Aquatic Biology (ZOU3161)
Session 1
Water

Contents

Introduction

More than 70 percent of the earth surface is covered by water, which is present in 3 major types of aquatic systems, namely; freshwater, estuarine and marine systems.

Freshwater systems occupy a relatively small portion of the earth's surface but it is the most important aquatic system for the life on land. The oceans contain 97.3% of the water in the earth surface and control the world's climates and the atmosphere. Estuaries are transition zones between freshwater and the sea and these habitats are with many unique features.

The **physical, chemical and biological characteristics** of water in each of the above systems vary enormously.

As you know water is a peculiar substance, it is the only liquid commonly found on the surface of the planet, and that is useful to life. Special properties of water create physical and chemical conditions which has made the organisms to exploit freshwaters.

This session gives you a description of these special properties which are mainly based on the structure of the molecule.

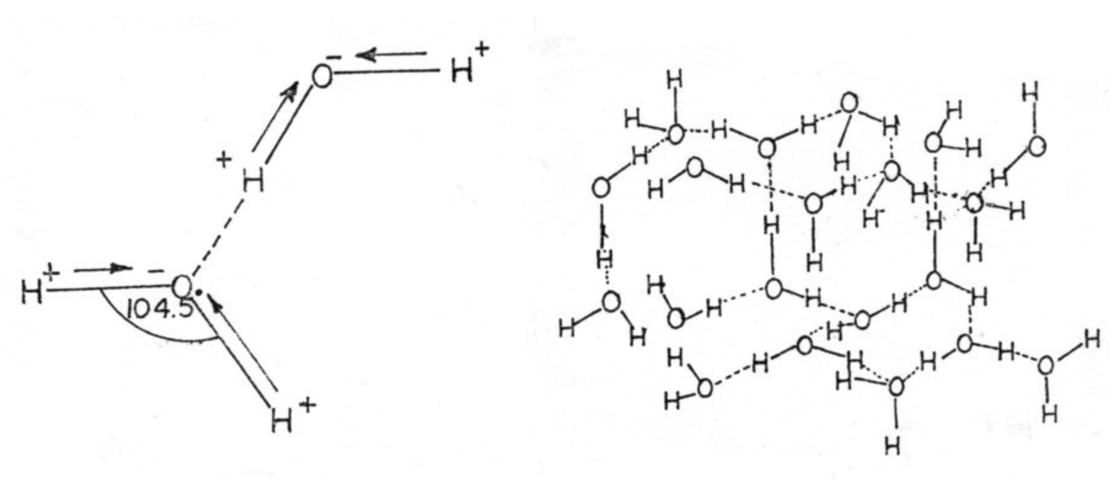
1.1 Structure of the water molecule

Water is a compound of hydrogen and oxygen, and you already know that it is a liquid at the room temperature, a gas at 100 ^{0}C and a solid at 0^{0}C(ice).

Many of the water's unique properties results from its molecular structure of which you have already studied in chemistry. You may remember that it is a “V” shaped molecule and the two hydrogen atoms of it, are arranged at an angle of 104.5^0 (Fig l.la). Oxygen atom in the water shares its outer shell valence electrons with, its

two associated hydrogen atoms. These shared electrons are attracted towards the oxygen atom, because of its electro negativity. This unequal sharing of electrons gives a slight negative charge on the oxygen atom and a slight positive charge on the hydrogen atoms. This unequal charge separation and the asymmetric shape make the water molecule a polar molecule.

This property makes the water molecule arrange in specific configurations with respect to other molecules and also it accounts for some of d physical and chemical characters of it. In a true fluid, individual molecules move freely. This is not true for water, which consist of a continuous network of randomly connected hydrogen bonds that form a liquid crystal. This uninterrupted network of hydrogen bonds runs in all directions throughout the entire volume of a water body (Fig. 1.1 b).



(a) (b)

Fig. 1.1 (a) Shape of the water molecule (b) Network of hydrogen bonds

1.2 Specific properties of water

High specific heat capacity

i. Thermal properties High specific heat of fusion

High specific heat of vaporization

ii. Density relationships

iii. High surface tension

iv. Low viscosity

v. High dissolving ability

Thermal properties

I. High specific heat capacity

This is the amount of heat in calories that is **required to raise the temperature by 1 ^{0}C** of a unit mass of a substance. Because of this high heat capacity, water can absorb large amounts of heat with only small increase in temperature. This character enables aquatic organisms to survive even intense solar radiation at the equator.

It also can have profound effect on the climatic conditions of adjacent air and land masses. (It stabilizes air temperature by absorbing heat from warm air or by storing heat from cool air). E.g. coastal areas generally have milder climates than inland regions as the gradually cooling water can warm the air at night.

II. High specific heat of fusion

This is the **amount of heat gained or lost per unit mass of a substance, changing from solid to liquid or liquid to solid phase** without an accompanying rise or fall in the temperature.

For water at 0^0C to freeze, 79.72 cal/g must be released, and conversely when ice at 0^0C melts to liquid water at 0^0C, an equal amount of heat must be absorbed.

This property helps to maintain the temperature at a critical point before freezing. It prevents the formation of ice in the tissues of organisms when the water body is freezing.

In temperate countries, the freezing of water and melting of ice also help to make the transition between seasons less abrupt, enabling organisms to adjust gradually to changing climate.

III. High specific heat of vaporization

Water has the highest specific latent heat of evaporation. When liquid water changes into vapour or vapour into liquid water at 100^{0}C, it requires large amount of energy.

This reduces the evaporation of water from lakes and sea, and transpiration from plant tissues.

High density

As we all know, ice floats. Water is one of the few substances that are less dense as a solid than it is as a liquid, while other materials contract when they solidify, water expands.

Water has its highest density at 4^{0}C (Fig. 1.2 a). On reaching 4^{0}C water sinks to the bottom and lighter surface water cools further and forms ice crust which act as an insulator, and prevents the total freezing of the water body (Fig. 1.2b).

This character enables the animals in water to survive in ordinary winters.

