Lecture 4

Environmental Factors influencing phytoplankton growth

Phytoplankton are greatly influenced by various environmental factors structuring the water column they live in such as light, temperature, salinity and nutrients. These factors can be used as indicators of environmental change and driving temporal and spatial changes in the phytoplankton community.

1- Light

Light is the most critical factor affecting the photosynthesis and growth of phytoplankton especially an organism with tendency to sink. The irradiance of solar radiation in the water column is affected by many atmospheric factors and components in the water,which govern the transmission and the wavelength distribution.

In aquatic habitats four aspects must be considered as follows:-

a) The light intensity of the incident light,
b) The immediate changes in the light on passing from air into water,
c) The chloroplasts and their pigments, means, by which phytoplankton cells utilize radiant energy,
d) The extent to which with increasing depth this light both penetrates and undergoes further alteration.

a) The light intensity of the incident light,

Illumination in all habitats (including aquatic habitats) will depend on the sun's position with latitude (locality) and season, the cloud cover and time of day, Fig. (1). Light intensity approaches its maximal value in the bright summer days, being reduced to half maximal value in the cloudy days, further reduced to 1/5 of the maximal value in the clear winter days and approaches its minimal value (1/10 of the maximum value) in the cloudy winter days, Table (1). Hence there will be variations in light intensity over the course of a day, in addition to the wavelength composition will change through the day with movement of the sun.

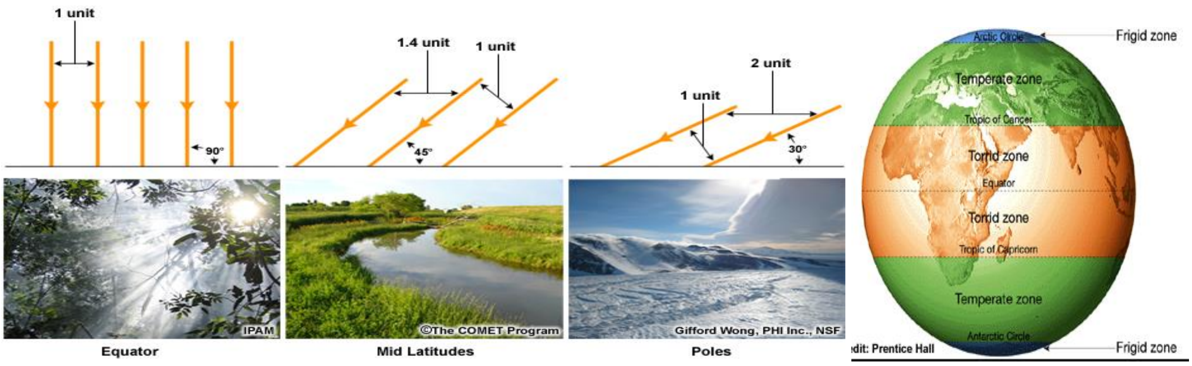


Fig. (1): Variations of the light intensity with latitude, season and the cloud cover.

Table (1): Variations of the light intensity with latitude, season and the cloud cover.

<table>
<tr><th colspan="2">Latitude
season and the cloud cover</th><th>Temperate region</th><th>Tropic region</th><th>North temperate region</th><th>Cold regions</th></tr>
<tr><td rowspan="2">Bright summer</td><td>Days with clear sky</td><td>The light intensity approaches its maximum</td><td rowspan="4">-A daily illumination similar temperate region
-lasts through the year except in the rainy season</td><td rowspan="2">The daily illumination approaches maximum intensity in May and June</td><td rowspan="4">* Ice will allow light penetration into the underlying water.
* Snow cover reduces this</td></tr>
<tr><td>Days with cloudy sky</td><td>The light intensity reduced to half the maximum value.</td></tr>
<tr><td rowspan="2">Winter</td><td>Clear sky</td><td>The light intensity reduced to 1/5 the maximum value.</td><td rowspan="2">Falling to approximately one-ninth of the summer level during December and January</td></tr>
<tr><td>with clouds</td><td>The light intensity reduced to 1/10 the maximum value.</td></tr>
</table>

b) The immediate changes in the light on passing from air into water

The penetration of light into the water is affected by the presence and the concentration of <u>dissolved organic and inorganic matters</u> (DOM&DIM) as well as <u>particulate organic and inorganic matters</u> (POM & PIM). A gradual attenuation or decrease in light intensity with depth is due to:- 1) Absorption by the water and suspended particulate matter. 2) Reflection by the plankton and other suspended matter. 3)Refraction of light by the water molecules. 4) Scattering of light by particulate matter.

Red light is **absorbed** mainly by the water molecules. The blue color of clear oceanic water is due to the upward **scattering** of blue light. Whilst **coastal waters** appear green, because the greater quantity of suspended particulate matter (including dissolved humic acids) tends to **reflect** the light of longer wavelengths and absorb the blue light.

