INTRODUCTION OF ECOLOGY

DEFINITION OF ECOLOGY

The traditional definition of ecology is '*the study of an organism and its environment*', however, different ecologists have defined it variously. **Ernst Haeckel** (1869) defined ecology as, *'the total relation of the animal to both its organic and its inorganic environment.'* In 1936, **Taylor** defined ecology as 'the *science of all the relations of all organisms to all their environments.'* **Charles Elton** (1947) in his pioneer book *Animal Ecology* defined ecology as *'scientific natural history.'* Although this definition does point out the origin of many of our ecological problems, yet it is much broad and vague like Haeckelian definition of ecology. **Allee** *et al.*, (1949), in their definition of ecology, clearly emphasize the all-encompassing character of this field of study. According to them ecology may be defined broadly as *'the science of the interrelation between living organisms and their environments, including both the physical and biotic environments, and emphasizing interspecies as well as intra-species relations.'* Though, **F.J. Vernberg** and **W.B. Vernberg** (1970) completely agree with **Allee** *et al's* definition, yet there are certain ecologists which are not satisfied with this definition and have provided their own definitions of ecology. For instance, **Andrewartha** (1961) defined ecology as *'the scientific study of the distribution and abundance of organisms.'* **G.A. Petrides** (1968) has defined ecology as *'the study of environmental interactions which control the welfare of living things, regulating their distribution, abundance, production and evolution.'* **Eugene Odum** (1963, 1969 and 1971) has defined ecology as '*the study of the structure and function of ecosystems*' or '*structure and*

Autecology and synecology

ecology, known as (iii) Habitat ecology.

[III] Based on levels of organisation

With such an approach to the ecology of area, units of study are either **individual organisms** or **groups of organisms.** Accordingly the other two, fourth and fifth subdivisions of ecology are (iv) **Autecology,** and (v) **Synecology,**

Autecology

This is also known as ecology of individuals, where we study the relation of individual species to its environment. Thus at a given time, emphasis is given on the requirements and reaction of an individual species together with the influence of environment upon it. With an autecological approach, individual species are the units of study. These are studied for details of their geographic distribution, morphology, taxonomic position and life-cycle etc., alongwith the various ecological factors which might influence different stages of their life cycles.

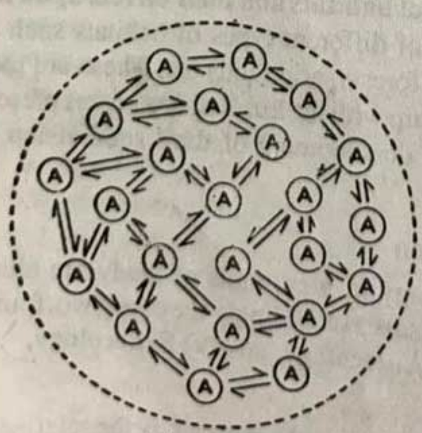
Synecology

Under natural conditions, however, organisms – plants, animals, microbes etc., live together as a natural group affecting each other's life in several ways. Thus, more complex situations exist where the units of study, instead of single organisms are groups of organisms known as a community. Such an approach where units of study are groups of organisms is called synecological approach.

Depending upon the conditions as these exist, synecology may deal with-

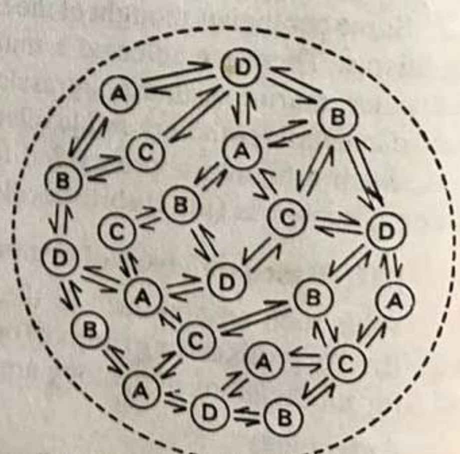
1. Population ecology. A recently developed field, where the units of study are pure stands of individuals of a single species - **population**. As a result of aggregation of these individuals, it becomes desirable to study the interdependencies between them, and the populations are studied in terms of their size, growth rates etc., which are chiefly governed by the interactions of the members of population (Fig. 2). Thus, population ecology is the study of such and other similar relationships of group of organisms. The main job of population ecologist is, "Why is this population of a particular density?" To answer this and other questions he studies **competition,** usually between population from the same trophic level (herbivores competing for same grass). Population ecology is also concerned with communities. A population ecologist also studies interactions between populations of different species in a community. For instance, study of prey-predator interactions between members of adjacent trophic levels of a community.

2. Community ecology. In contrast with population ecology, here the units of study are groups of individuals belonging to different species-plants as well as



population of species 'A'

Fig. 2. Diagrammatic sketch showing the population of species 'A' where its individuals interact with each other— **Population ecology.**



A community of four species A, B, C, D

Fig. 3. Diagrammatic sketch showing a community of four different species A, B, C & D interacting with each other—**Community ecology**

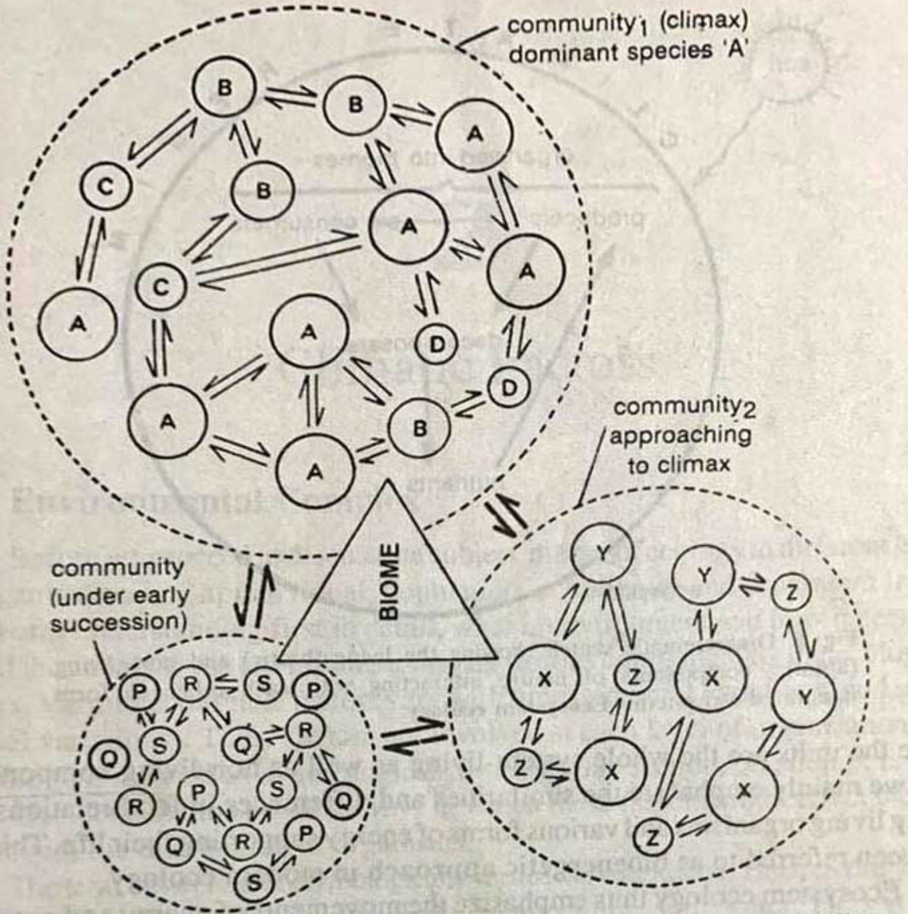


Fig. 4. Diagrammatic sketch showing a biome of three communities under different stages of development and interacting with each other—**Biome ecology.**

animals. The living (biotic) components of the community are studied mainly for the nature of interdependencies between individuals of different species (Fig. 3). Major concerns of community ecologist are, "Why is this community of a particular diversity? Why does a particular community occur at a given location? How communities interact and how these change through time?"