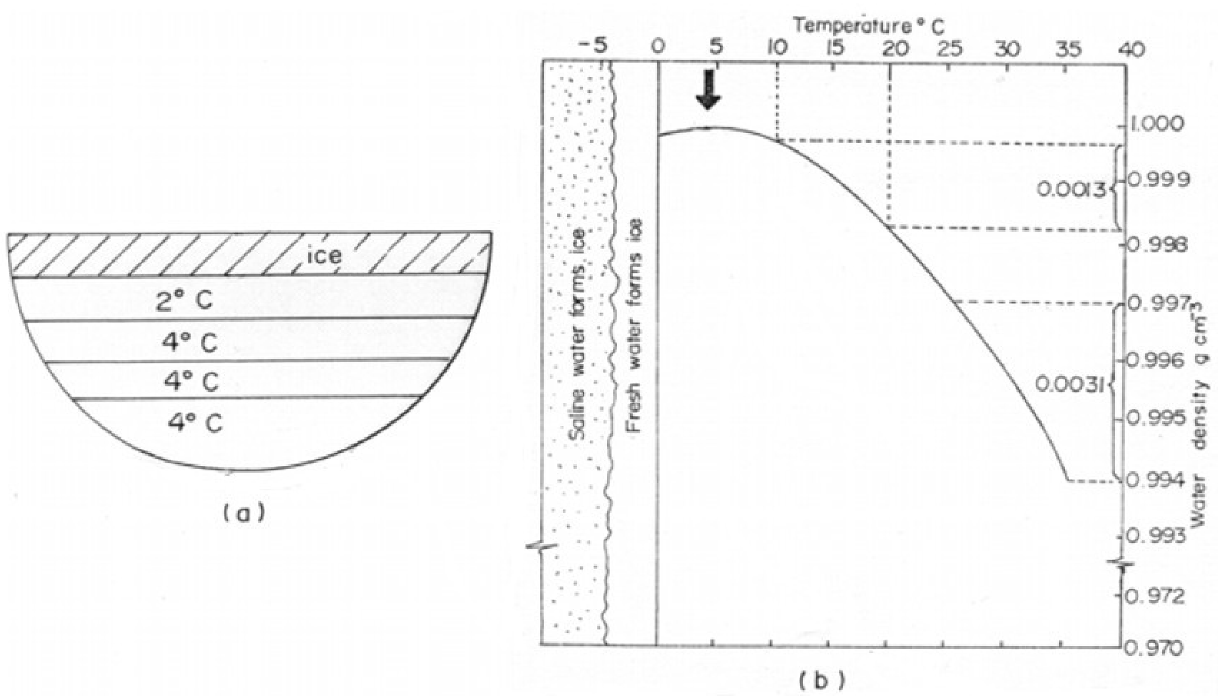


Fig. 1.2a Temperature variation with depth during winter

Fig. 1.2b Changes in freshwater density with temperature

Surface tension

Water molecules have a marked affinity for each other due to the electrochemical properties of individual molecules. At the air/ water boundary they stick together so thoroughly that a high surface tension is set up that will support light weight substances if they are spread out in a larger area. For example a floating leaf with a large surface area, or an insect like water strider that distributes its weight over a larger area (it has long legs that can be spread out over a larger area) can float on water.

Surface tension in water decreases with increasing temperature and increases slightly with dissolved salts.

Low viscosity

Viscosity **is a measure of a liquid's resistance to flow,** produces viscous drag to organisms moving through it and serves to slow the rate of sinking of plankton.

Viscosity is much higher at lower water temperatures.

High dissolving ability

Water's excellence as a solvent owes much to its polarity. Other types of ions in water are kept apart because they polarize water molecules around them. Whether it be the anions or cations, water molecules surround them, keeping them apart. (Since negative part of the water molecule attracts the positive part of the solute molecule while the positive part of the water molecule is attracted to the negative part of the solute molecules). This reduces the forces between the solute molecules and they separate, and become surrounded by the water molecules.

This is why, water is an effective solvent for electrolytes. Even gases such as carbon dioxide and oxygen dissolve in water, helping organisms to photosynthesize and respire.

Water **in the presence of non-polar molecules tend to produce hydrates**. Formation of hydrates is an important process that takes place between water and protein molecules.

1.3 Other properties of water

a. Conduction of heat - The highest of all common liquids except mercury.

b. Capillary action - Hydrogen bonding of water molecules to other kinds of molecules gives rise to capillary action; the rising of water and watery substances in narrow tubes. It is in this way that water creeps up through minute spaces in the soil and becomes available to the roots of the plants.

The ability of water to be pulled up through conducting tissues up to the top of trees as tall as 100 m is also a result of hydrogen bonding among water molecules.

c. Protective functions - Water absorbs harmful infra red radiation from the sun. Large portions of the incoming solar radiation are dissipated in the evaporation of water from the ecosystems of the world. It is this energy, that moderates the climate and makes it pleasant for life to exist on earth.

As a pollution disposal system - Natural water has come to the receiving end of the pollutant disposal systems. Affluents from industrial plants and factories, insecticides from agricultural lands are discharged into water where they become diluted and sometimes even change the chemical composition. Thus water makes them less dangerous to life.

Objectives

After you have studied this session, you should be able to:

- Understand the special properties of water in relation to its molecular structure.

Review Questions

1. Discuss how the specific properties of water affect the living organisms.

2. "One of the most biologically important and chemically interesting compound is water". Explain this statement.

Session 2
Physical characteristics of a water body

Contents

Introduction

From the first session you learnt about the special properties of water and that they create physical and chemical conditions of it. These conditions or characteristics affect the ecology of all aquatic habitats to some extent. However, the dominant influences of their characters vary from habitat to habitat (freshwater, brackish water and marine systems).

Abiotic characteristics of water

Abiotic characteristics include both physical and chemical properties. These are the non-living characters of water.

2.1 Physical properties of fresh water bodies

These include,

1. Light-colour, transparency/turbidity
2. Temperature
3. Water current
4. Substrate

The intensity, colour, direction and distribution of **light** in a water body are major components in the structure of that ecosystem. Light provides the energy for primary producers, signals for migration in plankton and fish and gives a characteristic colour to most of the water bodies.

Temperature affects all life processes, especially the growth rates, and life cycles. The productivity of a water body is strongly under its influence.

The **substratum** of a stagnant water body differs greatly from a running water body. In the latter it may vary from place to place and it is very important to many organisms, especially the bottom-dwelling forms.

The following section will describe the main features of light, temperature, current and substratum in different water bodies as it is essential to understand these variables if you want to know the functioning of any aquatic ecosystem.

I. Light

Light from the sun is a mixture of many different wavelengths; ranging from very short ultraviolet to very long infrared (Fig 2.1). When this light penetrates through the water it is scattered, as well as absorbed or refracted by particles and some molecules.

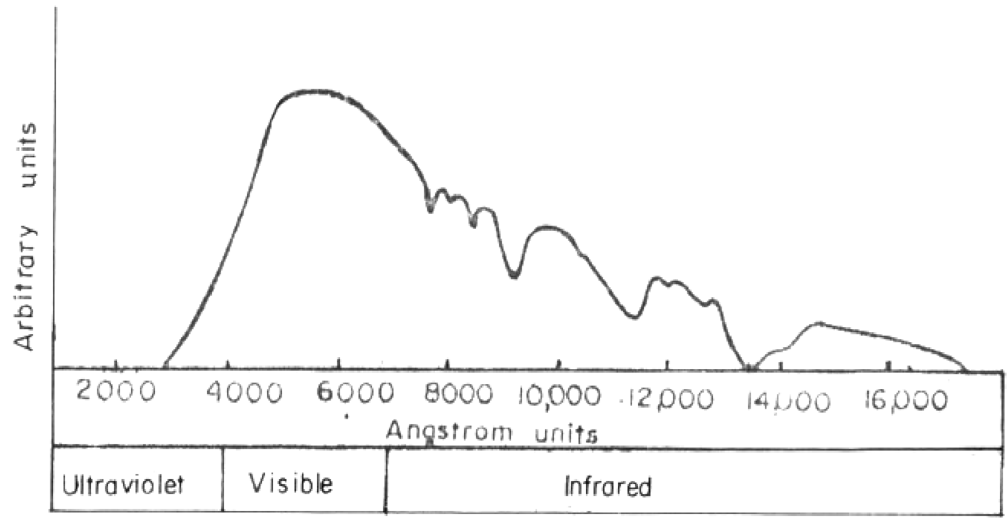


Fig. 2.1 Distribution of solar energy at the earth's surface

An unpolluted sky or a transparent lake appears blue because molecules in the air or pure water scatter blue light more than other colours.

Transmitted light passes through the water column. As the light penetrates 53% of it is absorbed and converted to heat, and the temperature of the water body rises. The rest of the light is available for photosynthesis and used by algae. Absorption differs slightly between cloudy and clear water because the scattering effect of turbidity permits greater penetration of long wavelengths.

i. Colour

Lake **colour** is composed of reflected light from two sources, **true and apparent colour**. **True colour** is the colour of water and its contents such as dissolved substances. **Apparent colour** is the colour as seen by the observer on the lakeshore.

These factors are important for primary productivity as well as for movement of organisms in water.

The shortest wavelengths are scattered the most. Blue colour is thus the dominant colour scattered back to the surface in transparent lakes. A clear water body where there is no suspended matter, will appear blue in colour as the water molecules scatter blue light back to the observer's eye.

