ALAGAPPA UNIVERSITY

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DIRECTORATE OF DISTANCE EDUCATION

M.Sc. (ZOOLOGY)

35033 - ENVIRONMENTAL BIOLOGY

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SYLLABI – BOOK MAPPING TABLE

ENVIRONMENTAL BIOLOGY

BLOCK – IV COMMNUNITY ECOLOGY AND ENVIRONMENTAL POLLUTION

CONTENTS

BLOCK -I: ECOSYSTEM

UNIT – I ECOSYSTEM

Structure

1.1. Introduction:

An ecosystem is a basic functional ecological unit. It consists of living organisms (biotic factors) and non-living substances (abiotic factors). It is an interacting system where the biotic and abiotic factors interact to produce an exchange of materials between the living and non-living factors.

1.2. Objectives:

This Unit's objectives are:

- To understand the structure and function of ecosystem.
- To study trophic structures in ecosystem

- To study about food chain, food web and energy flow in ecosystem
- To study about ecological pyramids

1.3. Ecosystem:

According to Odum an ecosystem is the basic fundamental unit of ecology which includes both the organisms and the non-living environment each influencing the properties of the other and each is necessary for the maintenance of life.

1.4 .Structure of Ecosystem:

The structure of any ecosystem is formed of two components, namely aboitic factors and biotic factors.

1.4.1. Abiotic Factors:

The abiotic factors of an ecosystem include the non-living substances of the environment. E.g. water, soil, air, light, temperature, minerals, climate, pressure, etc. The biotic factors of the ecosystem depend on the abiotic factors for their survival.

1.4.2 Biotic Factors:

The biotic factors include the living organisms of the environment. E.g. plants, animals, bacteria, viruses, etc. The biotic factors of an ecosystem classified into three main groups namely, producers, consumers and reducers or decomposers.

1.4.3Producers:

The organisms which carry out photosynthesis constitute the producers of an ecosystem. E.g. plants, algae and bacteria. The producers depend on the abiotic factors of the ecosystem for producing energy. They are provided with chlorophyll. Chlorophyll is used in the synthesis of energy rich compounds with the utilization of abiotic factors like light, CO_2, water and minerals. A portion of the energy synthesized, is used by the producers for their growth and survival and the remaining energy is stored for further use.

1.4.4 Consumers:

Consumers are organisms which eat or devour other organisms. The consumers are further divided into three or more types. They are primary consumers, secondary consumers and tertiary consumers.

1.4.5 Primary Consumers:

They eat producers like plants, algae and bacteria. The primary consumers are also called herbivores.

1.4.6 Secondary Consumers:

They kill and eat the herbivores. They are also called carnivores. As these carnivores directly depend on herbivores they are specifically called primary carnivores.

1.4.7 Tertiary consumers:

They kill and eat the secondary consumers. They also called secondary carnivores.

1.4.8 Reducers or Decomposers:

The decomposers are organisms that break up the dead bodies of plants and their waste products. They include fungi and certain bacteria. They secrete enzymes. The enzymes digest the dead organisms and the debris into smaller bits or molecules. These molecules are absorbed by the reducers.

After taking energy, the reducers release molecules to the environment as chemicals to be used again by the producers.

1.5 Trophic Structures in Ecosystem:

The various components of the ecosystem constitute an interacting system. They are connected by energy, nutrients and minerals. The nutrients and minerals circulate and recirculate between the abiotic and biotic factors of the ecosystem several times. The flow of energy, on the other hand, is one way, once used by the ecosystem, it is lost. The continuous survival of the ecosystem depends on the flow of energy and the circulation of nutrients and minerals in the ecosystem. Thus functions of the ecosystem include the following;

1. Energy
2. Primary production
3. Secondary production
4. Food chain
5. Food web
6. Trophic levels
7. Energy flow
8. Ecological pyramids
9. Biogeochemical cycles

1.5.1 Energy:

Energy is the ability to do work. The main source of energy for an ecosystem is the radiant energy or light energy derived from the sun. The amount of solar radiation reaching the surface of the earth is 2 Cals/sq.cm/min. It is more or less constant and is called solar constant or solar flux. About 95 to 99% of the energy is lost by reflection. Plants utilize only 0.02% of the energy reaching earth. The light energy is converted into chemical energy in the form of sugar by photosynthesis.

$6H_2O + 6\ CO_2 + \text{Light} \rightarrow 6C_6H_{12}O_6 + 6O_2$

The sugar synthesized is utilized for many purposes; it can be converted into starch and stored, it combines with other sugars to form cellulose, it combines with inorganic substances (N2, P, S, etc) to form amino acids, proteins, nucleic acids, pigments, hormones, etc., some amount of sugar is oxidised during respiration and the energy released to do various functions.

$6C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6H_2O + \text{Energy}$

1.5.2 Primary Production:

Plants convert light energy into chemical energy in the form of sugar by photosynthesis. The total amount of sugar and other organic materials produced in plants per unit area per unit time is called gross primary production.

During photosynthesis respiration is also going on side by side. During respiration some amount of sugar is oxidised. Hence it is not easy to measure gross primary production. The total organic material actually present (biomass) in plants is called net primary production.

Net Primary Production = Gross Primary Production – Respiration

i.e.,$P_n = P_g - R$

Whereas, P_g = Gross primary production, P_n= Net Primary production, R= Respiration.

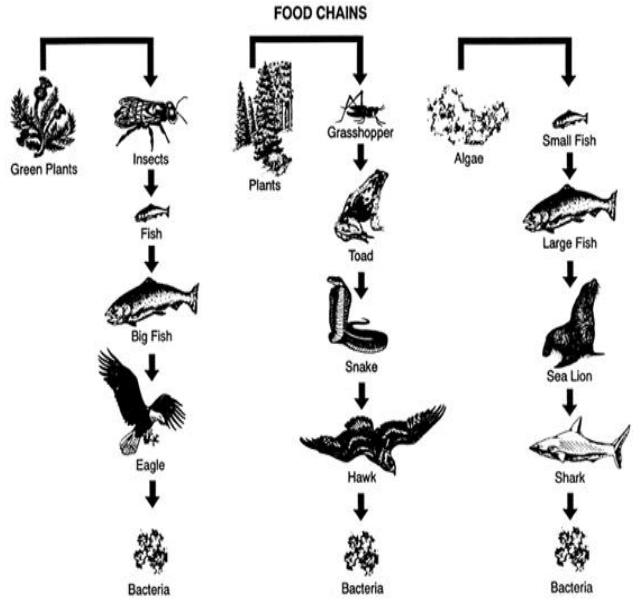
Thus the amount of organic material produced during a given period of time per unit area is called primary production. The productivity is generally expressed in terms of grams or kilocalories per square meter per day or per year. If Pg equals R no storage of energy occurs. When Pg is less that R productivity decreases. When Pg is greater than R, productivity increases.

1.5.3 Secondary Production:

The energy trapped by the producers (primary production) is utilized by the consumers. The producers are directly consumed by the herbivores that are eaten by the primary carnivores that in turn are consumed by the secondary carnivores. The consumers store some amount of energy in their tissues. This energy, stored by the consumers, is called secondary production. Only about 10 to 20% of the primary production is converted into secondary production. The remaining 80 to 90% is lost by the consumers in the form of faeces.

1.6 Food Chain:

The biotic factors of the ecosystem are linked together by food. For example, the producers form the food for the herbivores. The herbivores form the food for the carnivores. The sequence of the eaters being eaten is called food chain.



Producers ⟶ **Herbivores** ⟶ **Carnivores**

The various steps in a food chain are called trophic levels. Owing to repeated eating being eaten, the energy is transferred from one trophic level to another trophic level. This transfer of energy from one trophic level to another is called energy flow. A typical food chain can be seen in a pond ecosystem. The algae and phytoplankton are eaten by the zooplankton. The zooplanktons are eaten by fishes which are eaten by snakes.

Phytoplankton ⟶ **Zooplankton** ⟶ **Fishes** ⟶ **Snakes**

Tr. L_1 **Tr. L_2** **Tr. L_3** **Tr. L_4**

1.6.1 Types of food chains:

The food chains are of two type's namely grazing food chain and detritus food chain.

1.6.2 Grazing Food Chain:

This food chain starts from plants, goes through herbivores and ends in carnivores. This type of food chain depends on the autotrophs which capture the energy from solar radiation.

Plants → Herbivores → Primary Carnivores → Sec. Carnivores

A few chains are given below;

Grass → Grasshopper → Lizard → Hawk

Grass → Mouse → Snake → Hawk

Phytoplankton → Zooplankton → Fish → Snake

The grazing food chain is further divided into two types, namely predator chain and parasitic chain.

1.6.3 Predator Chain:

In predator food chain one animal captures and devours another animal. The animal which is eaten is called prey and the animal which eats other animals is called predator. The predator food chain is formed of plants, herbivores, primary carnivores, secondary carnivores and so on.

Parasitic Chain: The plants and animals of the grazing food chain are infected by parasites. The parasites derive their energy from their hosts. Thus the parasitic chain within the grazing food chain is formed.

1.6.4 Detritus Food Chain:

It starts from dead organic matter and ends in inorganic compounds. There are certain groups of organisms which feed exclusively on the dead bodies of animals and plants. These organisms are called detritivores. The detritivores include algae, bacteria, fungi, protozoans, insects, millipedes, centipedes, crustaceans, mussels, clams, annelid worms, nematodes, ducks, etc. These organisms ingest and digest the dead organic materials. Some amount of energy is trapped and the remainder is excreted in the form of simple organic compounds. These are again used by another set of detrivores until the organic compounds are converted into CO_2 and water.

Dead organic materials → Detrivores → $CO_2 + H_2O$

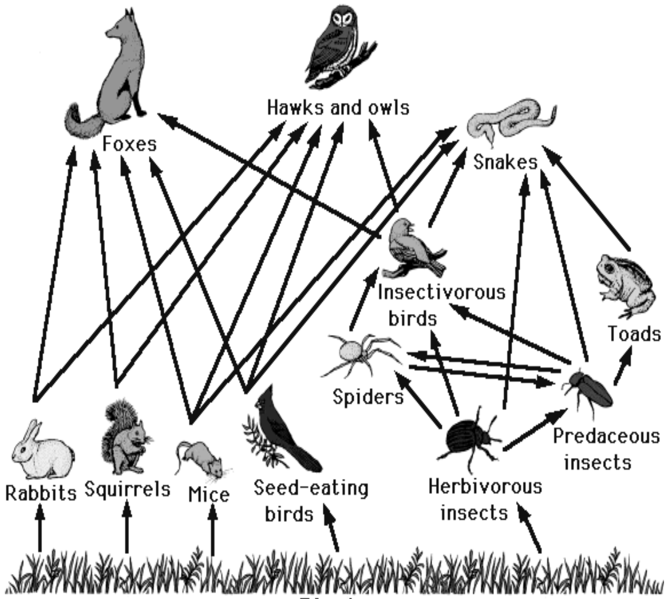
1.6.5 Linking of Grazing and Detritus Food Chains:

The two main food chains cannot operate independently. They are interconnected at various levels. The detritus feeders obtain energy from the dead bodies of animals and plants which are components of the grazing food chain. Again some of the detritus feeders are eaten by the consumers of the grazing food chain. For example, in a pond ecosystem earthworms belonging to the detritus food chain are eaten by fishes belonging to the grazing food chain.

1.7 Food Web:

In an ecosystem the various food chains are interconnected with each other to form a net work called food web. The interlocking of man food chains is called food web. Simple food chains are very rare in nature. This is because each organism may obtain food from more than one tropic level. In other words, one organism forms food for more than one organisms of the higher trophic level.

In a grassland ecosystem, grass is eaten by grasshopper, rabbit and mouse. Grasshopper is eaten by lizard which is eaten by hawk. Rabbit is eaten by hawk. Mouse is eaten by snake which is eaten by hawk. In addition hawk also directly eats grasshopper and mouse. Thus there are five linear food chains which are inter-connected to form a food web. This is a very simple food web. But in any ecosystem the food web is more complex. For example, in the grassland itself, in addition to hawk, there are many other carnivores such as vulture, crow, wolf, fox, man, etc.



1.7.1 Importance of Food Web:

Food webs are very important in maintaining the stability of an ecosystem. For example, the deleterious growth of grasses is controlled by the herbivores. When one type or herbivore becomes extinct, the other types of herbivores increase in number and control the vegetation. Similarly, when one type of herbivorous animal becomes extinct, the carnivore predating on this type may eat another type of herbivore.

1.7.1.1 Trophic Levels:

Each food chain contains many steps like producers, herbivores, primary carnivores and so on. Each step of the food chain is called trophic level. The number of trophic levels in a food chain is always restricted to four or five. But very often the chains are very much complicated with many trophic levels.

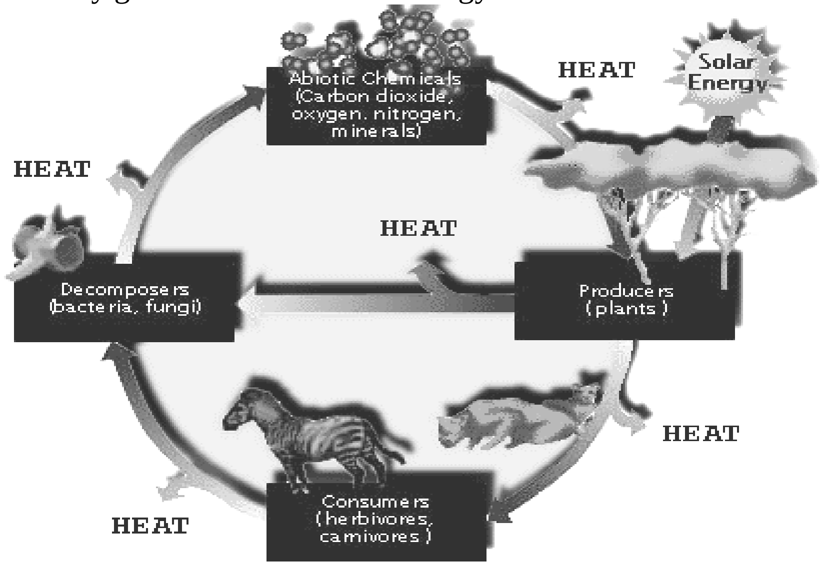
Grass ⟶ **Mouse** ⟶ **Snake** ⟶ **Hawk**

Tr. L_1 **Tr. L_2** **Tr. L_3** **Tr. L_4**

1.8 ENERGY FLOW:

The transfer of energy from one trophic level to another trophic level is called energy flow. The flow of energy in an ecosystem is unidirectional. That is, it flows from the producer level to the consumer level and never in the reverse direction. Hence energy can be used only once in the ecosystem. But the minerals circulate and recirculate many times in the ecosystem.

A large amount of energy is lost at each trophic level. It is estimated that 80% to 90% of the energy is lost when it is transferred from one trophic level to another. Hence the amount of the energy available decreases from step to step. When the food chain is short, the final consumers may get a large amount of energy. But when the food chain is long, the final consumer may get a lesser amount of energy.



As shown in the picture some amount of energy is lost in each trophic level in the form of heat.

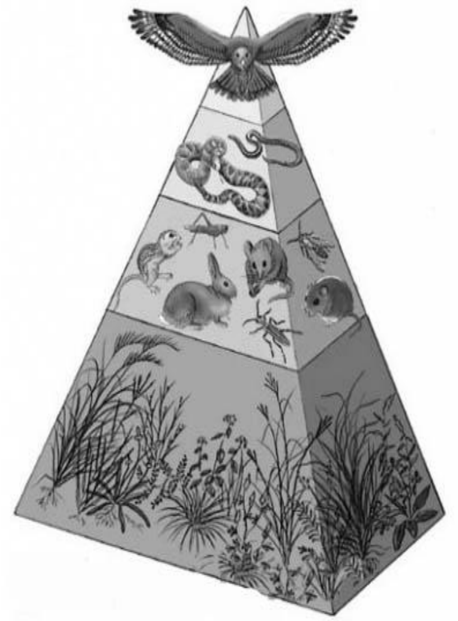
1.9 Ecological Pyramids:

The number, biomass and energy of organisms gradually decrease from the producer level to the consumer level. This can be represented in the form of a pyramid called ecological pyramid. Ecological pyramid is the graphic representation of the number, biomass, and energy of the successive trophic levels of an ecosystem. In the ecological pyramid the producer forms the base and the final consumer occupies the apex. There are three types of ecological pyramids, namely

1. The pyramid of number
2. The pyramid of biomass and
3. The pyramid of energy

1.9.1 The Pyramid of Numbers:

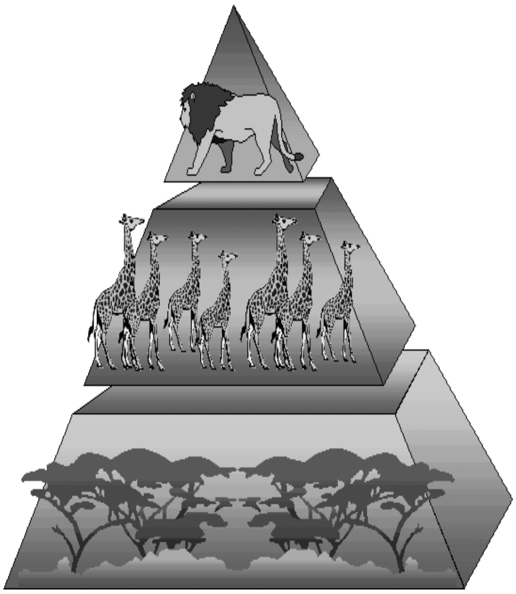
The number of individuals at the trophic level decreases from the producer level to the consumer level. That is, in an ecosystem the number of producers is far high. The number of herbivores is lesser than the producers. Similarly, the number of carnivores is lesser than the herbivores.



For example in cropland ecosystem the crops are more in numbers. The grasshoppers feeding on crop plants are lesser in number. The frog feeding on grasshopper is still lesser in number. The snakes feeding on frogs are fewer in number.

1.9.2 The Pyramid of Biomass:

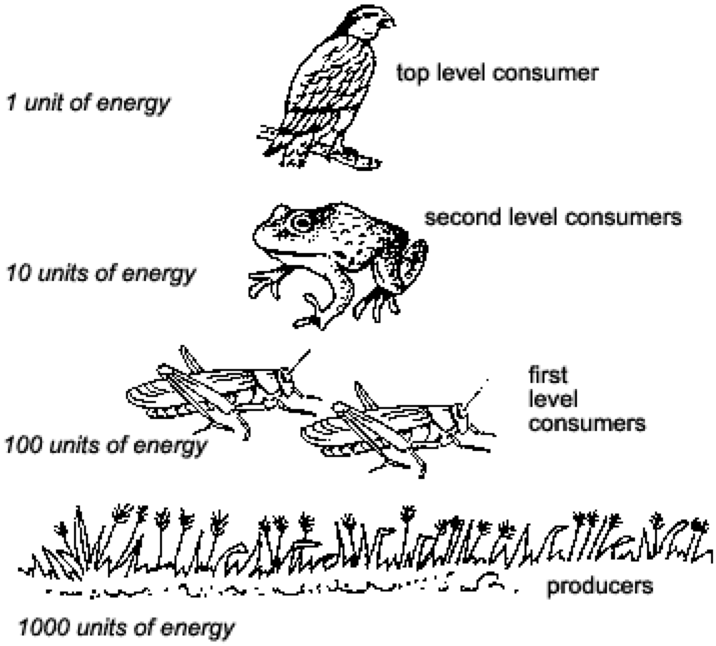
Biomass refers to the total weight of living matter per unit area. In an ecosystem the biomass decreases from the producer level to the consumer level.



For example in a forest ecosystem the biomass of trees is the maximum and the biomass of the top consumer is the minimum. The decrease in weight occurs in the order of Plants > Deer > Fox > Tiger.

1.9.3 The Pyramid of Energy:

The energy flows in an ecosystem from the producer level to the consumer level. At each trophic level 80 to 90% of energy is lost. Hence, the amount of energy decreases from the producer level to the consumer level. This can be represented in a pyramid of energy.



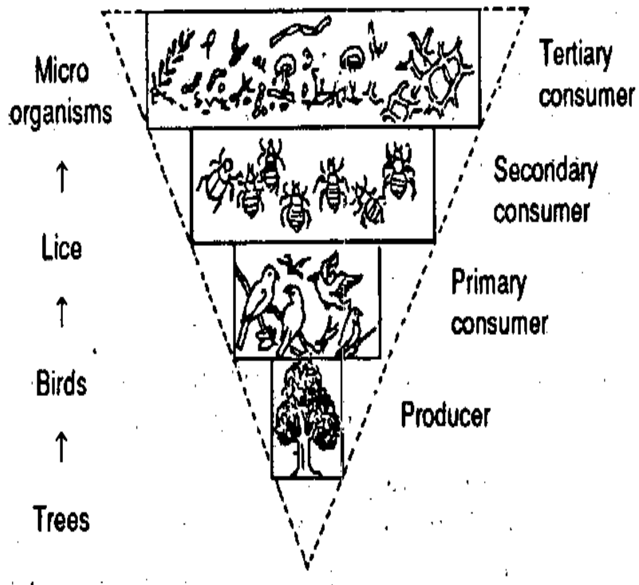
For example in a grassland ecosystem green plants trap the maximum light energy. The energy gradually decreases towards the top consumer level.

1.9.4 Inverted Pyramids:

In most of the ecosystems the number and biomass of producers are more and those of consumers are less. This type of ecosystem has pyramid where the apex is pointed upwards. This type of pyramid is called upright pyramid. In some ecosystems the number and the biomass of the producer are less and those of consumers are more. This type of ecosystem produces a pyramid where the apex is directed downwards. This type of pyramid is called inverted pyramid. Inverted pyramid occurs in numbers and biomass. The pyramid of energy is always upright.

1.9.4.1 Inverted Pyramids of Numbers:

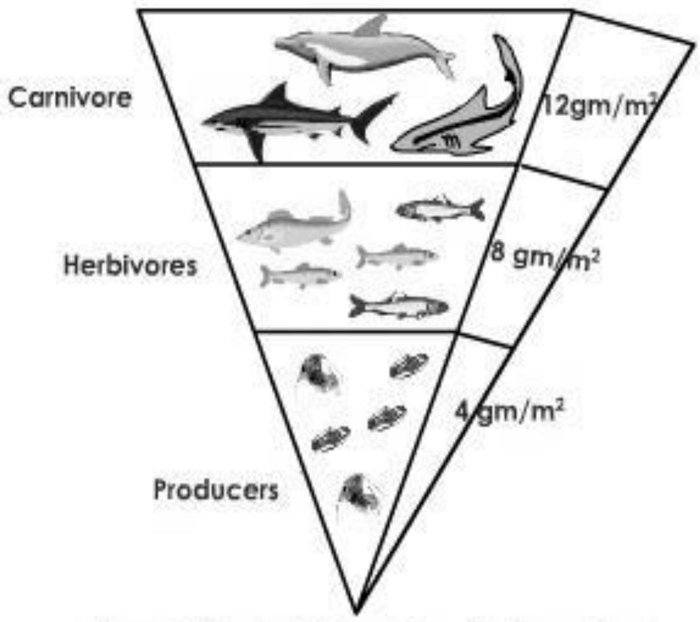
When the ecosystem contains lesser number of producers and more number of consumers, the pyramid will be inverted in shape. Inverted pyramid occurs in a tree ecosystem. A single tree (producer) contains many fruit eating birds (primary consumers). The birds contain numerous parasites (secondary consumers).



Inverted Pyramid of Numbers

1.9.4.2 Inverted Pyramid of Biomass:

When the biomass of producers is less and that of consumers is more the pyramid will have inverted shape. It occurs in a pond or lake ecosystem. Here the biomass of diatoms and phytoplankton are negligible as compared to that of crustaceans and small fishes.



Inverted Pyramid in an Aquatic Ecosystem

1.10. Summary

In this chapter we studied about the structure of ecosystem and its various components of the ecosystem which constitute an interacting system associated by energy, nutrients and minerals. Generally ecosystem can be utilized the nutrients and minerals which are circulated and reused between the abiotic and biotic factors. The biotic factors of the ecosystem are linked together by food. Hence, sequence of the eaters being eaten is called food chain. The flow of energy is defined as one way that can be used once by the ecosystem. The constant survival of the ecosystem depends on the energy flow and the circulation of nutrients and minerals in the ecosystem. Ecological pyramid is the graphic representation of the number, biomass, and energy of the successive tropic levels of an ecosystem. In the ecological pyramid the producer forms the base and the final consumer occupies the apex.

Check Your Progress:

1. Write notes on Ecosystem.
2. Write an essay on aboitic factors and biotic factors.
3. Explain Food chain and Food web
4. Define consumers
5. Write the significance primary consumers, secondary consumers
6. Energy flo

UNIT II: ABIOTIC FACTORS, SOIL ORGANISMS, BIOLOGICAL EFFECTS OF LIGHT AND TEMPERATURE.

Structure

2.1 Introduction:

Ecosystem consists of living organisms (biotic factors) and non-living substances (abiotic factors). It is an interacting system where the biotic and abiotic factors interact to produce an exchange of materials between the living and non-living factors.

2.2. Objectives:

The objectives of this Unit are;

- To know about abiotic factors of the ecosystem
- To learn about the soil organisms
- To understand the biological effects of light and temperature

2.3 Abiotic Factors:

The abiotic factors of environment include the atmosphere, hydrosphere, water and lithosphere. The abiotic components are characterized by physical and chemical factors such as light, temperature, rainfall, pressure, pH, the content of oxygen and other gases and so on. These factors exhibit diurnal, nocturnal, seasonal, and annual changes. The biotic components include all living organisms which interact with each other and with the abiotic components. Earth’s living organisms interacting with their physical or abiotic environment from a giant and vast ecosystem, called ecosphere or biosphere which is largest and most nearly self-sufficient biological system.

In physical terms, the biosphere is a relatively thin and incomplete envelope covering most of the world. It represents a mosaic of different biotic communities from simple to complex, aquatic to terrestrial, and tropical to polar. It does not exist in the extremities of the polar region, the highest mountains, the deepest ocean troughs, the most extreme deserts, or the most highly polluted areas of land and water. Its total thickness, including all portions of the earth where living organisms can exist, is less than 26 kilometres. Its zone of active biological production in terms of photosynthesis, is much narrower and varies from a few centimetres to over 100 metres. This zone would, for instance, be only a few centimetres in muddy or turbid water, whereas in very clear ocean water, it could be more than 100 metres in thickness. On land, the zone of biological production might be only a few millimetres in a desert or rock environment, whereas it might again be more than 100 metres in a sequoia or tropical rain forest.

2.3.1Type of Abiotic Environmental Factors:

The distribution, abundance, growth and reproduction of the organisms comprising the individual members of populations are controlled by certain environmental or ecological factors. An environmental factor is any external force, substance or condition which surrounds and affects the life of an organism in any way. Abiotic environmental factors are customarily classified as follows:

1. Climatic Factors
   (i) Light
   (ii) Temperature
   (iii) Water (including atmospheric water, rainfall or precipitation, soil moisture, etc.)
   (iv) Atmosphere (gases and wind)
   (v) Fire
2. Topographic or Physiographic Factors
   (i) Altitude
   (ii) Direction of mountain chains and valleys
   (iii) Steepness and exposure of slopes
3. Edaphic Factors (soil formation, physical and chemical properties of soil, nutrients).

Though climatic, edaphic and biotic factors affect plants/animals, their populations and community growth and dynamics take place in a holistic manner; but it is essential to understand the mechanism of environmental influences unless we study the different components of environment separately.

2.4 Soil Organisms:

Soil supports a wide array of organisms of different body-sizes and taxonomic groups. Generally, a oil organisms are classified into three major groups namely microfauna and micro flora, mesofauna, and macrofauna. Mesoflora and macroflora because occur above the surface of soil (land-surface), therefore, are excluded from this discussion:

2.4.1Microfauna:

It includes animals with body size within the range of 20µm to 200µm. It includes all Protozoa and small-sized mites, nematodes, rotifers,tardingades and copepodeCrustancea. Soil inhabiting protozoans such as amoeba, ciliates, zoomastigice flagellates occur near the surface soils, while the testate forms such as Thecamoeba, EuglyphoanadDifflugia, have a wider vertical distribution. The commonterrestrialpolyclad is Bipaliumm. The nematodes such as Rhabditis, Diplogaster, Tylenchus, Heerodera, Aphelenchoides, Mononchus, Pratylenchus, Xiphinema and Criconemoides, abound by as much as 1-3 million in raw humus soils to 20 million/m^2 in grassland soils.

2.4.2 Microflora:

The microflora of soil includes bacteria, soil fungi, soil actinomycetes, blue green algae and algae. In soil, microflora bacteria form about 90 per cent of the total population. Fungi and algae together represent one per cent and actinomycetes cover only 9 per cent.

2.4.2. 1 Soil bacteria:

Grow fairly well in the neutral soils richly supplied with organic nutrients. Soil inhabitant bacteria fall into categories namely autotrophic bacteria and heterotrophic bacteria. The autotrophic bacteria derive their energy from the oxidation of simple carbon compounds or from inorganic substances and their carbon from the atmospheric CO_2. The common autotrophic bacteria of soil are nitrifying bacteria, hydrogen bacteria, sulphur bacteria, iron bacteria, manganese bacteria, carbon monoxide bacteria and methane bacteria. Most of soil bacteria are heterotrophic bacteria, depending upon the organic matter of soil for their energy source and are primarily concerned with the mineralization of organic matter of soil and release considerable amount of nitrogen, phosphours and other nutrients for plants. The common nitrogen-fixing bacteria of soil are Rhizobium (occurs in root nodules of eguminous plants; Azotobacter and Clostridium pasteurianum (the latter two are free occurring in soil).

Majority of soil fungi are found in acidic soils. They may be parasitic, saprophytic and symbiotic. Parasitic fungiof soil infect roots of plants nad cause plant diseases such as cotton root rot and many kinds of wilts, rusts, blights, and smuts. Certain wilt-forming fungi produce toxins which are harmful, for example, Fusariumlini, which causes wilt of flax (Alsi) and secretes HCN and Fusariumudum, a fungus causing wilt of pigeon pea (Arhar) secretes fusaric acid in the roots of host plants. However, certain parasitic fungi produce growth stimulating substances for host plant. Fusarium sp., for example, have been found to secrete gibberellins and gibberallic acid ($C_{19}H_{22}O_6$). Symbiotic fungi of soil live on the roots of certain plants and both fungus and plants are benefited. Saprophytic fungi depend on dead organic matter of soil and derive the energy from decomposition of the latter. They break down cellulose, lignin, and gum, sugars, starch, protein, etc., into simple gradients to be utilized by higher plants as nutrients.

2.4.2.2 Actionmycete fungi:

It prefers saline soils and bring about the decomposition of organic matter such as cellulose. They produce a variety of antibiotics of great economic significance for man. The most important blue green algae of soil are those which fix nitrogen in soil. Anabaena, Nostoc, Microcystis are important nitrogen fixing blue green algae of soil. They also makes soil aggregates because of having mucilage.

2.4.3Mesofauna:

Mesofauna include animals with body size within the range 200µm to 1 cm. The micro-arthopodsAcari (mites) and Collembola (spring tails) are important members of this group which also include the larger nematodes, rotifers, and tardigrades, together with most of the isopods. Arachnida (spiders), Chelegnathi (pseudoscorpions) Opiliones (harvestmen), Enchytraeidac (potworms), insect larvae and small millipedes (Diplopoda), isopods and mollusks.

Among annelids the microscopic enchytraeids are represented by Enchytraeusfridericia and Achaetalimbricellus, which are more abundant in organic soils and forests than in grassland. Oniscus, Porcellio, and Armadillidum are the most common isopods (crustacean) of the tropics in the humid zone. Among the soil arachnids, mites are the most predominant. Mites flourish in moist organic soils and certain mites such as Galumna, Cepheus, Hemorobates occur in lichens and mosses. Certain mites, such as Schelorbates and Brachychthornus live in humus. The mites are saprophagous, predator and phytophagous and are involved in the process of organic decomposition and its resultant processes. Certain arachnids such as scorpions, Thelyphonus, Galeodes; and some spiders are crepuscular, hiding under rocks or in crevices in soil and in loose litter, and has no ecological significance in decomposition like other arachnids. Many opiliones or harvestmen occur in forest litter, frequently preying upon soil organisms.

Besides mites, only the pseudoscorpions or chelognathi occur in surface soils and most decaying vegetations. Of the xerophil litter inhabitants are Stenatemusindicus, Dhanusindicus, Feallaindica and the hygrophil inhabitants living in the litter nad under stones are-Comsadithaindica, Tyrannochthoniusmadrasensis, Tyrannochithoniuschelatus and Hygrocheliferindicus (Murthy, 1964), feeding on Collembola, enchytraeids, etc.

The common millipedes or diplospodes of forest soil which are chief decomposers of soils are Spirostreptus. Other insects such as Dermaptera, Psocopters, Dictyoptera, Isoptera, Coleoptera, a few Hymenoptera and some Diptera also occur in soil, sometimes as juveniles. The termites such as Reticulotermes and Odontotermes are important soil-dwellers of tropics and play an important role in the breakup of organic materials and mixing up with mineral soils. Among the Hymenoptera, ants are the most important soil dwelling forms. Among Collembola, Onchuridae, Isotomidae, Poduridae and Entomobrydae are richly represented in the soil both in number and species composition. Large-sizedCollumbola such as Tomocerus, Entomobrya and Orchesella occur in surface layer, while the smaller Onychurus, Tullbergia, etc., occur in deeper layers of soils.

Among Diplura, Anajapyx, Japyx and Compodea are often found in small numbers in moist soils under stones and in humus. Proturans are more abundant than Diplura and very common in moist forest and grassland soils which abound in species of Eosentomon, Acerentomon and Acerentulus.

2.4.4Macrofauna of soil:

Macrofauna of soil includes those animals whose body size is greater than 1 cm. Here belong the majority of Lumbricidae, the Mollusca, the largest insects and arachnids and the soil-dwelling vertebrates.

Earthworms usually occur in abundance in alkaline and moist soils and sparse inacid soils. They have been proverbial for their influence on the process of decomposition of organic materials, breaking up litter fragments and mixing them thoroughly with mineral soils resulting in the formation of organic soils. Some of the common Indian annelidan species of soil are Megascolex, Pheretima, Octochaetus, Drawida and Moniligaster. Among chilopods the carnivorous Scolopendra and Lithobius are common in moist soils feeding on leaf littr inhabitants.

Among soil vertebrates, following animals are well adapted for burrowing life in soils-Ichthyophis, Cacopussystema, Breviceps (Amphibia), Spheneodon, Uromastix, limbless lizards and snakes (Reptilia), Talpa, Dasyurus, Notoryctes and various insectivores and rodents (Mammalia).

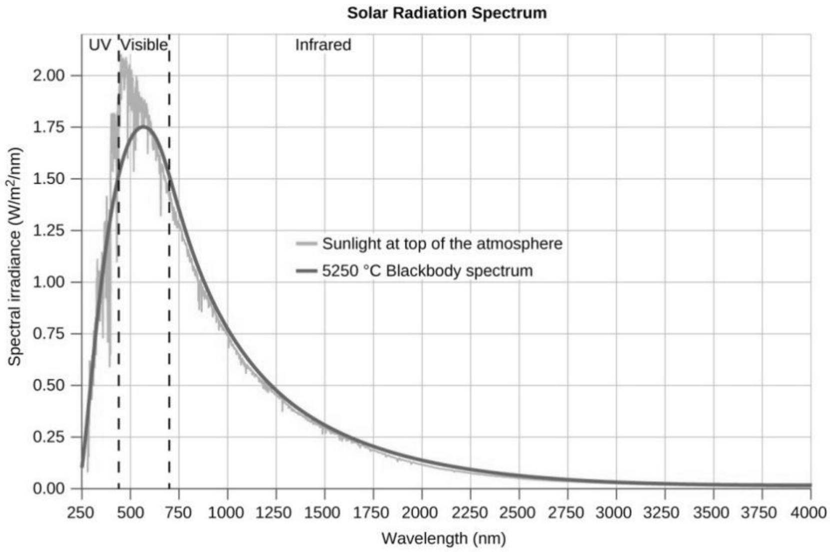
2.4.5 Adaptations of soli animals:

Animals which are adapted for digging the burrows and for subterranean mode of life are called fossorial animals. These animals may dig either for their food or simply for retreat. Zoologically they are primitive, defenseless and unambitious animals. They have following adaptation: 1. the body contour is either cylindrical (e.g., Ichthyophis, limbless lizards, snakes, earthworms, Scolopendra, etc.), or spindle-shaped or fusiform (e.g., Talpa, Echidna, etc.), so as to offer least resistance to subterranean passage. 2. The head tapers anteriorly to form a sort of snout for burrowing. 3. The tail is short or vestigial. 4. The eyes tend to become vestigial as they are of no use in dark habital. 5. The external ears also tend to disappear since they would be obstructing in burrowing. 6. For digging, many structures may be found in different fossorial animals, e.g., hands are well adapted for digging. In the insect Gryllotalpa, the fore-legs are modified for digging purpose.

The ground-dwelling animals which may be cursorial (running), such as ostrich, rhea, ungulates, wolves, cats, bears, hyaenas, etc., salutatory (jumping) such as rodents, rabbits, wallabies, kangaroos, etc., or graviportal (heavy) such as turtles, armadillos, elephants, hippopotami, etc., exhibit different kinds of adaptations for different kinds f soils. Fore example, if the soil is firm and hard, the large animals inhabiting the ecosystem tend to have small hooves or paws; if the soil is wet and spongy, they tend to have broad hooves or paws.

2.5 Biological Effects of Light:

The radiant energy from the sun is the basic requirement for the existence of life on the earth. This source of energy is of fundamental importance to the photosynthetic production of food by plants and as mentioned previously, the heat budget of the world is dependent on solar radiation. Although we generally, think only in terms of visible light, the sun emits other radiations of different wavelengths- cosmic rays, gamma rays, X-rays, ultraviolet rays, infra-red rays, heat waves, spark discharges, radar waves, radio waves, slow electro-magnetic waves. Biologists have been primarily interested in only three regions near the centre of the electromagnetic spectrum- (1) the infra-red, (2) the visible light and (3) ultraviolet regions. The infra-red wavelengths, which are the longest of these three, are not visible to the human eye; they contribute to the warmth of the earth at the high altitudes in the terrestrial atmosphere. Visible light, is only a small fraction of the radiation spectrum and contains the frequency of wave-spectrum and contains the fraction of wavelengths ranges from 390 to 700 millimicrons (mµ). It is made up of a series of colours ranging from violet through indigo, blue, green, yellow, orange and red, all constituting the visible spectrum. Light energy, thus, reaches the earth as electro-magnetic waves of solar radiation with tremendous velocity and supplies most of the warmth the earth receives from the sun and also supplies the main source of energy which is utilized in photosynthesis of plants, oriented and rhythmic behaviour of animals, bioluminescence, periodicities of occurrence and periods of inactivity. Unlike temperature light is a non-lethal ecological factor and it has a specific direction in its flow. The wavelength of ultraviolet light from the sun is shorter than that of visible light, and it produces the upper levels of the earth known as the ionosphere.



2.5. 1 Light Receptors of Animals:

Since animals depend on light for orientation, diurnal migrations and synchrony or rhythmic activities, light reception probable is the most important sensory modality in the exploration of the environment. It is not surprising, therefore, the receptors for light are common to almost all animals; in those with better developed photoreceptors, light greatly influences behaviour. Light receptors may be will-defined organs such as the vertebrate eyes, the compound eyes of Crustacea and insects, the simple eyes or ocelli of other arthropods and invertebrates , and the dermal light receptors.

Many homoeothermic animals with normal vision do not commonly respond to ultraviolet or infra-red rays, since their retinas are not stimulated. They also do not properly distinguish between the different colours of the visible spectrum. Dogs, cats, hamsters and opossums are colour blind, while horned cattle cannot identify red light. Horses, deer, sheep, pigs and squirrels cannot distinguish close to red and green. Primates can distinguish colours. Some insects such as honey bee can see ultraviolet radiation.

2.5. 2 Light Variations in Different Environments:

Light energy varies with different media. The transparency of air and water is important in intensity of regulating the amount and quantity of light that may be available in particular habitats. For example, the intensity of light reaching the earth's surface varies with the angle of incidence, degree of latitude and altitude, season, time of day, amount absorbed and dispersed by atmosphere and a number of climatic and topographical factors such as fog, clouds, suspended water drops, dust particles, etc., when the angle of incidence is smaller, light rays have to travel by a longer distance through the atmosphere, which results into relative reduction in intensity. Likewise, sun's altitude changes due to differences in latitude, changes in the season and in the time of day. When sun remains overhead, the intensity of sunlight over the earth's surface will be greatest. At higher latitudes the intensity of light becomes correspondingly reduced. The illumination or intensity of day light is greatly diminished by moisture, clouds, and dust in the atmosphere and also by forest vegetation. The direction and slope of the mountain also affect light intensity. There will be no light on the one side of the slope. Illumination is measured in lux or foot candle. One foot candle is 10.7 lux. One lux is equal to one lumen per square meter. A lumen is equal to 1/620 watt. Most organisms respond to moonlight particularly on a full moon, which has an illumination of 0.25 lux in cloudless weather.

The light which enters in the aquatic media, comes from sun by passing through the atmosphere existing above the water surface and, hence, that is subjected to all kinds of atmospheric factors like that of terrestrial media. About 10% of the sunlight which falls over the water surface, is reflected back and rest 90% of that pass downward in the water and is modified in respect to intensity, spectral composition, angular distribution (refraction) and time distribution. The phytoplankton, zooplankton, suspended organic and inorganic particles either reflect or absorb the light rays. Further in water there is a selective absorption of light at various depths. The longer light rays are absorbed near the surface and in general the shortest light rays penetrate deepest. Thus long infra-red rays are absorbed in the upper layers of water (about 4 metres); red and orange rays are completely absorbed up to the depth of 20 metres; yellow rays penetrate up to 50 metres and green and blue rays penetrate up to 80 to 100 metres deep. Depending upon the penetration of light, oceans are divided into euphotic zone (up to 50 metres depth), disphotic zone (up to 80 to 200 metres depth) and aphotic zone (above 200 metres of depth). In the ocean, algae are distributed according to length of light rays that their colours are best suited to absorb and to utilize. Photosynthesis in deeper waters occurs with blue and green rays, which are absorbed by the brown and red pigments of red algae (Phyllophora). The red and blue-green algae use pigments of phycocyanin and phycoerythrin for photosynthesis. Each plant performs optimum photosynthesis in complementary colours e.g. green pigment for red rays, brown pigment for green rays and red pigment for blue rays. Further, since the photosynthesis is a function of the illumination, a variation in the amplitude of which depends on the earth's rotation, altitude, season, presence or absence of clouds and dust and so on.

2.5.3. Effect of Light on the Plants:

Light energy influences almost all the aspects of plant life directly or indirectly. Thus, it controls plant's structure, form, shape, physiology, growth, reproduction, development, local distribution, etc. On the basis of light factor certain ecologists have classified plants into sciophytes, Shade loving, or potophobic plants which have best growth under lower intensities of light, and heliophytesiorprhotophilous plants which have best growth in full sunlight. The light factor affects following aspects of plant life.

2.5.3.1. Direct effects of light on plants:

Light affects directs the following physiological processes of the plants-1. It is an essential factor in the formation of chlorophyll pigment in chlorophyllous plants. 2. It has a very strong influence on the bumbler and position of chloroplasts. The upper part of the leaf which receives full sunshine has large number of chloroplast which are arranged in line with the direction of light. In leaves of plants which grow under shade, chloroplasts are very few in number and are arranged at right angle to the light rays, thus, increasing the surface of light absorption. 3. Light has its most significant role in photosynthesis. During photosynthesis, the green plants which are the “primary producers” of an ecosystem, synthesize their carbohydrate food from water and CO2 in the presence of sunlight. Thus, during photosynthesis, the solar radiant energy is transformed into the chemical or molecular energy which remains stored in chemical bonds of carbohydrates and this chemical energy is utilized by other chlorophyllousnad non-chlorophyllous parts of plants, all animals, bacteria and viruses in their different life activities. The rate of photosynthesis is greater in intermittent light than in the continuous light. At high intensity of light a photo-oxidation of chloriophylls and other enzymes takes place, which consequently reduces the rate of synthesis of carbohydrates and proteins. However, high intensity of light results in the formation of anthocyanin pigments. It is for this reason alpine plants have beautifully colored flowers. 4. Light inhibits the production of auxins or growth hormones as a result of which it influences the shape and sizes of plants. Plants grown in insufficient light or in the totaldarkness, produce maximum amount of growth hormones, as a result of which they are elongated with weak pale yellow stems with very few branches. 5. Light also influences certain chemical compounds of plants which affect the differentia to of specialized tissues and organs. 6. Leaf structure too is influenced by the intensity of light. 7. The development of flowers, fruits and seeds is greatly affected by light intensity. Diffused light or reduced light promotes the development of vegetative structures and causes delicacy. For example, vegetative crops such as turnips, carrots, potato and beets give highest yield in regions with high percentage of cloudy days. Intense light favors the development of flowers, fruits and seeds. 8. Duration of light is also very important. Actual duration or length of the day (photoperiod) is a significant factor in the growth and flowering of a wide variety of plants. The controlling effect of photoperiod is called photoperiodicity. According to the response to length of photoperiods, the plants have been classified into following three groups:

Short day plants. Which bloom when the ligh duration is less than 12 hours per day e.g., Nicotianatabacum (bobacco), Dalia variabilis, Chrysanthemum indicum, Cosmos bipinnatus, Cannabis sativa (hemp), etc.

Long day plants. Which bloom when the light duration is more than 12 hours per day, e.g., Allium cepa (onion), Beta vulgaris (beet root), Daucuscarota (carrot), Papaversomniferum (opiumpoppy), Viciafaba (broad bean), Brassica rapa (turuip), Avenasativa (oat), Secale cereal (rye), Sorghum vulgare (sorghum), etc.

Day neutral plants. Which show little response to length f day light, e.g., Cucumissativus (cucumber), Gossypiumhirsutum (cotton), Solanumtuberosum (potato), etc.

9. Light also affects the movement in some plants. The effect of sunlight on the plant movement is called heliotropism or phototropism. The stems elongate towards light (positive phototropism) and the roots are negatively phototropic. The leaves grow transversely to the path of light. 10. The seeds when most are very sensitive to light. In some cases the germination of seeds is delayed in light. 11. Light is an important factor in the distribution of plants. Some plants grow in full sunlight, while others prefer to grow in the shades.

2.5.3.2. Indirect effects of light on plants:

Light affects opening and closing of stomata, influences the permeability of plasma membrane and has heating effect. All these in turn affect transpiration which in turn affects absorption f water. Light affects respiration of plants indirectly, as in the presence of light the respiratory substrates are synthesized. In many plants the respiratory rate increases with the increase in the light intensity (e.g., Canna, Nerium, Bougainvillea). However, in certain plants respiration rate is decreased slightly intense light.

2.5.4Effects of Light on Animals:

Light affects divergent aspects of animal’s life. It influences cellular metabolism, growth, pigmentation, locomotion, reproduction, ontogenetic development, and also controls the periodicity and biological clocks of animals. Some of its significant effects can be discussed as follows:

2.5.4.1. Effect of light on protoplasm:

Thought the bodies of most animals remain protected by some sort of body covering which save animal tissues from the lethal effects of solar radiations. But, sometimes sun rays penetrate such covers and cause excitation, activation, ionization and heating of protoplasm of different body cells. Ultraviolet rays are known to cause mutational changes in the DNA of various organisms.

2.5.4.2. Effect of light on metabolism:

The metabolic rate of different animals is greatly influenced by light. The increased intensity of light results in an increase in enzyme activity, general metabolic rate and solubility of salts and minerals in the protoplasm. Solubility of gases, however, decreases at high light intensity. Cave dwelling animals are found to be sluggish in their habits and to contain slow rate of metabolism.

2.5.4.3. Effect of light on pigmentation:

Light influences pigmentation in animals. Cave animals lack skin pigments. If they are kept out of darkness for a long time, they regain skin pigmentation. The darkly pigmented skin of human inhabitants of the tropics also indicate the effect of sunlight onskin pigmentation. The skin pigment's synthesis is dependent on the sunlight. Light also determines the characteristic patterns of pigments of different animals which server the animals in sexual dimorphism and protective coloration. Animals that dwell in the depths of the ocean where the environment is monotonous, though pigmented do not show patterns in their coloration.

2.5.4.4. Effect of light on animal movements:

The influence of light on the movement of animals is evident in lower animals. Oriented locomotory movements towards and away from a source of light is called phototaxis. Positively phototactic animals such as Euglena, Ranatra, etc., move towards the source of light, while, negatively phototactic animals such as planarians, earthworms, slugs, copepods, siphonophores, etc., move away from the source of light.

The light directed growth mechanisms are called phototropisms which occur in sessile animals. Phototropisms also include responsive movement of some body part of some active animals to the light stimulus, such as the movement of flagellum of Euglena towards light and movements of polyps of many coelenterates.

The velocity or speed of the movement of certain animals is also regulated by light. It has been observed that animals when responding to light reduce their velocity of movement and these movements which are non-directional are called photokinesis. Photokinesis may be a change in linear velocity (rheokinesis) or in the direction of turning (klinokinesis). During photokinesis when only a part of the body of an animal deviates away from the source of light, the reactions termedphotoklinokinesis. Larvae of Muscadomestica show such movements. When animals are confronted with two lights of equal brightness they move towards or away to a position that is distanced between the two lights. This is termed phototropotaxis. Attraction of males towards the flash of the female is called telotaxis. Movement of animals at a constant angle towards the source of light is called light compass reactionor celestial orientation.

2.5.4.4.1. Celestial orientation:

Some organisms, particularly arthropods, birds and fish, utilize their time sense as an aid to find their way from one area to another. To orient themselves, the animals use the sun, moon, or stars as a compass. To do this, they utilize both their biological clock and observation on the azimuthal position of the sun in relation to an established direction. The azimuth is the angle between a fixed line on the earth's surface and a projection of the sun's direction the surface. Using the sun as a reference point involves some problems for animals because the sum moves. The target angle changes throughout the day. But animals which use the sun as a reference, correct their orientation somehow. Such celestial orientation has been observed in fishes, turtles, lizards, most birds, and such invertebrates as ants, bees, wolf spiders and sand hoppers.

2.5.4.5. Photoperiodism and biological clocks (Biorhythms):

During evolution, organismshve acquired a variety of endogenous rhythms, their periods are matched with the rhythmic events in the environment. A rhythm is a recurring process which is wave like in character, because maximum and minimum states appear at identical intervals of time. The time taken between two maxima (peaks) or two minima (troughs) is called a period or cycle and consists of two phases, a rise and fall in the biological process. The amplitude is the range of fluctuations from an average value. The response of different organisms to environmental rhythms of light and darkness is termed photoperiodism. Each daily cycle inclusive of a period of illumination followed by a period of darkness is called the photoperiod. The term photophase and scatophaseare sometimes used to denote the period of light and the period of darkness respectively.

Some rhythms of orgaisms are matched to 24 hours cycle of light and dark (circadian), other to the 12.4 or 24.8 hours tide cycle (circatidal), the 29 days lunar cycle (circalunar or circasynodic), the yearly seasons (circanular) or the time between successive spring low waters (14.7 day; semilunar or cirecasyzygic). prefixing word circa (which means about) with most typesof biological rhythms is very necessary because all these internal clocks are only approximately matched, e.g., 24 hours cycle or rhythm does not mean 24 hours by wrist watch, it means about 24 houror circadian (L.rirca=about+di(em)=day). This term was coined by an American ethologist Franz Halberg in 1959.

Now it is believed that all animals (and also plants) possess an internal (endogenous), and automatic clock that controls the rhythm of behavior and keeps it going with the help of internal stimuli. This clock is entrained (i.e., set and reset) by external environmental stimuli, called zeitgebers or entrainers such as day length, lunar phases, tides, temperature, humidity, etc. The biological clocks sow following general characteristics: 1. They keep almost the same timings at high and low temperatures. i.e., they are unaffected by metabolic inhibitors which are known to block biochemical reaction. 3. They are controlled by thephysiological processes of body. 4. They keep normal cycle even in the absence of environmental cues and are self sustained in nature. 5. They function through nerves (brain) and hormones.

2.5.4.5.1 Types of biorhythms:

2.5.4.5.1.1Circadian rhythms:

Operating on an approximately 24-hour day-night cycle of the earth's rotation, they are the most studied and well understood biological clocks or biorhythms. They are found in almost all the major taxonomic groups of animal kingdom. In their simplest form, circadian rththms are reflected in the alternating periods of activity and sleep which correlate with the light / dark cycle. In this cycle some animals remain most active at sunrise and sunset times, such animals are known as crepuscular, some animals are active during the night (nocturnal) but most animals are active during the day tme, tey are called diurnal. In the diurnal rhythm, the animal activity stage includes small cycles of flitting, flying, running and rest. Among plants showing diurnal rhythm, the flowers of some plants openup before the break of dawn (e.g., at 4 to 5 a.m. in Dogrose, Chicory and Poppy) and in some others, with the onset of dusk (e.g., evening primrose, matronalis, etc.) In fact, when a flower closed up, it does so to protect its inner organs from the cold of the night and against extra moisture. In the day, flowers open up for pollination under most favorable conditions. Such periodic change in the position of the organs (viz, petals and leaves) is called sleep. Such sort of movements of plant organs are called nyctinastc movements. Circadian rhythms also have been observed in metabolic rates, cell division, growth, heartbeat, rate of photosynthesis, cellular enzyme activity and a host of other activities.

2.5.4.5.1.2Circatidal rhythms:

The biological rhythms synchronized with the low and high tides (i.g., the alternate rise and fall of the sea due to gravitational pull exerted by moon) in the sea are called circatidal rhythms. Thus, the organisms living in the intertidal zone of the sea shore are alternately submerged in water and exposed to air and in doing this, these animals become exposed to various ecofactors such as pressure, salinity, food supply, temperature and risk of predation. Animals inhabiting tidal areas show behavioural periodicity associated with the tides, for example, bivalve molluscs (e.g., pearl oysters) increase filteration rates when high tide brings in more food and sea anemones increase the rate of body expansion and contraction during high tide, waving its tentacles actively to trap more food.

2.5.4.5.1.3Circalunar rhythms:

Biological rhythms which are synchronized with the phases of moon are called circalunar rhythms. For example, amarinepolychaetePlatynerisdumeri is a long worm-like non sexual creature which lives in a burrow. During its breeding season, this seaworm becomes brilliantly colorful, gets bigger in size, its parapodia, eyes and tentacles also get enlarged and it becomes a sexual form called heteronereis. Many Heteronereis swarm actively at sea shores during the full moon, perform nuptial dance and spawn.

2.5.4.5.1.4 Semilunar rhythms:

The biological rhythms which are synchronized with the fortnightly cycle of spring tide (i.e., high tide occurring a day or two after the new or full moon) and heap tide (i.e., low tide which occurs in the middle of the second and fourth quarters of the moon) are called semilunar rhythms. For example, the gastropod mollusc periwinkle, Littorinarudis shows a marked 14.5 day periodicity in its locomotory activity; the species lives high up on the shore and is only covered by the high water of spring tides, when it comes out of its burrow to move around and to feed.

2.5.4.5.1.5Circannual rhythms:

The activity of some animals and plants is influenced by the seasons occurring once in a year. They show circannual rhythms. For example, for most birds the height of the breeding season is the spring; for the deer the mating season is the fall. Likewise, brook trout spawns in the fall: bass and blue gills in late spring and summer. Many animals have a part of their life in the resting stage when they exhibit reduced metabolic activity. They either hibernate, aestivate or migrate from the place to avoid rig ours of temperature. Migratory birds undertake long distance migrations every year and show cyclic changes in their body weight, gonad size, plumage and coloration. The larvae of many insects (e.g., parasitic wasp, flesh fly, etc.) how two phases every year (i) active (when the insect does work actively) and (ii) inactive or diapause (a period of arrested growth and development in insects which is under the control of endocrine system. This is an adaptation to avoid adverse conditions.

2.5.4.5.1.6 Mode of function of biological clocks:

It is believed that in the course of evolution, DNA evolved the biological clock regulating growth, cell division, diurnal rhythmicity of metabolic processes and finally the activity pattern of organisms. Biological clocks show ecopysiological integrity of the DNA cell/organism; the evolutionary mechanism has brought stability to these clocks through the heredity.

It is hypothesized that the intracellular (=endogenous) clocks are located in the nucleu of the cell and can be compared with a spring which is tightened in one phase and gradually released in another phase without ever reaching a zero level. Oscillatory motion occurs between the winding (tension) and unwinding (relaxed) phases. The winding of the spring requires energy, which is received in plants from reaction initiated by light and in mammals from oxidation and reduction reactions. Many biochemical studies suggest that in the spring model, the winding phase corresponds to the synthesis of RNA and enzymes and unwinding phase to the breakdown of proteins in the cytoplasm. Such ahypothesis may work well in case of unicellular organisms, but in the case of multi cellular and complex organisms various processes occur simultaneously in different tissues and organ systems. It appears that in them a central mechanism may operate through the genes-hormones-organ systems.

Recent findings suggest that in invertebrates both neural and neuroendocrine products (hormones) are responsible for biological rhythms. In higher vertebrates, the central regulation of rhythms is largely performed by the hypothalamus-pituitary complex which is genetically controlled and influenced by environmental factors such as photoperiod. For example, in birds and mammals, the pineal gland receives light stimuli and entrains to show biological rhythms. In amphibians, reptiles and birds the pineal gland is located under the skull but in some terrestrial forms of vertebrates, it is placed over the brain in the form f the third eye. The information of potoperiod is received first by the eye and then via neural pathways reaches the pineal body which secretes hormones such as melatonin (Reiter, 1980) which has antigonadotropic effects in various organisms such as rats, mice and many other mammals. Melatoninisbelieved to pass to the anterior pituitary gland and decrease secretion of gonadotropic hormones (see Guyton and hall, 1996). Pineal body partly controls circannual rhythms of reproduction. In case of turtles, serotonin is synthesized during the day whereas melatonin during the night but this mechanism is completely lost during hibernation period.

