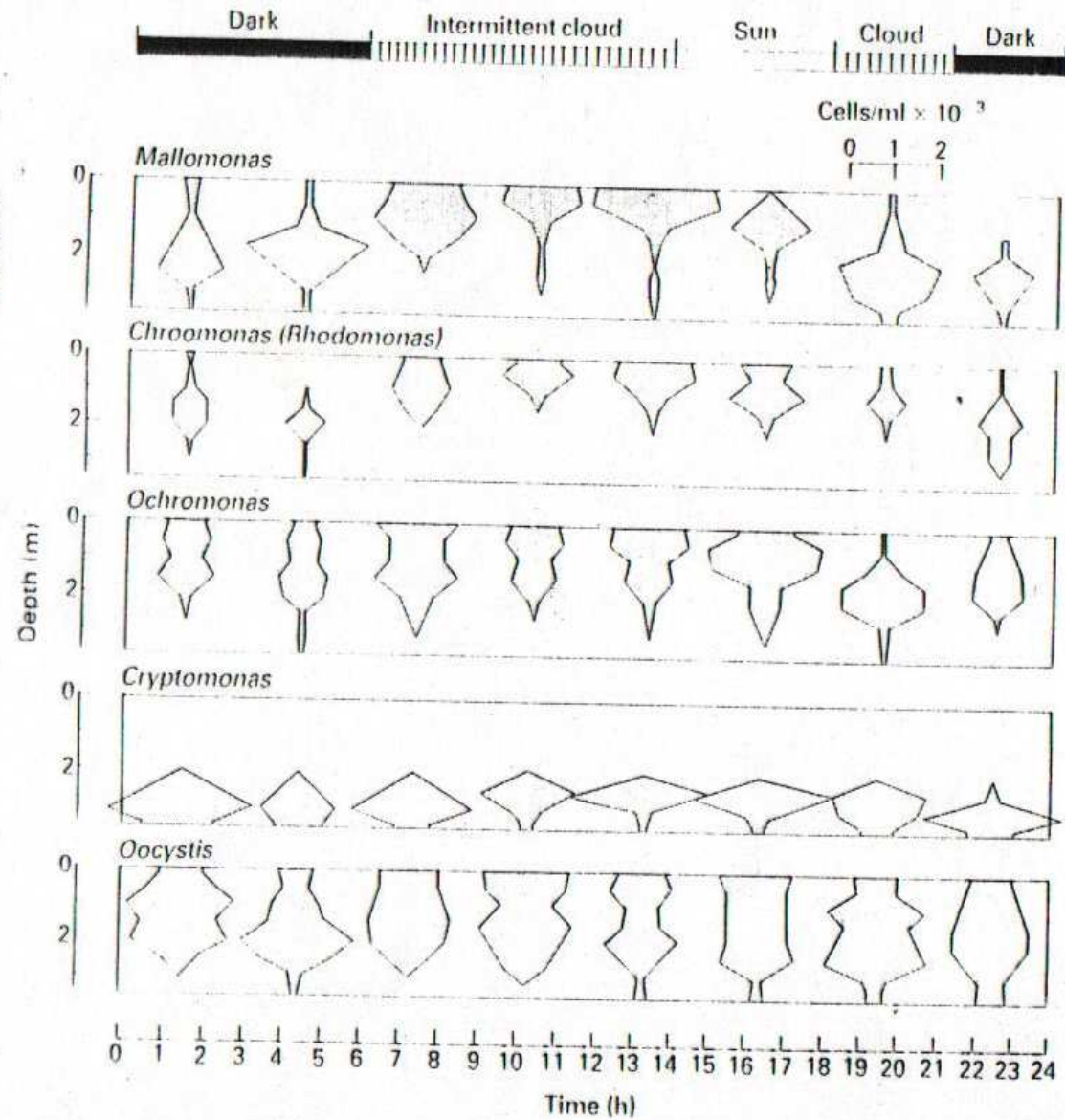


Fig. 7.8 Vertical distribution of phytoplankton in a pond over a 24-hour period. Top bar shows sky conditions.