In less transparent lakes, dissolved and particulate matter normally obscure back scattering of blue light. (Absorption of the scattered light due to suspended particles including living phytoplankton as well as coloured and dissolved substances). These lakes will appear green in colour. If there is a large quantity of dissolved material, especially organic matter the lake appears yellow or brown.

Light intensity, decrease exponentially with depth. This loss of light is expressed mathematically by the **extinction coefficient** $\text{å}_{\text{ë}}$ (epsilon -lambda) of the solutes, the fraction of light absorbed per meter of water. The higher the value of the $\text{å}_{\text{ë}}$ the lower the transmission of light or less transparent is the water.

For parallel beam of single wavelength (**monochromatic**) light, the intensity, I at water depth, Z when the sun is directly overhead is given by the formula,

$$I_Z = I_0 e^{-\text{å}_{\text{ë}} Z}$$

Where,

I_0 = Light intensity penetrating the surface

Z = Path length

$\text{å}_{\text{ë}}$ = Extinction coefficient for the wavelength in question

ii. Transparency / visibility

Transparency is a measure of the depth to which one may see in to the water. Obviously this is variable with the day condition and the eyesight of the observer. The **Secchi disk** is the sampling devise used to estimate this depth (Fig 2.2). To determine the secchi disk visibility, the following steps have to be followed. Slowly lower the disk into the water until it disappears, and note this depth. Lower the disk a little further, then slowly raise it until it reappears, and note this depth. The average of these two readings is taken for the final secchi disk visibility depth.

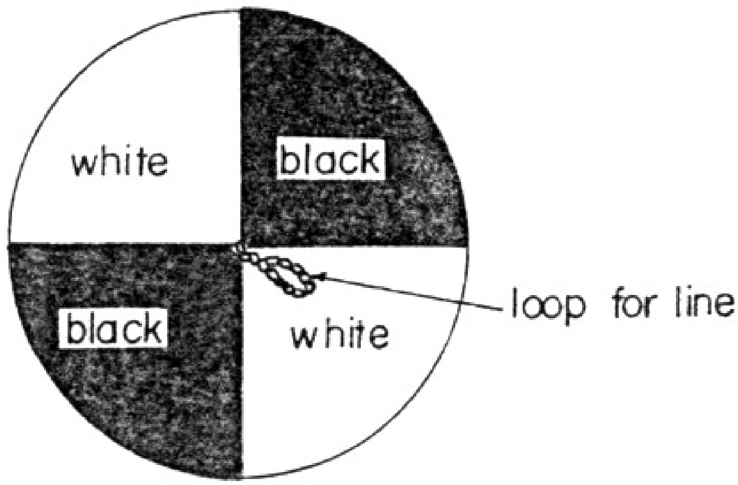
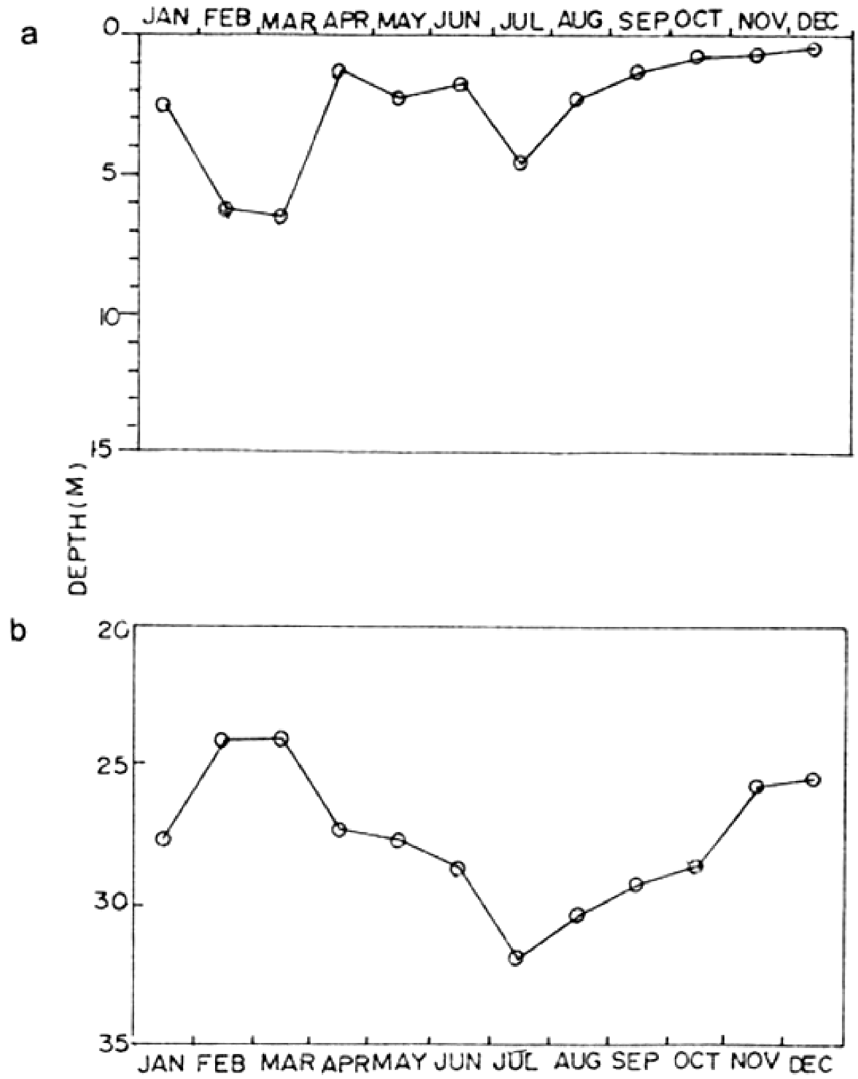


Fig. 2.2 Secchi disk for comparative studies of visibility in water

The secchi disk visibility is useful as a mean of comparing the visibility of different waters (Fig. 2.3) especially when measured by the same observer. However, clearness of the day, position of the sun, roughness of the water and the observer should be significantly considered when taking secchi disk measurements



Fig, 2.3: Seasonal variations in secchi depth in two contrasting lakes (a = moderately eutrophic, b = oligotrophic)

It was mentioned earlier that the different wave lengths are absorbed at different rates. Red and violet are absorbed most rapidly and blue, green light penetrates furthest. Eventually, if the water is deep enough all the light is absorbed and dark reigns at the bottom region.

If the lake water is coloured by pigments, light is absorbed more rapidly. Where the lake water contains suspended particles whether silt or plant cells, again light cannot penetrate as far. When such particles are there the water becomes turbid and the amount of these suspended particles could be measured.

Plants can only synthesize food in the lighted, surface waters of a lake and this region is called the **euphotic zone**. The region where only 1% of the light at the surface remains, is the **compensation level**. In a clear-water lake the euphotic zone may extend down to 20m or more but in many lakes it is often about 3-5 m or even as little as 0.5m deep. Below this level the plants cannot photosynthesise and they cannot grow. This deeper darker zone is called the **profoundal zone** (Fig. 2.4).

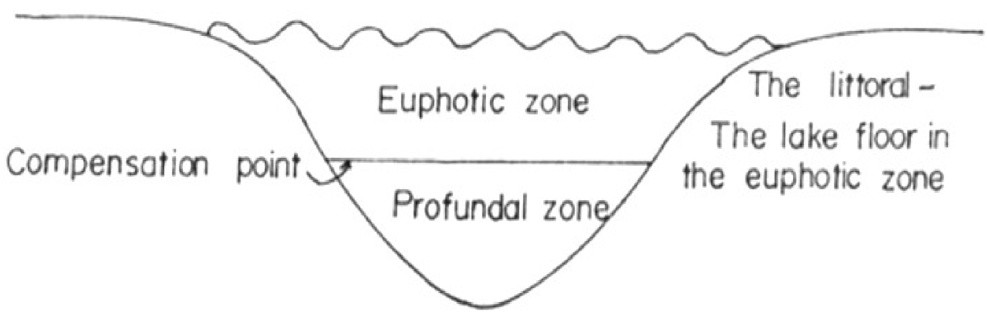


Fig. 2. 4: The zonation of a lake according to light penetration

iii. Turbidity

This is due to the suspended material and could be measured by the turbidity meters, or by filtrater. If the particles that produce turbidity are imported to the water body they are called **allochthonous material**. If they are produced within the system itself, they are called **autochthonous material** (dead parts of animals and plants).