2.5.4.6. Effect of light on reproduction:

In many animals (e.g., birds) light is necessary for the activation of gonads and in initiating annual breeding activities. The gonads of birds are fond to become active with increased illumination during summer and to regress during shorter periods of illumination in winter.

2.5.4.7. Effect of light on development:

Light in some cases e.g., Salmon larvae) accelerates development, whereas, in other (e.g., Mytilus larvae) it retards it.

Further, occasionally the output of sunlight is increased by the development of sunspots. A sa result of this excess energy is radiated to space and this naturally increases the output of solar energy near the earth. A direct consequence of this is the greater evaporation of water which results in cloud formation to prevent more exposure to sunshine and thus to equalize temperature and modify climate.

2.6 Temperature:

Temperature is one of the essential and change and environmental factor. It penetrates into every region of the biosphere and profoundly influences all forms of the life by exerting its action through increasing or decreasing some of the vital activities of organism, such as behavior, metabolism, reproduction, ontogenetic development (Viz., embryogenesis and blastogenesis) and death. Temperature is a universal influence and is frequently a limiting factor for the growth or distribution of animals and plants. Normal life activities go on smoothly at a specific temperature or at a specific range of temperatures. This is called the optimum temperature or the optimum range of temperature. Organisms react to any rise or fall of the optimum temperature range and biotic communities more often encounter alterations only due to extremes of temperature (viz., minimum or maximum temperatures). The interaction of temperature with certain other abiotic environmental factors such as humidity, etc., cause into many other climatic changes which influence the living organisms in one way or another.

2.6.1 Nature of temperature

Temperature is a measure of the intensity of heat in terms of a standardized unit, and is commonly expressed as degrees on either the Fahrenheit or Celsius scale. Heat is a form of energy, and as such is necessary for the very existence of life. Heat may be received or lost by animals as molecular vibrations transmitted from one part of an environment to another by radiation, convection, or conduction. It may be received as radiant energy, of course largely from the sun. Heat may be produced by mechanical work as in Hawk moth, the heat is generated by wings before take-off; or by chemical reactions.

2.6.2 Heat Budget

The temperature at the earth's surface is governed by the brightness of the sun; the constancy of brightness of sun has remained virtually unchanged for about 3 billion years. In fact, average terrestrial temperatures now probable do not differ radically from those at the earth's beginning (Schwarzschild, 1967). The total amount of heat entering the biosphere from the sun must balance the amount lost per unit time if temperatures are to remain unchanged, since the flow of geothermal heat from the interior of the earth is small by comparison and probably has been negligible for at least the past 500 million years. The estimate of this energy flow is referred to as the heat budget (Vernberg and Vernberg, 1970). Heat budge has been projected for the total surface of the earth as well as for special environments.

2.6.3 Temperature Stratification

Environmental temperatures fluctuate both daily and seasonally. Different environments such as freshwater, marine and terrestrial environments are subjected to varied responses to fluctuating temperature. Temperature fluctuations are comparatively less in the aquatic environment than in the terrestrial environment. The increases in depth of aquatic medium often increase the temperature fluctuations. There exists a distinct difference in the response of living organisms of the freshwater and sea to temperature fluctuations because of the presence of dissolved salts in sea water. The minimum temperature in the sea is 3ºC, while in freshwater pond it never goes below 0ºC. The maximum temperature of ocean generally goes up to 36 ºC, but in shallow pools of freshwater and tide of pools littoral zone, temperature may go higher. In deeper bodies of water, heating and cooling are restricted to the surface strata. But the deer layers also get a lot of heat as a result of what is usually termed vertical circulation, where in, due to circulatory movement of water, surface water are brought to the deeper regions, and vice versa. Studies on the vertical changes of temperature have led to the hypohthetical classification of the freshwater media into three strata. The superficial layer of freshwater is constantly stirred by wind and is called epilimnion. It is the layer of warmer water and its temperature may rise up to22 ºC during summers. The stagnant water of the bottom constitutes the hypolimnion. The hypolimnion has temperature of 5 ºC to 9 ºC. In between epilimnion and hypolimnion occurs an intermediate zone called thermocline or metalimnion, which has rapid vertical temperature changes. During winter, the temperature of epilimnion of freshwater lake becomes 0 ºC and the lake becomes ice covered. The process of differentiation of freshwater habitat into these three strata is called thermal stratification.

In the terrestrial environment the seasonal and daily fluctuations in temperature are varied and marked. The lowest temperature recorded for any land mass is - 70ºC (Siberia in 1947). Higher temperatures may likewise go often 85ºC as in certain deserts at noon. However, the water in hot springs and geysers may approach 100ºC, and even higher temperatures occur occasionally in the very special situation presented by volcanic areas. In Rajasthan the highest temperature exceeds 50ºC. On land, diurnal variations of temperature are quite staggering. The fluctuation between day and night temperatures may be 17ºC as in ordinary land masses or 40ºC as in deserts. The Desert of South Rajasthan (India) shows a diurnal range of 20-30ºC for all seasons. Differences in latitudes often cause variation in the annual temperature cycles with visible effects of the organisms. Further, with the increased altitude for every 150 meters, the decrease in temperature of 1 ºC takes place.

2.6.4 Range of Temperature Tolerance

Life in this universe exists within a range of -200 to 100ºC. Though normal life persists within narrow temperature limits of about-10 to + 50ºC. Individual species survive in a smaller range and are active within even narrower limits. Many nematodes, rotifers and tardigrades have shown to withstand cooling to -272ºC without ill effects. Larvae of chironomids and certain other Diptera have been found to thrive at temperatures near 55ºC. Praying mantis is reported to live in hot bare grounds at a temperature of 62ºC in deserts. Some algae and bacteria are reported to live in hot springs at 88 ºC. Non-photosynthetic bacteria inhabiting hot springs can actively grow at temperatures greater than 90ºC (Bott and Brock, 1969). On the other land, some arctic algae can complete their life cycle in places where the temperatures barley rise above 0ºC. Further, the eggs of the acanthocephalan Macracanthorhynchushirudinaceus have been known to withstand temperatures from – 10 to 45ºC for about 140 days, and desiccation at temperature up to 39ºC for a period of 265 days.

The organisms (microbes, plants and animals) which can tolerate very large fluctuations in temperature are called eurythermal organisms. For example, Cyclops, toad, wall lizard, grass snake, man, etc., are the eurythermal animals. The organisms which can tolerate only a small variation in temperature are termed stenothermal organisms. The common stenothermal animals are fishes, snails, coral reefs, etc. In organisms all metabolic processes necessary for life start at a certain minimum temperature and increase with rise in temperature until they reach the maximum level at a temperature called optimum temperature. Further rise in temperature beyond optimum brings about decrease in metabolic rate, until it ceases at a temperature called maximum temperature.

Thus, the favorable temperature range for any particular species is determined by the prevailing temperature at which normal physiological activities of the animals take place, as in the distribution of the rotifer Keratellaprocura (Nayar, 1970). This rotifer species is known to appear in the ponds of Pilani, Fajashthan (India), when the temperature is below 24ºC and to disappear when it rises above 24ºC, the frequency of distribution reaching a peak during months of October to March, with the fall in temperature.

2.6.5Poikilotherms and Homeotherms

An animal's response to wide ranges in temperature is influenced by its physiology. All invertebrates, lower chordates (hemichordates, urochordates and cephalochordates), cyclostomes, fishes, amphibians and reptiles have no internal mechanism for temperature regulation, and their body temperatures vary with the surrounding environmental temperatures. Such animas are called cold blooded, ectothermic or poikilothermic organisms. The temperature range that a poikilothermic animal tolerates can be correlated closely with the environmental temperatures normally encountered in nature: tropical animals cannot withstand low temperatures; polar animals cannot withstand high temperature; temperate-zone animalssurvivea wide temperature range. Many poikilothermic animals show a rather precise discrimination of temperature. If the temperature decreases or increases appreciably, these animals may tolerate and adjust to change, may avoid the change by seeking a less exposed environment or may become inactive. Some animals respond by becoming dormant during periods of extreme temperatures. Such dormancy is called aestivation at high temperatures and hibernation at low temperatures. For example, most poikilotherms become inactive when the temperature of their surroundings goes below 8ºCor rises to 42ºC.

A few exceptional pokilotherms, especially insects, certain amphibians and reptiles, exercise a degree of thermoregulation by either physiological or behavioral mechanisms. For example, Hawk-moths can rise the temperature of their flight muscle to 32ºC - 36ºC by vibrating the wings before take-off and gregarious butterfly larvae any raise their temperature 11/2-2ºC when clustered together. Locust, and grasshoppers may increase their temperature 10ºC by basking, sideways in the sun. Ants move their larvae to warm or cool places within the nest and bees maintain temperatures within their hives between 13ºC and 25ºC by fanning with their wings to evaporate water droplets when it is too hot, or releasing body heat through increased metabolic activity, when too cold.

When temperature drops, lizards bask in the sun to achieve the desired body temperature; once this thermal level is attained, they will divide their time between sun and shade to maintain it. Poikilotherms such as desert dwellers that live in environments where the temperature is apt to be very high are often nocturnal and, thus, avoid the highest temperatures of the day. Some poikilotherms, both vertebrates and invertebrates, lower their body temperatures slightly by evaporative cooling. In frogs and reptiles, evaporative cooling can occur through the skin or via the respiratory tract by panting (Warburg. 1967). Among the invertebrates, evaporative cooling has been reported in tropical intertidal-zone animals (Lewis, 1963).

In contrast to poikilotherms, birds and mammals can, within limits, maintain constant body temperatures, regardless of temperature variations of air and water. Such animals are termed warm blooded, homeothermic or endothermic animals. The life processes are adjusted to function at the animal's normal temperature, averaging a little less than 38ºC in mammals and 3 to 4ºhigher in birds.

If its temperature control fails, the animal dies. The homeothermicanimals are able to maintain the constancy of body temperature by a combination of several factors: (1) a thermoregulationcenter in the brain (hypothalamus) (2) insulation (3) a peripheral vascular response to ambient temperature; and (4) metabolic compensation.

Among these factors, insulation is highly important particularly in enabling large arctic animals to withstand very low temperature. If the temperature is lowered, the oxygen consumption rate of tropical mammals increases, whereas that of arctic mammals remains basal. This response patter is due to differences in insulation; some arctic animals are fur-insulated, whereas other are insulated with la layer of blubber. Many small animals, however, are not well insulated and must seek heat retention by other means, often by huddling together.

Homeothermic animals living in very hot environments cannot tolerate greatly elevated body temperatures and they utilize methods that facilitate heat transfer to the environment, including an increased peripheral blood flow and surface cooling by sweating or painting. Birds may accomplish this by rearranging their plumage so that more skin is exposed. There is however, no reduction in metabolic rate. Animals subjected to high temperature may exhibit diurnal patterns of behavior-that is, they may reduce locomotors activity during the heat of the day or may move into the shade to avoid direct sunlight. Some animals such as monodramas and marsupials have a limited power of temperature regulation; they are calledheterothermic animals; e.g., the pigmy mouse and the little pocket mouse, which respond to temperature extremes by a estivating or hibernating, and others such as the humming bird, which experience a nocturnal drop in temperature.

Plants too can be divided into the following three categories on the basis of their heat tolerating capacity: megatherms, microtherms and mesotherms. Megatherm plants occur in warm habitat (e.g., desert vegetation). Microtherm plants occur in cold habitat, (e.g., plants of high altitudes). Mesotherm plants are the plants of the habitat which is neither very hot nor very cold (e.g., aquatic plants). Hekistotherms include alpine vegetation which tolerates very low temperatures.

2.6.6. Factors or Variables Affecting Organismal Response to Temperature

The response of an organism to temperature is affected by a number of factors such as thermal history, genetic differences, diet, size, stage in life cycle, sex, molting, parasitism, hormones, etc.

1. Generally, animals found in warmer environment can withstand higher temperatures than animals from colder situations. It is also generally true that animals from coldr environments tolerate lower temperatures better than those from the warmer climates. These differences between warm-climate and cold-climate populations may reflect basic genetic differences or may be phenotypic expressions resulting from different thermal histories. 2. The thermal resistance of a species may be closely identified with the genetic composition of the parent stock, as illustrated by hybrid development in two anuran species, Bufovalliceps and B.luetkeni (Ballinger and Mckinney, 1966). The lower lethal temperature for development of B.valliceps is 18ºC; for B.luetkeni, 22ºC. In their hybrid the lower lethal limit is found to be in between that of the two parents at 19.5ºC. 3. In some animals a relationship between the total intake of food and resistance to thermal stress has been demonstrated. Some species are more sensitive to elevated temperatures when they are starved for even short periods of time. Goldfish showed increased resistance to high temperature when placed on a high fat diet (Hoar and Cottle, 1952). 4. The size of animal body is found to have some correlation with thermal lethal limits of animals. In some species, the smaller animals are more resistant to higher temperatures than the larger ones; in some species the reverse is noted, and in other species size in not an apparent variable. Further, some smaller animals die faster at low temperatures than do larger animals of the same species, but at higher temperatures body size is not a factor. 5. Many species of animals have exceedingly complex life cycles during which the larval stages are not only morphologically dissimilar from the adult but also occupy different ecological niches. In the wharf crab, Sesarmacinereum, thermal

requirements of the planktonic zonal stages are different from those of adults because these larvae are limited to a smaller temperature range than are the adults. 6. The female sex is found to be more tolerant than males to the temperature fluctuations. 7. Among certain invertebrates, such as, in some crabs, molting adversely affected heat resistance, but had no effect on other species. 8. Mud-flat snails, Nassarius obsolete, which are heavily infected with trematode larvae (i.e., parasites) cannot withstand high temperatures like the non-parasitized snails. 9. Hormones have been shown to influence cold and warm resistance as well as acclimatization (viz,, temperature adaptation) to temperature, especially in mammals and a few other invertebrates.

2.6.7. Effect of Temperature on Plants and Animals:

Temperature has been found to affect the living organisms in various ways. Some of well-studied effects of temperature on living organisms are the following:

2.6.7.1 Temperature and cell:

The minimum and maximum temperatures have lethal effects on the cells and their components. If too cold, cell proteins may be destroyed as ice forms, or as water is lost and electrolytes become concentrated in the cells; heat coagulates proteins (Lewis and Taylor, 1967).

2.6.7.2 Temperature and metabolism:

Most of metabolic activities of microbes, plants and animalsare regulated by varied kinds of enzymes and enzymes in turn are influenced by temperature, consequently increase in temperature, up to a certain limit, brings about increased enzymatic activity, resulting in an increased rate of metabolism. For instance, the activity of liver arginase enzyme upon arginine amino acid, is found to increase gradually and gradually, with the simultaneous increase in the temperature from 17ºC to 48ºC. But an increase in temperature beyond 48ºC is found to have an adverse effect on the metabolic rate of this enzymatic activity which retards rapidly.

In plants, the absorption rateis retarded at low temperature. Photosynthesis operates over a wide range of temperature. Most algae require lower temperature range for photosynthesis than the higher plants. The rate of respiration in plants, however, increases with the rise of temperature, but beyond the optimum limit high temperature decreases the respiration rate. The rate of respiration become doubled (like in animals) at the increase of 10ºC above the optimum temperature, provided other factors are favorable (Vant Hoff's law). However, optimum temperature for photosynthesis is lower than that for respiration (Smith, 1974).

2.6.7.3 Temperature and reproduction:

The maturation of gonads, gametogenesis and liberation of gametes takes place at a specific temperature which varies from species to species. For example, some species breed uniformly throughout the year, some only in summer or in winter, while some species have two breeding periods, one is spring and other in fall. Thus, temperature determines the breeding seasons of most organisms.

Temperature also affects fecundity of animals. Fecundity of an animal is defined as its reproductive capacity, i.e., the total number of young ones given birth during the life time of the animal. For example, females of the insect, acrididChrotogonustrachypterus became sexually mature at 30ºC. The number of eggs decreased from 243 to 190 when the temperature was raised to 30-35ºC (Grewal and Atwal, 1968). Likewise, in grasshopper species Melanopussanguinipes and Camnulapellucida when reared at 32ºC produce 20-30 times as many eggs than those reared at 22ºC (see Ananthakrishnan and Viswanathan, 1976). On the other hand, the fecundity of certain insects such as cotton stem weevil (Pempherulusaffinis) was found to decline with an increase in temper4ature beyond 32.8ºC (Ayyar and Margabndhu, 1941).

2.6.7.4Temperature and sex ratio:

In certain animals the environmental temperature determines the sex ratio of the species. For example, the sex ratio of the copepod Macrocyclopsalbidu is found to be temperature dependent. As the temperature rises there is a significant increase in number of males. Similarly in plague flea, Xenopsyllacheopis, males outnumbered females on rats, on days when the mean temperature remains in between 21-25ºC. But the position becomes reverse on more cooler days.

2.6.7.5 Temperature and ontogenetic development:

Temperature influences the speed and success of development of poikilothermic animals. In general, complete development of eggs and larvae is more rapid in warm temperatures. Trout eggs, for example, develop four times faster at 15ºC than at 5ºC. The insect, chironomid fly Metriocnemushirticollis, requires 26 days at 20ºC for the development of a full generation, 94 days at 10ºC, 153 days at 6.5ºC, and 243 days at 2ºC (Andrewarthan and Birch, 1954). However, the seeds of many plants will not germinate and the eggs and pupae of some insects will not hatch or develop normally until chilled. Brook trout grows best at 16ºC, but the eggs develop best at 18ºC.

2.6.7.6. Temperature and growth:

The growth rate of different animals and plants is also influenced by temperature. For example, the adult trout’s do not feed much and do not grow until the water is warmer than 10ºC. Likewise, in the oyster Ostraeavirginica, the length of the body increase from 1.4 mm to 10.3 mm when temperature is increased from 10ºC to 20ºC. Sea urchin Echinus esculentus shows maximum size in warmer waters. Corals flourish well in those waters which contain water below 21ºC.

2.6.7.7 Temperature and coloration:

The size and coloration of animals are subject to influence by temperature. In warm humid climates many animals such as insects, birds and mammals bear darker pigmentation than the races of some species found in cool and dry climates. This phenomenon is known as Gloger rule. In the frog Hyla and the horned toad Phrynosoma, low temperatures have been known to induce darkening. Some prawn (crustacean invertebrates) turn light colored with increasing temperature. The walking stick Carausius has been known to became black at 15ºC and brown at 25ºC.

2.6.7.8 Temperature and morphology:

Temperature also affects the absolute size of an animal and the relative properties of various body parts (Bergman’s Rule). Birds and mammals, for example attain a greater body size when they are in cold regions than in warm regions, and colder regions harbor larger species. But poikilotherms tend to be smaller in colder regions. Body size has played a significant role in adaptation to low temperature because it has influenced the rate of heat loss. According to Brown and Lee (1969), larger wood rats have a selective and vantage in cold climates, apparently because their surface to air ratio and greater insulation permit them to conserve metabolic heat. For opposite reasons small-size animals are favored in deserts.

Further, the extremities of organism such as tail, ears and legs of mammals often appear to be shorter in colder climate (Allen's Rule). Mice reared at 31ºC to 33.5ºC have longer tails than those of the same strain reared at 15.5ºC to 20ºC. Moreover, the races of birds with relatively narrow and more acuminate (i.e., tapered to a slender point) wings tend to occur in colder regions, while those in warmer climates tend to be broader (Rensch's Rule). Temperature also influences the morphology of certain fishes and is found to have some relation with the number of vertebrae (Jordon's Rule). Cod which hatches off New Found land at a temperature between 4ºC and 8ºC has 58 vertebrae, while that hatches East of Nantucket at a temperature between 10ºC and 11ºC has 54 vertebrae.

2.6.7.9 Temperature and cyclomorphosis:

The relation between seasonal changes of temperature and body form is manifested in a remarkable phenomenon termed cyclomorphosis exhibited by certain cladocerans such a Daphnia during the warm months of summer. These crustaceans show a striking variation in the size of their helmet or heat projection between the winter and summer month (Coker, 1931). The helmet develops on the Daphnia head in spring, it attains its maximum size in summer and disappears altogether in winter to provide usual round shape to the head. Such a kind of cyclomophosis in the terms of size of the helmet is clearly showing a correlation to the degree for warmth of different seasons. These prolongation of the helmet have been interpreted as an adaptation aiding floatation since the buoyancy of water becomes reduced as the temperature increase (the buoyancy hypothesis). According to other interpretation (viz., stability hypothesis), the helmet acts like the rudder and gives greater stability to the animal. Besides temperature such structural polymorphism can be caused by other environmental factors including the food.

2.6.7.10Temperature and animal behaviour:

Temperature generally influences the behavioral pattern of animals. In temperate waters the influence of temperature on the behavior of wood borers is profound. For example, in the winter months in general, both Martesia and Teredo occur in smaller numbers in comparison with Bankiacampanulata whose intensity of attack is maximum during the winter months. Further, the advantage gained by certain cold blooded animals through thermo taxis or orientation towards a source of heat are quite interesting. Ticks locate their warm blooded hosts by a turning reaction to the heat of their bodies. Certain snakes such as rattle snake, copper heads, pit vipers are able to detect mammals and birds by their body heat which remains slightly warmer than the surroundings. Even in the dark these snakes strike on their prey with an unnerving accuracy, due to heat radiation coming from the prey. The arrival of cold weather in temperate zones causes the snakes to coil up and huddle together.

2.6.7.11Temperature and animal distribution:

Because the optimum temperature for the completion of the several stages of the life cycle of many organisms varies, temperature imposes a restriction on the distribution of species. Generally the range of many species is limited by the lowest critical temperature in the most vulnerable stage of its life cycle, usually, the reproductive stage. Although the Atlantic lobster will live in water with a temperature range of 0ºC to 17ºC, it will breed only in water warmer than 11ºC. The lobster may live and grow in colder water but a breeding population never becomes established there. Not only temperature effects on breeding in the geographical distribution but also temperature effects on survivalist (i.e., lethal effect of temperature), feeding, and other biological activities which are responsible in geographic distribution of animals. As noted earlier in this chapter, the animals from colder geographic regions are generally less heat tolerant and more cold tolerant than those animals from warmer regions; for example, members of Aurelia, a jelly fish from Nova Scotia die at a water temperature of 29ºC-30ºC, while Aurelia from Florida can tolerate temperatures up 38.5ºC. Thus, lethal limit of temperature may regulate the range of distribution of Aurelia.

Terrestrial invertebrates, particularly arthropods generally are distributed in all thermal environments where life is found. Many arthropods that have invaded the colder areas have one stage in their life cycle which is very resistant to cold, enabling them to over-winter until warmer weather returns (Salt, 1964). Birds and mammals are also adapted to live in nearly all thermal environments. The distribution of amphibians and reptiles, however, is limited to the relatively warmer thermal climates. Hock (1964) has listed three factors that limit the invasion of reptiles into cold environments: the daily ambient (=atmospheric) temperature must be high enough and long enough to allow breeding and to allow adults and young's to acquire food for "overwintering" and there must be adequate sites for hibernation.

2.6.7.12 Temperature and moisture:

The differential heating of the atmosphere resulting from temperature variation over the earth's surface produces a number of ecological effects, including local and trade winds and hurricanes and other storms, but more importantly it determines the distribution of precipitation.

2.6.8 THERMAL ADAPTATION OF PLANTS AND ANIMALS

Most animals and plants of different ecological habitats have developed various sorts of thermal adaptations during the course of evolution to overcome the harmful effects of extremes of temperature. Some of the significant thermal adaptations of plants and animals are the following:

2.6.8.1 Formation of heat resistant spores, cysts, seeds, etc.

Some of the animals and plants produce heat resistant cysts, eggs, pupae, spores and seeds which can tolerate extremes of temperatures. Amoeba in encysted conditions, can tolerate temperature below 0ºC. Similarly, rye seed remain active even at 0ºC and can germinate at that temperature. As an adaptation against frost the starch of plants changes to fats or oils in the autumn. The fatty oils diminish the freezing points and, thus, increase the power of resistance in plants against frost. Many leaves that grow in the coldest lands store fats. Pentose's mucilage and pectin substances which have high moisture retaining power are abundant in many plants. They decrease the danger of plants from desiccation during extremes of heat and save them from death.

2.6.8.2 Removal of water from tissue:

Dried seeds, spores and cysts avoid freezing because there remains no liquid in them that can freeze. Due to removal of water from seeds, the cold resistance of seeds of certain plants increases up to the extent that their exposure for 3 weeks to 190ºC, does not diminish their germinating capacity.

2.6.8.3 Dormancy:

Dormancy includes two already discussed phenomena namely hibernation and aestivation. During both kinds of dormancies metabolic rate becomes reduced, body temperature becomes low and heart beat rate is also reduced.

2.6.8.4 Thermal migration:

Thermal migrations occur only in animals. They journeys taken by animals that enable them to escape from extremely hot or cold situations are referred to as thermal migrations. For example, desert animals move to shaded places to avoid burring heat of noon and some animals such as desert reptiles and snakes become nocturnal to avoid heat of the day. The frogs, toads, other amphibians, turtles, etc., make short trips into or out of water (or moist places) and this provides desired cooling and warming to the animal.

Summary

In this chapter we studied about the abiotic factors of environment include the atmosphere, hydrosphere, water and lithosphere. The abiotic components are characterized by physical and chemical factors such as light, temperature, rainfall, pressure, pH, the content of oxygen and other gases and so on. These factors exhibit diurnal, nocturnal, seasonal, and annual changes. Biotic components include all living organisms which interact with each other and with the abiotic components. Earth's living organisms interacting with their physical or abiotic environment from a giant and vast ecosystem, called ecosphere or biosphere which is largest and most nearly self-sufficient biological system. Soil supports a wide array of organisms of different body-sizes and taxonomic groups. Generally, soil organisms are classified into three major groups namely micro-fauna and micro flora, meso- fauna, and macro-fauna. The radiant energy from the sun is the basic requirement for the existence of life on the earth. This source of energy is of fundamental importance to the photosynthetic production of food by plants and as mentioned previously, the heat budget of the world is dependent on solar radiation.

Check Your Progress:

1. Write a note on abiotic factors.
2. Note on climatic factors
3. Define edaphic factors

4. Explain Effect of light on protoplasm
5. Write essay on Poikilotherms and Homeotherms
6. Define Microfauna

UNIT III: THERMAL STRATIFICATION, CONCEPT OF LIMITING FACTORS, SHELFORD'S LAW OF TOLERANCE AND ECOTYPES- GRASSLAND AND POND ECOSYSTEM.

Structure

3.1 INTRODUCTION:

Study about the thermal stratification will be useful in understanding the strata level diversity of organisms which will be decided by the temperature of the strata. The concept of limiting factors and law of tolerance will be useful in understanding the distribution of organisms based on the limiting factors. The description of the components of grassland and pond ecosystem will depict the two different ecosystems and their components.

3.2 OBJECTIVES:

This unit is designed to make the learner;

- To know about Thermal stratification
- To understand the concept of limiting factors and law of tolerance
- To study about ecotypes viz., grassland and pond ecosystem

3.3 THERMAL STRATIFICATION:

The density of water is a function of its temperature. When water is warmer than 4°C it gets less dense for each increment in degree Celsius. This allows for thermal layering; where warmer water is stored on top of colder water – defined as "thermal stratification".

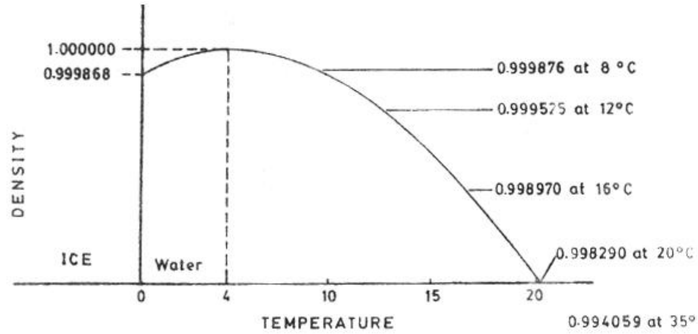


Figure – Density of water as a function of temperature

Thermal stratification is possible as water becomes less dense when heated; meaning water weighs less per unit volume. Therefore, warmer water will be lighter and colder water will be heavier. Due to this, there will always be a level of "self-induced" thermal stratification in water storage. However, this can be greatly disturbed by undesirable and uncontrolled water flows, which stirs the otherwise thermally separated layers together and mixes them into a uniform temperature.

3.3.1 Thermal Stratification of a Lake:

The thermal stratification of lakes refers to a change in the temperature at different depths in the lake, and is due to the change in water's density with temperature. Cold water is denser than warm water and the epilimnion generally consists of water that is not as dense as the water in the hypolimnion. However, the temperature of maximum density for freshwater is 4 °C. In temperate regions where lake water warms up and cools through the seasons, a cyclical pattern of overturn occurs that is repeated from year to year as the cold dense water at the top of the lake sinks.

Lakes in temperate latitudes exhibit marked seasonal temperature changes which may be described as follows:

3.3.1.1Winter:

During winter the coldest water forms ice at 0°C (32°F) and floats at the surface. The water at increasing depth below the ice is progressively warmer and denser. The heaviest water, at the bottom of the lake, has a winter temperature of 4°C and throughout winter the water remains relatively stable.

3.3.1.2 Spring:

Following the ice melt, the surface water gradually warms to 4°C. At this point the water column is nearly isothermal, i.e., all the water is of uniform temperature and density. Hence, the strong spring winds cause considerable stirring, which results in a complete mixing of water, dissolved oxygen, and nutrients from the lake surface to the lake bottom, a phenomenon known as the spring overturn or spring turnover As the spring progresses, however, the surface waters naturally become warmer and lighter than the water at lower levels, as a result, the lake becomes thermally stratified into the following three zones.

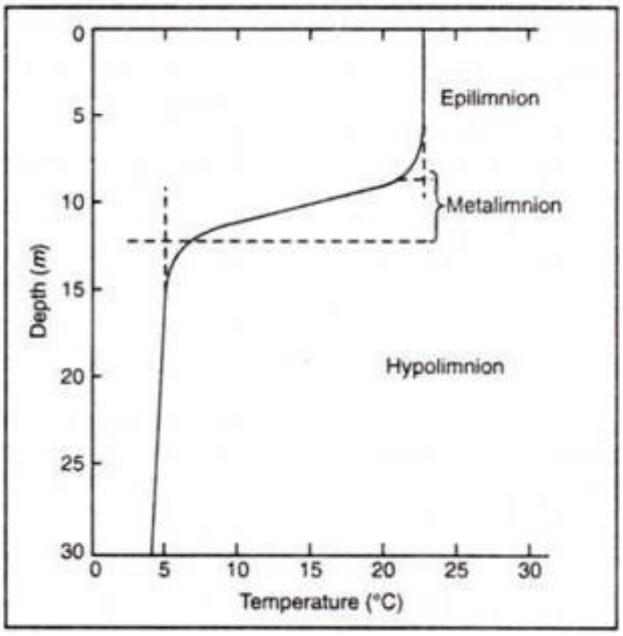


Figure – Typical thermal stratification of a lake into three strata

(a) Epilimnion: The upper stratum, which usually has the highest dissolved oxygen concentration and is characterized by a temperature gradient of less that 1°C per metre of depth, is the epilimnion (literally the "upon-lake" or the "upper lake"). This stratum contains more or less uniformly warm, circulating, and fairly turbulent water.

(b) Hypolimnion: The lower stratum of water characterized by a temperature gradient of less than 1°C per metre of depth is the hypolimnion (literally the "lake below" or "Bottom Lake"). This part contains more dense, cooler, and relatively quiet water.

(c) Metalimnion: It is the transitional stratum of marked thermal change between the epilimnion and hypolimnion. The middle layer of the lake, characterized by a temperature gradient of more than 1°C per metre of depth is the thermocline. The term thermocline refers to the plane or surface of maximum rate of decrease of temperature in the metalimnion.

The depth at which the thermocline forms is not fixed, being determined by the degree of solar heating, the transparency of the water, and the morphometry of the lake, but wherever it forms it effectively divides the lake into two layers, the upper epilimnion, and the lower hypolimnion. This division is not merely an interesting physical phenomenon but it has consequential effects on the ecology of the lake.

The epilimnion is well lit and oxygenated with sufficiently high temperatures to promote algal productivity and hence to support zooplankton and fish. When nutrients are in ample supply, algal growth is accelerated and blooms may occur. By contrast the hypolimnion is cold, dark and becomes progressively deoxygenated as the decaying remains of organisms sink down from the epilimnion.

Conditions in the hypolimnion may become so extreme that anoxia follows after which the biological productivity becomes least. Under less extreme conditions the epilimnetic material provides an energy source for benthic invertebrates. The sinking of dead algae and zooplankton from the epilimnion not only contributes to the potential deoxygenation of the hypolimnion but also prevents immediate recycling of nutrients. Nutrient depletion may become so high that algal growth is limited.

3.3.1.3 Summer:

Unless the lake is very clear and permits photosynthesis, the hypolimnion frequently becomes depleted of oxygen in summer because of the biological oxygen demand of bacterial decomposers, the reduced photosynthetic activity, and the minimal mixing with upper waters as a result of density differences.

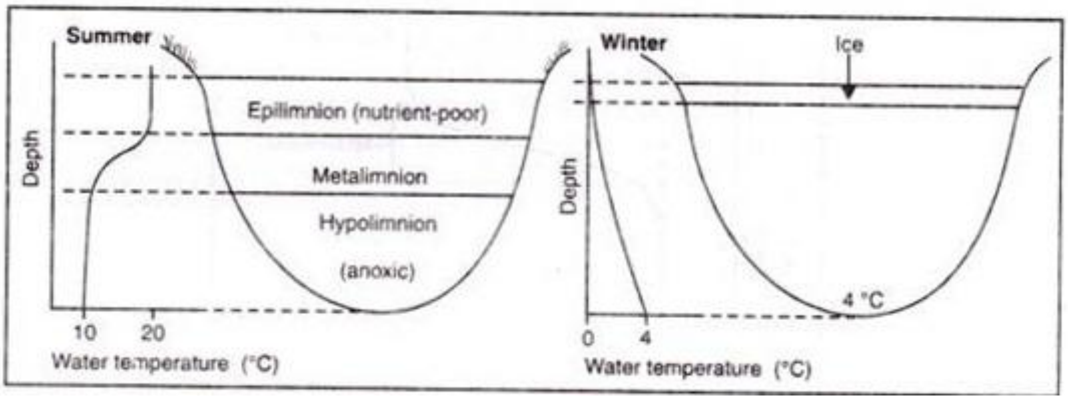


Figure – The temperature gradients produced in a lake in summer, and in winter. In summer, lakes often stratify into a layer of warm water (the epilimnion) which floats on denser cooler water (the hypolimnion). In winter the lake is warmest at the bottom, usually 4 C, and gradually becomes cooler towards the ice layer at the surface.

3.3.1.4 Autumn:

At the end of thermal stratification the surface waters of the epilimnion gradually cool as a result of conduction, evaporation and convection. Now the lake attains temperature uniformity from top to bottom. Because the water is now also of uniform density, it becomes well mixed by wind and wave action, a phenomenon known as the fall overturn or fall turnover As a result, the nutrients, dissolved oxygen, and plankton become uniformly distributed.

3.3.1.5 Winter:

As the winter approaches, the lake gets colder until the water attains a uniform temperature of 4°C at which it has maximal density. As the surface cools below it becomes lighter. Eventually the surface water may freeze at 0°C. During the winter season, the ice cover forms on the surface and in such ice-bound lakes there exists an inverse stratification of water temperature, with the coldest water (ice) at the surface and the warmest water (4°C) on the bottom.

Lakes undergoing complete circulation in spring and autumn separated by thermal summer stratification and winter inverse stratification are called dimictic lakes. Such lakes are quite common among temperate lakes of moderate size.

3.4 LIMITING FACTORS:

Organisms are surrounded and exposed to different environmental factors. Each species requires its own unique set of environmental conditions for survival. The organisms are constructed out of elements. These elements are essential for the survival of the organisms. They take up these elements from the environment in the form of nutrients. Certain elements such as C, H, N, O, P and S are required in large amounts and a number of others in small amounts. These factors influence the growth, reproduction, abundance, distribution, behaviour and survival of the organisms. These factors restrict the growth, reproduction and distribution of the organisms. Hence, they are called as limiting factors.

Temperature, light, soil, humidity, CO_2, O_2, pressure, etc. is the important limiting factors. When an environmental factor remains constant and abundant and if the organism has a wide range of tolerance, the factor is not a limiting factor. But if the factor fluctuates and if the organism has narrow limits of tolerance, the factor can be called a limiting factor. For example on land oxygen is abundant. Hence it is not a limiting factor. But it is scarce and the amount is highly variable in water. Thus O_2 is a limiting factor for aquatic organisms.

3.4.1Concepts of Limiting Factors:

There are three concepts to explain the mechanisms of limiting factors. They are;

1. The law of minimum
2. The law of tolerance and
3. The combined concept

3.4.1.1The Law of Minimum:

The law of minimum was proposed by Liebig in 1840. Organisms are exposed to a variety of environmental factors. Certain factors are present in the smallest quantity. According to Liebig, growth and reproduction of organisms are dependent on the factor that is present in minimum quantity in the environment. This is called law of minimum.

Example: Phosphorus is required by plant as a nutrient and it act as a limiting factor. In a lake, phosphorus is a limiting factor in the growth of algae. When phosphate containing detergent is added to the lake, algae will grow faster and produce a spectacular bloom of algae. This rapid growth consumes another essential elements of the water namely calcium. Hence the algae begin to die. The dead algae are decomposed by bacteria. As the bacteria increase in number, they begin to use up the O_2 of water. Eventually the amount of O_2 drops below the tolerance of fish and other organisms and these too begin to die.

3.4.1.2 Factor Interaction:

This is a subsidiary principle to the law of minimum. According to this principle, the amount of one nutrient taken is found to depend upon the amounts of other nutrients. In other words, high concentration of some substances may modify the rate of utilization of minimum nutrients.

Example: When calcium is deficient and strontium is abundant in the environment, organisms can substitute one for the other.

3.4.1.3Shelford's Law of Tolerance:

The law of tolerance was proposed by Shelford in 1913. According to this law, organisms are exposed to a variety of environmental factors such as light, temperature, nutrients, etc. They respond differently to the different intensities of a factor. Organisms survive well only at a particular range of intensity. This is called tolerance. Thus the law of tolerance states that organisms grow and reproduce well at a particular range of intensity of environmental factors. When the intensities are too high or too low, organisms are intolerant and hence they are excluded from the environment.

Each environmental factor has two zones, namely the zone of tolerance and the zone of intolerance.

The Zone of Tolerance: At a particular range of intensity, organisms survive well. This range is called the zone of tolerance. The zone of tolerance is further subdivided into three zones, namely optimum zone, critical maximum and critical minimum.

Optimum zone: It is the range of intensity at which the rate of growth, reproduction and survival capacity are high.

The Critical Maximum Zone: It is the highest intensity of the factor at which the activity slows down and the organisms come to a state of dormancy due to physiological stress.

The Critical Minimum Zone: When the intensity of an environmental factor is either too low or too high, organisms cannot survive. This high or low intensity of an environmental factor is called the zone of intolerance.

3.4.1.3.1 The salient Features of Shelford's Law of Tolerance:

1. Each factor has a range of intensity at which the organism survives well. This is called tolerance.
2. Species vary in their limits of tolerance of different factors. For example, the salmon can survive well at high salinities and low salinities. But when other marine fishes are placed in fresh water, they die.
3. The same species varies in its limits of tolerance of different factors. For example, certain fresh water fishes cannot tolerate major changes in salinity, but they can tolerate any high changes in temperature.
4. Organisms with wide ranges of tolerance for many factors have universal distribution.
5. The tolerance of any organism of the environmental factor can be represented in the form of a curve called tolerance curve.
6. When the species has a narrow range of tolerance, the prefix 'stno' is added to the factor. E.g. Stenothermal.

7. When the species has a wide range of tolerance the prefix 'eury' is added to the factor. E.g. Eurythermal.

3.4.1.4 The Combined Concepts of Limiting Factors:

Organisms are exposed to a variety of environmental factors. Almost all the factors are essential for organisms. But some factors become limiting factors. These factors are characterised by their minimum availability in the environment and the changes of intensity of the factor in the environment.

The successful survival of the organism depends on its adjustments to these factors. For survival the organism must obtain the factors which are present in minimum quantity in the environment. Secondly, the organism must be tolerant of the changes of intensity of the limiting factors.

3.5 GRASSLAND ECOSYSTEM:

The grassland biome is found where rainfall is about 25 to 75 cm per year, not enough to support a forest, yet more than of a true desert. The seasonality of grasslands is pronounced, both of with respect to rainfall, which is concentrated in the summer and to temperature. Grasslands typically occur in the interiors of continents and include the *tall grass prairies, short grass prairie* or Great Plains and arid grassland of North America as well as the *steppes* of Eurasia (Southern Russia, Siberia and Asia), the *veldt* of Africa and the *pampas* of South America (Argentina). The grassland communities are open land communities with limited moisture conditions, irregular rainfall, sharp seasonal and diurnal variations and very high radiations. Since tall trees or other thick variations are excluded from these communities there is a free movement of air. These winds carry the particles of sand or dust. These open habitats provide natural pasture for grazing animals (herbivore) which are excluded from predation by predators which hide in thick vegetation and prey upon them.

3.5.1. Grassland Flora:

The grasses comprising of grasslands can be divided into two basic groups, the tall grasses more than 1 m high, which are found in moist portions of the grassland and the short grasses less than 1 m high, which are found in the drier regions. Bluestrern *(Andropogon)* forms dense covers four to six feet tall. Westward, buffalo grass (*Buchloedactyloides*) and other grasses but a few centimeters high dominates the landscape. Other grasses such as wheat grass (Agropyron), panic grass (Panicum), needle grasses (Stipa), buffalo grass (Bunchioe) are also found. Flowering herbs including many kinds of composites are common, but much less important than grasses.

3.5. 2. Grassland Fauna:

Typical animals of grasslands tend to be quite small, with the exception of a few very large cursorial herbivore mammals such as the bison and pronghorn in North America, the wild horse, ass and saiga antelope of Eurasia, and zebra and antelopes of Southern Africa. The large herbivores are nowhere near as diverse as they are in savanna areas. Likewise, carnivores are relatively small such as coyotes, weasles, badgers, foxes, ferrets, owls and rattle snakes. Most herbivores characteristically aggregate into herds or colonies; this aggregation provides some protection against predators. Further, saltatorial motion is widespread, not only in mammals such as rabbits and kangaroo rats, but also insects, such as grasshoppers and crickets. The common insects of steppes are termites, locusts (*Locustamigratoria, schistoceragregaria*and *Melanoplus sp.*) bees, burrowing wasps mutilid wasps, bumble bees and blister bees. The steppes also harbor an undisturbed reptilian fauna. Lizard and snakes are met with in large numbers and posses, remarkable diversity. Most of them are fossorial, insectivorous and carnivorous. Rodents such as prairie dogs, rabbits and ground squirrels are common. The characteristic birds of grasslands are prairie chickens, meadow larks and rodent hawks.

3.5.3. Types of Grassland Ecosystem:

Grasslands tend to occupy about 20% of the earth's land surface and are of three types:

Tropical Grassland Ecosystem**:** These are situated 20 degrees away from the equator and the rainfall varies from 40 to 100 cm. Tall grasses rise to a height about 1.5 to 3.5 meters. The tropical grasslands of Africa include ungulates, deer, antelopes, giraffes, lions, etc.,

Temperate Grassland Ecosystem: They are found in Europe, Asia and North America. Their rainfall varies from 25 to 75 cm per year.

Alpine Grassland Ecosystem: They occur at higher latitudes. They are of the meadow type and many flowering herbs also grow here.

3.6. POND ECOSYSTEM:

Ponds, however, are considered as small bodies of standing water so shallow that rooted plants can grow over most of the bottom. Most ponds and lakes have outlet streams and both are more or less temporary features on the landscape.

3.6.1 Biotic Communities of Ponds:

Different organisms of the lentic environment can be ecologically classified based on whether they are dependent on the substratum are called *pendonic forms* and those that are free form it are the *limnetic forms*. Further, the aquatic organisms may also be classified into following groups depending upon their sizes and habits:

3.6.1. 1Neuston

These are unattached organisms that live at the air-water interface. They may include floating plants such as duckweed as well as many types of animals. Animals that spend their lives on the top of the air-water interface, such as water striders are termed epineuston, while others, including insects such as diving beetles and back swimmers, which spend most of their time on the underside of the air-water interface and obtain much of their food from within water, are termed as hyponeuston.

3.6.1. 2 Plankton

These are forms which are found in all aquatic ecosystems except for fast moving rivers. They are small plants and animals whose powers of self-locomotion are so limited that they cannot overcome currents. Thus their distribution is controlled largely by the currents in their ecosystems. Most plankton (phytoplanktons and zooplanktons) can move a bit, however, either to control their vertical distribution or to seize prey. Certain animal planktons or zooplanktons are exceedingly active and move relatively great distances considering their small size, but they are so small that their range is still controlled largely by currents and such planktons are also known as nekton planktons.

3.6.1. 3 Nekton

Nektonic animals are swimmers and are found in all aquatic systems except for the fastest moving rivers. In order to overcome currents, these animals are relatively large and powerful; they range in size from the swimming insects of quiet water, which may be only about 2 mm long to the largest animal that has ever lived on earth, the blue whale.

3.6.1. 4 Benthos

The benthos includes the organisms living at the bottom of the water mass. They occur virtually in all aquatic ecosystems. The benthos organisms living above the sediment-water interface are termed benthic epifauna and those living in the sediment itself are termed infauna.

3.6.2. Biota of littoral zone:

3.6.2. 1 Flora:

Lentic aquatic life is most prolific in the littoral zone. The littoral zone of a lake remains rich in pendonic flora especially up to the depth to which effective light penetration is possible facilitating the growth of rooted vegetation. At the shore, proper is the emergent vegetation which remains firmly rooted in the shore exposed. Certain rooted emergent plant species of littoral zone are *Ranumculus, Monochoria, Cyperus*and *Rumex.*Interspread with these plants are cattails (*Typha*), bulrushes (*Scirpus*), arrowheads (*Sagitaria*) and pickerelweeds. Out slightly deeper are the rooted plants with floating leaves such as the water lilies – *Nymphaea, Nelumbo, Aponogeton, Trapa, Marsilea*and *Potamageton*. The water surface of lake or pond contains neustons, free –floating hydrophytes such as *Wolffia, Lemna, Spirodella, Azolla, Salvinia, Pistia* and *Eichornia*. These plants remain in contact with water and air, but not soil. Still deeper in the littoral zone of lake are the fragile thin-stemmed water weeds, rooted but totally submerged. Such submerged vegetation includes plants like *Vallisneria, Myriophyllum, Isoetes, Hydrilla, Chara, Potamogeton,* etc. The phytoplankton of littoral zone of lake is chiefly composed of diatoms, blue greens algae and holophyic flagellates.

3.6.2.2 Fauna:

The littoral zone also contains great concentration of animals, which remain distributed in recognizable communities. In or on the bottom are various dragonfly nymphs, crayfish, isopods, worms, snails and calms. Other animals live in or on plants and other objects projecting up from the bottom. These include protozoans, larvae of *Dytiscus*, *Laccotrophes*, leech, climbing dragonfly, damsel fly nymphs, rotifers, flat worms, Bryozoa, hydra, snails (*Lymnaea*) and other. With the exception of a few rotifers like *Keratella*, *Brachionus*, *Diurella* and *Trichocerca* and crustaceans like *Cyclops*, *Daphnia* and *Moina*, larvae of Chironomous are found to inhabit the interior of rotting vegetation. Planarians are found underneath the leaves of floating plants. The zooplankton of littoral zone consists of water fleas such as Daphnia, rotifers and ostracods. The free swimming fauna (Nekton) includes *Paramaecium, Euglena, Ranatra, Corixa, Dytiscus,* larvae of Culex and of*Chaoborus, Gerris, Gyrinus,* etc. Floating members of the community (Neuston) are whirliging beetles, water spiders and numerous Protozoa. Among the vertebrates, frogs, salamanders, snakes and turtles are the nektons of littoral zone. Many pond fishes such as sun-fish, top minnow, bass, pike and gar spend much of their time in the littoral zone.

3.6.3. Biota of limnetic zone:

Limnetic zone is the region of rapid variation with the water level, temperature and oxygen content varying from time to time. . Many microscopic plants (*Volvox, Euglena*) and fishes also occupy this zone. The limnetic zone has autotrophs in abundance. Various protozoans which are capable of encystment during adverse ecological conditions, tardigrades like *Macrobiotus*, rotifers like *Rotaria, Philodina*, copepods, snails and frogs occupy the limnetic zone because of predators and lacking of permanent substratum for attachment.

3.6.4. Biota of profoundal zone:

In the profoundal zone, autotrophs cannot produce food and the main source of energy is detritus that rains out of the limnetic zone. All the organisms of this zone are heterotrophs, either as detritus feeder or as carnivores. The deep (profoundal) life consists of bacteria, fungi, clams, blood worms (larvae of midges), annelids and other small animals capable of surviving in a region of little light and low oxygen. Most of our largest lake fishes inhabit the dark waters of hypolimnion for their lives. In addition to detritus from the limnetic zone, food washed into lakes by rivers can settle out and serve as food for profoundal animals.

3.6.5. Benthos of Pond Bottom:

The pond bottom in young lakes may be of the original rock; in older lakes, it will have been covered with sediment to form a uniform substrate of mud or sand. The benthos community includes several species of insect larvae including those of small mosquito likes midges, burrowing mayflies, clams, snails and tubeworms.

Summary

In this chapter we studied about the thermal stratification for understanding the strata level diversity of organisms which will be decided by the temperature of the strata. The concept of limiting factors and law of tolerance for understanding the distribution of organisms based on the limiting factors. The description of the components of grassland and pond ecosystem will depict the two different ecosystems and their components.

Check Your Progress:

1. Write a note on epilimnion.
2. Note on Shelford's Law of tolerance
3. Define Critical Maximum Zone
4. Explain Grassland Flora
5. Write essay on Limiting factors
6. Define Nekton

UNIT IV: MARINE ECOLOGY

Structure

4.0. INTRODUCTION

Marine ecosystems are important to the overall health of both marine and terrestrial environments. Marine habitats provide a rich source of food and income. They serve as animal feed, fertilizers, additives in food and cosmetics. The marine organisms are not distributed evenly throughout the oceans. The ecosystems are sometimes linked with each other or replacing each other in other geographical regions. The reason for difference in habitats from another is because of the physical factors that influence the functioning and diversity of the habitats. Variations in characteristics of the marine environment including include temperature, salinity, tides, currents, wind, wave action, light, water depth, proximity to land and substrate create different habitats and influence what types of organisms will inhabit them.

4.0.1. OBJECTIVES

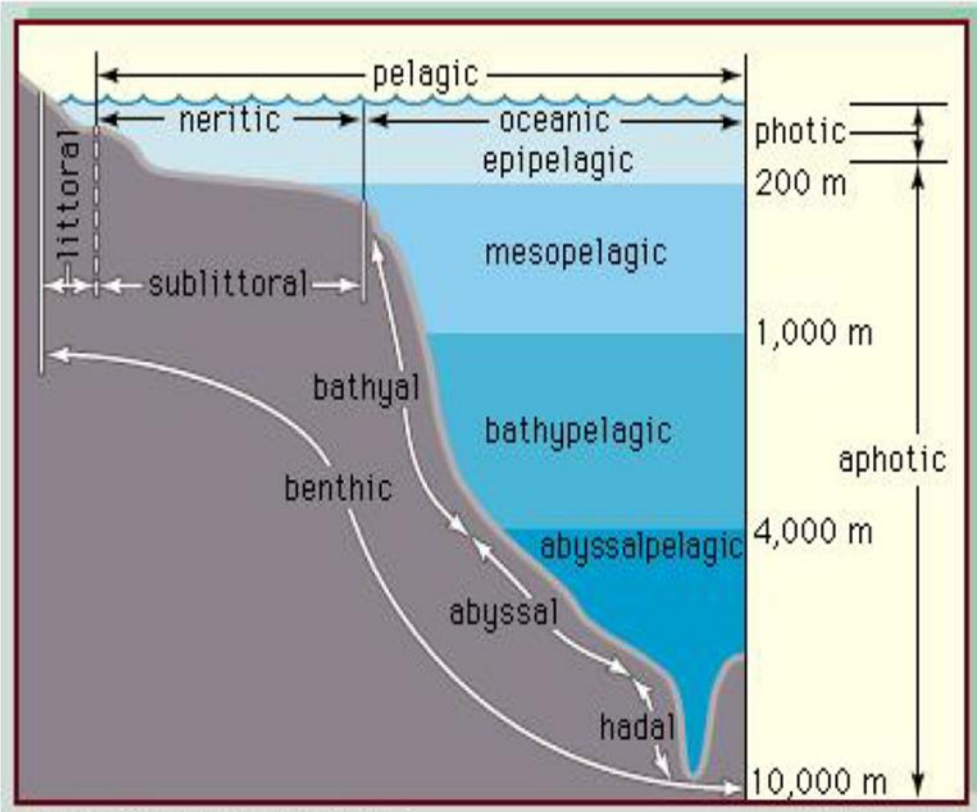
This chapter aims to introduce the following aspects:

- Divisions of marine environment
- Physical properties of seawater
- Chemical properties of seawater
- Particulate organic matter (POM)

4.1. DIVISIONS OF MARINE ENVIRONMENT

A number of environmental factors affect the growth, survival and productivity of marine organisms. These include light availability, oxygen levels, water movement, salinity, density and pH . These conditions often vary from habitat to habitat and will either support or limit the growth of organisms living there. Based on the light availability, marine environment can be divided into photic zone and aphotic zone. Light penetration decreases with increase in the depth of water and below a certain depth there is no light. This area of inky darkness, which occupies the great bulk of the ocean, is called the aphotic zone. The illuminated region above it is called the photic zone, within which are distinguished the euphotic and disphotic zones. The euphotic zone is the layer closer to the surface that receives enough light for photosynthesis to occur. Beneath the euphotic zone, lies the disphotic zone, which is poorly illuminated. In the disphotic zone, the rates of respiration exceed those of photosynthesis. In general, the euphotic zone can extend to depths of 80-100 metres and the disphotic zone to depths of 80-700 metres. Marine organisms are abundant in the photic zone, particularly the euphotic portion. However, many organisms that inhabit the aphotic zone may migrate vertically to the photic zone at night whereas other organisms such as the tripod fish, some species of sea cucumbers and brittle stars remain in darkness all their lives.

Spatially, the marine environment is divided into the pelagic (water) division and benthic (bottom) division. Within the pelagic environment the waters are divided into the neritic province, which includes the water above the continental shelf and the oceanic province, which includes all the open waters beyond the continental shelf. The high nutrient levels of the neritic province resulting from dissolved materials in riverine runoff distinguish this province from the oceanic. Epipelagic zone is the upper portion of both the neritic and oceanic waters where photosynthesis occurs and is roughly equivalent to the photic zone. Below this zone lie the mesopelagic, ranging between 200 and 1,000 metres, the bathypelagic, from 1,000 to 4,000 metres, and the abyssalpelagic, which encompasses the deepest parts of the oceans from 4,000 metres to the recesses of the deepsea trenches. The benthic environment is also divided into different zones. The supralittoral zone is above the high tide mark and is usually not under water. The intertidal or littoral zone ranges from the high tide mark (the maximum elevation of the tide) to the shallow, offshore waters. The sublittoral zone is lies beyond the low tide mark and is often used to refer to substrata of the continental shelf, which reaches depths of between 150 and 300 metres. The sediments of the continental shelf that affect marine organisms generally originate from the land, in the form of riverine runoff, and include clay, silt, and sand. Beyond the continental shelf is the bathyal zone, which occurs at depths of 150 to 4,000 metres and includes the descending continental slope and rise. The abyssal zone (between 4,000 and 6,000 metres) represents a substantial portion of the oceans. The deepest region of the oceans (> 6,000 metres) is the hadal zone of the deep sea trenches. Sediments of the deep sea primarily originate from dead marine organisms and their wastes.



4.2. PHYSICAL AND CHEMICAL PROPERTIES OF SEAWATER

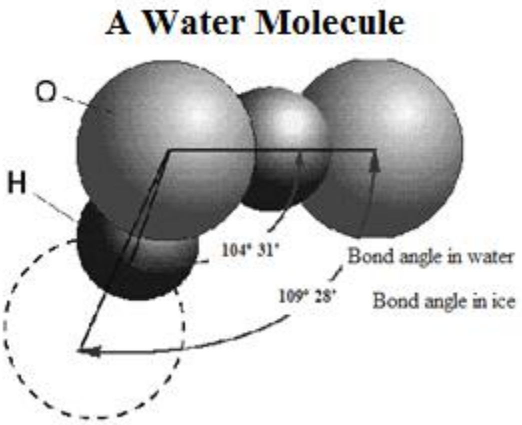
4.2.1. Introduction

Water is the most abundant compound, covering about covers 72% of the earth's surface. Of all the water on earth, 97% is salt water and only 3% is fresh water. Around 70% of fresh water is frozen as ice and snow. Seawater is more dense then freshwater and may contain 3.5% dissolved compounds. The ocean is alkaline with a pH between 7.5 to 8.4. Average salinity ranges between 3.1% and 3.8%. Ocean salinity is not uniform because the salt in ocean water comes from the weathering of earth's land surface over time.