3. Biome ecology. In nature, we generally find that there may exist a complex of more than one communities, some in their climax stages and others in different stages of succession, and these all communities grow under more or less similar climatic conditions in an area. Thus in biomes, as units of study there are studied interactions between different communities of area (Fig. 4).

4. Ecosystem ecology. This has been the most recent development in ecology. It is established that not only living (biotic) but also non-living (abiotic) components of the nature interact with each other. These interacting biotic and abiotic components, then interact with each other to form an integrated system—**ecosystem** or **ecological complex** or **ecological system** (Fig. 5). Thus it becomes the most complicated synecological approach to the ecology of an area,

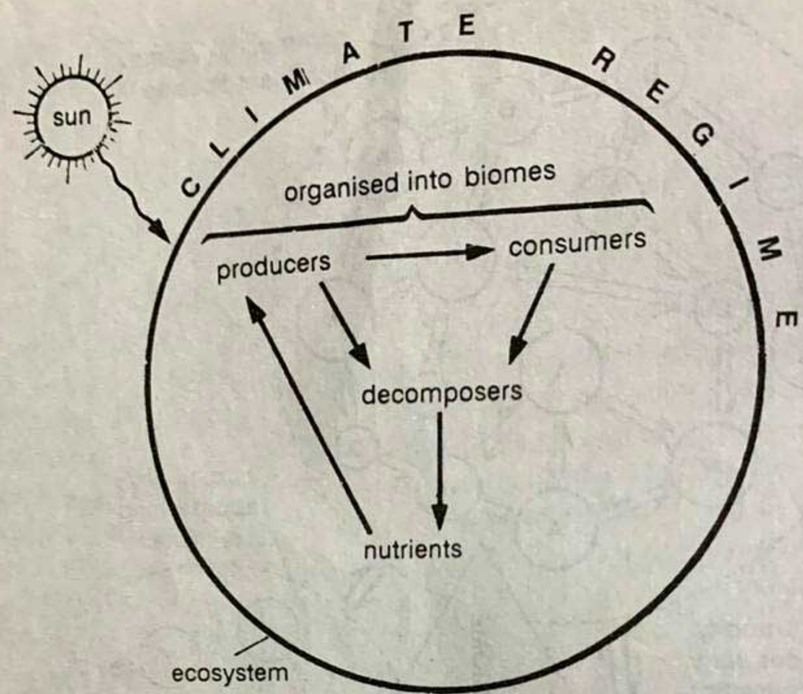


Fig. 5. Diagrammatic sketch showing the living (biotic) and non- living (abiotic) components of nature interacting with each other to form integrated ecosystem – **Ecosystem ecology.**

where the units are the whole system-living as well as non-living components. Here we mainly emphasize the similarities and differences in food relationships among living organisms and various forms of energy supporting their life. This has also been referred to as **bioenergetic approach** in modern ecology.

Ecosystem ecology thus emphasize the movements of energy and nutrients among the biotic and abiotic components of ecosystems. A major concern is, "How much and what rates are energy and nutrients being stored and transferred between components of an ecosystem?"

Questions

1. What is ecology? Give an account of phases of development of ecology in India.
2. What is ecosystem ecology? What are the different approaches to ecology based on levels of organisation of organisms?
3. Explain the following:
   (i) Autecology (ii) Synecology (iii) Population ecology.
4. Write short notes on :
   (i) Biosphere (ii)Ecosystem (iii) Communities

Ecosystem

9

Ecosystem : Structure and Function

Any ecological unit that includes all the organisms (*i.e.*, the communities in a given area) which interact among themselves and with the physical environment, so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycle (*i.e.*, exchange of materials) within the system, is known as **ecological system** or **ecosystem**. There exist nutritional relationships (or food links) amongst the living organisms of such a system. Keeping this in view, the earth can be considered as a giant ecosystem where abiotic and biotic components are constantly acting and reacting upon each other bringing forth structural and functional changes in it. This vast ecosystem — the **biosphere** is however, difficult to handle and, thus, for the sake of convenience, we generally study nature by making its artificial subdivisions into units of smaller ecosystems (such as **terrestrial** — forest, desert, grassland; **aquatic** — fresh water, marine; and **man-made** — cropland, etc.). An ecosystem may, thus, be as small as a single log, a pond, a cropland, or as large as an ocean, desert or forest. Though these unit ecosystems are separated from each other with time and space, but functionally they all are linked with each other, forming an integrated whole.

The term **ecosystem** was proposed by **A.G. Tansley** in 1935. There are many other parallel terms or synonyms for the ecosystem which have been proposed by various ecologists, *e.g.*, **biocoenonsis (Karl Mobius, 1877), microcosm (S.A. Forbes, 1887), holocoen (Friederichs, 1930), biosystem (Thienemann, 1939), geobiocoenosis (Sukhachev, 1944), bioenert body (Vernadsky, 1944)** and **ecosom**, etc.

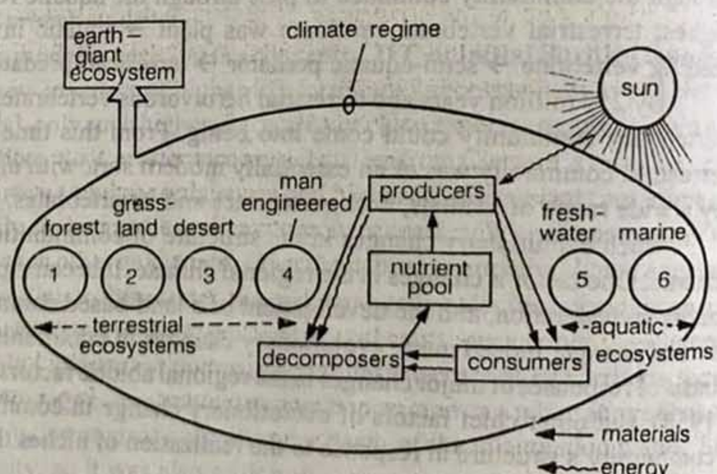


Fig. 9.1. Diagrammatic representation of the basic types of ecosystems all of which together constitute the giant ecosystem—the biosphere.

In recent years, ecological studies of ecosystems undertake besides structure, the similarities and differences in food and energy relationships among living components of ecosystem. This is called **bioenergetic approach** of modern ecology.