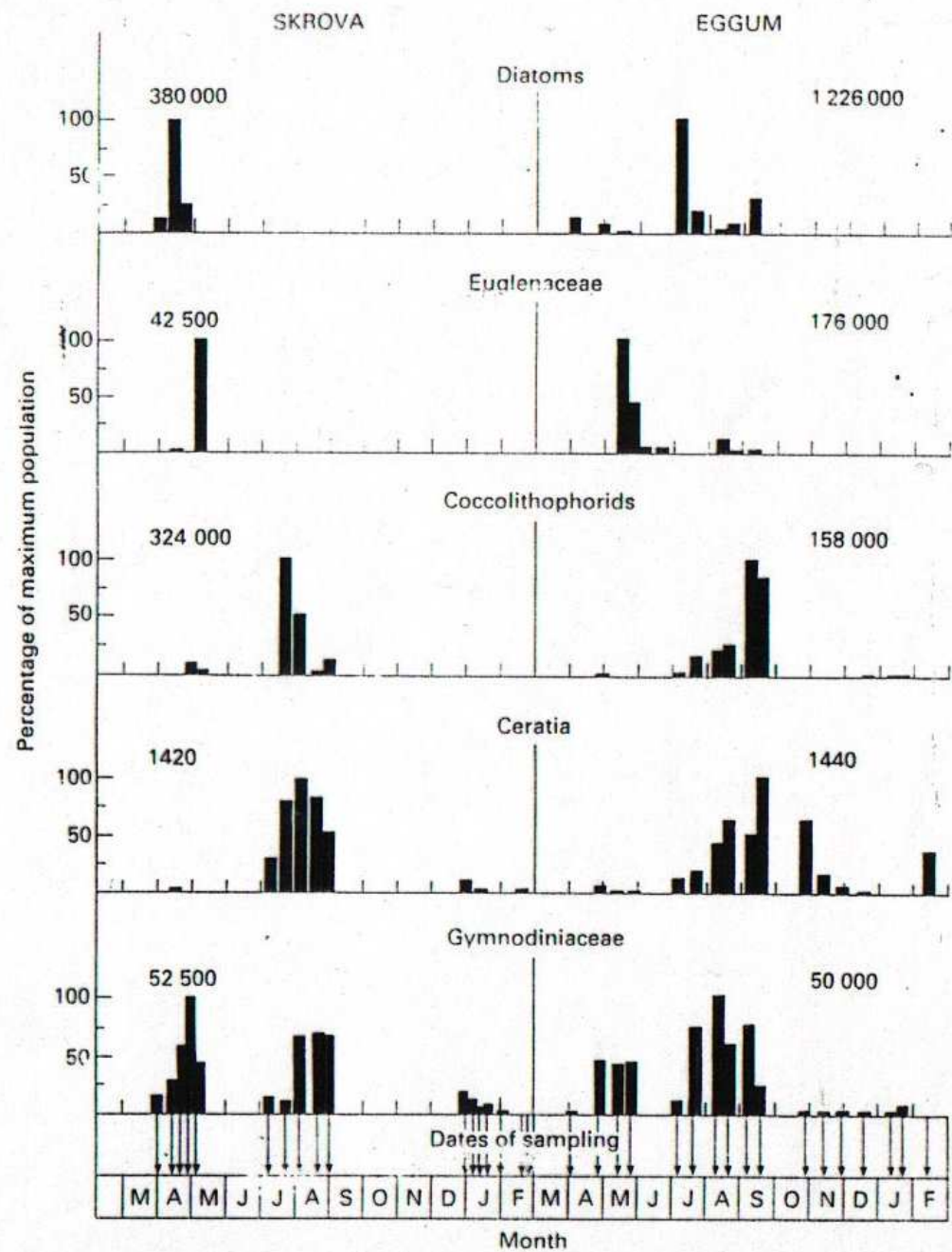


Fig. 7.12 Seasonal changes in the main components of the phytoplankton at two stations (Skrova and Eggum) in Norwegian coastal waters. For each date the maximum number recorded is presented as the percentage of the maximum population recorded for the group during the year.