4.2.1.1. Physical properties of seawater

1. The Structure of Water Molecule

The physical and chemical properties of water are due to its structure. In water molecule, atoms are arranged as H-O-H bonds at 105° rather than on directly opposite sides of the oxygen atom. The asymmetrical shape of the molecule arises from a tendency of the four electron pairs in the valence shell of oxygen to arrange themselves symmetrically at the vertices of a tetrahedron around the oxygen nucleus. The two pairs associated with covalent bonds holding the hydrogen atoms are drawn together slightly, resulting in the angle of 105° between these bonds. This arrangement results in a polar molecule, since there is a net negative charge toward the oxygen end (the apex) of the V-shaped molecule and a net positive charge at the hydrogen end. The electric dipole gives rise to attractions between neighboring opposite ends of water molecules, eacoxygen being able to attract two nearby hydrogen atoms of two other water molecules. Although considerably weaker than the covalent bonds holding the water molecule together, hydrogen bonding is strong enough to keep water liquid at ordinary temperatures. Various other properties of water, such as its high specific heat, are due to these hydrogen bonds. As the temperature of water is a lowered, cluster of molecules form through hydrogen bonding, with each molecule being linked to others by up to four hydrogen bonds, each oxygen atom tending to surround itself with four hydrogen atoms in a tetrahedral arrangement. Hexagonal rings of oxygen atoms are formed in this way, with alternate atoms in either a higher or lower plane than their neighbors to create a kinked three-dimensional structure.



2. Cohesion, Adhesion and Surface Tension, Viscosity

Water exhibits cohesion, adhesion, and surface tension. Cohesion is the ability of molecules to stick to themselves. As in the water droplet, strong hydrogen bonds are created between separate molecules as the negatively charged oxygen atoms of one water molecule are attracted to the positively charged hydrogen atoms on another. Simply put – they stick together!

Adhesion functions in a similar fashion to cohesion and it is also the result of intermolecular forces. The main difference being that it refers to the ability of dissimilar particles or surfaces to cling to one another. An example of this is dew drops clinging to the needles of a pine tree.

The cohesive forces among liquid molecules are responsible for the occurrence of surface tension. Surface tension results from the greater attraction of water molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion). The net effect is an inward force at its surface that causes water to behave as if its surface were covered with a stretched elastic membrane.

Cohesion is also responsible for the viscosity of water. Viscosity is a property of a material that measures the force necessary to separate the molecules and allow passage of an object through the liquid. Viscosity of seawater is altered by temperature and salinity. It increases with a decrease in temperature or an increase in salinity. This resistance to flow or movement is important in the sinking rate of objects and in problems of movement in the water by animals.

3. Temperature

Temperature is one of the most important physical factors affecting the distribution of life in the oceans. Oceanic waters become warmer as one moves toward the equator and conversely, cooler as one moves toward the poles. Ocean surface temperatures generally range from 0 to 30°C (32 to 86°F). Because salt lowers the freezing point of pure water, which is 0°C (32°F), ocean water freezes at about -1.1°C (30°F). Just as inorganic salts are left behind in the ocean water when freshwater is evaporated into the atmosphere, only the freshwater portion of the ocean surface freezes, thereby leaving the ocean water beneath the frozen surface layer saltier. The temperature of the Atlantic Ocean ranges from -2°C to greater than 30°C (28.4 to 86°F). Most ocean waters have a subsurface temperature feature known as a thermocline, it is an ocean where temperature changes very rapidly and separate warmer surface waters from the cooler waters below.

4. Density

Variations in density or the ratio of mass to volume, of the ocean are a function of salinity and temperature. Oceanic waters with higher salinities are denser than with lower salinities. In other words, a liter of water with a salinity of 36‰ weighs more than a liter of water with a salinity of 32‰. Additionally, waters that have cooler temperatures have higher densities than waters with warmer temperatures. Ocean waters with higher salinities and cooler temperatures have the greatest densities. Dense water masses actually "sink" toward the ocean floor, while less dense ocean water masses "float" at or near the ocean's surface. Water masses from each ocean basin must ultimately meet since the entire major ocean basins are interconnected and form one global ocean. The ocean is, therefore, made up of "layers" of different water masses that are continually sinking toward the ocean floor or rising toward the ocean surface, depending on their individual densities. It is the interactions among factors occurring at the ocean's surface, such as freezing, evaporation, precipitation, heating, and cooling, that determine the density of a certain water layer and thus, its vertical position in the "layered" global ocean.

5. Buoyancy

Just as water with different densities either sink below or float on top of one another, objects that are denser than water sink while objects that are less dense than water float. Buoyancy is defined as the ability to remain afloat in a liquid. Because salt water is denser than fresh water, salt water provides greater buoyancy to an object floating on the surface than does fresh water. A person or a boat is more buoyant in salt water than in fresh water. Denser liquids have a greater buoyancy force, or the force that makes an object float. In order for an object to float in a liquid, it must be less dense than that liquid. Some organisms living in the ocean float on top of the ocean's surface. These organisms are very buoyant, or less dense, than the sea water in which they live, and most of their body mass is, in fact, made up of water. Some of these organisms have specialized structures that make them more buoyant, such as the balloon-like floats of the Portuguese man-o war. Oil floats on the surface of the water and many marine organisms produce oil that makes them more buoyant. Even fish eggs may contain oil droplets, which enable them to remain at the surface or suspended in the water column. Increased body surface area and other unique adaptations, such as elongate spines and antennae, also retard the rate of sinking.

6. Waves

Wind is a form of energy. Wind energy blowing along the surface of the ocean is transferred to the ocean as waves and currents. Waves originate in the open ocean and, in many cases; the waves we see along the coast were generated far away at sea. Earthquakes, submarine landslides, and volcanic eruptions also produce waves by displacing the water, thereby setting it in motion in the form of a wave. As a wave approaches the shoreline, the depth of the water becomes shallower. An estimated 8,000 waves a day hit an average coastal beach. When ocean waves reach coastal shorelines, large amounts of energy are transferred from the wave to the beach and erosion of the land often takes place. Nevertheless, waves can also transport and deposit sediment onto the shore, and thus serve to build certain shorelines.

7. Tides

An ocean tide refers to the cyclic rise and fall of seawater. Tides are caused by slight variations in gravitational attraction between the Earth and the moon and the sun in geometric relationship with locations on the Earth's surface. Tides are periodic primarily because of the cyclical influence of the earth’s rotation.

8. Oceanic Currents

Movement of water along the surface of the open ocean, known as surface current circulation, is primarily caused by wind. Surface currents are slow, broad currents, the effects of which can extend to depths of 200 m (656 feet). Alternatively, density drives deep ocean currents to create currents, whether wind driven surface currents or density-driven thermohaline circulation, are major factors determining the distribution of life on earth, as many of the early life history stages of marine organisms are transported far from their points of origin to new locations by ocean currents. Ocean currents also have major effects on weather patterns throughout the world.

4.2.1.2. Chemical properties of seawater

Seawater contains 96.5% water and 3.5% salts. The components of seawater can be divided into suspended particles (also called particulate) and dissolved materials. The term **salinity** is used to describe the concentration of dissolved inorganic salts in seawater.

- Unit = ppt or ‰ (per mil) by weight
- Average for world's open ocean = 35 ‰
- Range for world's open ocean = 34-37 ‰
- The boundary between dissolved and particulate is an arbitrary one set at a size of 0.45 microns.

The dissolved ions make seawater a good conductor of electricity. The higher the salinity of the water the higher is its conductivity. So electricial conductivity is often used to estimate the salinity.

The dissolved components of seawater can be divided into five broad groups:

1. Major constituents
2. Minor and trace components
3. Nutrients
4. Gases
5. Organics - not part of the salinity

1. Major constituents comprise about 99.7% of all the dissolved materials.

Elements

1. Primary are **Cl^-** (55.04%) and **Na^+** (30.61%), which make up 85.65% of all the dissolved constituents.
2. **SO_4^{2-}, Mg^{2+}, Ca^{2+}, and K^+** brings the total to > 99% of the salts.
3. **HCO_3^-, Br^-, H_3BO_3, Sr^{2+}, F^-** brings the total to > 99.99%.
4. Almost all of the rest of the 92 naturally occurring elements are found in the ocean but they only total to 0.01% of the total dissolved solids.
5. Although the other components are present in a very small percent of the dissolved materials, they are essential for life on Earth.

The first seven dissolved constituents, in order of decreasing abundance.

Constituent	**‰**
Cl^-	19.2
Na^+	10.7
SO_4^{2-}	2.5
Mg_2+	1.3
Ca^{2+}	0.4
K^+	0.4
HCO_3^-	0.1

It was discovered that all of the major constituents occur everywhere in the same relative proportions. These major solutes are called **conservative** because their concentrations are constant throughout most of the ocean because the oceans are very well stirred. For example, from this list of constituents you can see that the ratio of the weight of sodium to the weight of chloride is:

$$\frac{Na}{Cl} = \frac{10.556}{18.980} = 0.556$$

No matter what the salinity, this ratio remains unchanged if only H_2O is added or taken away from the solution. The conservative behavior of the major constituents doesn't hold true at the mouths of large rivers and in estuaries because the local conditions can concentrate or dilute the salt content. Example: a humid climate where the influx of freshwater with a composition different from seawater dilutes the salts and decreases **‰**. Whereas estuaries in arid regions often have very saline waters due to excessive evaporation.

The conservative behavior also doesn't hold around mid-ocean ridges where there is exchange of elements. It doesn't hold for Ca^{2+} and HCO_3^- in places because of the dissolution and precipitation of $CaCO_3$ in tests of various organisms. In Polar Regions freezing and melting of sea ice causes minor variations as sea ice preferentially excludes salts. Finally it doesn't hold in virtually land-locked seas like the Black and Baltic. But in most places and at most times the ratios are constant. So if you determine the concentration of one of these constituents, you can calculate the rest by multiplying by these ratios. For example, if the chloride content (**‰**) is 18.980, we can multiply this number by the ratio we calculated above to determine the **‰** of sodium. It is also quite easy to determine the salinity of a seawater sample by measuring Cl^- because the overwhelming proportion of the salinity consists of the major conservative elements.

The salinity can be calculated from that using this formula: Chlorinity X 1.80655 = Salinity.

Chlorinity is determined by a procedure called a Mohr titration involving $AgNO_3$ as the titrant:

$$\text{Chlorinity} = 0.3285233 \; \frac{\text{gms Ag*}}{\text{kg seawater}}$$

(*grams of Ag required to precipitate all the halides in a 0.3285233 kg sample of seawater)

The conductivity is directly proportional to the dissolved salts concentration and can be used for salinity determination. When seawater evaporates or diluted by precipitation, only the proportion of H_2O changes but the proportions of these salts remain unchanged. In climates with an excess of evaporation over precipitation salinities get higher, but the ratios of the major components to one another remain the same. At the same time, in areas of excessive precipitation over evaporation salinities decreases, while their ratios remain the same. What do you get if you evaporate seawater?

If you

- evaporate it to 1/2 of its original volume, you get $CaCO_3$ to precipitate out.
- evaporate to 1/5, $CaSO_4.2H_2O$
- evaporate to 1/100, all the NaCl comes out
- evaporate to dryness, you get K and Mg chlorides and sulfates.

People extract NaCl from seawater by a partial evaporation to remove the $CaCO_3$. Then they drain off the remaining brine and evaporat it down to 1/100 of the original volume to get the NaCl out. Necessary care has to be taken so as not to evaporate it all the way to dryness or else very bitter K and Mg salts will be obtained.

2. Minor and trace elements

The minor constituents of seawater vary in abundance depending on locality and therefore are not reliable for determining salinity by the constancy of composition relationship. They are, however, important to the overall chemical scheme in the ocean. Some are economic importance, others are critical to various organisms in the sea. The vast majority of the elements in seawater occur in concentration of less than one part per million. Zinc, aluminum and iron all have economic value, but not in the dispersed state as they occur in the sea. Gold for example, occurs at about one part per trillion: however, even at this low concentration, there is about a million dollars' worth of gold in every cubic kilometer of seawater. Some of the minor elements in seawater play an important role in the precipitation of minerals on the seafloor. For example, iron and manganese are primary constituents of manganese nodules, which occur on the deep ocean floor around the globe. Some of the dissolved gases, such as oxygen and nitrogen, are critical to the life cycles of large groups of organisms. Silicon is incorporated into the skeletons of various organisms, both plants and animals. Many of these components are non-conservative. The ones which are involved in biological processes and the others which vary because of chemical processes such as oxidation are also non-conservative. Usually called trace constituent if it occurs in amounts < 1 ppm. For example the concentration of Fe is 0.01 ppm:

$$\frac{0.01 \text{ grams Fe}}{1{,}000{,}000 \text{ grams seawater}}$$

Many minor and trace elements are essential for the survival of organisms, both in the sea and on land. Some of these elements (Fe, Mn, Mo, Zn, Co, Cu, and V) are so rare that their concentrations are commonly described in terms such as parts per billion (ppb). The precise roles of many of these elements in organism metabolism have not been established.

3. Nutrients

The common limiting nutrients other than C, H, and O in the oceans are nitrogen, phosphorus, and silicon. Most marine plants can't use them in elemental form but must use the dissolved forms indicated

1. N = nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+)
2. P = phosphate (PO_4^{3-})
3. Si = SiO_2

There is a large variation of these components in seawater both vertically and horizontally. The typical profile of nutrient concentrations in the ocean is to be seriously depleted at the surface where photosynthesis occurs most rapidly. The nutrient concentration increases with depth as creatures die and release their absorbed nutrients back into the water column. The rate of nutrient increase decreases and stops with depth as the sinking organic matter is completely dissolved. Irregularities in the subsurface pattern of nutrient distribution are caused by variations in the circulation patterns for water masses in the various oceans. Remember the important link between biological activity and nutrient concentration.

4. Dissolved Gases

The concentrations of oxygen (O_2) and carbon dioxide (CO_2) vary significantly from place to place in the ocean. Their distributions are significantly influenced by biological activity near the sea surface.

5. Dissolved organics

The most important dissolved organics are fats, proteins, carbohydrates, hormones, vitamins, etc. They occur in low concentrations.

4.3. PARTICULATE ORGANIC MATTER

4.3.1. Introduction

The organic matter in the sea can be divided into two categories: dissolved and particulate. The particulate materials have a diameter greater than 0.5µm whereas the dissolved matter include true dissolved matter together with colloidal material passed by a 0.5µm membrane filter. The amount of the dissolved organic matter in the sea exceeds particulate organic matter (POM) by a factor of 10-20. All these organic materials have been produced by living organisms. These materials play a vital role in marine ecology since they provide part of the energy food, vitamin, and other requirements for bacteria, plants and animals. Growth promoting and inhibiting substances may have an important role in controlling the phytoplankton succession in the sea. The total soluble organic carbon content of ocean water usually lies in the range of 0.3-3mg C/l., although values as high as 20 mg/l may be found in coastal waters as a result of increased phytoplankton activity and pollution from land based activities.

The suspended material which can be removed from sea water by a filter having a pore size of a 0.5 µm is customarily referred to as particulate matter. The particulate organic material in the upper layers of the sea consists mainly of detritus (dead organisms) and phytoplankton; even in the euphotic zone the latter rarely constitute more than ¼ of the total particulate matter. Bacteria may also sometimes comprise a significant fraction of it. In addition, fungi and yeasts may be present as minor component. Zooplankton and fish represents only a very small fraction of the particulate carbon present in the water column. The concentration of detritus, phytoplankton, zooplankton and fish corresponded to about 125, 20, 2 and 0.02 µg/l respectively.

The concentration of particulate organic carbon in the euphotic zone is usually considerably higher than in the water lying beneath it. However, particulate matter, both organic and inorganic is present at all depths in the oceans. Particulate organic matter is an extremely important part of the marine food chain as it provides food for organisms at several trophic levels. In order to study the food balance in the sea, ecologists require information about the distribution and composition of this material.

4.3.2. Nature and origin of the particulate organic matter in the sea

Particulate organic matter in the sea comprises both living organisms mainly phytoplankton and detritus. The composition and relative proportion of these two classes is varying with depth and location.

4.3.2.1. Living organisms

Live plankton comprises the bulk of biomass and is confined to the euphotic zone and to the water immediately beneath it. The chemical composition of phytoplankton varies from species to species according to the environmental conditions. Amino acids, glutamic, aspartic acid, alanine and leucine and other 20 amino acids are usually present in the proteins of phytoplankton. The component of amino acid distribution in the proteins of plankton grown under similar conditions usually differ little from one species to another and little differentiation occurs when the amino acids are incorporated into the tissues of zooplankton and fish. The fatty acid composition of phytoplankton lipid is influenced by the temperature. Low temperature favors the production of more unsaturated acids. Amount of lipid in the organisms are influenced by the availability of nitrogen in the medium. The usual plant pigments of phytoplankton are carotene and chlorophylls, together with xanthophylls of many types. Carbohydrates occur in three principal forms: i) polysaccharide component or the cell wall which is resistant to bacterial attack ii) Mono- and di-saccharides in the cell sap iii) Polysaccharides which serve as a food reserves. The role of these saccharides differs from one class of algae to another. *Phaeodactlylum tricornutum* cell wall composed of sulphated glucuronomannan. But the *Chlorella pyrenoidosa* consist of cellulose, glycoprotein and hemicelllose. The cell sap contains variety of sugar including sucrose, fructose, glucose, galactose, di- and tri-saccharides. Phytoplankton also contains small amount of vitamin, nucleic acid. These substance plays are important role in the food chain. Many of them can be utilized directly by zooplankton.

4.3.2.2. Detritus

The detritus refers to the non-living particle suspended in the water of the ocean which include as clay, mud, silt, dust, pollen grains, siliceous skeletons of dead algae and other organisms. Dead organisms both plants and animals constitute one of the most important sources of particulate organic matter. These materials will decay slowly, eg. phytoplankton cell wall and zooplankton chitinous exoskeleton. Size of the detritus is 0.005 cm and the particle size decreases with increasing depth in the ocean. Coastal waters contain fragments of seaweed and other littoral and shallow water organisms. Coastal waters also contain terrestrial or industrial debris such as wood, spores, carbonaceous combustion products. All these material are transported to the ocean by wind and river water. Influence of these materials restricted to near shore area. Occasionally currents carry them into deeper ocean. Majority of these materials are readily oxidized bacterially and are utilized by filter feeders. The organic matter can be readily hydrolyzed by digestive enzymes such as trypsin and chymotrypsin.

3. Ecological significance

The particulate organic matter in the euphotic zone consists of phytoplankton and bacteria, together with detritus. The key role of phytoplankton in the marine food chain is known for a long time, but it is only in the 20 years that their nutritional value and those of bacteria and detritus have been understood. Many filter feeders are quite selective with regard to the species of phytoplankton which they are able to utilize, Not all species of zooplankton prefer the same species of phytoplankton and often better growth is obtained with a mixture of two or more species than with single one. Diatoms are probably stable diet of copepods and also feed on cocoliths and dinoflagellates. Zooplankton consumes more phytoplankton during blooming. During this superfluous feeding, the zooplankton excretes the phytoplankton in a semi digested state. This contribute considerable amount of assimiable material to the detritus. This may be important food source for filter feeders living below the euphotic zone. While phytoplanktons are abundant, detritus act only as supplement to the diet of zooplankton. In shallow waters, much detritus reaches the sea bed where it is digested by the benthic organisms. 75% of the benthic fauna depends on detritus. Bacterial decomposition is the principle mechanisms by which detritus is removed from the water and degraded. During the bacterial respiration and metabolic process CO_2, NH_3, phosphates are regenerated. Some species of benthic animals feed on bacteria as a food source. The total organic carbon in the water column is always high in the euphotic zone. This can be correlated with phytoplankton activity. Geographical and seasonal variations of POM are similar to that of primary productivity. Beneath euphotic zone the concentration of POM decreases with increasing depth rapidly. Below 200 m POM remain more or less constant to the bottom. Water circulation pattern also determines the distribution of POM in the sea.

4.4 Summary

In this unit, you have learnt about marine ecosystems and what are the physical and chemical factors that influence the functioning and diversity of the habitats. These habitats provide a rich source of food and income. They are very important to the overall health of both marine and terrestrial environments. Marine environment is broadly categorized as water or pelagic, environment and a bottom or benthic environment. Seawater is more dense then freshwater, it is composed of 96.5% water and 3.5% dissolved compounds. The ocean is historically alkaline with a pH between 7.5 to 8.4 and an average salinity between 3.1% and 3.8%. Many minor and trace elements are essential for the survival of organisms, both in the sea and on land. Some of these elements (Fe, Mn, Mo, Zn, Co, Cu, and V) are so rare that their concentrations are commonly described in terms such as parts per billion (ppb). The precise roles of many of these elements in organism metabolism have not been established. Particulate organic matter is an extremely important part of the marine food chain as it provides food for organisms at several trophic levels. Physical and chemical properties affect the nutrients and trace elements of seawater. Marine ecosystems are home to different species of organisms. Based on the mobility organisms are classified into plankton, nekton and benthos. The planktons are the base of the marine ecosystem.

UNIT V: PRIMARY AND SECONDARY PRODUCTION

Structure

5.0. INTRODUCTION

Food web and food chain mainly depends on the interactions of primary and secondary productions. They may be controlled by top down (predator control) or bottom up (nutrient limitation) and separating them may be difficult. Predator-prey interactions have been examined for both macroorganisms and microorganisms. But total food webs that include both have only rarely been described, and the descriptions are never really complete. It is apparent that both kinds of controls have effects that may be direct, indirect, or interactive. The incompleteness of many earlier studies, particularly with regard to microbial processes, limits our ability to interpret the model and ecosystem functions.

5.1. OBJECTIVES:

This chapter aims to introduce the following aspects:

- Primary production, estimation and factors influencing productivity
- Secondary production, Classification and estimation method
- Adaptations of Plankton,
- Red Tide and Intertidal

- Deep Sea Ecology

5.1.1. PRIMARY PRODUCTION

Production of organic matter in the ocean is called primary productivity. It is mainly done by phytoplankton, a tiny algae suspended in the ocean; mostly they are single - celled. Phytoplankton synthesis their own food by converting the inorganic carbon in to organic carbon through photosynthesis and therefore it is referred as autotrophs or primary producers. This organic carbon is abundantly available for numerous groups of heterotrophs. In the open ocean, the heterotrophs are; single celled bacteria, multi-celled zooplankton, nekton (mobile organisms in the water such as fishes, mammals and benthos- organisms living on the ocean floor). The productivity in the ocean can expressed with the following definitions:

Gross Primary Production (GPP): It is defined as the total rate of organic carbon produced by autotrophs or primary producers. This carbon energy is used by the autotrophs for cellular respiration and maintenance of existing tissues.

Net Primary Production (NPP): It is defined as the fixed energy that is available after utilization of autotrophs or primary producers.

Secondary Production (SP): It is defined as the production of heterotrophic which is produced by autotrophs, Therefore, the secondary production (SP) in the sea is small when compare to Net primary production (NPP). Fisheries in the ocean depend on both SP and NPP and the efficiency of organic mateer transferred in the food web (i.e., the ratio of SP/NPP). "Net ecosystem Production"(NEP) is defined as the fixed energy through GPP is available after utilization by all the organisms in the ecosystem. The values of NEP depends on the boundaries defined for the ecosystem.

Size variation of phytoplankton influences the fate of NPP. In general, small sized phytoplankton (which is <2µm in diameter are called picophytoplankton) account for most NPP. Under these conditions, the flow of organic carbon to harvestable fisheries and biological pump are relatively small. In contrast, larger sized phytoplankton (which is <20 µm in diameter are called microphytoplankton) account for > 90 per cent of NPP. The diatoms account for most NPP during spring blooms at high latitude and periods of coastal upwelling when NPP is high and nutrients are not limiting. The flow of organic carbon to fisheries and the biological pump is higher when larger cells account for most NPP. As a result the organic carbon broken down through respiration and excretion, death and decomposition and returned to the water can be utilized by autotrophs during primary production. Such a way, the organic matter is continuously cycled from inorganic to organic and back. The initial synthesis of organic material energy t the system is done with the help of sunlight. This energy is transferred to one trophic level to another through the cyclic process, and the energy being continuously lost from the system and in due course becoming dissipated as heat.

5.2. ESTIMATION OF PRIMARY PRODUCTION

The following methods used to measure the primary production in the aquatic system:

1. Light and dark bottle method

Primary productivity is the measure of the rate of carbon assimilation. During this process oxygen is produced and this can be used to monitor the

Primary productivity of an aquatic ecosystem. A measure of oxygen production over time provides a means of calculating the amount of carbon that has been bound in organic compounds during that period of time. Primary productivity can also be measured by determining the rate of carbon dioxide utilization or the rate of formation of organic compounds. One method of measuring the production of oxygen is the light and dark bottle method. In this method, a sample of water is placed into two bottles. One bottle is stored in the dark and the other in a lighted area. Only respiration can occur in the bottle stored in the dark. Respiration rate is the decrease in dissolved oxygen (DO) in the dark bottle over time. Both photosynthesis and respiration can occur in the bottle exposed to light. However, the difference between the amount of oxygen produced through photosynthesis and that consumed through aerobic respiration is the net productivity. The difference in dissolved oxygen over time between the bottles stored in the light and in the dark is a measure of the total amount of oxygen produced by photosynthesis. The total amount of oxygen produced is called the gross productivity.

2. ^{14}C Method

The collected samples are dissolved in inorganic carbon pool and marked with a known amount of radioactive ^{14}C-bicarbonate and keep the sample for incubation in a clear containers. carbon fixation is quantified by liquid scintillation and counting to detect the appearance of ^{14}C in organic form. Generally, oragnic carbon is collected as particles on a filter both dissolved and particulate organic inorganic carbon. It is prudent to correct measurements for the amount of label incorporated during incubations in the dark. The ^{14}C method is very sensitive, and good precision is obtained through replication and also adequate time given for scintillation counting. However, this method has some drawbacks. Use of radioisotopes requires special procedures for handling and disposal that can greatly complicate or preclude some field operations. Also because ^{14}C is added as dissolved inorganic carbon and gradually enters pools of particulate and dissolved matter, the dynamics of the labeled carbon cannot accurately represent all relevant transformations between organic and inorganic carbon pools.

3.^{18}O Method

Gross photosynthesis is measured as the production of ^{18}O-labeled O_2 from water labeled with this heavy isotope of oxygen. The detection is analyzed by mass spectrometry. Net primary production of the enclosed community is measured by means of increase of oxygen in the light bottle, and respiration is calculated by difference. In principle, the difference between gross productions of oxygen from light and dark method changes is due to light-dependent changes in respiration and photochemical consumption of oxygen. Respiration can also be measured directly by tracking the production of $H_2{}^{18}O$ from $^{18}O_2$. The ^{18}O method is sufficiently sensitive to yield useful results even in oligotrophic waters. It is not commonly used, but when the measurements have been made and compared to other measures of productivity, important insights have been developed.

5.3. FACTORS INFLUENCING PRODUCTIVITY

1. Light

Primary production is mainly depends on the intensity of sunlight or irradiation in the ocean. Irradiation is measured in photons reaching per square meter per second and varied depends upon the time of the day, the season and weather conditions. The portion of the ocean that receives more sunlight is called photic zone. Beyond the photic zone up to deeper layer of the ocean receives low light due to the absorbance of autotrophic organisms which are concentrated just below the surface. If the depth increases the light is absorbed by the water itself. In general, the photosynthesis is confined to the photic zone of the ocean. This productive layer is called "*compensation depth*". It is defined as the depth at which the rate of production of organic material by plant respiration. There is no net primary production below this depth and obviously varies with changes of illumination, and must be defined with respect to time and place. In the tropics the noon compensation depth may be well below 100m throughout the year due to clear water. The noon compensation depth commonly lies between 10 and 60m in high latitudes in the summer and reducing to zero during the winter months when virtually no production takes place.

Even exposure to strong light is harmful and depresses photosynthesis. The violet and ultraviolet spectrum has the most unfavourable effects. In bright daylight the illumination at the ocean surface seems often to be at or above the saturation level for most of the phytoplankton, and measurements of photosynthesis in these conditions show the maximum production occurs some distance below the surface, usually between 5 and 20 m depending upon light intensity, and falls off sharply above this level. Correspondingly, the maximum quantity of phytoplankton is seldom found very close to the surface, and except for a few species that seem to thrive in the uppermost few centimeters the greater part of the phytoplankton can be regarded as 'shade plants'. By absorbing light the plants themselves reduce light penetration through the water, and as the population increases the compensation depth tends to decrease. Above the compensation depth the rate of photosynthesis exceeds the rate of respiration and there is a net gain of plant material; below it there is a net loss. At a particular level the total loss by algal respiration in the water column above may exactly equal the total gain by photosynthesis. This level is termed the *critical depth*. The distance between compensation depth and critical depth depends upon the proportions of the phytoplankton stock above and below the compensation depth.

Survival of phytoplankton when little light energy is available during the winter is effected in several ways. During productive periods the plants build up food reserves as oil droplets which can draw when there is insufficient light is available for net production. Some species develop resting spores which pass unfavourable periods in a state of dormancy, germinating when conditions become favourable. The dissolved organic matter in seawater provides an energy source for some phytoplankton which can utilize if light is inadequate for their needs.

2. Temperature

The rate of photosynthesis increases with rising temperature up to a maximum, but then diminishes sharply with further rise of temperature. Different species are suited to different ranges of temperature. The photosynthesis is probably performed more efficiently in cold water by the phytoplankton of high latitudes than it is in warmer water by the phytoplankton native to the tropics. Seasonal variations of production rate in temperate latitudes are related to changes of both temperature and illumination. Apart from its direct effect on rate of photosynthesis, temperature also influences production indirectly through its effects on movement and mixing of the water, and hence on the supply of nutrients to the euphotic levels.

3. Nutrients

In general, the plants utilize the dissolved carbon dioxide which is present in the seawater in addition to other substances especially nutrients available in the water extracted by the plants for their essential growth. Many of these are minor constituents of seawater, present only in very low concentration, and their supply exerts a dominant control over production. Among the nutrients nitrate and phosphate are very important. The quantity of Iron determined the productivity of the water generally accord well with observed values. Other essential nutrients, such as manganese, zinc and copper and silicon is required by diatoms, and molybdenum and cobalt and probably other elements are necessary for some plants. In some cases, dissolved organic matters (DOM) dissolved in the water may be important. The intake of nutrients by the autotrophs/phytoplankton reduces the level of these substances in the surface layers, and this limits the extent to which the plant population can increase. A certain amount of the nutrients absorbed by phytoplankton may be regenerated and recycled within the euphotic zone, but in deep water plants are continually being lost from the surface layers through sinking and by consumption by zooplankton which moves to deep during the daytime. Many of the nutrients absorbed/utilized from the surface layers are therefore regenerated in the deeper and darker layers of water where plants cannot grow. These nutrients available in the surface water layer when upwelling is happened.

4. Upwelling

The most productive waters of the world are in regions of upwelling. Upwelling in coastal waters brings nutrients toward the surface. Phytoplankton reproduces rapidly in these conditions, and grazing by zooplankton also multiplies and provides abundant food supplies for nekton. Some of the world’s richest fisheries are found in regions of upwelling. To cite an example, the temperate waters off Peru and California. If upwelling fails, the effects on animals that depend on the nutrients can be disastrous. Fisheries also suffer at these times, as evidenced by the collapse of the Peruvian anchovy industry in the 1970s. The intensity and location of upwelling are influenced by changes in atmospheric circulation, as exemplified by the influence of El Nino conditions.

5.4. SECONDARY PRODUCTION OR ZOOPLANKTON PRODUCTION

5.4.1. Introduction

Zooplankters are the diverse, delicate and often very beautiful assemblages of animals that drift in the waters of the world oceans. The name zooplankton is derived from the Greek: Zoon, animal; planktos, wandering. They play a key role in the marine food web by transferring the organic energy produced by the unicellular algae to higher trophic levels such as pelagic stocks. Because of their critical role as food source for larval and juvenile fish, the dynamics of zooplankton populations, their reproductive cycles, growth and survival rates are all important factors influencing recruitment of fish stocks and thereby the magnitude of fishery. Majority of them are microscopic, unicellular or multicellular forms with size ranging from a few microns to a millimeter or more. In addition to size variations, there are differences in morphological features and taxonomic position. The zooplankton plays an important role to study the faunal bio-diversity of aquatic ecosystems. They include representatives of almost every taxon of the animal kingdom and occur in the pelagic environment. The zooplankton are more varied as compared to phytoplankton, their variability in any aquatic ecosystem is influenced mainly by patchiness, diurnal vertical migration and seasons.

5.4.2. Classification

Zooplankters are classified in five important groups based on different criteria. Firstly, they are divided into Holoplankton and Meroplankton. Species spending their whole life in the pelagic realm are termed holoplankton (eg. copepods, chaetognaths, salps etc.,) and those drift in the sea only for a part of their life cycle are called meroplankton (larvae of benthic mollusks, barnacles etc.,). Secondly, zooplankters are divided into Protozoa and Metazoa. Among the protozoan group, the ciliates form an ecologically important group. They rapidly multiply and are often the first grazers during algal blooms (diatom blooms). Metazooplankton have comparatively longer life span ranging from several days (eg. rotifers) and few weeks (eg. small crustaceans) to several years (eg. large euphausiids in Polar Regions). Thirdly, zooplankters are classified according to their size.

Plankton	Size of plankton	Types of plankton found in the specific size group	Commonly found zooplankton
Nano plankton	2 - 20 µm	Bacterio- plankton, **Myco-plankton**, **Phytoplankton**, Protozooplankton	Heterotrophic nanoflagellates feeding on bacteria
Micro plankton	20 - 200 µm	Myco-plankton, Phytoplankton, Protozooplankton, Metazooplankton	Most protozoans especially ciliates, eggs and early larval stages of crustacean plankton and meroplanktonic larvae
Meso plankton	0.2 – 2 mm	**Phytoplankton**, **Protozooplankton**, Metazooplankton	Small hydro medusae, ctenophores, chaetognaths, appendicularians, doliolids, fish eggs and larvae together with older stages of crustacean plankton and meroplanktonic larvae
Macro plankton	2mm-20 cm	Phytoplankton, Protozooplankton, **Metazooplankton**	Larger specimens of hydromedusae, siphonophores, scyphomedusae, ctenophores, mysids, amphipods, euphausiids, salps, eel larvae etc
Mega plankton	20- 200 cm	**Metazooplankton**	Jellyfish , siphonophores, scyphozoan, pelagic

Fourthly, zooplankters are classified into Neritic and Oceanic. Neritic plankton inhabits inshore waters upto about 200 m depth. Beyond that oceanic plankton prevails. In oceanic regime, they are again subdivided into epipelagic (0-200 m), mesopelagic (200- 1000 m) and beyond 1000 m depth. Of these, the epipelagic and mesopelagic is the main domain of zooplankton.

5.4.3. Methods of collection

The zooplankton collection involves primarily the filtration of water by net (plankton net), collecting the water in bottles/ water samplers or by pumps. The sampling success will largely depend on the selection of a suitable gear; mesh size of netting material, time of collection, water depth of the study area and sampling strategy. Nets are used most often, yet they have serious limitations in regard to obtaining good quantitative data, especially in nutrient and algae-rich waters. Nets are conical devices made of fine nylon mesh that are pulled through the water either vertically or horizontally for a known distance and time. Animals are captured in a vial or mesh-walled bucket at the bottom of the net and then can be rinsed into a storage bottle for counting. The amount of water from which zooplankton are removed is estimated as length of two times mouth diameter of the net. However, nets may not actually filter this volume of water. The main advantage to using a net is that samples of large volumes of lake water can be collected quickly. Nets can be obtained with various mesh sizes, depending on the requirements.

5.4.4. Estimation of zooplankton

Quantitative estimation

The term biomass denotes the live weight or the amount of living matter present in the zooplankton sample. The value obtained is used to evaluate the secondary productivity and fishery potentials of the study area. The biomass is estimated by the following methods.

1. Volumetric (displacement volume and settling volume) method
2. Gravimetric (wet weight, dry weight and ash free dry weight) method
3. Chemical method

Prior to determination of biomass, larger zooplankters such as medusae, ctenophores, salps, siphonophores and fish larvae should be separated from the zooplankton sample and their biomass taken separately. The total biomass would be the biomass of bigger forms plus the biomass of the rest of the zooplankton.

Volumetric method

The volume measurements are easy to make in the field or laboratory. The total zooplankton volume is determined by the displacement volume method. In this method the zooplankton sample is filtered through a piece of clean, dried netting material. The mesh size of netting material should be the same or smaller than the mesh size of the net used for collecting the samples. The interstitial water between the organisms is removed with the blotting paper. The filtered zooplankton is then transferred with a spatula to a measuring cylinder with a known volume of 4 % buffered formalin. The displacement volume is obtained by recording the volume of fixative in the measuring jar displaced by the zooplankton. The settled volume is obtained by making the sample to a known volume in the measuring jar. The plankton is allowed to settle for at least 24 hours before recording the settled volume.

Gravimetric method

The weight measurement should be done preferably in laboratory. It is carried out by filtering the zooplankton. The interstitial water is usually removed by blotting paper. While blotting, due care should be taken not to exert too much pressure as to damage the delicate organisms or specimens. The zooplankton weight is taken on predetermined or weighed filter paper or aluminum foil. The wet weight is expressed in grams. The dry weight method is dependable as the values indicate the organic content of the plankton. The dry weight is determined by drying an aliquot of the zooplankton sample in an electric oven at a constant temperature of 60ºC. The whole or total sample shouldn't be dried because the subsequent analysis such as enumeration of common taxa and identification of their species wouldn't be possible after drying of the sample. The dried aliquot is kept in a desiccator until weighing. The values are expressed in milligram. Ash free dry weight method is also occassionally used for biomass estimation.

Chemical method:

In this method, the live zooplankton samples are dry frozen. Before analysis, the samples are rinsed with distillated water. The measurement of element constituents such as carbon, nitrogen, phosphorus and biochemical elements viz. protein, lipid and carbohydrates are made. Sometimes the biochemical values of a particular taxon and species are undertaken to evaluate food energy transfer at higher trophic levels. The calorific content of the plankton can be used as an index of zooplankton biomass.

Qualitative estimation

The individuals in the sample will be identified and enumerated in this method. Enumeration of specimens in the whole sample is generally not practical because as most of the samples contain numerous individuals. Hence, a subsample or an aliquot of 10 to 25% is usually taken for enumeration. However, the percentage of aliquot can be increased or decreased depending on the abundance of zooplankton in the sample. Folsom plankton splitter is widely used for subsampling. By this, the sample can be divided into two equal halves at a time. This dividing process has to be continued till a suitable subsample is obtained for counting. For counting, a Sedgwick Rafter Counting Cell can be used which is kept under a stereoscopic microscope. The counts in the subsample have to be raised to the total volume. The numbers have to be expressed in per m^3 of water by considering the volume of water filtered by the net during sampling.

5.5. ADAPTATIONS OF PLANKTON, RED TIDE, INTERTIDAL AND DEEP SEA ECOLOGY

5.5.1. ADAPTATIONS OF PLANKTON

We know that phytoplankton and zooplankton exist primarily in the surface layer of the oceans. This layer of the ocean is receiving more sunlight which is available for photosynthesis and the zooplankton organisms can graze upon the phytoplankton. The majority of plankton has to remain in the upper surface waters but unfortunately, despite their small size, planktonic organisms still have a density greater than seawater; they can sink to the bottom of the ocean. To prevent sinking out of the photo zone many planktonic organisms have developed following adaptation for floating to match the environmental conditions they live in.

5.5.1.1. Surface area and volume

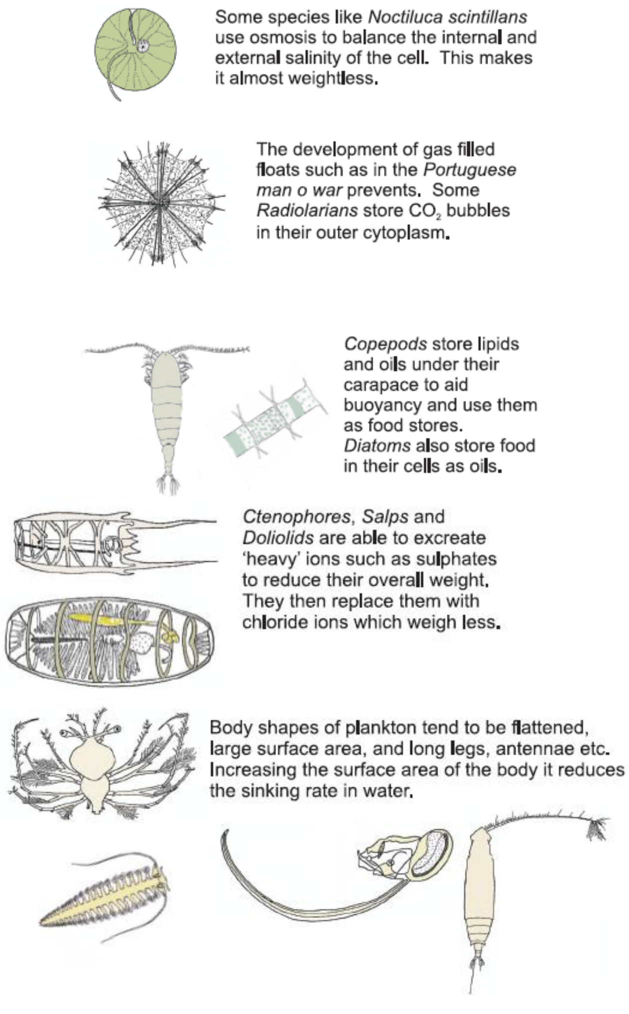
All phytoplankton and many zooplankton are microscopic in size. Their small size and complex shapes produce a high surface area-to-volume ratio. This ratio favors the rapid exchange of gases by diffusion and creates a rapid excretion of wastes across the body surface, light trapping, and nutrient absorption.

5.5.1.2. Increased buoyancy

Many plankton have buoyancy aids. To cite an example, phytoplankton, notably diatoms, and zooplankton such as copepods, fish eggs, and larvae, contain buoyant oil droplets helps to float in the surface layer. It also act as food stores. Some planktonic cyanobacteria and radiolaria contain gas-filled vesicles. Certain dinoflagellates, and various zooplankton, including salps and comb jellies, exclude or excrete heavy ions (e.g., Mg2+, SO4 2–) and retain less dense ones (e.g., NH4+, Cl–).

5.5.1.3. Body shape

Many plankton have body shapes that tend to make them sink more slowly. Some plankton **is** flattened. They sink slowly, moving back-and-forth in a "falling-leaf "pattern. Long projections and spines increase surface area and slow sinking. They may also deter potential grazers or predators from consuming the individual. Chains of individuals can assume shapes that encourage sinking in a slow spiral or zigzag path.



5.5.2. RED TIDE

Introduction

Red tide is a phenomenon caused by algal blooms during which algae become so numerous that they discolor coastal waters (hence the name "red tide"). The algal bloom may also deplete oxygen in the waters and/or release toxins that may cause illness in humans and other animals. Species that release **the** harmful toxins include:

- *Alexandrium tamarense*
- *Alexandrium fundyense*
- *Alexandrium catenella*
- *Gymnodinium breve*
- *Karenia brevis*
- *Protoceratium reticulatum*
- *Lingulodinium polyedrum*

Causes of Red Tide

Major factors influencing red tide events include warm ocean surface temperatures, low salinity, high nutrient content, calm seas, and rain followed by sunny days during the summer months. In addition, algae related to red tide can spread or be carried long distances by winds, currents, storms, or ships. Red tide is a global phenomenon.

The algae which cause Red tide produce potent natural toxins. It is unknown why these toxins are created, but some can be hazardous to larger organisms through the processes of bioaccumulation and biomagnification. Fish and krill are unaffected by the toxins, so they graze the algae through which the toxins are accumulated in a higher level. These toxic substances reaches to large animals when feed on them. Larger fish, kills and several mammals affected by diseases and sometime leads to death have been attributed because of the consumption of shellfish during red tide algal blooms. Diseases that may affect humans include:

1. *Paralytic Shellfish Poisoning (PSP)*

This disease is caused by the production of saxitoxin by the *Alexandrium* species. It is common along the Atlantic and Pacific coasts in the US and Canada. Poisoning occurs when one ingests shellfish contaminated with PSP toxins causing disruption of nerve function and paralysis. Extreme cases may result in death by asphyxiation by respiratory paralysis.

2. *Diarrhetic Shellfish Poisoning (DSP)*

This disease is caused by the *Dinophysis* species. It generally occurs in Japan and Europe, but it has also been found in other countries such as Canada, the US, Chile, New Zealand, and Thailand. Symptoms of DSP include diarrhea, nausea, vomiting, abdominal pain, and cramps. DSP is generally not lethal.

3. *Amnesic Shellfish Poisoning (ASP)*

This disease, which has been found along the eastern Canadian coast, is caused by domoic acid producing planktonic and benthic algae including *Pseudo-nitzschia pungens* forms. *Pseudo-nitzschia multiseries* and *Amphora coffaeformis*. It can also be found in soft shell clams and blue mussels infected by *Pseudo-nitzschia delicatissima*. Gastric and neurological symptoms include dizziness, disorientation and memory loss.

Monitoring

Technological advancements such as satellite imagery have allowed scientists to better track and monitor harmful algal blooms. Tracking and monitoring red tide algae helps reduce harmful effects of the algae by providing warnings against consumption of infected shellfish and against swimming in infected waters.

5.5.3. INTERTIDAL ECOLOGY

5.5.3.1. Introduction

The region between the lowest low tide and highest high tide mark is called as intertidal regions. This coastal area is periodically exposed to air by rise and fall of tides and submerged by rising water levels. In this region, a variety of distinctive ecosystems such as rocky shore, sandy shore and muddy shore are present. These ecosytem supports diversified assemblages of species. Rocky intertidal areas support predominantly of epifauna, whereas the sandy and muddy substrates have higher proportions of infaunal communities. The intertidal region is usually called as the transition between land and sea. This region consitute only a very small part of the total world oceans but they support rich and diverse communities or marine plants and invertebrates as well as birds and inshore species like fish. Even some mammals visit intertidal area to feed on easily available shellfish, and many shorebirds depend on the rich food supply to be found in these habitats.

5.5.3.2. ROCKY SHORE

A solid rock present in an intertidal area is referred as rocky shore environment. It is often a biologically rich environment and can include many different habitat types like steep rocky cliffs, platforms, rock pools and boulder fields. Because of the continuous action of the tides, it is characterized by erosional features. Together with the wind, sunlight and other physical factors create a complex environment. Organisms that live in this area experience daily fluctuations in their environment. They have special adaptation to live in the crevices of the rock and select a specific niche in order to avoid the desiccation. The morphology of the organisms living in the rocky environment in general shows compressed body structures. For this reason, they must be able to tolerate extreme changes in temperature, salinity, moisture and wave action to survive.

1. Zonation

Each region on the coast has a specific group of organisms that form distinct horizontal bands or zones on the rocks. The appearance of dominant species in these zones is called vertical Zonation. It is a nearly universal feature of the intertidal zone.

2. Supratidal zone

When the tide retreats, the upper regions become exposed to air. The organisms that live in this region are facing problems like gas exchange, desiccation, temperature changes and feeding. This upper region is called supratidal or splash zone. It is only covered during storms and extremely high tides and is moistened by the spray of the breaking waves. Organisms are exposed to the drying heat of the sun in the summer and to extreme low temperatures in the winter. Because of these severe conditions, only a few resistant organisms live in this region. Common organisms are lichens. They are composed of fungi and microscopic algae living together and sharing food and energy to grow. The fungi trap moisture themselves and from their algal symbiont. They are capable of surviving on the moisture of the sea spray from waves. During the winter, they are found lower on the intertidal rocks. The algae growing higher on the rocks gradually die when the air temperature changes. At the lower edge of the splash zone, rough snails (periwinkles) graze on various types of algae. These snails are well adapted to life out of the water by trapping water in their mantle cavity or hiding in cracks of rocks. Other common animals in this region are isopods, barnacles and limpets.

3. Intertidal zone

The intertidal zone or littoral zone is the shoreward region between the highest and lowest limit of the tides. It is a transition zone between the land and the sea. It causes various stresses such as heat, desiccation, oxygen depletion and reduced opportunities for feeding. At low tide, marine organisms face both heat stress and desiccation stress. The degree of this water loss and heating is determined by the body size and body shape. When body size increases, the surface area decreases so the water loss is reduced. Shape has a similar effect. Long and thin organisms dry up much faster than spherical organisms. Intertidal organisms can avoid overheating by evaporative cooling combined with circulation of body fluids. Higher intertidal organisms are better adapted to desiccation than lower intertidal organisms, because they encounter more hours of sunlight. The organisms are exposed directly to the air or they are enclosed in burrows. This results in oxygen depletion, so they can’t get rid of their metabolic waste. A solution for this problem is to reduce the metabolic rate.

The intertidal zone can be divided in to three zones: **High tide zone or high intertidal zone.** This region is only flooded with water during high tides. Organisms that available here are anemones, barnacles, chitons, crabs, isopods, mussels, sea stars and snails. **Middle tide zone or midlittoral zone.** This is a turbulent zone that is (un) covered twice a day. The zone extends from the upper limit of the barnacles to the lower limit of large brown algae (e.g. *Laminariales, Fucoidales*). Common organisms are snails, sponges, sea stars, barnacles, mussels, sea palms and crabs. **Low intertidal zone or lower littoral zone.** This region is usually covered with water. It is only uncovered when the tide is extremely low. In contrast to the other zones, the organisms are not well adapted to long periods of dryness or to extreme temperatures. The common organisms in this region are brown seaweed, crabs, hydroids, mussels, sea cucumber, sea lettuce, sea urchins, shrimps, snails, tube worms.

Tidal pools in the intertidal zone are rocky pools are filled with seawater. They are formed by abrasion and weathering of less resistant rock and washing of fractures and joints in the shore platform. This leaves holes or depressions where in seawater can be collected at high tide. They can be small and shallow or deep. When the tide retreats, the pool becomes isolated. Because of the regular tides, the pool is not stagnant and new water regularly enters in to the pool. This is very important to avoid temperature stress, salinity stress, nutrient stress etc. Pools that are located higher on the beach are not regularly changed by tides. These pools are basically occupied by euryhaline communities. There is also a difference in the composition between high and low area pools. In the low area pools, whelks, mussels, sea urchins and *Littorina littorea* are common. Periwinkles and *Littorina rudis* are found in high area pools. Other organisms that are commonly found in pools are flatworms, rotifers, cladocerans, copepods, ostracods, barnacles, amphipods, isopods, chironomid larvae and oligochaetes. Vertical zonation also has been documented in tidal pools.

4. Subtidal zone

The subtidal zone or sublittoral zone is the region below the intertidal zone and is continuously covered by water. This zone is much more stable than the intertidal zone. Temperature, water pressure and sunlight radiation remain nearly constant. Organisms do not dry out as often as organisms higher on the beach. They grow much faster and are better in competition for the same niche. More essential nutrients are acquired from the water and they are buffered from extreme changes in temperature.

5. Adaptations

The constantly changing environment makes the organisms to tolerate the changes.

i. Air

Intertidal organisms are frequently and alternatively exposed to air and water. Air differs physically from seawater in various ways. The air and seawater influences the ability to exchange gas and their overall thermal balance with the surrounding environment. Organisms are generally buoyant, because of their lower density than the water. In air, gravity induces retraction of tentacles and other feeding organs that make the body less resistant. For this reason, organisms need supporting structures especially for attachment and body changes when they are exposed to air. Also the organisms directly absorb sunlight when they are exposed to direct solar radiation. Because of the high rate of heat conductivity, the buffering capacity of water disappears and the body temperature increases. In contrast to this, heat loss is much lower in air than in water.

ii. Light

Sunlight is another parameter that influences the organisms. When there is very high sunlight, organisms dry out and the capacity to capture light energy can be weakened. The light that is not used or dissipated can cause damage to subcellular structures of the organisms. Very low sunlight reduces the growth and reproduction of the organisms, due to reduced photosynthesis. Algae can avoid absorbing too much light by changing the complement or amount of pigments they produce. They also can rearrange the pigmented organelles within their cells. When free radicals are produced from an excess of light, they can be scavenged and deactivated.

iii. Temperature

The intertidal zone can experience extreme temperature changes. The organisms in this zone must be resistant to these changes to survive. Most of the marine organisms are ectothermic and need the warmth from the environment. When the organisms are submerged, they are buffered against temperature changes, because the water is isothermal. When the organisms become exposed to the air, they can experience cool or warm temperatures. When the temperature is too low, the organisms must cope with physiological threats associated with cold stress. This can be the case in polar and temperate latitudes of the coastal zones. The body fluids can then reach their freezing point and ice crystals develop. This causes damage to cell membranes and increasing the osmotic concentration of the remaining fluids. To avoid this cold stress, organisms can migrate to suitable habitats. This can be a problem for sessile organisms. They can develop physiological and behavioral adaptations such as gaping in shells (mussels). Some organisms have developed antifreeze proteins. Increasing the concentration of small osmolytes such as glycerol in the body fluids can decrease the freezing point. Another strategy is to control ice crystal formation. When the ice formation is intracellular, it is lethal but extracellular ice formation can be tolerated. When the temperature is too high, heat stress appears. Heat stress accelerates rates of metabolic processes. This can be avoided by evaporative cooling combined with circulation of body fluids.

iv. Salinity stress

Salinity stress can occur in the external medium and also in surface films. The concentration of the fluids determines whether the organism will lose water or not. When the osmolality of the cell is lower than the surrounding medium, the cell loses water from the internal fluids to the environment (hyperosmotic stress). When the intracellular osmolality is higher than the surrounding environment, there is an influx of water into the cell from the environment (hypoosmotic stress). Multicellular organisms respond to this salinity stress by compartmentalization. When the tissue has an immediate contact with the external medium, a solution can be to regulate intercellular osmotic pressure by actively excreting salts or water. Another solution is to change the internal osmolality. This can be done by incorporating ions or compatible solutes in the internal fluids.

v. Desiccation stress

Organisms are threatened by desiccation during the low tides or when they are positioned in the high intertidal zones. Dehydration due to water loss is the most common mechanism. Fast moving organisms can avoid the desiccation by migrating to suitable place. Slow moving organisms restrict various activities (reduced metabolism) and attach more firmly to the substrate. Physiological features to tolerate water loss are desiccation resistant egg cases, reduction in water permeability of membranes, accumulation of metabolic end products, reduction of metabolic and developmental rates, maintenance of intracellular osmolytes and gene expression for production of protective macromolecules.

vi. Predation

A wide variety of strategies exists to escape from predation. The first strategy is calcification. It is difficult for the predator to eat these organisms. This strategy is applied by algae. The second one is the production of chemical constituents such as secondary metabolites. These chemicals can act as toxins, but other chemicals are only produced in response to stimuli (inducible defense). Another way to avoid predation is to have two distinct anatomical forms within one life cycle. For example, a crusty form when the predator is present and a more gentle form (e.g. blade) when the predator is absent. Bioluminescence is another strategy to avoid predators. Many intertidal and subtidal predators visually forage. The light is used for warning, blinding, making scare, misleading or attracting the predator. A commonly used form of protection against predation is camouflage. This can be visually or chemically. Visual camouflage means that the prey becomes invisible to the predator by using the same colors as in the environment. Chemical camouflage is the passive adsorption of chemicals. The predator does not smell the prey anymore, because the smell is masked.

vii. Wave action

One way to protect organisms from waves is permanent attachment. But this strategy cannot be used by organisms that have to move for food. These organisms have to make a compromise between mobility and attachment. Another way to protect is to burrow into the sediment. Attachment can be done by different structures. For example, bivalves usually use threads (byssal threads) to attach to rocky surfaces or to other organisms. But it can also be done by a foot. Cementation is the important process for bivalves such as oysters, scallops and some other forms. They lay on their side, with the lower valve cemented firmly to the bottom. This can be combined by reduction or enlargement of certain muscles.

Why are rocky shores important?

Providing a home for a lot of organisms, nursery area for many fish and crustacean species, shelter in areas where seaweeds break the waves power, providing food for fishes, algal beds important food source for rare and threatened species like sea turtles, feeding ground at low tide for wading birds and stabilization of inshore sediment.

5.5.3.3. SANDY SHORES

Sandy shores or beaches are loose deposits of sand, gravel or shells that cover the shoreline in many places. They make up two thirds of the world’s ice free coastlines. Beaches serve as buffer zones or shock absorbers that protect the coastline, sea cliffs or dunes from direct wave attack. It is an extremely dynamic environment where sand, water and air are always in motion. Beaches also provide important recreational areas for a many people. Fine grained sand beaches tend to be quite flat.

1. Formation

Sandy beaches are soft shores that are formed by deposition of particles that have been carried by water currents. The transported material is in part derived from the erosion of shores, but the major part is derived from the land and transported by rivers to the sea. The two main types of beach material are quartz (=silica) sands of terrestrial origin and carbonate sands of marine origin. The carbonate sand is weathered from mollusk shells and skeletons of other animals. Other material includes heavy minerals, basalt (=volcanic origin) and feldspar.

2. Characteristics

The grain size of sand varies from very fine to very coarse. The particle diameter is given below. As said before, the quartz (=silica) sand

and carbonate sand are the major constituents in the beach materials. Quartz sands have a slightly lower density (2.66.g Cm^{-3}) than carbonate sands (2.4 to 2.95g. Cm^{-3}). The quartz particles also seem to be more rounded. Calcium carbonate particles sink more slowly in water due to their more irregular shapes, even if their density is higher.

Generic Name	Particle Diameter (mm)
Very coarse	1.0 to 2.0
Coarse	0.50 to 2.0
Medium	0.25 to 0.50
Fine	0.125 to 0.50
Very Fine	0.0625 to 0.125

Porosity is the volume of concealed space in the sand. The fine sands have the greater porosity and lower permeability due to their smaller pore sizes. Permeability is the rate of flow or drainage of water through the sand. Fine sands have penetrability is related to particle size and porosity. This favours the macrofauna to burrow into the substratum. To determine the penetrability, the proportion of clay, silt and the water content are very important. The two basic beach types are dissipative and reflective. Together with the intermediate types, there are six major microtidal beach types. The reflective type occurs when conditions are calm and/or the sediment is coarse. There is no surf zone and waves flow upon the beach. It reflects a major part of the incoming wave. When bigger waves cut back a beach and spread out its sediments to form a surf zone, the reflective beaches create a series of intermediate types. When wave action is strong and/or sediment particle size is fine, the dissipative beach type is created. This type has a flat and the beach is eroded maximum. The sediments that are stored in a broad surf zone may have multiple sandbanks parallel to the beach. The intermediate types are characterized by high temporal variability, sand storage both on the beach and in the surf zone and sandbanks and troughs. Beach types can also be based on the degree of exposure. This ranges from very sheltered, over sheltered and exposed to very exposed.