KINDS OF ECOSYSTEM

An ecosystem can be natural or artificial, temporary or permanent and large or tiny. Thus, various constituent ecosystems of the biosphere fall into the following categories :

1. Natural ecosystems. These types of ecosystems operate by themselves without any major interference by man. Based upon the particular kind of habitat, these are further classified as :

(i) Terrestrial ecosystems such as forests, grasslands, deserts, a single log, etc.

(ii) Aquatic ecosystems which may be further distinguished as follows :

(a) Fresh water ecosystems. These may be **lotic** (running water as spring, brook, stream or river) or **lentic** (standing water as lake, pond, pool, puddle, ditch, swamp, etc.).

(b) Marine ecosystems. These include salt water bodies which may be deep bodies as an ocean or shallow ones as a sea or estuary.

2. Artificial ecosystems. These are also called **man-made** or **man-engineered ecosystems.** These are maintained artificially by man where, by addition of energy and planned manipulations, natural balance is disturbed regularly, *e.g.*, croplands such as sugarcane, maize, wheat, rice-fields ; orchards, gardens, villages, cities, dams, aquarium and manned spaceship.

Microecosystems

Natural ecosystems are usually large in size. In them numerous variables (factors) operate at one time leading to great complexity. As a result, it becomes usually difficult to study them with the normal scientific methods. Thus, to reduce the number of variables and to work in a system with a discrete boundary, ecologists are trying to simulate microecosystems in the laboratory, which can be replicated and manipulated at will. The microsystems can be laboratory systems build by taking one or very few species, at a time, from axenic cultures (An **axenic culture** is a bacterial culture that consists of only one species) and studying them in desired combinations. Recently, the concept of polyaxenic cultures has been developed. **Odum** (1971) and others have elucidated the microecosystem concept.

STRUCTURE OF ECOSYSTEM

The structure of an ecosystem is basically a description of the species of organisms that are present, including information on their life histories, populations and distribution in space. It is a guide to who's who in the ecosystem. It also includes descriptive information on the non-living (physical) features of environment, including the amount and distribution of nutrients. An ecosystem typically has two major components :

A. Abiotic or Non-living Components

Abiotic component of the ecosystem comprises three sort of components : (1) **Climatic condition** and **physical factors** of the given region such as air, water, soil, temperature, light (*i.e.*, its duration and intensity), moisture (relative humidity), pH, etc. (2). **Inorganic substances** such as water, carbon (C), nitrogen (N), sulphur (S), phosphorus (P) and so on, all of which are involved in cycling of materials in the ecosystem (*i.e.*, biogeochemical cycles). The amount of these inorganic substances, present at any given time in an ecosystem, is designated as the **standing state** or **standing quality**. (3). **Organic substances** such as proteins, carbohydrates, lipids, humic substances, etc., present either in the biomass or in the environment, *i.e.*, **biochemical structure** that link the biotic and abiotic components of the ecosystem.

B. Biotic or Living Components

In the trophic structure of any ecosystem, living organisms are distinguished on the basis of their nutritional relationships, which are discussed as follows :

1. Autotrophic component. Autotrophic (*auto* = self ; *trough* = nourishing) component of ecosystem includes the **producers** or **energy transducers** which convert solar energy into chemical energy (that becomes locked in complex organic substances such as carbohydrate, lipid, protein, etc.) with the help of simple inorganic substances such as water and carbon dioxide and organic substances such as enzymes. Autotrophs fall into following two groups : (i) **photoautotrophs** which contain green photosynthetic pigment **chlorophyll** to transduct the solar or light energy of sun, *e.g.*, trees, grasses, algae, other tiny phytoplanktons and photosynthetic bacteria and cyanobacteria (=blue green algae). (ii) **Chemoautotrophs** which use energy generated in oxidation - reduction process, but their significance in the ecosystem as producers is minimal, *e.g.*, microorganisms such as *Beggiatoa*, sulphur bacteria, etc.

2. Heterotrophic component. In the heterotrophic (*hetero* = other; *trophic* = nourishing) organisms predominate the activities of utilization, rearrangement and decomposition of complex organic materials. Heterotrophic organisms are also called **consumers**, as they consume the matter built up by the producers (autotrophs). The consumers are of following two main types :

(a) Macroconsumers. These are also called **phagotrophs** (phago = to eat) and include mainly animals which ingest other organisms or chunks of organic matter. Depending on their food habits, consumers may either be **herbivores** (plant eaters) or **carnivores** (flesh eaters). Herbivores live on living plants and are also known as **primary consumers**, *e.g.*, insects, zooplanktons and animals such as deer, cattle, elephant, etc. **Secondary** and **tertiary consumers**, if present in the food chain of the ecosystem, are carnivores or omnivores, *e.g.*, insects such as preying mantis, dragon flies; spiders and large animals such as tiger, lion, leopard, wolf, etc. Secondary consumers are the carnivores which feed on primary consumers or herbivores. Carnivores are, often, recognized as carnivore order - 1 (C_1), carnivore order - 2 (C_2) and so on, depending on their food habits.

Ticks and mites, leeches and blood-sucking insects (mosquito, bed-bug) are dependent on herbivores, carnivores and omnivores.

(b) Microconsumers. These are also called **decomposers, reducers, saprotrophs** (*sapro* = decompose), **osmotrophs** (osmo = to pass through a membrane) and **scavengers**. **Wiegert** and **Owen** (1971) have coined the term, **biophages** for heterotrophic decomposers which feed on the dead organic matter. Microconsumers include microorganisms such as bacteria, actinomycetes and fungi. Microconsumers breakdown complex organic compounds of dead or living protoplasm, absorb some of the decomposition or breakdown products and release inorganic nutrients in the environment, making them available again to autotrophs or producers. Some invertebrate animals such as protozoa, oligochaeta such as earthworms, etc., use the dead organic matter for their food, as they have the essential enzymes and, hence, can be classified as decomposer organisms. Some ecologists believe that microorganisms are **primary decomposers**, while invertebrates are **secondary decomposers**.

The disintegrating dead organic matter is also known as **organic detritus** (Latin word *deterere* means to wear away). By the action of **detritivores** (=decomposers), the disintegrating detritus result into particulate organic matter (POM) and dissolved organic matter (DOM) which play important role in the maintenance of the edaphic environment.

EXAMPLE OF ECOSYSTEM

A pond as a whole serves as a good example of an aquatic and freshwater ecosystem (Fig. 9.2). In fact, it represents a self-sufficient and self-regulating system. It has following components :

1. Abiotic Component

The chief non-living or abiotic substances are heat, light, pH value of water, and the basic inorganic and organic compounds, such as water itself, carbon dioxide gas, oxygen gas, calcium, nitrogen, phosphates, amino acids, humic acid, etc. Inorganic salts occur in the form of phosphates, nitrates and chlorides of sodium, potassium and calcium. Some proportion of nutrients exist in solution state but most of them are present as stored in particulate matter as well as in living organisms.