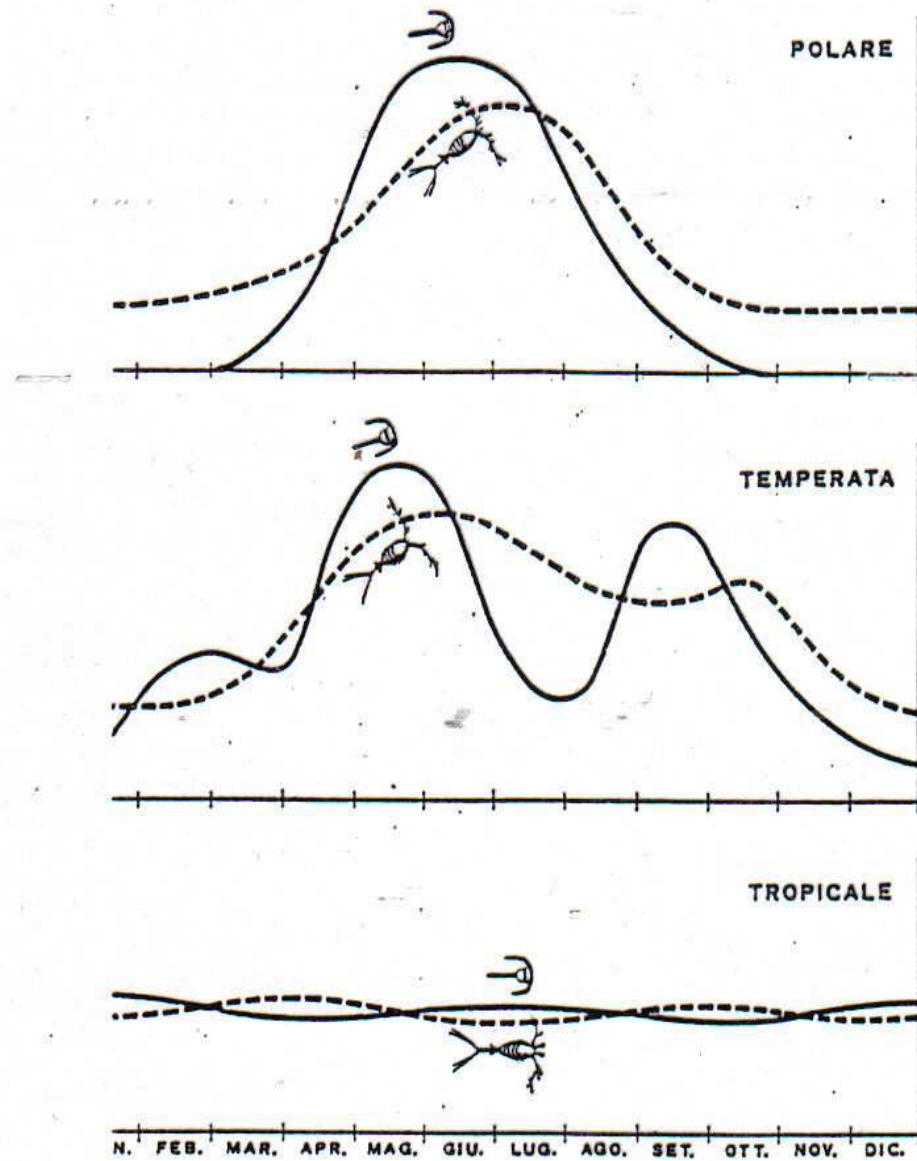


Fig. 7.2 - Andamento del fito e dello zooplancton nelle diverse stagioni a diverse latitudini (linea intera: fitoplancton; linea tratteggiata: zooplancton).

Fig. 22 - Growth of *Olisthodiscus* in dilutions of *Skeletonema*-conditioned medium with nutrients restored. 0% control (i.e. fresh medium); 100% undiluted conditioned medium.