3. Function and adaptations

The intertidal zone is exposed partly by water and partly by air in a day. High tides bring nutrients and food in this region. When the tide retreats, waste products, eggs and larvae are taken. This causes changes for the organisms that live here. However, they have adapted to this changing environment. The burrowing must be rapid and powerful on high energy sandy beaches. This is because the animals must not be swept away by incoming waves and swash. In order to tolerate with swash environment the organism need to move fast. In contrast with rocky shores, desiccation is not an overriding concern, because the animals can retreat into the substratum or below the water table. Intertidal filter feeders cannot feed while the tide has retreated. Many species of the meiofauna use vertical tidal migrations through the sand column. Other species move up and down the beach with the tides. This is inadequate for the maintenance of appropriate rhythmic behavior so responses to changing environmental factors are essential.

Some species are descent into the burrow to escape from high temperatures. Another solution is evaporative cooling by replacing water which is entering through the burrow, plunging into the sea or absorption from the substratum. Another problem for intertidal animals is the time of reproduction. There is a variation in the number of eggs, the anatomy of the reproductive organs, the morphology of the egg cases, times of breeding, mating behavior and developmental stages. Adaptations for this is to reproduce at frequent times (iteroparous) or to reproduce just once in a year (semelparous). This depends from species to species. Some species follow the lunar cycle to reproduce at the right time. To ovoid predation, several behaviors are developed. The first one is to burrow very deep. Another one is tidal migration, so the animals remain protected from predation. Other responses are escaping movements or an impressive threat display by crabs by holding their chelae open and aloft. According to circumstances, the behavior of the animals can be modified. This is called phenotypic plasticity. Several groups of vertebrates make use of sandy beaches for foraging, nesting and breeding. Turtles nest on the backshore of sandy beaches. Birds use the beach for foraging, nesting and roosting. Seals use several areas of the beach for nesting, molting, breeding and raising pups. Other terrestrial animals such as otters, baboons, raccoons and lions descend onto the beach to forage.

The distribution and abundance of the sediment infauna is mostly controlled by complex interactions between the physicochemical and biological properties of the sediment. The physicochemical properties are: Grain size, Water content, Flushing rate of water through the sediment, Oxidation, Reduction state, Dissolved oxygen, Temperature, Light and Organic content. The biological properties are: Food availability and feeding induces movement and aggregation, intraspecific competition, interspecific competition and competitive exclusion and Predation effects. Most invertebrate phyla are represented on sandy beaches, either as interstitial forms or as members of the macrofauna. The macrofaunal are better known forms. Some of them are found typical in intertidal sands and their surf zones, while others are found more characteristic of sheltered sandbanks, sandy muds or estuaries and are less common on open beaches of pure sand.

4. Macrofauna

Macrofauna are often abundant in the sandy beaches, in some cases, attain exceptionally high densities. Their main feature is the high degree of mobility displayed by all species. These animals may vary from a few mm to 20 cm in length. The macrofauna community consists of large organisms to move between the sand grains. The most important macrofauna of sandy beaches includes molluscs, crustaceans and polychaetes. There is a tendency for crustaceans to be more abundant on tropical sandy beaches or more exposed beaches and molluscs to be more abundant on less exposed and on temperate beaches. Polychaetes are sometimes more abundant than other taxa. Generally crustaceans dominate the sands towards the upper tidal level and molluscs the lower down level. Physical factors such as primary wave action and particle size of the sand beach largely determine distribution and diversity of the invertebrate macrofauna. Food input and surf zone productivity may determine the population abundance. Water movement is important parameter controlling macrofaunal distribution on beaches.

5. Meiofauna

The interstitial system is truly three dimensional, often having great vertical extent in the sand. The averages porous system is about 40% of the total sediment volume. Mostly inhabit by metazoans such as meiofauna, protozoans, bacteria and diatoms. The meiofauna is defined as those metazoan animals passing through 0.5 to 1.0 mm sieves and trapped on 30 mm screens. On most beaches the interstitial fauna is rich and diverse. The dominant taxa of sandy beach meiofauna are nematodes and harpacticoid copepods with other important groups including turbellarians, oligochaetes, gastrotrichs, ostracods and tardigdades.

5.5.3.4. MUDDY SHORES

Muddy shores are fairly calm with respect to wave conditions, or where there is abundant supply of fine sediments. It is characterized by a muddy shore face and sometimes in the form of muddy tidal flats and the lack of a sandy shore. They are normally vegetated with mangroves fronted by very flat slopes or tidal flats.

1. Characteristics

The area exposed to tidal fluctuations often supplied by fine particles brought by rivers are called muddy coast. This type of coast occurs in tropical and sub-tropical regions where rivers supply abundant fine materials to the coastal zone (CZ). The wave exposure is normally low to moderate in this region. Silt and clay are not stable in the littoral zone and are often washed offshore. This zone is ideal to develop mud flats and mangrove areas. Mangrove constitutes an important part of muddy coast. They are biologically diverse, ecologically sensitive, economically valuable and physiologically stable system. Cutting can cause severe problems, decreasing biodiversity and causing erosion and flooding. The connected coast type is often low wetland exposed to flooding. Mixed environments with wave exposed shores or sandy tidal flats alternating with mud dominated tidal flats and deeper muddy areas are common.

2. Salt Marsh areas and intertidal mud flats

Salt marshes and intertidal mud flats act as natural coastal defenses against rising sea level and natural calamities. However, it is questionable whether these areas are able to keep track with a changing sea level at the same time as adjusting to various anthropogenic impacts including stress caused by herbicides, nutrient loading etc. Sustainable development of an ecosystem requires the system to be fully understood and the future development to be adequately anticipated in order to make the right basis for management. In order to predict the future development of salt marshes under a changing climate, descriptions of the biogeochemical and geomorphological processes influencing this area are needed as well as an understanding the vulnerability of the present ecosystem. The interactions between human impacts and natural changes in the ecosystem include the aspects of biodiversity and global change.

Salt marshes and intertidal mud flats act as natural coastal defences against a rising sea level.

3. Processes

Estuarine areas and coastal lagoons are sinks for fine grains of sediment on an annual time scale. The processes responsible for the net import of sediment to estuaries include: 1. Settling and scour lag, 2. Estuarine circulation driven by horizontal density gradients, 3. Shoaling of the tidal wave causing an asymmetric distribution of the velocity and sediment concentration; 4. The aggregation of fine grained particles either by electrochemical or biological processes These processes together have the effect of accumulating fine grained sediments in shallow coastal lagoons, generally keeping pace with the magnitude of the local rise in sea level. However, there is large spatial variation in accumulation rates with the highest rates in the inner parts of the lagoons and the lowest rates close to the tidal inlet and in deeper parts of the area. Therefore, where accommodation space is available, salt marsh areas develop, especially fringing the inner parts of estuarine areas.

4. Local hydrodynamics

The local hydrodynamics depends on tidal currents and waves and thus determine the physical, morphological and biological characteristics of a mudflat. The degree of wave activity depends upon the nature of wind, and can vary significantly within an estuary. It is well known that even small waves are able to erode large amounts of surface sediment. These materials can be carried shoreward when the tide is advancing. The level of wave attack on the mudflat is the result of wave attenuation and the relationship between the mudflat slope and the water level. The mudflat profile will change in response to different forcing, altering the morphology and hydrodynamics, whilst evolving to reach some new equilibrium.

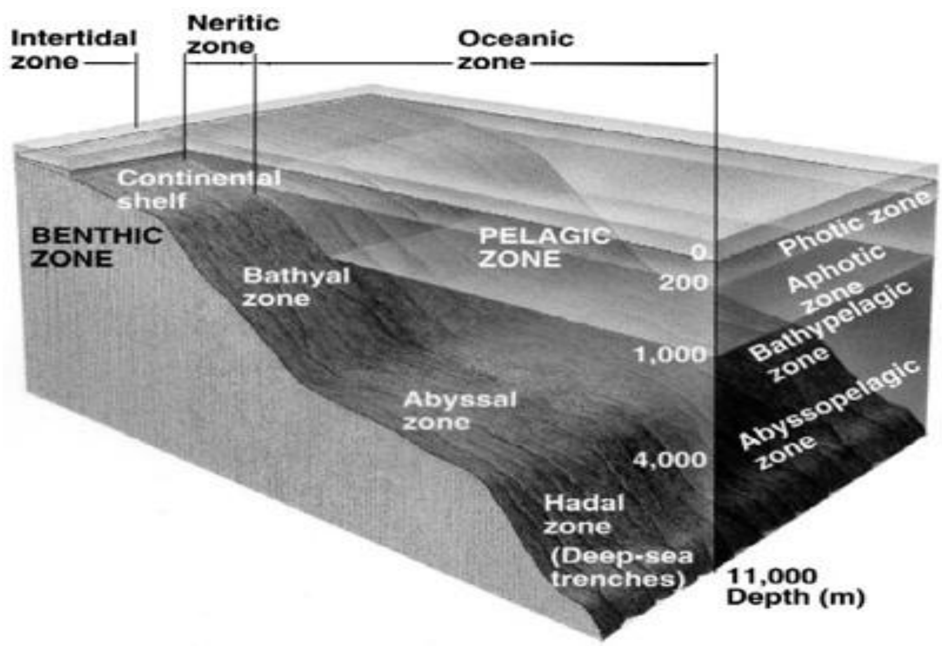
5. Ecomorphology of muddy coasts

Biological processes such as the effect of the macrofauna living in the mud and associated algae bed producing EPS (Extracellular Polymeric Substances) are of prime importance for stability and erodibility of mudflat. The nature and movement of surface sediment across the intertidal zone control by the biological, sedimentary and physical processes as they are interconnected. Therefore, alterations of key species on the tidal flats due to climate change may lead to significant changes in salt marsh development. The effect of storm events may alter the process of inundation and drying in the saltmarshes. Therefore, it is not a straightforward problem to foresee what will happen to a specific salt marsh area if the storm frequency increases or sea level rises faster than the current rate. Salt marsh areas build up vertically when inundated by turbid estuarine waters. This means that episodic events like storm surges and extreme high water levels are important. To cite an example, one storm event (as on 3rd December 2000, in the North Sea, also influencing the Danish Wadden Sea) may substantially contribute to the annual sedimentation rate. The timing and frequency of such events are likely to be very different in warmer climates than in colder climates with important implications for the stability of the system.

5.6. THE DEEP SEA ECOLOGY

1. Introduction

Most people familiar with the life exists in the intertidal zone,where the ocean water meets landand the epipelagic zone, the upper sunlit zone of the open ocean. Abundantlife is present in these zones because of the presence of sunlight that is available for photosynthesis. In fact, most part of the ocean is cold, dark and deep. It is understand that photosynthesis undertaken only up to 200m depth beyond that the sunlight gradually disappears when the depth increases.The maximum depth reported so far about 11,000 m in the Mariana Trench, Pacific Ocean.The World Oceans occupied71% of the earth surface or about 361 million sq. km with depths greater than 1,000 m. Until recently, the deep sea was largely unexplored. Due to advancement in technologies increases the scope of marine biologists to observe and uncover the mysteries of the deep ocean realm.There may be yet other life-altering discoveries to be found at the bottom of the ocean.



Until 2012, only submarine device has ever reached the bottom of Mariana trench at about 11,000 m: the bathyscaphe Trieste manned by Jacques Piccard and Don Walsh. During the Trieste's single dive in 1960, its windows began to crack, and it has never been used since. After 52 years, on March 25, 2012 James Cameron successfully dove in his commissioned one man submarine to the Challenger Deep. Don Walsh was also invited to join the expedition.

5.6.1. Physical Characteristics of the Deep Sea

The physical characteristics of the deep sea life are:

1. Abiotic: Light (or lack thereof), pressure, currents, temperature, oxygen, nutrients and other chemicals; and

2. Biotic: that is, organisms that may be potential predators, food, mates, competitors or symbionts.

All these factors have led to fascinating adaptions of deep sea life for sensing, feeding, reproducing, moving, and avoiding from predators.

1. Light

Below 200 m depth from the surface are considered as deep sea, where sunlight becomes inadequate for photosynthesis. From there to about 1000 m, sunlight continues to decrease until it is gone altogether is known as mesopelagic or "twilight" zone. This weak light is deep blue in color because all the other colors of light are absorbed at depth. The deepest ocean waters below 1,000 m are as black as night as far as sunlight is concerned. However there is a light in the deep because of body that creates light without heat. It is very common phenomenon and could see when you dive in to deep.The animals living here are similar as present in the mesopelagic zone and need some special sensory adaptations. Many deep-sea fishes have large eyes to capture the low light that is available. Other animalssuch as tripod fishes are essentially blind and instead rely on other, enhanced senses including smell, touch and vibration.

2. Pressure

Considering the volume of water above the deepest parts of the ocean, it's no wonder that hydrostatic pressure is one of the most important factors affecting deep sea life. One atmosphere (atm) pressure increases for every 10 m depth. The deep sea varies in depth from 200 m to about11,000 m, therefore pressure ranges between 20 atm and 1,100 atm respectively.High pressures can cause air pockets, such as fish swim bladders, to be crushed, but it does not compress water itself very much. Instead, high pressure alters the complex biomolecules especially membranes and proteins upon which all life depends.Animals brought to the surface from greater depthsby nets and submersible sample boxes generally die; in the case of some (but not most) deep-sea fishes, their gas-filled swim bladder (adapted to resist high pressure) expands to a fatal size. However, the vast majority of deep-sea life has no air pockets that would expand as pressure drops during retrieval.Instead, it is thought that rapid pressure as well as temperature change kills them because their biomolecules no longer work well. The microbes collected from 11,000m deep trenches have special adaptations (pressure – resistant biomolecules and piezolytes) to thrive in that environment.However, pressure adaptations have only been studied in animals down to about 5,000 m. We do not yet know if the adaptations found at those depths work at greater depths down to 11,000 m.

3. Temperature

Except in polar waters, the difference in temperature between the euphotic or sunlit zone near the surface and the deep sea can be dramatic because of thermoclines or the separation of water layers of differing temperatures. In the tropics, for example, a layer of warm water over 20^{o}C floats on top of the cold and dense deeper water. The water temperature of the most part of deep sea is more or less uniform and constant.With the exception of hydrothermal vents where hot water is emitted into the cold waters, the deep sea temperature remains between about -1 to about +4 ^{o}C.However, water never get freeze in the deep sea because of the salt content. The sea water can freeze at -1.8^{o}C.If it is freeze, it would just float on the surface as ice.Life in the deep sea is thought to adapt to this intense cold as like in shallow marine life does in the polar seas. To cite an example, butter, a saturated fat, is very hard in your refrigerator and would make a poor membrane in the cold, while olive oil an unsaturated fat is semi-solid and would make a good flexible membrane.However, as with pressure, there is a tradeoff: loose membranes and proteins of cold-adapted organisms readily fall apart at higher temperatures.

4. Oxygen

Deep seas have adequate oxygen even though it is dark and cold. Cold water can dissolve more oxygen than warm water, because the deepest waters generally originate from shallow polar seas.In certain places in the northern and southern seas, oxygen-rich waters cool off and they become dense enough to sink the seabottom.These thermohaline currents can travel at depth around the globe, and oxygen remains sufficient for life because of less biomass exist in the regions to use it.However, there are also oxygen-poor environments in the intermediate zones, because there is no oxygen made by photosynthesis and there are no thermohaline currents. These areas called oxygen minimum zones, usually lie at depths between 500 – 1,000 m in temperate and tropical regions. The animals as well as bacteria in these regions feed on decaying food materials descending through the water column use oxygen, which can consequently drop to near zero in some areas. Biologists are still investigating how animals survive under such conditions.Although most of the deep seafloor has oxygen, there are exceptions in isolated basins with no circulation. Some of these basins that have no oxygen are found at the bottom of the Mediterranean sea.In 2010, scientists made a surprising discovery that the animals living without oxygen at 3,000 m depths.This was first discovered in 1983 and the animals identified are Loriciferans, tiny animals.It is surprised, how can they survive in these condition is not yet known.

5. Food

Deep sea creatures have evolved some fascinating feeding mechanisms because food is scarce in these zones. In the absence of photosynthesis, most food consists of detritus, the decaying remains of microbes, algae, plants and animals from the upper zones of the ocean and other organisms in the deep. Deep-sea pelagic fish such as gulper eels have very large mouths, huge hinged jaws and large and expandable stomachs to engulf and process large quantities of scarce food. Many deep-sea pelagic fish have extremely long fang-like teeth that point inward. This ensures that any prey captured has little chance of escape. Many mesopelagic and deeper pelagic species also save energy by having watery, gelatinous muscles and other tissues with low nutritive content. Some mesopelagic species have adapted to the low food supply (and sometimes to the low oxygen content) in moderate-depth waters with a special behavior called vertical migration.

5.6.2. Adaptations of Deep-sea Animals

1. **Body Color:** This is often used by animals everywhere for camouflage and protection from predators. In the deep sea, animals' bodies are often transparent (such as many jellies and squids), black (such as blacksmelt fish), or even red (such as depths keeps them concealed from both predators and prey. Some mesopelagic fish such as hatchetfish have silvery sides that reflect the faint sunlight, making them hard to see.
2. **Reproduction:**
   Deep-sea anglerfish may use such light patterns as well as scents to find mates, but they also have another interesting reproductive adaptation. Males are tiny in compared to females and attach themselves to their mate using hooked teeth, establishing a parasitic-like relationship for life. The blood vessels of the male merge with the females so that the male receives nourishment from female. In exchange, the female is provided with a very reliable sperm source, avoiding the problem to locate a new mate every breeding cycle.
3. **Gigantism:** Gigantism in deep sea organisms is another possible adaptation not fully understood.This is the tendency for certain types of animals to become enormous in size. The colossal squidis the well-known example for gigantism. Similarly other organisms such as, the giant isopod, the king of herrings (which may be the source of sea serpent legends), and the recently captured giant amphipod from 7,000 m in the Kermadec Trench near New Zealand. While the giant tubeworms of hydrothermal vents grow well due to abundant energy supplies and other gigantic animals live in food-poor habitats. It is unknown how they achieve such growth.
4. **Long Lives:** Many deep-sea organisms, including gigantic found to live long years. Similarly, many smaller ones found to live for decades or even centuries. Long-lived fishes include tattails or grenadiers and the orange roughy, which are of special concern as they are targets of deep sea fisheries.These species reproduce and grow slowlyto attain maturity. Such populations may take decades to recover (if at all) after being overfished. This has happened repeatedly to the orange roughy, a deep-sea fish easily found congregation around seamounts in the southern oceans. Once fisheries have wiped out the population in one seamount undertake migration to another seamount.

5.7. Summary

In this unit, you might have learnt about the primary productivity in the ocean largely refers to the production of organic matter by "phytoplankton," plants suspended in the ocean. The zooplankton feed upon phytoplankton as secondary producers (primary consumers).A rocky shore is an intertidal area that consists of solid rocks. It is often a biologically rich environment and can include many different habitat types like steep rocky cliffs, platforms, rock pools and boulder fields. Sandy shores or beaches are loose deposits of sand, gravel or shells that cover the shoreline in many places. Muddy coasts are only found in environments that are fairly calm with respect to wave conditions, or where there is abundant supply of fine sediments. They are normally vegetated by mangrove plants. All phytoplankton and many zooplankton are microscopic in size. Their small size and complex shapes produce a high surface area-to-volume ratio. A high surface area-to-volume ratio favors the rapid exchange of gases by diffusion and creates a high frictional resistance, which means they sink slowly. It also facilitates the rapid excretion of wastes across the body surface, light trapping, and nutrient absorption.

UNIT VI: UNIQUE FEATURES OF CORAL REEFS, SEAWEEDS, SEAGRASSES AND MANGROVES

Structure

6.0 OBJECTIVES:

This chapter aims to introduce the following aspects:

- Types and distribution coral reefs found in India
- n of coral reefs in India
- Importance and threads of coral reefs
- seaweeds and classification
- Seagrasses taxonomy, distribution and Importance
- Mangrove distribution and Importance

- Estuarine ecosystem

6.1 CORAL REEFS INTRODUCTION

Corals are composed calcium carbonate secreted over time by hundreds of soft bodied animals called polyps. Each polyp lives in a symbiotic relationship with host zooxanthellae that gives color to the coral. Zooxanthellae take in carbon dioxide, process it through photosynthesis and give off oxygen and other important nutrients that are then used by the host polyp. Therefore the corals must be exposed to a sufficient amount of sunlight. That is why most corals grow fast and diverse only in shallow waters that are clean and clear. There are two kinds of corals: hard and soft. Hard corals (Scleractinia) such as brain, star, staghorn, elkhorn and pillar corals have rigid exoskeletons, or corallites, that protect their soft delicate bodies. Soft corals (Gorgonians) such as sea fans, sea whips and sea rods sway with the currents and lack an exoskeleton.

6.1.1 CONDITIONS REQUIRED FOR GOOD CORAL REEF FORMATION

The coral reefs are well adaptive in warm, shallow and well aerated places and these satisfactory conditions are found mostly in tropical and subtropical sea regions. Intensity of surface illumination of radiant energy is another important factor for good coral reef formation. Coral reefs are confined between 30^{o} North and 3^{0}S Latitude. They are well suited in a temperature range of 22ºC to 26ºC. If this range falls below 17ºC or rises above 28ºC then formation of reef is disturbed.

6.1.2 TYPES OF CORAL REEFS FOUND IN INDIA

There are mainly three types of coral reefs

1. Fringing reefs: These types of reefs are closely present with the shore of a mainland and these may be islands or an extended part of continental coast border. In both cases, a narrow channel called Lagoon has an intervening water body. The most significant growth of corals occurs at the edges of these reefs. Fringing reefs are found in Gulf of Manner, Palk bay and in Andaman & Nicobar islands of India.

2. Barrier reefs: These reefs are quite similar with fringing reefs but are disconnected from the mainland by a narrow region of sea. Barrier reefs are mainly found in Andaman & Nicobar islands of India. Outside India, the Great Barrier Reef is located in Australia.

3. Atolls: A**toll** is a ring-shaped coral reef including a coral rim that encircles a lagoon partially or completely. There may be coral islands or cays on the rim. The coral of the atoll often sits atop the rim of an extinct seamount or valcano which has eroded or subsided partially beneath the water

6.1.3 DISTRIBUTION OF CORAL REEFS IN INDIA

Coral reefs are restricted mainly in seven regions of India, such as Goa coast, Kerala coast, Palk Bay, Gulf of Kachchh, Gulf of Manner, Lakshadweep islands and Andaman and Nicobar Islands. In India, coral reef ecosystem is distributed along with both west and east coasts.

6.1.4 THE IMPORTANCE OF CORAL REEFS

Reefs play an important role in protecting the shoreline from storms and surge water. Barrier reefs help stabilize mangroves and seagrass beds, which can easily be uprooted by large waves and currents. Erosion prevention is particularly important in coastal areas where much of the shore is lined with residential homes and commercial buildings. Coral reef serves as a nursery and breeding ground of marine orgaisms. Fish and other marine life have been a primary source of protein for as long as people have lived along the coast. From small scale artisanal fisheries to major commercial fleets, harvesting of marine life is a major economic force in all of the world's oceans. Local fisheries such as lobster, stone crab, snapper and grouper, all directly rely on the reef for spawning and habitat. Other fisheries such as tuna, dolphin and other pelagic species rely on the reef indirectly, though the bait fish that they consume. Most corals and sponges are filter feeders. It enhances the quality and clarity of near shore waters. Coral reefs often form the backbone of local economies.

6.1.5 THREATS

Direct threats are generally isolated incidents involving boats, divers and fishermen on the reef. Propellers and anchors can break apart and crush coral and destroying years. Poorly informed and negligent divers also harm corals by touching and standing on them. Indirect threats are generally associated with water quality and clarity. Larger debris, coming from both the land and the sea, can break coral and suffocate marine life. Plastics are an especially large threat, as they often wrap around smaller branching corals, entangle marine life and kill animals such as sea gulls and turtles. Water quality is jeopardized on many reefs due to heightened pollutant and nutrient levels associated with inadequate waste water and storm water treatment. Storm water is rain water that enters the ocean after running off of the land.

Impervious surfaces, such as roads, parking lots, roofs and other residential and commercial spaces, magnify storm water by preventing absorption of water into the land. Storm water often includes harmful pollutants such as oil and gasoline, pesticides and fertilizers and other land based chemicals. Fertilizers are particularly harmful, as they cause wide spread algae blooms that out compete sea grasses and corals for sunlight. All storm water runoff alters the chemical composition of near shore waters and causes increased turbidity and sedimentation. This is especially harmful to corals, as they thrive in clean, clear nutrient free waters. Large channels and currents bring nutrients, pollutants, fertilizers and pesticides to the reef ecosystem. This highlights how long term marine conservation depends not only on local efforts, but on cooperation amongst various stakeholders in multiple regions is essential.

6.2 SEAWEEDS INTRODUCTION

Seaweeds or marine macro algae are the group of plants that live either in marine or brackish water environment. Like the land plants seaweed contains photosynthetic pigments and with the help of sunlight and nutrient present in the seawater, they photosynthesize and produce food. Seaweeds are found in the coastal region between high tide to low tide and in the sub-tidal region up to a depth where 0.01 % photosynthetic light is available. Plant pigments, light exposure, depth, temperature, tides and the shore characteristics combine to create different environment that determine the distribution and variety among seaweeds. They are basically classified according to color into three main groups i.e. green (Chlorophyta), brown (Phaeophyta) and red (Rhodophyta).

6.2.2 Green algae (Chlorophyta)

Morphology: They are found in the fresh and marine habitats. They range from unicellular to multi-cellular, microscopic to macroscopic forms. Their thalli vary from free filaments to definitely shaped forms. The photosynthetic portion of the thalli may be moderately to highly calcified appearing in variety of forms as fan shaped segments, feather like or star-shaped branches with teeth or pinnules, clavate or globose branchlets.

Pigments: They possess photosynthetic pigments such as Chlorophyll a & b, contained in the special cell structure known as chromatophores. The cell wall of this group composed of an outer layer of pectin and an inner layer of cellulose. The photosynthetic product of this group is starch.

Reproduction: Green algae can reproduce sexually and asexually by forming flagellate spores and sometimes non-flagellate spores. The vegetative propagation is achieved through fragmentation. Alternation of gametophytic and sporophytic generation occurs in this group.

6.2.3 Brown algae (Phaeophyta)

Morphology: Brown algae are exclusively marine forms. They have different forms from simple, freely branched filaments to highly differentiated forms. They can be distinguished into blades, stipes and holdfast.

Pigments: Photosynthetic pigments of the brown algae are Chlorophyll a & c, carotene, xanthophylls and fucoxanthin (pigment responsible for brown color). The cell wall composed of an outer layer of algin and an inner layer of cellulose. The photosynthetic products of the brown algae are Laminarian and Mannitol.

Reproduction: This group reproduces sexually and asexually. Several species of this group reproduce vegetatively by fragmentation. Members of this group produce biflagellate neutral spores found within one celled or many celled reproductive organs. The sexual reproduction is through union of flagellated male and female gametes or union of flagellated male and large non-flagellated female gametes. Alternation of gametophytic and sporophytic generations occurs in this group except in the members of *Fucales*.

6.2.4 Red algae (Rhodophyta)

Morphology: Except for few species they are exclusively marine. They vary in size and shape. They are either epiphytes, grows as crust on the rocks or shells as a large fleshy, branched or blade like thalli.

Pigments: They contain chlorophyll a & b, carotene, phycoerythrin (pigment responsible for red color). The cell wall of this group composed of an outer layer of pectin and an inner layer of cellulose.

Reproduction: This group seldom reproduces asexually. All the members of this group produce one or more kinds of non-flagellated spores that are either sexual or asexual in nature. Sexual reproduction is very complicated involving several structures after fusion of gametes. Some members of this group exhibit biphasic alternation of generation in which sexual generation (gametophyte) alternates with asexual (tetrasporophyte) generation, while others are triphasic with three generation or somatic phases (gamatophtye, caropsporophyte, tetrasporophyte) successively following one another.

6.2.5 IMPORTANCE OF SEAWEEDS

Seaweeds are used in many maritime countries as a source of food, for industrial applications and as a fertilizer. The present uses of seaweeds are as human foods, cosmetics, fertilizers and for the extraction of industrial gums and chemicals. They have the potential to be used as a source of long- and short-chain chemicals with medicinal and industrial uses. Marine algae may also be used as energy-collectors and potentially useful substances may be extracted by fermentation and pyrolysis.

1. As food: The sea weeds are also used as food. In Japan *Porphyra tenera* happens to be one of the most important edible algae and a product by the name of Amanori and Asakusa- Nori are made from it. The use of kelps ("kombu" in Japan; "haidai" in China) dates back to at least the 5^{th} century in China. In India Gracilaraia edulis (Kanchipasi) usually consumed as food by Ramanathapuram District of Tamil Nadu.

2. As a source of vitamins: Seaweeds are the richest source of vitamins. The vitamins A, B and E are found abundantly in sea weeds.

3. As a source of agar: The best agar is manufactured from Rhodophytes. The agar is used in several ways. It is employed in the preparation of ice creams, jellies, desserts etc. in sizing the textiles and clearing many liquids. It is also used in preparing shaving creams, cosmetics and shoe polishes. The agar has constantly been used in biological laboratories for media preparation.

4. Cosmetics, Medicines and minerals: There are several medicinal properties of seaweeds. Algae rich in iodine such *as Asparagopsis taxiformis*, *Sarconema* spp. can be used for controlling goitre disease caused by enlargement of thyroid glands. Many bioactive compounds can be obtained from seaweeds. Several diseases caused by vitamin deficiency such as vitex, asthma, tooth decay etc. may be eradicated, if flour of the sea weeds is added to the food. Iodine is the most important element to enable the thyroid glands to secrete the thyrosin which contains 60% iodine.

5. Alginic acid, algin and mannitol: The alginic acid is manufactured from the cell wall of phaeophyceae. It is insoluble in water and hard when dry. Sodium alginate is used in sizing material for water proof material, dyes, buttons, handles, combs and many of such things. This is also used as a sterilizer in daily use.

6. Used as fertilizers: Due to the presence of potassium chloride (KCI) in sea weeds, they are used as fertilizers in many countries. In India, freshly collected and cast ashore seaweeds are used as manure for coconut plantation either directly or in the form of compost in coastal areas of Tamil Nadu and Kerala. Seaweed manure has been found superior to farm yard manure.

6.3. SEAGRASSES

6.3.1 Introduction

Seagrasses are unique flowering plants that have evolved to live under sea water. Seagrasses belong to a group of plants known as angiosperms (flowering plants). Like terrestrial (land living) plants, a seagrass can be divided into its veins (lignified conducting tissue that transports food, nutrients and water around the plant), stem, roots (buried in the substrate) and reproductive parts such as flowers and fruits. Algae do not have veins in their leaves nor do they possess roots (anchoring to the surface of the substrate by a holdfast) or produce flowers or seeds.

6.3.2 Seagrass taxonomy

Seagrasses are monocotyledons that are not true grasses (true grasses belong to the family Poaceae), but are rather more closely related to the lily family. Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in a least three separate lineages or families. Worldwide, there are about 12 major divisions, consisting approximately 60 species of sea grasses. The highest concentration of species occurs in the Indo-West Pacific region. Over 30 species can be found within Australian waters. In India, 14 species belonging to 6 genera was recorded. Various common names are applied to seagrass species such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass.

6.3.3 Distribution of sea grasses

Seagrasses are found in ocean throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the Arctic (freezing) regions. Seagrass are mainly found in bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 meters. Most species are found in clear shallow inshore areas between mean sea-level and 25 meters depth.

6.3.4 Importance of seagreasses

Seagrass communities are one of the most productive and dynamic ecosystems. Seagrasses may significantly influence the physical, chemical and biological environments in which they grow. Seagrass meadows are highly productive and the animal diversity is 40 times higher on bare sand. One of the most important roles of seagrasses is providing a nursery and shelter area for fish and prawns which are valuable to fisheries. The species which depend on seagrass meadows include fish such as perch, mullet, whiting, tailor, bream, snappers, emperors and sweetlips; commercial penaeid prawns and lobster. Shellfish such as some oysters survive where there is seagrass. Larger predatory animals such as herons, cormorants, sharks, barramundi, salmon, crocodiles, etc. are also attracted to the seagrass meadows by the schools of forage fish which seek shelter there. Seagrass meadows are a major food source for a number of grazing animals and are considered very productive pastures of the sea. The dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*) mainly feed on seagrass. Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The decaying leaves are broken down by fungi and bacteria which in turn provide food for other microorganisms such as flagellates and plankton. Microorganisms provide food for the juveniles of many species of marine animals such as fish, crabs, prawns and mollusks. The rhizomes and roots of the grasses bind sediments on the substrate, where nutrients are recycled by microorganisms back into the marine ecosystem. The leaves of the grasses slow down the water flow allowing suspended material to settle on the bottom. Seagrasses are nutrient sinks, buffering or filtering nutrient and chemical inputs to the marine environment. Seagrasses uptake nitrogen and phosphorus from coastal run-off in overabundance, can lead to algal blooms that can impair water quality.

6.3.5 THREATS TO SEAGRASSES

Seagrass meadows are fragile ecosystems. Approximately 54% of seagrass meadows globally have lost part of their distribution. Some losses are natural due to storms and herbivores; however most losses are the result of human activities. Human pollution has contributed most to seagrass declines around the world. The most widespread and pervasive cause of seagrass decline is a reduction in available light. Processes that reduce light penetration to seagrasses include turbidity events during floods, enhanced suspended sediment loads and elevated nutrient concentrations. Poor farming practices can result in excess sediments and fertilizers washing down creeks to the sea. Sewage discharge and storm water runoff from urban development can elevate nutrients in coastal areas. Boating activity may also stir up sediment, reducing light levels. Phytoplankton and fast-growing macro-algae are also better competitors for light than benthic plants and their biomass can shade seagrasses during progressive eutrophication.

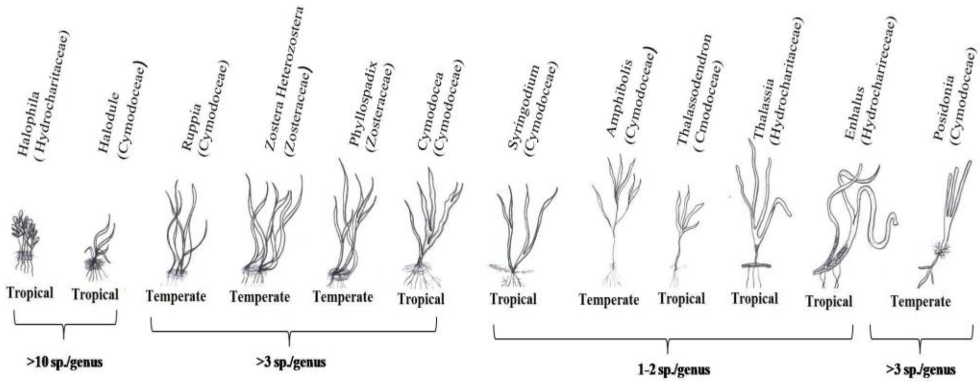
Oil and trace metal contamination can exert direct toxic effects on some seagrass species. Seagrasses are able to bioaccumulate the trace metals and this can have ramifications for grazers such as dugongs. People can also physically damage or destroy seagrass. Coastal developments can also cause changes in water movement. Dredging boat channels to provide access to these developments not only physically removes plants, but can make the water muddy and dump sediment on seagrass. Litter and rubbish can also wash into the sea if not properly disposed. Rubbish can physically and chemically damage seagrass meadows and the animals that live within them. One of the other significant impacts to seagrass is climate change. The greatest impact is expected to result from elevated temperatures, particularly in shallower habitats.

6.3.6 Monitoring

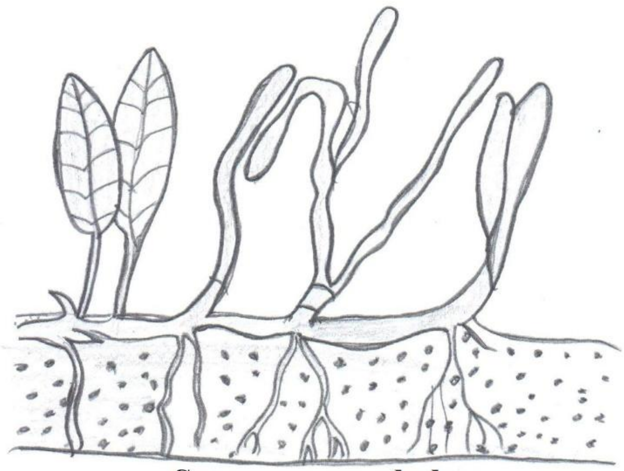
Monitoring seagrass resources is important for two reasons: it is a valuable tool for improving management practices; and it allows us to know whether resource status and condition is stable, improving or declining. Successful management of coastal environments (including seagrass resources) requires regular monitoring of the status and condition of natural resources. Early detection of change allows coastal management agencies to adjust their management practices and/or take remedial action sooner for more successful results. Monitoring is important in improving our understanding of seagrass resources and to coastal management agencies for:

- Exposing coastal environmental problems before they become intractable,
- Developing benchmarks against which performance and effectiveness can be measured,
- Identifying and prioritizing future requirements and initiatives,
- Determining the effectiveness of management practices being applied,

- Maintaining consistent records so that comparisons can be made over time,
- Developing within the community a better understanding of coastal issues,
- Developing a better understanding of cause and effect in land/catchment management practices,
- Assisting education and training, and helping to develop links between local communities, schools and government agencies, and
- Assessing new management practice.



Generic seagrass model



Seagrass morphology

6.4 MANGROVES

6.4.1 INTRODUCTION

Mangrove forests are found between 32 degrees north and 38 degrees south of the equator, in sheltered, inter-tidal areas that receive a high annual rainfall. The most extensive area of mangroves is found in Asia, followed by Africa and South America. According to the FAO, the total mangrove area is around 150,000 km^2. Four countries (Indonesia, Brazil, Nigeria and Australia) account for about 41% percent of all mangroves. Although a wide variety of plant species are found in mangrove forests, only some 54 species belonging to 16 families are recognized as "true mangroves" - species which are rarely found outside mangrove habitats.

1. Mangrove Roots: There are two most common mangroves by their roots. The rhizophora has “prop roots” and bruguiera mangrove has “breathing roots”. Prop roots are arising from the branches of the tree. Breathing roots come in and out of the soil. Mangrove roots have different functions – the roots anchor the plant, absorb minerals, exchange gases (O_2 and CO_2). Roots can only absorb water from the surroundings and excludes most of the salt. The extensive root systems slow down waves and water flowing through them. This reduces erosion by holding the earth together so it does not wash away from the land into the lagoon and reef, killing the coral. As a result, mangrove shores continue to grow towards the sea.

2. Mangrove Leaves: Mangroves have a medium-sized, thick waxy leaf that helps prevent excessive water loss. Like other plants, the green leaves of the mangrove use the sunlight to make food. When dead leaves fall into the water, they decay providing nutrients for soil and food for animals like crabs, prawns and some fish. The rhizophora leaves have blunt tips while bruguiera have a pointed tips.

3. Mangrove Seeds: Mangroves usually grow in flat, soft muddy ground. When the long, thin and pointed mangrove seeds fall vertically to the ground, they are able to stick upright in the soft mud. Some mangroves trees have seeds that start to grow while they are still on the tree. When the young plant is big enough to survive it falls into the water or mud. These young plants float around until they find a muddy area to grow. The seeds can float which helps them dispense and grow in new areas. Mangrove trees are constantly exposed to strong wind and waves. The new plants, when established in the soil, are able to withstand wave action. It is easy to distinguish between the seeds of rhizophora seed curves on the top, while the bruguiera seed is straight

6.4.2 OCCURRENCE AND DISTRIBUTION OF MANGROVES IN INDIA

India has around 4,461 sq. km under mangrove of which 59% are found along the east coast (Bay of Bengal), 23% along the west coast (Arabian Sea) and the remaining 18% on the Bay Island (Andaman and Nicobar Islands in Bay of Bengal). In India, mangroves exist on three major types of coastal settings. They are 1) deltaic, 2) backwater-estuarine and 3) insular categories. Mangroves are wide spread on the east coast of India owing to the nutrient rich alluvial soil formed by perennial supply of freshwater by the mighty rivers along the deltaic coast.

6.4.3 IMPORTANCE OF MANGROVES

Like coral reefs, mangrove forests are also exceptionally productive ecosystems that is beneficial to both the marine environment and people.

1. Organic transformation: Mangrove forests play a key role in transferring organic matter and energy from the land to marine ecosystems. This organic matter and energy comes from detritus from fallen leaves, twigs and forms the base of important marine food chains. Microorganisms break down the detritus, releasing useful nutrients into the water that can be used by marine animals.

2. Fisheries: Mangrove forests are home to a various types of fish, crab, shrimp and mollusk species. These fisheries form an important source of food for thousands of coastal communities around the world. Mangrove forests also serve as nurseries for various fish species, including coral reef fish.

3. Timber and plant products: Mangrove wood is highly resistant to rot and insects, making it extremely valuable. Many coastal and local communities use this wood as construction material and fuel. Mangrove ecosystems provide medicinal plants and animal fodder. Recently, the forests have also been commercially harvested for pulp, wood chip and charcoal production.

4. Coastal protection: The dense root system of mangrove forests help to stabilize the coastline and prevents erosion from waves and storms by trapping sediments flowing down rivers and off the land. Coastal damage from hurricanes and typhoons is much more severe in the areas where mangroves have been cleared. By filtering out sediments, the forests also protect coral reefs and seagrass meadows from being smothered in sediment.

5. Tourism: The diversity of life inhabiting mangrove systems, and their proximity to other tourist attractions such as coral reefs and sandy beaches, increases the tourism potential of the mangrove forests. It offers snorkeling expeditions in and around mangroves to witness a marvelous variety of baby fish, jellyfish and urchins against a magical background of interwoven roots delving deep into the sandy substrate.

6.4.4 THREATS TO MANGROVES

Mangrove forests are one of the world's most threatened tropical ecosystems. More than 35% of the world's mangroves was lost and 50% in countries such as India, the Philippines and Vietnam, while in– America they are being cleared at a faster rate than the tropical rainforests. Threats to mangrove forests and their habitats include:

1. Clearing: Mangrove forests are considered as unproductive and smelly. They are cleared to make room for agricultural land, human settlements, harbors, industrial areas, tourist developments, shrimp aquaculture and salt farms. This clearing is a major factor behind mangrove loss around the word.

2. Overharvesting: Mangrove trees are harvested for firewood, construction wood, wood chip and pulp production, charcoal production and animal fodder. In some parts of the world, mangrove is no longer sustainable, threatening the future of the forests.

3. River changes: Dams and irrigation reduce the amount of water reaching mangrove forests. This changes the salinity level of water in the forest. The mangroves cannot survive at higher salinity. Freshwater diversions can also lead to mangroves drying out. In addition, increased erosion due to land deforestation can massively increase the amount of sediment in rivers. This can overcome the mangrove forest's filtering ability leading to the forest being smothered.

4. Overfishing: The ecological balance of food chains and mangrove fish communities can also be altered due to overfishing.

5. Destruction of coral reefs: Coral reefs act as barrier against currents and strong waves. When they are destroyed, the stronger-than-normal waves and currents reaching the coast can undermine the fine sediment in which the mangroves grow. This can prevent seedlings from taking root and wash away nutrients essential for mangrove ecosystems.

6. Pollution: Fertilizers, pesticides and other xenotoxic chemicals carried by river systems can kill animals living in mangrove forests, while oil pollution can smother mangrove roots and suffocate the trees.

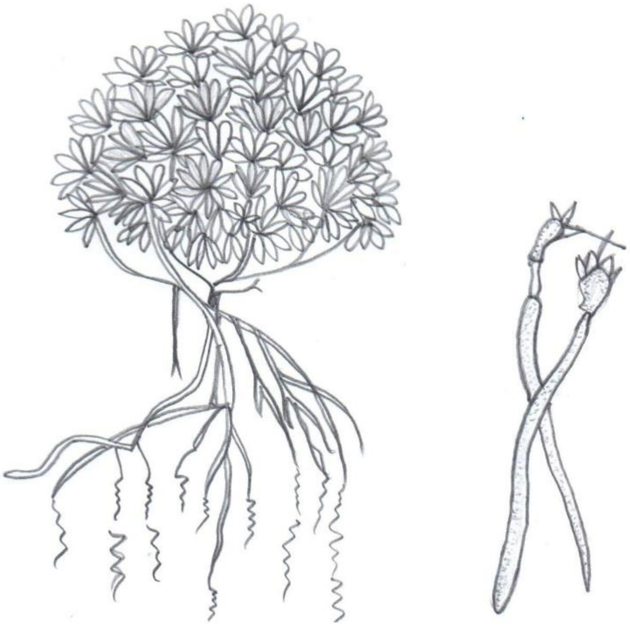
7. Climate change: Mangrove forests require stable sea levels for long-term survival. Rising sea levels caused by global warming and climate change can affect the mangroves.

6.4.5 CONSERVATION OF MANGROVES

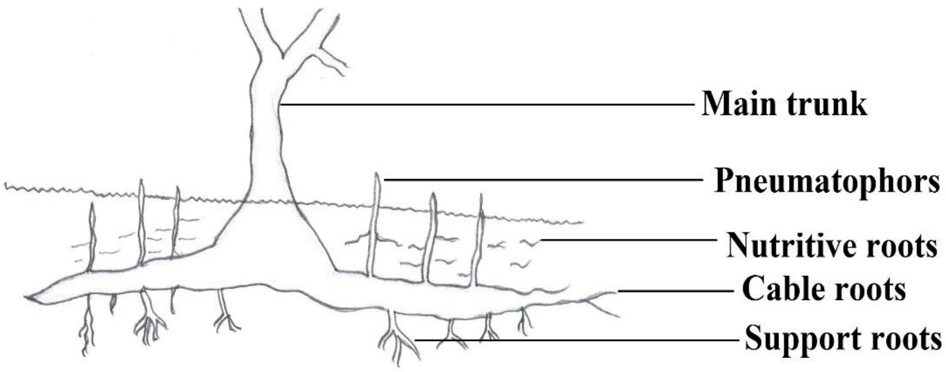
It is essential to systematically conserve the biodiversity in the mangrove ecosystem and manage well for the use of mankind. The management issues are categorized into:

(a) Conservation of the ecosystem:
- Afforestation (distinct conservation effort);
- Legislation (including laws and policies);
- Monitoring and Surveys (land and aerial, etc.);
- Protection (including conservation, parks and reserves development, etc.);
- Recommendations;
- Soil conservation;
- Status studies.

(b) Sustainable use:
- Culture (Agriculture, Aquaculture - capture fisheries, culture fish, etc.),
- Natural products useful for medicinal purposes, drugs, etc.); other products (timber, salt production, honey, etc.);
- Socio-economic aspects;
- Tourism.



Red mangrove (*Rhizophora mangle*)



Black mangrove (*Avicennia sp.*)

6.5 ESTUARINE ECOSYSTEM

6.5.1 INTRODUCTION

Waters of all streams and rivers ultimately drain into the sea; the place where the freshwater joins the salt water is called an *estuary*. Estuaries are the transitional zone between sea and rivers and are the sites of unique ecological properties possessing a characteristic biological make up. They are semi enclosed coastal bodies of water that have a free connection with the open sea and within which sea water is measurably diluted with freshwater from rivers. Not all rivers open into estuaries; some simply discharge their runoff into the ocean. Estuaries differ in size, shape and volume of water flow, all influenced by the geology of the region in which they occur. As the river reaches the encroaching sea, the stream carried sediments are dropped in the quite water. These accumulate to form deltas in the upper reaches of the mouth and shorten the estuary. When silt and mud accumulations become high enough to be exposed at low tide, tidal flats develop which divide and braid the original channel of the estuary. At the same time, ocean currents and tides erode the coast line and deposit the material on the seaward side of the estuary, also shortening the mouth. If more material is deposited than is carried away, then barrier beaches, islands and brackish lagoons appear.

6.5.2 PHYSICO – CHEMICAL FEATURES OF ESTUARIES

Physical features

1. Tides: Tides are the most important factors of an estuary. Semidiurnal tides are common in estuaries. At the time of high tide, there is an influx of saltwater from the sea. This incoming seawater is termed as ‘flow’. The water recedes towards the sea during the low tide, which is known as ‘ebb’. In most estuaries, there will be a net discharge of water from the estuary equal to the amount of river discharge. The environmental factors such as salinity, temperature, etc depends on the tidal cycles.

2. Waves: Waves are also the influencing factors in almost all estuaries. Waves of an estuary may be small because the bottom is shallow and the estuary is surrounded by land. The height of the waves is also less in all estuaries. The waves bring nutrients from the sea into the estuary.

3. Currents: Currents in the estuaries are mainly caused by tides and also by river flow. If the estuary is broad, the river current will be slow and if it is narrow, the velocity will be high. The velocity of current is also high during monsoon as the river is flooded. If the river opens into a shallow open estuary and if the estuary has a sand bar, the velocity of the tidal currents will diminish. Sedimentation and salt distribution are caused by currents in the estuaries. The currents in an estuary often tend to be stronger near the low water mark than at the high water mark. Hence, the sedentary forms find it difficult to find a suitable site for attachment since the high velocity of currents disturbs them.

4. Salinity: Salinity variation is one of the most characteristic features of estuaries. Salinity varies daily with tides and also with seasons. If the mouth of an estuary is small, a limited exchange with sea occurs then the salinity of the estuarine water may rise above that of the sea. As a result, an increase in salinity is found as one progress inland from the mouth of the estuary. In some areas, the river flow may cease completely during the dry season so that the estuary becomes a lagoon in which seawater becomes concentrated by evaporation.

5. Temperature: Temperature in an estuary is not constant and varies quite often. This is due to the mixing of waters of different temperatures. The temperature in shallow estuary shows the temperature of the atmosphere. Generally, the shallow estuarine water is much colder in winter and much warmer in summer than the open sea water.

6. Turbidity and light: A unique characteristic feature of all estuaries is that the inflowing water from the river is always turbid. This turbidity is due to the silt particles carried down by the river currents. The tidal currents are also responsible for turbidity in the estuary. The turbidity of estuarine waters varies widely throughout the year, reaching the maximum during the rainy season.

8. Presence of pollutants: The effluents from the various industries situated near the river, flow into the water which are ultimately carried to the estuary. The important pollutants are the chemicals like mercury, arsenic, fertilizers, copper, zinc, benzene, etc., that are found dissolved in the estuarine water. The solid undissolved pollutants may have the *blanketing effect* on the burrowing animals found in the bottom of the estuary. They may clog the gills and other parts of the animal like oysters inhabitating the bottom of the estuary. The pollutants are not only toxic but also deplete the oxygen content of the water.

6.5.3 CHEMICAL FACTORS

1. Oxygen: The oxygen content in any estuary is less when compared to the marine and freshwaters. The solubility of oxygen is influenced by salinity. At higher salinities the solubility of oxygen falls more or less at the same rate. Temperature is much more potent factor than salinity over the normal brackish range in determining the solubility of oxygen. The metabolic rate of organisms is increased when the temperature is raised, thus making greater demands on the available oxygen. During the day time, the oxygen content in the estuarine waters may be increased by the photosynthetic activities of phytoplanktonic organism and macrophytes. At night, these plants cease photosynthesis but continue respiring so that the oxygen content of surrounding water will lower at night. The decomposing sewage produces hydrogen sulphide which also depletes the oxygen content. The presence of chemical pollutants is also responsible for lowering the oxygen content in almost all estuaries.

2. Carbon dioxide and pH: The solubility of carbon dioxide in estuarine water is determined by the amount of seawater present and temperature. In seawater, carbon dioxide is present in the form of bicarbonates and carbonates. Thus, in the mouth of an estuary where the amount of seawater is greater owing to the tidal influx, the amount of carbon dioxide present correspondingly lesser. But the concentration of carbon dioxide remains more stable here. Hence, the pH of an estuary does not significantly change as seawater is a best buffer. In those regions of an estuary where the influence of freshwater is greater, the carbon dioxide and hydrogen ion concentration vary greatly. When carbon dioxide concentration is higher, the carbonic acid concentration goes up and the pH becomes lower. Thus, during the day time, the pH goes up because of the utilization of carbon dioxide for photosynthesis. At night, the pH becomes lower as carbon dioxide is produced by the organisms during respiration.

3. Hydrogen sulphide: Presence of hydrogen sulphide is another unique feature of estuaries. The formation of hydrogen sulphide takes place by the activities of the decomposing bacteria. For example, *Desulphovibrio aeestuarii* is an anaerobic sulphate reducing bacteria which liberate hydrogen sulphide during decomposition. In the deep waters of estuaries, the concentration of hydrogen sulphide reduces the oxygen content making the area inhospitable to aerobic organisms.

4. Other chemical factors: Sulphur is also one of the most important elements in the biology of estuaries. The formation if ferrous sulphide in intertidal areas is responsible for the black coloration of sand and mud. The anaerobic decomposing bacteria use sulphate as a hydrogen acceptor and liberate hydrogen sulphide. Iron salts available in the nearby sand and mud are converted into ferrous sulphide. Estuaries are usually rich in phosphates and nitrates which form nutrients for the phytoplanktonic organisms. The concentration of phosphorous is higher in the upper region of the estuary than near the mouth. Nitrogen is present as nitrate, nitrite and ammonia. The silicate is abundant in estuarine water as silicates. All these elements are the nutrients for the various organisms of estuaries.

6.5.4 BIOTIC COMMUNITIES OF ESTUARIES

1. Estuarine flora: In the estuaries, the plants of different groups are found which include phytoplankton and benthic diatoms, bacteria, fungi and larger macrophytes. Though the estuaries are rich in their nutrients, phytoplanktonic organisms are not abundant. This is due to the reduction of light penetration as a result of turbidity. Most of them are marine origin and freshwater phytoplankton is poorly represented. The important estuarine phtoplanktonic organisms are diatoms and dinoflagellates. The diatoms are *Skeletonema coatatum, Parallia sulcata, Chaetoceras debills,* etc. *Ceratium furga* and *C. buceros* are the dinoflagelltes of the estuaries. The benthic diatoms are bottom dwelling organisms which are the primary producers and serve as food for a variety of estuarine animals. *Euglena obtuse* is quite common in the bottom of estuaries.

Both aerobic and anaerobic bacteria inhabit the estuarine environment. Sulphate reducing bacteria are found in the mud. Generally, all types of bacteria decompose the organic substances of the estuaries. The fungi such as *Mucor* and *Penicillium* are also found in the estuaries which also decompose the organic materials. The macrophytes are the larger plants which are also found in the estuaries. Brown algae like *Fucus, Cladophora, Vaucheria,* etc. chlorophyceae and xanthophyceae are the common algae of the estuaries. Besides, sea grasses *Halophila ovalis* and the *eel-grass, Zostera marina* are the typical vegetation of estuaries.

2. Estuarine fauna

i. Plankton: The planktonic organisms of the estuaries are not true estuarine forms, but are brought into the estuaries from the sea by tides. They are again carried out on the ebb. Thus, only temporary plankton which stays in the estuary is being limited to the duration of a single tide. Planktonic organisms of freshwater origin may be brought into the estuary by river which are finally carried to the sea and are perished. The freshwater plankters such as *Daphnia, Bosmina, Holopedium, Cyclops* and *Diaptomus* are usually found in the estuarine water. In estuaries with a long flushing time and fairly stable salinity gradient there is the possibility of permanent plankton. Many of the zooplankter’s in the estuaries undergo diurnal vertical migration may be influenced by the vertical salinity stratification present in the estuaries. Example: *Pleurobrachia globosa, Bougainvilla sp., Paracalanus dubia, Mesocyclops absoletus,* etc.

ii. Nekton: Nekton of the estuaries consists of fishes only. Cephalopods are conspicuously absent they are exclusively found in the sea. Certain crustaceans casually visit the estuaries. The estuarine fishes can be classified into two categories namely those spend all their life in the estuaries and those that move to estuary for a short period. Besides, the migratory fishes such as salmon and eel are also found in the estuary. *Boleopthalamus* and *Periopthalamus* are the two air breathing fishes found in the mud flats of the estuaries. These two are the typical estuarine fishes. Besides, *Mugil cephalus* and *M. tade* are the typical estuarine fishes of the tropics. *Gastorsteus aculeatus* is another typical teleost of Europe. *Anguilla bicolor* and *A. anguilla* are the migratory fishes which migrate to the sea for breeding. They stay in the estuary for a short period before entering the sea. Similarly, the salmon which ascend the rivers during anadromus migration is also found temporarily in the estuaries. The other temporary dwellers of the estuaries are *Harpodon, Clupea, Scomber*. These fishes acclimatize themselves before entering the sea or freshwater river. Besides, daily migrants such as *Lates calcifer, Chanos chanos, Engraulius,* etc., are also included under the estuarine nekton.

iii. Benthos: Many of the estuarine animals found in the bottom of the estuary which are either buried themselves or live in the tubes (tube dwelling). Such animals are known as *benthos*. To escape from the effects of the current, the benthic forms are found always at the bottom of the estuary. Among the annelids, *Nereis diversicolar* and *Arenicola marina* are the typical estuarine benthos. The former is quite abundant in estuarine muds and the latter lives in burrows of the bottom of the estuary. They thrive well in varying salinity. The bivalve *Mytilus edulis* are found attached to the surface of the mud. *Scrobicularia plana* is also a bivalve found in the bottom of the estuary which is well adapted to live in deep soft mud. *Tellina sp.* and *mya sp.* are also bivalves of the estuaries well adapted for salinity variation. Besides the above the animals, crabs like *Eriocheir sp. Carcinus, Maia* (the spider crab), *Uca*, etc. are quite common in the estuaries especially in the sand bar of the estuary. The freshwater and terrestrial animals such as the nymphs of dragon flies, larvae of Chirnomous flies, Aedes and Anoples are also inhabitating the bottom of estuary.