2. Biotic Component

It includes various organisms which are classified into the following types :

(a) Producers. These are photoautotrophic green plants and photosynthetic bacteria. The producers fix radiant energy of sun and with the help of minerals derived from water and mud, they manufacture complex organic substances as carbohydrates, proteins and lipids. Producers of pond are of following types :

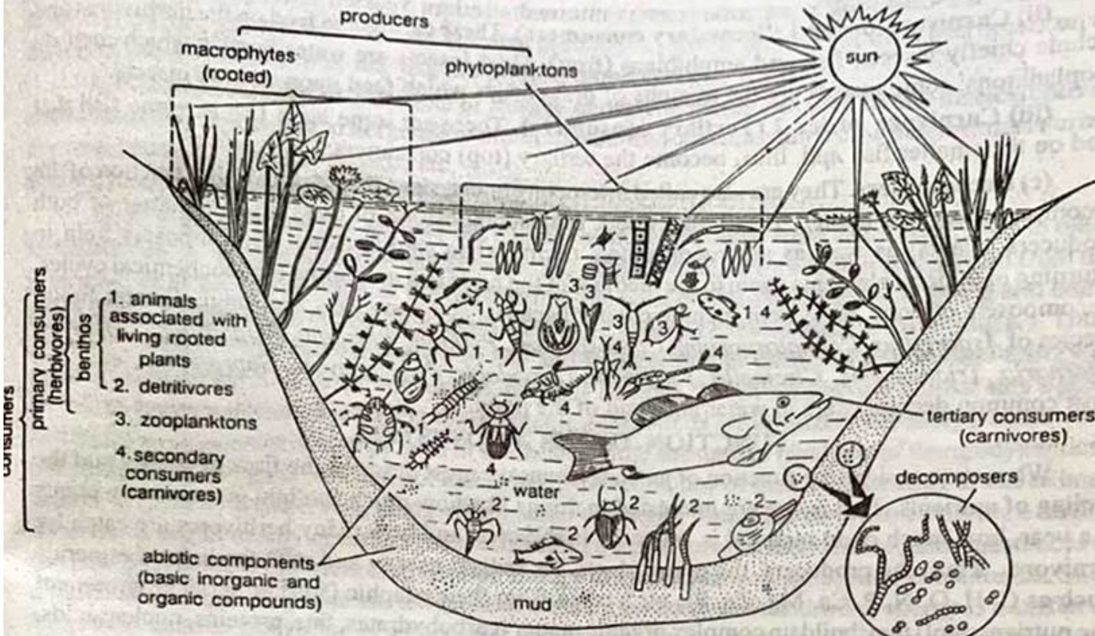


Fig. 9.2. A pond ecosystem showing its basic structural units – the abiotic (inorganic and organic compounds) and biotic (producers, and consumers – herbivores, carnivores and decomposers) components.

(i) Macrophytes. These include mainly the rooted large-sized plants which comprise three types of hydrophytes : partly or completely submerged, floating and emergent aquatic plants. The common plants are species of *Trapa, Typha, Eleocharis, Sagittaria, Nymphaea, Potamogeton, Chara, Hydrilla, Vallisneria, Utricularia, Marsilea, Nelumbo*, etc. Besides these plants, some free floating forms also occur in the pond ecosystem, *e.g., Azolla, Salvinia, Wolffia, Eichhornia, Spirodella, Lemna*, etc.

(ii) Phytoplanktons. These are microscopic (minute), floating or suspended lower plants (algae) that are distributed throughout the water, but mainly in the photic zone. Most of them are filamentous algae such as *Spirogyra, Ulothrix, Zygnema, Cladophora* and *Oedogonium*. There also occur some chlorococcales (*e.g., Chlorella*), *Closterium, Cosmarium, Eudorina, Pandorina, Pediastrum, Scendesmus, Volvox*, Diatoms, *Anabaena, Gloeotrichia, Microcystis, Oscillatoria, Chlamydomonas, Spriulina*, etc., and some flagellates.

(b) Macroconsumers. They are phagotrophic heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Macroconsumers are of following three types :

(i) Herbivores (Primary consumers). These animals feed directly on living plants (producers) or plant remains. They may be large or minute in size and are of following two types : 1. **Benthos** which are the bottom dwelling forms such as fish, insect larvae, beetles, mites, molluscs (*e.g., Pila, Planorbis, Unio, Lamellidens*, etc.), crustaceans, etc. 2. **Zooplanktons** which feed chiefly on phytoplanktons and are chiefly the rotifers as *Brachionus, Asplanchna, Lecane*, etc., although some protozoans as *Euglena, Coleps, Dileptus*, etc., and crustaceans such as *Cyclops, Stenocypris*, etc., are also present in the pond.

Besides these small-sized herbivores, some mammals such as cow, buffaloes, etc., also visit the pond casually and feed on marginal rooted macrophytes. Some birds also regularly visit the pond to feed on some hydrophytes.

(ii) Carnivore order-1 (Secondary consumers). These carnivores feed on the herbivores and include chiefly insects, fish and amphibians (frog). Most insects are water beetles which feed on zooplanktons; some insects are the nymphs of dragonflies which feed upon aquatic insects.

(iii) Carnivore order-2 (Tertiary consumers). These are some large fish as game fish that feed on the smaller fish and, thus, become the tertiary (top) consumers.

(c) Decomposers. They are also called microconsumers, since they absorb only a fraction of the decomposed organic matter. They bring about the decomposition of dead organic matter of both producers (plants) as well as macroconsumers (animals) to simple forms. Decomposers help in returning of mineral elements again to the medium of the pond and in running biogeochemical cycles. Decomposers of pond ecosystem include chiefly bacteria, actinomycetes and fungi. Among fungi, species of *Aspergillus, Cephalosporium, Cladosporium, Pythium, Rhizopus, Penicillium, Thielavia, Alternaria, Trichoderms, Circinella, Fusarium, Curvularis, Paecilomyces, Saprolegnia,* etc., are most common decomposers in water and mud of the pond.

FUNCTION OF AN ECOSYSTEM

When we consider the function of an ecosystem, we must describe the flow of energy and the cycling of nutrients. That is, we are interested in things like how much sunlight is trapped by plants in a year, how much plant material is eaten by herbivores, and how many herbivores are eaten by carnivores. Thus, the producers, the green plants, fix radiant energy and with the help of minerals (such as C, H, O, N, P, Ca, Mg, Zn, Fe, etc.) taken from their edaphic (soil) or aerial environment (the nutrient pool) they build up complex organic matter (carbohydrates, fats, proteins, nucleic acids, etc.). Some ecologists prefer to refer to the green plants as **converters** or **transducers**, since in their view, the most popular and prevalent term 'producer' from energy view point is somewhat misleading. Their view point is that green plants produce carbohydrates and not energy and since they convert or transduce radiant energy into chemical form, they must be better called **converters or transducers**. The two ecological processes of energy flow and mineral cycling involving interaction between the physico-chemical environment and the biotic communities, may be considered the 'heart' of ecosystem dynamics. In an ecosystem, energy flows in non-cyclic manner (**unidirectional**) from sun to the decomposers via producers and macroconsumers (herbivores and carnivores), whereas the minerals keep on moving in a cyclic manner.

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FOOD CHAIN IN ECOSYSTEM

year basis.

