5.

ECOSYSTEM

Meaning and Definition

The earth and its various parts *viz* land, water bodies, atmosphere and living organisms function an integrated system that determines the pattern of life. This system is known as ecosystem or ecological system. The biosphere is a giant ecosystem, within which several smaller ecosystems exist.

The idea of ecosystem is by no means so recent, as allusions to the idea of unity of organisms and environment can be traced back to late 1880s. We find parallel terms *e.g.* 'biocoenosis' (Karl Mobius—1877), 'microcosm' (S.A. Forbes—1887), 'geo-biocoenosis' (V.V. Dokuchaev—1846-1903), 'holocoen' (Friederichs—1930), 'biosystem' (Thienemann—1939), and 'eco cosm' etc.

The term 'ecosystem' was coined by **A.G. Tansley** in 1935, who defined it as "the system resulting from the integration of all the living and non-living factors of the environment." He further stated that "the whole system includes not only the organism complex but also the whole complex of physical factors forming what we call the environment of the biome—the habitat factors in the widest sense. It is the systems so formed which are basic units of nature on the face of the earth."

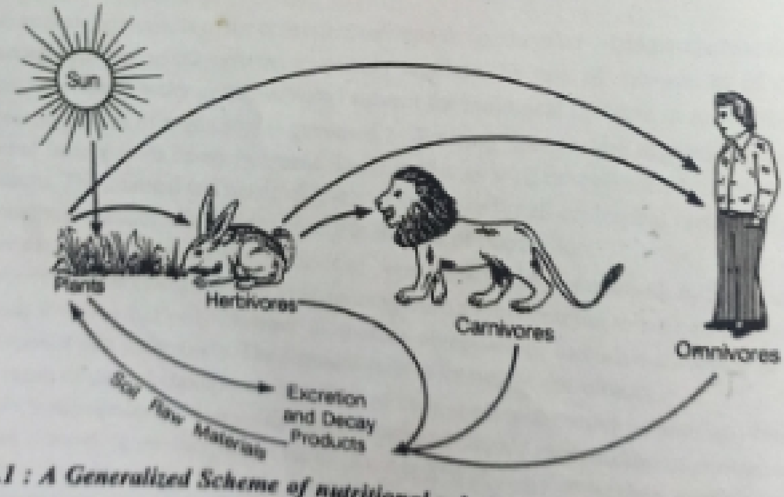

Fig. 5.1 : A Generalized Scheme of nutritional relationships among different biotic components of an ecosystem

According to **R.L. Lindeman** (1942), the term ecosystem applies to "any system composed of physical-chemical—biological processes within a space-time unit of magnitude."

F.R. Fosberg (1963) has defined ecosystem as "a functioning, interacting system composed of one or more living organisms and their effective environment, both physical and biological."

E.P. Odum (1971) opines that "living organism and their non-living (abiotic) environment are inseparably inter-related and interact upon each other. Any unit that includes all of the organisms in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycle within the system is an ecological system or ecosystem."

According to **Monkhouse and Small**, ecosystem is an organic community of plants and animals viewed within its physical environment or habitat."

The habitat or physical environment controls the whole world of organic community *viz.*, plants and animals.

P. Haggett (1975) defined ecosystems as "ecological systems in which plants and animals are linked to their environment through a series of feedback loops."

Strahler (1976) defined ecosystem as "the total assemblage of components entering into interactions of a group of organisms." He further elaborated that "to the geographer, ecosystems are the part of the physical composition of the life layer."

On the basis of various definitions of ecosystem **P.A. Furley** and **W.W. Newey** (1983) concluded that "ecosystems are unities of organisms connected to one another and to their environment." **C.C. Park** (1980) opined that "ecosystem is the sum of all natural organisms and sub stances within an area, and it can be viewed as a basic example of an open system in physical geography."

From the above definitions of ecosystem, the following basic properties of an ecosystem emerge :

(*i*) Ecosystem of any given space-time unit represents the sum of all living organisms and physical environment.

(*ii*) Ecosystem is composed of three basic components *viz.* energy, biome and habitat.

(*iii*) It occupies a well defined area.

(*iv*) It is viewed in terms of time unit.

(*v*) It is an open system characterised by continuous input and output of matter and energy.

(*vi*) It is mainly powered by the solar energy.