6.6 SUMMARY

In this unit you have studied in details about unique features of Coral reefs, Seaweeds, Sea grasses, Mangroves and estuaries. The salient features are as follows: Corals are composed of calcium carbonate secreted over time by hundreds of soft bodied animals called coral polyps.. Each polyp lives in a symbiotic relationship with host zooxanthellae that gives the coral its color. Seaweeds are found in the coastal region between high tide to low tide and in the sub-tidal region up to a depth where 0.01 % photosynthetic light is available. Plant pigments, light exposure, depth, temperature, tides and the shore characteristics combine to create different environment that determine the distribution and variety among seaweeds. Seaweeds are used in many maritime countries as a source of food, for industrial applications and as a fertilizer. The present uses of seaweeds are as human foods, cosmetics, fertilizers and for the extraction of industrial gums and chemicals. They have the potential to be used as a source of long- and short-chain chemicals with medicinal and industrial uses.

Sea grasses are found in ocean throughout the world.

They occur in tropical (hot), temperate (cool) and the edge of the Arctic (freezing) regions. Seagrass are mainly found in bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 meters. Most species are found in clear shallow inshore areas between mean sea-level and 25 meters depth. Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The mangrove are large wide spread on the east coast of India due to the nutrient rich alluvial soil formed by the mighty rivers and a perennial supply of freshwater along the deltaic coast. Like coral reefs, mangrove forests are extremely productive ecosystems that provide numerous good and services both to the marine environment and people. Waters of all streams and rivers ultimately drain into the sea; the place where the freshwater joins the salt water is called an *estuary*. Estuaries are the transitional zone between sea and rivers and are the sites of unique ecological properties possessing a characteristic biological make up.

6.7. Unit End exercise

1. Write an essay on physical and chemical properties of seawater.
2. Give an account on particulate organic matter.
3. Write short notes on the unique features of Coral reefs.
4. Explain about the Intertidal ecology.
5. Give an account on Factors influencing productivity.
6. Give a short note on primary production.
7. Write an essay on importance and conservation of mangroves.

BLOCK III: BIO-GEOCHEMICAL CYCLE

UNIT VII: BIOSPHERE: TYPES-HYDROSPHERE, LITHOSPHERE AND ATMOSPHERE.

Strucutre

7.1 Introduction:

As organisms are built up on chemical substances they require certain chemicals like N_2, O_2, H_2, P, C, etc. continuously for their survival. These chemicals enter the organisms from the environment and come out after undergoing changes or without changes. Thus these elements tend to circulate in a characteristic path from the environment to the organism and back to the environment. This cyclical path of the elements from the abiotic system to the biotic system and back is called biogeochemical cycles. As these chemicals form the components of food, these cycles are also called nutrient cycles.

7.2 Objectives:

- To know about biosphere types viz., hydrosphere, lithosphere and atmosphere.
- To learn about general account of biogeochemical cycles
- To know about cycling of non-essential elements and organic nutrients
- To study about recycling pathway of elements

7.3 Biosphere Types:

Each and every living organism has its specific surrounding, medium of environment to which it continuously interacts and remains fully adapted. The environment is the sum total of physical and biotic conditions influencing the responses of the organisms. The life supporting environment of planet earth-the biosphere is composed of following three chief media-air, water and soil, which are the components of three major sub-divisions of the biosphere-atmosphere, hydrosphere and lithosphere, respectively. These media are not completely isolated from each other, however, some of the atmospheric gases are dissolved in all natural waters, and some moisture is present almost everywhere in the atmosphere. Each of these media can be discussed separately in the following manner:

7.3.1 Atmosphere:

The multilayered gaseous envelope surrounding the planet earth is called atmosphere. The atmosphere remains in contact with all the major types of environment of earth, interacting with them and greatly affecting their ability to support life. It filters sunlight reaching the earth, affect climate, and is a reservoir of several elements essential for life.

7.3.2 Various Zones of Atmosphere:

The atmosphere is divided into five distinct layers or zones: troposphere, stratosphere, mesosphere, ionosphere and exosphere. The tropopause separates the stratosphere from the troposphere and stratopause separates mesosphere from stratosphere.

7.3.2.1 Troposphere:

It is the lowest region of atmosphere which subjects to differential heating, temperature inversions and convection currents and which extends from the surface of the earth up to a height of 8 to 10 km at polar latitudes (poles), 10 to 12 km at moderate latitudes and 16 to 20 km at the equator. For the organisms, troposphere forms a most important zone of atmosphere. Many important climatic events such as cloud formation, lightening, thundering, thunder storm formation, etc., all take place in troposphere. In this zone the percentage concentration of different gases in air does not vary with an increase in height. But the water vapor content in air depends upon the weather (e.g., part of the troposphere over an ocean carries more moisture than that over a land surface) and it decreases sharply with an increase in height as does the air temperature. Air temperature in this zone gradually decreases with height at the rate of about 6.5ºC per km (more specifically 5ºC per km (more specifically 5ºC per km in the lower troposphere and 7ºC per km in the upper troposphere). In fact, towards the upper layers of troposphere, the temperature may decrease up to-60ºC. Upper region of the troposphere has a narrow boundary called the tropopause which has a constant temperature.

Further, the non-uniform heating of the ground surface by sun's radiations produces ascending and descending air currents, which cause turbulence and mixing of air masses vertically. Moreover, the average air pressure at the earth's surface is 1,014 millibars (viz., 1 millibar = 1/1000 bar; 1 bar = 1.019 kg per cm^2 close to 1 atmosphere, 1.332 millibars = 1 mm of mercury (Hg). At an altitude of 5 km, the air pressure is half that at the surface; at 11 km it is 225 millibars and at 17 km it is only 90 millibars.

7.3.2.2 Stratosphere:

Next to troposphere is the second zone, called stratosphere, which is about 30 km in height. This zone is free from clouds and aeroplanes usually fly in its lower zone. The temperature of stratosphere increases up to 90ºCan such an increase in temperature is due to ozone formation under the influence of ultraviolet component of sunlight. Such a layer of ozone is called ozoneosphere. In ozonosphere, the sunlight ionize oxygen to ozone by photochemical dissociation. The ozonosphere completely absorbs solar radiation, ultraviolet radiation from the sun and also a lot of the solar infrared, thus, becoming warmer than adjacent layers above or below. There is a serious threat to this ozone layer now due to the harmful effects of gaseous pollutants. A big hole (i.e., thinning of the O_3 layer) has occurred in it, above the antarctic region. Upper layers of stratosphere form stratopause.

7.3.2.3 Mesosphere:

Stratosphere is followed by next zone called mesosphere which is 40 km in height. In mesosphere, temperature shows again a decrease up to-80ºC. Upper layers of this zone form the mesopause.

7.3.3.4 Ionosphere:

The remaining part of atmosphere above the mesosphere, up to the height of about 300 km above earth's surface, is called ionosphere. Ionosphere contains several layers of ionized air. Thus, most of the gaseous components which become ionized under the influence of radiant energy, remain as ions Ionosphere reflects short radio waves, making telecommunication possible over long distances.

7.3.3.5 Exosphere:

The exosphere is the outer fringe of earth's atmosphere and outer space begins after it. The air density is very low in this zone; hydrogen being dominant element of it.

7.3.3.6Air:

The gaseous mixture of troposphere, is utilized by most organisms in respiration to liberate energy from food during oxidation and is called air. In atmosphere, about 95 per cent of the total air is present up to the height of about 20 km above earth's surface and the remaining 5 per cent in the rest, of about 280 km height. In the gaseous mantle, there is found a mixture of gases in different proportion. Of these various gases nitrogen and oxygen are the major components of air.

Composition of atmospheric air

Component	% by volume	% by weight
Nitrogen (N_2)	78.09	75.54
Oxygen (O_2)	20.93	23.14
Argon (A)	0.93	1.27
Carbon dioxide (CO_2)	0.032	0.46
Miscellaneous	0.02	0.02

Miscellaneous component includes traces of hydrogen, ozone, helium, neon, krypton, xenon, sulphur dioxide, hydrogen sulphide, ammonia, methane, etc., Besides these gases, air may carry suspensions of liquids such as water in clouds and solids such as dust from the ground (soil), smoke from fires or salt from ocean spray. Air also contains microorganisms (viruses, bacteria, etc.), pollen grains and fungal spores, all forming biological constituents of the atmosphere.

In general, the composition of these gases in air and in other media on earth, such as water or soil, is in equilibrium with the atmosphere. In special ecological habitats such as the anaerobic regions of deep lakes or sand-mud flats, however, the composition of gases of air is altered dramatically. Slight differences occur in the atmosphere at different latitudes and, at places where gases are entering or leaving the atmosphere, such as volcanoes, fires, smelters, cities, metropolitan areas, and vegetation.

7.3.4 Physiologic-ecologic inter-relationships of gases and animals:

This atmospheric composition is not always the most important factor to organism; rather, it tis the partial pressure of a gas, especially oxygen and CO_2, which influences the existence of life, as illustrated by altitudinal studies on organisms. The partial pressure of a gas is the product of the total barometric pressure times the concentration of gas in dry air.

The solubility characteristics of oxygen and carbon dioxide in water are different, for carbon dioxide is about 200 times more soluble than oxygen. Both temperature and salinity have evident effects on the solubility of these two gases; with either increased temperature or increased salinity, there is a decrease in their solubility in water as has been shown in table.

Coefficients of saturation of CO2 in water at different temperatures and salinity (ml/liter in equilibrium with 760 mm Hg).

Temperature, °C	**Salinity, %**		
	0	28.91	36.11
0	1715	1489	1438
12	1118	980	947
24	782	695	677

In the process of photosynthesis, green plants use CO_2 and release O_2 during the day time; oxygen is used in respiration by all the organisms all the time. Photosynthesis, thus, regulates the oxygen and carbon dioxide balance in nature. Nitrogen which is abundantly present in the atmosphere is not used directly by plants or animals except by some bacteria and blue green algae. If gases are to be functionally important to an organism, there must be a mechanism whereby gas3es can enter and leave the body. Apparently the passage of oxygen across a membrane is accomplished by diffusion. The rate of diffusion can be calculated by Fick's Law, which is based on concentration coefficient, amount of surface thickness of the membrane, and time, and is expressed as the diffusion coefficient. The diffusion coefficient value is not the same for different animal tissues. For example, some representative values of diffusion coefficient of $O_2$are ; muscle, 0.000014; connective tissue, 0.000111; water, 0.000034; air, 11.0; chitin, 0.000013. Not only is the diffusion rate different in various tissues, but the behaviour of each gas also differs. Carbon dioxide, for example, diffuses through water and animal tissues 25 times faster than oxygen.

7.3.5 Air as a medium for living organism:

Air is not an easy and suitable medium to support life (biota) and actually no organism ever originated in air, though, certain aquatic and terrestrial organisms have become secondarily adapted for aerial existence. Air has so much less buoyancy than water that organisms emerging from water or land are immediately subjected to a stronger pull of gravity which holds them to the earth. They are also exposed to evaporation of water from their bodies, which threatens loss of water from the protoplasm and death by desiccation. Changes in temperature are much more drastic in air and there is great danger of chilling or overheating. Further, periods of light exposure are much longer and much more intense in air than in water or upland. The problem of mineral supply becomes acute in the air.

7.3.6 Biota of the air:

Only a few microorganisms, plants and animals have invaded the air. The most common examples of aerially adapted animals are insects, flying fish (Exocoetusvolitans), fling frog, flying lizard (Draco volans), flying phalangers (Petaurus), bats (Eptesicus), and birds.

7.4 HYDROSPHERE:

The oceans, rivers, streams, lakes, ponds, pools, polar ice caps, water vapour, etc., from the hydrosphere. About three-fourth of the earth's surface (75%) is covered with hydrosphere, the main component of which is water. Water is one of the most unusual natural compounds found on earth, and it is also one of the most important. The water remains in solid (snow), liquid (water) and gaseous (water vapor) forms. Life on earth began in the seas, and water in some form or the other is absolutely essential for the maintenance of all life. Water is one of the main agent in pedogenesis (soil formation) and is the medium for several different ecosystems,. It permeates the atmosphere and the outer layers, of lithosphere and has uneven distribution on earth, so that, some of the great ocean depths are approximately six or seven miles (9750 meters). Further water in its two forms, salt water and freshwater, forms two chief aquatic environments-namely marine environment and fresh water environment of earth. The oceans holding marine environment are two and one half times more extensive than land and provide over 300 times the living space, since they are habitable throughout their entire depth by certain groups of organisms. Water is obviously heavier than air which imparts a greater buoyancy to the aquatic medium enabling organisms to float at variable levels. The most unique features of water concern its physical properties.

7.4. 1Physical Properties of Water:

Henderson (1913, 1924) listed in his stimulating book, The Fitness of the Environment, the following characteristics of water which are favourable to biological systems:

1. A tremendous quantity of water exists on earth in three forms: gaseous, liquid, and solid. Not only is 75 per cent of the earth's surface covered by water but the atmosphere also contains an abundance of aqueous vapour, and the polar region is ice-covered. Moreover, at least 60 per cent of active protoplasm is water.

2. Water is an extremely inert body in relation to most other chemical substances.

3. It has unique thermal properties such as heat capacity, latent heat and higher freezing point.

(a) Heat capacity: Water has high heat capacity and it can withhold large amounts of heat. Because of the high heat capacity of water, oceans and lakes tend to maintain a relatively constant temperature, and therefore, the temperature of the biosphere is relatively stable. This property of water is functionally important to animal life. For example, a 165 lb (about 75 kg) man at rest produces sufficient heat to raise his body temperature more than 32ºC, but if the heat capacity of his body were to correspond to that of many other substances, this amount of heat production would raise his temperature 100-150ºC.

(b) Latent heat of melting and evaporation: The latent heat of melting is the number of calories required to convert 1 gram of solid at the freezing point into 1 gram of liquid at the same temperature. This value is about 90 for water, and means that the amount of heat necessary to melt ice is the same as that required to raise the temperature of the resulting ice water to 80ºC. The latent heat of evaporation is defined as the number of calories required to change 1 gram of liquid into vapor. For water this value is 536; therefore, as much heat is required to boil away 1 gram of water as to raise the temperature of 536 grams through 1ºC. These properties of water are important not only because they moderate the temperature of the biosphere, but also because they play a basic role in the evaporation of water and its precipitation as rain and as dew in the hydrological (water) cycle.

(c) Thermal conductivity: Although water is a poor thermal conductor compared to metals, among the common liquids it is excellent: for example, the conductivity value for silver is 1.10, for water, 0.0125, for alcohol, 0.00048, and for benzene, 0.00033.

(d) Expansion before freezing: The relationship between temperature and density, or mass per unit volume, is very unusual. When water is cooled from room temperature, it contracts, becoming denser until it reaches a maximum density at 3.94ºC. If cooled further, it begins to expand again. At the freezing point (0ºC) it expands markedly, unlike almost all other substances. Thus, ice will always float on the top of a lake or stream, and it is very unusual for an aquatic ecosystem ever to freeze solid, unless it is very small.

4 **.**No other compound compares to water as a solvent. So many different substances can be dissolved in it that it is known as the universal solvent. More things, in fact, can be dissolved in water than in any other liquid. This is especially true for inorganic chemicals which split, or dissociate to form electrically charged entities termed ions. Ionization influences most electrical phenomena and many chemical phenomena of solution. It is probable that all natural elements are soluble in water, at least in trace amounts, and that they are all found in natural water at some place or other on the earth's surface. In addition, many organic chemicals are water-soluble. Thus, water is the main medium by which chemical constituents are transported from one part of an ecosystem to the other. It is the only medium by which these constituents can pass from the abiotic portion of the ecosystem into the living portion.

Even in the driest of terrestrial environments, nutrient materials pass into the roots of plants in aqueous solution; when air is breathed by animals, oxygen is dissolved in water at the surface of the lung before it can cross the mucous membrane and be absorbed by the blood.

5.Water has the greatest surface tension of all common liquids, except mercury. The role of surface tension is most obvious in the way it allows certain things, such as pollen, dust, and water striders, to remain at the surface of a water body even though they are denser than the water. More important, however,, the high surface tension of water allows soils to contain a significant amount of water through capillary attraction and to make it available to terrestrial plant.

Visualizing these unique physical properties of water, Henderson (1913) concluded that no other known substance could be substituted for water as a basic abiotic environmental factor. Now, ecologists have known certain other important physical properties of water which affect life in some way. Some of the additional important physic-chemical properties of water are the following:

(i) Viscosity: Water is a fairly viscous liquid. Animals that live and move in water need to be much more streamlined than those that move through air, because the resistance to motion in a viscous medium is high. But at the same time, the viscosity of water allows organisms to swim using relatively simple movements. Further, high viscosity of water protects the aquatic animals and plants from the mechanical disturbances.

(ii) Buoyancy: Water is buoyant medium. Organisms can exist in it without specialized supportive structures such as those that are needed by organisms that inhabit terrestrial environments.

(iii) Transparency: Water is transparent medium. Its transparency enables the penetration of light to the depths where it is ultimately absorbed. Different wavelengths are absorbed at different depths. The long heat waves are stopped near the surface. Shorter waves with more energy penetrate successively farther. The ultraviolet rays penetrate beyond 100 meters. The zone up to which light rays penetrate is called as photic zone and below this zone there is complete darkness and organisms that require light cannot live. The transparency of water is greatly affected by the presence of suspended particles, phytoplankton, etc., which absorb light and so penetration of light in turbid water is less.

(iv) Pressure: Salinity has been defined as "the total amount of solid material in gram contained in one kilogram of the water, when all the carbonate has been converted into oxide, bromine and iodine replaced by chlorine and all organic matter completely oxidized." All types of natural water contain various amounts of different salts (ions) such as Na, K, Mg, CI, SO_4, PO_4, CO_3, HCO_3, NO_3, etc., and all these salts are responsible for the saltiness, salinity or salt content of water. The salinity of marine water is rather constant being about 3.5%. The salinity of fresh water varies greatly. Some salt lakes may have a salinity of 25% to 30% which greatly restricts life in them.

Comparison of some of the principal ions found in different kinds of water.

Water	Na	K	Ca	Mg	CI	SO_4	CO_3	Total per liter
1. Soft water	0.016	-	0.01	0.0005	0.019	0.007	0.012	0.065
2. Hard water	0.021	0.016	0.62	0.014	0.041	0.025	0.119	0.301
3. Sea	10.56	0.30	0.40	1.27	18.98	2.65	0.71	34.85
4. Great salt lake	65.51	3.76	0.065	4.47	110.08	13.04	-	197.51

Salinity of water acts as an important limiting factor for the distribution of a number of species of plants and animals. Certain animals such as, spider crab, Maia, etc., can tolerate only narrow fluctuations in salinity of water and are known as stenohaline animals. While some animals such as Mytilus, Aplysia, etc., can withstand wider ranges of salinity and are called euryhaline animals. However, there are certain animals, such as, Anguilla, Salmon, etc., which are both stenohaline and euryhaline.

7.4 2. Chemical Properties of Water:

Water consists primarily of a single compound, H_2O. It is a universal solvent and most chemical compounds ionize readily in water and provide many radicals and considerable versatility in the rearrangement of chemical substances. It has following chemical properties:

7.4.2.1 Solubility of gases in water:

Most gases dissolve readily in water, most notably those that are essential for life. The concentration of any gas in water generally varies between zero and a theoretical maximum or saturation. The latter is the amount of gas that can be dissolved in water when the atmosphere and the water are in equilibrium with one another. Except for waterfalls and very turbulent streams, the water in natural ecosystem is seldom in equilibrium with the atmosphere. A gas may show a deficit, if it is being utilized in the ecosystem faster than it is going into solution across the air water interface, or it may be supersaturated, if it is being produced in the ecosystem faster than it is being released from solution across the interface. The concentration of important gases may vary widely in any ecosystem, both horizontally and vertically.

Comparison between equilibrium concentrations of important gases in the atmosphere and in water (Clapham, Jr. 1973).

Gas	**Atmospheric concentration**	**Saturation in water**
Oxygen	210 cc./1.(21%)	7cc./1.(32.9%)
Nitrogen	780 cc./1.(78%)	14cc./1.(65.7%)
Carbon dioxide	0.3cc./1.(0.03%)	0.3cc./1.(1.4%)

The saturation level of any gas in water depends on several variables, most notably temperature, salinity, the concentration of the gas in the atmosphere, and its relative solubility in water. The greater the concentration of a gas in the atmosphere, the greater it's concentration in the water will tend to be, depending on its relative solubility in water.

7.4.2.1.1 Oxygen:

One of the most critical factor in an aquatic environment is the amount of oxygen in the water because most living organisms (excepting anaerobic forms) require this gas for respiration. In contrast to atmosphere, the oxygen becomes limiting factor for aquatic animals as the saturation concentration of oxygen in water is governed by temperature and salinity. As is evident in table 3-5.the lower the temperature, the greater the oxygen retaining capacity of water, whether it is fresh water or sea water.

Table: Comparison of the saturation concentration of oxygen in fresh water and salt water environment with varying temperature.

Water	Temperature, ºC	Saturation point in milliliter per liter
Fresh water	0	10.27
Salt water	0	8.08
Fresh water	30	5.57
Salt water	30	4.52

7.4.2.1.2 Nitrogen:

Nitrogen is significantly less soluble in water than oxygen. But because it constitutes 78 per cent of the atmosphere, it still accounts for about 65 per cent of the dissolved gases at equilibrium. It is fairly inert chemically and does not react with water, although some bacteria, fungi, blue-green algae, and so on, can se it to satisfy their nitrogen requirements; and other bacteria can produce it through reduction of nitrate under conditions of very low oxygen concentration.

7.4.2.1.3. Carbon dioxide:

The decomposition of organic matter and the respiratory activity of aquatic plants and animals produce carbon dioxide. This gas is one of the essential raw materials necessary for photosynthetic activity by green plants. Carbon dioxide combines chemically with water to produce carbonic acid (H_2CO_3), which influences the hydrogen ion concentration (pH) of water. Carbonic acid dissociates to produce hydrogen (H^+) and bicarbonate (HCO_3^{--}) ions. The bicarbonate radical may undergo further dissociation forming more hydrogen (H^+) and carbonate ($CO_3^=$).

The amount of free or uncombed carbon dioxide in water is of ecological importance: it governs the precipitation of calcium in the form of calcium carbonate ($CaCO_3$). Calcium precipitates when temperature and salinity are high and the amount of uncombined carbon dioxide is low. This means more carbonate ($CO_3^=$) is present to combine with the calcium caption (Ca^{++}). These conditions exist in shallow tropical waters, where evaporation is high. This raises the salinity and photosynthetic activity of plants and reduces the quantity of free carbon dioxide in water. The precipitation of calcium carbonate in tropical areas as the Bahamas explains the preponderance of thick calcareous shells of shallow water tropical mollusks, plankton and algae. In deep oceanic water, temperature is low and there are no photosynthetic plankton, consequently, the carbon dioxide content of the water is high. Deep water fauna (mollusks, crustaceans) possess very fragile skeleton because the precipitation of calcium carbonate is minimum.

7.4.2.1.4 Hydrogen sulphide:

The deeper layers of many bodies of water, including ponds, lakes, and some estuaries, may contain significant amounts of the toxic gas, hydrogen sulphide, which is released by decaying organic matter. If concentration of the gas builds up, all life but anaerobic bacteria excluded from the area (e.g., deeper strata of Black sea).

7.4.3Effect of Factor of Aquatic Environment on Aquatic Organisms:

The aquatic environment is subject to water movements ranging from small vertical circulations to strong currents. The streams have a unidirectional movement and in seas the movement is reversible. Many aquatic animals have accordingly taken to sedentary or sessile lives depending on water movements. Radial symmetry is a characteristic of such animals. Transformation from a sessile to a locomotive existence favors a bilateral symmetry. The water currents of water often abrade (= rub off) the inhabiting flora and fauna and varied modifications are encountered to withstand this abrasive action.Thick scales, strong shells and many attachment devices such as the holdfasts and suckers all are the results of this environmental stress. The ability to breathe air dissolved in water, at times even resorting to anaerobic existence, the modification of various senses to respond to stimuli characteristic of aquatic environments, the phenomenon of osmoregulation, and above all the phenomenon of external fertilization are other remarkable physiological adaptations to live in an exclusively aquatic medium.

7.4. 4 Water and Ecological Adaptations:

Water makes up a large proportion of the bodies of plants and animals, whether they live on land or in water. Active cytoplasm holds about 70-90 per cent of water. It has several important physiological properties. There exists a strong relationship between the water status of soil, plant and atmosphere. The rooting zone of the soil (zone of soil in which the water absorbing organs, roots, root hairs are present), the plant body and the lower layer of atmosphere behave as a continuum, called SPPAC or soil plant atmosphere continuum in relation to water transfer (Phillip, 1966). Solar radiation is the primary energy source for the water transport process in the SPAC. On the other hand, animals obtain water (i) by drinking (ii) by absorbing it through their skin from contact with some damp ground, (iii) directly from their food or (iv) from water produced by metabolism. The method of obtaining water and the relation to the supply of liquid water as well as resistance to the drying effects of the surrounding atmosphere are important in determining the distribution of animals.

The scarcity or abundance of water brings about adaptations in living organisms. Plants which grow in areas where water is available in plenty, are classified as mesophytes and terrestrial animals living under such conditions are called mesocoles. Plants growing in water are called hydrophytes, while animals that live in the aquatic environment are called aquatic animals of hydrocoles. Some plants can grow in ecosystems where water is scarce and where the day temperature is very high. These plants are called xerophytes and the animals living in such xeric conditions are called desert animals or xerocoles. Xerophytes living in physiologically dry soils, i.e., saline soils with high concentrations of salts such as NaCl, $MgCl_2$ and $MgSO_4$, are called halophytes. Based on their specific habitat, halophytes can be further classified into lithophilous, psammophilous, Pelophilous and helophilous plants growing on rock and stones, sand, mud and swamp, respectively. Helophilous helophytes include mangroves of sea shores of Bombay such as Rhizophoramucronata and Sonneratia.

7.4 4. 1 Hydrophytes and hydrocoles and their adaptations:

Hydrophytes include: (a) free-floating hydrophtes (e.g., Wolffia, Lemna, Spirodella, Azolla, Eichhoriacrassipes, Salving and Pistia), (b) rooted hydrophyte with floating leaves (e.g., Trapa, Nelumba, Nymphaea, Marsilea, etc.), (c) Submerged floating hydrophytes (e.g., Ceratophyllm, Utricularia, Najas, etc.). (d) rooted submerged hydrophytes (e.g., Hydrilla, Chara, Vallisneria, etc.), (e) rooted emergent hydrophytes or amphibious plants (e.g., Sagittaria, Ranunculus, etc.). Teneagophytes are amphibious plants-they grow in water bodies as well as in water logged soil.

These hydrophytes grow in hydric conditions and show the following general adaptive features: They possess poor mechanical, absorbing, conductive and protective tissues. They also contain an extensive development of air spaces (aerenchyma) in the tissues. Roots are either absent (e.g., Wolffia) or poorly developed (e.g., Hydrilla). Roots may not have root hairs, root cap (instead of root cap Eichhornia has root pockets) and vascular tissue. Roots of hydrophytes are generally fibrous and adventitious, when present. The stem of hydropytes is weak, slender and spongy. In some it is like a horizontal rhizome covered with mucilage, while it may be hard, as in Nelumbo. The aerial leaves may be broad but the submerged leaves are thin, long or ribbon-shaped. Stomata are completelyabsent in submerged leaves (e.g., Anacharis), but in floating forms, stomata are confined only to the upper surfaces of leaves as in Nymphaea.

Aquatic animals or hydrocoles in general exhibit an elongated stream-lined body having a compressed head, body and tail. Hydrocoles include fishes, sea turtles, mammals such as whales, and many others. There are also amphibious forms such as frog, toad, crocodile, etc., and many birds which visit water bodies either for reproduction or for collection of food.

7.4. 4. 2 Xerophytes and Xerocoles and their Adaptations:

Xerophytes grow in conditions of water scarcity, high temperature, strong winds, high transpiration rate and evaporation higher than precipitation. The soil is very dry and porous. The essential adaptations of xeropytes involve increased water absorption by roots, storing of water and retardation of transpiration. Thus, in search of water, xerophyutic tree may go very deep in the soil and have extensive root hairs to absorb it. The roots of plants such as Calotropisprocera, Ficus, and Acacia nilotica may go as deep as 10 to 16 meters and may reach the water table. As a consequence, these plants survive in deserts or arid conditions even if their rate of transpiration is higher. The storage of water is facilitated either by modifications of leaves, as in Mesembryanthemum and in the malacophyllous xerophytes (in which leaves contain turgescent parenchymatous cells) as Aloe, Begonia, Bryophyllum, Agave, Yucca, etc., or modification of stems, as in cacti such as Opuntia (phylloclade) and Euphorbia. In some xerophytes the water is stored in their roots as in Asparagus and Ceibaparvifolia. All these xerophytes are called succulents because they possess thick, fleshy, water storage organs such as stems, leaves and roots. Non-succulent xerophytes such as Aalotropis, Prosopis, Acacia, Zizyphus, Casuarina, Nerium, Saccharum and Pinus possess other sort of xerophytic adaptations, viz., extensive root syste, high osmotic pressure and other modification in the leaves. Reduced transpiration is achieved by decreasing the leaf surface, as in Casurina, Acaia and Asparagus or by modifying the leaves into spines and barbed bristles, as in cacti, or by having thick, leathery, thick cuticle or wax-coating bearing leaves with well-developed hypoderma and sunken stomata to reduce transpiration, as in Calotropis and Nerium. Halophytes (e.g., mangroves) resemble xerophytes and have high osmotic pressure; succulent organs; thin, evergreen, small leathery leaves with water storing tissues and thick cuticles and special air-breathing roots called pneumatophores.

Different animals have evolved the following adaptive features to live in arid environment:

Nocturnal life style:Most desert animals are nocturnal and seek shade or burrow deep in the soil in the day time to avoid excessive heat and dryness. Some xerocole rodents passively lose heat through conduction by pressing their bodies against the burrow walls.

Deceptive coloration:Desert animals are usually grey, brown or red matching with the color of the sand or rock.

Suspended animation: Certain animals, usually with simpler organization, such as rotifers, nematodes, tardigradse, desert snails, etc., retain their vitality in long dry environment. Other forms (frogs, toads, etc.) aestivate during droughts and are active during moist season of the year.

Fast movement:Desert animals move much faster than other land animals, since they have to travel long distances in search of food and water.

Migration: Many birds and mammals of arid zones migrate when water becomes scarce or as a result of drought or for other reasons, the food supply is less.

Heat loss by radiation:Animals such as jack-rabbits (Lepus) and fox (Vulpesvelox) hae large ears that reduce the need of water evaporation to regulate the body temperature. Their ears function as efficient radiators to the cooler desert sky, which on clear days may have a radiation temperature 25ºC below than that of the animal body. By seeking shade and sitting in depressions, Lepus could radiate 5 kcal/day through its two large ears (400 cm^2).

Impervious skin: The drier habitats (deserts, etc., are invaded by only those animals which contain a thick impermeable body covering. Such integuments occur in many insects, birds and mammals. Some mammals such as men, apes and horses lose much water (and salt) through sweat glands in heat regulation. Most rodents and some ruminants such as antelope nearly or completely lack sweat glands. Moist skinned forms (most amphibians and earthworms), certain mites and soft-bodied insects are restricted to swamps, stream margins, moist soils and other similarly damp places.

Upturned nostrils: Desert animals have nostrils directed upwards; this may provide a protection from clogging by windblown sand.

Water from food and from metabolism: Most herbivores and carnivores live on the moisture obtained with food. Many insects utilize the high water contents of plants to meet their water requirements. In fact, most animals make use of water released during metabolism when fats and carbohydrates are broken.

Kangaroo rat, which seals its burrow by day to keep its chamber moist, can live throughout year without drinking water. It obtains its water from its own metabolic processes and from hygroscopic water in its food.

Internal lungs or tracheal system: Mode of respiration has some correlation with water. Crustaceans, with their gills covered by a water-retaining carapace, carry with them a liquid environment for their gills. The scaly body covering of a fish may be practically impermeable to water and exchange of gases may be limited to gills and gut. Internal lungs, whether in pulmonate snails, land isopods, spiders or higher vertebrates (amphibians, reptiles, birds and mammals) together with the internal tracheal system of insects are water saving. Much water is lost in breathing even in animals having internal lungs.

Dry excretion: A further water-saving device is the excretion of concentrated, relatively dry nitrogenous and fecal waste materials. Water-saving insects, reptiles and birds excrete nitrogenous waste as solid uric acid.

Camel and African antelope, Oryx provide good examples of xerocoles or drought-resistant animals. Camel can go without food and water as longs as 10 day at a stretch. For water conservation, camel has following adaptations: (1) When camel drinks water, it can take in up to 50 litres in one gulp and tis water is evenly distributed all over its body in tissues and not in specific pockets or organs (e.g., in stomach) as the common misconception holds. (2) Camel excretes highly concentrated urine. Its dung also contains very little water, compared to the dung of the donkey or the cow (both of which are xerocoles). (3) It perspires very little and its breathing rhythm is very slow. (4) Camel can withstand dehydration up to 25 per cent of body weight and it loses water from body tissues rather than from blood. (5) Body temperature of camel is labile, dropping to 33.8ºC overnight and raising to 40.6ºC by day, at which point it begins to sweat. Due to such thermoregulation, the amount of water loss by perspiration and in other ways is greatly reduced. (6) Camel accumulates its fat in the hump rather than all over body. This speeds heat flow away from the body and its thick coat prevents the flow of heat inward towards the body.

7.5 LITHOSPHERE:

The earth is a cooled, spherical, solid planet of solar system, which rotates on its axis and revolves around the sun at a certain constant distance. The solid component of earth is called lithosphere. The lithosphere is multilayered including following main layers-crust, mantle, and outer and innercore. The core is the central fluid or vaporized sphere having diameter of about 2500 kms from the Centre and is possibly composed of Nickel-Iron. The mantle extends about 2900 kms above the core. This is in molten state. The outer most solid zone of the earth is called crust which is about 8 to 40 kms above the mantle. The crust is very complex and its surface is covered with soil supporting rich and varied biological communities, for living organisms find in the soil an environment providing food, shelter, and concealment from predators (Wallwork, 1970).

7.5. 1 Soil:

The word soil is derived from a Latin word 'Solum' meaning earthy material in which plants grow. The scince which deals with the study of soil is called Soil Science, Pedology (pedos=earth) or Edaphhology (edaphous=soil). The study of soil is significant for us due to various reasons. Soil is a natural habitat for microorganisms, plants and animals. Its knowledge is helpful in practices of agriculture, horticulture, forestry, etc., such as cultivation, irrigation, artificial drainage, and use of fertilizers. Pedology is important also for geology, petrology, mineralogy, palaeobotany and palaeozoology.

The soil can be defined as the weathered surface of the earth's crust which is mixed with organic material and in which microorganisms live and plants grow. Soil consists of the inorganic materials (the mineral matter) derived from parent rocks; the organic materials (the humus) derived from dead organisms; the air and water occupying the pores between the soil particles which are loosely-packed (the soil water and the soil atmosphere); small organisms (the biological systems) such as bacteria, fungi, algae, protozoa, rotifers, nematodes, oilgochaetes, molluscs and arthropods, and higher plants which live in it. Soil is the ultimate source of all food production since plants form the base of all ecological pyramids and plants grow in soil and derive nutrition from them. It provides mechanical anchorage to plants, besides serving as a reservoir of food materials and water. It is the site where nutrient elements are brought into biological circulation by mineral weathering. The soil harbours the bacteria which incorporate atmospheric nitrogen into the soil. Plant's roots occupy a considerable portion of the soil; tie the vegetation to the soil; and pump water and its dissolved minerals to other parts of the plant for photosynthesis and other biochemical processes.

Further, a mature soil is that state of soil that has assumed the profile features (i.e., succession of natural layers) characteristic of predominant soils on the smooth uplands within the general climatic and botanic regions in which it is found.

7.5. 1.1. Soil formation or Pedogenesis:

Soil is a stratified mixture of inorganic and organic materials, both of which are decomposition products. The mineral constituents of soil are derived from some parent material, the soil forming rocks by fragmentation or weathering, while, organic components of soil are formed either by decomposition (or transformation) of dead remains of plants or animals or through metabolic activities of living organisms present in the soil. Before discussing the soil-forming processes, let us describe in brief the nature of soil forming rocks as follows:

7.5. 1.2. Soil forming rocks:

Basically, there are following three kinds of soil forming rocks:

Igneous rocks which are formed due to cooling of molten magma or lava, e.g., granite, diorite and basalt.

Sedimentary rocks which are formed by deposition of weathered minerals which are derived from igneous rocks, e.g., shale's, sandstone and limestone.

Metamoirphic rocks which are formed by change of pre-existing rocks (e.g., igneous or sedimentary rocks) through heat and pressure, e.g., gneiss, schist, slate, quartzite and marble.

7.5.1.3. Chemistry of minerals of soil-forming rocks:

Rocks are the chemical mixture of numerous kinds of minerals. The chemical nature of certain most common and abundant minerals of soil-forming rocks has been listed in table.

Chemical composition of some common soil minerals.

Minerals	Chemical constituents
A. Sand and silt minerals	
1. Quarts or silica	SiO_2
2. Feldspars	
a. Orthoclase	$K_2Al_2Si_6O_{16}$
b. Plagioclase	$NaAlSi_3O_8$
c. Calcium feldspar	$CaAl_2Si_2O_8$
3. Micas	
a. Muscovite	$K(OH_2)Al_2(AlSi_3)O_{10}$
b. Biotite	K, Mg, Fe, Al silicate
4. Pyroxene	(Mg, Fe) SiO_3
5. Amphibole	$(Mg, Fe)_7 (Si_4O_{11})_2(OH)_2$
6. Olivine and serpentine	$(Mg, Fe)_2SiO_4$
7. Calcite; magnesite; and dolomite	$CaCO_3$, $MgCO_3$, and ($CaCO_3$, $MgCO_3$)
8. Iron oxides	
a. Haematite	Fe_2O_3
b. Magnetite	Fe_3O_4
c. Limonite	FeO (OH), xH_2O
B. Clay minerals	
1. Kaolin	Al_2O_3, $2SiO_2$, $2H_2O$
2. Montmorillonite	Ca,MgO)Al_2, O_3, $5SiO_3$, $5H_2O$

7.5.2 Process of Soil Formation:

The processes which are involved in the formation of mature soil can be studied under the following heads:

7.5.2.1 Weathering of Soil Forming Rocks:

Soil formation is started by disintegration or weathering of parent rocks by some physical, chemical and / or biological agents, because of which the soil-forming rocks are broken down in small particles called regolith's. Regolith's are the basic materials which under the influence of various other pedogenic processes finally develop into mature soil.

7.5.2.1.1Physical weathering:

The physical weathering agents are primarily climatic in character, exerting a mechanical effect on th substratum with the result that fragments are pulverized into progressively decreasing particle size (i.e., regoliths). Such climatic weathering of rocks does not cause any chemical transformation of rock-minerals and commonly occurs in deserts, in high altitudes, in high latitudes, and in localities with marked topographic relief and sparse vegetation cover. The agents which are involved in climatic weathering of rocks, are temperature, water, ice, gravity and wing.

The temperature causes break sown of those rocks which have heterogeneous structure, due to the fact of differential expansion and contraction coefficient of materials composing the rocks. Minerals composing the rocks have got different degrees of expansion. These minerals expand in the high temperature of day and contract when the temperature falls. The differential expansion and contraction of differe4nt minerals of rocks set up internal tensions and produce cracks in the rocks and consequently, the rocks weather into finer particles.

In its liquid state water causes mechanical weathering of rocks by following methods: (i) Rain water. Natural water falling either in the form of rain drops or hail storm on the surface of rock with beating effect bring about abrasion of massive rocks into smaller particles. (ii) Torrent water. Rapidly flowing water rolls the heavy rock masses such as rock boulders along the bottom of stream and grinds them into finer particles. (iii) Wave action.The wave actions are most effective in sea shores. The rapidly striking water waves dislocate solid particles of varying diameters from sea shore rocks and the debris is then settled at the sea bottom to form marine soil. Water also acts as a mechanical carrier. Nearly 5 billion tons of mineral matter is annually carried away in solution from land to sea.

In its freezing and ice-melting states water causes rock-weathering by frost action and glacier formation. Water in the form of frost or ice, is an extremely effective physical weathering agent of rocks. It seeps into rock crevices, freezes due to sudden fall of temperature of rocks, expands about nine per cent of its original volume, exerts a pressure (expansion force) of approximately 150 ton/ft_2 and eventually cracks the rock into smaller pieces. Likewise, in summer when ice at mountain tops starts melting and glaciers (huge sliding masses of ice) move downwardly on the slope, then during the glacier movement, the rock over which they move is gradually worn down to produce fine particles which are deposited as drift or till, when glacier finally retreats.

Gravitation weathering action is most effectively demonstrated by landslides and rock slippages caused by earth quakes and faulting during which the rock is fragmented by abrasion and the forces of impact. Lastly, the rapid stormy wind carrying suspended sand particles causes the abrasion of exposed rock. It acts like a mechanical carrier in moving the particles over the surface of earth as dunes or drifts and in transporting large quantities of fine suspended particles long distances.

7.5.2.1.2Chemical weathering:

The physical weathering produces a greater surface area of rock exposed to the chemical weathering, which occurs simultaneously with physical weathering and continues much beyond that. During chemical weathering, a chemical transformation or decomposition of parental mineral materials into new mineral complexes or secondary products occurs. For example, primary minerals that contain aluminium and silicon, such as feldspar, are converted to secondary mineral such as clay. Because4 chemical weathering requires the presence of moisture and air as essential factors; therefore, chemical weathering is not effective in deserts. It includes reactions such as solution, hydrolysis, oxidation, reduction, carbonation and hydration.

7.5.2.1.3Biological weathering:

Though the surface of bare rock is unsuitable for many forms of life, even then a number of microorganisms (bacteria, protozoan, fungi, nematodes, etc.), lichens and mosses can gain a foothold. These early colonizers transform the rock into a dynamic system, storing energy and synthesizing organic material (Jacks, 1965). Their activities alter the mineral composition as well as the physical structure of the rock. For example, lichens are present in the initial stages of biological succession and their growth may cause cracking or flaking, exposing greater area of rock to further weathering. The lichens and mosses extract mineral nutrients such as P, S, Ca, Mg, K, Na, Fe, Si, and Al, from the rock. These elements are combined with organic complexes, and eventually return to the developing soil when the vegetation decomposes.

7.5.2.2 Products of Weathering and soil Types:

The soil which is formed by weathering of soil-forming rocks is called embryonic or primary soil. The secondary or transported soils are those which are carried to other places by carriers such as gravity, water, glacier and wind. Soil material transported from one area to another is known as loess or eloign; that transported by water as alluvial, lacustrine (lake soil) and marine deposits; that transported by gravity as colluvial soil and that transported by sand storms as sand dunes. In a few places soil material comes from accumulated organic matter as peat. The soil which develops in situ above parent bedrock is called residual or sedentary soil.

7.5.2.3Mineralization and Humification:

The weathering of inorganic soil matter is followed by decomposition of organic matter, which starts at an early stage of pedogenesis, and continues up to much later stages. During early stages of pedogenesis, the organic contents of the embryonic soil are not very high, as the vegetation and its associated fauna are not richly developed. Also, the products of organic complexes, not easily separable into component parts in these initial stages. However, as both the size of soil particles and the spaces between them become smaller with the result that the water holding capacity increases. This together with the increasing amount of plant nutrients and organic material, allows the soil to support higher plant life, such as grasses; the protective covering effect and binding action of root systems so provided, promotes a greater stability of soil structure. Thus, soil development begins under some influence of plants. The root, draw nutrients from mineral matter, reproduce and die. Their roots penetrate and further breakdown the regolith. The plants pump up nutrients from its depth and add them to the surface, and in doing so recapture minerals carried deep into the material by weathering processes. By photosynthesis plants capture the sun's energy and add a portion of it as organic carbon to the soil each year. This energy source, the plant debris, enables bacteria, fungi (such as Rhizoctoniasolani, Armiliariamellea, etc.), earthworms and other soil organisms to colonize the area.

The breakdown of organic debris into humus is accomplished by decomposition and finally mineralization. Higher organisms in the soil-millipedes, centipedes, earthworms, mites, springtails, grasshoppers, and other-consume fresh material and leave partially decomposed products in their excreta. This is further decomposed by microorganisms, the bacteria and fungi, into various compounds of carbohydrates, proteins, lignin, fats, waxes, resins and ash. These compounds are broken down into simpler products such as carbon dioxide, water, minerals and salts. This latter process is called mineralization. The residual amorphous, incompletely decomposed black coloured organic matter which undergoes mineralization is called humus. The process of humus formation is called humificationMuller (1879, 1884) has recognized two kinds of humus-more and mull. Morhumus is acidic and support an abundant fungal growth and low number of soil bacteria. Fungal mycelia may help to bind together particles of humus and decomposition litter into matted layers and in a well-developed more, three such layers can be distinguished, namely a surface litter or Flayer, in comprising undecomposed leaves and twigs, below which is the fermentation or Flayer, in which decomposition has proceeded same way toward the development of humus, and beneath this, the humus or H layer, in which degraded humus fraction accumulate. More has low calcium content and developed on sandy soils under conifers. Mull humus is neutral or slightly alkaline and contain rich microflora of bacteria. It lacks distinct layering of the More, largely because the presence of calcium compound favours the development of a rich earthworm fauna which promotes a greater mixing of organic and mineral materials. The mull humus develops in brown forest soils under tree species having a relatively high calcium content, such as alder, elm, bad wood, aspen and few conifers (red cedar). Intermediate between the two types of humus is the 'moder' which has richer and varied fauna.

In order to emphasize the part played by living plants and animals in soil formation, Taylor (1930) proposed the following formula:

$$S=M(C+V+VA+A)\ t+D$$

Where, A signifies animal; C=climate; D=erosion or deposition; M=parent material, S=soil; t=time and V=vegetation.

7.5.2.3.1Role of earthworms in soil formation and soil fertility:

Earthworms play a significant role in soil formation. They may burrow two meters into the soil, make numerous transverse furrows and produce worm casts by eating the soil and soil organic matter (litter). These casts are very rich n nitrogen, water soluble aggregate and mineral substances and increase soil fertility. The burrows facilitate aeration and increase water holding capacity of the soil. Dash and Patra (1979) have calculated 77 tons of dry weight of earthworm cast production per hectare per year in an Indian grassland site. It is estimated that soil turn over due to earthworm action provides a stone-free layer about 15 cm deep on the surface.

7.5.2.3.2 Formation of Organo-Mineral Complexes:

During final stage of pedogenesis, colloidal particles which are formed due to weathering, humification and mineralization accumulate and may aggregate into crumbs or concretions. Some colloidal humus particles may become associated with mineral particles to from organo-mineral complexes. According to Wallwork (1970) the crumbs or organo-mineral complexes are formed by following two mechanisms-electro chemical bounding and cementing. In electrochemical bonding method of crumb formation, aggregation of negatively charged colloidal clay and or humus particles of water molecules and metallic ions, particularly calcium takes place. The cementing mechanism of crumb formation involves the action of substances absorbed on the surface of soil particles which effectively glues them together.

The crumbs increase the total pore space in the soil allowing good aeration and drainage. Eventually, a characteristic profile develops under the influence of climate, vegetation, parent material and the activities of the soil communities. The mature soil, thus, becomes a complex system of living and non-living materials not inert but active.

7.5.2.4 Soil Profile:

Soil profile is the term used for the vertical section of earth curst generally up to the depth of 1.83 meter or up to the parent material to show different layers or horizons of soil for the study of soil in its undisturbed state. It is made up of a succession of horizontal layers or horizons, each of which varies in thickness, color, texture, structure, consistency, porosity, acidity and composition. A pedon is the smallest three-dimensional volume of soil needed to give full representation of horizontal variability of soil.

In general, soils have following four horizons an organic or O-horizon and three mineral (A,B,C) horizons. Some workers recognized a D-horizon, in which rocks are in active weathering state, in between C and R-horizons. R-horizon is the consolidated bed rock on which a soil profile rests. A and B-horizons form the true soil or slum. Each horizon of soil profile is further subdivided. Horizon subdivisions are indicated by Arabic numbers, eg, O_1, O_2, A_1, A_2, etc. Different horizons of soil-profile have following characteristics:

O-horizon: The O-horizon, once designated as L,F,FH, or Ao and Aoo, is the surface layer forming above the mineral layers and composed of fresh or partially decomposed organic material, as found in temperate forest soils. It is usually absent in cultivated soils and grasslands. O-horizon contains both kinds of humus (eg., mull and mor) and is subjected to the greatest changes in soil temperatures and moisture conditions and contains most organic carbon. O-horizon and upper part of A horizon is the region where life is most abundant. The O horizon is divided into following two sub-layers:

O_1 (Aoo) region: It is the uppermost layer which consists of freshly-fallen dead leaves, branches, flowers and fruits, dead remains of animals, etc. All these do not show evident breakdown.

O_2 (Ao) region: Below the O_1 region is the O_2 layer of partly decomposed organic matter. The process of decomposition of the litter is started in O_2 region. Thus, organic matter is found under different stages of decomposition and microorganisms such as bacteria, fungi, actinomycetes are frequently found in it. Upper layers contain detritus in initial stage of decomposition, in which material can be faintly recognized, whereas the lower layers contain fairly decomposed matter, the duff.

A-horizon. It is characterized by major organic matter accumulation, by the loss of clay, iron and aluminum and by the development of organo-mineral complexes, granular crumbs or platy structures. The A-horizon is divided into following two sub-layers:

A_1 region. This region is dark and rich in organic matter and is called humic or melanized region. The amorphous, finely-divided organic matter here becomes mixed with the mineral matter, which is now known as humus and is dark brown or black-colored.

A_2 region. It is light-colored region where the mineral particles of large size as sand (silica) are more with little amount of organic matter. In areas of heavy rainfall, the mineral elements and organic chemicals are rapidly lost downwards in this region, making it light-colored. A_2 region is, thus, also called podsolic or eluvial zone or zone of leaching.

B-Horizon. It lies below A-horizon and also called subsoil or illuviation or illuvial zone, since, the nutrients received from A-horizon due to leaching are accumulated in this region. B-horizon is dark-colored and coarse textured due to the presence of silica rich clay, organic compounds, hydrated oxides of aluminum, iron, etc. It is poorly developed in dry areas. B-horizon can be divided into $B_1(A_3)B_2$ and B_3 regions, depending upon the stages of soil development in the area.

C-horizon. Below B-horizon and above the surface of weathered parent rock, is the zone of regolith or C-horizon. It is a light colored horizon containing weathered parent material.

R-horizon. Below all these horizons may lie the R-horizon, which is the parent, un- weathered bedrock. The percolated soil water tends to collect at the surface of the bedrock.

7.5.2.5Climate and Soil Types:

Variation in climatic factors and rock properties, therefore, lead to different types of soil development in different climatic conditions, as follows:

7.5.2.5.1Laterization:

Laterite (L. Latus=brck) soil are reddish brown in colour and are found in the warm and humid (=heavy rainfall) tropics. In the process of laterization, iron and aluminium oxides which are resistant to decomposition, do not leach down but remain in the surface soil. Silicic acid (i.e., colloidal form of silica) on the other hand leaches to lower horizons. Late rites are comparatively less fertile soils and are found in Australia, India, Some warm parts of Europe and North America.

Lotsolis a wider term than laterite and currently used to refer to soils f warm humid belt of the earth where silica usually leaches to lower horizons while oxides of iron and aluminum remain on the surface. Lotosol soil is also called oxide and ferrasol and is poor in bases and contains low organic content. It is rich in free quartz grains and kaolinite clays.

Vertisolsare the other characteristic soils where there is a long dry season. These soils are formed from limestones, marl or ferromagnesium rocks and rich in montmorillonite clays. During dry summer, deep cracks are formed in vertisols and these cracks get filled with clay due to dust blow which in the rainy season on wetting swells so much as to form small bumps. Thus, vertisols are characterized by cracks in summer and bumps in rains.

7.5.2.5.2 Podsolization:

It is most actively studied soil forming process. It takes place in cold humid climate under forest vegetation (chiefly of genera of Ericaceae and conifers) where leaf litter and other organic matter decompose slowly, chiefly through fungal activity. Litter contains high lignin and low nutrient (particularly calcium) contents; it is also rich in phenolic compounds which inhibit microbial activities. In consequence, such a litter is acidic in nature. The water percolating through such litter, being acidic dissolves out with it minerals and humus contents (such as carbonates, sulphates and iron and aluminum compounds) from A-horizon of soil. These leached materials reach to the lower horizons, being collected in the form of a hard, distinct layer in the B-horizon. Leaching results into a grey ash like surface called podsol (Russian pod=under, ole=ash). In the Indian conifer forests of the Himalayas true podosols are not met with, mainly due to alternate phases of wet and dry seasons.

7.5.2.5.3Gleization:

In humid climates, due high ground level or retention of surface water in the soil, water-logging and consequent reducing conditions are fairly common. Under such reduced conditions firstly due to ferrous compounds, the soil color becomes blue-grey or grey, and secondly the rates of decomposition of the organic matter are slow. These together result into the accumulation of a sticky compact layer of blue-grey color at the bottom of B horizon. This process in called gleization and the soil as gleys.Gleization also takes place in ice covered regions of arctics (also tundra) where soil is not saline.

7.5.2.5.4Melanization:

The process is very common in regions of low humidity where humus is formed from the organic matter. As a result of melanization, the balck humus along with water is mixed in the A-horizon of the soil which turn dark-colored. Such a blackish brown top soil is called chernozem and it has a minimum leaching, so it is rich in organic detritus.

7.5.2.5.5 Calcification:

It is common process found in North India, where calcium in the form of calcium bicarbonate dissolves in water and leaches down escaping adsorption around dry particles. The leached CaCO3 gets precipitated at the depths of about half to three meters, depending on the quantity of rainfall and depth of infiltration. The precipitated calcium remains in the form of nodules or kankar and form a hard pan. This gradually reduces soil fertility. In the Northern India the kankar nodules are unearthed and are used in the building of roads and in the preparation of lime.

Calcification is typical of grassland and a layer of calcium carbonate generally occurs at the base of B horizon. Sometimes, a layer of more soluble calcium sulphate (gypsum) is also present.

There are some other types of soils such as a hydromorpic, halomorphic and azonal. Hydromorphic soils are formed on poorly drained water filled regions with poor aeration, i.e., they are highly reducing soils in which ferric ions are reduced to ferrous. But in dry seasons the soil becomes aerated and ferrous is again converted into ferric. The hydromorphic soils of tropicl paddy fields are called grey soil. Halomorphic soils are characterized by the presence of high salt contents on the surface. Salinity and alkalinity are commonly found in big patches in the North Indian states resulting into the formation of usar or reh soils. In fact, such soils result due to upward capillary movement of dissolved salts from the rising water table in too frequently irrigated and fertilized regions, or from nutrient rich water received in different forms are left on the surface. Grazing animals often lick suck salt deposits to fulfil their metabolic needs. Azonal soils lack horizon B and the horizon A is also thin. Among azonal soils, the common are lithosols found on mountain tops where parent rock is quite hard and resistant to weathering. Regosols are formed from volcanic deposits.

7.5.2.6Morphology of soil:

In the field, differences among soils and among horizons within a soil are primarily reflected by variations in texture, arrangement, structure and color.

7.5.2.6. 1 Texture of soil:

The texture of a soil is determined by the production of different sized soil particles. Mineral fractions or particles of soil are called “soil fraction” or “soil separates”. The soil particles have been classified into grave, sand, silt and clay on the basis of their size differences. Gravel consists of coarse particles larger than 2.0 mm. Sand ranges from 0.02 mm in diameter and is easily seen and feels gritty. Silt consists of particles from 0.002 to 0.02 mm in diameter, which scarcely can be seen by the naked eye, feels and looks like flour. Clay particles range below 0.002 mm in diameter, are too fine to be seen even under the ordinary microscope, and are colloidal in nature. Clay controls the most important properties of soils, including plasticity and exchange of ions between soil particles and soil solution.

Most soils are mixture of these various particles. Based on the proportions of the various particles contained in them, soils can be grouped into 5 textural groups: (1) Coarse textured soils are loose, consist mainly of sand and gravel. They retain very little moisture and supply some plant nutrients. (2) Moderately coarse soils include sandy loam to very fine sandy loam. (3) Medium textured soils are mixture of sand, silt and clay, high enough to hold water and plant nutrients. (4) Moderately fine textures soils are high in clay. They are moderately sticky and plastic when wet, they may form a crust on the surface if organic matter is low. They have & high moisture-holding capacity. (5) Fine textured soils contain more than 40 per cent clay, may be sticky and plastic when wet and hold considerable water and plant nutrients, but may have restricted internal drainage. All these 5 textural soil-groups include 12 textural classes which have been recognized on the basis of relative percentage of soil particles (i.e., sand, silt and clay).

Textural classes of soils.