Food chains in ecosystems

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) with repeated eating and being eaten, is known as a **food chain.** Producers utilise the radiant energy of sun which is transformed to chemical form, ATP during photosynthesis. Thus green plants occupy, in any food chain, the first trophic (nutritional) level – the producers level, and are called the **primary producers.** The energy, as stored in food matter manufactured by green plants, is then utilised by the plant eaters-the

herbivores, which constitute the second trophic level – the primary consumers level, and are called the **primary consumers** (herbivores). Herbivores in turn are eaten by the carnivores, which constitute the third trophic level-the secondary consumers level, and are called the **secondary consumers** (carnivores). These in turn may be eaten still by other carnivores at tertiary consumers level i.e. by the **tertiary consumers** (carnivores). Some organisms are omnivores eating the

In nature, we generally distinguish two ...

1. **Grazing food chain.** This type of food chain starts from the **living** green plants, goes to grazing herbivores (that feed on living plant materials with their predators), and on to carnivores (animal eaters). Ecosystems with such type of food chain are directly dependent on an influx of solar radiation. This type of chain thus depends on autotrophic energy capture and the movement of this captured energy to herbivores. Most of the ecosystems in nature follow this type of food chain. From energy standpoint, these chains are very important. The phytoplanktons – zooplanktons – fish sequence or the grasses – rabbit – fox sequence are the examples of grazing food chain.

2. **Detritus food chain.** This type of food chain goes from **dead** organic matter into microorganisms and then to organisms feeding on detritus (detritivores) and their predators. Such ecosystems are thus less dependent on direct solar energy. These depend chiefy on the influx of organic matter produced in another system. For example, such type of food chain operates in the decomposing accumulated litter in a temperate forest. A good example of a detritus food chain is based on mangrove leaves described by Heald (1969) and W.E. Odum (1970). In the brackish zone of Southern Florida, leaves of the red mangrove – *Rhizophora mangle* fall into the warm, shallow waters. Only 5% of the leaf material was removed by grazing insects before leaf fall. As shown in Figure 7 A the fallen leaf

fragments (acted on by such saprotrophs as fungi, bacteria, protozoa etc. and colonized mainly by phytoplanktonic and benthic algae) are eaten and re-eaten (coprophagy) by a key group of small animals. These animals include crabs, copepods, insect larvae, grass shrimps, mysids, nematodes, amphipods, bivalve molluscs etc. All these animals are **detritus consumers.** These detritivores are the key group of small animals, comprising only a few species but very large number of individuals. They ingest large amounts of the vascular plant detritus. These animals are in turn eaten by some minnows and small game fish etc. i.e. the **small carnivores,** which in turn serve as the main food for larger game fish and fish eating birds which are the large (**top**) **cornivores**. The mangroves considered generally as of less economic value make a substantial contribution to the food chain that supports the fisheries, an important economy in that region. Similarly, detritus from seagrasses, saltmarsh grasses and seaweeds support fisheries in many estuarine areas.

FOOD WEBS- INTERLOCKING PATTERN OF ORGANISM

Food webs – interlocking pattern of organisms

However, food chains in natural conditions never operate as isolated sequences, but are interconnected with each other forming some sort of interlocking pattern, which is referred to as a **food web.** Under natural conditions, the linear arrangement of food chains, hardly occurs and these remain indeed interconnected with each other through different types of organisms at different trophic levels. For example, in grazing food chain of a grassland, in the absence of rabbit, grass may also be eaten by mouse. The mouse in turn may be eaten directly by hawk or by snake first which is then eaten by hawk. Thus, in nature there are found **alternatives**.which all together constitute some sort of interlocking pattern – the **food web.**

In such a food web in grassland, as shown in Figure 8, there may be seen as many as **five** linear food chains, which in sequences are:

(1) Grass→Grasshopper→Hawk
(2) Grass→Grasshopper→Lizard→Hawk
(3) Grass→Rabbit→Hawk (or vulture or fox or even man, if present)
(4) Grass→Mouse→Hawk
(5) Grass→Mouse→Snake-Hawk

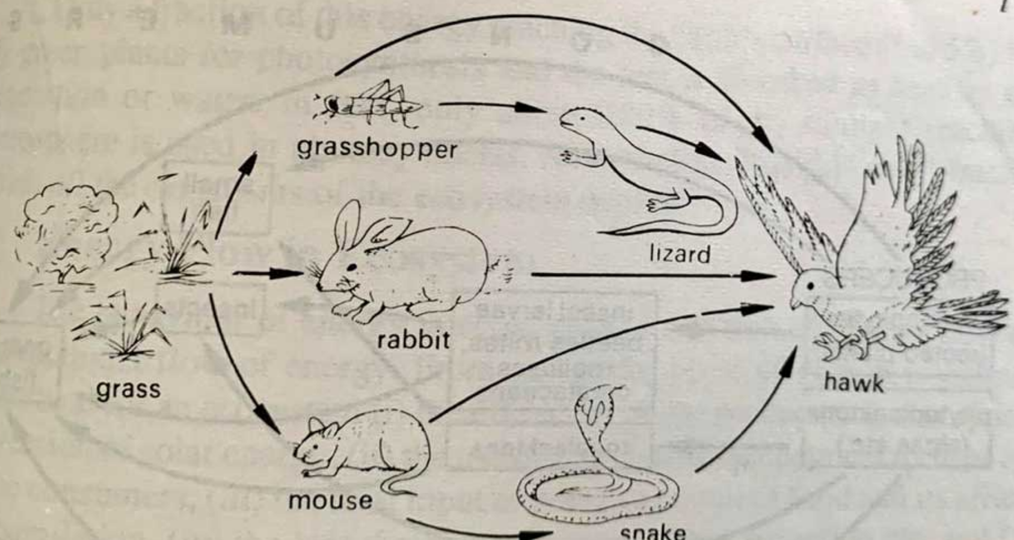

Fig. 8. Diagrammatic sketch showing a food web in a grassland ecosystem. There may be seen five possible food chains interlocked together making the food web.

ECOLOGICAL PYRAMID

ECOLOGICAL PYRAMIDS

In the successive steps of grazing food chain–photosynthetic autotroph, herbivorous heterotroph, carnivores heterotroph, decay bacteria–the number and mass of the organisms in each step is limited by the amount of energy available. Since some energy is lost as heat, in each transformation the steps become progressively smaller near the top. This relationship is sometimes called **"ecological pyramid"**. The ecological pyramids represent the trophic structure and also trophic function of the ecosystem. In many ecological pyramids, the producer form the base and the successive trophic levels make up the apex.

