ZOOLOGY – (PAPER – VIII)
ENVIRONMENTAL BIOLOGY AND APPLIED ZOOLOGY

1. **Define ecology.**

   Eudgene Odum (1963) has defined ecology as **the study of the structure and the function of nature.**

   According to Charles J. Krebs (1972), Ecology **is the scientific study of interactions that determine the distribution and abundance of organisms.**

   Smith R. L. (1972) defined ecology as **multidisciplinary science which deals with organisms and their environment, both biotic and abiotic.**

2. **Define pollution.**

   Pollution is an undesirable change in the physical, chemical or biological characteristics of air, land, and water that may or will harmfully affect human life.

3. **What is climax community?**

   An orderly and progressive replacement of one community by another until a relatively stable community, called climax community.

4. **Define first Law of thermodynamics.**

   The first law of thermodynamics called law of conservation of energy states that energy is neither created nor destroyed. It may transfer from one form to another.

5. **What is water pollution?**

   Water pollution is an undesirable change in the physical, chemical or biological characteristics of water that may or will harmfully affect human life.

6. **Mention the types of ecosystem.**

   Natural ecosystem

   Aquatic ecosystem - Freshwater ecosystem, Marine ecosystem and Estuaries

   Terrestrial ecosystem - Forest ecosystem, Grassland ecosystem and Desert ecosystem

   Artificial ecosystem

   Crop land, Dams and Manmade lakes

7. **Define mortality.**

   The ratio of total number of deaths to the total population of that area per unit time.

8. **Define natality.**

   The ratio of total number of births in the total population of that area per unit time.

9. **Mention any two examples for endo parasites.**

   Tapeworm, roundworm, liver fluke, certain intestinal bacteria, ect.

10. Gause's Principle.

a. Competition for resources that occurs between members of different species is called inter-specific competition.
b. Competition for food also applies to individuals of different species that require the same type of food.
c. For example, two different predatory species may compete for the same prey species.
d. Gause's competitive exclusion principle states that **no two species can coexist if they occupy the same niche**.
e. In other words, **an ecological niche cannot be simultaneously and completely occupied by stabilized populations of more than one species**.
f. In his classic experiment Gause (1934) first grew ***Paramecium caudatum*** and ***Paramecium aurelia*** in separate cultures and found that each species grew in numbers according to the logistic equation.
g. However, ***P. aurelia*** grows in numbers more quickly than **P. caudatum** and shows more individuals in the same volume of culture medium.
h. But when he grew the <u>two species together in same culture volume</u>, he observed that initially both species grew in numbers, but eventually ***P. caudatum*** <u>declined</u> and became <u>extinct</u>.
i. He repeated has experiment and found that ***P. aurelia*** always won the competition between the two species.
j. Gause attributed the result to the need of 'but a single niche in the conditions of the experiment'.

(Refer graph from your class notes)

11. What is food chain? Write a note on types of food chain.

The number of organisms of each species, or more precisely their total mass, is determined by the rate of flow of energy through the biological part of the ecosystem that includes them. The transfer of energy from its ultimate source in plants, through **a series of organisms in which one eats and being eaten by the following**, is known as food chain.

In a generalized form, a food chain may be represented as under:

Photosynthetic Organisms → Herbivores → Carnivores → Microorganisms of decay

The energy originally derived from the sun by plants thus passes in material form through the various trophic levels of a food chain.

Types of food chain:

Detritus food chain: A type of food chain in which plant material is converted into dead organic matter, detritus, before being eaten by animals such as millipedes and earthworms on land, by marine worms and mollusks, or by bacteria and fungi.

In a community of organisms in the shallow sea, about 30 per cent of the total energy flows via detritus chains, but in a forest community, with a large biomass of plants and relatively small biomass of animals, as much as 90 per cent of energy flow may be via detritus pathways. In an intertidal salt marsh, where most of the animals—shellfish, snails and crabs—are detritus eaters, 90 per cent or more of the energy flow is via detritus chains.

Grazing food chain:

On land, grass grows by synthesizing food from carbon dioxide of air and water and minerals of soil with the help of chlorophyll and sunlight. Grass is eaten by rabbits, which are preyed upon by cats. The latter may be taken by wolves, and the tigers may capture the wolves. The tigers as well as the other participants of the chain, on death, are reduced by bacteria and fungi of decay to simple inorganic materials. The latter are reused by grass.

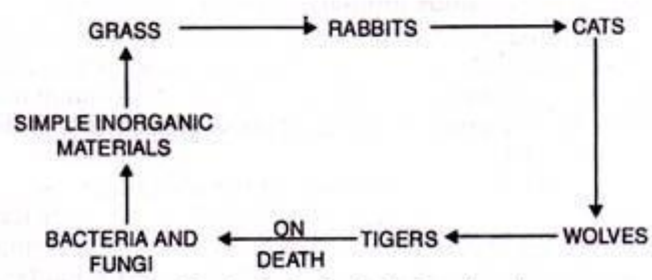


Fig. 3.6. A simple food chain on land.

Another land food chain is grass → grass shopper → frog → snake → peacock → Hawk.

12. What is food web?

Food chains are not strictly linear. They may have branches that may link one food chain with another. Thus, there may be several interlinked food chains in a community, and one animal may be a link in more than one food chain.

The various interlinked food chains in a community constitute a food web, or food cycle. A food web includes all the feeding relationships in an ecosystem.

Normally a food web operates according to taste and food preferences of the organisms at each trophic level. However, availability of food source and other compulsions are equally important. In Sunder-bans, the tigers eat fish and crab in the absence of their natural preys. Some organisms normally operate at more than one trophic level. Thus human beings are not only herbivores but also carnivores of various levels.

Jackals are both carnivores and scavengers. Snakes feed on mice (herbivores) as well as frogs (carnivores). Wild cats prey upon mice as well as birds and squirrels. A wolf eats not only fox but also rabbit and deer. Therefore, the concept of food web appears more real ecologically than the concept of a simple food chain.

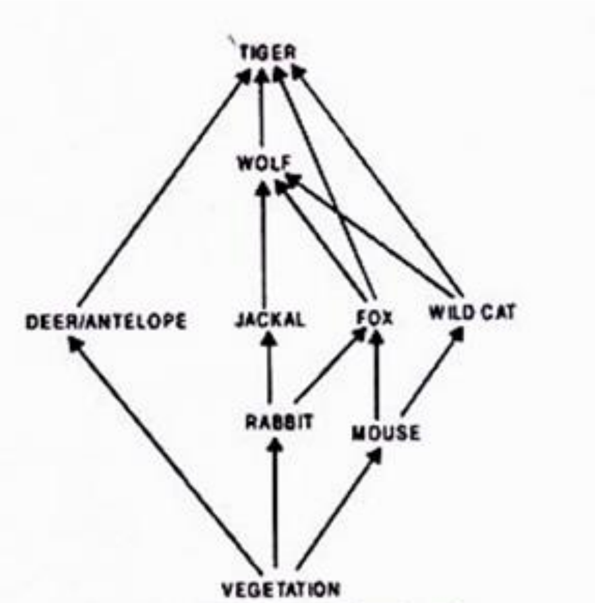


Fig. 3.8. A Terrestrial food web.

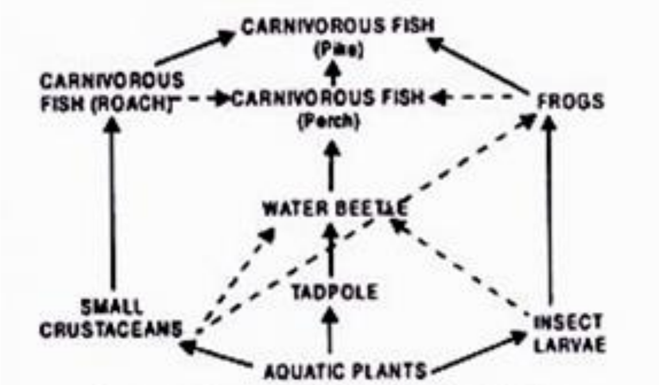


Fig. 3.9. An aquatic food web with the interconnected food chains.

13. Ecological succession.

An orderly and progressive replacement of one community by another until a relatively stable community, called climax community. This climax community occupies the area is called ecosystem development or ecological succession.