Soil classes or Textural names	Range in relative percentage of soil separates		
	Sand	Silt	Clay
1. Sandy soil	85-100	0-15	0-10
2. Loamy sand	70-90	0-30	0-15
3. Sandy loam	43-80	0-50	0-20
4. Loam	23-52	28-50	7-27
5. Silt loam	0-50	50-88	0-27
6. Silt	0-20	8-10	0-12
7. Sandy clay loam	45-80	0-28	20-35
8. Clay loam	20-45	15-53	27-40
9. Silty clay loam	0-20	40-73	27-40
10. Sandy clay	45-65	0-20	35-45
11. Silt clay	0-20	40-60	40-60
12. Clay	0-45	0-40	40-100

7.5.2.6.2. Structure of soil:

Soil separates (sand, silt and clay) are held together in clusters or shapes various sizes, called aggregates or peds. The arrangement of these peds in earth crust is called structure. Like texture, there are many types of soil structure. Soil peds may be classified as granular, crumb-like, and blocky plate-like or platy, and prismatic or columnar. The properties of different soil peds have been tabulated.

Characteristics of peds

Types of ped	Propeties
1. Granular	Small, spherical and non-porous.
2. Grumb-like	Small, porous and spheroidal.
3. Agranular blocky	Block-like with sharp ends, one end may be pointed
4. Sub-granular blocky	Block-like but bounded by other aggregates
5. Platy	Plate-like, sometimes plates are overlapped
6. Prismatic or columnar	Prism-like but without rounded surface

Structure less soil can be either single-grained or massive soil aggregates (peds) tend to become larger with increasing depth. Structure is influenced by texture, air, moisture, organic nutrients, microorganisms, root-growth and soil chemical status.

7.5.2.6.3Soil colour:

Soils exhibit a variety of colours. Soil colour may be inherited from the parental material (i.g., lithochromic) or sometimes it may be due to soil forming processes (acquired or genetic colour). Thought colour has little direct influence on the functions of a soil, but is important in the identification of soil type. In temperate regions dark-coloured soils generally are higher in organic matter than light coloured ones. Well-drained soil may range anywhere from very pale brown to dark brown and black, depending upon the organic matter-content. Red and yellow soils are the result of iron oxides, the bright colours indicating good drainage and good aeration. Other red soils obtain their colour from parent material and not from soil-forming processes. Well-drained yellowish sands are white sands containing a small amount of organic matter and such colouring matter as iron oxide. Red and yellow colours increase from the cool regions to the equator. Quartz, kaolin, carbonates of lime and magnesium, gypsum and various compounds of ferrous iron give whitish and grayish colours to the soil. The grayest are permanently saturated soils in which the iron is in the ferrous form.

7.5.2.6.4 Soil color and temperature:

Soil color influences the soil temperature. The dark colored soils absorb heat more readily than light colored soils. Ramdas et al., (1936) showed that black cotton soils of Poona absorbed 86% of the total solar radiations falling on the soil surface as against 40% by the grey alluvial soil.

7.5.2.6.5 Physical Properties of Soil:

Soil possesses many characteristic physical properties such as density, porosity, permeability, temperature, water and atmosphere, each of which can be studied under following separate headings:

Soil density: Average density of soil is 2.65 gms. per ml. Density of soil varies greatly depending upon the degree of weathering.

Porosity: The spaces preset between soil particles in a given volume of soil are called pore spaces. The percentage of soil volume occupied by pore space or by the interstitial space is called porosity of the soil. Porosity of the soil increases with the increase in the percentage of organic matter in the soil.

The pore spaces are of two types (1) Micro-pore spaces (capillary pore spaces) and (2) Macro-pore spaces (non-capillary pore spaces) Capillary pore spaces can hold more water and restrict the free movement of water and air to a considerable extent, whereas macro-pore spaces have little water holding capacity and allow free movement of moisture and air in the soil under normal conditions.

Permeability of soil: The characteristic of soil that determines the movement of water through pore spaces in known as soil permeability. Soil permeability is directly dependent on the pore size, therefore, it is higher for the loose soil with large number of macro-pore spaces than it is for compact soil with numerous micro-pore spaces.

Soil temperature: Soil gets heat energy from different sources such as solar radiation, decomposing organic matter, and heat formed in the interior of earth. The temperature of soil is affected by its color, texture, water content, slope, altitude of the land and also by climate and vegetation cover of the soil. Evaporation of water from soil makes it cooler. Black soils absorb more heat than white soils. Sandy soils absorb more heat and radiate it out quickly at night than clay or loam soils.

The soil temperature greatly affects the physic-chemical and biological processes in the soil. For example, the germination of seeds, normal growth of roots and biological activity of soil-inhabiting micro-and macro-organisms which require proper and specific temperature.

Soil water: In soil, water is not only important as a solvent and transporting agent but in various ways it maintains soil texture, arrangement and compactness of soil particles and makes soil habitat livable for plants and animals. It comes in soil mainly through infiltration of precipitated water (dew, rain, sleet, snow, and hail) and irrigation. According to improved classification method of Bouyoucos (1920), soil water is classified into following types gravitational and ground water, capillary water, hygroscopic water, combined water and water vapor.

Gravitational water: In a well-saturated soil, the accessory (extra) amount of water displaces air from the pore spaces between soil particles and percolates downwardly under gravitational influence and finally it is accumulated in the pore spaces. This accumulated excess water of large soil spaces is called gravitational water. When this gravitational water further percolates down and reaches to the level of parent rock, it is called ground water. Both kinds of these soil water are ecologically important in the leaching of nutrients.

Capillary water: The water which is held by capillary forces (i.e., surface tension and attraction forces of water molecules) in smaller soil channels, when the gravitational water and ground water have been drained, is called capillary water. Capillary water occurs as a thin-film around soil particles in the capillary spaces and represents the normal available water to the plants. It remains in soil for long periods and carries with it nutrients in solution. Humus has more capillary water than soil minerals.

Hygroscopic water: Soil particles retain some water so firmly that the plants cannot absorb this. Such soil water is called hygroscopic water.

Combined water: Combined water s the water f chemical compounds held by chemical forces of molecules such as hydroxides of silicon, iron and aluminum. It is of no ecological significance.

Water vapour: Some soil water occurs as moisture or water vapours in the soil atmosphere. Further, the total amount of water present in the soil is called hoards. The quantity of water that plant-roots can absorb out of hoards is called creased and that amount of soil water which cannot be absorbed by plant-roots is called chards. Moreover, there are some terms that reflect the water status of soil and are generally used for comparative studies of different soils.

Soil water potential: This is an expression of the total reduction of water potential in the soil, due to mineral matrix, solubility external pressure and gravitation effects.

Field capacity: When a soil holds all the water it can, but no gravitational water, it is said to be at its field capacity. Field capacity is generally defined as the water content of an undisturbed soil (% oven-dry weight) after it is saturated by rainfall and drainage of gravitational water has completely stopped. Field capacity of soil may be taken as the total amount of capillary, hygroscopic and combined water plus water vapour.

Moisture equivalent: It is defined as the water content (% oven dry weight) retained by the undisturbed soil.

Water holding capacity (or storage capacity): This is the extent to which soil can hole capillary water against gravity. It is equal to field capacity less hygroscopic water.

Hygroscopic-coefficient: it is defined as the water vapor (5) absorbed by unit weight of dry soil, when placed in an atmosphere completely saturated with water vapours.

Permanent wilting percentage (or wilting coefficient): It is the amount of water (% oven dry weight) that remains in a soil when permanent wilting is present in the plants growing in soil.

The status of soil water is also represented in terms of capillary potential (=metric potential). The relationship that exists between soil water content and water potential is usually determined by a pressure membrane apparatus, called densitometer.

7.5.2.6.6Soil atmosphere:

Gases found in pore spaces of soil profiles form the soil atmosphere. The soil atmosphere contains three main gases namely O_2, CO_2, and N_2, Soil air differs from atmospheric air in having more of moisture and CO_2 and less of O_2. The soil atmosphere is affected by temperature, atmospheric pressure, wind, rainfall, etc. Loam soils with humus contain normal proportion of air and water (about 34% air and 66% water) and, therefore, are good for majority of crops.

Course-textured or well-structured soils contain higher gaseous diffusive transfer rates than fine-textured or poorly-structured soils under wet conditions. This is because they contain many large pores which remain gas-filled. The water-filled pores of the fine-textured soils form potent barriers of gaseous diffusion; O_2 diffuses ten thousand times more slowly in water than in gas. In dry soil, the situation is reversed, as the fine textured soils have a greater total pore space and provide a larger gas-filled cross sectional area for diffusion. Soil aeration is very important in growth of roots, seed germination and microbial activity. Poor soil aeration suppresses root hair development, and may reduce rate of absorption of water and nutrients.

7.5.2.6.7 Soil solution:

There exists a weak solution of various salts, along with other liquids and gases in the soil mass. This soil solution contains almost all the essential minerals. Complex mixture of minerals such as carbonates, sulphates, nitrates, chlorides, and organic salts of Ca, Mg, Na, K, etc., are found as dissolved in water. The chemical nature of soil solution depends on the nature of parent matter, chemical nature of organic matter and climatic factors and other factors involved in pedogenesis. The soil solution is the primary source of inorganic nutrients for plant roots. Soils with optimal concentration of various nutrient solutes are called eutrophic, whereas those with suboptimal concentration of these nutrient salts are calledoligotrophic.

7.5.2.6.8 Chemical Properties of Soil:

Soil is a mixture of various inorganic and organic chemical compounds and exhibits certain significant chemical properties, all of which can be discussed as follows:

7.5.2.6.8.1. Inorganic elements and compounds of soil:

The chief inorganic constituents of soils are the compounds of following elements Al, Si, Ca, Mg, Fe, K and Na, Soil also contains smaller amounts of compounds of following inorganic elements B, Mn, Cu, Zn, Mo, Co, I, F, etc.

7.5.2.6.8.2. Organic matter of soil:

The chief organic component of soil is humus which chemically contains amino acids, proteins, purines, pyrimidines, aromatic compounds, hexose sugars, sugar alcohols, methyl sugars, fats, oils, waxes, resins, tannins, lignin and some pigments. Further humus is black colored, odourless, homogeneous complex substance.

7.5.2.6.8.3. Colloidal properties:

As soil is composed of crystalloids and colloids, therefore, it exhibits all the physico-chemical properties which are related with these two soil particles. Colloids for example exhibit absorption, electrical properties, coagulation, Tyndal phenomenon, Brownian movement, dialysis, etc.

7.5.2.6.8.4. Soil pH:

Many chemical properties of soils centre on soil reaction. As regards their nature, some soils are neutral, some are acidic and some basic. The acidity, alkalinity and neutrality of soils are described in terms of hydrogen-in concentration or pH values. A p value of 7.0 indicated neutrality, a value above this figure (7.1-14.00) indicates alkaline condition and a value below (0-6.9) indicates acid conditions. Normally, the pH value of soils lies between 2.2 and 9.6. In India, acidic soils (pH below 5.5 to 5.6) occur in the high rainfall areas of Western Ghats, Kerala, Eastern Orissa, West Bengal, Tripura, Manipur and Assam. The saline, alkaline or basic soils (called ‘Usar’, contain pH upto 8.5) of India, occur in U.P., West Bengal, Punjab, Bihar, Orissa, Maharashtra, Madras, M.P., A.P., Gujarat, Delhi and Rajasthan.

Some pH value are ecologically significant for the plants (Pearsall, 1952); plants regarded as calcicoles usually occur in soil with pH 6.5, whereas calcifuges occur in soil with pH value below 3.8-4.0. Soils above pH 6.5 are generally caution –saturated (those containing free CaCO3 called calcareous soils) whiles soil below pH 3.8-4.0 contain a considerable content of exchangeable hydrogen. These limits of pH value are also reflected in the nature of the soil’s organic matter: raw humus or mor which is associated with soils below of pH 3.8, while mull is characteristic of the more caution saturated soils of pH 4.8-5.0 and above.

Highly acidic and highly saline or alkaline soils often remain injurious for plant growth, micro-organisms, etc. Soil pH strongly affects the microbial activities, as at below pH 5.0 bacterial as well as fungal activities are reduced. Neutral or slightly acidic soil, however, remains best for the growth of majority of plants.

7.5.2.6.9Soil as Habitats for Animals:

Soil is used by various animals as a hideout from enemies, to escape desiccation and extremes of temperature; as material for abodes, and as a highway. Clay is cold, dense, pcorly aerated and though it holds much water, does not give up water readily to plants and animals. Sand is dry, loose (cave in readily) and has a variable temperature. Rock heats and cools quickly, has little available water and practically no air, and is usually to resistant to allow penetration by burrowing animals. Alkaline soils are "physiologically dry" because the salts present hold the water so that it is not readily available to organisms. Humus has a great water capacity and gives up water readily, is usually well-aerated and furnishes nitrogen as well as mineral salts and water. It remains rich in biota. Peaty soils are raw humus and are uninhabitable for most animals because they are poorly aerated and have an acid reaction. In general, the character of the vegetation cover serves as a good index of the habitability of soils for animal; conditions that make plants flourish are usually favourable for animals.

Summary

In this chapter we studied about the existence supporting environment of planet earth-the biosphere is composed of following three chief media-air, water and soil, which are the foremost components of three major sub-divisions of biosphere-atmosphere, hydrosphere and lithosphere, respectively. Since organisms are built up on chemical substances they require certain chemicals like N_2, O_2, H_2, P, C, etc. constantly for their survival. However, the exchanges of elements have a tendency to circulate in a characteristic path from the environment to the organism to the environment. This cyclical path of the exchange of elements from the abiotic system to the biotic system is called biogeochemical cycles. Chemicals form the major components of food, hence, these cycles are also called nutrient cycles.

Check Your Progress:

1. Write a note on Biosphere.
2. Note on Ionosphere
3. Define Buoyancy
4. Explain transparency in water
5. Write essay on Xerophytes and Xerocoles
6. Define Soil pH

UNIT- VIII GENERAL ACCOUNT OF COMPLETE AND INCOMPLETE CYCLE; GASEOUS CYCLE

Structure

8.0. INTRODUCTION

A biogeochemical cycle or an inorganic-organic cycle is a circulating or repeatable pathway by which either a chemical element or a molecule moves through both biotic (biosphere) and abiotic (lithosphere, atmosphere and hydrosphere) components of an ecosystem. Let us try to understand this definition. Firstly let us understand that the Earth only receives energy from the Sun, all other elements on Earth remain within a closed system. These chemicals, however, are the building blocks of life, they are the raw materials all living organisms use as nutrients to produce energy. These chemicals are called biogeochemicals. Some of the main elements that are in a cyclic pattern are Carbon, Oxygen, Nitrogen etc and Water. Let us now take a look at few of these cycles.

8.1. TYPES OF BIOGEOCHEMICAL CYCLES:

The biogeochemical cycles are classifies into two types, namely gaseous cycles and sedimentary cycles.

8.1.1 Gaseous Cycles

In gaseous cycles the main reservoirs of chemicals are the atmosphere and ocean. E.g. Carbon cycle, N_2 cycle, O_2 cycle, etc.

8.1.2 Sedimentary Cycles:

In sedimentary cycles the main reservoirs are soil and rocks. E.g. Sulphur cycle, Phosphorus cycle, etc.

8.1.3 Carbon cycle:

The cycling of carbon between biotic and abiotic systems is called carbon cycle. It is a gaseous cycle. The main source of carbon is the carbon dioxide (CO_2). CO_2 is present in the air and water. Air is the main reservoir. CO_2 content of air is 0.03%. This amount remains constant.

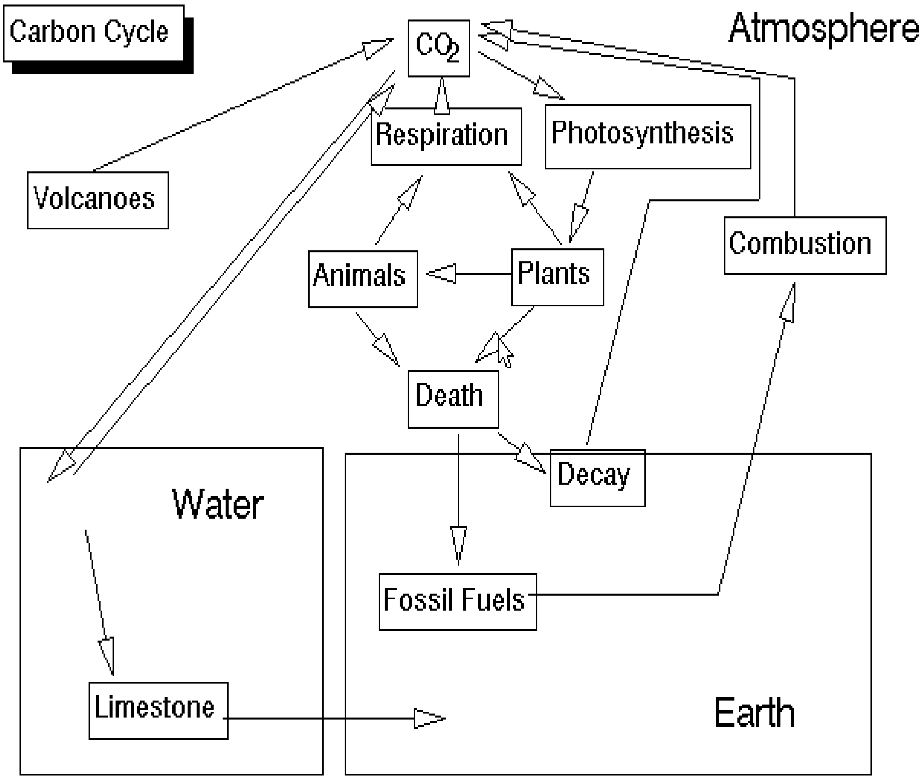
8.1.4 Flow of Carbon into the Biotic System:

Caron flows into the biotic system in two ways, namely photosynthesis and formation of shell.

8.1.5 Photosynthesis:

Carbon enters the biotic system through photosynthesis. In photosynthesis green plants utilize CO_2 and incorporate the carbon of CO_2 in glucose. Glucose is used for the synthesis of other types of carbohydrates, proteins and lipids.

$$6\ CO_2 + 6H_2O \longrightarrow 6C_6H_{12}O_6 + 6O_2$$



These compounds, containing carbon, are stored up in the plant tissues. When plants are eaten up by herbivores, the carbon flows into the body of herbivorous animals through food chain. When herbivores are eaten by carnivores, the carbon enters the body of carnivore's animals.

8.1.6 Formation of Shell:

The CO_2 dissolved in sea water is utilized by the marine animals like protozoans, corals, molluscs, algae, etc. for the construction of shell. In

General account of complete and incomplete cycle; Gaseous cycle

NOTES

these animals CO_2 is converted into calcium carbonate ($CaCO_3$) which is used for the construction of shells.

$CO_2 + H_2O \longrightarrow H_2CO_3$ (Carbonic acid)

$H_2CO_3 \longrightarrow H^{+3} + HCO_3$ (Bicarbonate)

$HCO_3 + Ca_+ \longrightarrow H^+ + CaCO_3$ (Calcium carbonate)

8.1.7 Flow of Carbon into the Abiotic System:

The carbon of the biotic system flow into the abiotic system in five ways:

8.1.8 Respiration:

Plants and animals release CO_2 by respiration (biological oxidation).

$C_6H_{12}O_6 \longrightarrow CO_2 + H_2O$ + Energy

8.1.9 Decomposition:

When plants and animals die, the dead bodies are decomposed into CO_2 by decomposers like bacteria, algae, etc.

8.1.10 Shells:

After the death of marine animals $CaCO_3$ stored in the shells is either deposited as sedimentary rocks or dissolved in water to release CO_2 by the reversion of the above said reaction.

8.1.11 Coal:

A certain proportion of carbon from plants is deposited as coal. Carbon from coal returns to air in the form of CO_2 through combustion and weathering.

8.1.12 Forest Fire:

Combustion of wood in the forest, releases carbon from plants in the form of CO_2.

8.2. Nitrogen Cycle:

Nitrogen is an important nutrient of plants. But plants cannot utilize free N_2 of air. They obtain N_2 from ammonium salts, nitrites and nitrates. These compounds are formed from atmospheric N_2 by a process called nitrogen fixation.

Nitrogen fixation is a process by which atmospheric free N_2 is converted into soluble salts like nitrites and nitrates. It occurs in two ways namely electrochemical fixation and biological fixation.

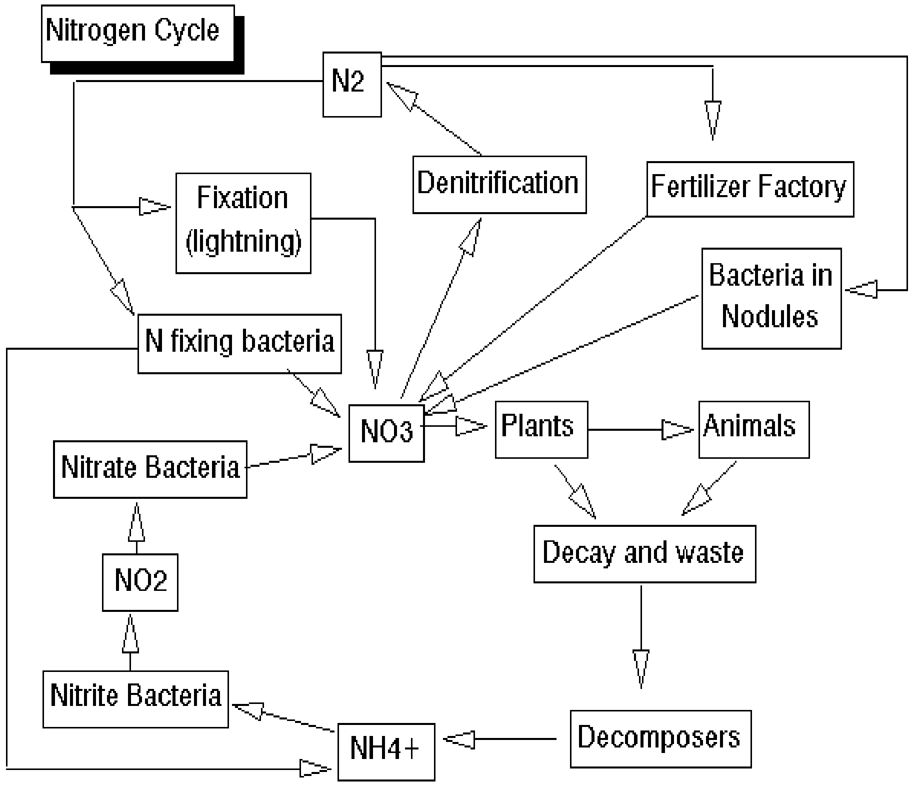
8.2.1. Electrochemical Fixation:

A certain amount of free N_2 is fixed by the action of lightning. The amount of nitrate formed by this method is about 35mg / m^2 / year.

8.2.2. Biological Fixation:

It refers to the conversion for free N_2 into soluble salts by the activity of certain organisms. These organisms are called N_2 fixing organisms. The amount of nitrate formed by this method is about 140 to 700 mg / m^2/ year, and in a fertile area it exceeds 20000 mg / m. The N_2 fixing organisms are bacteria, blue green algae, fungi and other microorganisms. E.g. *Rhizobium, Azotobacter, Clostridium, Bacillus, Nitrosomonas, Nitrococcus, Nitrobacter, Anabena, Nostoc,* etc.

The fixed N_2 is absorbed by plants through the root system and is incorporated into the proteins. When herbivorous feed on these plants, the N_2 flows into the body of herbivorous animals. From herbivores, the N_2 flows on the carnivores through food chain.



8.2.3. Flow of N_2 into the Abiotic System:

The nitrogen of the biotic system flows into the abiotic system by four methods, namely decomposition, excretion, denitrification and sedimentation.

8.2.4. Decomposition:

Plants and animals contain nitrogen in their body-protein. After death, the proteins of dead bodies are decomposed by decomposers into amino acids and ammonia. The conversion of protein from dead bodies into ammonia by decomposition is called ammonification. This ammonia may be converted into nitrates or free nitrogen.

8.2.5. Excretion:

Animals excrete nitrogenous waste products in the form of ammonia, urea and uric acid. These compounds are decomposed to release N_2.

8.2.6. Denitrification:

The conversion of nitrate into ammonia or free nitrogen is called denitrification. This is done by denitrifying bacteria. E.g. *Pseudomonas*. These bacteria utilize the O_2 present in the nitrate for the oxidation of carbohydrate.

8.2.7. Sedimentation:

Some amount of nitrate is lost from the ecosystem by sedimentation.

8.3.Oxygen cycle:

The cycling of oxygen between biotic and abiotic systems is called oxygen cycle is a gaseous cycle. Air is the reservoir for O_2. Oxygen enters the biosphere through respiration. The O_2 taken into the body is used for oxidation of carbohydrates, proteins and fats. Certain amount of O_2 in atmospheric air is converted into ozone (O_3). The ozone forms an umbrella-like layer in the outer atmosphere. This layer prevents the ultraviolet radiations from reacting the earth's surface.

O_2 + 0 O_3 ⟶

Carbon monoxide is released from volcanoes. This CO is unstable. It combines with O_2 to form CO_2.

O_2 combines with a variety of elements to form compounds. For example, it forms CO_2 with carbon, water with hydrogen, nitrates with N_2 ferricoxide with iron etc. O_2 returns to air by two main methods, namely photosynthesis and photodissociation.

$O_2 + C \longrightarrow CO_2$
$O_2 + 2H_2 \longrightarrow 2H_2O$
$O_2 + N_2 \longrightarrow NO_3$

8.3.1. Photosynthesis: Green plants synthesixe carbohydrate by photosynthesis. During photosynthesis water molecules break up into hydrogen and O_2. O_2 is released into the atmosphere and H_2 is trapped and turned into carbohydrates.

$12H_2O + 6\ CO_2 \longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

8.3.2. Photodissociation: Water vapour is dissociated to release H_2 and O_2.

8.4. SUMMARY:

In the chapter the details of various types of biosphere was discussed. Also we studied about phases of biogeochemical cycles and types of biogeochemical cycles. Upon considering gaseous cycles we dealt with carbon cycle, nitrogen cycle and oxygen cycle and thus this chapter described various kinds of biogeochemical cycles in detail.

Check Your Progress:

1. Write notes on Gaseous Cycles.
2. Write notes on Photosynthesis.
3. Write an essay Nitrogen fixation.
4. Write notes on biological nitrogen fixation
5. Explain about Denitrification

UNIT IX SEDIMENTARY CYCLE:

Structure

9.0. INTRODUCTION

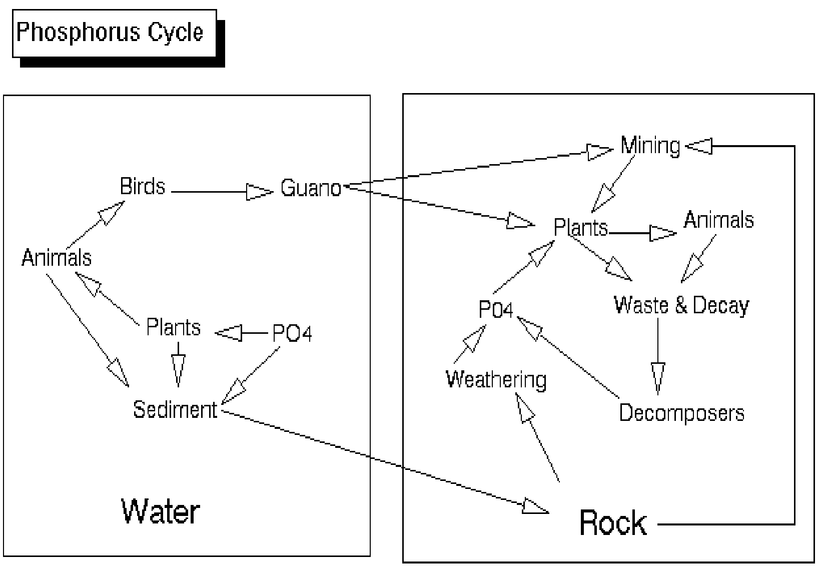
Sedimentary cycle: This comprises the weathering of an existing rock, followed by the erosion of minerals, their transport, deposition and then burial. First-cycle sediments are characterized by the presence of less resistant minerals and rock fragments. If this material is reworked through a second cycle, the less resistant minerals will be eliminated, or altered to more stable products. The more sedimentary cycles that sediment has passed through, the more mature it will become and it will be dominated by well-rounded, resistant minerals

9.1 Sedimentary Cycles:

In sedimentary cycles the main reservoirs are soil and rocks. E.g. Sulphur cycle, Phosphorus cycle, etc.

9.2. Phosphorus cycle:

The cycling of phosphorus between biotic and abiotic system is called phosphorus cycle. It is a sedimentary cycle. Phosphorus is an important mineral nutrient. The main source of phosphorus is rocks. Through erosion and weathering phosphorus is made available in the soil. Plants absorb ionic phosphate through roots. In plants it is incorporated into the protoplasmic components like DNA, RNA, AMP, ADP, ATP, GDP, GTP, NADP, phospholipids, etc. From plants, it passes into herbivores and animals, the organic molecules containing phosphate are decomposed and phosphate is liberated as inorganic ionic phosphate. It is again used by plants.



The excess of phosphate in the bodies of animals is excreted out through faeces. The bird excreta (guano) contain a large amount of phosphate.

Phosphate is also released to the soil through the combustion of forest trees and grasses.

A large amount of phosphate is lost in the sea by sedimentation. A certain amount of phosphorus gets locked in bones and teeth.

9.3 .Sulphur cycle:

The cycling of sulphur between biotic and abiotic system is called sulphur cycle. It is a sedimentary cycle. Sulphur is an important component of proteins and amino acids.

Sulphur exists in a number of states. Of these, three are important. They are elemental sulphur, sulphides and sulphates. Sulphur is present in rocks. It is made available for plants in the form of inorganic sulphate by weathering and erosion. Sulphur passes into the animals through food chain. By the death of plants and animals, the decomposers again bring the sulphur to the soil for the use of plants.

Some sulphur in dead bodies is released into the air as hydrogen sulphide by the bacteria called *Escherichia coli* under anaerobic combustion. Similarly incomplete combustion of fossil fuel releases sulphur dioxide in to the air.

Certain bacteria (green and purple photosynthetic bacteria) oxidise H_2S of air to sulphate which can be used by plants.

$$H_2S + 2O_2 \longrightarrow SO^-_4 + 2H^+$$

Certain amount of sulphur is lost in the sediments. If iron is present in the sediments, sulphur combines with it to form iron sulphide.

$$Fe + S^- FeS \longrightarrow$$

4.16. SUMMARY:

In this chapter we studied about sedimentary cycles the main reservoirs are soil and rocks deals with the Sulphur cycle and Phosphorus cycles have been discussed.

Check Your Progress:

1. Write notes on sedimentary cycles.
2. Write an essay on Sulphur cycle.
3. Write an essay Phosphorus cycles.

UNIT X: POPULATION AND COMMUNITY ECOLOGY

Structure

OBJECTIVES:

- To understand the population concept
- To study about natality, mortality, growth rate, population density, etc

10.1. INTRODUCTION:

It is important to know about the concepts of population and community. Population refers to a group of organisms of the same species living in a particular area at a given time. A community is a group of populations living in a particular area. It is formed of many species. It comprises many kinds of plants, animals and micro-organisms of a given area. They interact with each other.

10.2. POPULATION CONCEPT:

Population refers to a group of organisms of the same species living in a particular area at a given time. A population has the following salient features:

- All the individuals of a population belong to one species
- The individuals are morphologically and anatomically similar
- The individuals are genetically related
- There is free gene-flow between the individuals of a population
- The individuals are reproductively isolated from other species

Populations are of two types. They are monospecific population and polyspecific population. A monospecific population is formed of only one species. A polyspecific population is formed of many related species.

Each population has the following characteristics:

1. Density
2. Natality
3. Mortality
4. Age distribution
5. Growth
6. Equilibrium
7. Population fluctuations
8. Biotic potential

9. Dispersal
10. Dispersion
11. Population regulation
12. Population interaction

10.3. DENSITY:

Population density refers to the total number of individuals in a unit area or unit volume at a given time. It may be expressed in various parameters. For example, the number of bacteria in a litre of water; the number of plants per acre of land; the number of people per square mile and so on. The density of any population can be expressed by the following formula:

$$D = \frac{n/a}{t}$$

where, D = Density
n = Number of individuals
t = Time
a = Area

10.3.1. Measurement of Population Density: Several methods are followed to measure the population density. They are as follows:

10.3.1.1 Total Count: In this method all the individuals of a population are counted one by one. It is direct method and it gives the accurate density. But it is practically possible only in the case of plants. It is not possible to count all animals because they are not static. Again this method cannot be employed in the case of smaller organisms.

10.3.1.2. Sampling Method: In this method suitable samples are selected: the organisms per sample are counted and then the density is calculated by extrapolation.

In a terrestrial habitat the total area of the population is subdivided into sampling units. The sampling units are in the form of quadrates (squares) or transect (rectangles) or circlets. The area of the sampling unit should be based on the size of the organism. For example, if the density of trees in a forest is to be measured then the quadrate (sampling unit) must be about 50 square meter. If the density of grass is to be measured then the quadrate must be about 5 square meters. Individuals in each sampling unit are counted and the total density is calculated by extrapolating the data.

10.3.1.3. Tagging Method: This method is used in counting larger animals like fishes, birds, squirrels, etc. From the population a definite number of animals, say 100, are captured, marked and released. After some days, another set of animals are captured (say 80 animals). This batch contains tagged and untagged animals. From the proportion of tagged animals and untagged animals the total number of individuals in the population can be calculated as follows:

Total number of tagged animals in the population, say = 100
Total number of tagged and untagged animals
Captured on the second day (say) = 75
Tagged animals captured (say) = 10

$$\frac{\text{Total population size}}{\text{Number of marked animals}} = \frac{\text{Total caught in the sample}}{\text{Number of marked animals in the sample}}$$

in the population

x/100 = 75/10

$$x = \frac{100 \times 75}{10}$$

Total population size = 750

10.3.1.4. Pellet Counting Method: In this method the faecal pellets in an area are counted. The population size is calculated from this by knowing the average rate of defecation. This method is used for mice, snowshoe horses and rabbits.

10.4. NATALITY OR BIRTH-RATE:

Birth-rate refers to average number of new individuals produced by a population in a given time. Natality is due to birth, hatching, germination or fission. The size of population increases because of natality. Natality is of two types, namely potential natality and realised natality.

10.4.1. Potential Natality or Maximum Natality: The maximum possible rate of reproduction for a population under optimal conditions is called potential natality.

10.4.2. Realised Natality or Ecological Natality: It refers to the actual number of new individuals added to the population in a given time. Realised natality is considerably lesser than the potential natality.

$$\text{Natality or Birth Rate} = \frac{\text{Number of births per unit time}}{\text{Average Population}}$$

10.5. MORTALITY OR DEATH RATE:

Mortality refers to the number of individuals dying in a population at a given time. The size of the population decreases because of mortality. There are two aspects of mortality. They are potential mortality or minimum mortality and realized mortality or actual death rate. Potential mortality refers to the number of deaths due to old age. But realized mortality is the number of deaths that occur at all ages from gametes to adults due to environmental factors like predation, diseases and other hazards. Realized mortality is higher than potential mortality.

$$\text{Mortality or Death Rate} = \frac{\text{Number of deaths per unit time}}{\text{Average Population}}$$

10.6. VITAL INDEX:

The ratio between birth rate and death rate is called vital index. It is represented by the formula:

$$\frac{\text{Birth}}{\text{Death}} \times 100$$

Vital index helps to understand the rate of growth of a population. When birth rate is higher the population grows progressively. When death rate is higher, the population declines. When the birth-rate equals death rate, the population is stable and remains at equilibrium.

10.7. AGE DISTRIBUTION:

A population is formed of individuals in different age groups. The individuals in a population can be classified into three groups according to their ages. They are; the pre reproductive group which includes immature animals, the reproductive group comprising sexually mature individuals and the post reproductive group comprising old animals where the reproductive ability has been stopped.

The birth rate, death rate and the growth of a population are determined by the age groups of the population. When a population is formed predominantly of prereproductive age group, it is in a state of growth. In growing populations the birth rate is high. When a population is formed predominantly of postreproductive age group, it is said to be declining. When a population contains predominantly pre-reproductive and reproductive age groups, it is said to be in a stable condition.

10.8. AGE PYRAMIDS:

The different age groups of a population can be represented in the form of a graph called age pyramid. In the age pyramid the prereproductive age group is represented at the bottom, the reproductive age group in the middle and the post reproductive age group at the top. The shape of the pyramid shows the growth or decline or equilibrium of the population. For example, when a population contains more of prereproductive and reproductive age groups, the pyramid is bell-shaped. The bell-shaped pyramid shows that the population is stable.

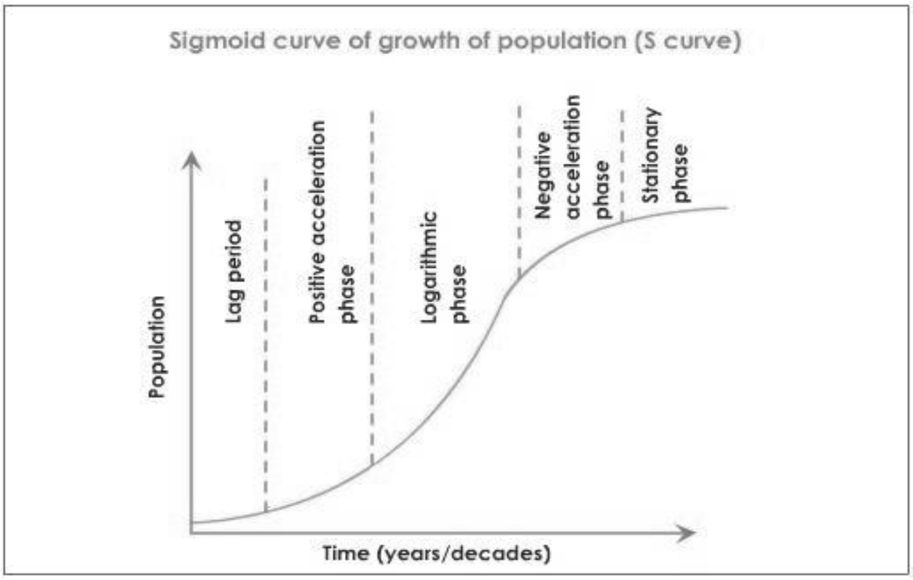
10.8.1. Salient Features of Age-Pyramids:

1. An age-pyramid is a graph showing the different age groups of a population.
2. It indicates whether the population is growing or declining or stable.
3. When the pyramid is triangular, population is growing; when urn-shaped, the population is declining, when bell-shaped, it is stable.
4. An age-pyramid represents the age distribution of a living population at a specific time. Hence when the age distribution changes over a period of time, the shape of the pyramid also changes.

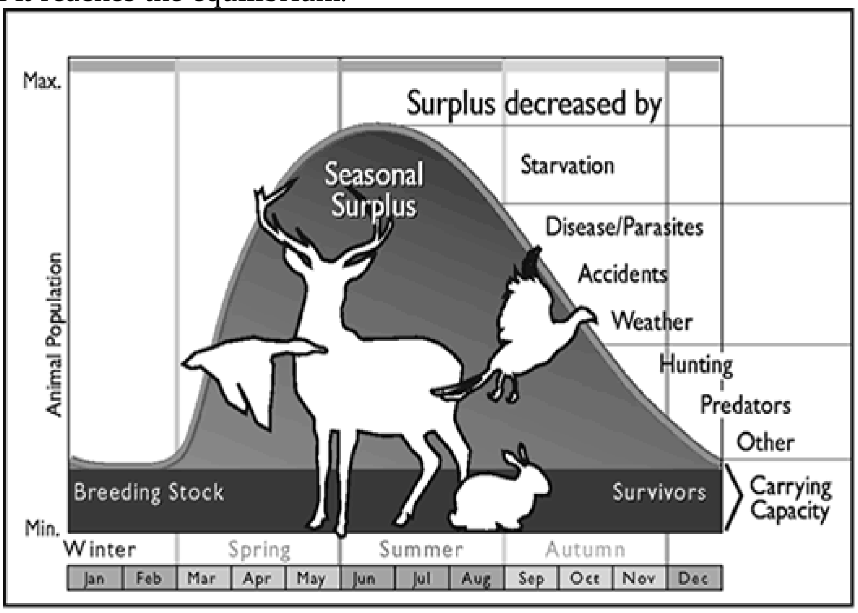
10.9. POPULATION GROWTH:

The increase in size of population is called population growth. A population grows when the birth-rate is high and the death-rate is low. It is also aided by immigration i.e., migration of animals into the population from another similar population. When the increase in the number of animals is plotted against time factor, a curve is obtained called the growth curve. The pattern of growth curve is different for different populations. Mainly, two patterns of growth curves are significant. They are; S-shaped growth curve or sigmoid curve and J-shaped curve.

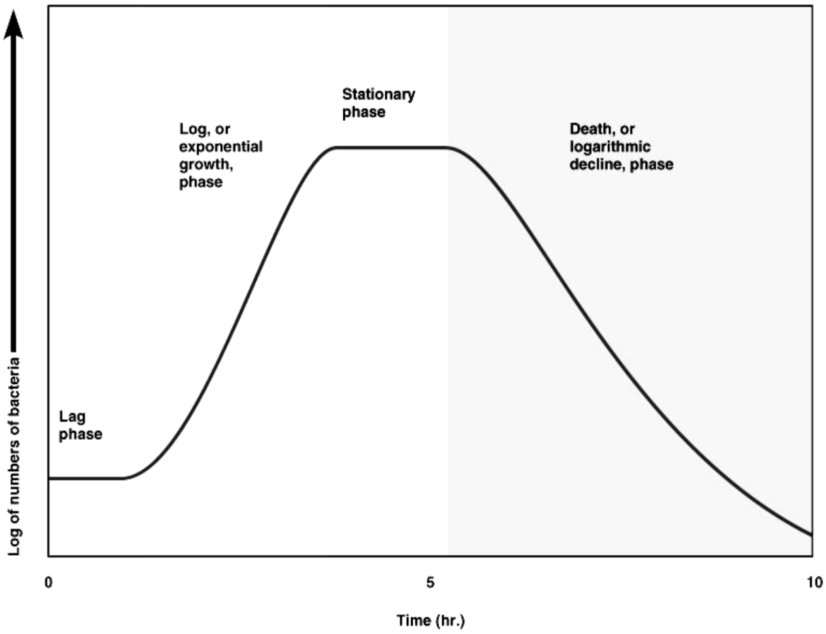
10.9.1. S-shaped Growth Curve: When a few organisms are introduced into an unoccupied area, the population there grows gradually. In the beginning, the growth is slow and this stage of growth is called positive acceleration phase. Then, the growth is rapid and the population increases steeply. This stage of growth is called logarithmic phase. After reaching the maximum size, the growth rate slows down due to environmental resistance. This stage is called negative acceleration phase. After this the population reaches an equilibrium level in which there is neither an increase nor decrease. This pattern of growth curve is exhibited by the yeast and bacteria grown in the laboratory.



10.9.2. Carrying Capacity: The upper level beyond which no more increase can occur in a population is called carrying capacity or upper asymptote. Thus carrying capacity is defined as the maximum number of individuals of a population that can be supported in a habitat at a given time. Once a population reaches the carrying capacity, it fluctuates around it till it reaches the equilibrium.



10.9.3. J-Shaped Growth Curve: In certain populations, the growth is very rapid and the number of organisms increases in compound interest fashion and then growth stops abruptly and the population declines suddenly. The decline is caused by environmental factors. This type of growth-pattern gives a J-shaped curve and it is exhibited by Lemmings, certain insects like thrips in roses, algal blooms, etc.



POPULATION FLUCTUATIONS:

When a population is exposed to favourable environmental condition it grows and establishes equilibrium. It remains in the equilibrium level continuously if conditions are suitable. However, from time to time the number of individuals increases or decreases. As a result, the curve moves up or down from the equilibrium level. It is called population fluctuations. If these changes are small and negligible the population curve is said to be flat. If the changes are larger and regular the curve is said to be cyclic. If the changes are irregular, the curve is said to be irruptive.

The fluctuations are caused by either extrinsic factors or intrinsic factors. Extrinsic factors are the factors of the environment such as temperature, light, rainfall, space, food, etc. Extrinsic factors cause irregular fluctuations. Intrinsic factors arise inside the populations, such as density interaction and so on. They cause cyclic fluctuations.

10.10. REGULATION OF POPULATION:

Any population has the inherent capacity to increase. But it does not increase indefinitely. After reaching the maximum growth, it maintains itself at the equilibrium level. After reaching the equilibrium level, the population remains there or declines depending on the environmental conditions. It is regulated by many factors. These factors are broadly classified into two types, namely density independent factors and density-dependent factors. The density-independent factors are extrinsic and they include space, shelter, weather, food, etc. They cause drastic changes in the size of the population. The density dependent factors are intrinsic and they include competition, predation, emigration, disease, etc. The density-dependent factors stabilize the population at an asymptote.

10.12. SUMMARY:

Population refers to a group of organisms of the same species living in a particular area at a given time. Population density refers to the total number of individuals in a unit area or unit volume at a given time. Several methods are followed to measure the population density including Total Count, Sampling Method, Tagging Method and Pellet Counting Method. The different age groups of a population can be represented in the form of a graph called age pyramid. The increase in size of population is called population growth. Population fluctuations are caused by either extrinsic factors or intrinsic factors.

Check Your Progress:

1. Write notes on population growth curve.
2. Write notes on Natality.
3. Write notes on Density.
4. Write notes on Mortality.
5. Write notes on carrying capacity and population fluctuation.
6. What is population?

UNIT -XI COMMUNITY STRUCTURE:

Structure

11.1 INTRODUCTION

One of the most important considerations about communities is their stability, or lack of variation in time. There are two discrete senses in which this term is used. The first, community stability, refers to the degree of fluctuation in population size of the populations comprising the community. The second, environmental stability, refer to the fluctuations in the abiotic factors of the ecosystem. The two types of stability are closely related, and stable communities are generally to be found in stable environments, while unstable environments are more often characterized by unstable communities.

The global range of variation in community stability is extraordinarily broad. Some communities such as the tropical rainforest or the coral reef appear exceedingly stable, and the densities of their populations are constant over long periods of time. Others, such as the tundra, are extremely variable, and they are made up of populations that fluctuate widely in abundance. Much of this fluctuation is due to variations in environmental factors which the community cannot avoid. However, genetically determined adaptations that have arisen through natural selection also play a part in determining the responses of a population to environmental fluctuations.

Further, the structure of community in which a population is found, has a major role in determining the degree of environmental variability to which the species is subjected. There are at least two mechanisms by which community structure affects the stability or variability of a community. The first mechanism involves the relationship between community structure and microenvironment. Many organisms are protected from the full impact of environmental fluctuations because of the presence of other members of the community. For example, the floor of a conifer forest is protected from winds, evaporation, and temperature shifts, making it a much less harsh and variable environment for organisms than the forest canopy or an open field adjacent to the forest. The second mechanism by which community stability and community diversity, many ecologists have expressed their doubts (Harirston et al., 1968).

11.2. ECOTONE AND EDGE EFFECT:

In the ecocline (i.e., gradient op ecosystems), the line of demarcation (boundary-line) between two communities is often very difficult in view of the chances of overlapping of one community over another. Such demarcation will be conspicuous only when the dominants of the adjacent communities show clear and characteristic differences. The transition zone between two or more diverse communities is called the eccotone. The common examples of ecotone are following the border between forest and grassland, the bank of a stream running through a meadow or between a soft bottom and hard bottom marine community.

Aecotone, thus, presents conditions that are intermediate to the communities which are on either side of the ecotone may be narrow or very wide, extending to large areas. The community on either side of the ecotone may have a typical structure, but the ecotone is strikingly different. The ecotone has a higher diversity than either of the main communities, a diversity that is not directly controlled by the climate or further fundamental environmental factors, but because of the migrations of individuals of different species-population from both communities. Further, a number of special populations can become adapted specifically to the ecotone, even when both of the major communities are too simple or are otherwise unsuited for successful colonization by the species. The potential for the ecotone to act as habitat for species found in neither major community is termed as the edge effect. A common example of the edge effect in action can be seen in those species of owl that live in or near ecotones between forests and grassland. They depend on forest trees for nesting, and they do their hunting in the grassland, where they depend on field or dents for food. In man-made communities such as agricultural fields, the transition zone (ecotone) between the field and the forest may act as a refuge for animal species formerly found in the plowed area, as well as for other plants such as weeds. Ecotones of this type are also the prime habitat of many species of insect, game bird, and mammal.

11.3. SUMMARY:

In this chapter we studied about community structure, ecotone and edge effects.

Check Your Progress:

1. What is community stability?
2. Write short notes on ecotone
3. What is edge effect

UNIT XII. COMMUNITY SUCCESSION

Structure

INTRODUCTION:

The communities in any are not stable. They are changing into other forms or communities from time to time. Thus in a particular area one community may be replaced by another community or by a series of communities. For example, a pond community can be transformed into a marshland community, if the pond is gradually filled with sand and mud. The marshland in the course of time may give rise to a grassland community or a forest community according to the environmental factors prevailing there. This process of development of new communities is called community succession. It can be defined as an orderly and progressive replacement of one community by another till the development of a stable community in that area.

12.1. Salient Features of Community Succession:

Community succession is characterized by the following salient features;

1. It is directional and predictable
2. The succession is caused due to the modification of the physical environment by the community.
3. There is an increase in structural complexity during succession.
4. The kinds of animals and plants change continuously with succession.
5. The diversity of species tends to increase with succession. But the microorganisms and heterotrophic animals reach their maximum diversity in the later stage of succession.
6. Biomass of the community increases. As biomass increases, many new habitat niches are created.

12.2. Climax:

The succession of a stable community can be compared to the embryogenesis of an organism. In the development of a stable community a series of communities develop and they replace one another in an orderly sequence until the stable community is produced. The various developmental stages of a community are called sere, and each stage is called a seral stage. The final stable community is called climax community.

Concepts of Climax: The final stage of succession is called climax. Climax is a stable community. It is self-perpetuating and in equilibrium. There are three main concepts regarding climax. They are 1. Monoclimax theory, 2. Polyclimax theory and 3. Climax pattern theory.

12.2.1.Monoclimax Theory: This concept was proposed by Clemants. According to this concept, each climatic or geographical region has only one climax community.

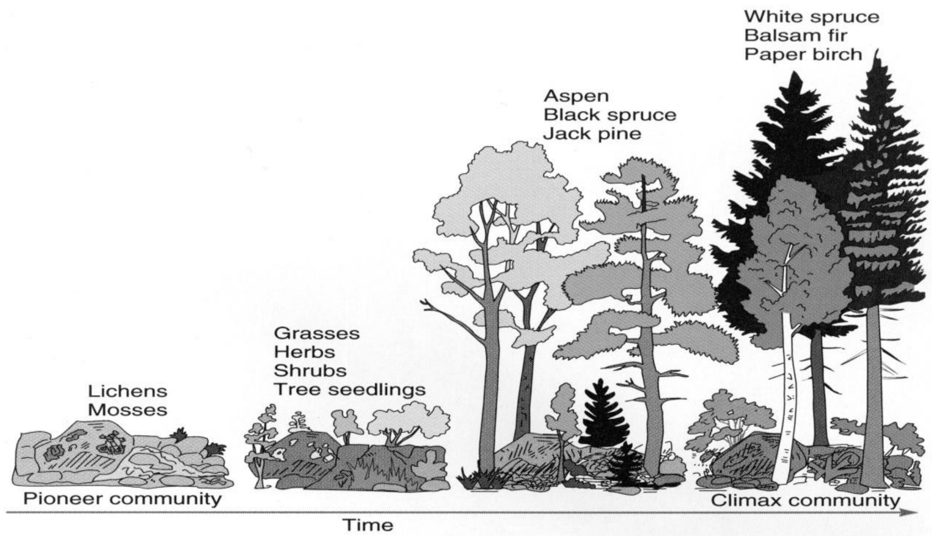
12.2.2.Polyclimax Theory: This theory was proposed by Tansley. It says that each are is occupied by many climax communities. They are controlled by soil moisture, soil nutrients and several other factors. This theory argues that climate is only one of the several characters. As there are several environmental factors, many climax communities are established.

12.2.3. Climax Pattern Theory: This theory was proposed by Whittaker. According to this theory, the climax community of an area is determined by the total environmental factors of the area in which it exists. According to him, nine major factors are involved. They are the genetic structure of each species, climate, soil, site, biotic factors, fire, wind, the availability of species and the chances of dispersal.

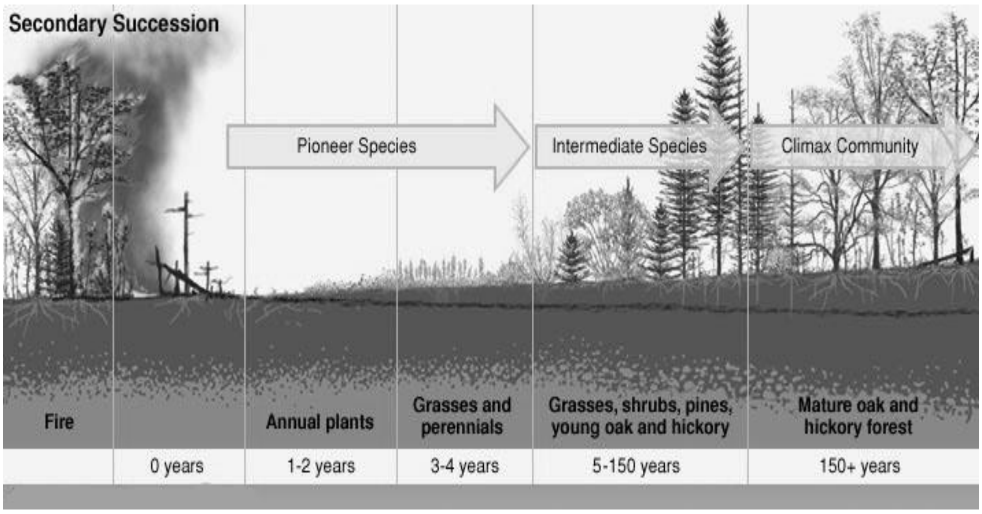
12.3. Types of Succession:

Community succession can be classified into two types, namely Primary Succession and Secondary Succession.

12.3.1. Primary Succession: If community development starts on a sterile area which has not been occupied by any community previously, the succession is called primary succession. Example: the colonization on a newly exposed island. The first group of organisms which initiate ecological succession is called pioneer community. The development of a community on a rock is another example of primary succession. The rock is, first of all invaded by lichens, the pioneer communities. In course of time moss appears and the moss is followed by herbs and shrubs and finally by trees.



12.3.2. Secondary Succession: When community development starts on sites previously occupied by well-developed communities, the succession is called secondary succession. The development of communities in cut-over forests, abandoned crop lands and ploughed fields are examples of secondary succession.



Further, based on the dominating species in the community, succession is classified into two types, namely autotrophic succession and heterotrophic succession.

12.3.3.Autotrophic Succession: It is characterized by early and continued dominance by autotrophic organisms. The succession begins predominantly in inorganic environments. The primary and secondary successions come under autotrophic succession.

12.3.4.Heterotrophic Succession: It is characterized by early and continued dominance by heterotrophic organisms. The succession begins in organic environments.

12.3.5.Pattern of Succession:

Base on the place where succession occurs, three different pattens of succession, can be recognized. They are; 1. Xerarch or Xerosere, 2. Hydrarch or Hydrosere and 3. Mesarch or Mesosere.

12.3.5.1.Xerarch or Xerosere: When succession begins on a dry place, it is called xerarch or xerosere. Succession starting on rocks are examples of xerarch. The pioneer community on rocks will be lichens. In course of time lichens disintegrate the rocks, and sand begins to appear. As sands are formed, masses begin to appear. Then herbs and shrubs come to exist. These are followed by trees which form the forest community.

12.3.5.2.Hydrarch or Hydrosere: When succession starts in water, it is called hydrarch or hydrosere. Hydrarch succession stats in newly build pond. First of all, the pond is filled with water. The first organisms to inhabit the pond are the plankton which form the pioneer community. The plankton include phytoplankton and zooplankton like Paramecium. Amoeba, Euglena, etc. Then submerged plants like Vallisneria and Utricularia and floating plants like Nymphae, Nelambium, Lemna, etc appear. The plankton and plants enrich the pond with organic matter by their death. The thick growth of vegetation invites nymph of dragon flies, may flies and crustaceans like gammarus, Daphnia, Cyclops, Cypris, coelenterates like Hydra, beetles, snails, frogs, etc. These are followed by carnivorous fishes, snakes, turtles, etc. Thus a climax pond community is produced.

When there is flood, water brings in silt and the silt is deposited at the bottom. So the pond becomes gradually shallow. As the water becomes shallow, the submerged aquatic plants will be displaced by floating rooted aquatic plants. Later the rooted plants are replaced by emergent aquatic plants like Typha, Sagittaria, Rumex, etc. With the advent of emergent plants, dragon flies and mayflies begin to make their appearance. Lung-breathing snails appear. Birds like heron, kingfisher, ducks, etc. appear. As more and more silt is deposited, the area becomes a marshland occupied by marshy plants like sedges and rushes. Then the marshland becomes dry and all the aquatic animals disappear completely. Small species of trees appear. This is followed by large trees. Thus a forest is formed. Then forest animals appear forming a climax forest community.

12.3.5.3.Mesarch or Mesosere: Mesarch succession is intermediate between xerarch and hydrarch. This succession occurs in places with moisture. It occurs in the process of hydrarch or xerarch.

12.4.Significance of Succession:

Community succession creates a stable community in the fluctuating physical environment. The stable or climax community has the ability to buffer and control the physical forces like water, temperature, etc. It plays an important role in the slow dispersal of animals.

12.5. SUMMARY:

In this chapter we studied about community succession, climax and significance of succession have been discussed. Community succession can be defined as an orderly and progressive replacement of one community by another till the development of a stable community in that area the final stage of succession is called climax. Based on the place where succession occurs, three different pattens of succession, can be recognized. Community succession creates a stable community in the fluctuating physical environment.

Check Your Progress:

7. Write notes on climax and climax theories.
8. Write an essay on community succession and its types.
9. What are the different patterns of succession
10. Write the significance of community succession.