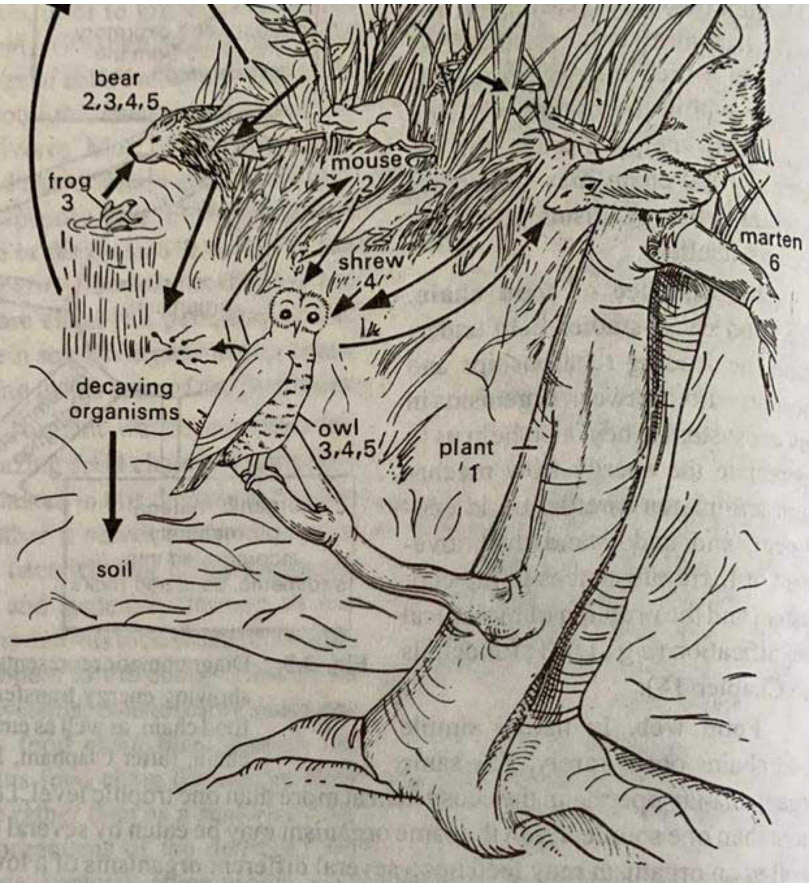

Fig. 9.6. Food web showing 1–6 trophic levels : 1–Plants ; 2–Grasshopper, mouse and bear ; 3–Praying mantis, frog, owl and bear ; 4–Owl, shrew and bear ; 5–Owl and bear ; 6–Marten.

Thus, communities of terrestrial ecosystems and shallow water ecosystems contain gradually sloping ecological pyramids because these producers remain large and characterized by an accumulation of organic matter. This trend, however, does not hold for all ecosystems. In such aquatic ecosystems as lakes and open sea, primary production is concentrated in the microscopic algae. These algae have a short-cycle, multiply rapidly, accumulate little organic matter and are heavily exploited by herbivorous zooplankton. At any one point in time the standing crop is low. As a result, the pyramid of biomass for these aquatic ecosystems is inverted: the base is much smaller than the structure it supports.

Types of Ecological Pyramids

The ecological pyramids may be of following three kinds :

1. Pyramid of number. It depicts the number of individual organisms at different trophic levels of food chain. This pyramid was advanced by **Charles Elton** (1927), who pointed out the great difference in the number of the organisms involved in each step of the food chain. The animals at the lower end (base of pyramid) of the chain are the most abundant. Successive links of carnivores decrease rapidly in number until there are very few carnivores at the top. The pyramid of number ignores the biomass of organisms and it also does not indicate the energy transferred or the use of energy by the groups involved. The lake ecosystem provides a typical example for pyramid of number.

2. Pyramid of biomass. The biomass of the members of the food chain present at any one time forms the pyramid of the biomass. Pyramid of biomass indicates decrease of biomass in each trophical level from base to apex. For example, the total biomass of the producers ingested by herbivores is more than the total biomass of the herbivores in an ecosystem. Likewise, the total biomass of the primary carnivores (or secondary consumer) will be less than the herbivores and so on.

3. Pyramid of energy. When production is considered in terms of energy, the pyramid indicates not only the amount of energy flow at each level, but more important, the actual role the various organisms play in the transfer of energy. The base upon which the pyramid of energy is constructed is the quantity of organisms produced per unit time, or in other words, the rate at which food material passes through the food chain. Some organisms may have a small biomass, but the total energy they assimilate and pass on, may be considerably greater than that of organisms with a much larger biomass. Energy pyramids are always slopping because less energy is transferred from each level than was paid into it. In cases such as in open water communities the producers have less bulk than consumers but the energy they store and pass on must be greater than that of the next level. Otherwise the biomass that producers support could not be greater than that of the producers themselves. This high energy flow is maintained by a rapid turn over of individual plankton, rather than an increase of total mass.

ECOLOGICAL SUCCESSION

Ecological succession (primary, secondary, autogenic, allogenic). Vegetation is hardly stable, and thus dynamic, changing over time and space. Although comparatively less evident than vegetation, animal populations, particularly lower forms, also show dynamic character to some extent. Succession is a natural process by which different groups or communities colonize the same area over a period of time in a definite sequence. The succession, which starts from a primitive substratum without any previous living matter, is known as the **primary succession**, whereas that starting from previously built up substratum where living matter already exists, is known as the **secondary succession.** If the existing community, as a result of its reaction with the environment, causes its own replacement, such a succession is known as **autogenic succession** but if the eplacement of the existing community takes place due to the influence of any xternal force, condition etc., such course is known as the **allogenic succession.**

Types of Succession

Basic Types of Succession

The various types of succession have been grouped in different ways on the basis of different aspects. Some basic types of succession are, however, as follows:

1. Primary succession. In any of the basic environments (terrestrial, fresh water, marine), one type of succession is **primary succession** which starts from the primitive substratum, where there was no previously any sort of living matter. The first group of organisms estabilishing there are known as the **pioneers**, **primary community** or **primary colonisers**.

2. Secondary succession. Another general type of succession is **secondary succession** which starts from previously built up substrata with already existing living matter. The action of any external force, as a sudden change in climatic factors, biotic intervention, fire etc., causes the existing community to disappear. Thus, area becomes devoid of living matter but its substratum, instead of primitive, is built up. Such successions are comparatively more rapid.

3. Autogenic succession. After the succession has begun, in most of the cases, it is the community itself which, as a result of its reactions with the environment, modifies its own environment and thus causing its own replacement by new communities. This course of succession is known as **autogenic succession.**

4. Allogenic succession. In some cases, however, the replacement of the existing community is caused largely by any other external condition and not by the existing organisms. Such a course is referred to as **allogenic succession.**

On the basis of successive changes in nutritional and energy contents, successions are sometimes classified as :

5. Autotrophic succession. It is characterised by early and continued dominance of autotrophic organisms like green plants. It begins in a predominantly inorganic environment and the energy flow is maintained indefinitely. There is gradual increase in the organic matter content supported by energy flow.

6. Heterotrophic succession. It is characterised by early dominance of heterotrophs, such as bacteria, actinomycetes, fungi and animals. It begins in a predominantly organic environment, and there is a progressive decline in the energy content.

In ecological literature, there are mentioned still so many other kinds of succession, depending mainly upon the nature of the environment (primarily based upon moisture relations), where the process has begun, and thus it may be a **hydrosere or hydrarch** – starting in regions where water is in plenty, as ponds, lakes, streams, swamp, bog, etc; a **mesarch** – where adequate moisture conditions are present; and a **xerosere** or **xerarch** – where moisture is present in minimal amounts, such as dry deserts, rocks etc. Sometimes, there are further distinguished, the **lithosere** – initiating on rocks, **psammosere** – on sand and **halosere** – in saline water or soil.

General process of succession

Genertal Process of Succession

The whole process of a primary autotrophic succession is actually completed through a number of sequential steps, which follow one another. These steps in sequence are as follows :

[I] Nudation

This is the development of a bare area without any form of life. The area may develop due to several causes such as landslide, erosion, deposition, or other catastrophic agency. The cause of nudation may be :

1. Topographic. Due to soil erosion by gravity, water or wind, the existing community may disappear. Other causes may be deposition of sand etc., landslide, volcanic activity and other factors.