(*vii*) It is a functional unit wherein the biotic components (plants animals including man and micro organisms) and abiotic (physical environment) components are intimately related to each other through a series of large scale cyclic mechanisms.

(*viii*) There are complex sets of interactions between biotic and abiotic components on the one hand and between and among organisms on the other.

(*ix*) It has its own productivity which is the process of building organic matter.

(*x*) It has scale dimension, *i.e.* it varies in spacial coverage. It may be as small as a cowshed and as large as the whole biosphere.

(*xi*) There are different sequences of ecosystem development from 'sere' to 'climax'.

(*xii*) Ecosystem tends to be in relatively stable equilibrium unless there is disturbance in one or more limiting factors.

(*xiii*) Ecosystems are natural resource systems.

(*xiv*) It is structured and well organised system.

Kinds of Ecosystem

Ecosystems may be categorised as follows :

I. Natural Ecosystem

There operate by themselves under natural conditions without any major interference by man. Based upon the kind of habitat, these are further divided as :

1. **Terrestrial :** *e.g.* forest, grassland, desert, etc.
2. **Aquatic :** further classed as :
   (*i*) **Fresh water :** which may be lotic (running water) or lentic (standing water).
   (*ii*) **Marine :** *e.g.* ocean, sea, estuary, etc.

II. Artificial (man-engineered) Ecosystems

These are maintained artificially by man. Examples include croplands, where man tries to control the biotic community as well as physico-chemical environment.

In addition to the above, some new ecosystems *e.g.* space ecosystem, have also been recognised.

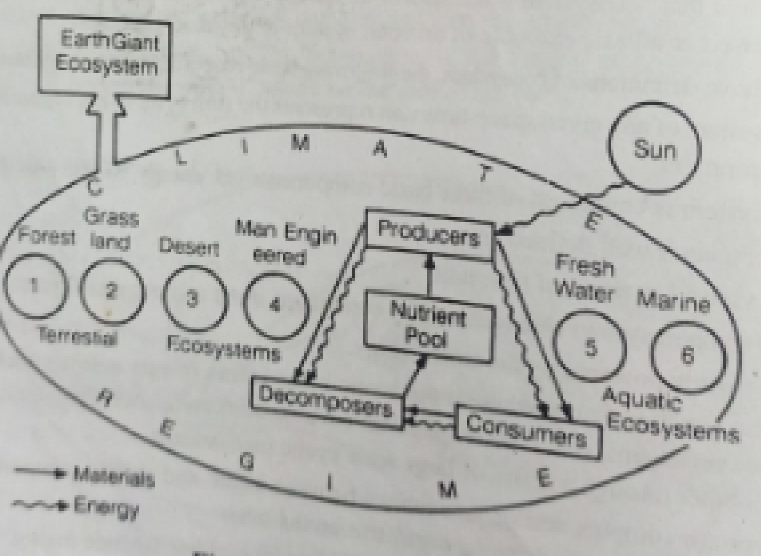

Fig. 5.2 : Kinds of Ecosystem

Structure (Components) of Ecosystem

Ecosystem are composed of a non-living (abiotic) component (biota) and a living (biotic) component (biota). Both interact to provide the materials and energy necessary for organisms to survive.