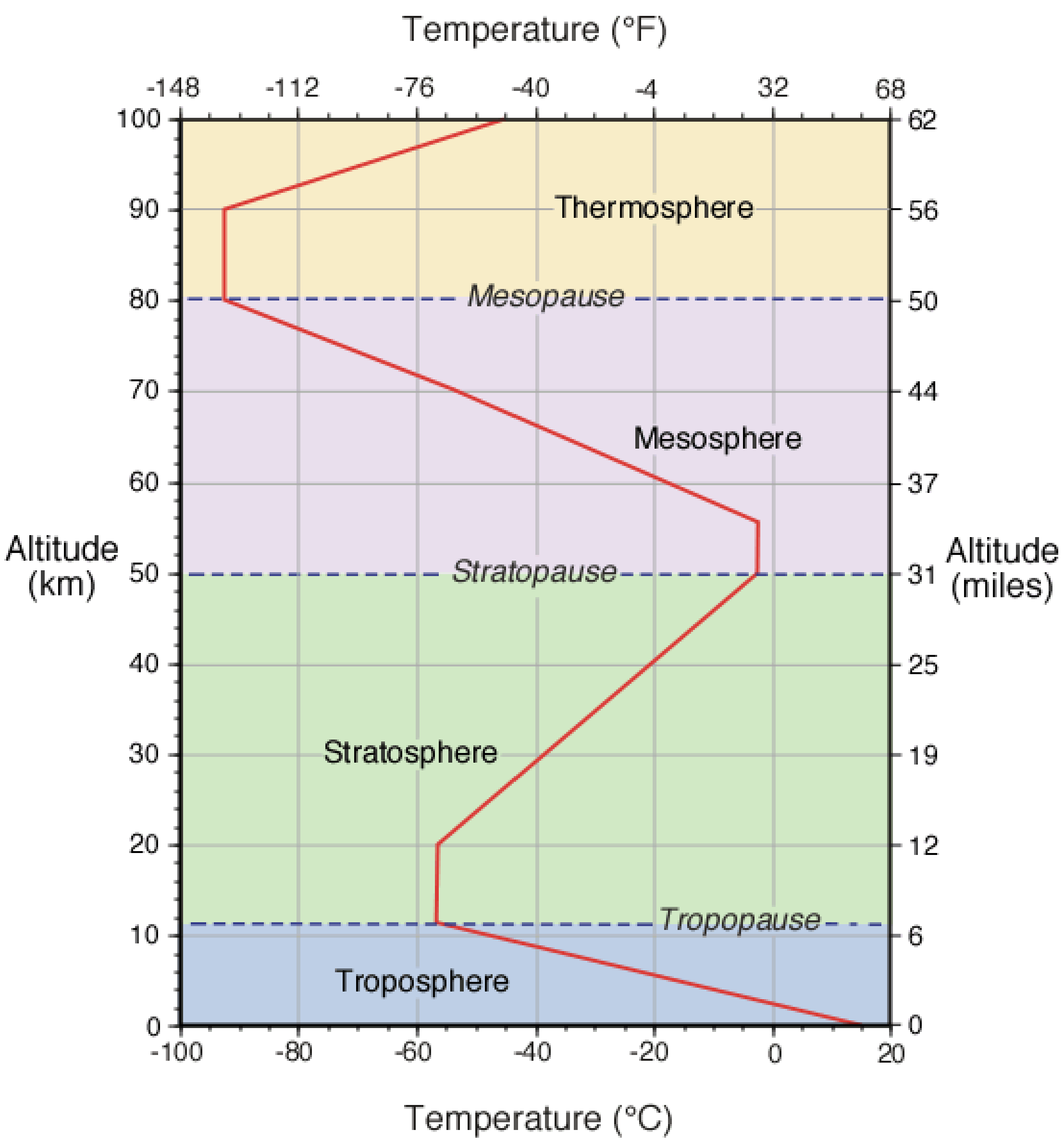
14. Ecotone.

An **ecotone** is a transition area between two biomes. It is where two communities meet and integrate. It may be narrow or wide, and it may be local (the zone between a field and forest) or regional (the transition between forest and grassland ecosystems).

15. Edge effect.

The **edge effect** is an ecological concept that describes how there is a greater diversity of life in the region where the **edges** two adjacent ecosystems overlap, such as land/water, or forest/grassland.

16. Atmosphere.



There are five major layers of the atmosphere. The regions are: 1. Troposphere 2. Stratosphere 3. Mesosphere 4. Thermosphere 5. Exosphere.

1. **Troposphere:**

   Almost 70% of the mass of the atmosphere is contained in this layer. It is more or less homogeneous in composition where there is no air pollution. The water content here also depends on the hydrological cycle.

   The air is far from uniform, depending on density and temperature. In the troposphere, temperature decreases uniformly with increasing altitude. Near the ground level, the air is heated by radiation from the earth. At the top of the troposphere is the tropopause. This is the cold layer (-56°C) which marks temperature inversion, i.e. transition from negative to positive lapse rates.

2. **Stratosphere:**

   The temperature increases with increase in altitude. At the upper limit of the stratosphere it is -2°C. This region has the maximum concentration of Ozone. The gas absorbs ultraviolet radiation of the sun, raising the temperature and causing a positive lapse rate.

   The importance of ozone lies in the fact that it acts as a protective shield for life on earth and from the detrimental effects of the scorching ultraviolet rays. It also supplies the heat for dividing the earth into a quiescent stratosphere and turbulent troposphere.

   Since mixing in the stratosphere is very slow, the molecules or particles here persist for a long time. Therefore, once the pollutants are able to reach the stratosphere, they pose long-term global hazards, compared to their impact in the more dense troposphere.

3. **Mesosphere:**

   This layer has been so named because of its situation in the middle of the five layers that is divided according to the thermal conditions of the atmosphere. The mesosphere stretches at altitudes between 50 and 80 km. It is also known as upper Troposphere since, due to the absence of ultraviolet absorbing species, temperature falls with increasing altitude, i.e. negative lapse rate prevails, basically similar to what happens in the troposphere.

   During summer, the temperature of the mesopause over Arctic region can drop to as low as -100°C. The upper part of this layer remains colder while the lower part is warm. Due to this, there arises a connective motion of air. A significant feature of this layer is the formation of noctilucent cloud or an ice-cloud, formed by the deposition of a very small amount of water vapour on the nickel containing cosmic dust (by depositing, it means here the process by which water vapour turns into ice-crystals directly on the condensation nuclei).

   The noctilucent cloud is silver-white and light blue in colour. It is cirrus-like in shape and appears over higher latitudes before sunset and disappears after sunset. A series of intense photochemical reactions, i.e. dissociations and recombination's of different elements of the atmosphere, take place in the mesosphere under the action of the sun's ultraviolet radiation.

   In the layer below the mesosphere, the air is homogeneously mixed since both horizontal and vertical motions are present. For this reason, the atmosphere up to 90 km is termed as the homogeneous atmosphere.

4. **Thermosphere:**

   This layer that extends from the mesopause up to about 800 km is noted for two striking features:

   a) Temperature rises with increasing altitude i.e. positive lapse rate prevails here. Satellite data shows that at 200 km temperature stays around 700°C, and at 300 km it exceeds 1,000°C. The high temperature results from the heat released by the dissociation of oxygen and nitrogen molecules and atoms. The dissociation is caused by the sun's ultraviolet radiation with wavelengths shorter than 0.175 microns that can absorb the gases in the layer.

b) The air is highly ionized. The gases present here, especially nitric oxide and oxygen, split into atoms and undergo ionization, following absorption of solar radiation in the far ultraviolet region. Over higher latitudes, the resplendent aurora appears in the Thermosphere. It is the outcome of the collision of some of the charged particles thrown out of the sun with the molecules and atoms of gases in the thermosphere, under the action of the earth's magnetic field.

5. **Exosphere:**

This is the outermost layer of the atmosphere, and also the transition zone between the earth's atmosphere and interplanetary space. The air is inconceivably thin and almost completely ionized. It consists of helium and hydrogen, the lightest constituents of air.

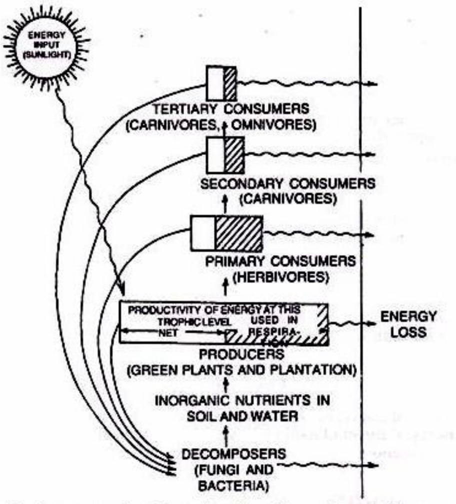
17. Energy flow in an ecosystem.

All the potential energy of plant material eaten is not converted into flesh of herbivores. A part of it is excreted as undigested food and another part is lost by respiration i.e., dissipates in the form of heat. Therefore, only a small part of energy is fixed in the form of potential chemical energy in the protoplasm.

The same process is repeated at the secondary consumer level and so on. Thus, at each step of transfer of energy, large amount is degraded and dissipates and never returns to ecosystem. The flow of energy from one to another trophic level takes place according to second law of thermodynamics which states that "whenever energy is transformed from one kind to another, there is an increase in entropy (relative disorder) and decrease in amount of useful energy."

