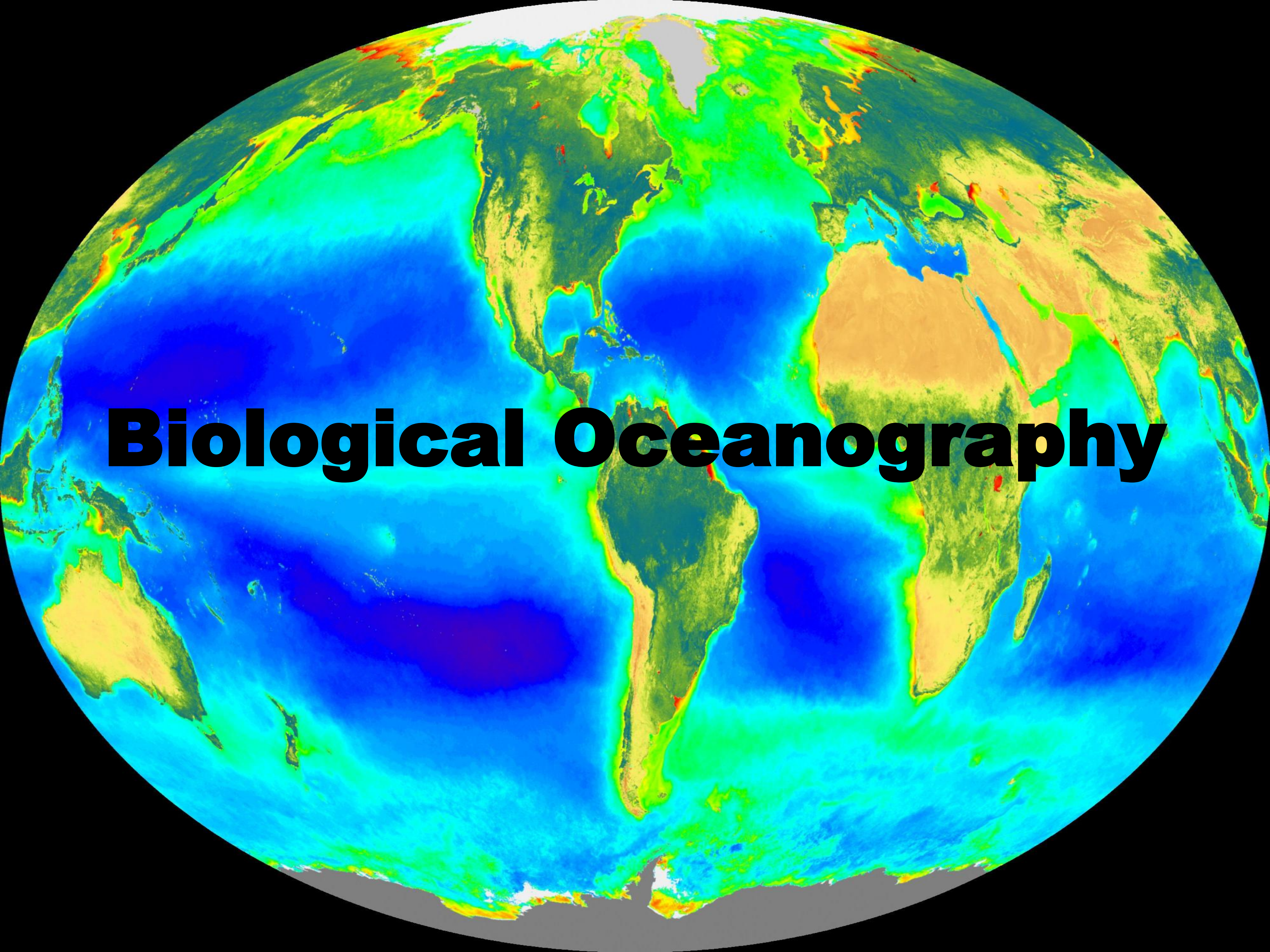
Biological Oceanography

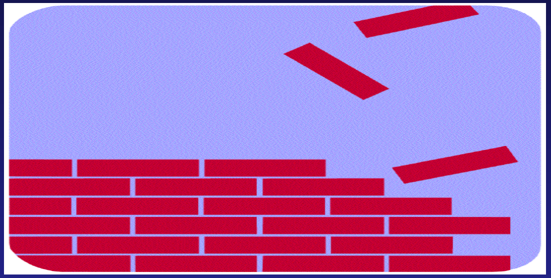


What controls production in the sea?

The BIG 2:

1) Light (energy)

2) Nutrients (matter)



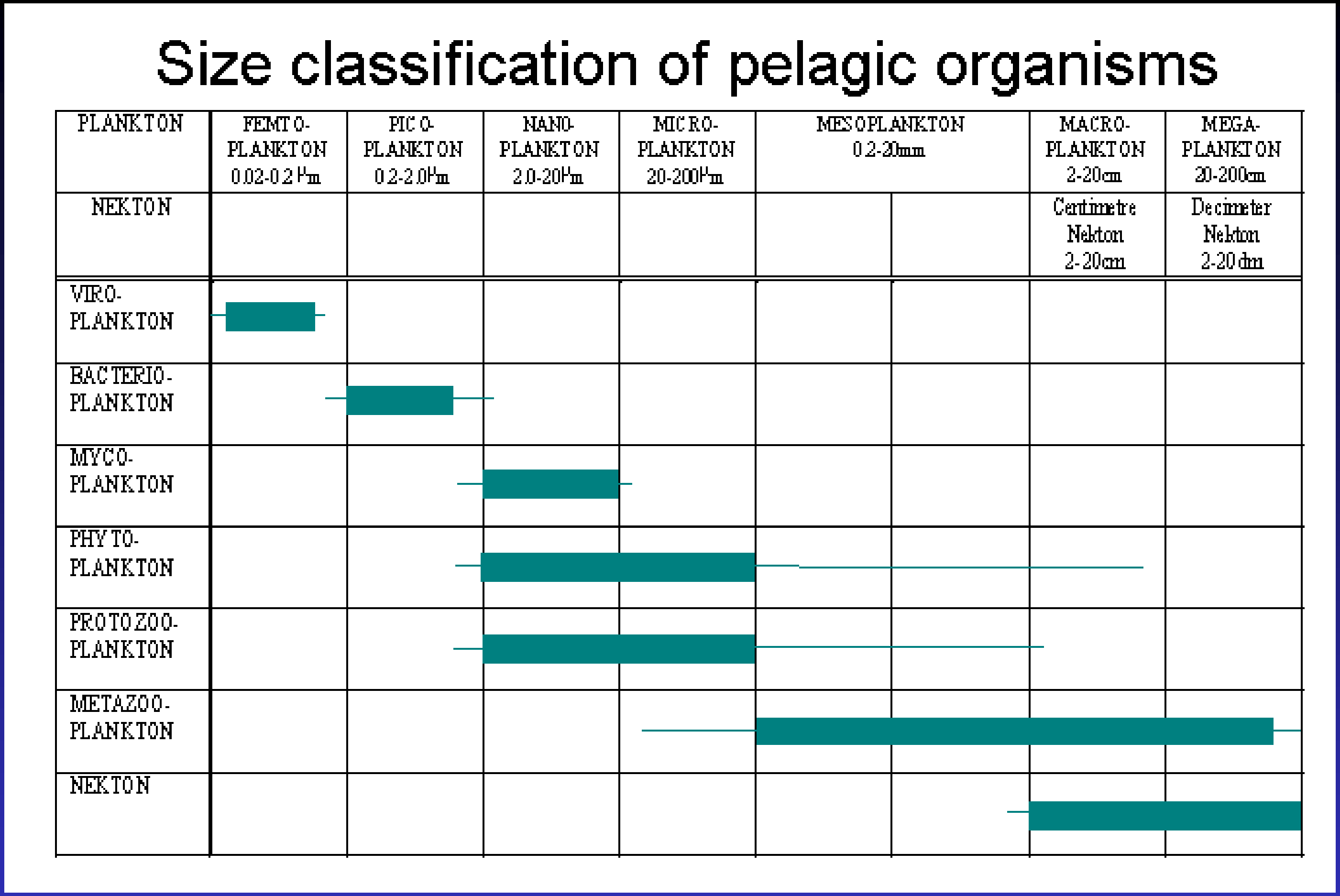
Secondarily

3) Temperature

4) Stratification (coupled to 2 & 3)