2. Climatic. Glaciers, dry period, hails and storm, frost, fire etc. may also destroy the community.

3. Biotic. Man is most important, responsible for destruction of forests, grasslands for industry, agriculture, housing etc. Other factors are disease epidemics due to fungi, viruses etc. which destroy the whole population.

[II] Invasion

This is the successful establishment of a species in a bare area. The species actually reaches this new site from any other area. This whole process is completed in following three successive stages :

1. Migration (dispersal). The seeds, spores, or other propagules of the species reach the bare area. This process, known as **migration**, is generally brought about by air, water, etc.

2. Ecesis (establishment). After reaching to new area, the process of successful establishment of the species, as a result of adjustment with the conditions prevailing there, is known as **ecesis**. In plants, after migration, seeds or propagules germinate, seedlings grow, and adults start to reproduce. Only a few of them are capable of doing this under primitive harsh conditions, and thus most of them disappear. Thus as a result of ecesis, the individuals of species become established in the area.

3. **Aggregation**. After ecesis, as a result of reproduction, the individuals of the species increase in number, and they come close to each other. This process is known as **aggregation.**

[III] Competition and coaction

After aggregation of a large number of individuals of the species at the limited place, there develops **competition** (inter-as well as intraspecific) mainly for space and nutrition. Individuals of a species affect each other's life in various ways and this is called **coaction**. The species, if unable to compete with other species, if present, would be discarded. To withstand competition, reproductive capacity, wide ecological amplitude etc. are of much help to the species.

[IV] Reaction

This is the most important stage in succession. The mechanism of the modification of the environment through the influence of living organisms on it, is known as **reaction**. As a result of reactions, changes take place in soil, water, light conditions, temperature etc. of the environment. Due to all these the environment is modified, becoming unsuitable for the existing community which sooner or later is replaced by another community (seral community). The whole sequence of communities that replaces one another in the given area is called a **sere**, and various communities constituting the sere, as **seral communities, seral stages** or **developmental stages**. The pioneers are likely to have low-nutrient requirements, more dynamic and able to take minerals in comparatively more complex forms. They are small-sized and make less demand from environment.

[V] Stabilization (climax)

Finally, there occurs a stage in the process, when the final terminal community becomes more or less stabilised for a longer period of time and it can maintain itself in equilibrium with the climate of the area. This final community is not replaced, and is known as **climax community** and the stage as **climax stage.**

Example of ecosystem - pond ecosystem

EXAMPLE OF ECOSYSTEM

A pond as a whole serves as a good example of an aquatic and freshwater ecosystem (Fig. 9.2). In fact, it represents a self-sufficient and self-regulating system. It has following components :

1. Abiotic Component

The chief non-living or abiotic substances are heat, light, pH value of water, and the basic inorganic and organic compounds, such as water itself, carbon dioxide gas, oxygen gas, calcium, nitrogen, phosphates, amino acids, humic acid, etc. Inorganic salts occur in the form of phosphates, nitrates and chlorides of sodium, potassium and calcium. Some proportion of nutrients exist in solution state but most of them are present as stored in particulate matter as well as in living organisms.

2. Biotic Component

It includes various organisms which are classified into the following types :

(a) Producers. These are photoautotrophic green plants and photosynthetic bacteria. The producers fix radiant energy of sun and with the help of minerals derived from water and mud, they manufacture complex organic substances as carbohydrates, proteins and lipids. Producers of pond are of following types :

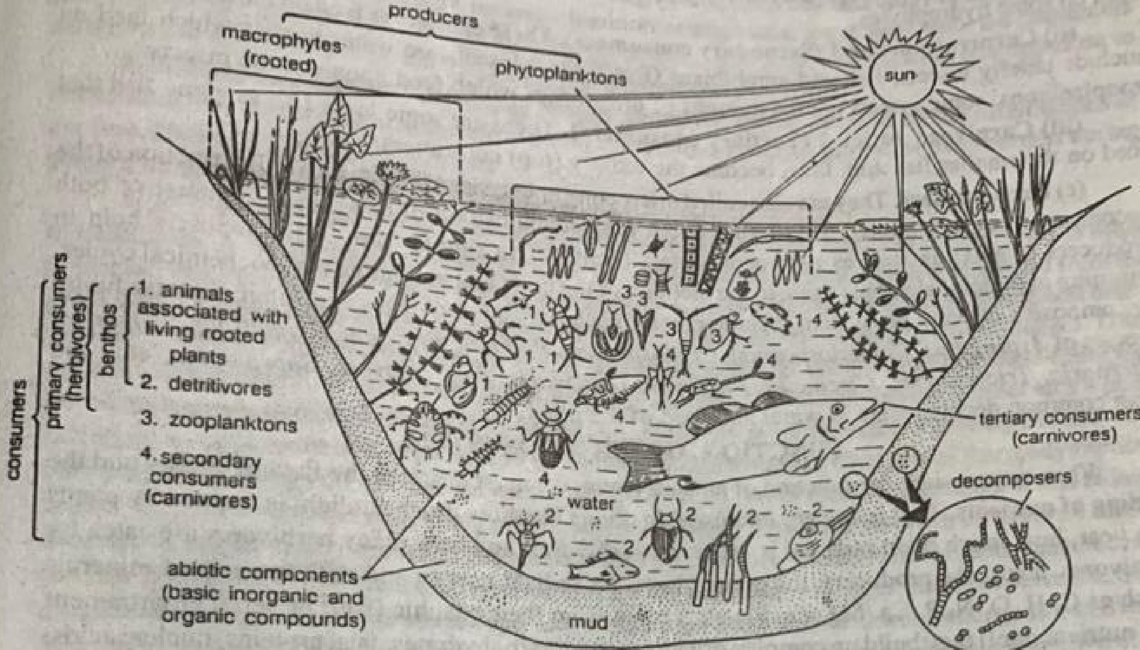

Fig. 9.2. A pond ecosystem showing its basic structural units – the abiotic (inorganic and organic compounds) and biotic (producers, and consumers – herbivores, carnivores and decomposers) components.

(i) Macrophytes. These include mainly the rooted large-sized plants which comprise three types of hydrophytes : partly or completely submerged, floating and emergent aquatic plants. The common plants are species of *Trapa, Typha, Eleocharis, Sagittaria, Nymphaea, Potamogeton, Chara, Hydrilla, Vallisneria, Utricularia, Marsilea, Nelumbo,* etc. Besides these plants, some free floating forms also occur in the pond ecosystem, *e.g., Azolla, Salvinia, Wolffia, Eichhornia, Spirodella, Lemna,* etc.

(ii) Phytoplanktons. These are microscopic (minute), floating or suspended lower plants (algae) that are distributed throughout the water, but mainly in the photic zone. Most of them are filamentous algae such as *Spirogyra, Ulothrix, Zygnema, Cladophora* and *Oedogonium.* There also occur some chlorococcales (*e.g., Chlorella*), *Closterium, Cosmarium, Eudorina, Pandorina, Pediastrum, Scendesmus, Volvox,* Diatoms, *Anabaena, Gloeotrichia, Microcystis, Oscillatoria, Chlamydomonas, Spriulina,* etc., and some flagellates.