C)The chloroplasts and the pigments

i) Cell surface – area to volume ratio

The cell surface is the means of the entry for nutrients, light and dissolved gasses and of exit for excretory products and extracellular substances. A large surface–area to volume ratio is an essential feature of the light absorption which allows the intensive rates of metabolism including photosynthesis and rapid multiplication of phytoplankton cells shown in the seasonal population explosions which occur in seas and lakes.

ii) The chloroplasts

Of phytoplankton organisms, only blue green algae (BGA) lack discrete cell organelles of chloroplast nature. Chloroplasts are organelle systems which lie close to the cell membrane to be directly exposed to light. By which, the light energy and carbon are obtained in phytoplankton cell. They trap and utilize light energy to convert CO_2 to carbohydrate.

They show great diversity in size, shape, number and colour to obtain sufficient light for an optimal photosynthesis. There are one or two large chloroplasts per in many phytoplankton cell, but in some (e.g. certain diatoms) numerous small discoid chloroplasts are present. There are many variable shapes and parietal arrangements of phytoplankton chloroplasts. These adaptations of the chloroplasts to ensure maximum light absorption and carbohydrate synthesis in relation to the volume of the cell.

The efficiency of the chloroplast as a photosynthetic structure is directly related to the surface area exposed to the incident light, and can be estimated by its output of carbonaceous compounds.

ii) Chloroplast pigments

With the exception of BGA, the colors of other phytoplankton organisms are mainly due to the pigments in their chloroplasts (chlorophyll a, b, c and auxiliary pigments). Chlorophyll a is the most common to all phytoplankton cells and the primary pigment involved in photosynthesis. It is the one pathway by which the absorbed radiation is converted to chemical energy. However, species can adapt to different light climates by increasing the chlorophyll *a* concentration in their cells or using other pigments.

Chlorophylls labeled b and c are found in phytoplankton. Chlorophyll b present only in algae with green chloroplasts. Chlorophyll c has been identified in a number of brown – colored organisms. Chlorophylls b & c differ from Chlorophyll a both in molecular structure and in their absorption spectra in organic solvents. Phytoplankton may be placed in one of two major colour groups, those green-and those brown – coloured according to the other pigments (auxiliary pigments).

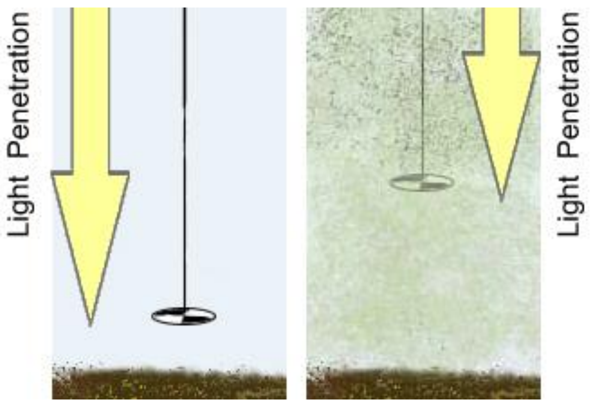
Auxiliary pigments are secondary pigments, such as the carotenes and xanthophylls which function on an auxiliary way by absorbing radiant energy from certain wavelength and transferring this to chlorophyll a. Their relative predominance gives the brown and yellow-brown colours to algae. These pigments appear to be characteristics of particular classes.

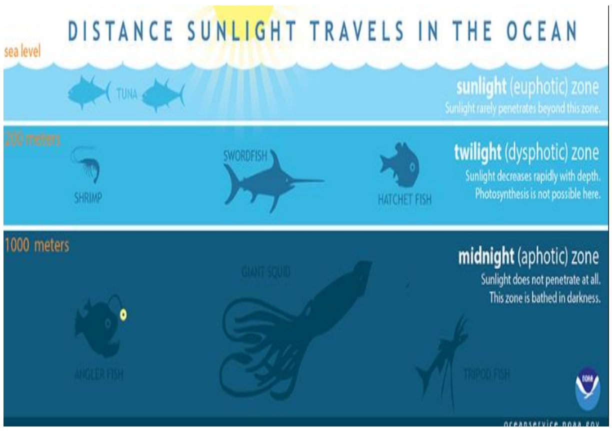
d)The extent to which with increasing depth this light both penetrates and undergoes further alteration.

i) Distance light penetrate

-In both the sea and freshwater lakes, there are three vertical zones regard to available light; the euphotic (or photic), the dysphotic and the aphotic zones. The euphotic zone has enough light for photosynthesis but the dysphotic zone is too dim, the aphotic zone is dark and devoid of photosynthesizing plants. The depth of the euphotic zone will be variable with <u>time of day and location</u>. Hence any prolonged stay of phytoplankton cells in the aphotic or dysphotic zones may well prove harmful.