5) Grazing/predation

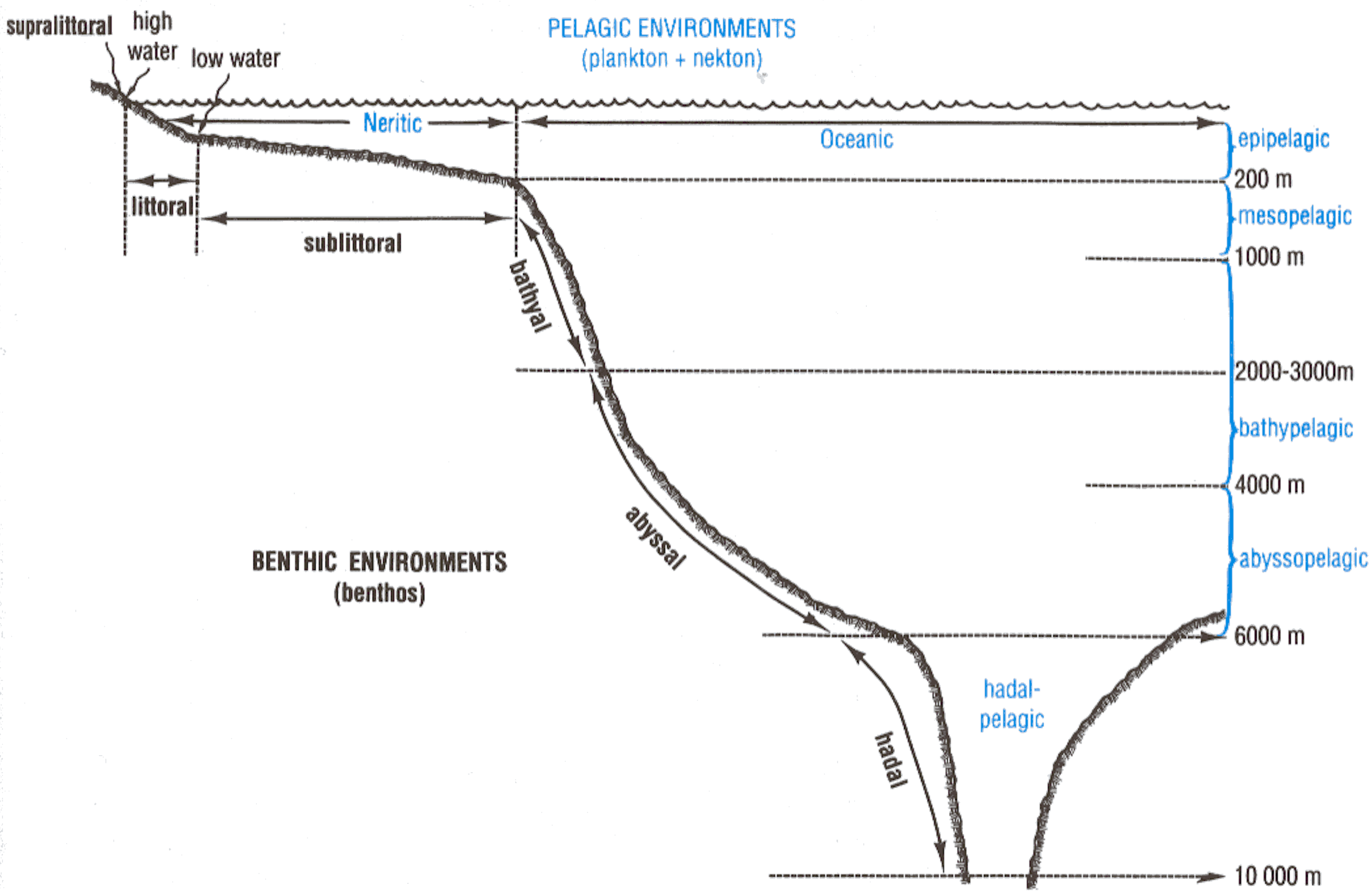
The majority of the ocean's production begins within the plankton



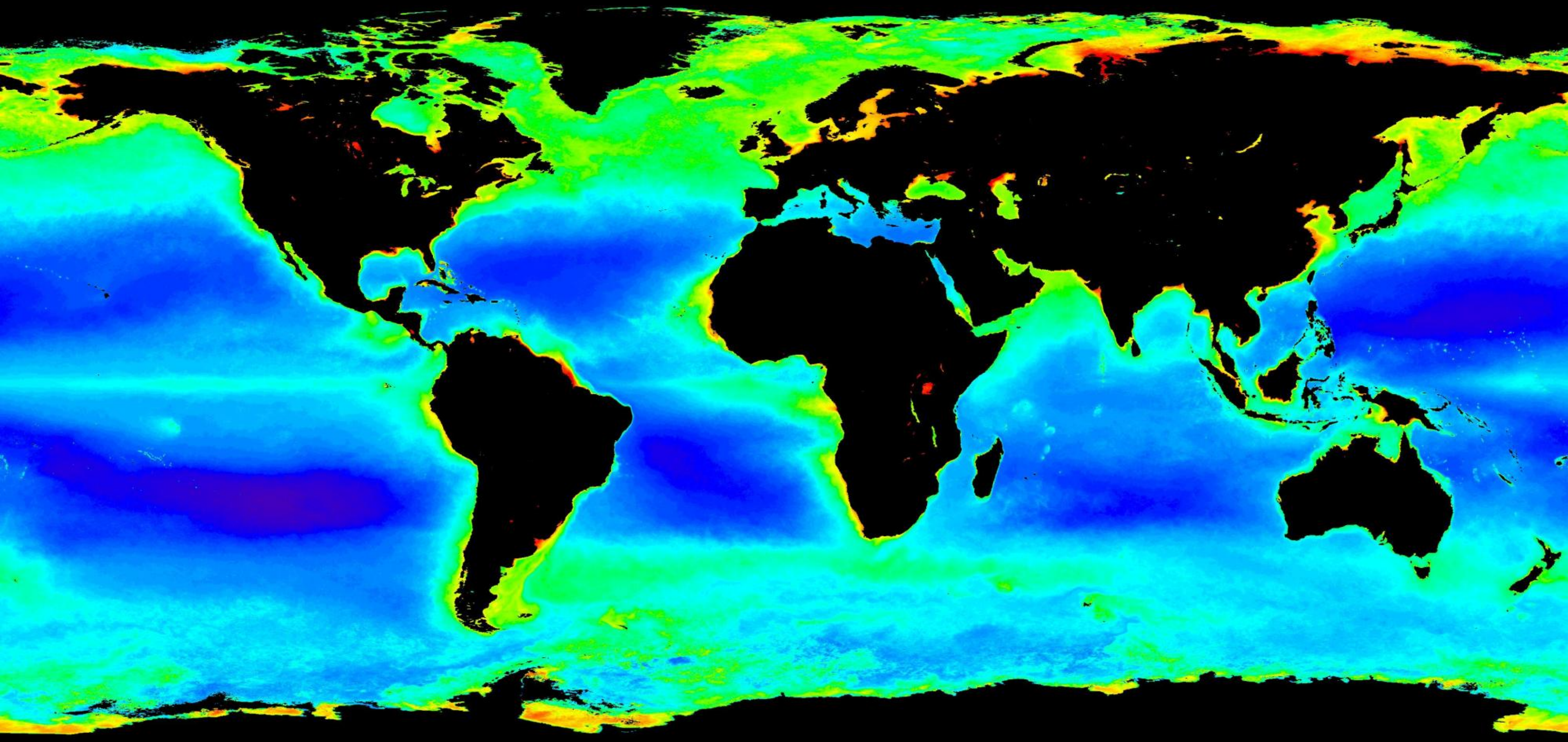
Classification:

- Size (usually on log scale)
- Function: Autotroph (Chemotrophic, Phototroph), Heterotroph/Phagotrophic, Mixotroph
- Taxonomic (classically morphological, increasingly molecular)

Oceanic realms



Remote Sensing of Ocean Color ~ algal biomass and production



Major theme: getting nutrients from where they are into an environment where they are needed, then seeing how communities use them

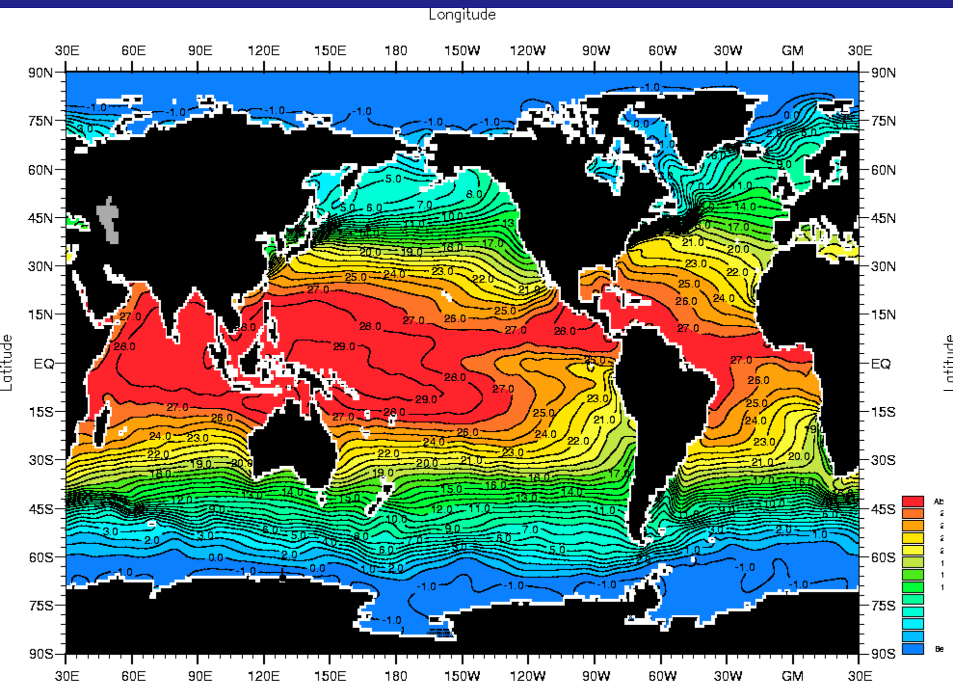


Fig. A2-1. Annual mean temperature (°C) at the surface .