Turbid and coloured waters are generally less transparent and the secchi disk depth is low. When turbidity is high it limits the growth of organisms which are adapted to clear water conditions.

II. Temperature

It was mentioned earlier that 53% of the solar energy that reaches water body is transformed to heat energy to warm the surface of the water body. Penetration of heat to deeper layers depend on:

- the rate at which it is conducted downwards
- the extent to which the surface water mixes with the below (mainly as a result of wind)

The temperature of a water body changes horizontally (with time) a vertically (with depth). We can recognize two patterns of temperature variations.

1. Daily temperature variation

2. Seasonal temperature variation

i. Daily temperature variation

Aerial temperature has a significant correlation with the surface water temperature. When aerial temperature rises surface temperature also rises. However temperature in a water body alters much rapidly than that of the air. As a result there is no abrupt difference in temperature by day and night as on land.

In **tropical** countries daily variation of temperature in water is very prominent. Fig. 2.5 shows how temperature fluctuates in Beira Lake within the day. It fluctuates between 6 ^{0}C and the highest temperature was recorded between 1-3 p.m.

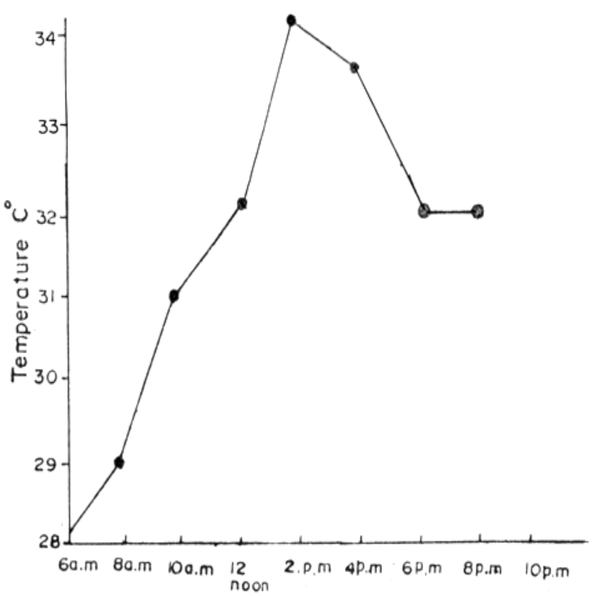


Fig. 2.5 Diurnal variation in water temperature in Beira Lake

Usually water is colder than the air in the mornings and is warmer than air in the evenings. Although surface variation is as such, bottom strata of a deep-water body do not show significant changes, and remain cooler.

The water temperature in **temperate** water bodies closely follows the air temperature as in tropical countries. However in winter water temperature does not fall below 0^{0}C and in spring air warms more rapidly than water.

ii. Seasonal temperature variation

The seasonal temperature variation of a shallow body of water in a tropical country is shown in Fig. 2.6. The daily average was measured from the minimum and maximum temperatures. According to this figure, mean water temperature remained higher than mean air temperature except during March- April.

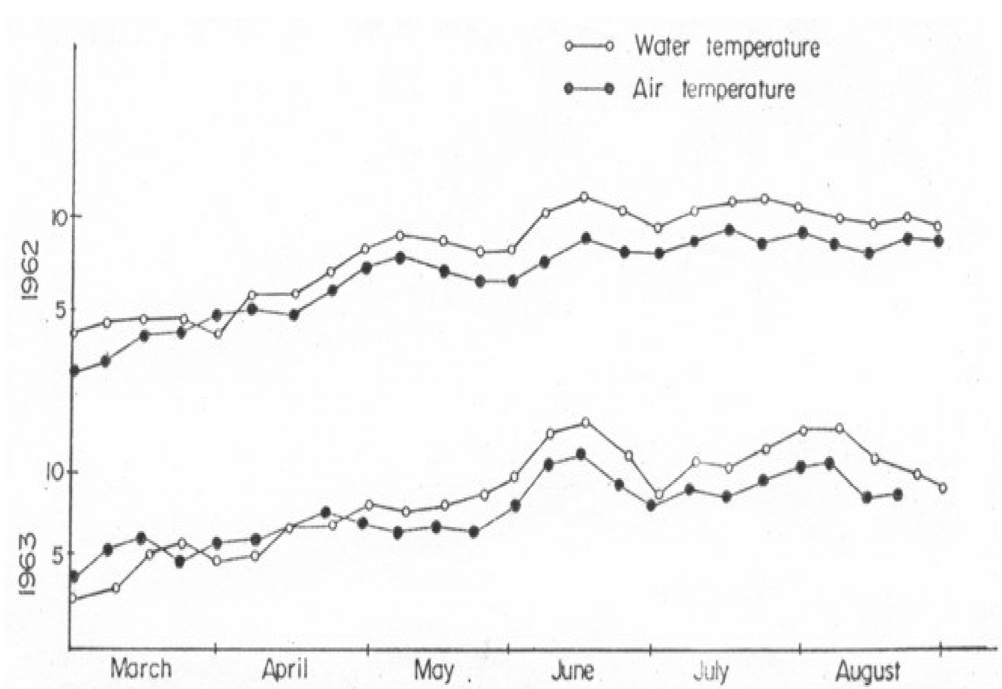


Fig. 2.6 Relationship between water and air temperature in a tropical lake (Hodson's Tarh)

iii. Temperature variation with depth

As you know a water body gets heated due to sunlight and this heat is penetrated to deeper layers by conduction and mixing. Conduction is a very slow process and if there is no wind (calm day) water does not mix. On such a day it will take a long time to penetrate the heat down through the water column in deep water bodies.

Gradually, a situation is developed where there is a marked difference in temperature between the waters of upper layers and deep layers. This means that there is also a density difference in the water column as the top layers which are with high temperature have low densities (as the temperature increases in the water, density decreases and they move upwards) and lower cooler water have high densities. In a situation like this a **thermal discontinuity** is present in a water body and this is known as **thermal stratification** (Fig. 2.7).

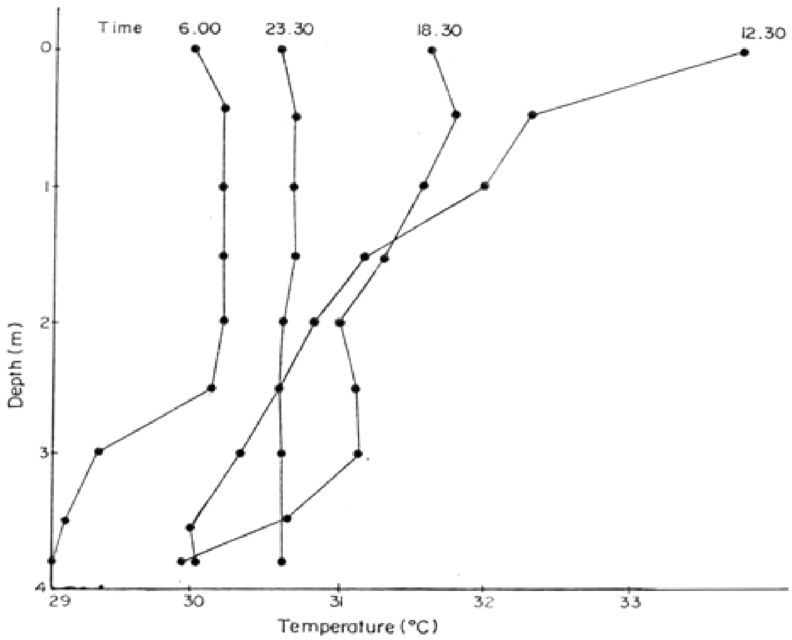


Fig. 2.7 Thermal stratification in Parakrama Samudra

Thermal stratification is the most important physical event in the lake's annual cycle and dominates most aspects of lake structure. Therefore let's learn about it in detail.