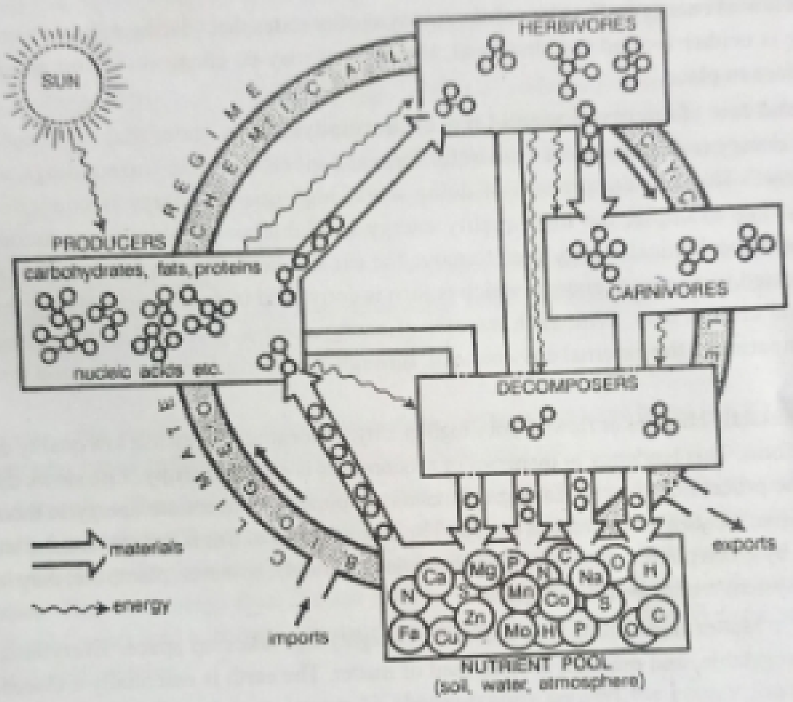

Fig. 5.3 : A generalized model of an ecosystem to show its structure and functions

Abiota

Abiotic component of ecosystem includes : energy, matter (nutrients and chemicals) and physical factors such as temperature, humidity, moisture, light, wind, and available space.

1. Energy : It is the ability to do work, to move matter from place to place, or to change matter from one form to another. It is used for various purposes *e.g.* to build shelters and warm or cool them, to precess and transport food, to keep the cells of our bodies active and functioning properly.

Energy reaches the earth in a continuous but unevenly distributed manner as sun light. Less than 1% (0.023 percent) of the total energy reaching the earth's atmosphere each day is actually captured through photosynthesis by living things, the rest is reflected by the earth's cloud cover, or is radiated by the earth's surface back into space as heat. Huge amounts of energy are stored deep below the earth's surface which make their way to the surface through volcanoes, deep sea vents, and terrestrial crachs or fissures.

Energy cannot be recycled. When it is used, it is changed to another form and eventually radiated into space as heat. The vast majority of energy is supplied by the sun, and the internal energy of the earth accounts for only a small percentage. Thus, the earth is an open system for energy, continuously receiving and using energy from the sun and radiating waste heat into space.

The **first law of energy** or **first law of thermodynamics** states that "during a physical or chemical change energy is neither created nor destroyed. However, it may be changed in form and it may be moved from place to place."

The **second law of energy** or **second law of thermodynamics**, states that "with each change in form, some energy is degraded to a less useful form and given off to the surroundings, usually as low-quality heat." Thus, in the process of doing work, high quality energy is converted to low quality energy. For example, the high-quality energy available as gasoline in an automobile is converted to both mechanical energy used to move the car and heat. The energy stored in the sugar we eat is converted to chemical energy, which is turn is converted to mechanical energy that move, our muscles and creates heat. With each transfer of energy, heat is given off to the surroundings, eventually dissipating to the external environment, through our atmosphere to space, and throughout the universe.

Energy constantly changes or flows from a high quality, concentrated form to a low quality dispersed and less useful form. This tendency to dispersal or randomness is called **entropy**. Life slows down, but does not stop the process of entropy. Living organisms temporarily concentrate energy in their tissues and thus, for a time, create a more ordered system. The best example of this is the capture and storage of the solar energy by green plants, algae, and some bacteria. Inevitably, however, plants die, they lose their leaves, and the system tends toward entropy.

2. Matter : Matter is anything that has mass (weight) and takes up space. Everything on the earth—animal, vegetable, and mineral, is composed of matter. The earth is essentially a closed system for matter.

All matter is composed of elements. Elements are substances that cannot be changed to simpler substances by chemical means. Each element has been given a name and a letter symbol, *e.g.* oxygen (O), carbon (C), nitrogen (N), sulfur (S) and hydrogen (H).

There are 92 naturally occuriring elements and 15 synthetic ones, each having special characteristics that make it unique from all others. Each element is unique in its atomic structure. All elements are composed of atoms. Atoms are the smallest parts of atoms. Their subatomic parts are called protons, neutrons and electrons.

Molecules are formed when two or more atoms combine. Some elements, *e.g.* oxygen (O_2), Nitrogen (N_2) and hydrogen (H_2) are found in nature as molecules. Molecules composed of two or more different elements are known as **compounds**. Water is a compound formed of two hydrogen atoms and one oxygen atom, designated by the symbol H_2O. Most matter exists as compounds held together by the force of attraction in the chemical bonds between their constituent atoms.

All organic compounds contain atoms of carbon. These may be combined with other carbon atoms or with atoms of one or more other elements. Hydro-carbons such as methane is an organic compound. All other compounds are inorganic.