Minimum Value= -1.93 Maximum Value= 29.90 Contour Interval: 1.00

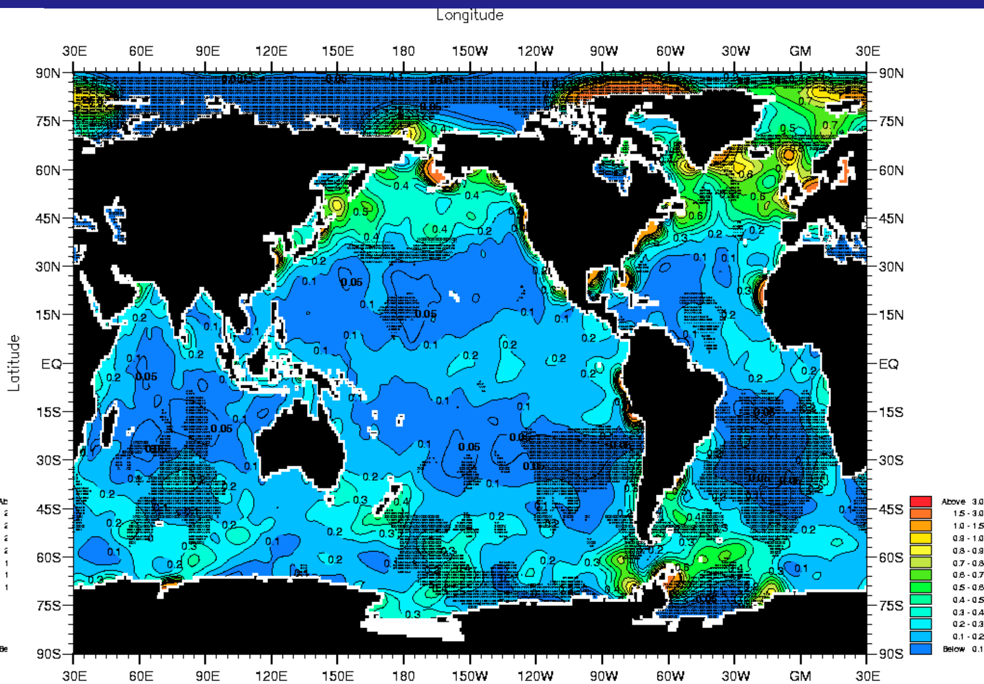
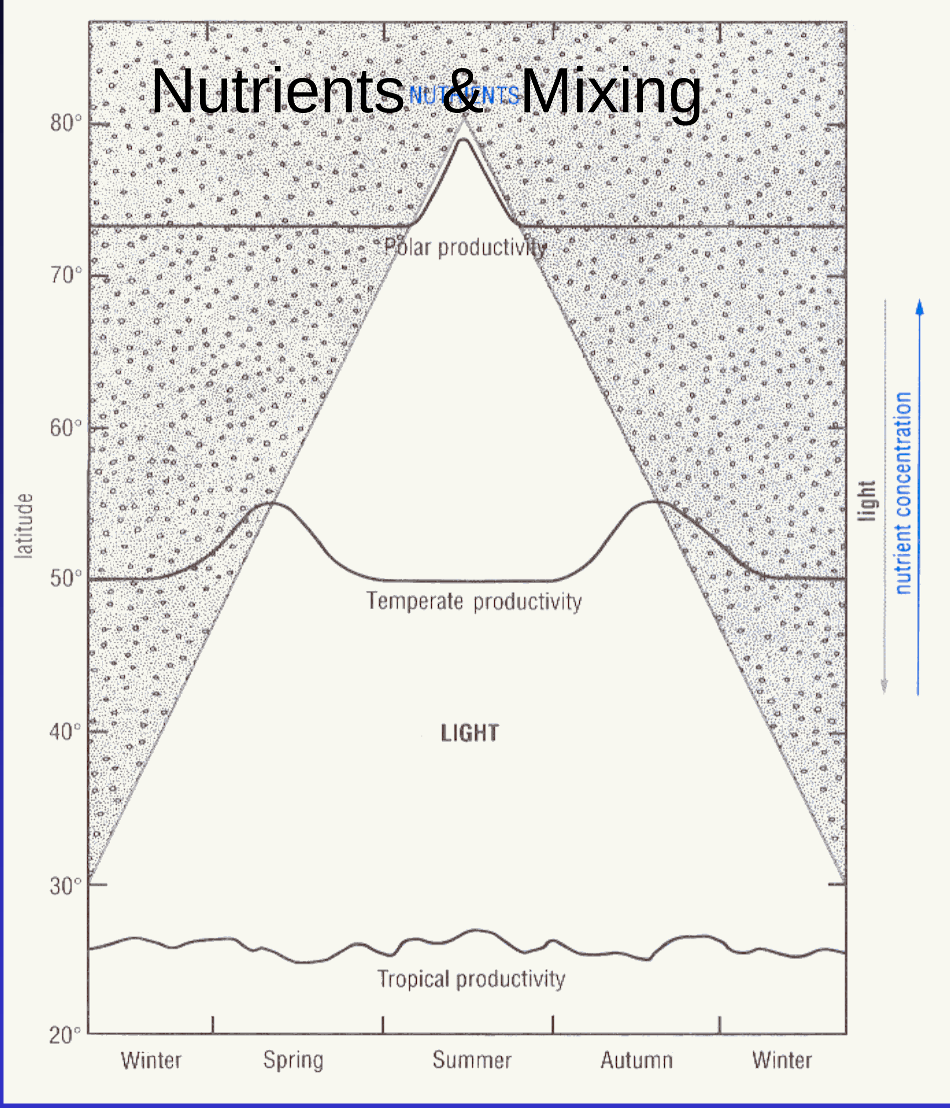


Fig. G2-1. Annual mean chlorophyll (μg/l) at the surface .

Minimum Value= 0.00 Maximum Value= 3.97

- **Nutrients** are the main factor controlling the geographic differences in the amount of primary production in ocean surface waters.
- Nutrients are the chemical substances that a plant needs to grow in addition to carbon dioxide and water
- They include phosphate and fixed nitrogen (usually ammonium or nitrate). They also include silica (for siliceous organisms only) and iron.
- **Light** (or, rather, lack of light) limits primary production in waters beneath the photic zone (depths greater than 100-200 m) and in temperate and polar regions in winter.