Light intensities in water are too low or too high, for example, at depth or near the surface, respectively, can limit phytoplankton growth.





ii) <u>Water turbidity and transparency</u>

Freshwater input from rivers can transport both coloured dissolved organic material (CDOM) and suspended particulate material (SPM) to the coast, reducing both water transparency and phytoplankton growth. In addition, re-suspension of sediments from the sea floor may reduce available light. Hence where there is appreciable turbidity in the sea or lake waters, the deep underwater illumination will be predominantly of green light.

Actual measurements of underwater radiant energy requires complex apparatus. A rapid assessment of water transparency can be obtained with Secchi disc (A white disc 30 cm in diameter, lowered horizontally into the water). The mean depth at which it disappears and reappears on being raised can be taken as a measure of the transparency of the water. It has been estimated that approximately 16 % of the incident light at the surface penetrates to the depth at which the disc disappears in moderately clear water.

iii) Gradient in radiant energy absorption with depth

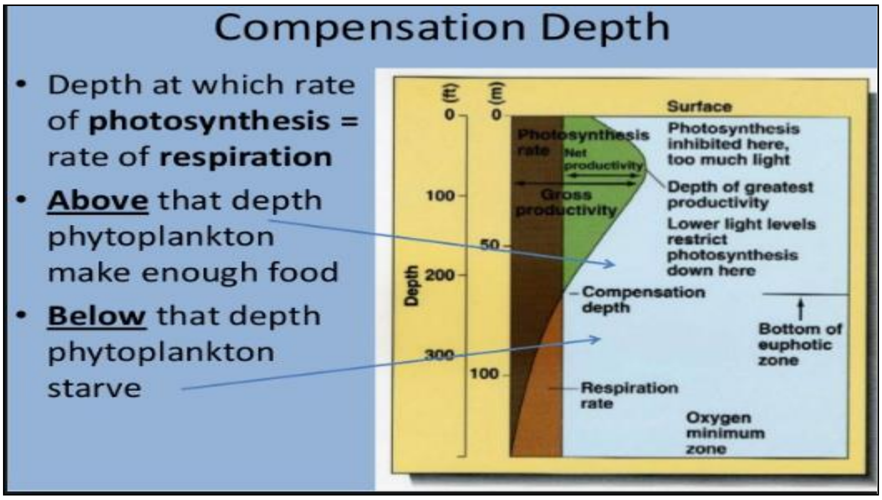
The energy potential of this light will depend on the wavelength penetration. The level at which the light intensity is 1 % of that at the surface approximates to the lower limit of photosynthetic activity, and hence can be regarded as the physiological lower limit of the euphotic zone in both the sea and freshwater lakes. The absorption of radiant energy in passing down a water column is appreciable. In the sea, even in the cleanest ocean samples 62.3 % of the incoming energy has been absorbed at a depth of 1m, and 83.9% at 10 m. In coastal waters with much suspended particulate matter, some 99.5% of the energy has been absorbed at 10 m depth.

vi) Compensation depth

The production of organic matter (OM) will be limited by the breakdown of carbohydrates for respiratory requirements. When the available light just permits the rate of synthesis of organic compounds to balance with the rate of the respiratory breakdown –then the compensation point is reached.

a) Phytoplankton at compensation depth

The compensation depth is a feature of depth at which, the available light just permits the rate of photosynthesis of phytoplankton to balance with the rate of the respiratory breakdown, but doesn't permit to phytoplankton to multiply. In addition to, the production of substance ceases.



b) **Phytoplankton below the compensation depth**

Prolonged sinking of phytoplankton cell below this level will place the cell under stress if the respiratory rate remain unchanged.

c) Phytoplankton at excessive light

In addition to the essential nature of underwater illumination, excessive light can be detrimental. light saturation at high levels of illumination inhibit the photosynthesis of phytoplankton organisms.

d) <u>Compensation depth in temperate seas</u>

For temperate seas, the compensation depth may be conveniently regarded as the level where the available light is 1 % of that at the surface. This may be only 10 m in turbid inshore temperate waters compared with 120 m in clear tropical seas.

	Temperate seas	
Compensation depth	the available light is 1 % of that at the surface	
	10 m in turbid inshore temperate waters	120 m in clear tropical seas

Light and phytoplankton control

The excessive growth of phytoplankton which causes drastic problems in freshwater reservoirs can be controlled by reducing illumination which considered as a possible measure. The problems of excessive algal growth can led to both clog the filter beds and effect the taste of the water. Various methods of artificial shading for control of phytoplankton growth have been (e.g. use of plastic netting, or of aluminized plastic sheeting). Seasonal light intensity is closely associated with temperature although monthly changes in sea and lake temperatures are outpaced by variations in illumination.

Questions

1- Discuss the following:-

- Atmospheric and water factors affect the light availability for phytoplankton.

- Depth of water column affects radiant energy absorption.

- Cell surface – area to volume ratio affects the light interception

-chloroplast and their pigments **affects the light acquisition**

-Although light is the primary factor for phytoplankton, it is used to control phytoplankton

2- Define the following:

-Compensation depth

-Water transparency