In **shallow ponds and tanks** the typical thermal stratification may not be seen, although there is some form of temperature discontinuity. In such water bodies' temporary thermocline may be present between 2-3 m during the daytime which disappears at night. In **deep water bodies** in tropical countries thermal stratification is present throughout the year while in temperate water bodies it is found only during summer.

Let's consider a temperate water body, to learn thermal stratification. It is instructive to begin this discussion by examining the typical conditions of a temperate lake that experience strong contrasts in seasonal conditions. As you know there are 4 seasons in temperate countries; spring, summer, autumn and winter.

Spring:

Ice cover on the lake commonly deteriorates in the spring in a relatively slow, progressive way (Fig. 2.8 a & b).

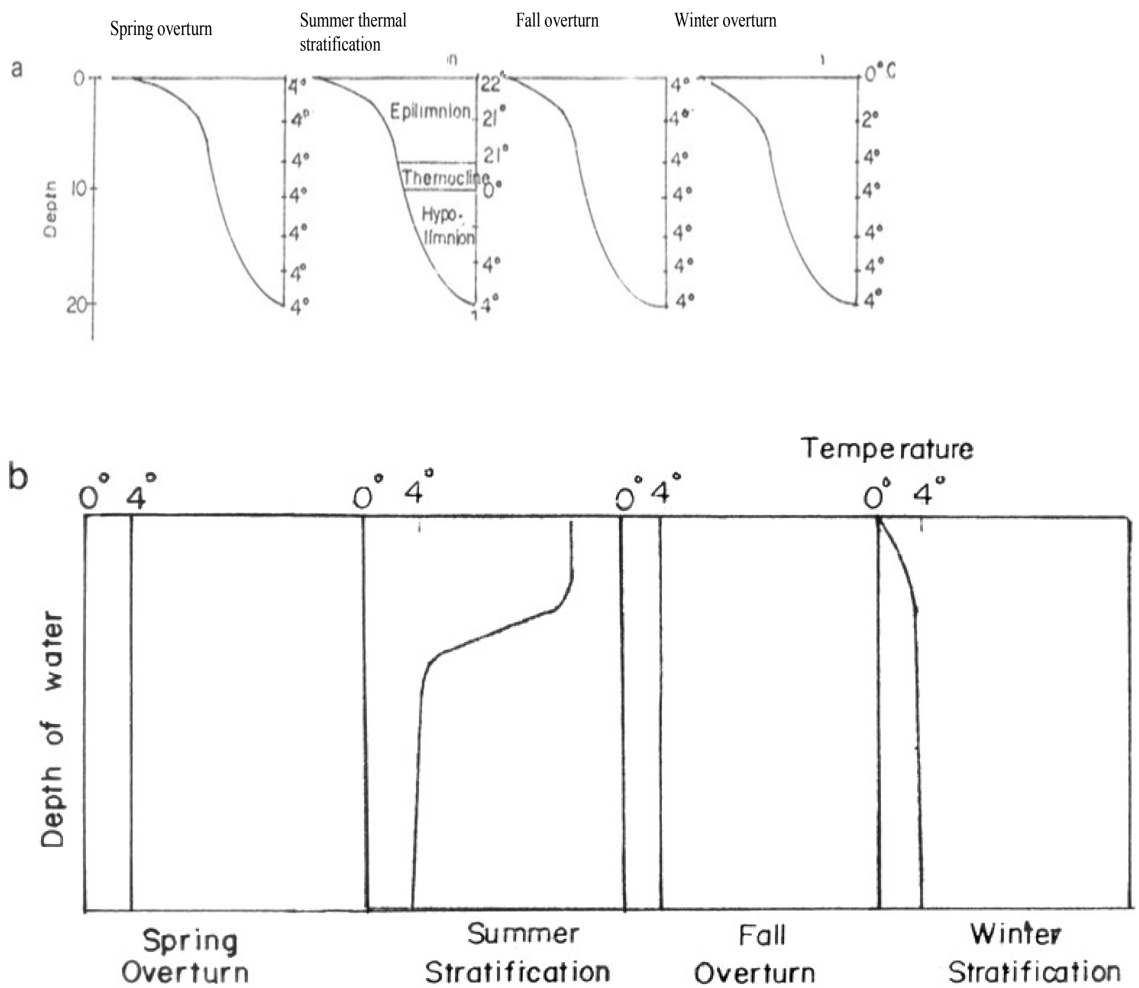


Fig. 2 8 (a) Temperature variation with depth during the 4 seasons

(b) Thermal stratification patterns in a typical temperate lake through a year's cycle

Warm rains often accelerate this process of ice erosion. Loss of ice cover is usually rapid, especially if there are strong winds. At this time of the season, the water at all depths is near the temperature of maximum density, except at the surface water where is less than 4 ^{o} C. As the whole water column is at 4 ^{o} C there is no density differences in the water column and there is relatively little thermal resistance to mixing and only small amount of wind energy are required to mix the water column. This is called spring overturn (Fig. 2 9).

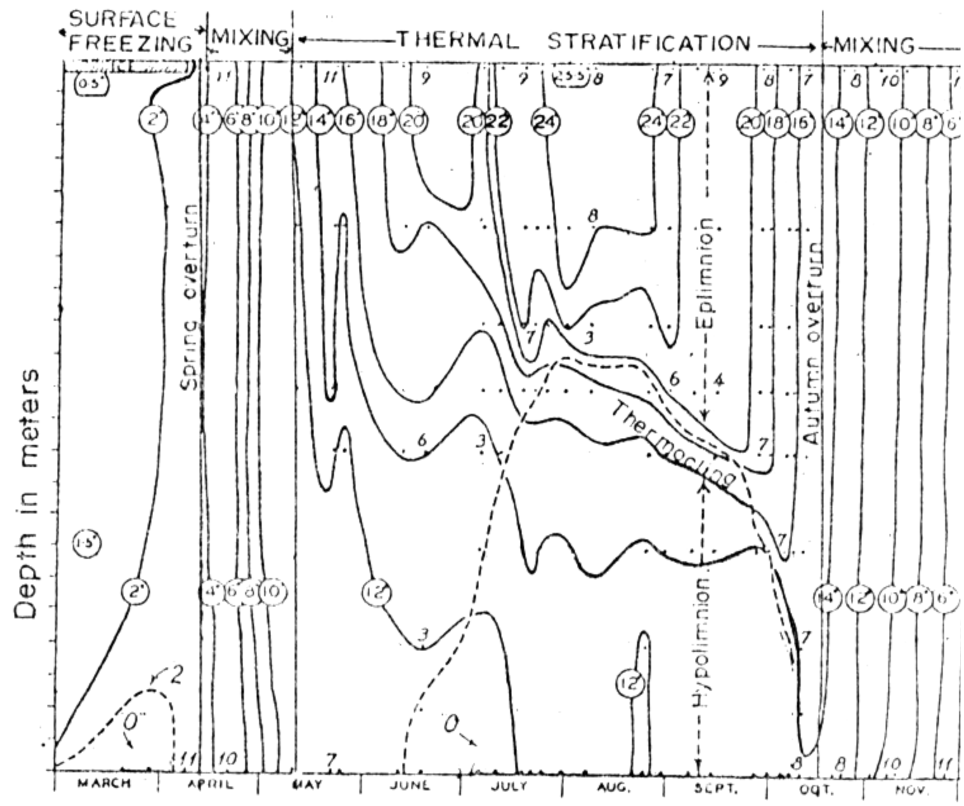


Fig.2.9 Seasonal variations of temperature at different depths in Lake Mendota (Isotherms)

Summer

As the summer approaches, day lengthens and more solar radiation is absorbed by the water. Most of the absorption takes place in the uppermost layers of the lake. If all the absorbed radiation is transformed into heat and if the water is perfectly still, we could expect the surface of the lake to be quite warm and the temperature to be decreasing gradually with depth. The level below, with no light penetration, could only be heated by diffusion, which is negligible.