The 10% Law:

If the net primary production is taken to be 100 units in producers, only 10 units of potential energy of plant material is actually assimilated by the herbivores. Similarly only 1 unit of potential energy of herbivores is assimilated in carnivores. Thus, during energy flow in ecosystem, the energy fixed in one level is only 10% of its previous level.



Energy flow in an ecosystem. Energy input from the sun is needed to compensate for the energy lost as heat produced by metabolism at each trophic level.

Thus, in an ecosystem, there is:

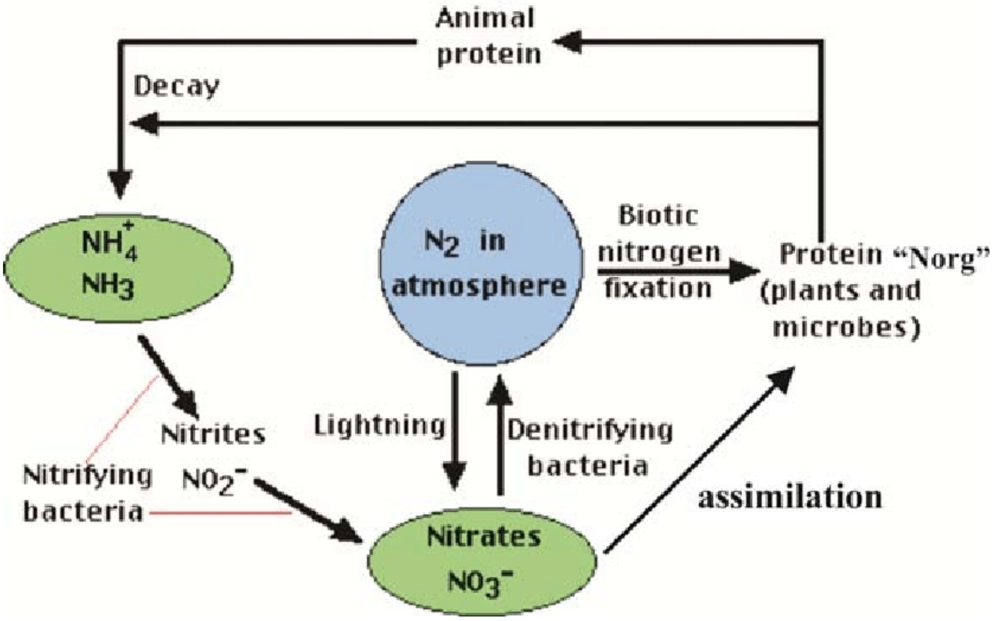
i. A constant flow or transfer of energy from sunlight through plants and plant-eating animals to flesh-eating animals in the form of food.

ii. A decrease in useful energy at each successive level of nutrition due to loss of some energy as heat at each transformation of energy, and

iii. Return of entire solar energy that entered the living systems back to the nonliving world as heat but not as light.

iv. Every food chain or web is essentially a system of energy transfer. In fact, energy transfer is the very basis of life. Food is the means of transfer of both matter and chemical energy in the living world.

18. Nitrogen and phosphorus cycle.



Nitrogen Cycle:

Nitrogen is the fourth most prevalent element in living systems. It is a constituent of a number of organic compounds like amino acids, proteins, nucleotides, nucleic acid, hormones, chlorophyll, many vitamins, etc.

However, its availability from soil is limited and even for that plants have to compete with microbes both in natural and agricultural ecosystems. Nitrogen is available in the atmosphere in abundance (78% of atmosphere as di-nitrogen or N_2) but plants cannot directly absorb the same.

Therefore, nitrogen is the most critical element. A regular supply of nitrogen to the plants is maintained through nitrogen cycle. Nitrogen cycle is regular circulation of nitrogen amongst living organisms, reservoir pool in the atmosphere and cycling pool in the lithosphere. Nitrogen compounds are obtained from reservoir pool through nitrogen fixation.

Reservoir pool is replenished through de-nitrification of nitrates and release of nitrogen from decaying organic matter. Cycling pool is augmented by ammonification and nitrification. Plants obtain nitrogen from soil as NO_3^- (nitrate), NH_4^+ (ammonium) and NO_2– (nitrite) ions. Nitrate and nitrite are reduced to ammonium state which is then incorporated into amino acids, proteins and other organic substances.

Nitrogen Fixation:

It is the conversion of inert atmospheric nitrogen or di-nitrogen (N_2) into utilizable compounds of nitrogen like nitrate, ammonia, amino acids, etc. There are two methods of nitrogen fixation—abiological and biological. Abiological nitrogen fixation is further of two kinds, natural and industrial.

Natural Abiological Nitrogen Fixation:

Atmospheric nitrogen combines with oxygen in the presence of electric discharges, ozonization and combustion. Different types of nitrogen oxides are produced. The nitrogen oxides dissolve in water and give rise to hyponitrous, nitrous and nitric acids. They enter soil along with rain water forming hyponitrites, nitrites and nitrates.

$$N_2 + O_2 \xrightarrow[\text{Discharges}]{\text{Electric}} \underset{\text{Nitrogen oxide}}{2NO}$$

$$2NO + 2[O] \xrightarrow[\text{Ozonization}]{\text{Electric Discharges}} \underset{\text{Nitrogen peroxide}}{2NO_2}$$

$$2NO + 3[O] \xrightarrow{\text{Ozonisation}} N_2O_5$$

$$H_2O + 2NO \rightarrow HNO + HNO_2$$

$$H_2O + 2NO_2 \rightarrow HNO_2 + HNO_3$$

$$H_2O + N_2O_5 \rightarrow 2HNO_3$$

Industrial Abiological Nitrogen Fixation:

Ammonia is produced industrially by direct combination of nitrogen with hydrogen (got from water) at high temperature and pressure. It is changed to various types of fertilizers including urea.

Biological Nitrogen Fixation:

It is the second most important natural process and the major source of nitrogen fixation which is performed by two types of prokaryotes, bacteria and cyanobacteria (= blue green algae).

They include both free living and symbiotic forms:

a. **Free Living Nitrogen Fixing Bacteria:** Azotobacter, Beijerinckia (both aerobic) and Bacillus, Klebsiella, Clostridium (all anaerobic) are saprotrophic bacteria that perform nitrogen fixation. Desulphovibrio is chemotrophic nitrogen fixing bacterium. Rhodopseudomonas, Rhodospirillum and Chromatium are nitrogen fixing anaerobic photoautotrophic bacteria. Free living nitrogen fixing bacteria add 10-25 kg of nitrogen/ha/annum.
b. **Free Living Nitrogen Fixing Cyanobacteria:** Many free living blue- green algae (BGA) or cyanobacteria perform nitrogen fixation, e.g., Anabaena, Nostoc, Calothrix, Lyngbia, Aulosira, Cylindrospermum, Trichodesmium. They add 20-30 kg of nitrogen per hectare of soil and water bodies. Cyanobacteria are also important ecologically as they occur in waterlogged soils where denitrifying bacteria can be active. Aulosira fertilissima is the most active nitrogen fixer in Rice fields while Cylindrospermum is active in Sugarcane and Maize fields.
c. **Symbiotic Nitrogen Fixing Cyanobacteria:** Anabaena and Nostoc species are common symbionts in lichens, Anthoceros, Azolla and Cycad roots. Azolla pinnata (a water fern) has Anabaena azollae in its fronds. It is often inoculated to Rice fields for nitrogen fixation.
d. **Symbiotic Nitrogen Fixing Bacteria:** Rhizobium is nitrogen fixing bacterial symbiont of papilionaceous roots. Sesbania rostrata has Rhizobium in root nodules and Aerorhizobium in stem nodules.
   Out of these Rhizobium is the most important for crop lands because it is associated with pulses and other legumes of family fabaceae.

Symbiotic nitrogen fixing organisms hand over a part of their fixed nitrogen to the host in return for shelter and food. Free living nitrogen fixers do not immediately enrich the soil. It is only after their death that the fixed nitrogen enters the cycling pool. It occurs in two steps, **ammonification** and **nitrification**.

Ammonification:

It is carried out by decay causing organisms. They act upon nitrogenous excretions and proteins of dead bodies of living organisms, e.g., Bacillus ramosus, B. vulgaris, B. mesentericus, Actinomyces. Proteins are first broken up into amino acids. The latter are deaminated. Organic acids released in the process are used by microorganisms for their own metabolism.

$$\text{Proteins} \xrightarrow{+H_2O} \underset{\text{Amino acid}}{R-NH_2} \xrightarrow{H_2O} \underset{\text{Organic acid}}{ROH} + \underset{\text{Ammonia}}{NH_3}$$

Ammonia does not remain in the gaseous state in the soil but is changed to ionic form (NH+). It can be used by plants directly provided pH of soil is more than 6 and the plant contains abundant organic acids. Unlike nitrates, very few plants can store ammonium ions (e.g., Begonia, Oxalis).