The law of the conservation of matter states that during a physical or chemical change, matter is neither created nor destroyed. However, its form may be changed, and it can be moved from place to place. Ecosystems function within the law of the conservation of matter by using processes that constantly recycle matter.

Carbon, oxygen, hydrogen, nitrogen, phosphorus, and sulfur are **macro nutrients**, chemicals needed by living organisms in large quantities for the construction of proteins, fats and carbonhydrates. These six macro nutrients are the major constituents of the complex organic compounds found in all living organisms. Substances such as copper, zinc, selenium, and lithium are also needed in trace amounts.

3. Physical Factors : Physical factors are important abiotic component of the ecosystem. These include temperature, precipitation, humidity, wind, light, shade, fire, salinity, and available space. They do not remain constant, but vary over space and time.

Biota

The biota, or living organisms of an ecosystem, are grouped into two broad categories : autotrophs and heterotrophs, based on their nutritional needs and feeding type.

1. Autotrophs : These are self-nourishing organisms (*auto* = 'self', *troph* = 'nourishment'). They are also called producers. They need water, nutrients, and a source of energy, they can produce the compounds necessary for their survival. Most producers such as green plants and algae are known as **photo trophs**. They use energy from the sun (*photo* = 'light') to convert relatively simple chemicals (carbon dioxide, water, and nutrients) into complex chemicals—carbohydrates (sugars, starches), lipids (oils, waxes), and proteins.

A second group of producers, known as **chemo-trophs** convert the energy found in inorganic chemical compounds into energy. The bacteria which live in and around the thermal vents of the deep trenches of the oceans is a type of chemotroph. These special bacteria use the energy of the compound hydrogen sulphide for their nutritional needs. They are the producers that supply the food energy for the consumers of that special ecosystem.

2. Heterotrophs : They are also called consumers they eat by engulfing or pre digesting the cells, tissues, or waste products of other organisms. All heterotrophic organisms obtain the energy-rich chemicals they need either directly or indirectly from autotrophs and thus indirectly from the sun. Because they cannot produce their own food, they live at the expense of other organisms. They can be broadly categorised as macro consumers and micro consumers.

Macro Consumers : Feed by ingesting or engulfing particles, parts, or entire bodies of other organisms, either living or dead. They include herbivores, carnivores, omnivores, scavengers, and detrivores. **Herbivores** or **Primary consumers** (grasshoppers, mice, deer, etc.) eat green plants directly. Other consumers (meadowlarks, black rat, snakes, bobcats) feed indirectly on plants by eating herbivore. Because they eat other animals, they are called **carnivores** or **secondary consumers**. Consumers that eat both plants and animals (black bears, humans), are **omnivores.** Carnivores that eat secondary consumers (hawks, large-mouth bass) are **tertiary consumers.**

Scavengers are those organisms that consume dead organisms. Vultures and hyenas belong to this category. Consumers that ingest fragments of dead or decaying tissues or organic wastes are called **'detrivore'**, (*e.g.* earth worms, dung-bettles, shrimp).

Micro Consumers : These are also called **decomposers** which feed on the waste products of living organisms or the tissues of dead organisms. They digest materials outside of their cells and bodies, through the external activities of enzymes, and then absorb the predigested materials into their cells. Decomposers live on or within their food source. They decay the food. They include some bacteria, some protozoans, and fungi. They play the major in reducing complex organic matter to inorganic matter and returning nutrients to the physical environment in a form that can be used by producers.

They biotic component of any ecosystem may be thought of as the functional kingdom of nature, since they are based on the type of nutrition and the energy source used. The trophic structure of an ecosystem is one kind of producer-consumer arrangement, where each "food level" is known as **trophic level.** The amount of living material in different trophic levels or in a component population is known as the **standing crop** applicable to both plants as well as animals. The standing crop may be expressed in terms of (*i*) number of organisms per unit area, or (*ii*) biomass *i.e.* organism mass in unit area (measured as weight or calories).

Ecological Pyramids

Trophic structure, *i.e.* the interaction of food chain and the size metabolism relationship between the linearly arranged various biotic components of an ecosystem is characteristic of each type of ecosystem. The trophic structure and function at successive trophic levels, *i.e.* producers—herbivores—carnivores, may be shown graphically by means of **ecological pyramids** where the producer level constitutes the base of the pyramid and the successive levels, the tiers making the apex.