This results in a warm top layer, heated by the sun and homogenized by the wind and other currents, and it is termed as the **epilimnion**. The cool deeper layer that

is not heated by the sun and is too deep to be circulated directly by the wind is termed as the **hypolimnion.**

In both the layers temperature drop is not very prominent. As shown in Fig 2.10a in the epilimnion up to a depth of 6 m, the decrease in temperature is by 3-4^{0}C. In the hypolimnion too, the drop in temperature is by about 1- 2^{0}C from 7 to 12m. The warm water in the epilimnion circulates within that zone, without mixing with other zones.

In the deeper layers of the hypolimnion cold water too circulate within itself but does not rise upwards (Fig 2.l0b). The zone which is in between the hypolimnion and the epilimnion is termed as the **Metalimnion,w**here there is a region of greater change in temperature known as the **thermocline**. In this region there is a sudden temperature drop within a short vertical distance and as you see in Fig. 2.10 a, the temperature has dropped by 4^0C within a depth of lm. Thus a largest temperature difference is observed within the smaller depth variation in the thermocline.

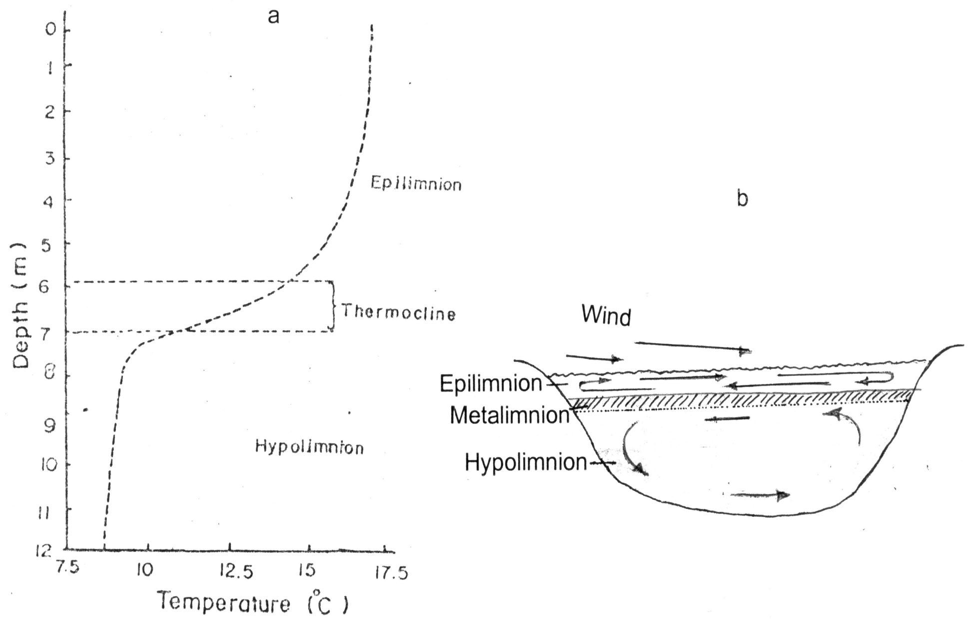


Fig. 2.10 (a) Temperature variation with depth during summer in temperate lake

(b) and the water currents in the epilimnion and hypolimnion

In the temperate countries the thermocline is marked by a change of several degrees centigrade across the thermocline as mentioned and it is a seasonal phenomenon.

In tropical and subtropical countries it is a significant feature and the difference in temperature is quite small, as there is no greater difference in the temperature in the hypolimnion and the epilimnion. For example in Lake Malawi of Tanzania, there is a stable thermocline between 200-250m depth, but the difference between the top and the bottom layers of the thermocline is only 1^0C. This type of thermocline has been observed in Mahaweli reservoirs of Sri Lanka (Victoria).

Such a small temperature difference constituting a thermocline is not confined to large lakes but can also be found in small ones such as Sunbang Lake in Malaysia, where the temperature discontinuities of the order of 0.5^0C at 3-4 m were sufficient to establish thermocline effects.

The reason why such small differences can create a thermocline in tropics is due to the fact that the density of water decreases disproportionately with increasing temperature, so that for example increase from $26.5\text{-}27.5^0C$ gives a density decrease equivalent to a change from $4\text{-}10^0C$ at the lower end of the scale.

In other words, small changes in the tropics, where water tend to be between $20\text{ -}30^0C$, give quite a large change in water density, which is sufficient to create a stable thermocline with its resulting barrier effect.

The thermocline is not fixed to a particular depth. It gradually descends during the summer until the lake turn over in the autumn.

Unlike these seasonal thermoclines which occur in the metalimnion, **temporary thermoclines** are common in the epilimnion. These thermoclines are mixed on a daily basis down to intermediate depths by afternoon winds or nocturnal convection currents. Two or three thermoclines may form this way (multiple thermoclines) but all are mixed down to the seasonal thermocline by the next strong wind (Fig. 2.11)

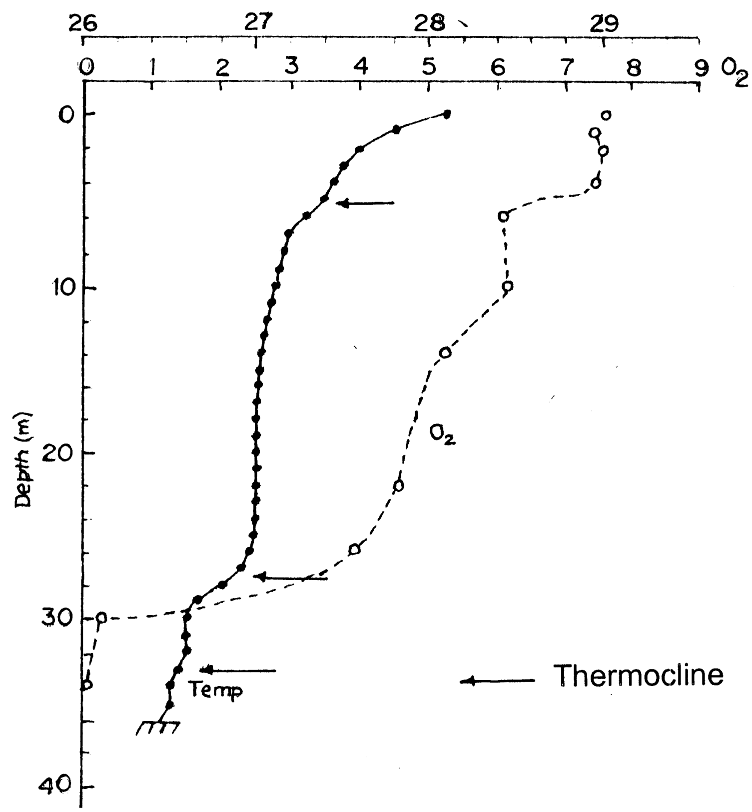


Fig. 2.11 Multiple thermoclines in Lake Valencia, Venezula.