UNIT XIII – ENVIRONMENTAL POLLUTION AND MANAGEMENT

Structure

13.0. OBJECTIVE

This chapter aims to introduce the following aspects:

- Types of environmental pollution and their biological effects
- Effect of climate change, global warming and its impact on living organisms
- Role of microbes in bioremediation
- Environmental awareness
- Organizations involved in ecological protection –
- Principles of conservation:
- Application of the environmental tenets –
- Germplasm conservation
- Environmental laws

13.1 TYPES OF ENVIRONMENTAL POLLUTION AND THEIR BIOLOGICAL EFFECTS

13.1.1 INTRODUCTION

Pollution may be defined as an undesirable change in the physical, chemical or biological characteristics of air, water, and land which may be harmful to human, animal and plant life, living conditions, industrial progress, and cultural assets. Pollution can be natural or man-made. The agents that pollute are known as ***pollutants***. Pollutants are the elements of pollution that can be foreign substances / energies or naturally occurring contaminants when they exceed natural levels.

Pollutants

Pollutants are by-products of man's action. The important pollutants are summarized below:

- Agricultural pollutants- pesticides, herbicides, fungicides, and fertilizers.
- Photochemical pollutants-ozone, oxides of nitrogen, aldehydes, ethylene, photochemical smog, and proxy acetyl nitrate.
- Radiation pollutants-radioactive substances and radioactive fall-outs of the nuclear test.
- Deposited mater-soot, smoke, tar or dust, and domestic wastes.
- Gases-CO, nitrogen oxides, sulphur oxides, halogens.
- Metals-lead, zinc, iron, and chromium.
- Industrial pollutants-benzene, ether, acetic acid, etc., and cyanide compounds.

Classification of pollutants

1. Based on *disposal*, pollutants are classified into two types-
   a. *Non-degradable pollutants*- These are the pollutants, which degrade at a slow pace by the natural biological processes. These are inorganic compounds like salts (chlorides), metallic oxides, waste-producing materials, other materials like aluminum cans, mercuric salts, and DDT. These continue to accumulate in the environment.
   b. *Biodegradable pollutants*- These include domestic sewage that easily decomposed by natural/artificial methods. These cause serious problems when accumulated in large amounts.
2. Based on the *form in which they persist after their release into the environment*, pollutants categorized into two types:

a. ***Primary pollutants***- These include those substances, which are emitted directly from some identifiable sources. This include-
   - Sulfur compounds- SO_2, SO_3 H_2S produced by the oxidation of fuel.
   - Carbon compounds- Oxides of carbon ($CO+CO_2$) and hydrocarbons.
   - Nitrogen compounds- NO_2 and NH_3.
   - Halogen compounds- Hydrogen fluoride (HF) and hydrochloric acid (HCl).
   - Particles of different size and substances- These are found suspended in the air. The fine particles below the diameter of 100 µm are more abundant and include particle of metals, carbon, tar, pollen, fungi, bacteria, silicates and others.

b. ***Secondary pollutants***- Secondary pollutants are produced by the combination of emitted primary pollutants in the atmosphere. In bright sunlight, photochemical reaction occurs between nitrogen oxides and hydrocarbons from the gasoline to form peroxyacetylene nitrate (PAN) and ozone (O_3). Both of them are toxic components of smog and cause smarting eyes and lung damage.

c. ***Smog*** The fog deposited with smoke and chemical fumes forms a dark and thick covering. Smog is widespread in almost all the industrial areas as the smog is trapped for several days by the stagnant air.

13.1.2 AIR POLLUTION

13.1.2.1 INTRODUCTION

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damage the ecosystem. The World Health Organization (WHO) defines air pollution as the presence of materials in the air in such concentration which is detrimental to man and his environment.

13.1.2.2 KINDS AND SOURCES OF AIR POLLUTION

The source of air pollution are burning fossil fuels, industries, agricultural activities, wars, natural causes and emission from vehicles.

1. **Emission from automobiles:** Vehicles are mainly responsible for more than 80% of total air pollution. The significant pollutants come from automobiles, locomotives, aircraft, etc. include carbon monoxide (CO), unburnt hydrocarbons and nitrogen oxide.
2. **Industries:** Paper and pulp factories, petroleum refineries, fertilizer plants and steel industries, thermal power plants are the primary source of pollution. They add various harmful gases like CO, SO_3, NO, hydrocarbons, *etc.* to the atmosphere. Textile factories release cotton dust into the air. Cities experiencing this type of pollution are Kanpur, Surat, and Ahmedabad. The pesticide and insecticide industries are posing serious threat to the environment. Food processing industries and tanneries emit unpleasant odors. Release of toxic gases due to accidents also poses serious threats. E.g. Bhopal Gas Tragedy in which methyl isocyanate (MIC) gas leakage killed

several people. In Tokyo, concerning 34 tons of carbon particles mixed with other suspended particles settle per square kilometer every day.

3. **Burning fossil fuels:** Burning of wood, charcoal, and other fossil fuels cause air pollution by the release of carbon dioxide, sulfur dioxide, *etc*. Petroleum consists mainly of hydrocarbons, sulfur, and nitrogen.
4. **Agricultural activities:** Spraying of insecticides and herbicides also cause air pollution. These, when inhaled create major problems for both animals and human.
5. **Wars:** Diverse forms of explosives used in war also pollute the air by releasing poisonous gases. This greatly disturbs the ecology of the area. Nuclear explosions pollute air by radioactive rays. The effects of atomic explosions on Hiroshima and Nagasaki are well-known instances.
6. **Natural causes:** Gas emissions from active volcanoes, marsh gas, spores, fungi and pollens also cause air pollution.

Category	**Examples**	**Important pollutants**
Chemical plants	Petroleum refineries, fertilizers, cements, paper mills, ceramic clay products, glass manufacture	H_2S, sulhur oxide, fluorides, organic vapors and dust
Crop spraying	Pesticides and weedicides	Organophosphates, chlorinated hydrocarbons, lead, arsenic
Fuel-burning	Domestic burning, thermal power plants	Sulfur and nitrogen oxides
Metallurgy plants	Aluminium refineries and steel plant	Metal flumes (Pb and Zn) fluorides and particulates
Nuclear device testing	Bomb explosions	Radioactive fallout, Sr-90, Cs-137, C-14 etc.
Ore preparations	Crushing, grinding and screening	Uranium and beryllium dust, other particulates
Spray painting, ink, solvent cleansing	Printing and chemical separations, furniture, dyeing	Hydrocarbons and other organic vapors

Transportation	Cars, trucks, aeroplanes, and railways	CO, NO, NO_2, Pb, smoke, soot, smoke, vapors, etc.

13.1.2.3 VARIOUS EFFECTS OF AIR POLLUTION

Effect on plants

i. Smoke and dust cover the leaf surface and reduce the photosynthetic ability of plants.
ii. SO_2 causes chlorosis which results the death of cells and tissues.
iii. Fluorides and PAN harms the leafy vegetables like lettuce and spinach.
iv. Oxides of nitrogen and fluorides reduce crop yield.
v. Smog bleaches and blaze foliage of important leafy plants.
vi. Hydrocarbons cause premature yellowing, fall of leaves and flower buds, discoloration and curling of sepals and petals.

Effect on animals

Toxic chemicals emitted into the atmosphere over a long period cause a deleterious effect on animals. For instance, the cattle that graze in pastures near smoke emitting factories are getting poisoned with pollutants leading to inflammation of the respiratory and intestinal tract, kidney damage and destruction of RBC. Birds mainly feed on the smaller insects like grasshopper, beetles, and rodent pests of the cultivated crops. So, the disappearance of the local predators may increase insect and rodent pests. Again to control the pests, pesticides are used which in turn may act as non-degradable pollutants and hampers the environment.

Effect on man

The impact of pollutants on animals and man are as follows.

i. SO_3, CO, and NO_2 diffuse into the bloodstream and reduce oxygen transport. CO damages the cardiovascular system. Hydrocarbons and other pollutants act as carcinogen that lead to different type of cancers.
ii. Cotton dust leads to respiratory disorder, e.g., bronchitis and asthma.
iii. Ozone cause dryness of mucous membranes changes eye vision, causes headache, pulmonary congestion, and edema.
iv. Ozone has reported to produce aberrations.
v. SO_2 causes drying of the mouth, scratchy throat, smarting eyes, and disorders of respiratory tract.

Change in climate - CO_2 content of air is increasing due to deforestation and combustion of fuel. This in augment affects the composition and balance of gases in the atmosphere. Increase in CO_2 concentration may increase the atmospheric temperature producing *greenhouse effect*. A rise in global temperature by more than 2-3°C may melt glaciers and polar ice. This would lead to an increase in ocean level and consequent flooding and submergence of coastal areas. Alters the rainfall pattern, reduces agriculture production in various regions of the world. Aerosols deplete the ozone layer in the stratosphere. Thinning of ozone layer would permit more of the harmful ultraviolet rays to reach the earth. This may cause sunburn, blindness, and inactivation of proteins, RNA, DNA and plant pigments.

13.1.2.4 AIR POLLUTION CONTROL

Following measures have been taken to control air pollution.

1. Pollution control laws should be enforced strictly.
2. Trees should be planted on roadside, riverbanks, parks, and open places as they keep the environment fresh.
3. Some gases which are more soluble in a particular liquid than air, for example, ammonia in water can be separated by dissolving in it.
4. Particles larger than 20 microns are separated in gravity settling tanks. Using cyclone collectors or electrostatic precipitators separates fine particles.
5. The height of chimneys should be increased to the highest possible level to reduce pollution at ground level.
6. SO_2 pollution can be controlled by extracting sulfur from the fuel before use.
7. Nuclear explosion should be restricted.

13.1.3 WATER POLLUTION

13.1.3.1 INTRODUCTION

Water is essential for life. The undesirable substances added to the water resources to a great extent changes the basic chemistry of water.

The sources of water pollution are classified as a ***point source*** or a ***non-point source*** of contamination. *Point sources* of pollution occur when harmful substances are emitted directly into a body of water. A *nonpoint source* delivers pollutants indirectly through environmental changes. An example of this type of water pollution is when fertilizer from a field is carried into a stream by rain, in the form of run-off, which in turn affects aquatic life. The technology exists for point sources of pollution to be monitored and regulated, although political factors may complicate matters. Nonpoint sources are much more difficult to control. Pollution arising from nonpoint sources account for a majority of the contaminants in streams and lakes.

13.1.3.2 DIVERSE SOURCES OF WATER POLLUTION

1. **Pathogenic organisms:** Sewage and domestic wastes from house introduce the pathogenic organisms viz., protozoa, worm eggs, and bacteria into water. This contaminated water if consumed caused jaundice, typhoid, cholera, dysentery, tuberculosis, etc.
2. **Mineral oils:** Oil from oil spills and washings of automobiles find a way into the river water through sewers.
3. **Domestic sewage:** This includes household wastes like food wastes, synthetic detergents used for washing clothes, bathrooms, and lavatories and water based paints.
4. **Industrial effluents:** The industrial wastes from the textiles, sugar and fertilizers factories, oil refineries, drugs manufacture, rubber and fibers production units are discharged in the adjoining rivers and streams through flush lines of factories. The paper industries and the chemical factories all produce chemical pollution.
5. **Agricultural source:** Excess application of nitrates in the farm field as fertilizers seep into groundwater and carried into lakes and ponds. On entering the drinking water supply system these create several health problems.

6. **Pesticides:** These include insecticides, fungicides, nematicides, rodenticides, herbicides, and soil fumigants. These contain chlorinated hydrocarbons, organophosphates, metallic salts, carbonates, acetic acid derivatives, etc. Several pesticides are non-degradable. They pass through the food chains and accumulate in fatty tissues causing several health hazards.
7. **Underground water pollution:** Underground water especially in cities and industrial areas is no more pure and safe. The sources of underground water pollution are sewage, seepage, pits, industrial effluents, septic tanks, fertilizers and pesticides, garbage, etc.
8. **Thermal pollution:** Power plants and nuclear power stations are the primary source of thermal pollution of water where water is initialized for cooling and becomes hot. The hot water on entering the main water body raises its temperature which kills fishes and other aquatic animals and increases the rate of respiration in aquatic plants.
9. **Marine water pollution:** River and stream network sources of water eventually end up ocean and seas. Thus, these acts as the sink of all-natural and human-made water pollutants. The chief sources of oceanic pollution are discharges of oil, petroleum products, greases, detergents, sewage and garbage comprising radioactive wastes.

13.1.3.3 EFFECTS OF WATER POLLUTION

The chief effects of water pollutants are

1. Presence of dyes and compounds in the discharged water changes the color of the water.
2. Compounds of mercury, arsenic, and lead are poisonous and chemically harmful as they even affect water treatment plant, e.g. organic sulfur compounds interfere with nitrification.
3. Mercury when dissolved in water, is absorbed by aquatic plants and enters the food chain. Lead impairs metabolism and brings about congenital deformities, anemia, etc.
4. Cadmium damages kidneys and liver.
5. Detergents, soaps, and alkali results in foam formation.
6. Industrial effluents comprising iron, free chlorine, phenol, manganese, oils, hydrocarbons, ammonia, algae, and microorganisms impair the taste and odors of water.
7. The nitrates and phosphates dissolved in water accelerate the development of microorganisms including alage, which consume much of the dissolved oxygen depriving fish and other aquatic life (Eutrophication).
8. Biomagnifications is the increase of toxic materials at each trophic level of a food chain. For instance, DDT after reaching a water system is absorbed by the microorganisms on which smaller fishes feed. From there, DDT enters the carnivorous animals. Since bigger fishes consume more food, large amounts of DDT accumulate in their body.

13.1.3.4 WATER POLLUTION CONTROL

1. Rivers and lakes should not be used for bathing or washing as it contaminates water.
2. Before discharging them into drains, the domestic sewage and industrial wastes should be treated.

3. Separate ponds and tanks should be used for cattle and animals.
4. Use of pesticides, insecticides, and fertilizers should be done judiciously, and rapid biodegradable substitutes for pesticides should be employed.
5. In towns, where sewage facilitates are not available, septic tanks should be made in the houses.

Treatment of wastewater

Domestic sewage and industrial wastes should be treated appropriately before these are drained in the mainstream water. Treatment involves the following two steps:

1. Sewage treatment, or domestic wastewater treatment, is the process of removing contaminants from wastewater and household sewage, both runoff (effluents) and domestic. It includes physical, chemical, and biological processes to remove physical, chemical, and biological contaminants. Its objective is to produce an ecofriendly discharge of materials to the environment by treating the effluent, a reliable waste treated sludge) suitable for disposal or reuse (usually as farm fertilizer). Advanced technology is now available to re-use the treated sewage effluent for household consumption and drinking purposes.

Primary treatment: Primary treatment comprises physical processing of floatation sedimentation and filtration where sewage water is passed through screens to remove larger particles to a smaller size. The sewage is ultimately adopted through settling tanks to remove suspended impurities.

Secondary treatment: Sewage obtained after primary treatment is sent to aeration tank where it is contaminated with air and sludge laden with bacteria and algae. The algae provide oxygen to the bacteria and bacteria decompose organic matter into pure compounds. Chlorination is ultimately done to remove bacteria.

Tertiary treatment: Water is passed in the third and last step through ion exchangers to remove dissolved salts.

2. Treatment of industrial effluents: Treatment of industrial effluents includes neutralization of acids and bases, removal of toxic compounds, coagulation of colloidal impurities, precipitation of metallic compounds and reducing the temperature of effluents to decrease thermal pollution.

13.1.4 SOIL POLLUTION

13.1.4.1 INTRODUCTION

Like water and air, the soil is also equally important for living organisms. It supports plants on which all other living organisms depend. The process of soil formation is so slow that the soil may be regarded as a non-renewable source. Therefore, the study and control of soil pollution are important. Any materials that reduces soil productivity is known as soil pollutant. Soil pollution is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment.

13.1.4.2 SOIL POLLUTANTS

A soil pollutant is any factor which deteriorates the quality, texture, and mineral content of the soil or which disturbs the biological balance of the organisms in the soil. Pollution in soil has adverse effect on living organisms. Pollution in soil is associated with i) indiscriminate use of fertilizers, ii) indiscriminate use of pesticides, insecticides, and herbicides, iii) Dumping of large quantities of solid waste, iv) Deforestation and soil erosion.

Indiscriminate use of fertilizers

Farmers generally use fertilizers to compensate nutrient deficiencies. Fertilizers contaminate the soil with impurities from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate (NH_4NO_3), phosphorus as P_2O_5, and potassium as K_2O. For instance, As, Pb and Cd present in traces in rock phosphate mineral get transferred to superphosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers becomes a strong poison for crops. The overuse of NPK fertilizers reduces quantity of vegetables and plants grown on soil over the years. It also reduces the protein content, carbohydrate quality of wheat, maize, grams, etc., produced on that soil. Excess potassium content in soil reduce Vitamin C and carotene content in vegetables and fruits. The vegetables and fruits are grown on over-fertilized soil are more prone to attacks by insects and disease.

Indiscriminate use of pesticides, insecticides, and herbicides

Farmers use pesticides to kill unwanted populations like insects, fungi, bacteria, viruses, rodents, and other animals, living in or on their crops for the successful production,. The first widespread insecticide use began at the end of World War II and included DDT (dichlorodiphenyltrichloroethane) and Lindane, (also known as *gamma*-hexachlorocyclohexane). Insects soon became resistant to DDT, and as the chemical did not decompose readily, it persisted in the environment. Since it was soluble in fat rather than water, it enters into the food chain and disrupted calcium metabolism in birds, causing eggshells to be thin and fragile. As a result, large birds of prey such as the brown pelican, ospreys, falcons, and eagles became endangered. DDT was banned in most western countries. The most critical pesticides are DDT, BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furodan, etc. The remnants of such pesticides used on pests may get adsorbed by the soil particles, which then contaminate root crops grown in that soil. The consumption of such crops causes the pesticides remnants enter human and other biological systems, affecting them adversely. Pheromones and hormones to attract or repel insects and to use natural enemies or sterilization by radiation have been suggested.

Dumping of solid wastes

Generally, solid waste includes garbage, domestic refuse, and discarded solid materials such as those from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboard, plastics, glass, old construction material, packaging material, and hazardous substances. Since a significant amount of urban solid waste tends to be paper and food waste, the majority is recyclable or biodegradable in landfills. In the same way, most agricultural waste is recycled, and mining waste is left on site. The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones that need more attention. In the long run, they get deposited in the soils of the surrounding area and pollute them by altering their chemical and biological properties. They also contaminate drinking water aquifer sources. More than 90% of hazardous waste is produced by chemical, petroleum, metal-related industries, dry cleaners and gas stations. Toxic chemicals leached from oozing storage drums into the soil underneath homes, causing an unusually large number of congenital disabilities, cancers and respiratory, nervous and kidney diseases.

Deforestation

Soil erosion take place when the weathered soil particles are displaced and carried away by wind or water. Deforestation, agricultural development, human activities, temperature extremes, precipitation including acid rain contribute to this erosion. Humans speed up the erosion process by cutting of timber, construction, mining, over cropping and overgrazing which results in floods. Forests and grasslands are excellent binding material that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide many feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. During the past few years quite a lot of vast green land has been converted into deserts. The precious rain forest habitats of South America, tropical Asia, and Africa are coming under pressure of population growth and development (especially timber, construction, and agriculture). Many scientists believe that a wealth of medicinal substances including a cure for cancer and AIDS lie in these forests. Deforestation is slowly destroying the most rich flora and fauna areas in the world.

13.1.4.3 EFFECTS OF SOIL POLLUTION

Agricultural

- Reduced soil fertility
- Reduced nitrogen fixation
- Increased erodability
- More considerable loss of soil and nutrients
- Deposition of silt in tanks and reservoirs
- Reduced crop yield
- Imbalance in soil fauna and flora

Industrial

- Dangerous chemicals entering underground water
- Ecological imbalance
- Release of pollutant gases
- Release of radioactive rays causing health problems
- Increased salinity
- Reduced vegetation

Urban

- Clogging of drains
- Inundation of areas
- Public health problems
- Pollution of drinking water sources
- Foul smell and release of gases
- Waste management problems

13.1.4.4 CONTROL OF SOIL POLLUTION

The following methods have been recommended to control soil pollution. To prevent soil erosion, we can limit construction in a sensitive area, use less fertilizer and fewer pesticides. If we could all adopt the three R's: Reduce, Reuse, and Recycle, this would yield lesser solid waste.

Reducing chemical fertilizer and pesticide use: Applying bio-fertilizers and manures can reduce chemical fertilizer use. Biological methods of pest control can also reduce the use of pesticides and thereby minimize soil pollution. Pheromones and hormones to attract or repel insects and using natural enemies or sterilization by radiation have been suggested

Reusing of materials: Materials such as glass containers, plastic bags, paper, cloth, etc. can be reused rather than being disposed of, reducing substantial waste generation.

Recycling and recovery of materials: This is a reasonable solution for reducing soil pollution. Materials such as paper, some kinds of plastics and glass are being recycled. This decreases the volume of refuse and helps in the conservation of natural resources. For example, recovery of one ton of paper can save 17 trees.

Reforesting: Control of land loss and soil erosion can be attempted through restoring forest and grass cover to check wastelands, soil erosion, and floods. Crop rotation or mixed cropping can improve the fertility of the land.

Solid waste treatment: Appropriate methods should be implemented for the management of solid waste disposal. Industrial wastes can be treated physically, chemically and biologically until they are less hazardous. Acidic and alkaline residues should be first neutralized. Biodegradable insoluble material should be allowed to degrade under controlled conditions before being disposed. Burying solid waste away from residential areas is the simplest and most widely used technique for the management of solid waste. Environmental and aesthetic considerations must be taken into account before selecting the dumping sites. Incineration of other wastes is expensive, leaves a substantial residue and adds to air pollution. Pyrolysis is a process of combustion in absence of oxygen or the material burnt under controlled atmosphere of oxygen. It is an alternative to incineration. The gas and liquid thus obtained can be used as fuels. Pyrolysis of carbonaceous wastes like firewood, coconut and other agricultural waste yield charcoal along with products like tar, methyl alcohol, acetic acid, acetone, and fuel gas.

Anaerobic/aerobic decomposition of biodegradable municipal and domestic waste is also done to get organic manure. Cow dung which releases methane into the atmosphere should be processed further in 'gobar gas plants' to produce 'gobar gas' and good fertilizer.

13.1.5 NOISE POLLUTION

13.1.5.1 INTRODUCTION

Noise pollution usually refers to surplus sound produced by human activities. It gets in the way with communication, work, rest, recreation, or sleep. Unlike other forms of pollution, noise does not remain long in the environment. However, while its effects are immediate in terms of annoyance, they are cumulative in terms of temporary or permanent hearing loss. In simple terms, noise is unwanted sound. Noise generation is associated with most of our daily activities. A healthy human ear responds to an extensive range of Sound Pressure Level (SPL) from the threshold of hearing at zero dB, uncomfortable at 100-120 dB and painful at 130-140 dB.

13.1.5.2 SOURCES OF NOISE

1. The overarching source of noise is generated by ***transportation systems***, principally motor vehicle noise, but also including aircraft noise and rail noise. Poor urban planning also give rise to noise pollution, since juxtaposition of industrial to residential land uses, for example, often results in adverse consequences for the residential acoustics environment.
2. Besides transportation noise, other prominent sources are office equipment, factory machinery, appliances, power tools, lighting hum, and audio entertainment systems. Furthermore, the popularity of digital audio player devices, individuals in a noisy area might increase the volume to drown out ambient sounds. Construction equipment also produces noise pollution.
3. Noise from recreational vehicles has become a severe problem in rural areas. ATVs, also known as quads, have increased in popularity and are joining the traditional two-wheeled dirt motorcycles for off-road riding.

13.1.5.3 EFFECTS OF NOISE POLLUTION

Some of the adverse effects of noise pollution are summarized below.

Noise health effects

The collection of health consequences of elevated sound levels, constitute one of the most widespread public health threats in industrialized countries. The most important sources of sound level are motor vehicles and aircraft noise, with industrial worker noise exposure also being notable. Current conditions expose ten millions of people to sound levels capable of causing hearing loss but are also known to induce tinnitus, hypertension, vasoconstriction, and other cardiovascular impacts. Vasoconstriction can also be contributory to erectile dysfunction. Beyond these effects, elevated noise levels create stress, increase workplace accident rates and stimulate aggression and other anti-social behaviors. Secondary exposures may arise from loud audio media especially if practiced as a lifestyle such as prolonged digital audio player use. Extreme and prolonged exposure to noise causes NIHL (Noise-Induced Hearing Loss).

Cardiovascular disease and other health effects

Important cardiovascular consequences follow from elevated sound levels, principally because the high adrenaline levels trigger a narrowing of the blood vessels (vasoconstriction). Sound levels from typical roadway noise exposure are known to constrict arterial blood flow and lead to elevated blood pressure. Independently, high noise levels are known to produce medical stress reactions, another risk associated with cardiovascular disease. Noise-induced medical stress is significant for two reasons. First, it often results from prolonged exposure for 8 to 16 hours per day. Second, unlike emotional stress, it has an obvious effect on blood pressure. Other proven effects of high noise levels and are increased frequency of headaches, fatigue, stomach ulcers, and headrush.

Physiological Effects

Noise can change man's physiological state by speeding up the pulse and respiratory rates. It can impair hearing either permanently or temporarily. Millions of industrial workers are threatened with hearing damage.

- Noise can cause heart attacks.
- Noise can cause chronic effects as hypertension or ulcers.
- Noise can cause deafness.
- Noise can affect breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol.

Psychological effects

There are psychological and behavioral effects that result from elevated sound levels, including sleep disturbance, reading development in children, stress, and mental health (including disengagement and increase in aggressive behavior). It affects the sleeping thereby inducing the people to become restless and lose concentration and presence of mind during their activities. It creates annoyance to the receptors due to sound level fluctuations. The periodic sound due to its irregular occurrences causes displeasure to hear and causes irritation. Closely associated with annoyance are sleep disturbance and speech interference phenomena. When young children are exposed to speech interference levels of noise regularly, there is a likelihood of developing speech or reading difficulties, because the auditory processing functions are compromised. In particular, the writing, learning impairment is known as dysgraphia commonly associated with environmental stressors in the classroom.

Noise Pollution Effects on Wildlife

Noise pollution causes adverse effects on wildlife. There is decline in migratory birds to a habitat if it becomes noisy. Deer and lions affected by the traffic noise as observed in some Zoo. Physiological and environmental consequences of sound could be acute to the survival of wildlife.

Effects of Noise on Non-Living Things

The high intensity of noise such as vibrations emanating from heavy machinery cause shattering of window glasses, losing the plaster of house walls, cracks in walls, cracks in household crockery and breaking down the hanging in the house. The buildings and materials may get damaged by exposure to infrasonic/ultrasonic waves and even get collapsed.

13.1.5.4 CONTROL OF NOISE POLLUTION

Due to the various adverse impacts of noise on humans and the environment, noise should be controlled. There are multiple options available to control noise pollution. The possibilities of noise pollution can be selected as per the particular needs. The techniques employed for noise control can be broadly classified as i) Control at source, ii) Control in the transmission path, iii) Using protective equipment

Noise Control at Source

The noise pollution can be controlled at the source of generation itself by employing techniques like-

- ***Reducing the noise levels from domestic sectors:*** The domestic noise coming from radio, tape recorders, television sets, mixers, washing machines, cooking operations can be minimized by their selective and judicious operation. By usage of carpets or any absorbing material in the house can reduce the sound level.
- ***Maintenance of automobiles:*** Regular servicing and tuning of vehicles will reduce the noise levels. Fixing of silencers to cars, two-wheelers etc., will reduce the noise levels.
- ***Control over vibrations*****:** The vibrations of materials may be controlled using proper foundations, rubber padding, etc. to reduce the noise levels caused by vibrations.
- ***Prohibition on the usage of loudspeakers:*** By not permitting the usage of loudspeakers in the habitant zones except for important meetings/functions. Now-a-days, the urban administration of the metro cities in India is becoming stringent on usage of loudspeakers.
- ***Selection of machinery:*** Optimum selection of machine tools or equipment reduces excess noise levels. For example, range of specific machinery/equipment which generates less noise (Sound) due to its superior technology, etc. is also an essential factor in noise minimization strategy.
- ***Maintenance of machines:*** Proper lubrication and maintenance of computers, vehicles, etc. will reduce noise levels.
- ***Low voice speaking:*** Speaking at low voices enough for communication reduces the excess noise levels.

Control in the transmission path

Controlling the noise along its transmission path can do the isolation of every source of the noise. Wall partitions and doors possess excellent insulation properties only a small portion of sound energy from source goes to the individual. Most sound waves are reflected bouncing back and forth from wall and other obstacles in an enclosed space with each impact the noise gets weaker.

Acoustic material lined on walls and ceilings can reduce noise levels within a room for a small area.

Using protection equipment

Protective equipment usage is the *ultimate* step in noise control technology. The usage of protective equipment and the worker's exposure to the high noise levels can be minimized by -

- ***Job rotation:*** By rotating the job between the workers working at a particular noise source or isolating a person, the adverse impacts can be reduced.
- ***Exposure reduction:*** Regulations prescribe that the noise level of 90 dB for more than 8 hr continuous exposure is prohibited. Persons who are working under such conditions will be exposed to occupational health hazards. The schedule of the workers should be planned in such a way that they should not be overexposed to the high noise levels.

- ***Hearing protection:*** Equipment like earmuffs, earplugs etc. are the commonly used devices for hearing protection. The attenuation provided by ear-muffs varies widely concerning their size, shape, seal material, etc. Literature survey shows that average noise attenuation up to 32 dB can be achieved using earmuffs.

13.2 CLIMATE CHANGE, GREEN HOUSE EFFECT AND GLOBAL WARMING

13.2.1 Introduction

Earth's average temperature has risen by 1.5°F over the past century and is projected to rise another 0.5 to 8.6°F over the next hundred years. Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather. Rising global temperatures have been accompanied by changes in weather and climate. Recent years in many places changes in rainfall pattern resulting in sudde **Aesthetic loss, more** floods, on the other side extreme droughts, and severe heat waves. The planet's oceans and glaciers have also experienced some significant changes like the oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment.

13.2.2 Causes of climate change

Earth's temperature depends on the balance between energy entering and leaving the planet's system. When incoming energy from the sun is absorbed by the earth system, earth warms. When the sun's energy is reflected into space, earth avoids warming. When absorbed energy is released back into space, earth cools. Many factors, both natural and human, can cause changes in earth's energy balance, including:

- Variations in the sun's energy reaching Earth
- Changes in the reflectivity of earth's atmosphere and surface
- Changes in the greenhouse effect, which affects the amount of heat retained by Earth's atmosphere

13.2.3 Greenhouse Gases

The earth is surrounded by a cover of gases as the atmosphere. This atmosphere allows most of the light to pass through, which reaches the surface of earth. This light from sun is absorbed by the earth surface and converts into heat energy. This heat energy is reemitted by the surface of the earth during night. Due the presence of excess gasses in the atmosphere, the escape of heat from earth surface is prevented, resulting in heating of earth called 'global warming.' The gasses which are responsible for causing global warming are called 'greenhouse gasses. The harmful effects of the presence of greenhouse gasses in atmosphere are global warming, climate change, ozone depletion, sea-level rise, adverse effects on biodiversity, etc. One way or another these adverse impacts are all directly or indirectly related to the presence of greenhouse gases in the atmosphere. A number of human activities, processes, and consumptions produce waste gasses or greenhouse gasses that are harmful to the environment. They include:

(a) Fuel combustion

(b) Energy industries

(c) Manufacturing industries and construction
(d) Vehicle Transport and automobiles
(e) Fugitive emissions from fuels
(f) Burning of solid fuels
(g) Use of oil and natural gas
(h) Mineral products
(i) Chemical industry
(j) Metal production
(k) Production of halocarbons and sulfur hexafluoride
(l) Consumption of halocarbons and sulfur hexafluoride
(m) Solvent and other product use
(n) Enteric fermentation
(o) Manure management
(p) Rice cultivation
(q) Agricultural soils
(r) Prescribed burning of savannas
(s) Field burning of agricultural residues
(t) Solid waste disposal on land
(u) Wastewater handling
(v) Waste incineration

Much of these harmful gases are produced either naturally or by various human activities; which we should reduce. Brief description and effects of six important greenhouse gases are given below:

Carbon dioxide (CO_2)

A naturally occurring gas produced by living organisms and fermentation. It is a normal component of the breath we exhale; it is hazardous in concentrated volumes. Large quantity of carbon dioxide is produced by the combustion of carbonaceous fuels. Carbon dioxide emissions from fuel burning, responsible for about 87 percent of global warming, have increased by about 27 percent since the industrial revolution.

Nitrogen oxides (NO)

Nitrogen oxides are naturally occurring from microbial action in the soil. NO is also produced by fuel burning. Scientists say its production is increased by the use of nitrogen-based fertilizers in agriculture, as well as by the use of catalytic converters in automobiles.

Methane (CH_4)

Methane is a naturally occurring, flammable gas. Methane is produced by geological coal formations and by the decomposition of organic matters. Related sources of methane are landfills, livestock digestive processes and waste, especially ruminants (cud-chewing animals), and wetland rice cultivation.

Hydrofluorocarbon gasses (HFCs) – Chlorofluorocarbons (CFC)

The coolant, cleaning, and propellant gases were blacklisted internationally due to its ozone eating characteristics. HFCs do contribute to global warming. Global warming potential of HFCs is 4,000 to 10,000 times that of CO_2.

Perfluorocarbons (PFC), or Perflurocompounds

Human-made replacement gases for CFCs but result also as a byproduct of aluminum smelting. PFCs also used as a purging agent for semiconductor manufacture, and small amounts are produced during uranium enrichment processes. Global warming potential of Perfluorocarbons (PFC) or perfluoro compounds is 6,000 to 10,000 that of CO_2.

Sulfur hexafluoride (SF_6)

Very low atmospheric concentration makes it an ideal test gas for gas concentration monitors. Principle uses as insulating material for high voltage equipment like circuit breakers at utilities. Also used in water leak detection for cable cooling systems. SF_6 is a man-made gas.

13.2.4 Global warming

For the last 10000 years, the temperature across the globe remained unusually stable changing by little more than 2°F on an average. Even during the 'Little Ice Age' (1300 AD to 1850 AD), which resulted advancing of glaciers, average temperatures were little more than 2°F. The effects of global warming could change average temperatures five times as much as little ice age did – though in the opposite direction. Over the next century, the rate of the effects of global warming should follow a steep upward curve. The adverse effects of global warming are enormous. The results are already being felt on our planet, on human life, plants, and animals worldwide. The predicted effects of global warming on the environment and for human life are numerous and varied. It is generally difficult to attribute specific natural phenomena to long-term causes, even though, some effects of recent climate change already we are witnessing; rising sea levels, glacier retreat, Arctic shrinkage, and altered patterns of agriculture are cited as direct consequences. Among secondary and regional effects, extreme weather events, expansion of tropical diseases, changes in the timing of seasonal patterns in ecosystems, and drastic economic impact are predicted.

Major adverse effects of global warming are listed below:

(i) Polar ice caps melting –

The ice cap melting is a four-pronged danger.

a) It will raise sea levels. There are more than 57,73,000 cubic miles of water in ice caps, glaciers, and permanent snow. According to the National Snow and Ice Data Center, if all glaciers melted today, the seas would rise about 230 feet. It may not happen at once, but sea level will increase certainly and consequently, low lying areas will be submerged.

b) Melting ice caps will throw the global ecosystem out of balance. The ice caps are freshwater, and when they melt, they will desalinate the ocean. The desalinization of the gulf current will distort ocean currents, which regulate temperatures. It will give very confusing and irregular pattern of cooling and warming effects in some areas.

c) The temperature rises and changing landscapes in the artic circle will endanger several species of animals. Only the most adaptable will survive.

d) Global warming will undoubtedly reduce ice caps substantially. Ice caps are white, and reflect sunlight, much of which is reflected into space, further cooling Earth. If the ice caps melt, the only reflector is the ocean. Darker colors absorb sunlight, also warming the earth.

(ii) Increased probability and intensity of droughts and heatwaves. Although some areas of Earth will become wetter due to global warming, other areas will suffer severe droughts and heatwaves. Africa will receive the worst of it, with more severe droughts also expected in Europe. Water is already a scarce commodity in Africa, and global warming will worsen the conditions.

(iii) Warmer waters and more hurricanes. As the temperature of oceans rises, so will the probability of more frequent and stronger hurricanes.

(iv)Spread of disease – As northern countries warm, disease-carrying insects migrate north, bringing plague and disease with them.

(v) Economic consequences – Most of the effects of global warming will not be good. These effects bring economic consequences badly for almost all the countries of the world.

Rise in global warming

The ocean might have become 'saturated' with our emissions – An alarm bell: When the industrial revolution started, the level of CO_2 in the atmosphere was around 280 parts per million by volume (ppmv), but that has risen to around 380ppmv due to our burning of fossil fuels. Because of tremendous rise in CO_2 (about 35% rise), the global warming scenario has been deteriorated or faster. The melting of arctic ice, severe climate changes are some of the effects among many, of global warming. This unexpected growth of CO_2 level in the atmosphere, scientists suspect, is due to mainly two reasons:

i. Inefficiency in the use of fossil fuels which increased the CO_2 concentration by 17% and
ii. Other 18% came from a decline in the natural ability of land and oceans to soak up CO_2 from the atmosphere, i.e., reduction in global carbon sinks. Besides, the growth of global population is responsible for significant increase of atmospheric CO_2, as well.

The decline in global sink (there are two major carbon sinks in the biological cycle: the oceans and the land "biosphere", which includes plants and the soil) efficiency suggests that stabilization of atmospheric CO_2 is even more challenging to achieve than previously thought. The study suggests, about half of emissions from human activity are absorbed by these natural "CO_2 sinks" but it has been observed that the efficiency of these sinks has fallen. Scientists believe global warming might get worse if the oceans soak up less of the greenhouse gas.

The weakening of the Earth's ability to cope with greenhouse gases is thought to be a result of changing wind patterns overseas and droughts on land. Whether this change in behavior of ocean is due to climate change or natural variations is not clear. It is a tremendous surprise and troublesome factor because there were grounds for believing that in time the ocean might become 'saturated' with our emissions – unable to soak up any more. This phenomenon of ocean being saturated, leave us with all our discharge to heat our globe – results from rapidity in global warming.

We have to find out the ways to deal with this rapid pace in global warming. Implementation of carbon sink technology, iron fertilization of Southern oceans, etc., have to be thought of. The major responsible factors such as the issues like reduction of emission of greenhouse gasses in the atmosphere are to be tackled efficiently.

13.2.5 Expected impacts of global warming:

Scientific studies has produced a long list of possibilities of effects of global warming.

Expected impacts are:

1. Most places may continue to get warmer, especially at night and in winter. The temperature change will benefit some regions, at least for a time, while harming others like, patterns of tourism will shift. The warmer winters will benefit health in some areas, but globally, mortality will rise due to summer heatwaves and other effects.
2. Sea levels will continue to rise.
3. Weather patterns will keep changing, probably toward an intensified water cycle with stronger floods and droughts. Most regions facing droughts are expected to get drier (because of warming as well as less precipitation), and most wet areas will get wetter. Mountain glaciers and winter snowcap will shrink, jeopardizing many water supply systems. Each of these changes has been noted in some regions.
4. Ecosystems will be stressed. Uncounted valuable species, especially in the Arctic, mountain areas, and tropical seas, must shift their ranges. Many that cannot will face extinction. Each of these problems has been observed in numerous places.
5. Increased carbon dioxide levels will affect biological systems independent of climate change. Some crops will be fertilized, as will some invasive weeds. The oceans will continue to become markedly more acidic, gravely endangering coral reefs, and probably harming fisheries and other marine life.
6. There will be significant unforeseen impacts. Most of these will probably be harmful since human and natural systems are well adapted to the present climate.

Abnormal rise in greenhouse gas, methane, in the earth atmosphere causing arctic ice to vanish in a couple of years. It has been reported that, due to rapid, unchecked and unethical industrialization in many parts of the globe, the concentration of methane, a very prominent greenhouse gas, has been rising and in last one year alone it has risen by about 0.5%. We all know that methane is the second most important gas causing manmade climate change. Each molecule causes about 25 times more warming than a molecule of CO_2, though it survives for shorter times in the atmosphere before being broken down. Further, it has also been known to us that, already global climate is a excellent disastrous condition because of present rise in carbon dioxide (CO_2) levels, which is significantly higher than the average annual increase for the last 30 years. It has also been recently reported that CO_2 concentration has risen by 2.4 parts per million (ppm) in last one-year ; as against the average annual increase of 1.65 ppm between 1979 and 2007. Thus, it shows evidence that concentrations of greenhouse gases are rising faster than they were a decade ago. The methane concentration figure is more impressive and potentially of more concern. Because of the above abnormal rise in greenhouse gases in the last one year or so, scientists fear that it could reflect melting of permafrost and drying of tropical wetlands more rapidly. It has also been reported that concentrations of greenhouse gases have been more or less stable since about 1999 and after thatrapid increases.

13.3 BIOREMEDIATION

13.3.1 INTRODUCTION

Many substances introduced into the environment through human activities known to have toxic properties. These substances are a danger to human health and other organisms. Conventional methods to remove, reduce, or mitigate toxic substances introduced into soil or groundwater via anthropogenic activities and processes include pump and treat systems, soil vapor extraction, incineration, and containment. The utility of traditional methods of treatment of contaminated soil and/or water, suffers from recognizable drawbacks and may involve some level of risk. Microbes utilize these contaminants in the soil as an energy source through oxidation-reduction reactions. By-products (metabolites) released back into the environment are typically in a less toxic form than the parent contaminants.

Advanced bioremediation techniques offer an alternative method to detoxify contaminants. Bioremediation can be defined as any process that uses microorganisms, fungi, green plants, or their enzymes to return the natural environment altered by contaminants to its original condition. Bioremediation is also defined as use of biological processes to degrade, break down, transform and essentially remove contaminants or impairments of quality from soil and water. Bioremediation has been demonstrated and is being used as an effective means of mitigating: hydrocarbons, halogenated organic solvents, halogenated organic compounds, non-chlorinated pesticides and herbicides, nitrogen compounds, metals (lead, mercury, chromium) and radionuclides.

Classifications of Bioremediation

There are three classifications of bioremediation: i) **Biotransformation:** The alteration of contaminant molecules into less or nonhazardous particles ii) **Biodegradation:** The breakdown of organic substances in smaller organic or inorganic molecules iii) **Mineralization:** The complete biodegradation of natural materials into inorganic constituents such as CO_2 or H_2O. These three classifications of bioremediation can occur either *in situ* (at the site of contamination) or *ex-situ* (contaminant is taken out of the place of contamination and treated elsewhere).

BIOREMEDIATION

Different techniques are employed depending on the degree of saturation and aeration of an area. ***In situ*** techniques are defined as those that are applied to soil and groundwater at the site with minimal disturbance. ***Ex-situ*** methods are those that are used to soil and groundwater at the site which has been removed from the website via excavation (soil) or pumping (water).

13.3.2 BIOREMEDIATION STRATEGIES:

IN SITU BIOREMEDIATION

These techniques are generally the most desirable options due to lower cost and fewer disturbances since they provide the treatment in place, avoiding excavation and transport of contaminants. *In situ* treatment is limited by the depth of the soil that can be effectively treated. In many soils, effective oxygen diffusion for desirable rates of bioremediation extends to a range of only a few centimeters to about 30 cm into the soil, although depths of 60 cm and greater have been effectively treated in some cases.

The most essential land treatments are:

Bioventing is the most common *in situ* treatment and involves supplying air and nutrients through wells to contaminated soil to stimulate the indigenous bacteria. Bioventing employs low airflow rates and provides only the amount of oxygen necessary for the biodegradation while minimizing volatilization and release of contaminants to the atmosphere. It works for, pure hydrocarbons and can be used where the contamination is under the surface.

In situ biodegradation involves supplying oxygen and nutrients by circulating aqueous solutions through contaminated soils to stimulate naturally occurring bacteria to degrade organic contaminants. It can be used for soil and groundwater. Generally, this technique includes conditions such as the infiltration of water-containing nutrients and oxygen or other electron acceptors for groundwater treatment.

Biosparging involves the injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria. Biosparging increases the mixing in the saturated zone and thereby increases the contact between soil and groundwater. The ease and low cost of installing small-diameter air injection points allow considerable flexibility in the design and construction of the system.

Bioaugmentation frequently involves the addition of microorganisms indigenous or exogenous to the contaminated sites. Two factors limit the use of added microbial cultures in a land treatment unit: 1) nonindigenous cultures rarely compete well enough with an indigenous population to develop and sustain useful population levels and 2) most soils with long-term exposure to biodegradable waste have indigenous microorganisms that are effective degrades if the land treatment unit is well managed.

EX SITU BIOREMEDIATION

These techniques involve the excavation or removal of contaminated soil from the ground.

Land farming is a simple technique in which contaminated soil is excavated and spread over a prepared bed and periodically tilled until pollutants are degraded. The goal is to stimulate indigenous biodegradative microorganisms and facilitate their aerobic degradation of contaminants. In general, the practice is limited to the treatment of superficial 10–35 cm of soil. Since land farming has the potential to reduce monitoring and maintenance costs, as well as clean-up liabilities, it has received much attention as a disposal alternative.

Composting is a technique that involves combining contaminated soil with nonhazardous organic amendments such as manure or agricultural wastes. The presence of these organic materials supports the development of a wealthy microbial population and elevated temperature characteristic of composting.

Biopiles are a hybrid of landfarming and composting. Primarily, engineered cells are constructed as aerated composted piles. Typically used for treatment of surface contamination with petroleum hydrocarbons they are a refined version of landfarming that tend to control physical losses of the contaminants by leaching and volatilization. Biopiles provide a favorable environment for indigenous aerobic and anaerobic microorganisms.

Bioreactors

Slurry reactors or aqueous reactors are used for *ex-situ* treatment of contaminated soil and water pumped up from a contaminated plume. Bioremediation in reactors involves the processing of contaminated solid material (soil, sediment, sludge) or water through an engineered containment system. A slurry bioreactor may be defined as a containment vessel and apparatus used to create a three-phase (solid, liquid, and gas) mixing condition to increase the bioremediation rate of soil-bound and water-soluble pollutants as a water slurry of the contaminated soil and biomass (usually indigenous microorganisms) capable of degrading target contaminants. In general, the rate and extent of biodegradation are more significant in a bioreactor system than *in situ* or solid-phase systems because the contained environment is more manageable and hence more controllable and predictable. Despite the advantages of reactor systems, there are some disadvantages. The contaminated soil requires pre-treatment (e.g., excavation) or alternatively the contaminant can be stripped from the soil via soil washing or physical extraction (e.g., vacuum extraction) before being placed in a bioreactor.

MICROBIAL POPULATIONS FOR BIOREMEDIATION PROCESSES

Microorganisms can be isolated from different environments. Microbes will adapt and grow at different environmental conditions with the presence of hazardous compounds or on any waste stream. The main requirements are an energy source and a carbon source. Because of the adaptability of microbes and other biological systems, these can be used to degrade or remediate environmental hazards. We can subdivide these microorganisms into the following groups:

Aerobic (in the presence of oxygen): Examples of aerobic bacteria recognized for their degradative abilities are *Pseudomonas, Alcaligenes, Sphingomonas, Rhodococcus,* and *Mycobacterium*. These microbes have often been reported to degrade pesticides, hydrocarbons, alkanes and polyaromatic compounds. Many of these bacteria use the contaminant as the sole source of carbon and energy.

Anaerobic (in the absence of oxygen): Anaerobic bacteria are not as frequently used as aerobic bacteria. There is an increasing interest in anaerobic bacteria used for bioremediation of polychlorinated biphenyls (PCBs) in river sediments, dechlorination of the solvent trichloroethylene (TCE) and chloroform.

Ligninolytic fungi: Fungi such as the white-rot fungus *Phanaerochaete chrysosporium* can degrade an incredibly diverse range of persistent or toxic environmental pollutants. Common substrates used include straw, sawdust, or corn cobs.

Methylotrophs: Aerobic bacteria that grow utilizing methane for carbon and energy. The initial enzyme in the pathway for aerobic degradation, methane monooxygenase has a broad substrate range and is active against a wide range of compounds including the chlorinated aliphatics, trichloroethylene, and 1,2-dichloroethane.

Examples of microbes used for bioremediation include:

Deinococcus radiodurans bacteria have been genetically modified to digest solvents and heavy metals, as well as toluene and ionic mercury from highly radioactive nuclear waste. *Geobacter sufurreducens* bacteria can turn uranium dissolved in groundwater into a non-soluble, collectable form. *Dehalococcoides entheogens* bacteria are being used to clean up chlorinated solvents that have been linked to cancer. The bacteria are naturally found in soil. An enzyme from a bacterium, *Thermus brockianus* located in Yellowstone National Park, breaks down hydrogen peroxide 80,000 times faster than current chemicals in use. The bacterium, *Alcaligenes eutrophus*, naturally degrades 2, 4-D, the third most widely used as herbicide.

ADVANTAGES OF BIOREMEDIATION

Bioremediation is a natural process and widely acceptable waste treatment process for soil. Microbes able to degrade the contaminant multiply when the contaminant is present; when the contaminant is degraded, their number declines. The residues after treatment are usually harmless intermediate products, carbon dioxide and water. Bioremediation is useful for the destruction of a wide variety of contaminants. Instead of transferring contaminants from one environmental medium to another, the destruction of target pollutants is possible. Bioremediation can often be carried out on-site, without causing a significant major disruption of normal activities. This also eliminates the need to transport quantities of waste off-site and the potential threats to human health and the environment that can arise during transportation. Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste.

DISADVANTAGES OF BIOREMEDIATION

Bioremediation is limited to those compounds that are biodegradable. All compounds are not susceptible to rapid and complete degradation. Sometimes the products of biodegradation may be more persistent or toxic than the parent compound. Biological processes are often highly specific. Important site factors required for success include the presence of metabolically capable microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants. It is difficult to extrapolate from the bench and pilot-scale studies to full-scale field operations. Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration. Regulatory uncertainty remains regarding acceptable performance criteria for bioremediation.

13.4 ENVIRONMENTAL AWARNESS

13.4.1 INTRODUCTION

Environmental Education is a process of recognizing values and clarifying concepts in order to develop skills and added tools necessary to understand and appreciate the inter-relationship among man, his culture, and his bio-physical surrounding. It creates an overall perspective, which acknowledges the fact that natural environment and man-made environment are interdependent. It should consider the environment in its totality and should be a continuous lifelong process beginning at the pre-school level and continuing through all stages. It should be inter-disciplinary and examine major environmental issues from local, national and international points of view. It should utilize various educational approaches to teach and learn about and from the environment with stress on practical activities and first-hand experience. It is through this process of education that people can be sensitized about environmental issues. To achieve the above objectives, the Ministry has been implementing several schemes and programs. Some of the significant projects implemented for imparting ecological education and for creation of environmental awareness among the general public are as follows:

13.4.2 NON-FORMAL ENVIRONMENT EDUCATION AND AWARENESS

Environmental Education, Awareness, and Training plays a significant role in encouraging and enhancing people's participation in activities aimed at conservation, protection, and management of the environment, essential for achieving sustainable development. The Ministry, therefore, accords priority for the promotion of non-formal environment education and creation of awareness among all sections of the society through diverse activities using traditional and modern media of communication. Some of the major activities undertaken in this regard are as follows:

National Environment Awareness Campaign (NEAC)

The NEAC was launched in mid-1986 with the objective of creating environmental awareness at the national level. It is a multi-media campaign which utilizes conventional and non-conventional methods of communication for disseminating environmental messages to a wide range of target groups. Under this campaign, nominal financial assistance is provided to registered NGOs, schools, colleges, universities, research institutions, women and youth organizations, army units, State Government Departments, etc. from all over the country for organizing/conducting awareness-raising activities. These activities which include seminars, workshops, training programmes, camps, padayatra, rallies, public meetings, exhibitions, essay/debate/painting/poster competitions, folk dances and songs, street theatre, puppet shows, preparation and distribution of environmental education resource materials etc., are followed by action like plantation of trees, management of household waste, cleaning of water bodies etc. Diverse target groups encompassing students, youth, teachers, tribals, farmers, other rural population, professionals, and the general public are covered under NEAC. The program is being implemented through 28 designated Regional Resource Agencies (RRAs) for specific states/regions of the country. The applications for participation in this program are invited every year through advertisement in major national and regional newspapers during May/June.

Eco-clubs (National Green Corps)

The main objectives of this program are to educate children about their immediate environment and impart knowledge about the eco-systems, their inter-dependence and their need for survival, through visits and demonstrations and to mobilize youngsters by instilling in them the spirit of scientific inquiry into environmental problems and involving them in the efforts of environmental preservation. Considering that the total number of schools covered was grossly inadequate compared to the total number of schools in the country and keeping in view the potential of this program in sensitizing the school students. It was decided to intensify this program to cover every district of the country.

A program of raising 'National Green Corps' through the Eco clubs was, therefore, launched during 2001-2002. Under this program, Eco-clubs are being set up in 100 schools of each District of the country. 47,000 Eco-clubs have been set up so far in the country. This program is implemented in each State/UT through the Nodal agency appointed by the State/UT Govt. The Government of India provides financial assistance for the establishment of Eco clubs @ Rs.1000 per Eco-club, Training of Master Trainers, teacher training and distribution of resource materials.

Global Learning and Observations to Benefit the Environment (GLOBE)

The GLOBE is an International Science and Education Programme, which stress on a hands-on participatory approach. India joined this program during August 2000. This program, which unites students, teachers, and scientists all over the world, is aimed at school children. The students of GLOBE schools are required to collect data about various basic environmental parameters under the supervision of a GLOBE trained teacher and use it for explaining hypothesis as well as to enhance their scientific understanding of the earth. This data is also used by scientists in their research work. The GLOBE also provides an opportunity for the students to interact not only with the GLOBE scientists but also with the students from GLOBE schools in other parts of the world. About 100 schools spread over different parts of the country have already joined this program. The teachers of these schools have also been trained in various GLOBE protocols. An International training workshop for trainers was successfully organized at New Delhi during January 2002. The participants at this workshop, which included representatives from Nepal and Thailand besides India, were trained in Basic and Advanced GLOBE Protocols by a training team from GLOBE Headquarters in USA.

Mass Awareness

Despite significant efforts to spread environmental awareness by the Ministry through several schemes, it is felt that a large population,, especially in rural areas, is still left out. The best way to reach out to them and make them aware of the environmental problems is through media, particularly electronic media. "Mass Awareness" has therefore been identified as one of the thrust areas of the Ministry, not only to intensify the efforts already being made in this direction but also to launch new initiatives. The Doordarshan and few other television channels are proposed to be extensively used for telecasting environment based programs and infomercials. Professional Media agencies which are hired to assist the Ministry in carrying out the campaign also play a significant role. To encourage individual efforts in producing films/documentaries on environment/wildlife related themes in the country, the Ministry has sponsored organization of a film festival "Vatavaran – 2001" by Centre for Media Studies, Delhi on April 2002.

13.4.3 OTHER AWARENESS PROGRAMS

The Ministry also sponsors various programs which do not fit into straitjacketed plans like NEAC, NGC, etc. and are aimed at creating environmental awareness among children. These include environment quiz (both written as well as televised), organization of activities for observation of special occasions such as earth day, special programs for children, etc. These proposals which are received throughout the year from various NGOs and other agencies are considered on merit as and when received and are supported. Few examples such programs are:

- An international written Environment Quiz program is known as Green Olympiad conducted by TERI.
- Awareness activities/events by NGOs, academic institutions, etc. on the occasion of special Environment days like Earth Day, etc.
- Written environmental quiz programs in different regional languages are being started. The winners of the written quiz would participate in a televised quiz program.
- Organization of an annual Vacation Program on Environmental Resources for high school level students, namely “Vacation program on Natural resources- building a broader constituency of support for conservation” by ATREE.

13.4.4 NATIONAL ORGANIZATIONS

In recognition of the felt need for environmental protection, various regulatory and promotional measures have been taken by the Indian Government over the past two decades are as follows:

Legal

1. The Wildlife (Protection) Act, 1972, amended in 1983, 1986 and 1991.
2. The Water (Prevention and Control of Pollution) Act, 1974, amended in 1988.
3. The Water'(Prevention and Control of Pollution) Cess, Act, 1977, amended in 1991.
4. The Forest (Conservation) Act, 1980, amended in 1988.
5. The Air (Prevention and Control of Pollution) Act, 1981, amended in 1988.
6. The Environment (Protection) Act, 1986.
7. The Motor Vehicle Act, 1938, amended in 1988.
8. The Public Liability Insurance Act, 1991.
9. A Notification on Coastal Regulation Zone, 1991.

Institutions

The various institutions were established by the Government of India in specialized subject areas to protect the environment, and its resources are as follows:

1. Department of Environment in 1980 and the integrated Ministry of Environment & Forests in 1985
2. Department of Science and Technology
3. Department of Agriculture and Cooperation
4. Department of Biotechnology
5. Department of Ocean Development
6. Department of Space
7. Department of Non-Conventional Energy Sources
8. Energy Management Centre
9. Council of Scientific and Industrial Research
10. Departments of Environment at the State and Union Territory level
11. Central Pollution Control Board and State Pollution Control Boards
12. Central Forestry Board
13. Indian Council of Forestry Research and Education.
14. Forest Survey of India (FSI)
15. Wildlife Institute of India (VAI)
16. Botanical Survey of India (BSI)
17. Zoological Survey of India (ZSI)
18. Central Zoo Authority (CZA)**:** Statutory body under Ministry of Environment & Forests, Government of India, in New Delhi to regulate the functioning of zoos in India; aims conservation of wildlife, evaluating and providing technical & financial assistance to zoos, training personnel.
19. National Land-use and Wasteland Development Council.
20. National Wastelands Development Board
21. Indian Board of Wildlife
22. National Museum of Natural History
23. Centre for Environmental Education
24. Institute for Himalayan Environment and Development

13.4.5 Prevention and Control of Pollution

1. Water and air quality monitoring stations in selected areas.
2. Use-based zoning and classification of rivers.
3. Notification and enforcement of standards for polluting industries through the Central and State Pollution Control Boards.
4. Rules for manufacture, storage, transportation, and disposal of hazardous substances.
5. On-site and off-site emergency plans for preparedness against chemical accidents.
6. Fiscal incentives for the installation of pollution control devices.
7. Ganga Action Plan to prevent pollution of the river and restore its water quality which could be expanded to cover other major river systems subject to availability of resources.
8. Identification of critically polluted areas and of highly polluting industries.