Ecological Pyramids are of three types : (*i*) Pyramid of numbers, (*ii*) Pyramid of biomass, and (*iii*) Pyramid of energy.

The pyramids of numbers and biomass may be upright or inverted depending upon the nature of the food chain in the particular ecosystem, whereas pyramids of energy are always upright.

1. Pyramids of numbers : They show the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number. The pyramids of numbers in three different kinds of ecosystem are shown in Fig. 5.3.

In a grassland, the producers (mainly grasses) are always maximum in number. This number decreases towards apex as primary consumers (herbivores) like rabbits, mice, etc. are lesser in number than grasses. The secondary consumers (snakes and lizards) are lesser in number than rabbits and mice. Finally, the tertiary consumers (hawks and other birds) are least in number. This pyramid is upright. In a pond-ecosystem too, the pyramid is upright because the phytoplankton (algae, bacteria, etc.) are maximum in number. The herbivores (smaller fish, rotifers, etc.) are lesser in number than producers, and the secondary consumers (carnivores) such as small fish eating each other, water beetles etc. are lesser in number than the herbivores. Finally the tertiary consumers (bigger fish) are least in number. In a forest ecosystem the pyramid of numbers in somewhat different in shape. The producers (large sized trees) are lesser in number, and form the base of the pyramid. The herbivores (fruit eating birds), elephants, deers, etc. are more in number than the producer. Then there is a gradual decrease in the number of successive carnivores, thus making the pyramid again upright. In a parasitic food chain, however, the pyramids are always inverted, because a single plant may support the growth of many herbivores and each herbivore in turn may provide nutrition to several parasites which support many hyper parasites. Thus, from the producer towards consumers, the number of organisms gradually increases making the pyramid inverted in shape.

However, the pyramids of numbers do not give a true picture of the food grain, as they are not very functional.

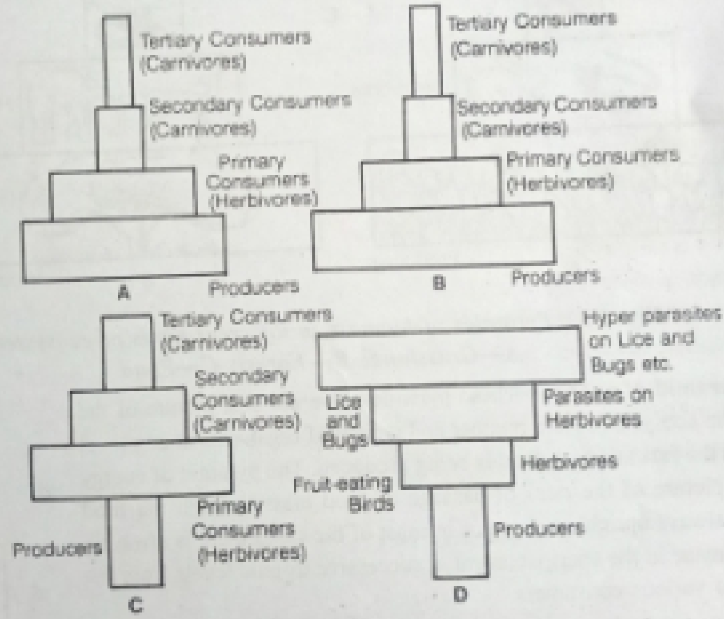

Fig. 5.4 : Pyramids of numbers in different kinds of ecosystems/food chains
A—Grassland ecosystem; B—Pond ecosystem
C—Forest ecosystem; D—Parasitic food chair

2. Pyramids of biomass : These pyramids show the quantitative relationships of the standing crops and, therefore, are more fundamental. In grassland and forest, there is generally a gradual decrease in biomass of organisms at successive levels from the producers to the top carnivores. Thus, pyramids are upright. In a pond, however, the producers are small organisms their biomass is least, and there is an increase towards the apex, thus making the pyramid inverted in shape.