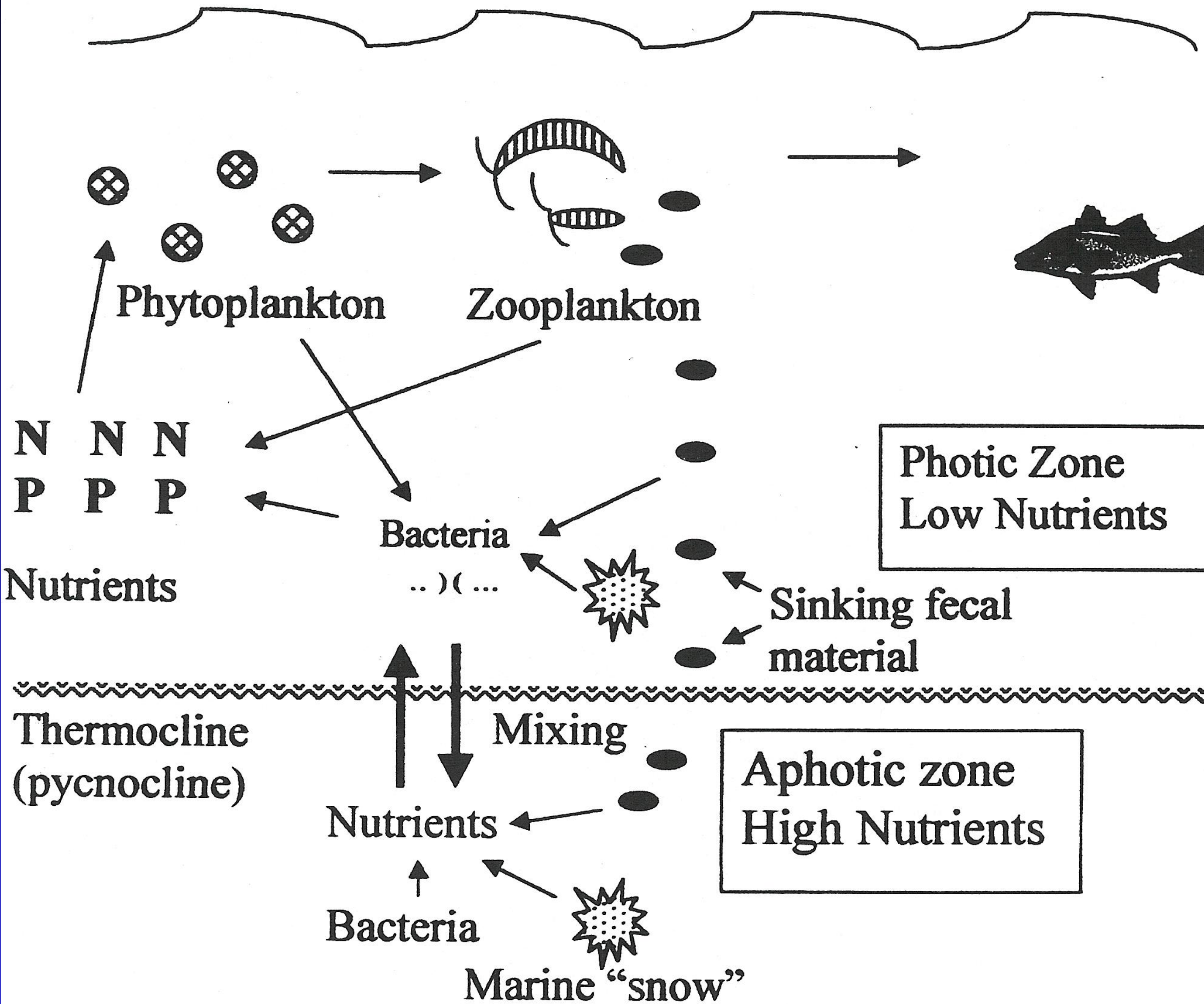
The Spring Bloom

- The spring bloom is an obvious seasonal event in temperate waters
- It occurs during a short period when neither light or nutrients are limiting
- It is probably the earliest example of a mechanistic link between the oceans physics, chemistry and biology
- To understand it we first need a basic understanding of nutrient cycles, phytoplankton and finally the interplay of stratification

The Nutrient Cycle

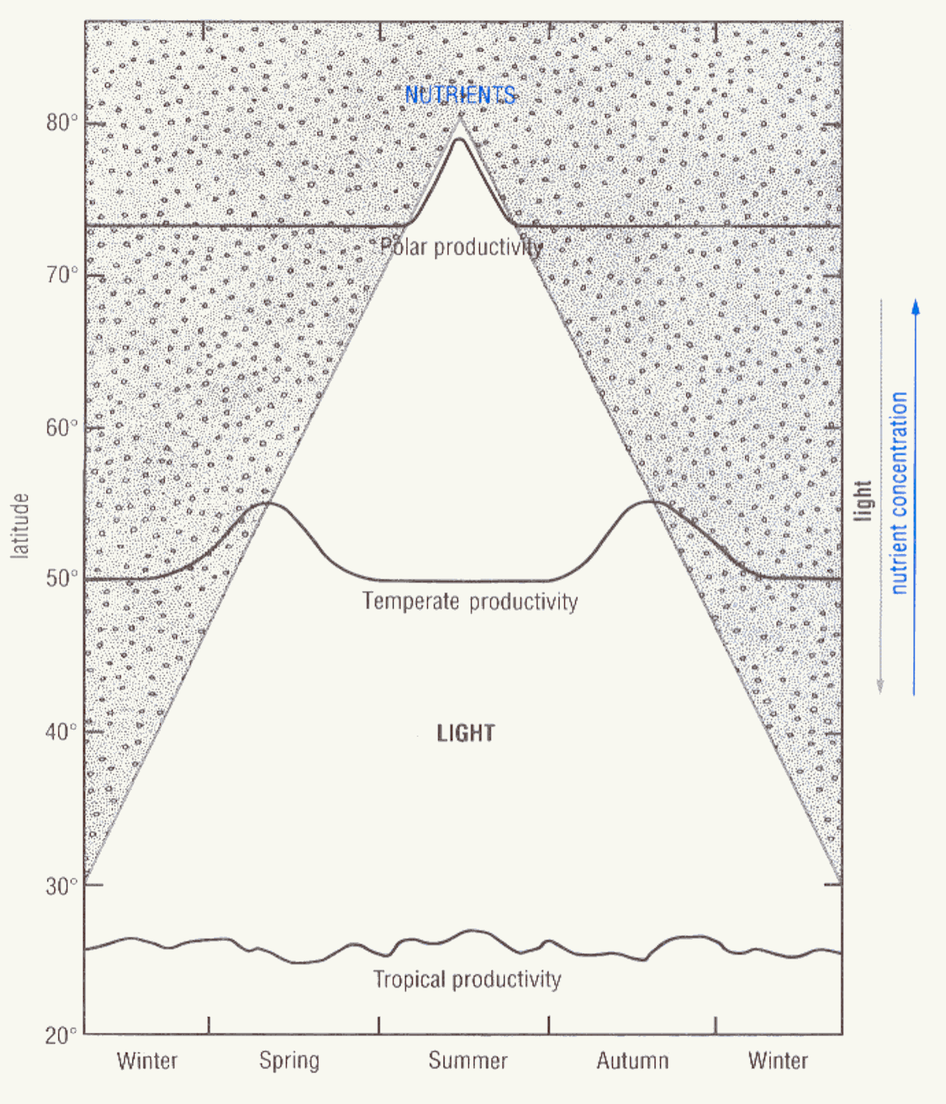
- The **nutrient cycle** refers to the recycling of nitrogen, phosphorus, silica, and other substances that phytoplankton need in order to grow.
- Dead organic matter (dissolved or particulate) is broken down by bacteria, producing carbon dioxide and the nutrients ammonium, nitrate, and phosphate.
- If the nutrients are recycled in the photic zone, they are rapidly used again by the phytoplankton.
- Some organic matter sinks out of the photic zone and decomposes deeper in the ocean. This strips nutrients out of surface waters, and results in high nutrient concentrations in the aphotic zone.
- Nutrient resupply to the photic zone occurs when surface and deeper waters mix or when there is upwelling.

The Nutrient Cycle

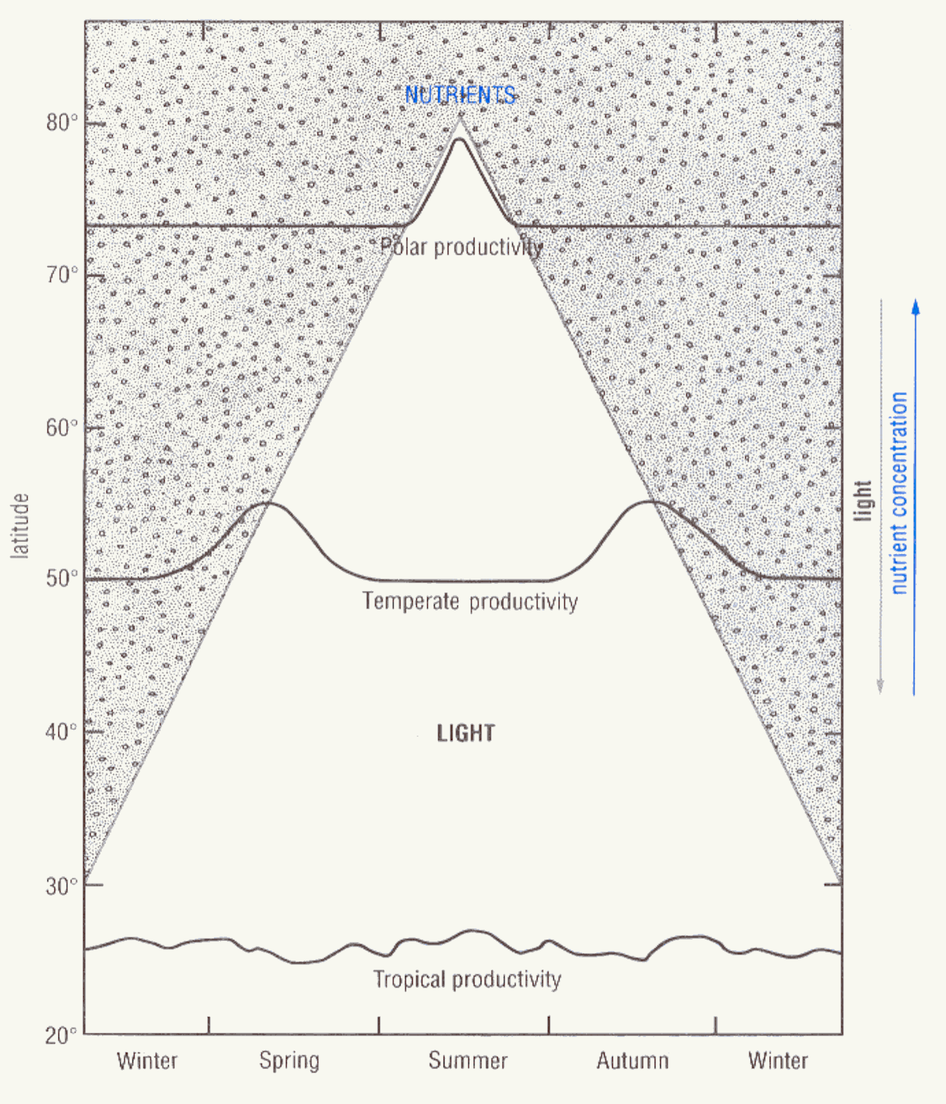


Geographic variations in nutrient availability:

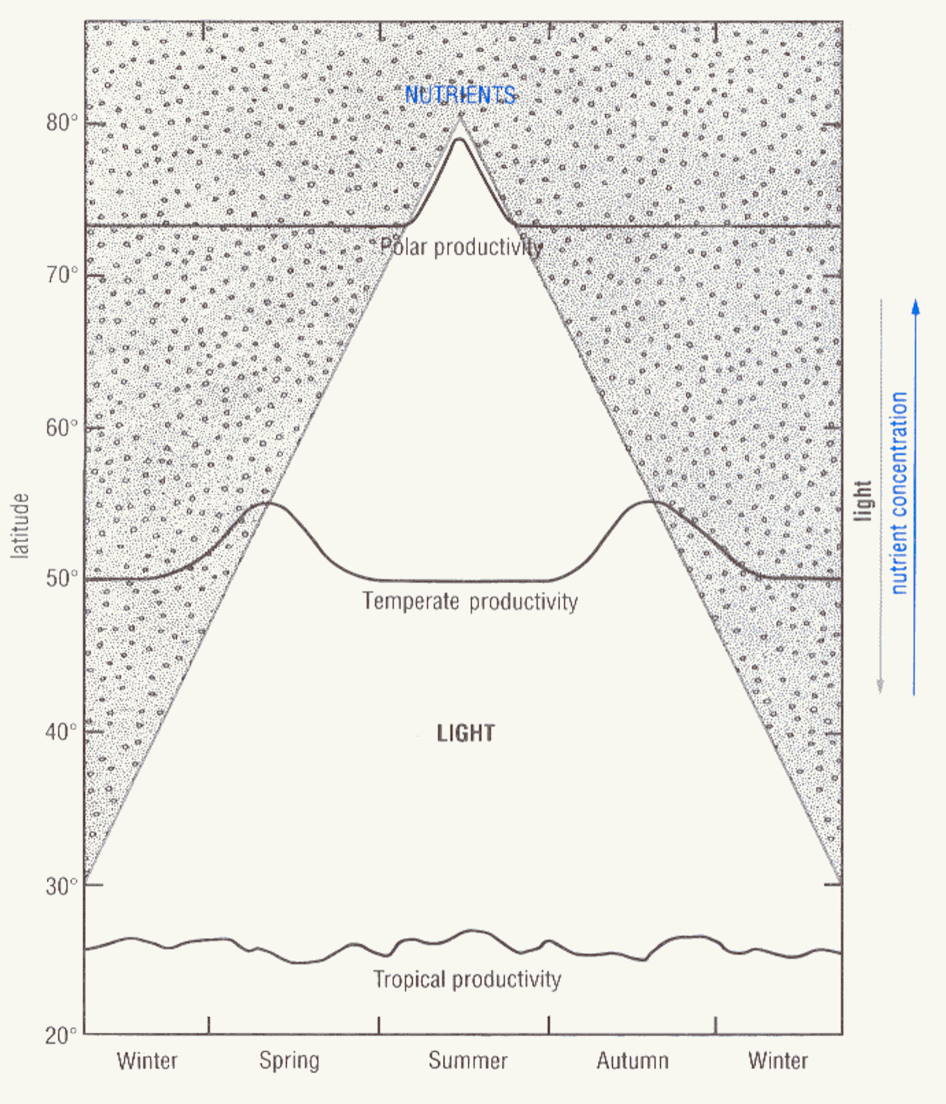
- **Oligotrophic** ocean areas have **low primary productivity.** They are found in tropical ocean areas, away from land. This corresponds to the central regions of the major ocean gyres.
- At these latitudes (about 10°-35°) thermal stratification is fairly strong year-round. (Surface waters are warm year-round).
- This means that there is little vertical mixing of the water, so the supply of nutrients (fixed nitrogen and phosphate) from deep waters to surface waters is small.
- Fixed nitrogen and phosphate concentrations in the photic zone are extremely small.



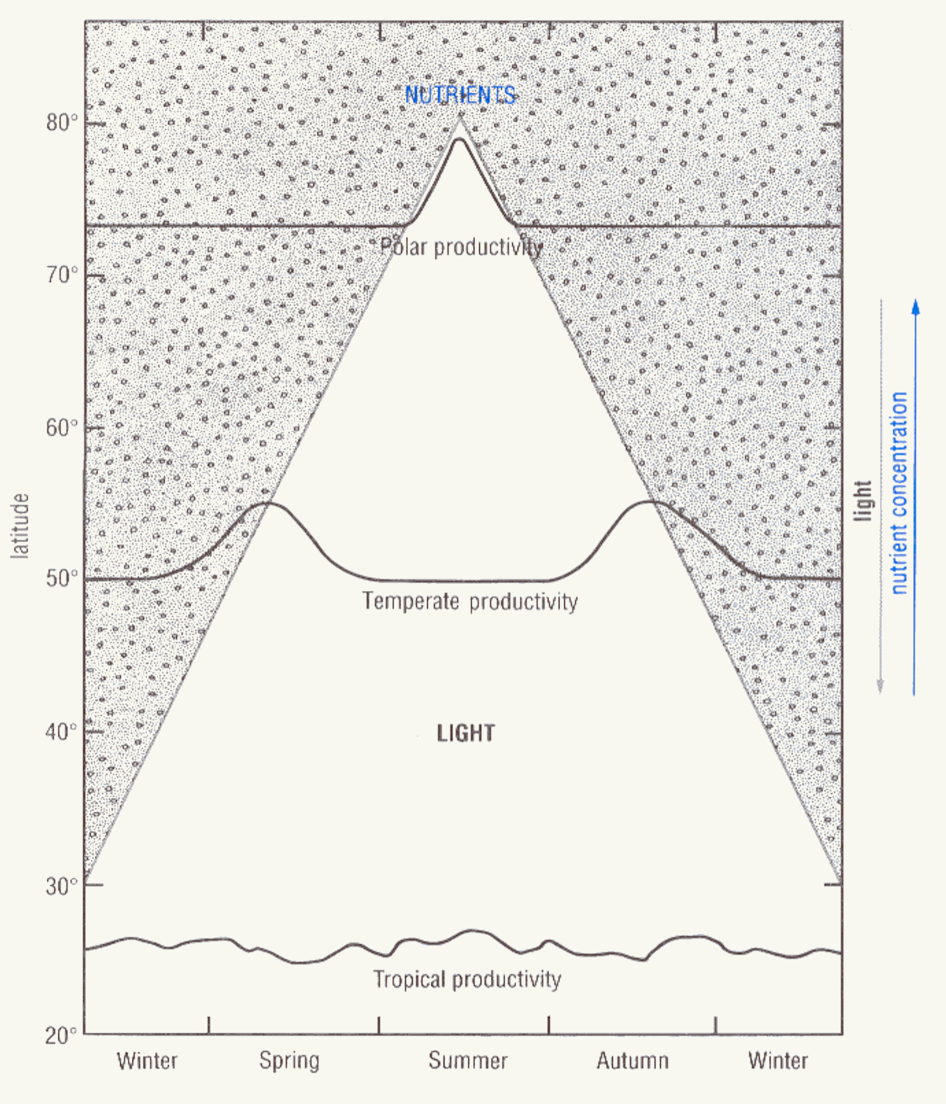
- Since fixed nitrogen is usually depleted before phosphate, fixed nitrogen has been called the **limiting nutrient** for ocean primary productivity.
- However, **nitrogen fixation** by blue green algae can allow primary productivity where fixed nitrogen concentrations are very low.
- **Iron** concentrations are extremely low in seawater, less than 5 nanograms of iron per liter of water (1 nanogram = 0.000000001 g), and seem to limit the productivity of diatoms.



- **Temperate** ocean areas have medium levels of primary productivity.
- **Seasonal cooling** of the surface water leads to absence of stratification in winter.
- Vertical mixing is strong and supplies nutrients to the surface, but, phytoplankton are mixed too deeply to get enough light to grow.
- In spring, surface water warms and the water becomes stratified. Vertical mixing decreases, and phytos get enough light to grow.
- Phytoplankton grow rapidly until the nutrients supplied by winter mixing are used up, a **spring phytoplankton bloom**
- Primary productivity continues at a lower rate through the summer, largely using nutrients recycled from dead or eaten phytoplankton.
- Fall mixing, as surface water cools, can cause another bloom until mixing extends too deeply and light limitation prevents plant growth.



- **Polar oceans** (Arctic and Antarctic) have low to medium productivity.
- The seasonal changes are similar in temperate and polar oceans, but the productive season becomes shorter with increasing latitude.
- Areas of the ocean that have permanent ice cover (mainly the central Arctic) have very low productivity due to lack of light under the ice.