13.4.6 Conservation of Forests and Wildlife

- Adoption of a new Forest Policy (1988) with the principal aim of ensuring ecological balance through conservation of biological diversity, soil and water management, increase of tree cover, meeting the requirements of the rural and tribal population, increase in the productivity, efficient utilization of forest produce, substitution of wood and people's involvement for achieving these objectives.
- Under the Forest (Conservation) Act, 1980 stringent provisions for preventing diversion of forest land for any other purpose.
- Setting up of the National Wastelands Board to guide and oversee the wastelands development programme by adopting a mission approach for enlisting people's participation, harnessing the inputs of science and technology and achieving interdisciplinary coordination in programme planning and implementation.
- Formulation of a National Wildlife Action Plan.
- An exercise for preparation of a National Forestry Action Programme.
- Establishment of National Parks and Sanctuaries covering about 4% of the country's area.
- Eco-development plans for sanctuaries and National Parks.
- Identification of biogeographical zones in the country for establishing a network of protected areas including seven Biosphere Reserves set up so far.
- Management Plans for identified wetlands, mangrove areas, and coral reefs.
- Formulation of a National River Action Plan.

Land and Soil

1. Surveys by the All India Soil and Land-Use Survey Organization.
2. Treatment of catchment in selected river valley projects and integrated watershed management projects in the basin of flood-prone rivers.
3. Assistance to States to control shifting cultivation.
4. Assistance for reclamation and development of ravine areas.
5. Drought prone areas program.
6. Desert development programme.

Environmental Impact Assessment

- Establishment of procedures for environmental impact assessment and clearance about selected types of projects requiring approval of the Government of India.
- Prior clearance of projects requiring diversion of forests for non- forest purpose under the Forest (Conservation) Act 1980
- Formulation of Environmental guidelines for projects in various sectors.

Other Activities

1. Eco-Task Forces of ex-servicemen for ecological restoration through afforestation and soil conservation.
2. National Environmental Awareness Campaigns for creating environmental awareness through non-governmental organizations.
3. Surveys and research studies.
4. Training programs, workshops, and seminars for building up professional competence and for creation of awareness

13.4.7 NON-GOVERNMENTAL ORGANIZATIONS

1. Bombay Natural History Society

Bombay Natural History Society is today the largest non-government organization (NGO) in the Indian subcontinent engaged in nature conservation research. In the 125 years of its existence, its commitment has been and continues to be, the conservation of India's natural wealth, protection of the environment and sustainable use of natural resources for a balanced and healthy development for future generations. The Society's guiding principle has always been that conservation must be based on scientific research - a tradition exemplified by its late president, Dr. Sálim Ali.

2. Greenpeace India

Greenpeace is an Indian non-profit organization, has been working on various issues related to the environment since 2001. Greenpeace has been working on broad campaigns, namely, stop climate change, sustainable agriculture, preserving the oceans and preventing another nuclear catastrophe. Over the years, Greenpeace India has built a strong base of supporters spread across the country. Greenpeace exists because the earth and all life on it deserve a clean and safe environment - now and in the future. As a global organization, Greenpeace focuses on the most critical worldwide environmental issues such as:- Oceans and ancient forests protection, Fossil fuel phase-out and the promotion of renewable energies to stop climate change, nuclear disarmament and an end to nuclear contamination, Elimination of toxic chemicals and Preventing the release of genetically engineered organisms into nature. Actions often speak louder than words and non-violent direct action is at the heart of Greenpeace campaigns, which have also grown to include lobbying and research over the past years.

3. Wildlife Trust of India

The non-profit organization set up to prevent destruction of India's wildlife, especially endangered species (tigers, elephants, rhinos) & threatened habitats; aids research & projects, educates public, acquire land for wildlife conservation.

4. Bombay Environment Action Group (BEAG)

Environmental NGO started in 1975; aims at the protection of environment and ecology including conservation and protection of natural resources, wildlife and forests, human-made heritage, air, water, and noise pollution issues.

5. **Madras Crocodile Bank Trust**

The Madras Crocodile Bank Trust and Centre for Herpetology are one of the largest reptile zoos in the world and one of the oldest non-government environmental organizations in Asia. The main aim is to promote the conservation of reptiles and amphibians on the Indian subcontinent, but our inference is multidisciplinary and extends worldwide. The Crocodile Bank believes that successful conservation is built on sound scientific research and the two actions are tightly knit. To this end, the Croc Bank has joined forces with many of the world’s foremost experts and organizations to better achieve these immense tasks.

6. Ashoka Trust for Research in Ecology & the Environment (ATREE)

ATREE's organizational structure is designed to promote creative interdisciplinary approaches that integrate research with policy and action in addressing key environmental problems. The organization working for conservation of India's biological resources & natural ecosystems in Western Ghats & Eastern Himalayas; conducts research, education & outreach programs through offices in spread over the country.

7. India Habitat Centre (IHC)

Centre in New Delhi, encouraging interaction between individuals and institutions working for the conservation of environment; promotes education, spreads awareness among the public, & advises the government on matters relating to habitat & human settlement.

8. Sloth Bear Foundation

Foundation set up to protect and preserve the endangered sloth bears and their habitats from destruction; headquartered at Bellary, it has a tie-up with the Karnataka forest department; also organizes internship programs for international students.

9. Southern Bird wing

Enterprise (run by Harvey D'Souza & Neil Alvares) organizing eco-friendly tourist expeditions in Goa; promotes conservation of nature, organizes educational workshops, runs a helpline to rescue animals and writes articles on eco-issues.

10. The People's Commission on Environment & Development India

Non-governmental, non-profit association launched in New Delhi in 1990; holds public hearings in India to gather the views of the public & NGOs on environmental and development issues and to involve them in government's decision-making process.

11. Wildlife Protection Society of India (WPSI)

A non-profit organization founded by Belinda Wright in 1994, to conserve Indian wildlife; supports government in combating poaching & illegal wildlife trade; conducts workshops and campaigns to protect endangered species.

12. Chipko Movement

Chipko Movement, started in the 1970's, was a nonviolent movement aimed at protection and conservation of trees and forests from being destroyed. The name of the Chipko moment originated from the word 'embrace' as the villagers used to hug the trees and protect them from wood cutters from cutting them. Chipko movement was based on the Gandhian philosophy of peaceful resistance to achieve the goals. It was the strong uprising against those people, who were destroying the natural resources of the forests and disturbing the whole ecological balance. Prominent Chipko figures include Sunderlal Bahuguna, a Gandhian activist and philosopher, whose appeal to Mrs. Gandhi results in the green-felling ban and whose 5,000-kilometer trans-Himalaya foot march in 1981-83 was crucial in spreading the Chipko message. Bahuguna coined the Chipko slogan: 'ecology is permanent economy.'

13.4.8 INTERNATIONAL ORGANIZATIONS

1. United Nations Environment Programme (UNEP)

2. International Institute for Sustainable Development (IISD)
3. Commission for Environmental Cooperation (CEC)
4. European Environment Agency (EEA)
5. Intergovernmental Panel on Climate Change (IPCC

13.5 SUMMARY

1. Pollution may be defined as an undesirable change in the physical, chemical or biological characteristics of air, water, and land that may be harmful to human life and other animals, living conditions, industrial processes, and cultural assets. The pollutants can be classified based on *natural disposal*; pollutants are of two types- i) non-degradable pollutants, ii) Bio-degradable pollutants
2. Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere. Diverse of air source of air pollution are fossil fuels, industries, agricultural activities, wars, natural causes, and emission from vehicles. The various impact of pollution on plants, animals and human beings.
3. The CO_2 content of air is increasing due to deforestation and combustion of fuel. This increase affects the composition and balance of gases in the atmosphere. Increase in CO_2 concentration may increase the atmospheric temperature producing *greenhouse effect*. A rise in global temperature by more than 2-3 degrees may melt glaciers and polar ice. This would lead to an increase in ocean level and consequent flooding and submergence of coastal areas.
4. Water is extremely essential for life. The undesirable substances added to the water resources to a great extent alter the basic chemistry of water. The sources of water pollution are categorized as a *point source* or a *non-source point* of pollution. *Point sources* of pollution occur when harmful substances are emitted directly into a body of water.
5. Soil pollution is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment. A soil pollutant is any factor which deteriorates the quality, texture, and mineral content of the soil or which disturbs the biological balance of the organisms in the soil. Pollution in soil has adverse effect on living organisms. Pollution in soil is associated with i) indiscriminate use of fertilizers, ii) indiscriminate use of pesticides, insecticides, and herbicides, iii) Dumping of large quantities of solid waste, iv) Deforestation and soil erosion.
6. Noise pollution generally refers to unwanted sound produced by human activities. It interferes with communication, work, rest, recreation, or sleep. Noise pollution refers typically to unwanted sound produced by human activities. Unlike other forms of pollution, noise does not remain long in the environment. The techniques employed for noise control can be broadly classified as i) Control at source, ii) Control in the transmission path, iii) Using protective equipment

7. Rising global temperatures have been accompanied by changes in weather and climate. Due excessive presence of some gasses in the atmosphere, this escape of heat from earth surface is prevented, resulting in heating of earth called 'global warming'. The gasses which are responsible for causing global warming are called 'greenhouse gasses'. The harmful effects of the presence of greenhouse gasses in atmosphere are global warming, climate change, ozone depletion, sea-level rise, adverse effects on biodiversity.
8. Bioremediation can be defined as any process that uses microorganisms, fungi, green plants, or their enzymes to return the natural environment altered by contaminants to its original condition. Bioremediation is also defined as use of biological processes to degrade, break down, transform and essentially remove contaminants or impairments of quality from soil and water. The residues for the treatment are usually harmless products and include carbon dioxide, water, and cell biomass. The disadvantage of Bioremediation is limited to those compounds that are biodegradable
9. *In situ* techniques are defined as those that are applied to soil and groundwater at the site with minimal disturbance. *Ex-situ* methods are those that are used to soil and groundwater at the site which has been removed from the website via excavation (soil) or pumping (water).
10. Environmental Education is a process of recognizing values and clarifying concepts in order to develop skills and added tools necessary to understand and appreciate the inter-relationship among man, his culture, and his bio-physical surrounding.
11. The Ministry also sponsors various programs which do not fit into straitjacketed plans like NEAC, NGC, etc. and are aimed at creating environmental awareness among children. These include environment quiz (both written as well as televised), organization of activities for observation of special occasions such as earth day, special programs for children, etc.

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UNIT XIV CONSERVATION OF NATURAL RESOURCES

Structure

14.0 CONSERVATION OF NATURAL RESOURCES

14.1 INTRODUCTION

Nature provides numerous resources and economical support to the people either directly or indirectly. Natural resources can be defined as all natural things in other words; natural resources may be anything found by man in natural environment. Natural resources include the wood, rocks, soil, water and mineral ores etc. Most of the natural resources are being extensively exploited by man. If the present situation continues, the natural resources may become completely exhausted and the availability of natural resources will become none for the future generation. Environmentalists are therefore concerned about the indiscriminate exploitation of natural resources. During the last several decades both the developed and the developing countries have mined out minerals, mineral oils, natural gases and so on for their economic benefits. These kinds of activities are going on without any check. Conservationists and ecologists have voiced their concern to preserve natural resources.

14.1 KINDS OF NATURAL RESOURCES

Globally, natural resources are categorized by two types (i) Renewable (ii) Non-renewable. However the perpetual resources are not affected by human use examples are sunlight and wind.

14.1.1 Renewable Natural Resources

Renewable resources are those are able to replenish through biogeochemical and physical cycles, continuously over a relatively short period of time. They include plants, animal species, water and certain gases like oxygen. Some essential renewable resources have an endless supply such as solar energy, wind energy and geothermal pressure, while other resources are considered renewable even though some time or effort must go into their renewal such as wood, oxygen, leather and fish. Most precious metals are considered renewable as well, they are not naturally replaced, and they can be recycled because they are not destroyed during their extraction and use.

14.1.2. FOREST RESOURCES

Forests are the most important natural resources as they are responsible for recharge of water resources. It also prevents soil erosion, maintains ecological balance and protects us from heat radiation. In India the forest area is approximately 75 million hectares constituting 23% of the total land area. This is against 33 percent according to the National Forest Policy. It has been estimated that over 4 million hectares of forest land have been lost for the last 25 years. About 0.15 million hectares of forests are lost due to development projects annually.

Several factors are responsible for decline of forest: clearing for agriculture, fuel wood cutting, and harvesting of wood products. The general depletion of forest resources is due to biotic pressure and human interference. By far the most important of these is clearing for agriculture. After a few years, soil fertility declines and people move on, usually to cut another patch of trees and begin another garden. The degraded soil at first supports only weeds and shrubby trees. Later, soil fertility and trees return, but that may take decades.

In many tropical countries there is a critical shortage of firewood. For millions of rural poor people, survival depends on finding enough wood to cook the meal. Every year destruction of forest increases, and the distance from home to the forest increases. Selective logging leaves the forest cover intact but usually reduces its commercial value because the biggest and best trees are removed. Selective logging also damages remaining trees and soil, increases the likelihood of fire, and degrades the habitat for wildlife species that require large, old trees-the ones usually cut. In addition, logging roads open up the forests to shifting cultivation and permanent settlement.

Forest conservation

The conservation of forests includes the following methods: i) Afforestation-social and environmental forestry, ii) Agro forestry programmes, iii) Plantation of trees of aesthetic/ornamental values

Afforestation

It is the process of converting barren land or uncultivated area into the forest area by planting young saplings.

Conservation of resource forests

In areas where water is available and forests are maintained (Western and Eastern Ghats are some examples) no commercial exploitation is allowed. They should be protected from poachers, encroachers and fodder-starved cattle.

Commercial forestry

It is also called exploitative forestry. The main aim of this type of forestry is to supply goods and services to meet the local demand for firewood, fodder, food, fertilizers, fiber, timber, medicines etc. It is classified into two types namely:

Social forestry and environmental forestry

Trees which are useful to the tribal people are planted on community land, individual properties and other public land. The main objectives of social forestry are:

- Efficient use of public and private land to produce firewood, fodder and timber in a decentralized manner for the local people
- Soil and water conservation
- To aid conservation of forests

Captive plantation or agro forestry

A purely commercial forestry is developed to fulfill the needs of various forest-based industries. It requires large quantities of raw materials. This type of plantation is done on land, which is not being used for any agricultural practices.

Plantation of trees of aesthetic/ornamental values: Growing of trees for aesthetic value and ornamental trees in the botanical gardens.

14.1.3. LAND RESOURCES

Like forests, land is also one of the important natural resources. It is the most fundamental need of a man because it basically provides shelter and food to mankind. They are the most important endowment of nature. Land is being used by man for various purposes such as agriculture, construction of houses and other buildings, laying roads, railways and so on. At present there is always a rising demand for land; in future also the same condition may continue. The demand of land for non-agricultural purposes is increasing every year. In India, the total geographical area is about 329 million hectares. It is 13% of the total land area of the world. The land in India extends from the snow clad, the Himalayas in the north to near the equatorial region in the south. Since India is a very big country it shows different climatic zones and also endowed with mineral resources. The land resources of India consist of cultivable waste land, forests, barren land, etc. Though the land size in India is quite large its utilization is not to its optimum potential. Only about 30.5 crore hectares of land is being utilized in India. This is about 92.7 percent of the total geographical area.

Soil erosion

Soil erosion is a natural and worldwide phenomenon causing loss of land. Soil erosion is being increased in almost all countries due to natural causes as well as by the activities of man. In India, in the year 1971 alone it was estimated that 6000 million tons of soil was lost. Along with the soil the nutrients such as nitrogen, phosphorous and potassium are also lost resulting in infertility of the soil. The annual soil loss due to erosion is tremendous and the consequences are disastrous. Silting of reservoirs, lakes, tanks, rivers, etc. is also caused by the soil erosion. As a result, their capacity to hold the water is considerably reduced.

Causes of soil erosion

Rainfall: Soil loss is closely related to rainfall. Rain splash is the most important detaching agent. As a result of raindrops striking a bare soil surface, the soil particles may be thrown over a distance of several centimeters. Continuous exposure to intense rainstorms considerably weakens the soil. The erodibility of the soil thus occurs during the rainfall.

Over land flow: The run off flow or over land flow is another major factor for soil erosion. The amount of soil loss resulting erosion by overland flow varies with the velocity and the turbulence of flow. Overland flow occurs on hill slides where the velocity of water is very high; in such places the intensity of erosion is also high.

Wind erosion: Wind is also a natural factor responsible for soil erosion. Transportation of soil and sand particles by wind takes place in suspension, surface creep and saltation. Suspension describes the movement of fine particles usually less than 0.2 mm diameter. Surface creep is the rolling of course grains along the ground surface. Saltation is the movement of sand grains in a series of jumps.

Nature of soil: The organic and chemical constituents of the soil are important because of their influence in aggregate stability. Soil with less than 2 percent of organic matter can be erodible.

Biotic factors

1. Grazing is also one of the biotic factors for soil erosion. Over grazing leads to the hardening of the soil and finally causing soil erosion. India has about 15% of world's cattle population.
2. Deforestation results in soil erosion. When trees in the forest are cleared off, the soil is directly exposed to the raindrops resulting gradual erosion. A few centimeters of top soil is lost in the treeless hill slopes.
3. Agricultural activities, construction of buildings, laying of roads, etc. are the man-made factors of soil erosion.

Soil conservation

Soil is one of the most valuable assets and base of agriculture for mankind. The basic aim of soil conservation is to increase the food production without loss of soil. The conservation of soil mainly lies in the protection of land from erosion. The following measures are usually recommended for the conservation of the soil.

- Growing legume and grasses in the soil erosion area increase the organic content of the soil. This will prevent the soil erosion considerably.
- Rotation of crops is commonly practiced on grazing land. Generally grass lands should not be over exploited to more than 40 – 50 percent of their annual production.

- Grazing land has to be very carefully managed, because over grazing can lead to deterioration of the range and the onset of erosion rapidly when grazed.
- *National Wasteland Development Board (NWDB)* was set up by the Central government in 1955 to bring 5 million hectares of wasteland per year, under fuel wood and fodder plantation. When the wastelands were covered by tree cover, the soil erosion can be considerably reduced.

14.1.4. WATER RESOURCES

Water is a good example of a renewable resource. Water gets cycled back to nature through evaporation, rain and many other ways. Uses of water include agricultural, industrial, household, recreational and environmental activities. Virtually all of these human uses require freshwater. The only time it becomes non-renewable is when it is taken from somewhere faster than nature can replace it and something happens to either the source of the renewing or the place the water was taken from and water is no longer there. Another type of energy that water helps produce is through dams and other aqueducts. These harness the power of the water passing through them and convert it to energy, as long as we don't use up the water faster, then it can be replaced that is another endless supply of energy.

Water Conservation

Even though fresh water is a renewable resource, world's fresh water content is steadily decreasing. With rising world population, water demand already exceeds supply in many parts of the world. Awareness of the global importance of preserving water for ecosystem services has only recently emerged. During the 20th century, more than half the world’s wetlands have been lost along with their valuable environmental services. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems. The framework for allocating water resources to water users (where such a framework exists) is known as water rights.

A step to conserve water is the step to secure the future. Water is the most essential natural resources on the earth. Water conservation is the most effective method to fight global warming. Water conservation refers to those that can reduce the scarcity of water. It aims to improve the efficiency of use of water, and reduce losses and waste.

Tips to save water:

- Avoid water leakage from the taps.
- Turn off the tap when not in use especially when you brush your teeth or wash clothes.
- Rainwater harvesting is another method to conserve water.
- The water supply should be limited in those areas which enjoys the unlimited water supplies.
- Educate the people in the rural areas to save the water.
- Promote the conservation of water through media and wall posters.
- Never throw the water unnecessary on roads which can be used for gardening and cleaning.
- Improvement in the water distribution system.

14.1.5. NON-RENEWABLE OR EXHAUSTIBLE NATURAL RESOURCES

A non-renewable resource is a natural resource which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can create them. The economic valuable resource cannot be readily replaced by natural means on a level equal to its consumption. Fossil fuels (such as coal, petroleum and natural gas) and nuclear power (uranium) are examples. These are considered as non-renewable resources because their use is not sustainable as their formation takes billions of years. The coal in reserve is about 170 billion tones. The largest deposits are in Bihar, Orissa, West Bengal and Madhya Pradesh. In South India, South Arcot district of Tamil Nadu, 3300 million tons of lignite (90%) is in reserves in the country. In India recoverable oil reserves is of 700 million tones and the annual output is 30 million tones. The present reserves will not last more than 15 years. Hence strong conservation measures have to be adopted for future generation.

Conservation measures of non-renewable natural resources

The natural resources like minerals, mineral oils, natural gases, coal, etc are exhaustible and can be used only once. Until recently little attention was paid for conservation of non-renewable natural resources, because it was assumed that they were plenty, for centuries. Now it is quite clear that some of the non-renewable resources like minerals and mineral oils will be exhaustible within two or three decades. Hence conservationists have already warned for serious conservation measures. In almost all countries there is a high demand for the natural resources. However, the exploitation of natural resources should be immediately curbed. The using of minerals and other non-renewable energy fuels should be managed and regulated properly. Otherwise, the non-renewable minerals and mineral oils will be completely exhausted within a short period of time. The real conservation is against unplanned development that breaks ecological as well as human laws.

To conserve energy the alternate sources of power *i.e.* sunlight, wind, biomass and tidal waves can be utilized which are not only unpolluting but also inexhaustible. In India both Tamil Nadu and Gujarat have the best wind potential. It is estimated that these two states alone have the capacity to generate 10,000 MV of wind generated electricity. India is a tropical country there is possibility for generating electricity from the solar energy. It is estimated that about 40,000 MV of electricity can be generated by the wave energy in Indian coastal lines. Already wind energy project in Vizhinjam of Kerala state is coming up to produce electricity. Both the environmentalists and conservationists have consensus that the exploitation of natural resources should not result in the disturbances of the ecological balance. The mismanagement of natural resources not only results in the ecological imbalance but also pollute the environment in a large scale. So, the utilization of natural resources should be prudent and judicious.

14.2 BIODIVERSITY HOT SPOTS OF INDIA

14.2.1 Introduction

Biodiversity is the variety of different forms of life on earth, including plants, animals, and microorganisms. It refers to genetic variation, ecosystem variation, species variation (number of species) within an area, biome or planet. Biodiversity is explored at three level: 1.Genetic diversity, 2. Species diversity and 3. Ecosystem diversity. These three levels work together to create the complexity of life on Earth.

14.2.2 Genetic diversity

Genes are the basic units of all life on Earth. They are responsible for both the similarities and the differences between organisms. The variation of genes within a species called genetic diversity. Each species is made up of individuals that have their own particular genetic structure. This means a species may have different populations, each having different genetic structures. This genetic variability is essential for a healthy breeding population of a species. If the number of breeding individuals is reduced, the dissimilarity of genetic makeup is reduced and in-breeding occurs. To conserve genetic diversity, different populations of a species must be conserved. The diversity in wild species forms the 'gene pool' from which our crops and domestic animals have been developed over thousands of years. Today the variety of nature's bounty is being further harnessed by using wild relatives of crop plants to create new varieties of more productive crops and to breed better domestic animals. Modern biotechnology manipulates genes for developing better types of medicines and a variety of industrial products.

14.2.3 Species diversity

Species diversity is the variety of species within a habitat or a region. Some habitats, such as rainforests and coral reefs, have several species. This diversity is seen both in natural ecosystems and in agricultural ecosystems. Natural undisturbed tropical forests have much greater species richness than plantations developed by the Forest Department. A natural forest ecosystem provides a large number of non-wood products that local people depend on such as fruit, fuel wood, fodder, fiber, gum, resin and medicines. Thus the value of a natural forest, with all its species richness is much greater than a plantation. Modern intensive agricultural ecosystems have a relatively lower diversity of crops than traditional agropastoral farming systems where multiple crops were planted. At present conservation scientists have been able to identify and categories about 1.8 million species on earth. However, many new species are being identified, especially in the flowering plants and insects. Areas that are rich in species diversity are called 'hotspots' of diversity. India is among the world's 15 nations that are exceptionally rich in species diversity.

14.2.4 Ecosystem diversity

An ecosystem is referred to as 'natural' when it is relatively undisturbed by human activities or 'modified' when it is changed to other types of uses, such as farmland or urban areas. There are a large variety of different ecosystems on earth, which have their own complement of distinctive inter linked species based on the differences in the habitat.

Ecosystem diversity can be described for a specific geographical region, or a political entity. Distinctive ecosystems include landscapes such as forests, grasslands, deserts, mountains, etc. as well as aquatic ecosystems such as rivers, lakes, and the sea. Each region also has man-modified areas such as farmland or grazing pastures. Ecosystems are most natural in wilderness areas. If natural ecosystems are overused or misused their productivity eventually decreases and they are then said to be degraded. India is exceptionally rich in its ecosystem diversity.

14.2.5 Hot Spots of India

India is one of the 12 mega biodiversity nations in the world. The country is divided into 10 biogeographic regions. Diverse physical features and climatic situations have formed different ecological habitats like grasslands, forests, wetlands, desert, coastal and marine ecosystems which harbor and sustain immense biodiversity. Biogeographically, India is situated at the tri-junction of three realms - Afro-tropical, Indo-Malayan and Paleo-Arctic realms, and therefore, has characteristic elements from each of them that makes the country rich and unique in biological diversity. The country is also one of the 12 primary centers of origin of cultivated plants and domesticated animals. It is considered to be the homeland of 114 breeds of domesticated animals and 167 important plant species of cereals, millets, fruits, condiments, vegetables, pulses, fibre crops and oilseeds.

About 4,900 species of flowering plants distributed among 141 genera belonging to 47 families are endemic to India. These are concentrated in the floristically rich areas of North-East India, North-West Himalayas, the Western Ghats, and the Andaman and Nicobar Islands. These areas constitute two of the 18 hot spots identified in the world. It is estimated that 62% of the known amphibian species are endemic to India of which a majority is found in Western Ghats. Approximately 65% of the total geographical area has been surveyed so far. Based on this, over 46,000 species of plants and 81,000 species of animals have been described by the Botanical Survey of India (BSI) established in 1890 and Zoological Survey of India (ZSI) established in 1916, respectively. This list is being constantly upgraded, especially in lower plants and invertebrate animals. The Forest Survey of India established in 1981 assesses the forest cover with a view to develop an accurate database for planning and monitoring purposes.

Hot- spots

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is threatened with destruction. An area is designated as a hot spot when it contains at least 0.5% of plant species as endemic. There are 25 such hot spots of biodiversity on a global level, out of which two are present in India. These are:

1. Indo- Burma (earlier The Eastern Himalayas) and
   - The western Ghats & Sri Lanka
   - These hot spots covering less than 2% of the world’s land area are found to have about 50% of the terrestrial biodiversity.

Criteria for determining hot-spots:

- No. of Endemic Species *i.e.* the species which are not found elsewhere.
- Degree of threat, which is measured in terms of habitat loss

Indo- Burma (Eastern Himalayas) Hotspot

- The hotspot includes all of Cambodia, Vietnam & Laos, and nearly the entire areas of Thailand, Myanmar & Bhutan as well as part of Nepal, far eastern India and extreme southern China.
- In addition, it covers several offshore islands including Mainan Islands in the South China Sea and Andaman & Nicobar Islands in Indian Ocean.
- Indo-Burma is one of the most threatened biodiversity hotspots, due to the rate of resource exploitation and habitat loss.

Western Ghats and Sri Lanka:

- Western Ghats and Sri Lanka, also known as the "Sahyadri Hills" encompasses the mountain forests in the southwestern parts of India and on the neighboring Islands of Sri Lanka.
- The entire extent of hotspot was originally about 1,82,500 square kms, but due to tremendous population pressure, now only 12,445 square Km or 6.8% is in pristine condition.
- The important populations include Asian elephant, Indian tigers, the endangered lion and tailed macaque.

14.2.6 National Parks and Sanctuaries of India

India has a wealth of about 80 National Parks, 441 sanctuaries and 23 tiger reserves. Many of the wildlife sanctuaries and a few national parks have been established in erstwhile British Raj as private hunting reserves for British and Indian aristocracy. Often, a park is better known for a particular animal. Thus Gir (Gujarat) is famous for its Asiatic lions, the Indian rhinoceros is the pride of Kaziranga (Assam), elephants steal the show in Periyar (Kerala), and tigers are synonymous with Kanha (Madhya Pradesh) and Bandavgarh (Madhya Pradesh). The mangrove forests of Sunderbans are the unique habitat of the Royal Bengal Tiger. These are literally a living museum of nature's creations with a variety of animals, plants, landscapes and rock formations. Though, the Indian subcontinent has a great variety of wildlife, but the thick and dense forests account for poor visibility. The spotting of wild animals depends greatly on their habit and distinct daily and seasonal patterns of activity. The frequency of wildlife sightings in national parks and sanctuaries varies depending on the time of the year.

14.3 Endangered and Threatened species

Most people grow up hearing about how a particular animal is an endangered species. Many times researching the animal brings up small information listing it as endangered, threatened, and vulnerable or other terms related to it. The three most common descriptors are endangered, threatened and vulnerable.

Vulnerable

A species classified as vulnerable faces threats, like loss of habitat and poaching, in the wild that may cause it to go extinct. These species have come under threats that have pushed them out of near threatened and into the first of the IUCN's danger-zones: vulnerable. The threat of extinction for vulnerable creatures, like the African lion, remains higher than for species of least concern while near threatened species are approaching its status or kept stable via captive breeding programs. In other words, near threatened species' problems have intensified or continued so their population has decreased to a worrying level; they are now vulnerable.

Endangered

Endangered species populations are in severe decline and are at risk for extinctions based on several factors, such as pollution, deforestation and hunting. One notable example of this has been the bald eagle. Once highly endangered in the 1980s and early 90s due to DDT poisoning, conservation efforts have since worked so the species is classified as least concern today.

Critically Endangered

Critically endangered species are those that are almost extinct in the wild. Their numbers have become so few that they may have trouble breeding to keep the entire species viable without help from conservationists. In other words, they cannot find mates to produce young, or they take such a long time to mature that they often die before they can reproduce. By capturing members of the wild population to raise them in captivity and breed them there for later release back into the wild, conservationists try to keep the species alive. The Western gorilla falls into this category and has had rigorous conservation efforts undertaken to bolster its wild population; it remains critically endangered as wild populations continue to decrease due to deforestation and poaching.

Threatened

The term "threatened" is not a category in itself but an umbrella term the IUCN uses to encompass all three of their levels of most concern: vulnerable, endangered and critically endangered. Any species that has entered these three categories is officially described as a threatened species overall, and one of the levels in particular. In order to become threatened, a species must have been observed decreasing in numbers over a period of time due to loss of habitat, over-hunting, poaching and pollution. Reduction in population must be one that biologists and environmentalists note as detrimental to the species and which therefore places difficulties in its path to regaining those numbers without outside help.

To appreciate the endemic and endangered species of India it is important to understand the wide variety of plant and animal species that are found in the country. Of the well-known species, there are several which are endangered by human activity. The endangered species in the country are categorized as Vulnerable, Rare, Indeterminate and Threatened.

14.3.1. COMMON ENDANGERED, THREATENED AND VULNERABLE ANIMALS OF INDIA

ENDANGERED ANIMALS

Fish

- Knifetooth sawfish (*Anoxypristis cuspidata*)
- Asian arowana (*Scleropages formosus*)

- Red line torpedo barb (*Sahyadria denisonii*)
- Tambraparini Barb (*Dawkinsia tambraparniei*)

Birds

- Narcondam hornbill (*Rhyticero*)

Reptiles

- Assam roofed turtle (*Pangshura sylhetensis*)

Mammals

- Asiatic lion (*Panthera leo persica*)
- Bengal tiger (*Panthera tigris tigris*)
- Blue whale (*Balaenoptera musculus*)
- Banteng (*Bos javanicus*)
- Central Kashmir vole (*Alticola montosa*)
- Dhole (*Cuon alpinus*)
- Fin whale (*Balaenoptera physalus*)
- Fishing cat (*Prionailurus viverrinus*)
- Ganges river dolphin (*Platanista gangetica gangetica*)
- Gee's golden langur (*Trachypithecus geei*)
- Kolar leaf-nosed bat (*Hipposideros hypophyllus*)
- Hispid hare (*Caprolagus hispidus*)
- Hoolock gibbons (*Hoolock* spp.)
- Indian elephant (*Elephas maximus indicus*)
- Indian tiger
- Indian wild ass (*Equus hemionus khur*)
- Lion-tailed macaque (*Macaca silenus*)
- Mandelli's mouse-eared bat (*Myotis sicarius*)
- Nicobar flying fox (*Pteropus faunulus*)
- Nilgiri langur (*Trachypithecus johnii*)
- Nilgiri tahr (*Nilgiritragus hylocrius*)
- Nicobar treeshrew (*Tupaia nicobarica*)
- Palm rat (*Rattus palmarum*)
- Red panda (*Ailurus fulgens*)
- Red goral (*Naemorhedus baileyi*)
- Snow leopard (*Uncia uncia*)
- Smooth-coated otter (*Lutrogale perspicillata*)
- Sei whale (*Balaenoptera borealis*)
- Stump-tailed macaque (*Macaca arctoides*)
- Sloth bear (*Melursus ursinus*)
- Servant mouse (*Mus famulus*)
- Swamp deer (*Rucervus duvaucelii*)
- Takin (*Budorcas taxicolor*)
- Tibetan antelope (*Pantholops hodgsonii*)
- White-bellied musk deer (*Moschus leucogaster*)
- Wild water buffalo (*Bubalus arnee*)
- Wild goat (*Capra aegagrus*)
- Woolly flying squirrel (*Eupetaurus cinereus*)

Threatened animal

Arthropoda

- Rameshwaram parachute spider (*Poecilotheria hanumavilasumica*)
- Peacock tarantula (*Poecilotheria metallica*)

Birds

- White-bellied heron (*Ardea insignis*)
- Great Indian bustard (*Ardeotis nigriceps*)
- Forest owlet (*Athene blewitti*)
- Baer's pochard (*Aythya baeri*)
- Spoon-billed sandpiper (*Calidris pygmaea*)
- Siberian crane (*Grus leucogeranus*)
- White-rumped vulture (*Gyps bengalensis*)
- Indian vulture (*Gyps indicus*)
- Slender-billed vulture (*Gyps tenuirostris*)
- Bengal florican (*Houbaropsis bengalensis*)
- Himalayan quail (*Ophrysia superciliosa*)
- Jerdon's courser (*Rhinoptilus bitorquatus*)
- Red-headed vulture (*Sarcogyps calvus*)
- Sociable lapwing (*Vanellus gregarius*)

Fish

- Wayanad mahseer (*Barbodes wynaadensis*)
- Pondicherry shark (*Carcharhinus hemiodon*)
- Ganges shark (*Glyphis gangeticus*)
- Glyptothorax kashmirensis (*Glyptothorax kashmirensis*)
- Kudremukh glyptothorax (*Glyptothorax kudremukhensis*)
- Nilgiri Mystus (*Hemibagrus punctatus*)
- Horalabiosa arunachalami (*Horalabiosa arunachalami*)
- Hypselobarbus pulchellus (*Hypselobarbus pulchellus*)
- Red Canarese barb (*Hypselobarbus thomassi*)
- Deccan labeo (*Labeo potail*)
- Mesonoemacheilus herrei (*Mesonoemacheilus herrei*)
- Bovany barb (*Neolissochilus bovanicus*)
- Deolali minnow (*Parapsilorhynchus prateri*)
- Common sawfish (*Pristis pristis*)
- Largetooth sawfish (*Pristis microdon*)
- Longcomb sawfish (*Pristis zijsron*)
- Deccan barb (*Puntius deccanensis*)
- Humpback mahseer[5]
- Schistura papulifera (*Schistura papulifera*)

Insects

- Pygmy Hog Sucking Louse (*Haematopinus oliveri*)

Reptiles and amphibians

- Madras spotted skink (*Barkudia insularis*)
- Northern river terrapin (*Batagur baska*)
- Red-crowned roofed turtle (*Batagur kachuga*)
- Cnemaspis anaikattiensis(*Cnemaspis anaikattiensis*)
- Hawksbill sea turtle (*Eretmochelys imbricata*)
- Gharial (*Gavialis gangeticus*)
- Ghats wart frog (*Fejervarya murthii*)
- Jeypore ground gecko (*Geckoella jeyporensis*)
- Gundia Indian frog (*Indirana gundia*)
- Toad-skinned frog (*Indirana phrynoderma*)
- Charles Darwin's frog (*Ingerana charlesdarwini*)

- Rao's torrent frog (*Micrixalus kottigeharensis*)
- Dattatreya night frog (*Nyctibatrachus dattatreyaensis*)
- Sacred grove bushfrog (*Philautus sanctisilvaticus*)
- Amboli bush frog (*Pseudophilautus amboli*)
- White-spotted bush frog (*Raorchestes chalazodes*)
- Green eyed bushfrog (*Raorchestes chlorosomma*)
- Griet bush frog (*Raorchestes griet*)
- Kaikatti bushfrog (*Raorchestes kaikatti*)
- Mark's bushfrog (*Raorchestes marki*)
- Munnar bush frog (*Raorchestes munnarensis*)
- Ponmudi bush frog (*Raorchestes ponmudi*)
- Resplendent shrubfrog (*Raorchestes resplendens*)
- Shillong bubble-nest frog (*Raorchestes shillongensis*)
- Anaimalai flying frog (*Rhacophorus pseudomalabaricus*)
- Sushil's bushfrog (*Raorchestes sushili*)
- Amboli toad (*Xanthophryne tigerina*)
- Ghats wart frog (*Zakerana murthii*)

Mammals

- Asiatic cheetah: Extinct form India (*Acinonyx jubatus venaticus*)
- Sangai
- Namdapha flying squirrel (*Biswamoyopterus biswasi*)
- Himalayan wolf ("*Canis himalayensis*")
- Elvira rat (*Cremnomys elvira*)
- Andaman shrew (*Crocidura andamanensis*)
- Jenkins' shrew (*Crocidura jenkinsi*)
- Nicobar shrew (*Crocidura nicobarica*)
- Northern Sumatran rhinoceros: Extinct from India (*Dicerorhinus sumatrensis lasiotis*)
- Kondana soft-furred rat (*Millardia kondana*)
- Pygmy hog (*Porcula salvania*)
- Indian Javan rhinoceros: Extinct from India (*Rhinoceros sondaicus inermis*)
- Malabar large-spotted civet (*Viverra civettina*)
- Chinese pangolin (*Manis pentadactyla*)

VULNERABLE ANIMALS OF INDIA

Mammals

- Barasingha (*Rucervus duvaucelii*)[7]
- Clouded leopard
- Dugong
- Gaur
- Indian rhinoceros
- Marbled cat (*Pardofelis marmorata*)
- Rusty-spotted cat (*Prionailurus rubiginosus*)
- Sperm whale (*Physeter macrocephalus*)
- Yak (*Bos grunhniens*)

Reptiles and amphibians

- Olive ridley sea turtle

14.4 GERMPLASM CONSERVATION

14.4.1 INTRODUCTION

Germplasm is the genetic material which forms the physical basis of heredity and which is transmitted from one generation to the next by means of the germ cells. It also refers to an individual or clone representing a type, species or culture that may be held in a repository for agronomic, historic or other reasons. Specifically, genetic conservation encompasses the collection, maintenance and preservation of intra- and inter-specific variation, e.g. a representative sample of the genetic variation of a particular species.

METHODS OF GENETIC RESOURCES CONSERVATION

There are two methods of conserving germplasm: *in situ* and *ex situ*.

14.4.2 IN SITU CONSERVATION

Conservation *in situ* involves the setting aside of natural reserves to conserve species in natural habitats. This type is also classified as dynamic evolutionary conservation. Plants and animals are conserved in entire biomes free to evolve through natural selection. Extinction of species is deterred but this method has little impact on useful plants. This type of conservation applies only to wild fauna and flora and not to the domesticated animals and plants. It is on-site conservation or the conservation of genetic resources in natural populations of plant or animal. It includes a system of protected areas of different categories, e.g. National Parks, Sanctuaries, Nature Reserves, Natural Monuments, Cultural Landscapes, Biosphere Reserves, *etc.* This is considered the most appropriate way of conserving biodiversity. In-situ conservation protects an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. It is applied to conservation of agricultural biodiversity in agroecosystems by farmers, especially those using unconventional farming practices.

14.4.3 EX SITU CONSERVATION – OUT OF THE NATURAL HABITAT (SPECIES-BASED)

Ex situ conservation means literally, "off-site conservation". Conservation *ex situ* is the conservation of species out of their natural habitat. It is the process of protecting an endangered species of plant or animal outside of its natural habitat; for example, by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans. In agriculture, ex-situ conservation measures maintain domesticated plants which cannot survive in nature unaided. There are three main methods of *ex situ* conservation: seed banks, field genebanks and tissue culture. Collections of germplasm using any of these methods are often called genebanks. With the advent of biotechnology a genebank may also include a collection of cloned DNA fragments from a single genome and, ideally, representing the whole of the genome. Some of these include:

- Gene banks, e.g. seed banks, sperm and ova banks, field banks
- *In vitro* plant tissue and microbial culture collections

- Captive breeding of animals and artificial propagation of plants, with possible reintroduction into the wild
- Collecting living organisms for zoos, aquaria, and botanic gardens for research and public awareness
- Seed Repository (storage at – 20°C)
- Cryo Bank (storage at -1° C)
- Tissue Culture Repository (10-25°C)

Which germplasm should be stored?

The individual genotypes need to be identified to become part of the conservation scheme. Some general criteria can be defined concerning the desirable genetic properties of the sample:

- It should represent the genetic portfolio of the breed.
- It should have a maximum effective population size.
- Special genetic traits should be conserved.

14.4.4 CRYOPRESERVATION

Cryopreservation is the storage at ultra-low temperature (–196°C, i.e., the temperature of liquid nitrogen) of organs and tissues from *in vitro* culture, such as buds, shoot tips, zygotic and somatic embryos, pollen and cell cultures. Although the technique was first introduced in plants in the 1970s, it has never been applied on a wide scale due to the high cost of cryo-freezers; indeed, in order to escape the formation of lethal intracellular ice crystals, time-consuming and laborious slow-cooling procedures have to be used. New cryogenic techniques are now available, aiming at the direct immersion in liquid nitrogen (“one-step freezing”) of plant specimens from tissue culture, without resorting to expensive apparatus for slow cooling and with a considerable simplification of procedures. This technology is based on the induction of cell vitrification during a very fast decrease of temperature. “Vitrification” of cells and tissues is the physical process which avoids intracellular ice crystallization during ultra-freezing by the transition of the aqueous solution of the cytosol into an amorphous glassy state. As a consequence of this process, plant tissues are protected from damage and remain viable during their long-term storage at –196°C. In the most recent approaches to cryopreservation, vitrification can be induced in two different ways, i.e., (i) by treating the explants with a highly concentrated vitrification solution (mainly, a mixture of glycerol, ethylene glycol and dimethyl sulfoxide (DMSO) named “PVS2”), or (ii) by partial dehydration over silica gel desiccant of explants, naked or encapsulated in calcium-alginated beads. It is noteworthy that, following these procedures, the plant specimens can be directly plunged into liquid nitrogen, where they can be stored for an indefinite period of time without undergoing the risks of contamination or genetic alteration.

14.5 ENVIRONMENTAL LAWS

14.5.1 INTRODUCTION

Environmental law is a complex and interlocking body of treaties, conventions, statutes, regulations and common law that operate to regulate the interaction of humanity and the natural environment toward the purpose of reducing the impacts of human activity. Growing public awareness of threats to the environment informed by warnings of scientists has led to demands to protect the natural surroundings on which human well-being depend. Under growing pressure from national and international public opinion, governments began to demonstrate concern over the general state of the environment during 1960s and introduced legislation to combat pollution of inland waters, ocean and air, and to safeguard certain cities or areas. Simultaneously, they established special administrative organizations, ministries or environmental agencies to preserve the environment and improve the quality of life of their citizens. Developments in international environmental law paralleled this evolution within states reflecting a growing consensus to accord priority to resolve the environmental problems. Today, national and international environmental law is complex and vast comprising thousands of rules that aim to protect the earth's living and non-living elements and its ecological processes. Environmental problems stem from two main categories of human activities: i) Use of resources at unsustainable levels, and ii) Contamination of the environment through pollution and waste at levels beyond the capacity of the environment to absorb them or render them harmless.

14.5.2 NATIONAL ENVIRONMENTAL LAWS

In the Constitution of India it is clearly stated that it is the duty of the state to protect and improve the environment and to safeguard the forests and wildlife of the country. It imposes a duty on every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife. Reference to the environment has also been made in the Directive Principles of State Policy as well as the Fundamental Rights. The Department of Environment was established in India in 1980 to ensure a healthy environment for the country. This later became the Ministry of Environment and Forests in 1985. The constitutional provisions are backed by a number of laws acts, rules and notifications. The Environment Protection Act of 1986 (EPA) came into force soon after the Bhopal Gas Tragedy and is considered an umbrella legislation as it fills many gaps in the existing laws. Thereafter a large number of laws came into existence as the problems began arising e.g. Handling and Management of Hazardous Waste Rules in 1989.

Air Pollution Act, 1981

The Act provides for the prevention, control and abatement of air pollution. It also provides for the establishment of Boards with a view to carrying out the aforesaid purposes. Decisions were taken at the United Nations Conference on the Human Environment held in Stockholm in June, 1972, in which India participated, to take appropriate steps for the preservation of the natural resources of the earth which, among other things, include the preservation of the quality of air and control of air pollution. The Air (Prevention and Control of Pollution) Act, 1981 extends to the whole of India.

The Environmental Protection Act, 1986

The Environmental protection Act provides for protection and improvement of environment and for matters connected therewith. The United Nations conference on human environment, held in Stockholm in

June 1972, proclaimed that "Man is both creator and molder of his environment, which gives him physical sustenance and affords him the opportunity for intellectual, moral, social and spiritual growth. In the long and tortuous evolution of the human race on this planet a stage has reached when through the rapid acceleration of science and technology man has acquired the power to transform his environment in countless ways and on unprecedented scale. Both aspects of man's environment, the natural and manmade are essential to his well-being and to the enjoyment of basic human rights even the right to life itself.

Water Pollution Act, 1974

An act provides for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water, for the establishment, in order to carrying out the purposes aforesaid, of Boards for the prevention and control of water pollution, for conferring on and assigning to similar Board powers and functions connecting thereto and for matters connected therewith. Whereas it is expedient to give for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water, for the establishment, in order to carry out the purposes aforesaid, of Boards for the prevention and control of water pollution and for conferring on and assigning to similar Boards powers and functions connecting thereto.

The Wildlife (Protection) Act, 1972

The Act provides for the protection of Wild animals, birds and plants and for matters connected therewith or ancillary or incidental thereto. It extends to the whole of India, except the State of Jammu and Kashmir.

"Animal" includes amphibians, birds, mammals and reptiles, and their young, and also includes, in the cases of birds and reptiles, their eggs.

"Animal article" means an article made from any captive animal or wild animal, other than vermin, and includes an article or object in which the whole or any part of such animal has been used and ivory imported into India and an article made there from.

"Hunting" includes,

a. capturing, killing, poisoning, snaring and trapping or any wild animal and every attempt to do so
b. driving any wild animal for any of purposes specified in sub clause
c. injuring or destroying or taking any part of the body of any such animal, or in the case of wild birds or reptiles, damaging the eggs of such birds or reptiles, or disturbing the eggs or nests of such birds or reptiles

The Forest (Conservation) Act 1980

An Act to provide for the conservation of forests and for matters connected therewith or ancillary or incidental thereto. The Indian Forest Act, 1927 was largely based on previous Indian Forest Acts implemented under the British. The first and most famous was the Indian Forest Act of 1878. Both the 1878 act and the 1927 one sought to consolidate and reserve the areas having forest cover, or significant wildlife, to regulate movement and transit of forest produce, and duty leviable on timber and other forest produce. It also defines the procedure to be followed for declaring an area to be a Reserved Forest, a Protected Forest or a Village

Forest. It defines what is a forest offence, what are the acts prohibited inside a Reserved Forest and penalties leviable on violation of the provisions of the Act.

India's Forest Policies

Development of forest is guided by the policies adopted by a nation to manage them. Scientific forestry was adopted in India since over a century back. Country's first forest policy was enunciated in 1894. After the independence, Indian Republic formulated the National Forest Policy in 1952. The National Commission on Agriculture established in 1970 went into the forestry situation in the country and advised for a new forest policy, in their report of 1976. The Constitution of the Independent India placed forests under the State List of the Seventh Schedule in 1950. The States were vested with the administration of the forests. The Constitution has recognized the significance of protection of forests and their improvement. It is stipulated in Article 48-A that the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country. The period between 1950 and today has witnessed large-scale depletion of forests and attrition of forestlands. Forestlands were cleared and diverted to other uses such as industries, agriculture, settlement of displaced persons and foreign refugees, hydroelectric project, etc. This also led to diminishing wildlife in the country due to loss of their habitat. Realizing the importance of forests for the well-being of the nation, the Parliament, by the 42nd Amendment to the Constitution in 1976, brought Forests and Wildlife on the concurrent list in Seventh Schedule. In the year 1980, the President of India promulgated the Forest (Conservation) Ordinance, 1980, which put severe restrictions on de-reservation of forest or utilize of forestland for non-forest purposes, in absence of prior approval of the Central Government. Forests play three important roles in national economy of any country, they are: a) protective, b) productive and c) as a way of accessory benefits. This calls for an effective legislation. The Indian Forest Act, 1972 is in force today for the same purposes. Similarly, a extensive legislation for the protection of wildlife and nature is to be found in the Wildlife (Protection) Act, 1972.

Forest policy of 1894

Started in 1894 India's first Forest Policy laid down 'public benefit' as the sole purpose of the administration of public forest. The Policy advised the maintenance of forests in hilly areas for preservation of climatic and physical conditions and for protection of cultivated plains below from the divesting action of hill torrents. Forests with valuable timbers were to be managed on commercial lines. The forests of inferior quality were to be managed primarily in the interest of local population. India's Forest Policy is revised once again in 1988. The main plank of the revised Forest Policy of 1988 is protection, conservation and growth of forests.

14.5.3 INTERNATIONAL ENVIRONMENTAL LAWS

Pollution does not respect political boundaries, making international law an important aspect of environmental law. A plethora of legally binding international agreements encompasses a wide variety of issue-areas from terrestrial, marine and atmospheric pollution through to wildlife and biodiversity protection.

International Treaties, protocols and conventions

International environmental agreements are generally multilateral (or sometimes bilateral) treaties (a.k.a. convention, agreement, protocol, etc.). The majority of such conventions deal directly with specific environmental issues. There are also some general treaties with one or two clauses referring to environmental issues but these are rarer. There are about 1000 environmental law treaties in existence today; no other area of law has generated such a large body of conventions on a specific topic. Protocols are subsidiary agreements built from a primary treaty. They exist in many areas of international law but are especially useful in the environmental field, where they may be used to regularly incorporate recent scientific knowledge. They also permit countries to reach agreement on a framework that would be contentious if every detail were to be agreed upon in advance. The most widely known protocol in international environmental law is the Kyoto Protocol.

Conventions or treaties generally set forth international environmental regulations. These conventions and treaties often result from efforts by international organizations such as the United Nations (UN) or the World Bank. However, it is often difficult, if not impossible to enforce these regulations because of the sovereign rights of countries. In addition, rules and regulations set forth in such agreements may be no more than non-binding recommendations, and often countries are exempted from regulations due to economic or cultural reasons. Despite these shortcomings, the international community has achieved some success via its environmental agreements. These include an international convention that placed a moratorium on whaling (1986) and a treaty that banned the ocean dumping of wastes (1991).

The UN often facilitates international environmental efforts. In 1991, the UN enacted an Antarctica Treaty, which prohibits mining of the region, limits pollution of the environment and protects its animal species. The United Nations Environment Program (UNEP) is a branch of the UN that specifically deals with worldwide environmental problems. It has helped with several key efforts at global environmental regulations:

- The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. As a result of this global agreement, industrialized countries have ceased or reduced the production and consumption of ozone-depleting substances such as chlorofluorocarbons.
- The Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. This agreement enhances the world's technical knowledge and expertise on hazardous chemicals management.
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This agreement protects over 30,000 of the world's endangered species.
- The Rotterdam Convention (1998) addressed the growing trade in hazardous pesticides and chemicals. Importing countries must now

give explicit informed consent before hazardous chemicals can cross their borders.

- The International Declaration on Cleaner Production (1998). The signatories commit their countries to implement cleaner industrial production and subsequent monitoring efforts.

In 1992, the UN member nations committed their resources to limiting greenhouse gas (e.g., carbon dioxide) emissions at or below 1990 levels, as put forth by the UN Framework Convention on Climate Change. Unfortunately, the agreement was non-binding and by the mid-1990's, it had no effect on carbon emissions. The 1997 Kyoto Protocol was a binding resolution to reduce greenhouse gases. Although the United States initially supported the resolution, the Senate failed to ratify the treaty, and by 2001 the resolution was opposed by President Bush as threatening the United States economy.

Customary international law

Customary international law is an important source of international environmental law. These are the norms and rules that countries follow as a matter of custom and they are so prevalent that they bind all states in the world. When a principle becomes customary law is not clear cut and many arguments are put forward by states not wishing to be bound. Examples of customary international law relevant to the environment include the duty to warn other states promptly about icons of an environmental nature and environmental damages to which another state or states may be exposed.

Judicial decisions

International environmental law also includes the opinions of international courts and tribunals. While there are few and they have limited authority, the decisions carry much weight with legal commentators and are quite influential on the development of international environmental law.

The courts include: the International Court of Justice (ICJ); the international Tribunal for the Law of the Sea (ITLOS); the European Court of Justice; and regional treaty tribunals. Arguably the Organization's Dispute Settlement Board (DSB) is getting a say on environmental law also. Important cases have included:

- the Trail Smelter Arbitration, 33 AJIL (1939)
- the various nuclear weapons testing cases such as between New Zealand and France before the International Court of Justice Gabcikovo-Nagyramos Dam Case, ICJ Rep (1997).

14.6 Summary:

Natural resources include the forest, rocks, soil, water, and mineral ores and so on. The energy sources include mineral oils, coal and natural gases. Renewable resources are considered natural resources that replenish faster than humans consume them. In other words, resources can be reproduced continuously over a relatively short period of time. Forests are the most important natural resources as they control the climate, the monsoon and are responsible for recharge of water resources. Forests also conserve soil from erosion and protect us from heat radiation. The conservation of forests includes i) Afforestation-social and environmental

forestry, ii) Agro forestry programmes, iii) Plantation of trees of aesthetic/ornamental values.

Land is the most fundamental need of a man because it basically provides shelter and food to mankind. It is the most important endowment of Nature. Land is being used by man for various purposes such as agriculture, construction of houses and other buildings, laying roads, railways and so on. At present there is always a rising demand for land, in future also the same condition may continue. Soil erosion is being increased in almost all countries due to natural causes as well as by the activities of man. The basic aim of soil conservation is to increase the food production without loss of soil. The conservation of soil mainly lies in the protection of land from erosion.

Fresh water is a renewable resources, yet the world's supply of clean, fresh water is steadily decreasing. Water conservation is the most effective and environmentally sound method to fight global warming. Water conservation is what that can reduce the scarcity of water. It aims to improve the efficiency of use of water, and reduce losses and waste.

A non-renewable resource is a natural resource which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate. Biological diversity deals with the degree of nature’s variety in the biosphere. Species diversity is seen both in natural ecosystems and in agricultural ecosystems. Some areas are richer in species than others. Ecosystem diversity can be described for a specific geographical region, or a political entity such as a country, a State or a taluka. Distinctive ecosystems include landscapes such as forests, grasslands, deserts, mountains, etc., as well as aquatic ecosystems such as rivers, lakes, and the sea.

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is threatened with destruction. An area is designated as a hot spot when it contains at least 0.5% of plant species as endemic. A species classified as vulnerable faces threats, like loss of habitat and poaching in the wild that may cause it to go extinct. These species have come under threats that have pushed them out of near threatened and into the first of the IUCN's danger-zones: vulnerable. Endangered species populations are in severe decline and are at risk for extinctions based on several factors, such as pollution, deforestation and hunting. Critically endangered species are those that are almost extinct in the wild. The term "threatened" is not a category in itself but an umbrella term the IUCN uses to encompass all three of their levels of most concern: vulnerable, endangered and critically endangered. Germplasm is the genetic material which forms the physical basis of heredity and which is transmitted from one generation to the next by means of the germ cells. Ex-situ conservation means literally, “off-site conservation”. Conservation ex *situ* is the conservation of species out of their natural habitat. Cryopreservation is the storage at ultra-low temperature (–196°C, i.e., the temperature of liquid nitrogen) of organs and tissues from *in vitro* culture, such as buds, shoot tips, zygotic and somatic embryos, pollen and cell cultures. Environmental law is a complex and interlocking body of treaties, conventions, statutes, regulations and common law that very broadly operate to regulate the interaction of humanity and the rest of biophysical or natural environment towards the purpose of reducing the impacts of human activity, both on the natural environment and on humanity itself.

14.7 SUGGESTED READINGS

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