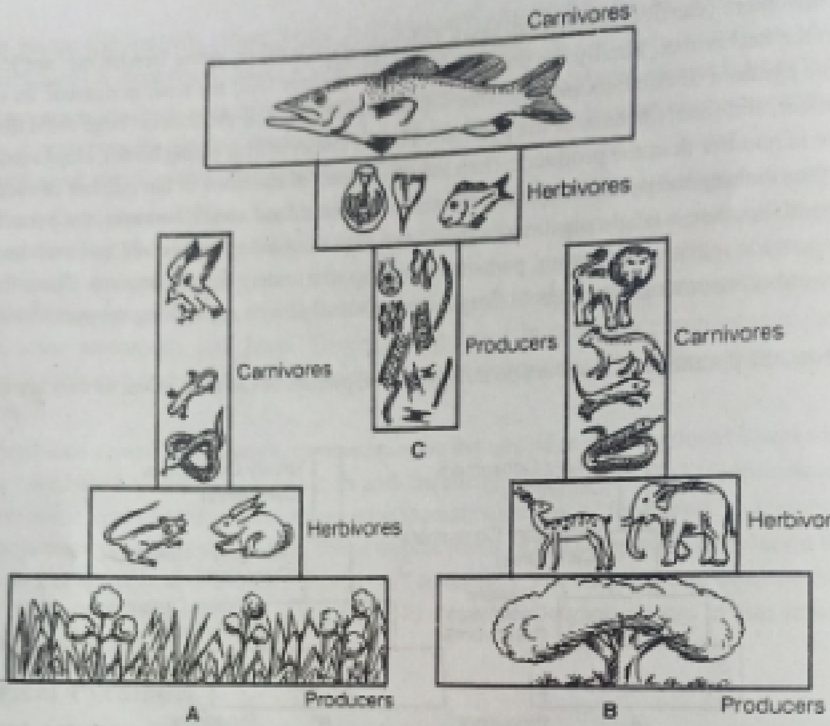

Fig. 5.5 : Pyramids of biomass in different kinds of ecosystems
A—Grassland; B—Forest; C—Pond

3. Pyramid of energy : These pyramids give the best picture of the nature of the ecosystem. Here number and weight of organisms at any level depends on the rate at which food is being produced. The pyramid of energy presents a picture of the rates of passage of food mass through the food chain. It is always upright in shape as in most of the cases there is always a gradual decrease in the energy content at successive trophic levels from the producers to various consumers.

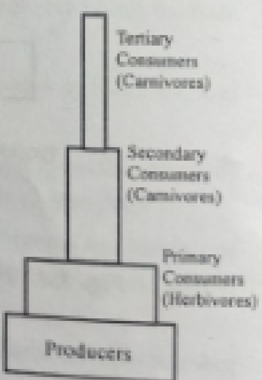

Fig. 5.6 : Pyramid of energy

Functioning of an Ecosystem

From the operational view point the living and non-living components of ecosystem are so interwoven into the fabric of nature that they cannot be separated from each other. The mode of movement of materials and energy in an ecosystem is shown in a simple model (Fig. 5.2).

The producers, green plants, fix radiant energy with the help of minerals taken from their soil and aerial environment (nutrient pool); they build up complex organic matter (carbohydrates, fats, proteins, nucleic acids, etc.). The two ecological processes of energy flow and mineral cycling, involving interaction between the physico-chemical environment and the biotic communities, may be thought as the 'heart' of the ecosystem dynamics. Energy flows in non-cyclic manner (uni-direction) from sun to the decomposers via producers and macro consumers, whereas the minerals keep moving in a cyclic manner. The cycling of the minerals is accomplished by different biogeochemical cycles super-imposed upon uni-directional energy flow through the biotic component of the ecosystem.

Productivity of Ecosystem

The productivity of an ecosystem refers to the rate of production *i.e.* the amount of organic matter accumulated in any unit time. Productivity is of the following types :

1. Primary productivity : It is defined by **Odum** (1971) as the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producer organisms (chiefly green plants) in the form of organic substances which can be used as food materials. Primary productivity is of two types :

(*i*) **Gross primary productivity :** It is the total rate of photosynthesis including organic matter used up in respiration during a particular period.

(*ii*) **Net primary productivity :** It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilisation by plants during the measurement period. It refers to balance between gross photosynthesis and respiration and other plant losses as death etc.

2. Secondary productivity : It refers to the consumers (heterotrophs). These are the rates of energy storage at consumers level. Since consumers only utilise food materials in their respiration, simply converting the food matter to different tissues by an overall process, secondary productivity is not divided into 'gross' and 'net' amounts. Secondary productivity remains mobile and does not live in situ live the primary productivity.