These phytoplankton cycles are tracked by the zooplankton, and directly or indirectly shape the seasonal life cycles of all higher trophic levels

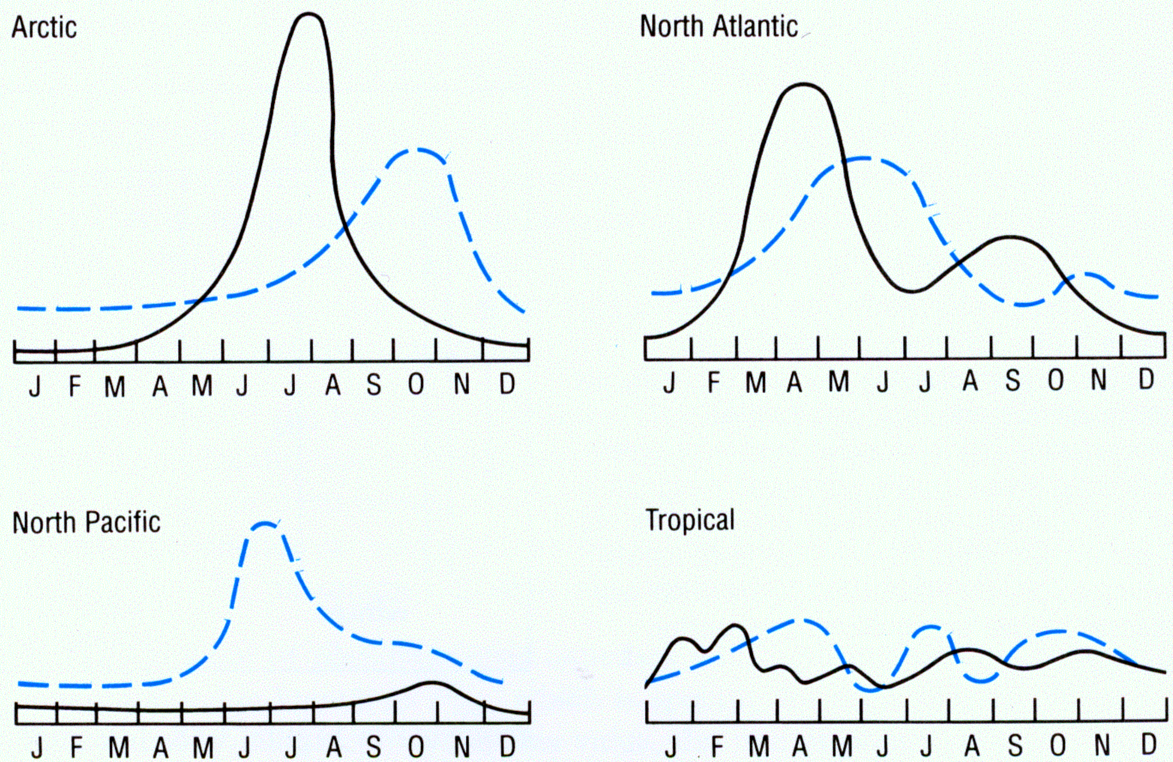


Figure 3.17 Summary of annual cycles in plankton communities in different regions. The solid black lines represent changes in phytoplankton biomass; the dashed blue lines indicate changes in zooplankton biomass (arbitrary units).

An example

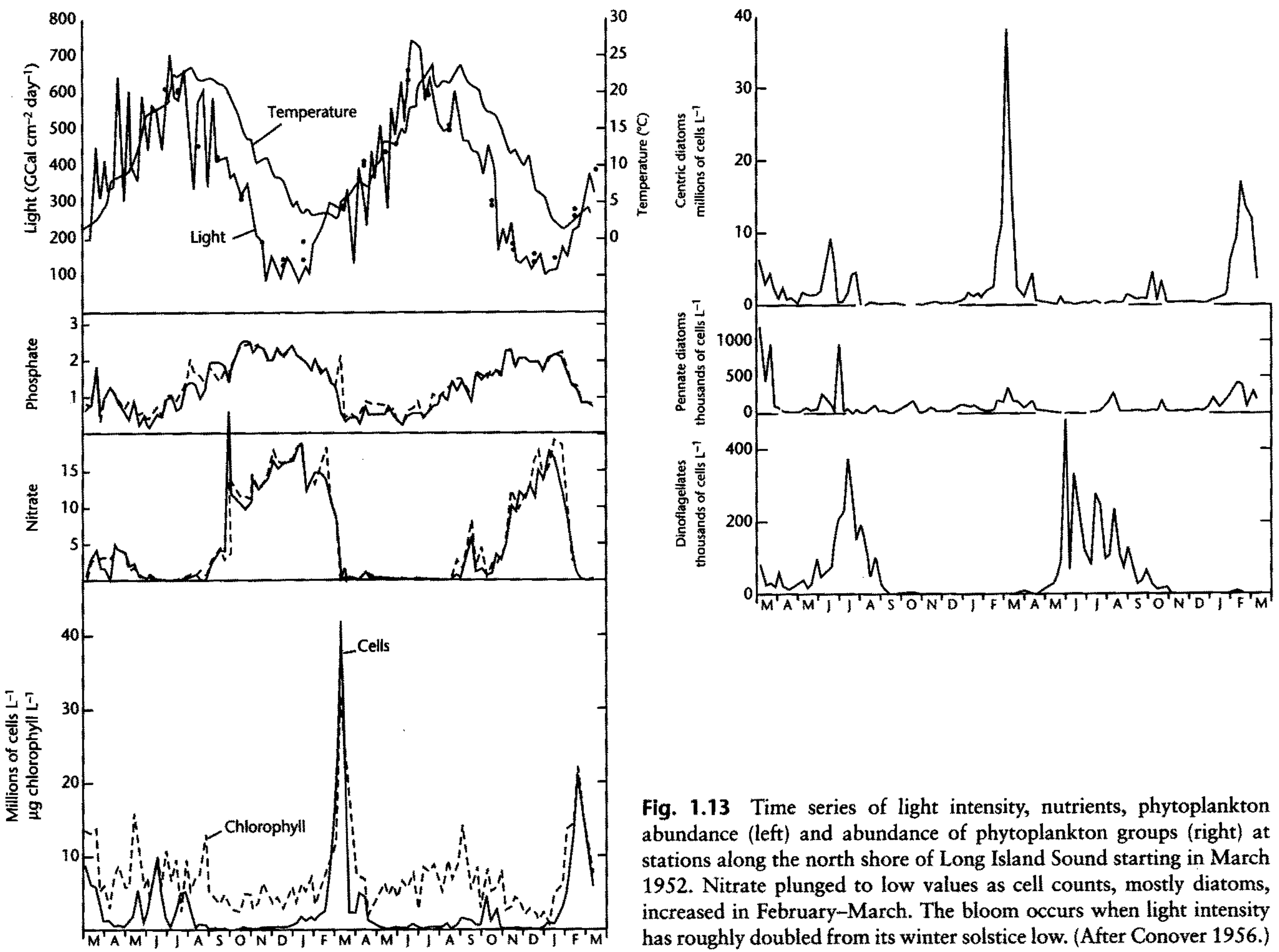


Fig. 1.13 Time series of light intensity, nutrients, phytoplankton abundance (left) and abundance of phytoplankton groups (right) at stations along the north shore of Long Island Sound starting in March 1952. Nitrate plunged to low values as cell counts, mostly diatoms, increased in February–March. The bloom occurs when light intensity has roughly doubled from its winter solstice low. (After Conover 1956.)