The significance of thermoclines

The thermocline acts as a physicochemical barrier to diffusion and consequently can isolate the epilimnion from the hypolimnion with respect to the circulation of dissolved substances. Once a thermocline is formed, organic material can sink through, but salts or gases in solution cannot diffuse across it.

Dying phytoplankton and detritus sink through the thermocline into hypolimnion where decomposition takes place. These materials incorporate phosphorus and nitrogen which are very significant to plankton, and they are released as inorganic compounds by decomposition in the hypolimnion. Due to the thermocline barrier, mixing does not take place efficiently and these nutrients are not brought on to the epilimnion but remain trapped in the hypolimnion.

Accumulation of such materials may lead to severe deoxygenation of the hypolimnion as oxygen is used to decompose them.

The presence of a permanent thermocline can lead to permanent nutrient shortage of the surface waters and this can lead to very low productivity in water bodies, though high light energy levels are present. This can be seen in deep lakes such as Lake Tanganyika and Lake Malawi of Africa. But in many lakes some degree of mixing occurs causing enrichment of surface waters with nitrates and phosphates from deeper areas.

Not only this, thermocline becomes a barrier for the movement of small organisms, especially zooplankton which move downwards due to various factors.

Before we discussed the thermocline, our attention was on the changes in temperature during summer. Now let's learn how the temperature changes during autumn and winter.

Autumn

As autumn progress, atmospheric temperature decreases and heat is lost from the epilimnion to the atmosphere faster than it is absorbed, therefore the temperature of the water drops. Finally the epilimnion reaches a point where it is essentially the same temperature as the hypolimnion. The thermocline no longer exists to prevent circulation between the upper and lower layers; hence the entire lake can mix from top to bottom. This period of lake wide circulation is called the **overturn** (Fig. 2 .8a & 2. 9).

Winter

As the winter approaches, the regional temperature continues to drop, water at the top of the lake continues to lose heat and becomes less dense than the lower layers. A thermocline tends to reform with a cold epilimnion (0-4^{0}C) overlying a warm (4^{0}C) hypolimnion. In typical temperate zone lakes, the winter **inverse stratification** is not as strongly developed as the summer stratification, because ice forms if the temperature at the surface drops 4^{0}C or more and seals the water body from effects of the wind (Fig. 2 . 8a).

With the onset of spring, the lake again absorbs heat from the sun, and its temperature rises until it is uniform (about 4^{0}C from top to bottom) and the lake turns over and the cycle begins again. Fig. 2.9 summarizes the thermal cycle for a typical lake of the temperate zone.

Lakes undergoing above mentioned type of complete circulation in spring and autumn, separated by summer thermal stratification and winter inverse stratification are called **dimictic** lakes and they are very common among temperate lakes of moderate size.

Not all lakes undergo two overturns a year and many other types of density-related stratification patterns occur among lakes in relation to the interacting effects of climate, morphometry and chemistry. On the basis of circulation patterns the lakes can be classified in to several forms and this will be considered later.

Isotherms

The variation of temperature with depths can be measured for different months continuously and mapped out to give an overall view of the changing temperature of the lake. Such a map for Lake Menoda in United States of America is shown in Fig. 2 .9.

This figure shows that the thermocline is not stationary throughout the summer. The thickness of the thermocline gets reduced towards the latter part of the summer. During spring and autumn, when there is sufficient mixing due to strong winds, the thermocline disappears and the temperature remains constant from surface to bottom.

Instruments used in measuring the temperature

Mercurial thermometers are useful for measuring surface temperatures by direct immersion but are of limited use for subsurface measurements.

The most accurate device for measuring subsurface temperatures is the **reversing thermometer**.

Bathythermograph is the instrument used for measuring and recording continuous vertical profiles of temperature with depth.

Thermal classification of lakes

Lakes can be classified according to thermal stratification, mixing and the formation of the hypolimnion. When the circulation occurs throughout the entire water column, such lakes are called **holomictic lakes.**

A number of lakes do not undergo complete circulation, and the primary water mass does not mix with the lower portion. Such lakes are termed **meromictic lakes**. In meromictic lakes the deeper stratum of water and the upper stratum are separated by a steep salinity gradient which is called the chemocline.

Effect of temperature on organisms

Species that occupy a narrow temperature range are referred to as **stenothermal**, while those that thrive over a wide range are called **eurythermal**.

Cool adapted species often cannot withstand summer temperatures much above those they normally experience. Warm adapted species of the temperate zone usually must survive freezing temperatures, because they experience these seasonally. Their absence from streams that are cool in summer is because their efficiency of feeding and ability to grow are insufficient to maintain populations or because their reproductive needs are not met.

Because species differ in their temperature requirements, the flora and fauna of rivers change gradually in composition with latitude or altitude.

Temperature has diverse effects on the activity and the life cycles of the biota of running waters. It triggers development.In addition, temperature influences the rate at which eggs develop and juveniles grow. These in turn determine voltinism rates of growth and the productivity of the biological community.

Temperature also influences body size which in turn affects fecundity, because body size and number of eggs are positively correlated.

Water movement

Wind is the primary force moving the water at all depths of a water body. Temperature, density differences and gravity are also important factors that cause water movements.

These movements have profound consequences for the chemistry and biology of water bodies and you will come to know about these, when you learn about running water bodies.

There are two types of water movements;

1. Waves

2. Currents

1. Waves-These movements are periodic and rhythmic. They consist of the rise and fall of water particles (parcel) which involved some oscillation but not lateral flow.

2. Currents -Consist of net unidirectional flow of water. They built up much more slowly than the waves, but they contain most of the kinetic energy it that water body.

However currents and waves normally occur together.

Types of currents

The flow of the water can be laminar, turbulent or shooting, depending on the bottom topography of the water body.

Laminar flow is the smooth slipping of water particles, past each other or an obstruction and has little drag on moving objects (Fig. 2.12a). Most fish possess

body designs that maximize laminar flow past them, causing minimal energy expenditure.

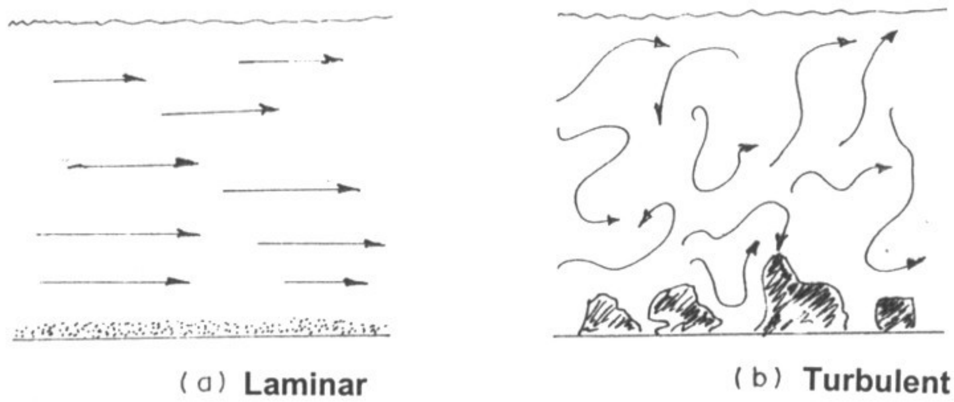


Fig. 2.12 : Differences between laminar and turbulent flow of water.

(a) Laminar (b) Turbulent

In contrast, **turbulent current** is the random, chaotic tumbling of the water particles around each other, or any object passing through the water. These tumbling motions are described as **eddies**. Turbulent currents occur in mountain streams and shooting in waterfalls.

As described earlier, in thermally stratified lakes the circulation of water and the direction of the current may be different in the epilimnion and the hypolimnion as the density of water in these two regions differ very much. Even when there is a laminar flow, eddy system can be produced between different density layers and such is normally seen in thermally stratified lakes (Fig. 2.13).