Nitrification:

It is the phenomenon of conversion of ammonium nitrogen to nitrate nitrogen. It is performed in two steps— nitrite formation and nitrate formation. Both the steps can be carried out by Aspergillus flavus. In the first step, ammonium ions are oxidised to nitrites Nitrosococcus, Nitrosomonas. Nitrites are changed to nitrates in the second step, e.g., Nitrocystis, Nitrobacter.

$$2NH_3 + 3O_2 \xrightarrow[\textit{Aspergillus flavus}]{\textit{Nitrosococcus, Nitrosomonas}} 2\,NO_2^- + 2H^+ + 2H_2O + \text{energy}$$

Most of the bacteria performing nitrification (e.g., Nitrosococcus, Nitrosomonas, Nitrobacter) are chemoautotrophs. They use the energy liberated during nitrification in synthesis of organic substances from CO_2 and a hydrogen donor. They are thus autotrophs which do not use solar energy for synthesis of food.

De-nitrification:

Under anaerobic conditions (e.g., water logging, oxygen depletion), some microorganisms use nitrate and other oxidised ions as source of oxygen. In the process, nitrates are reduced to gaseous compounds of nitrogen. The latter escape from the soil. Common bacteria causing de-nitrification of soil are Pseudomonas denitrificans, Thiobacillus denitrificans, Micrococcus denitrificans.

$$2\,NO_3' \longrightarrow 2\,NO_2' \longrightarrow 2NO \longrightarrow N_2O \longrightarrow N_2$$

Nitrogen oxides escaping into atmosphere or formed during abiological fixation can also be broken down by raidations to form molecular nitrogen. De-nitrification of soil not only depletes the soil of an important nutrient but also causes acidification which is equally harmful in solubilisation of harmful metals.

Nitrate Assimilation:

Nitrate is the most important source of nitrogen to the plants. It can accumulate in the cell sap of several plants and take part in producing osmotic potential. However it cannot be used as such by the plants. It is first reduced to level of ammonia before being incorporated into organic compounds. Reduction of nitrate occurs in two steps.

(i) Reduction of Nitrate to Nitrite:

It is carried out by the agency of an inducible enzyme called nitrate reductase. The enzyme is a molybdoflavoprotein. It requires a reduced coenzyme (NADH or NADPH) for its activity. The reduced coenzyme is brought in contact with nitrate by FAD or FMN.

$$NO_3 + NAD(P)H + H^+ \xrightarrow[\textit{FAD/FMN}]{\textit{Nitrate Reductase}} NO_2^- + H_2O + NADP^+$$

(ii) Reduction of Nitrite:

It is performed by enzyme nitrite reductase. The enzyme is a metalloflavoprotein which contains copper and iron. It occurs inside chloroplasts in the leaf cells and leucoplasts of other cells. In contrast nitrate reductase is found attached loosely to cell membrane. Nitrite reductase requires reducing power.

It is NADPH in illuminated cells and NADH in others. The process of reduction also requires ferredoxin which occurs in higher plants mostly in green tissues. Therefore, it is presumed that in higher plants either nitrite is trans-located to leaf cells or some other electron donor (like FAD) operates in un-illuminated cells. The product of nitrite reduction is ammonia.

$$2\,NO_2^- + 7NAD(P)H + 7H^+ \xrightarrow[\text{Ferredoxin}]{\text{Nitrite reductase}} 2NH_3 + 4H_2O + 7NAD(P)^+$$

Ammonia is not liberated. It combines with some organic acids to produce amino acids. Amino acids then form various types of nitrogenous compounds.

Synthesis of Amino:

The first organic compounds of nitrogen assimilation are ammo acids.

Phosphorus Cycle:

The Phosphorus cycle, unlike those of Carbon and Nitrogen cycles lacks an atmospheric component.

The global phosphorus cycle involves only aquatic and soil compartments. As a basic constituent of nucleic acids, phospholipids and numerous phosphorylated compounds, phosphorus is one of the nutrients of major importance to biological systems.

Basic source and the great reservoir of phosphorus are the rocks or other deposits which have been formed in the past geological ages. These are gradually eroding, releasing phosphates to ecosystems. But much phosphate escapes into the sea where part of it is deposited in the shallow sediments and part of it is lost to the deep sediments (Fig. 5.9).

However, the means of returning phosphorus to the cycle are inadequate to compensate for the loss. The principal global flux of phosphorus consists of the movement of about 21 x 10^{12} g P yr^{-1} from the terrestrial pool to the oceans through the rivers. Phosphate fertilizers, used in agriculture, are added to the soil at a rate of about 14 x 10^{12} g yr^{-1}, which is also carried into the oceans by runoff and rivers.

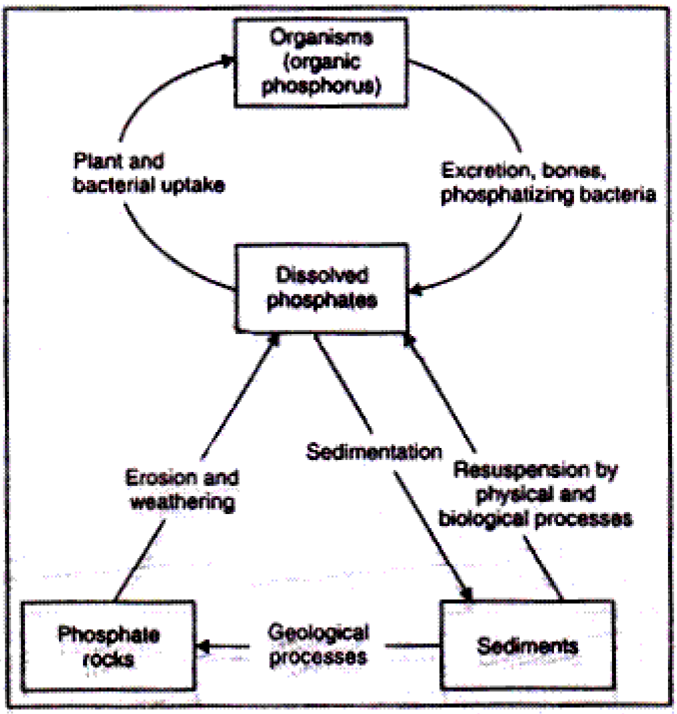


Fig. 5.9. A simplified diagram of the phosphorus cycle. (after E.P. Odum, 1993)

Much phosphate becomes lost to this central cycle by physical processes, such as sedimentation, which take it out of the reach of upwelling and major water circulation. Biological process, such as the formation of teeth and bone, and excretion also account for considerable losses from the major portion of cycle.

The fish and marine birds are also important in phosphorus cycle. The latter have apparently played an important role in returning phosphorus to the cycle. In this context we can consider the tremendous deposits of guano (the manure of sea birds) along the western coast of South America.

Although man harvests a lot of marine fish, according to Hutchsinson, only about 60,000 tons of elementary phosphorus per year is returned in this manner, compared with one to two million tons of phosphate rocks which are mined and most of which are washed away and lost.

For their nutrition plants absorb water dissolved inorganic phosphates from the soil either as di-hydrogen phosphate (H_2PO_4) or as hydrogenphosphate (HPO_4) and convert these into organic phosphate. The latter is transferred to animal consumers and decomposers.

Decomposers return phosphorus to the soil as the phosphate ion. Phosphate absorbed from the soil is returned to it in dead plant and animal organic residues, which are converted to humus by the action of soil microorganisms. Much of the phosphate in the soil is fixed or adsorbed on to soil particles but some is lost through leaching out into watercourses.

In fresh water, the floating algae or phytoplankton rapidly absorb soluble inorganic phosphates and convert them into organophosphates. Algae provide food for zooplankton which in turn are consumed by other animals. All plants and animals eventually die and in due time their organic remains or debris decay through the action of microorganisms, and phosphates are released into the water for recycling. In aquatic plants, phosphorus, limits plant growth.

19. Ecological pyramids.

An ecological pyramid is a graphic representation of a specific parameter (aspect) of a food chain developed by Charles Elton (1927). Since in any food chain there is a loss of energy at each step, it follows that there is a smaller biomass in each successive step.

A food chain may be visualized as a pyramid, each step in the pyramid is much smaller than the one on which it feeds. There are three important parameters of each trophic level in a food chain, namely, number of individuals, amount of biomass and amount of energy.

Accordingly, three types of ecological or food pyramids are recognized:
Pyramid of numbers, Pyramid of biomass and Pyramid of energy.

In a food pyramid, the first trophic level forms the base and the last forms the apex.