A less clear example

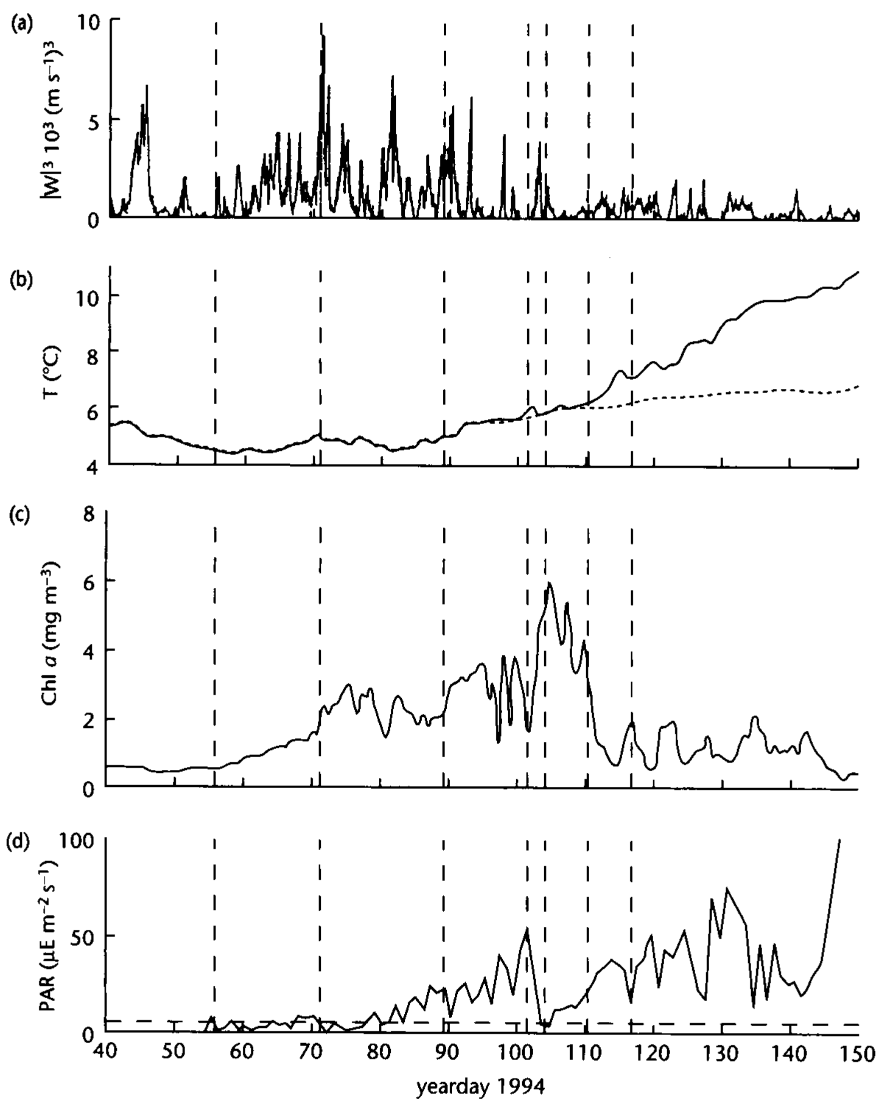
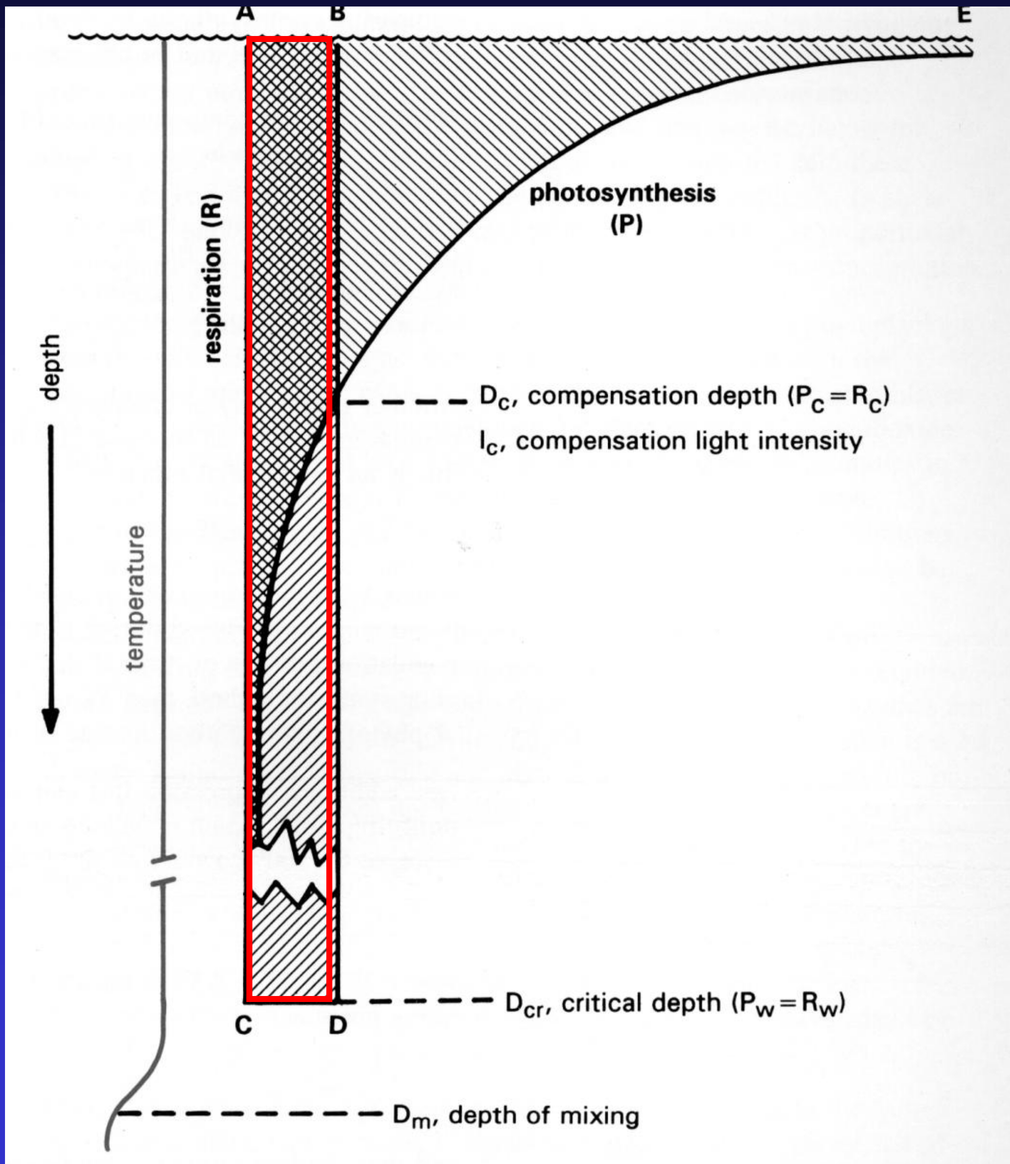


Fig. 1.5 Time series from a shallow mooring site in the North Sea of (a) wind-mixing force, (b) temperature at 11 m (solid) and 43 m (dashed), (c) chlorophyll *a*, and (d) photosynthetically active radiation (PAR) at $Z = 11$ m. Chlorophyll *a* began to increase as soon as PAR exceeded 6.5 $\mu E\ m^{-2} s^{-1}$, an approximation of the physiological compensation ($PS - R \geq 0$) intensity in these waters (Tett 1990), shown by the flat dashed line in (d). Note that chlorophll increased long before water column stratification, indicated by separation of temperature curves for 11 m and 43 m. The bottom at 45 m limits mixing to within the euphotic zone after year day 57. (After van Haren *et al.* 1998.)

Photosynthesis and Light



Critical depth

D_{cr}: depth at which integrated photosynthetic gain equals respiratory loss

Compensation depth

D_c: depth at which photosynthetic gain equals respiratory loss

"…there must be a critical depth such that blooming can occur only if the mixed layer is less than the critical value."

The bloom

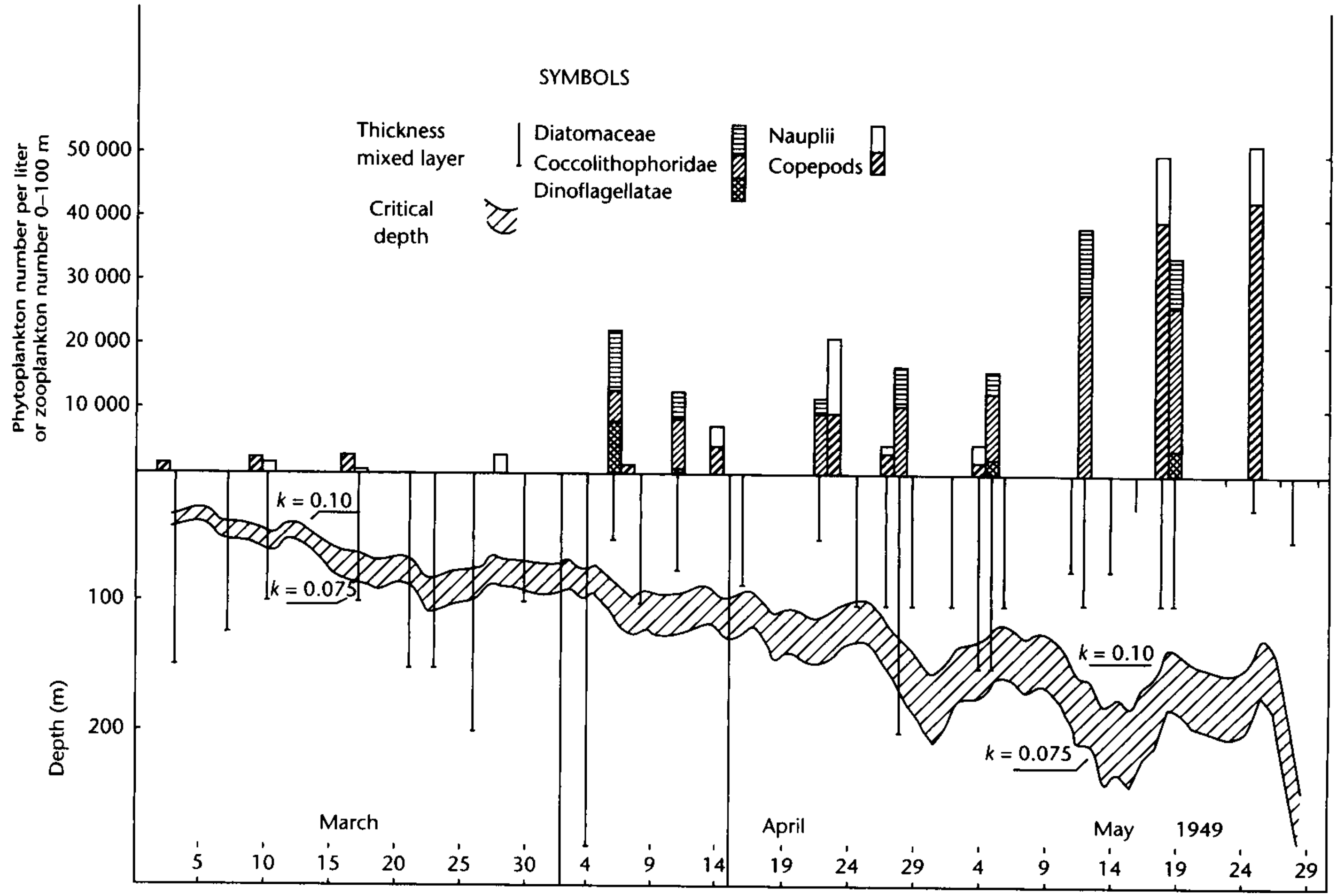


Fig. 1.4 Data for 1949 from Weathership "M" (66°N, 2°E) showing the relationship between the approximate critical depth (shading between approximate *k* values of 0.075 and 0.10) and mixing depth. Phytoplankton counts increased in April–May, when critical depth exceeded the mixing depth. While these data are crude, the observation set has never been duplicated. (After Sverdrup 1953.)