(b) Macroconsumers. They are phagotrophic heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Macroconsumers are of following three types :

(i) Herbivores (Primary consumers). These animals feed directly on living plants (producers) or plant remains. They may be large or minute in size and are of following two types : 1. **Benthos** which are the bottom dwelling forms such as fish, insect larvae, beetles, mites, molluscs (*e.g., Pila Planorbis, Unio, Lamellidens,* etc.), crustaceans, etc. 2. **Zooplanktons** which feed chiefly on phytoplanktons and are chiefly the rotifers as *Brachionus, Asplanchna, Lecane,* etc., although some protozoans as *Euglena, Coleps, Dileptus,* etc., and crustaceans such as *Cyclops, Stenocypris,* etc., are also present in the pond.

Besides these small-sized herbivores, some mammals such as cow, buffaloes, etc., also visit the pond casually and feed on marginal rooted macrophytes. Some birds also regularly visit the pond to feed on some hydrophytes.

(ii) Carnivore order-1 (Secondary consumers). These carnivores feed on the herbivores and include chiefly insects, fish and amphibians (frog). Most insects are water beetles which feed on zooplanktons; some insects are the nymphs of dragonflies which feed upon aquatic insects.

(iii) Carnivore order-2 (Tertiary consumers). These are some large fish as game fish that feed on the smaller fish and, thus, become the tertiary (top) consumers.

(c) Decomposers. They are also called microconsumers, since they absorb only a fraction of the decomposed organic matter. They bring about the decomposition of dead organic matter of both producers (plants) as well as macroconsumers (animals) to simple forms. Decomposers help in returning of mineral elements again to the medium of the pond and in running biogeochemical cycles. Decomposers of pond ecosystem include chiefly bacteria, actinomycetes and fungi. Among fungi, species of *Aspergillus, Cephalosporium, Cladosporium, Pythium, Rhizopus, Penicillium, Thielavia, Alternaria, Trichoderms, Circinella, Fusarium, Curvularis, Paecilomyces, Saprolegnia*, etc., are most common decomposers in water and mud of the pond.

Forest ecosystem

Forest Ecosystem

Forests occupy roughly 40 per cent of the land. In India, the forests occupy roughly one-tenth of the total land area. The different components of a forest ecosystem, like others, are as follows:

Abiotic component

These are the inoganic as well as organic substances present in the soil and atmosphere. In addition to the minerals present in forests we find the dead organic debris – the litter accumulation, chiefly in temperate climate. Moreover, the light conditions are different due to complex stratification in the plant communities.

Biotic component

The living organisms present in the food chain occur in the following order:

1. Producers. These are mainly trees that show much species diversity and greater degree of stratification especially in tropical moist deciduous forests. The trees are of different kinds depending upon the kind of the forest formation developing in that climate. Besides trees, there are also present shrubs and a ground vegetation. In these forests, dominant members of the flora, the producers, are such trees as *Tectona grandis, Butea frondosa, Shorea rubusta* and *Lagerstroemia parvifiora*. In temperate coniferous forests, shrubs and ground flora are insignificant. In temperate deciduous forests the dominant trees are species of *Quercus, Acer, Betula, Thuja, Picea* etc., whereas in a temperate coniferous forests, the producer trees are species of *Abies, Picea, Pinus, Cedrus, Juniperus Rhododendron* etc.

2. Consumers. These are as follows:

(a) Primary consumers. These are the herbivores that include the animals feeding on tree leaves as ants, flies, beetles, leafhoppers, bugs and spiders etc., and larger animals grazing on shoots and/or fruits of the producers, the elephants, nilgai, deer, moles, squirrels, shrews, flying foxes, fruit bats, mongooses etc.

(b) Secondary consumers. These are the carnivores like snakes, birds, lizards, fox etc. feeding on the herbivores.

(c) Tertiary consumers. These are the top carnivores like lion, tiger etc. that eat carnivores of secondary consumers level.

3. Decomposers. These are wide variety of microoganisms including fungi (species of *Aspergillus, Coprinus, Polyporus, Ganoderma, Fusarium, Alternaria, Trichoderma* etc.), bacteria (species of *Bacillus, Clostridium, Pseudomonas, Angiococcus* etc.), and actinomycetes, like species of *Streptomyces* etc. Rate of decomposition in tropical and subtropical forests is more rapid than that in the temperate ones.

Crop land ecosystem

Cropland Ecosystem

The ecosystems, described so far, are natural in the sense that they all operate as self-regulating systems without much direct interference and manipulations by man. However, in nature we also find another kind of ecosystems, where man is very much involved in their operation. These are the cropland ecosystems, that are artificial or man-engineered, where, in order to obtain more food, cloth, timber, medicines and other useful products, man becomes responsible for the replacement of natural systems. To secure maximum production, man makes much planned manipulations in the physico-chemical environment. These include addition of fertilisers to soil, use of chemicals for disease control, proper irrigation practices etc. Thus, a cropland ecosystem is an artificial system aimed primarily to grow a single species of one's choice. We have ecosystems of dominant crop species like wheat, maize, jowar, paddy, sugarcane, vegetable etc. under most suitable conditions of their growth and yield. It is generally argued that in a natural ecosystem, the nature maximizes for gross production, whereas in an artificial ecosystem, man maximizes for net production. In a cropland ecosystem, there is not necessarily an increase in the total dry matter production of the **whole plants,** but generally most of the production goes into grain and less into leaves, stems and roots. Thus, in agriculture (where all the systems are artificial), there is an objective to achieve high **rates of production** (P) of readily harvestable products with little **standing crop** (biomass – B) left in the field for accumulation, or we may say that there is a high P/B efficiency. Nature (natural ecosystem), on the other hand, follows just a reverse efficiency--i.e. a high B/P ratio, where the standing crop is generally accumulated to its maximum. The following are the chief components of a maize cropland ecosystem.

Abiotic component

These include the climatic conditions of the region, where the crop may grow most successfully, and the various minerals particularly C, H, O, N, P, K in soil and atmosphere. In such field man generally makes additions of a number of chemical fertilisers to soil. Maize generally grows best in slightly alkaline soil with good aeration.

Biotic component

The various living organisms in the food chain occur as follows:

1. **Producers.** The dominant plant species would naturally be *Zea mays.* Besides maize, a number of weeds like *Cynodon dactylon, Launaea nudicaulis, Euphorbia hirta, Cyperus rotundus, Digitaria* spp. and *Alysicarpus* sp. also contribute to primary production of the field.

2. **Consumers.** These are ***(a) Primary consumers.*** These are the herbivores represented by a variety of animals, big as well as small. The smaller animals include chiefly the insects as aphids, thrips, beetles etc. which feed and lay their eggs on maize leaves. Larger animals are rabbits, rats, birds and man feeding on leaves, flower and fruits of maize.

*(b) **Secondary consumers.*** These are carnivores like frogs and some birds that eat insect.

*(c) **Tertiary consumers.*** These are carnivores like snakes and hawks which feed on the secondary consumers, frogs and smaller birds.

3. Decomposers. These are microbes present in soil as well as air, that decompose the dead organic matter of plants and animals. These are chiefly bacteria, actinomycetes and fungi, responsible for decay, decomposition and humification, making the minerals available again to the producers.