CHAPTER 08

REGIONAL AND SEASONAL VARIATIONS IN PHYTOPLANKTON

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The phytoplankton are the main energy source for marine ecosystems. They are the main producers of oxygen and form the basis of marine food web. The distribution of phytoplankton is not unique all over the world. Some regions are more productive while others are not. The map (Figure 1) shows the phytoplankton production on a global scale.

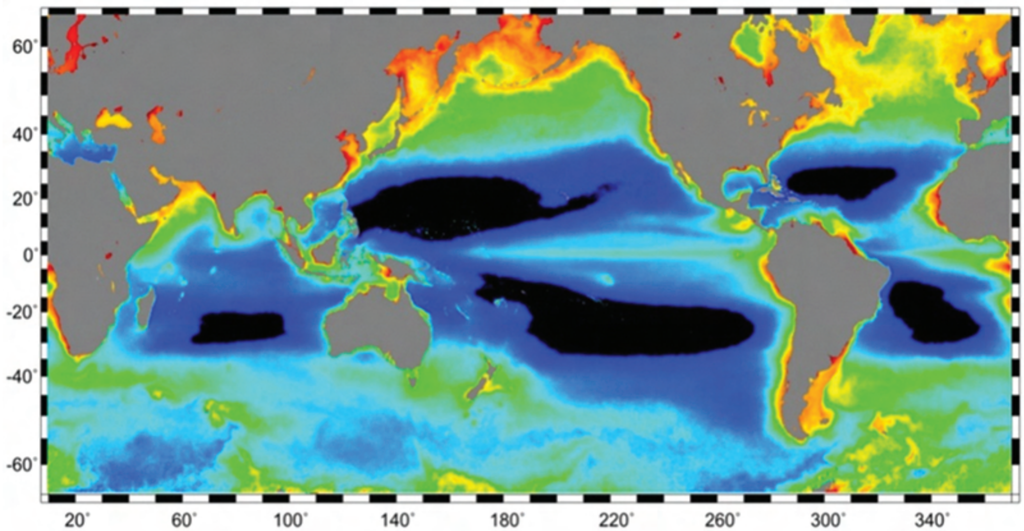

Fig. 1. Map showing the phytoplankton productivity in the Oceans, Red and yellow are most productive, followed by green and blue. Black is least productive.

Vertical variation in phytoplankton production

Vertical variation in production is also observed in oceans. The deep layers of ocean are light limited and hence photosynthesis, a process associated with sunlight cannot proceed leading low phytoplankton production. Another requirement for photosynthesis are sufficient concentration of nutrients (nitrates, phosphates, silicates, iron, *etc.*). In stratified waters, growth of phytoplankton is "nutrient limited". The nutrients in the upper mixed layer are consumed by phytoplankton. The growth of phytoplankton occurs in the layer where both light and nutrient concentration are sufficient. The depth at which maximum phytoplankton growth occurs is known as deep chlorophyll maxima (Figure 2).

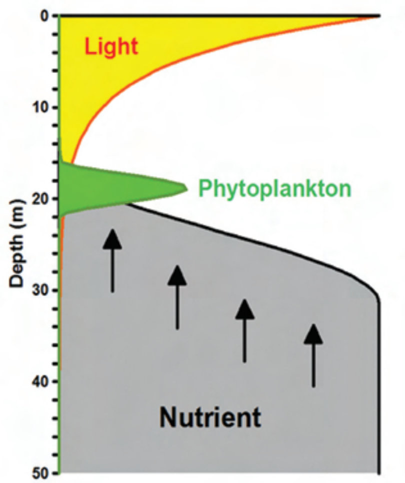

Fig. 2. Vertical variation of phytoplankton production in stratified waters

During upwelling, the bottom nutrients are brought to the surface and hence the conditions of phytoplankton become better and the maximum of its vertical distribution moves to more shallow layer.