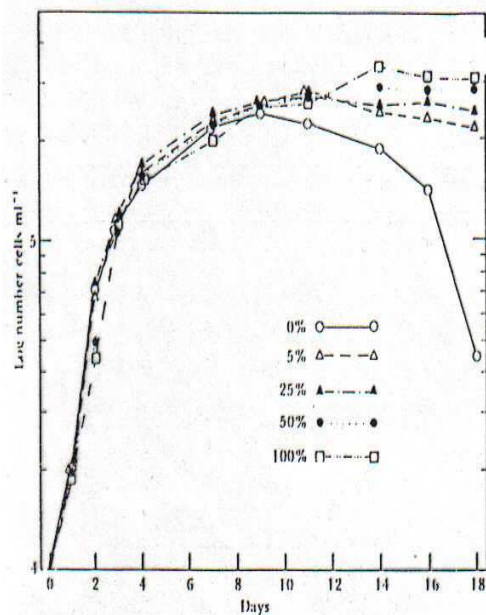


Fig. 23 Growth of *Skeletonema* in dilutions of *Olisthodiscus*-conditioned medium with nutrients added. 0% is the control (i.e. fresh medium); 100% is the undiluted *Olisthodiscus* medium

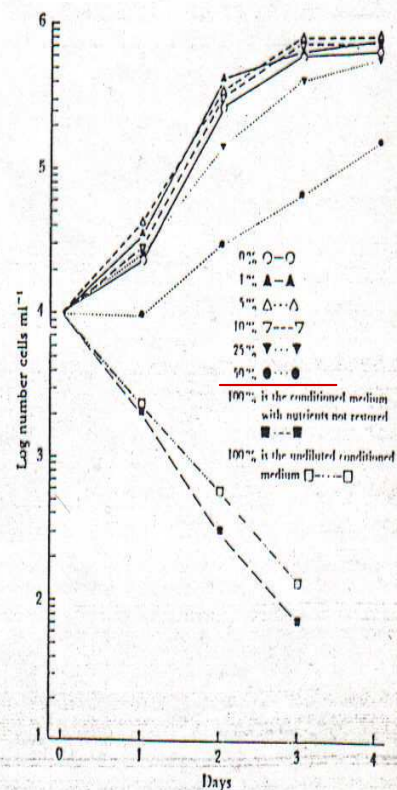


Fig. 21 Inhibition of growth in several volvocacean genera by culture filtrates from members of the same family.

Culture filtrate from	Inoculum										
	<i>E. cylindrica</i>	<i>P. charkoviensis</i>	<i>G. pectorale</i>	<i>P. morum</i>	<i>V. globator</i>	<i>E. illinoisensis</i>	<i>V. pringsheimii</i>	<i>V. tertius</i>	<i>E. elegans</i>	<i>E. californica</i>	<i>P. caudata</i>
<i>Eudorina cylindrica</i>	O	I		I	I	I	I	I			
<i>Pandorina charkoviensis</i>	—	O	—	I	—	—	I	—	I	—	—
<i>Gonium pectorale</i>	—	I	O	—	I	—	I	I	—	—	I
<i>Pandorina morum</i>	I	I	I	O	I	I	I	I	I	—	I
<i>Volvox globator</i>	—	I	—	I	O	I	I	—	I	—	—
<i>Eudorina illinoisensis</i>	I	I	—	I	I	O	—	I	I	—	—
<i>Volulina pringsheimii</i>	—	I	I	I	I	—	Λ	I	I	—	I
<i>Volvox tertius</i>	—	—	—	—	—	I	I	O	—	—	—
<i>Eudorina elegans</i>	—	I	I	I	I	—	I	—	O	—	—
<i>Eudorina californica</i>	I	I	—	I	I	—	I	I	I	O	—
<i>Platydorina caudata</i>	—	I	—	—	I	—	I	I	—	—	Λ

I, at least 20% inhibition of growth; Λ, autoinhibition; O, no autoinhibition.

Phytoplankton as indicators of changing environments

Alien species

Effects of Ozone Layer Depletion on Phytoplankton Production

Effect of ozone depletion on phytos:

- Increase in UVB radiation (wavelength most damaging to DNA)
- Decrease in phytoplankton production during this period (among other things)

TEMP C
≥ 13
10.9

12

11

10

9

8

7

6

≤ 5.0