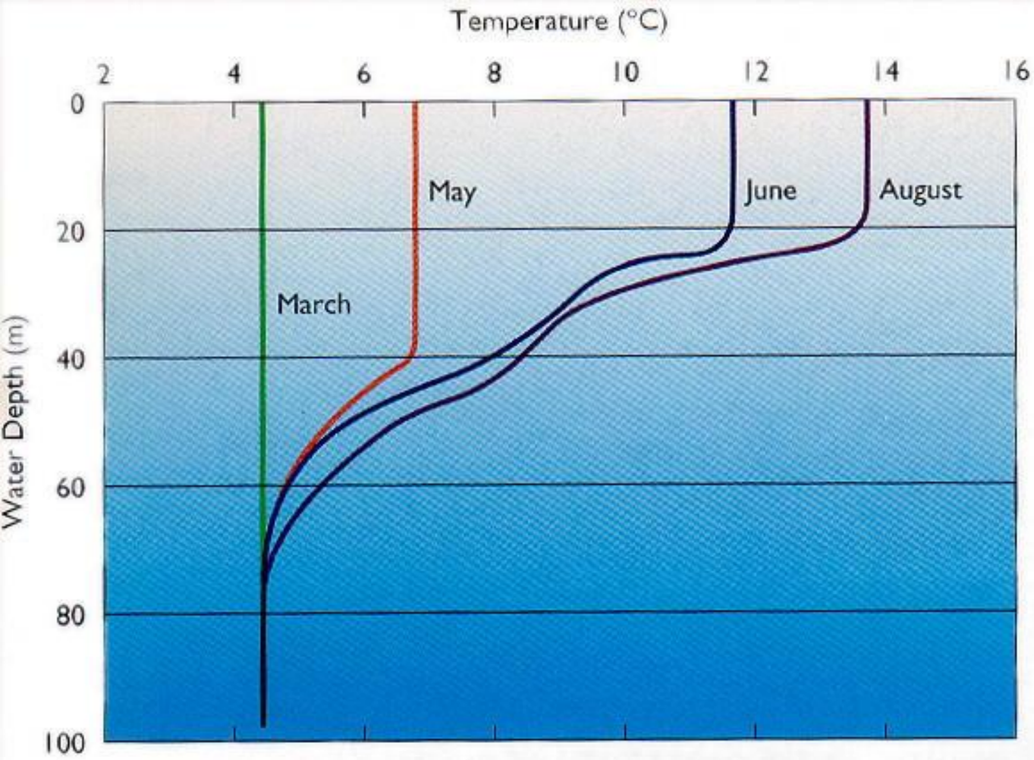
Measuring Phyto Biomass

- Chlorophyll is generally determined from filtering seawater collected in bottles, extracting the pigment in acetone the measuring fluorescence of the extract
- In situ fluorescence can be measured as an index of chlorophyll (and calibrated against extractions) – *why only an index?*
- Carbon is harder to estimate because of detritus in seawater, and carbon to chlorophyll ratios in cells are variable
- The best carbon estimates come from scaling up cell counts and either measuring cell sizes or assuming constant species specific carbon content per cell (i.e. labor intensive)

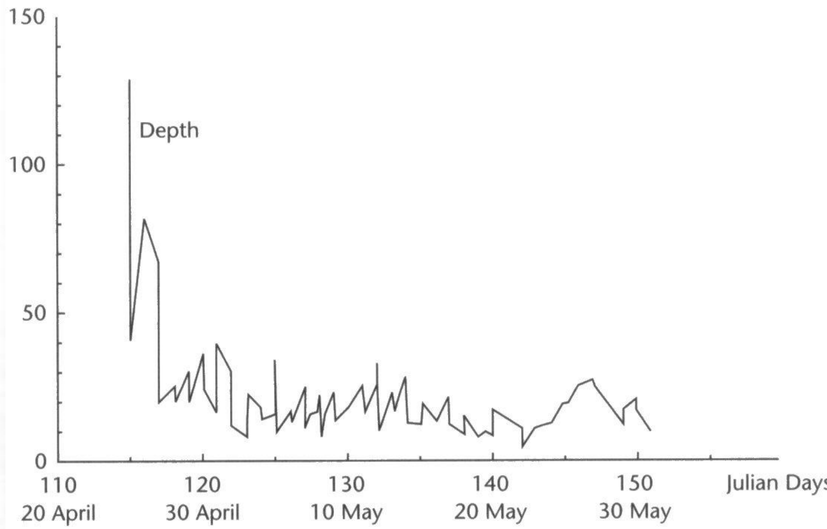
Variations in Critical Depth

- Critical depth varies as a function of latitude, season, and cloud cover- any parameter that influences the amount of sunlight onto the sea surface.
- Increased solar radiation, increases depth of penetration and heat gain of the sea surface, increasing stratification.
- Stratification leads to a decrease in the depth of vertical mixing by wind.
- Wind-induced turbulence creates mixing which may break down the stratification, mixing deeper waters into surface waters.

Mixed layer



(a) GROWTH OF SEASONAL THERMOCLINE



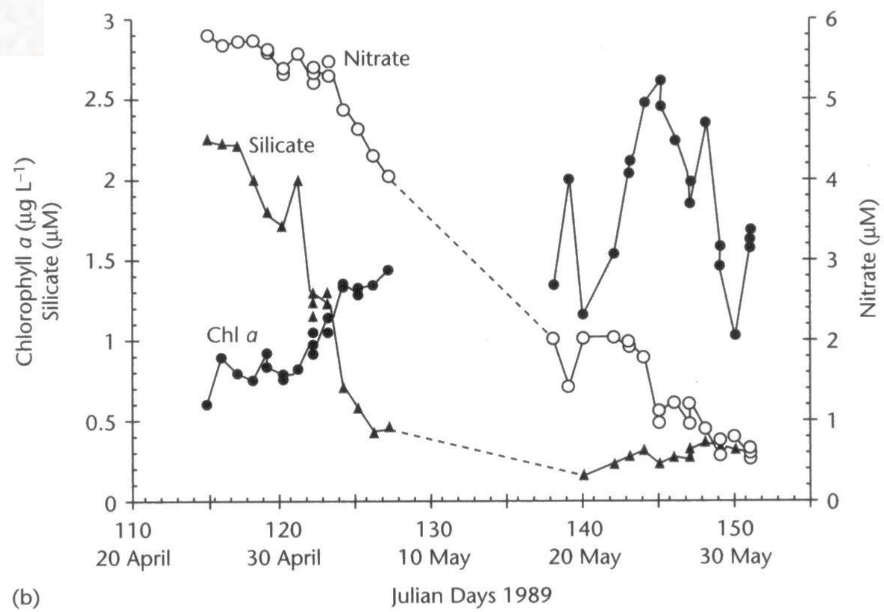


Fig. 1.6 (a) Time series of mixed layer depth at 47°N, 20°W, April–May 1989. Observations began just before sharp shoaling of the seasonal thermocline. (After Lochte *et al.* 1993.) (b) Time series of chlorophyll, nitrate, and silicate at 46°N, 18°W in April–May 1989. (After Sieracki *et al.* 1993.)

BUT….

- Phytoplankton is not a homogenous assemblage:
- During periods of low turbulence and stratification heavy phytoplankton cells will sink out of the photic zone.
- Sinking out of the photic zone is usually fatal to organisms that rely on photosynthesis.
- So it is advantageous to maintain buoyancy.

Seasonal cycles

- The interplay of:
  - the success/failure of buoyancy mechanisms
  - Declining nutrient concentrations
  - Species-specific nutrient uptake kinetics
  - Predation

All contribute to driving the collapse of the large-cell dominated spring bloom and the seasonal succession of the phytoplankton community to a summer one dominated by small cells

Several interesting pattern arise because of these interactions