When intensive nutrient flux occurs, phytoplankton biomass proliferates and the maximum of vertical distribution of phytoplankton is located at the surface. This results in a direct correlation between total phytoplankton (or chlorophyll) concentration in water column (or within the euphotic layer) and in the thin surface layer (Figure 3). Hence, both the surface chlorophyll concentration and the chlorophyll concentration above the penetration depth can be used as a measure of water productivity, *i.e.*, phytoplankton biomass. Vertical distribution of ecosystem characteristics at a typical station in the oligotrophic waters shows deep phytoplankton maximum and nutricline. Deeper from the surface less light is reflected or scattered by phytoplankton cells and contributes to the colour of ocean surface.

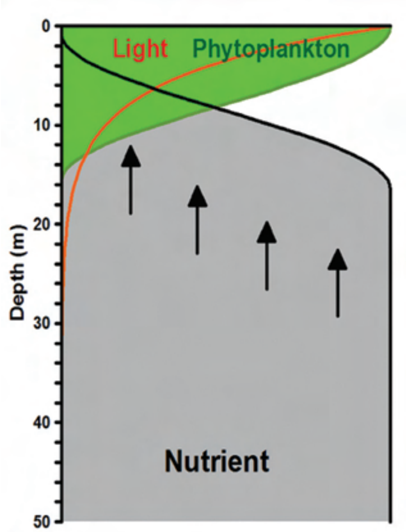

Fig. 3. Vertical variation of phytoplankton production in well mixed waters

Regional distribution of Phytoplankton

The distribution of phytoplankton varies spatially and temporally. Nearshore waters are rich in phytoplankton. River runoff and upwelling are considered as the events for higher production in coastal waters. In tropical regions, the production is comparatively low because of the limited availability of trapped nutrients below the thermocline. In polar regions, insufficient light acts as the limiting source for phytoplankton production. Highest production occurs in the temperate regions. Sufficient light and nutrients acts as the driving forces for increased production in these areas. The production pattern follows a two peak cycle in the regions. Spring peak is attributed with increased sunlight while fall peak is associated with increased mixing of nutrients.

Satellites equipped with colour scanners measure the concentration of chlorophyll in the ocean. Chlorophyll is an indicator of plankton and can be used to study plankton populations.

Seasonal cycles of phytoplankton biomass

One of the main goals of remote-sensing observations is the study of seasonal cycles of phytoplankton biomass in different regions of the World Ocean. In many regions these cycles repeat every year including minor details. This pattern is a result of seasonal oscillations of physical environment. In high latitudes these oscillations are more pronounced, and the response of phytoplankton is more evident.

Typical pattern of seasonal variations of phytoplankton in temperate latitudes is known since the beginning of 20th century. The main feature is a short-period (1-2 weeks) "vernal bloom" called in parallel with seasonal cycle of terrestrial plants. The cycle contains the period of exponential growth and then abrupt decrease resulting from grazing of phytoplankton by zooplankton (Figure 4). The hydrological conditions of start of the spring bloom of phytoplankton were described and explained by Harold Sverdrup in 1953. He attributed the beginning of spring bloom to the formation of seasonal thermocline, when the upper mixed layer is separated from deeper water column and phytoplankton is retained in illuminated (euphotic) layer. The strengthening of seasonal thermocline in summer results in nutrient limitation of phytoplankton growth. Stratification within the euphotic layer is a primary factor controlling phytoplankton growth. We consider two main factors limiting phytoplankton growth: illumination and nutrients. Light limitation is crucial under low stratification (eg., winter convection), because algal cells are dispersed by turbulent mixing within deep dark layers.

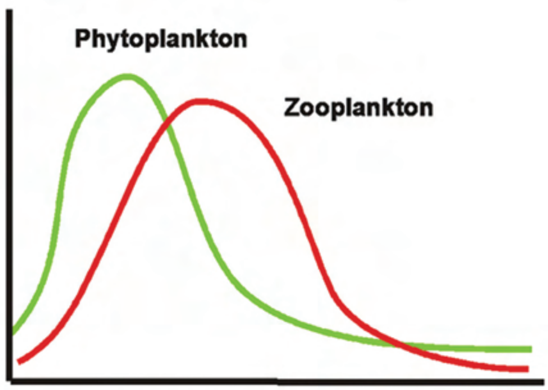

Fig. 4. Typical pattern of seasonal variations of Phytoplankton in temperate waters