1. Pyramid of Numbers:

The pyramid of numbers represents numerical relationship between different trophic levels of a food chain. Starting from the base of the pyramid and moving towards the apex, one finds a gradual decrease in the number of organisms and an increase in the body size.

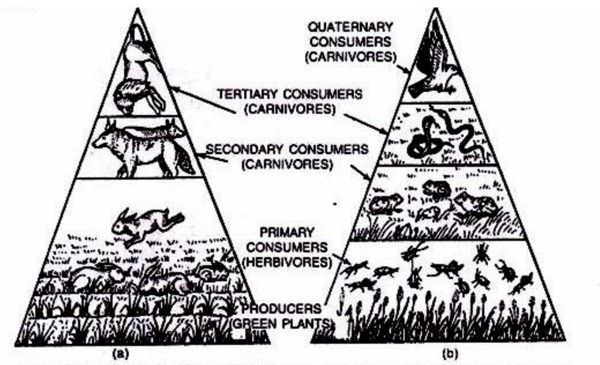


Fig. 3.11. Upright pyramid of numbers showing decreasing number at successive stages (*a*) Grassland ecosystem (*b*) Crop ecosystem.

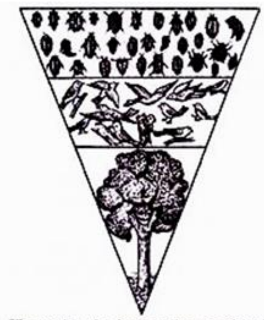


Fig. 3.12. An inverted pyramid of numbers of a tree ecosystem showing increase in a number of successive trophic levels.

In a lake ecosystem, the base of the pyramid is occupied by producers, such as diatoms and algae, whose number is maximum. The second trophic level is represented by zooplanktons, which are primary consumers and are less abundant than the producers. The third trophic level is represented by medium-sized fishes which feed upon primary consumers, these are still smaller in number. The apex or fourth trophic level is represented by large fishes which are very few in number.

Similarly in a grassland ecosystem, the base of the pyramid (i.e., first trophic level) is occupied by grasses (producers), and the apex by large carnivores, such as tigers (Fig. 3.11a). In parasitic food chains the pyramid of numbers is reversed (Fig. 3.12). For instance, a tree supports a large number of fruit or seed-eating birds, which in turn are infested by a large number of ecto- and endoparasites.

However, the pyramids of numbers is not an ideal device to illustrate the food chain because of its various drawbacks and limitations.

2. Pyramid of Biomass:

As the name itself indicates, the pyramid of biomass represents total weight of living matter present at each trophic level of the food chain. As one moves from base to apex, one finds gradual loss of biomass at each trophic level. For example, in a water ecosystem, the first trophic level (i.e. base) is occupied by a huge mass of phytoplankton; the second trophic level is occupied by zooplankton; the third trophic level is occupied by the primary carnivores, such as worms, mollusks and small fishes; the apex or fourth trophic level is occupied by large fishes.

Here also, in a parasitic food chain the pyramid of biomass is inverted.

The pyramid of biomass is relatively more illustrative than the pyramid of numbers because it represents quantitative relationship of the standing crop biomass.

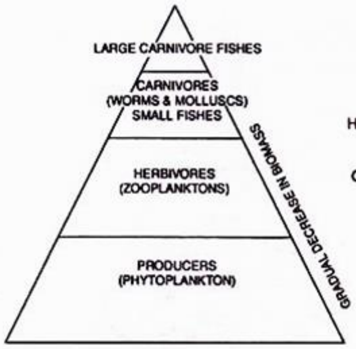


Fig. 3.13. Pyramid of biomass in a shallow water ecosystem.

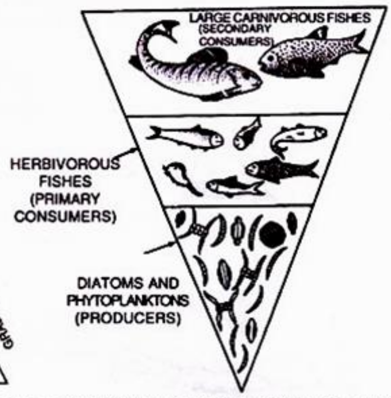


Fig. 3.14. An inverted pyramid of biomass of a pond ecosystem showing decrease in number but increase in biomass.

3. Pyramid of Energy:

The pyramids of number and biomass do not take into consideration the rate of energy flow (i.e., rate of passage of food mass), while a pyramid of energy illustrates the total available energy at each trophic level of the food chain. Here also, as one moves from base to apex there is a gradual loss of energy.

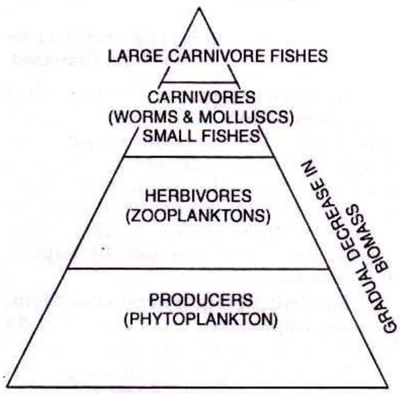


Fig. 3.15. Pyramid of energy.

20. Pond ecosystem.

Pond is an example of fresh water ecosystem (Fig. 3.3). It is limited to a small area of shallow standing water containing abundant vegetation and aquatic animals. It is an example of lentic habitat and completely self maintaining and self regulating ecosystem. It is composed of the following components.

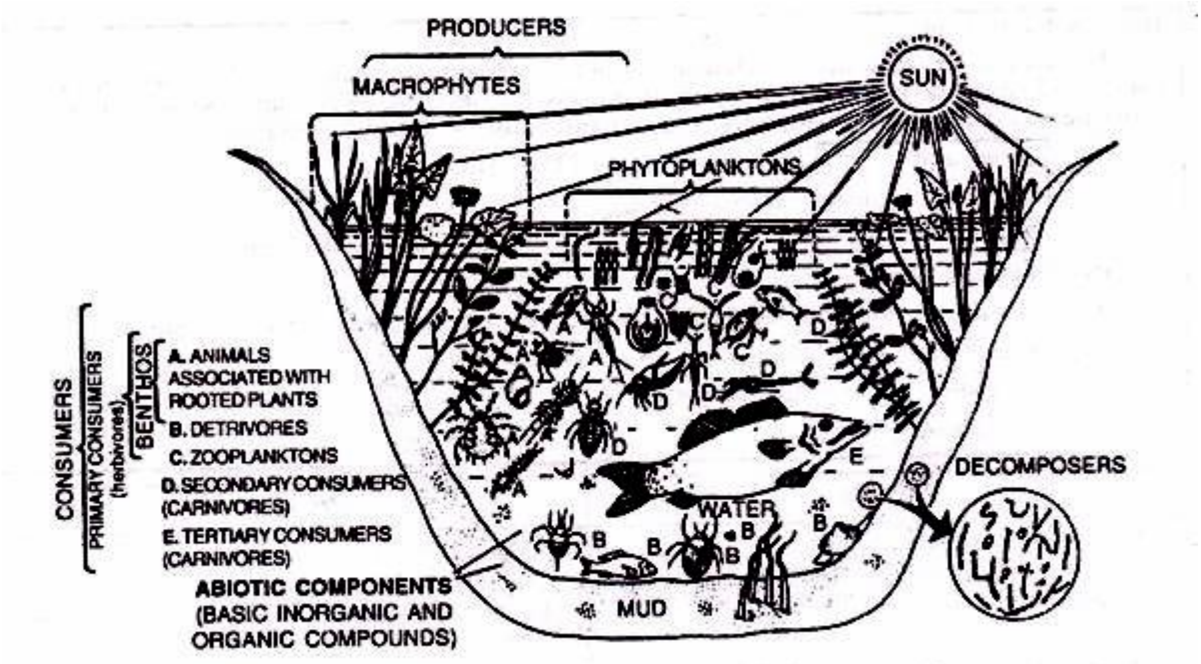


Fig. 3.3. A pond ecosystem with its biotic and abiotic components.

1. Abiotic Components:

The non-living substances of pond are its standing water and the sediments below water. Sunlight penetrates into it during daytime. Oxygen and CO_2 from atmosphere dissolve into water. Various organic and inorganic compounds of calcium, phosphorus and nitrogen, amino acids, humic acids are available in the sediment or to some extent in dissolved state.

2. Biotic Factors:

Producers:

The chlorophyll bearing phytoplankton's and hydrophytes are the producers. The phytoplankton's are minute floating algae such as Eudorina, Volvox, Clostridium, Oscillatoria, Euglena and Ceratium etc. The hydrophytes are filamentous algae floating and rooted plants and submerged plants. They synthesize carbohydrates for the nutrition of the biotic components.