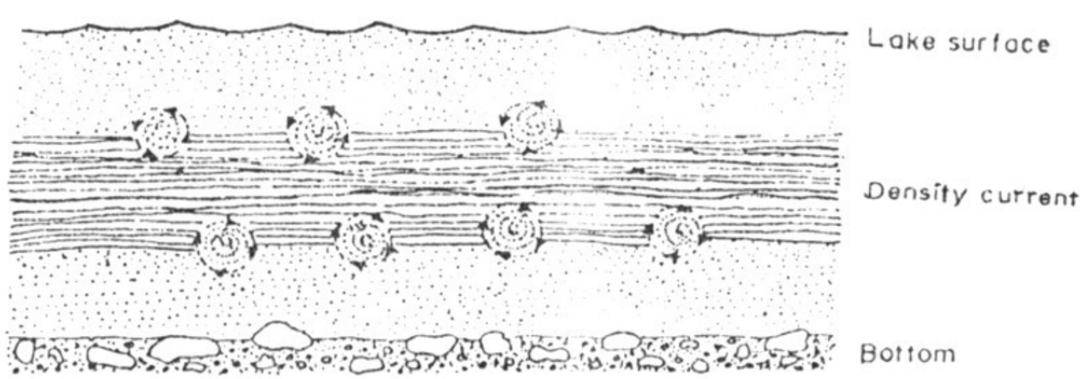


Fig. 2.13: Eddy systems produced in a thermally stratified lake

The velocity of current

The velocity of the current is defined, **as the distance, a mass of water moves in unit time**. This can be measured by current meters and flow meters.

If the velocity of the current is strong the sediments can be washed off. There is a relationship between the critical velocity and the particle size of sediments by

which deposition or erosion can be predicted (Fig. 2.14). According to this figure the first to dislodge is not clay particles but sand particles. The first to get deposited is silt. As the velocity of the current is reduced, the sediments get deposited on the bottom and along the sides of the water body.

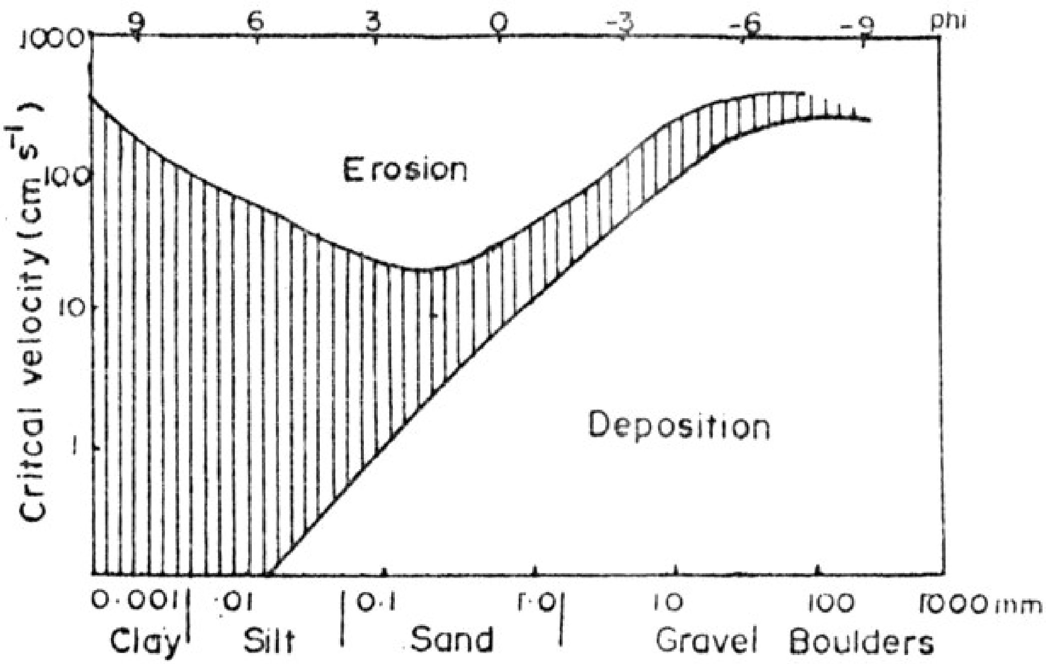


Fig.2.14 Relationship between critical velocity and particle size

Since water is 'dense' the direct action of current is a very important limiting factor, especially in streams. It determines the distribution of vital gases, salts and small organisms. The rapid top-to-bottom stirring in shallow lakes during the summer is extremely recycling the nutrients, which often support high level of productivity.

Effects of current on organisms

Earlier it was described how the speed of the current influences size of particles of the substrate. It disturbs the substrate, thus making the water turbid.

Current also affects food resources of animals, especially delivery path and also removal of nutrients.

Current velocity presents a direct physical force on the organisms that live within the water column as well as the substrate surface. Animals that live in places where there are currents show various adaptations and these will be discussed later.

Substrate

Substrate is a complex aspect of the physical environment. It may vary from cobbles and boulders in the bed of a mountain stream, and the silts and sands in a slow flowing river to organic detritus and minerals in a stagnant water body.

There are instances where substrate of a water body is relatively uniform, as in sandy bottoms of low gradient rivers but normally it is very heterogeneous.

Different kinds of substrates

Because substrate is so diverse, it is not easily categorized on a linear scale as can be done with current, temperature, and other physical variables.

For simplicity we will separate inorganic from organic substrate, but this distinction is mainly a convenience.

Inorganic substrates

Probably no substrate is totally lacking in organic matter, but the bed material of many streams consists primarily of inorganic particles ranging in size from clay and silts to boulders and bed rock. Particle size, factors relating to the particles, persistency of bed material are among the most critical physical aspects of mineral substrates.

Organic substrates

Very small organic particles (less than 1mm) usually serve as food rather than as substrate, except perhaps for the smallest invertebrates and microorganisms. Larger organic materials from plant stems to submerged logs generally function as substrate rather than food. These large substrates also serve in capturing food items that are carrying with the water curreent.

Organisms and substrate

In general, diversity and abundance of animals increase with substrate stability and the presence of organic detritus. Other factors which appear to play a role include the mean particle size of mineral substrates, the variety of sizes, and surface texture.

Many aquatic animals live in close association with the substrate and some of them show some degree of substrate specialization. For instance most larvae occupy the underside of the roots or attached and encrusting growth. They require a substrate that is not easily overturned by current.

Sand is generally considered to be a poor substrate, especially for macroinvertebrates. This is due to its instability, and tight packing nature of sand grains which reduces the trapping of detritus and availability of oxygen.

The **meiofauna**, defined as invertebrates passing through a 0.5mm sieve can every abundant (among sand particles), dwelling interstitially to considerable depth.

Borrowing taxa can be quite specific in the particle size of substrate they inhibit. For instance the may flies, *Ephermra danica* burrow effectively in gravel while *Hexagenia limbata* cannot, but does well in fine sediments.

Substrates composed of fine sediments generally are low in oxygen. Aquatic plants too form substrates for many of the animals. The invertebrate taxa that live in association with aquatic plants are refered to as phytophilous. Many species utilizes moss as a substrate and others are found on the surface of the submerged macrophytes.

Objectives

After you have studied this lesson you should be able to:

- List the physical properties of water and how they affect the living components of a stagnant water body.
- Discuss the thermal stratification of temperate lakes.

Review Questions:

1. Explain the effects of suspending particles on lake structure.
2. Distinguish between the temperature variation of tropical and temperate countries.
3. Discuss how the temperature variation in a temperate lake affects the organisms.
4. “Strong winds can cause drastic changes in a lake”. Justify the statement.