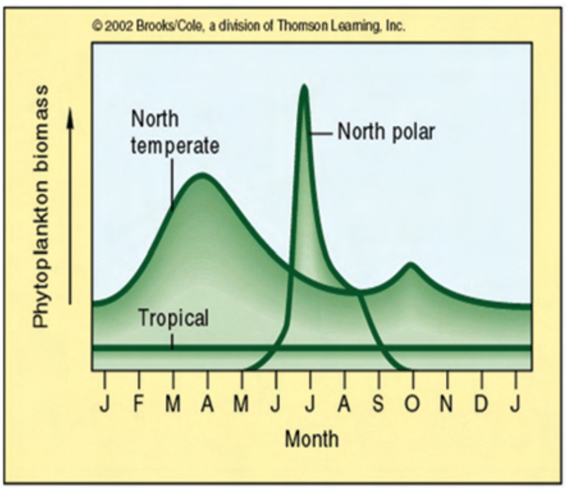

Fig. 5. Seasonal distribution of Phytoplankton in tropical, temperate and polar regions.

Nutrient limitation is crucial under enhanced stratification (eg., seasonal thermocline in summer), because nutrients do not penetrate into the euphotic (*i.e.*, well illuminated) upper mixed layer. The hydro-meteorological factors (heat flux, wind, freshwater load with precipitation and river discharge) either increase or decrease the stratification within the euphotic layer. Typical seasonal cycles of phytoplankton result from the combined effect of seasonal cycles of hydro-meteorological factors influencing water stratification within the euphotic layer. The most illustrative is the phytoplankton seasonal cycle in mid-latitudes with two maxima in spring and autumn:

In high latitudes (cold and windy) winter minimum is more pronounced and summer minimum is less pronounced. In low latitudes (warm and less windy) winter minimum is less pronounced or absent and summer minimum is more pronounced (Figure 5). Deviations from typical seasonal pattern of hydro-meteorological factors result in local peculiarities of phytoplankton cycle. Typical seasonal cycles of phytoplankton described by Alan Longharst are given below Table 1.

Table 1. Typical seasonal cycles of phytoplankton in high latitudes

Season	Hydro-meteorological factors	Stratification	Phytoplankton growth
Winter	Maximum wind mixing; Maximum cooling of upper layer	Deep convection	Winter minimum resulting from light limitation
Spring	Wind mixing weakens; Heating of upper layer increases	Formation of seasonal thermocline	Spring bloom
Summer	Maximum heating of upper layer; Minimum wind mixing	Maximum stratification	Summer minimum resulting from nutrient limitation
Fall	Cooling of upper layer increases; Wind mixing increases	Erosion of seasonal thermocline	Autumn bloom

The winter will be dark and summer with sunlight. Phytoplankton (diatoms) bloom occurs at this period and Zooplankton (mainly small crustaceans) productivity follows. Example: Arctic Ocean's Barents Sea.

Regional variation in phytoplankton size

In upwelling regions, rich in macronutrients, larger phytoplankton dominate and recycling of nutrient is inefficient (Dugdale and Goering, 1967). In weakly productive Subtropical Gyres, where macronutrients are at low levels, small picoplankton have been recorded to account for most of the primary productivity. picophytoplankton, owing to their high surface-area-to-volume ratio, can absorb nutrients with high efficiency under nutrient-limited conditions, and therefore dominate oligotrophic waters. They sink more slowly than larger cells. Microphytoplankton, represented chiefly by diatoms and dinoflagellates, dominate nutrient-rich waters and are the principal agents of the export of carbon to deeper waters. The contribution of smaller (eg., <2 μm) phytoplankton to total phytoplankton biomass decreases in the colder, high-latitude waters and as temperature rises a shift to smaller species within a diatom community was reported.

References

Dugdale, R. C., Goering, J. J., 1967. Uptake of new and regenerated forms of nitrogen in primary productivity. Limnology and Oceanography 12, 677 – 680.

Sverdrup H.U., 1953. On conditions for the vernal blooming of phytoplankton. Journal du Conseil International pour l'Exploration du Mer, 18, pp. 287-295.