Consumers:

The first order of consumers are Zooplanktons (herbivores) are ciliates, flagellates, rotifers, crustaceans, tadpole larvae of frog etc. These are fed by insect larvae, adult insects, small fishes which are primary carnivores making the second order of consumers. The secondary carnivores are large carnivorous fishes and frogs. Frogs and snakes temporarily come in for food and shelter. Birds like herons, cranes, king fishers depend upon pond for food. The bottom dwelling forms called benthos are molluscs and annelids.

Decomposers:

These are saprophytes like bacteria, flagellates and fungi which are abundant in mud at the bottom of the pond. They decompose dead and decaying organisms and derive their nutrition. Simultaneously, they release the abiotic raw materials which are reused by the producers for photosynthesis and nutrition.

21. Air pollution.

Sources of Air Pollution:

a) Transportation (42%)
b) Fuel combustion in stationary sources (21%)
c) Industrial processes (14%),
d) Solid waste disposal (5%),
e) Forest fires (8%) and
f) Miscellaneous sources including radioactive fallout (10%).

So far, six pollutants, that account for most of the air pollution worldwide are carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x), Ozone (O_3), particulate matters (PM_{10}) and lead. They may come from natural sources or from human activities. Natural sources of air pollution are volcanic eruption, discharge of spores, conidia, endospores etc. of airborne micro-organisms, pollens of certain flowers, dust particles suspended in air.

Man Made Sources are, burning of fossil fuels (coal, natural gases, kerocine, petroleum products, etc.), burning of firewood for domestic purpose, automobile exhausts, smokes of domestic and industrial sources, particulate matters and aerosol etc.

A brief description of atmospheric pollutants released through manmade sources is given below:

1. Gases:

A large amount of air pollution results from burning of coal and oils in furnaces and steel plants. They are burnt to produce heat energy along with gaseous and solid waste products. Gases produced during fuel combustion are CO, CO_2, SO_2, various oxides of nitrogen (NO, NO_2, N_2O_4) and assorted hydrocarbons. Carbon monoxide (CO) is produced due to incomplete combustion of the carbon content of fossil fuels. Carbon dioxide (CO_2) is produced due to complete combustion of carbon content.

2. Particulate Matters:

These are solid particles and liquid droplets suspended in air. They may be settled down where particle size is more than 10 µm or remain suspended in air when particle size is below 10 µm. Particulate matter in the size range of 0.01 µm to 50 µm or less in size), aerosols (less than 1 µm) flash and dust 0.25 to 500 µm), grit (more than 500 µm).

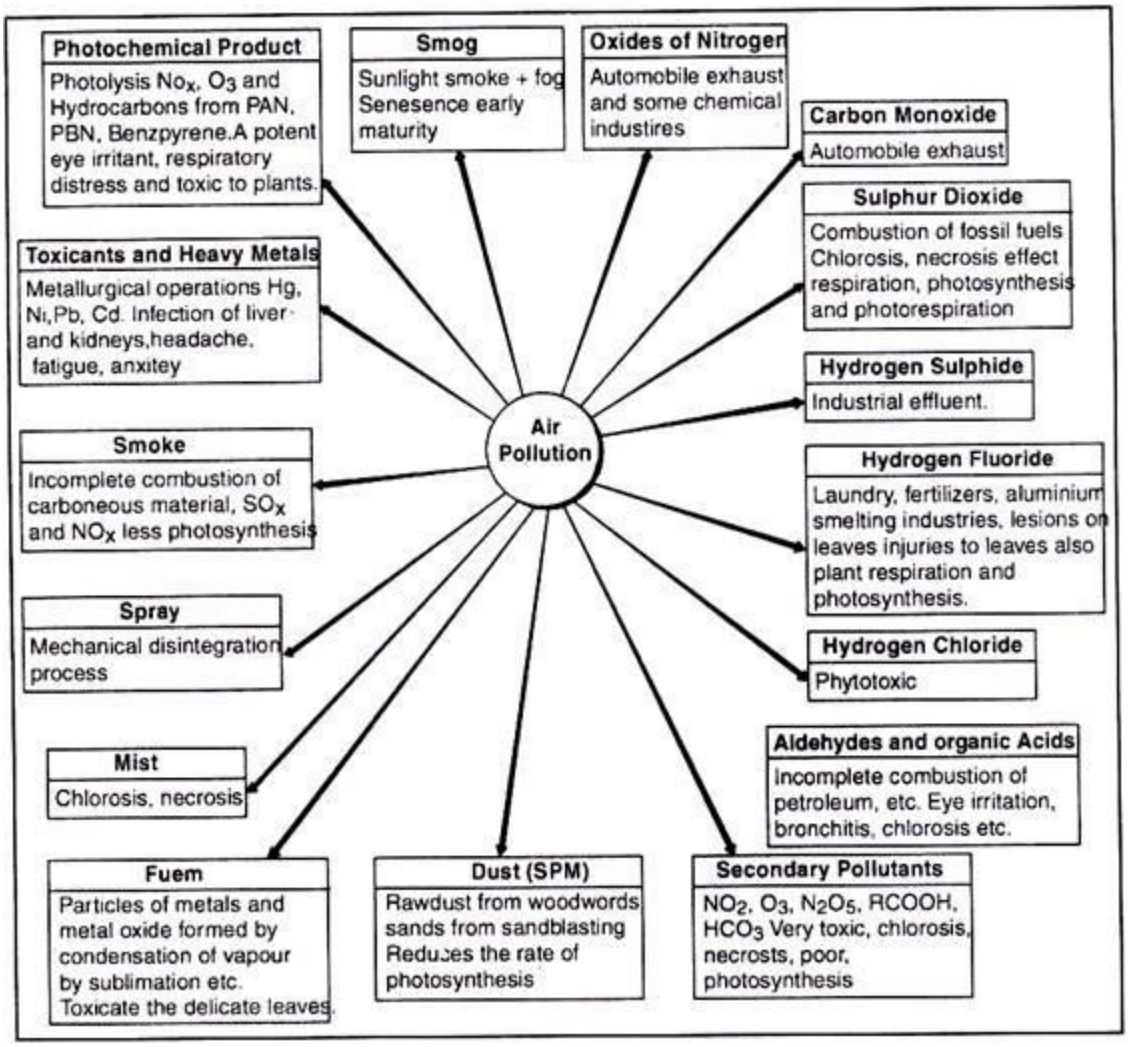
3. Toxic Chemicals:

Some highly toxic chemicals are emitted directly from different source^. For example, Arsenic emitted from coal and oil furnace and also from glass manufacturing units are directly delivered to air which is highly toxic. Similarly, C_6H_6 from refineries and motor vehicles, cadmium from smelters, burning waste, and coal and oil furnaces are some of the highly toxic chemicals acting as air pollutants.

4. Secondary Pollutants:

As stated earlier, these are formed from primary pollutants through wide range of photochemical reactions and cause greater damage than primary pollutants.

When hydrocarbons from exhaust are exposed to light, alkanes, ethylenes, unsaturated hydrocarbons, aldehydes and aromatics are formed. One of these compounds is benzopyrene which induces cancer in man. Two other photochemically originated pollutants are peroxybenzoil nitrate and peroxyacetyl nitrate (PAN).



Effects of Air Pollution:

The effect of air pollution has been extensively studied in man and animals, in plants and in climatic changes.

A few of them are described below:

1. Acute health hazard:

Smog in Donora, Pennsylvania along Monogahila River in 1948 resulted 6,000 illness and 20 deaths in a population of 14,000. Photochemical smog in London in 1952 and 1956 has caused eye and throat irritation. In India, a most terrible effect of air pollution has been witnessed in Bhopal on December 3, 1984. Leakage of Methyl Isocyanate from Union Carbide factory caused number of deaths in a few minutes.

2. Chronic diseases:

Incidence of respiratory diseases in Delhi is about 12 times higher than the national average. Carbon monoxide if present in air can combine with blood haemoglobin 7 to 10 times faster than O_2. CO concentration 30 ppm for 4 hours can convert 5% of body haemoglobin into carboxy haemoglobin. Prolonged exposure to CO could cause death due to lack of O_2 supply to living cells of the body.

Diseases like bronchitis, lungs cancer and emphysema are caused by air pollution. $N0_2$ in air causes bronchitis and lowers resistance to influenza. SO_2 obstructs breathing and irritates eyes. Silicon tetrafloride irritates lungs. Nitric acid, nitrous acid and sulphuric acid initiate respiratory disease. Photochemical smog causes eye irritation and headache. Constant exposure to peroxyacetyl nitrate (PAN) aggravates asthma and can damage lungs.

Air pollution produces offensive odours and gives general discomfort, anxiety or suffering to

3. Reduction in Visibility:

Smokes, fumes, fog and particulates in air absorb solar radiation and reduce the quantity of solar radiation reaching the earth surface. Smokes and fumes increase atmospheric turbidity. Particulates absorb and reflect incoming solar radiation, thus reducing 15 to 20% of total radiation reaching the earth surface. Cause of many accidents is reduction of visibility due to smoke and fog in the atmosphere.

4. Effects on plants:

Air pollution has devastating effect on plants, ultimately resulting in lower yield. It damages the crops and trees. According to an estimate there has been 5 to 10% crop loss due to ozone pollution. SO_2 causes bleaching of leaves, chlorosis, growth suppression and yield reduction. PAN produces glazing, silvering or bronzing on the lower surface of leaves. Hydrogen fluoride (HF) could also cause chlorosis, dwarfing, leaf abscission and lower yield. Chloride (Cl_2) develops bleaching spots and leaf abscission. Ethylene (C_2H_4) causes leaf abnormalities and withering, flower dropping and failure of the flower to open.

5. Effect on Climate:

Particulates of air play a vital role in producing temperature changes and air movements. Solid particulates take part in cloud formation. Since urban air pollution is more, there is increased particulate matter in air, increased cloud formation (upto 10% in comparison to rural areas) and 10% more wet days. There is increased amount of mist, fog and smog in industrial areas.

Control of Air Pollution:

Atmospheric pollution can be controlled effectively by using some of the following techniques.

1. Use of tall chimneys:

Industries should be asked to build up high chimneys for escape of smoke, fumes so that harmful gases may not spread in the lower layer of atmosphere.

2. Use of CNG:

Automobiles in Delhi account for 50% of air pollution and 90% of CO are released to air from automobiles. Recently Delhi Administration has emphasized use of Compressed Natural Gas' (CNG) in place of petrol and diesel to reduce air pollution.

3. Removal of pollutant from fuel:

A lead compound, tetraethyl lead (TEL) is mixed in petrol for smooth and easy running of the vehicles. But the exhaust is leaded gas and particulate lead. Lead mixed air when inhaled, is injurious for kidney, liver and blood. When mixed with food and water, it may lead to poisoning. Therefore unleaded petrol must be available in the petrol pumps.

4. Use of catalytic converters:
Removal of pollutants from fossil fuel with be possible by use of catalytic converters in two, three and four wheelers. The catalytic converter has expensive metals like platinum, paladium and rhodium as catalysts. When the poisonous exhaust gases pass through catalytic converter, unburnt hydrocarbons are converted into carbon dioxide and water. Carbon monoxide and nitric oxide are changed to carbon dioxide and nitrogen gas respectively.

5. Use of scrubber: A scrubber can remove gases like sulphur dioxide and ammonia. scrubber, the exhaust is passed through a spray of water or lime.

6. Use of electrostatic precipitator:
For removing particulate matter from air, electrostatic precipitator is used, which can remove 99% particulate matter present in the exhaust of thermal power plants. It has electrodes with supply of several thousand volts of electric current, which produce a corona that releases electrons. These electrons attach to particles giving them net negative charge. The collecting plates are positively charged and attract the negatively charged particles.

7. Proper treatment of Organic Wastes:
Public awareness regarding air pollution potential of sewage and many other solid wastes will help in reducing air pollution. It should be mandatory for municipalties to carry-out proper treatment of sewage and other wastes before disposal.

8. Development of green covers:
More effort should be made for extensive green coverage development because the green plants serve as sinks for air pollutants. Many plant species have been evaluated for their scavenging potential against air pollutants.

9. Bioremediatieon:
Many countries have started the use of microorganisms to treat air, water and instrial wastes. Japan is exploring various uses of biovemediation. For example, use of microorgnisms to manufacture advanced biodegradable polymers or to produce clean burning fuel like hydrogen.

10. Pollution Control at source is a better preventive measure. This would facilitate not releasing pollutant into air.
In India, the Air (Prevention and control of Pollution) Act came into force in 1981 but was amended in 1987 to include noise as an air pollutant. Government has established pollution Control Boards in State Headquarters. In spite of all reactions, public awareness is the basic need to fight against pollution.

22. Animal relationships - Inter specific interactions.

The interactions between populations of species in a community are broadly divided into two categories:

(i) Positive (beneficial) and (ii) Negative (inhibition) interactions.

Positive Interactions:

Symbiosis or Mutualism:

When two species live together in a close association that is helpful to both species, the relationship is known as symbiosis.

The oxpecker bird and the rhinoceros exhibit this relationship. The oxpecker receives protection and obtains food from the ticks and other pests infesting the rhino's skin.

The rhino receives cleaning and warning of approaching dangers.

Fig. 11.9. Crab and sea anemone mutualism.

Sea anemone is a typical example of facultative mutualism, wherein animal gets attached to the shell of hermit crab. The sea anemone growing on the back of the crab provides camouflage and protection, and in turn, the sea anemone is transported to reach new sources of food. This type of mutualism in called **protoco-operation**.

Commensalism:

Some organisms live together so that one organism benefits by the relationship while the other organism is neither helped nor harmed. This type of relationship is known as commensalism. An example of this association is the relationship between the shark and the small remora fish.

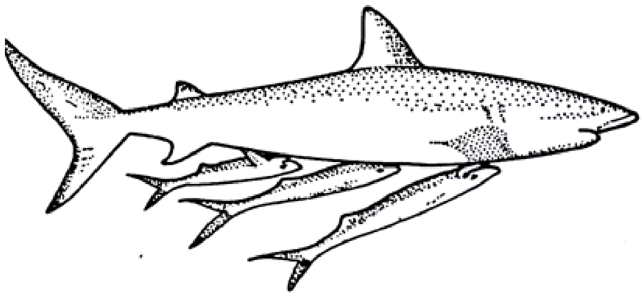


Fig. 11.10. Commensalism of shark and remora fish.

The remoras may attach themselves to the shark as it swims through the water. When the shark finds food, the remoras eat some of the food not consumed by the shark. The shark is not harmed by the remora, while the remora is helped. The attachment of the sedentary sea anemone to the body of a hermit crab and barnacles to a whale are other examples of commensalism.

Negative Interactions:

Certain interactions between different species give rise to negative effect on either or both species. Parasitism and predation are interaction where one species gains and the other suffers. While in the interaction called competition both species are harmed.

Parasitism:

This is a relationship in which one organism, the parasite spends much or all of its life living in or another organism, the host. The parasite is dependent upon the host for food.

The parasite benefits from the relationship and the host is always harmed. Parasites may bring about the death of their host, but most often only weaken their host. Human parasites may be external (ectoparasites) such as body lice, ticks, mites and leeches, or internal (endoparasites) such as tapeworms, some types of roundworms, malarial parasite, microfilaria and guineaworm.

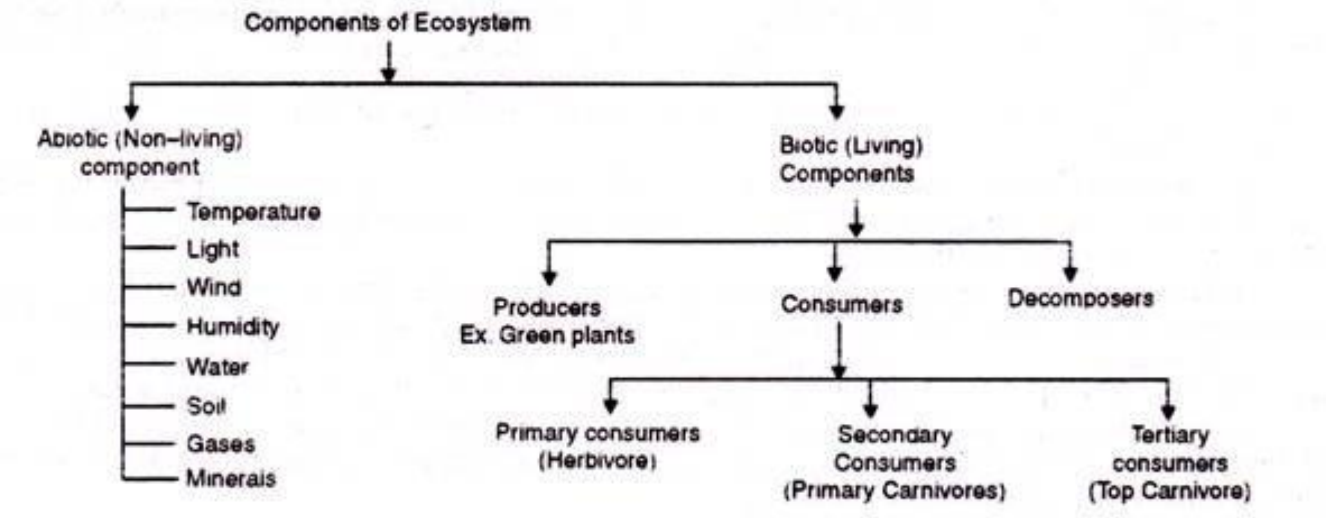
A parasite usually parasitizes a host which is larger in body size than it, and ordinarily it does not kill the host, at least not until it has completed its reproductive cycle.

Predation:
This is commonly associated with the idea of strong attacking the weak such as the tiger pouncing upon the deer, the hawk upon the sparrow, and the frog upon the insects and so on. A species such as the frog may be both a prey and a predator. The relationship between a snake and a rat is more than that between a prey and a predator as the snake also seeks shelter in the rat holes.

Thus **"predation represents a direct and often complex interaction of two or more species, of the eaters and being eaten."** This is a negative interaction which results in negative effects on the growth and survival of one of the two populations.
In this type of association and interaction one species (predator) kills and feeds on second species (prey). Predation is important process in the community dynamism. Predator is always stronger than pery. From population ecology point of view predation is the action and reaction in the transfer of energy from one trophic level to the other.

23. Biotic and abiotic factors of an ecosystem.

The necessary components of an ecosystem are matter (water, minerals, carbon dioxide, oxygen) and several species of organisms. An ecosystem must also receive a continuous supply of energy. The components of an ecosystem may be divided into two main types : biotic and abiotic.



I. Biotic Components:

The living organisms present in an ecosystem form the biotic component. They are classified into three main categories: plants, animals and microorganisms (bacteria and fungi). These are respectively called producers, consumers and reducers or decomposers according to their role in keeping the ecosystem operating as a stable unit.

(i) Producers:

These are the green plants, some protists and certain bacteria. They, with the help of their chlorophyll, entrap the light energy of the sun and change it into the chemical energy of a simple carbohydrate glucose produced by them from simple inorganic compounds, namely, carbon dioxide and water. The process is called photosynthesis.

It may be briefly represented by the following equation:

$$6\,CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

From the basic organic material (glucose), the plants then form complex organic compounds such as starches, proteins and lipids. Materials and energy- stored by producers are utilized by consumers. As the green plants and other green organisms prepare their organic food themselves, they are known as the photoautotrophs. The producers dominate the terrestrial ecosystems, being the most abundant and massive of all groups of organisms there. Some bacteria capture energy released during certain inorganic chemical reactions and prepare organic food with it. They are called chemoautotrophs.

(ii) Consumers:

These are mainly the animals. They are unable to synthesize their food. Therefore, they consume other organisms or parts of organisms. They are known as the heterotrophs.

The consumers are of 3 or 4 types:

(a) Primary or First Order Consumers:

These are the animals which eat plants or plant products. They are called herbivores. Cattle, deer, goat, rabbit and hare belong to this category. Elton has used the term "key industry animals" for the primary consumers because they convert the plant material into animal material. Plants that are parasites on plants and bacteria and fungi which flourish on living plants are also primary consumers.

(b) Secondary or Second Order Consumers:

These are the animals which eat herbivores. They are called carnivores, cats, dogs, and foxes are examples.

(c) Tertiary or Third Order Consumers:

These are larger carnivores which feed on secondary consumers. For instance, wolves.

(d) Quaternary or fourth Order Consumers:

These are the largest carnivores which take tertiary consumers. They are not eaten by other animals. Tigers and lions are examples.

(iii) Reducers or Decomposers:

These are mainly bacteria and fungi. They obtain their food molecules from the organic materials of dead producers (plants) and consumers (animals) and their waste products.

II. Abiotic Components:

Abiotic component of an ecosystem consists of non-living substances and factors. The important ones are as follows:

1. Temperature:

Organisms generally live within a narrow range of temperature (5° – 35°C) with the exception of spores, seeds, some prokaryotes and other lowly organized individuals. The latter can be found in hot springs (60°-90°C) or permafrost (- 30° to – 50°C). Temperature range vanes in different parts of the earth.

It has created different life zones — tropical, sub tropical, temperate, arctic or alpine. High or low temperature causes inactivity and death of organisms. It is immediate in case of poikilothermal (= ectothermal = cold blooded) animals and delayed in case of homoiothermal (= endothermal = warm blooded) animals. Therefore, organisms show adaptations to avoid extremes of temperature.

Plants belonging to both hot and cold areas possess adaptations to reduce transpiration and retain water, e.g., tannins, hair, thick covering, mucilage, high solute content, thick leaves. Animals of cold areas possess thick coat of hair, scales, feathers and subcutaneous fat. In warm blooded animals, including humans, pigmentation is little in colder areas, yellow brown to red in arid climates and black in humid hot areas.

2. Light:

It provides solar energy to the ecosystem for heating and photosynthesis. Maximum solar or light energy is available at equator. It decreases towards poles. In a tree more energy is available to upper leaves than the lower ones. Their rate of photosynthesis is accordingly higher. In a forest, trees have higher productivity than shrubs and herbs growing underneath.

Floating hydrophytes have higher photosynthetic rate than the submerged hydrophytes. Besides photosynthesis, light controls morphogenesis (photo-morphogenesis). Photoperiods influence leaf fall, appearance of new leaves and flowering in plants. They control migration and breeding in several animals.

3. Wind:

It controls weather, transpiration, pollination and dissemination of propagates. High speed winds inhibit free growth and flight animals. Unidirectional wind does not allow growth of branches on the wind-ward side.

4. Humidity:

It is the amount of water vapours present in the atmosphere. Humidity controls formation of clouds, dew, fog, etc. Epiphytes grow only in humid areas. Evaporation of water from the body of land organisms in transpiration and perspiration is regulated by humidity. Both plants and animals develop modifications for reducing water loss from their body in arid areas.

5. Precipitation:

It may occur as rainfall, snow, dew, hail, etc. Periodicity and amount of rainfall determines type of forest in an area —evergreen, deciduous, chaparral, grassland, savannah, desert, etc. Animals are also adopted accordingly.

6. Water:

Land plants meet their water requirements from soil. Land animals obtain the same from pools, lakes, rivers, springs, etc. Plants and animals show modifications according to availability of water in the area and requirement of conserving the obtained water. Plants of dry areas are called xerophytes. They develop modifications to increase water absorption, reduce transpiration and at times store absorbed water.

Certain animals of the dry areas do not drink water at all, e.g., Kangaroo, rat. They use water from food and its metabolism to run their body machinery. Animals of dry areas often reduce water loss by producing solid faeces and excreting solid urine.

Water is abundant in aquatic habitats. Plants of aquatic habitats are called hydrophytes. Hydrophytes possess aerenchyma or air storing parenchyma to support themselves in water. Clarity of water, salt content, depth and water waves or speed determine the growth and distribution of plants and animals. In rivers and streams, animals obtain most of their food from organic materials coming from outside the water.

9. Gases:

Nitrogen is present in abundance (4/5th of atmosphere) but is itself chemically inert. It forms useful salts through electrochemical, photochemical and biological fixation. Carbon dioxide concentration of the atmosphere is always a limiting factor for photosynthesis.

However, excess of carbon dioxide concentration is harmful to animals as well as climate. Its-concentration increases during night but decreases during day. In water it occurs as bicarbonate and carbonate ions. Oxygen concentration is supra-optimal for C_3 plants, optimal for C_4 plants and animals except at high altitudes.

In water oxygen concentration determines distribution of organisms. In the middle or intermediate stratum photosynthesis increases oxygen concentration during day but it becomes little during night depending upon population, pollution and decomposition. In deep waters, animals are faced with very low oxygen concentration.

10. Soil:

It determines vegetation growth and pattern, under-ground flora and fauna through its constitution, origin, temperature range, water retentively, aeration, minerals, etc. Soil present on the slopes as well as the one which is uncovered are liable to be eroded by water and air respectively.

11. pH (Hydrogen ion Concentration):

There is very little change in pH in oceans. Terrestrial animals are also not much influenced by pH of the substratum. However, distribution of land plants and soil organisms is determined by pH of soil. A similar control on distribution is found in fresh water habitats. Snails and earthworms do not occur in acidic soils. At this pH, Euglena and other flagellates are quite abundant. Animals having calcareous shells live in media having neutral or alkaline pH.

12. Mineral Elements:

A large number of minerals, also called biogenic or biogenetic nutrients, are required by organisms for their proper growth. Deficiency or absence of any one results in abnormal growth which may lead to death. Excess minerals are equally harmful. Abundance of some minerals favour the growth of some tolerant species.

Snails occur in soils rich in calcium content. Soils deficient in nitrogen salts often possess nitrogen fixing bacteria and cyanobacteria. Plants having symbiotic relationship with these bacteria also abound in the soils. Carnivorous plants meet their requirement of nitrogen by catching small insects, worms, etc. Salinity of ocean is overcome by many animals through salt secreting glands. Similar glands occur in halophytes or plants growing in saline soils and marshes.

Special adaptations are found in animals inhabiting estuaries where there are wide fluctuations in salt content. Areas having very high salt content are usually devoid of much vegetation, e.g., Dead Sea, Great Salt lake.