3. Net productivity : It refers to the rate of storage of organic matter not used by the consumers, *i.e.* equivalent to net primary production minus consumption by the heterotrophs during the unit period. It is the rate of increase of biomass of the primary producers which has been left over by the consumers.

The ecosystem productivity, whether gross or net, is generally measured in gram/m^2/day or year.

Biomass refers to the quantity or weight of living materials (animals, plants, etc.) per unit area and is represented in terms of dry weight **Whittaker** and **Woodwell** have measured the net primary productivity and biomass of plants of the major natural ecosystems and of the whole earth's surface. Mean net primary productivity for the whole earth is 320 gm/m^2/year, whereas the mean values for the tropical rain forests, swamps and marshes and estuaries are 2000 gm/m^2/year each. Very low net primary productivity is found in extreme desert, rock and ice (3 gm/m^2/year), desert scrub (70 gm/m^2/year), open ocean (125 gm/m^2/year) and Tundra and Alpine ecosystem (140 gm/m^2/year).

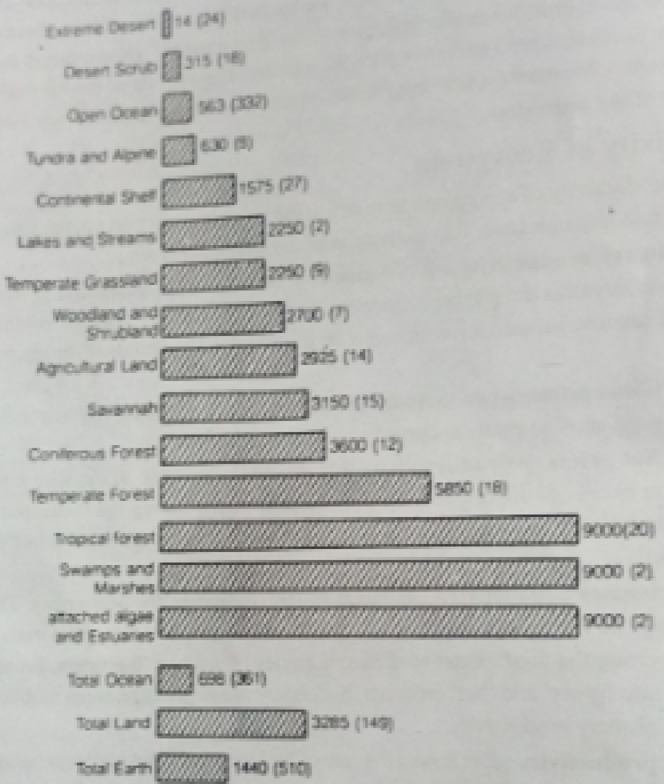

Fig. 5.7 : Average annual production rate of net plant production in various ecosystems

There exists a positive correlation between primary productivity and solar radiation. With the marked decrease in solar radiation at the earth's surface from equators toward the poles, primary productivity also decreases poleward from the equator. **E.P. Odum** (1959) has identified three levels of productivity at world scale :

1. The regions of high ecological productivity represented by shallow water areas, moist forests, alluvial plains, and regions of intensive farming.
2. The regions of low ecological productivity, represented by arctic snow covered areas, deserts and deep oceans, and
3. The regions of intermediate ecological productivity, e.g. grasslands, shallow lakes, farmlands etc.

Food Chains in Ecosystems

Food chain may be defined as the transfer of food energy from the producers, through a series of organisms (herbivores—carnivores—decomposers) with repeated eating and being eaten. Producers utilise the radiant energy of sun which is transformed to chemical form, ATP during photosynthesis. Thus, green plants occupy in the food chain the first trophic (nutritional) level—the producer level, and are called primary producers. The energy stored in food matter manufactured by green plants is then utilised by the plant enters—the herbivores, which constitute the second trophic level—the primary consumer level, and are called primary consumers (herbivores). The herbivores in turn are eaten by the carnivore, which constitute the third trophic level—the secondary consumers level, and are called secondary consumers (carnivores). These, in turn may be eaten by other carnivores at tertiary consumers level. Some organisms eating producers as well as carnivores are called omnivores. Such organisms may occupy more than one trophic levels in the food chain. In any food chain, energy flows from primary producers to primary consumers (herbivores), from primary consumers to secondary consumers (carnivores), and from secondary consumers to tertiary consumers (carnivores/omnivores) and so on.

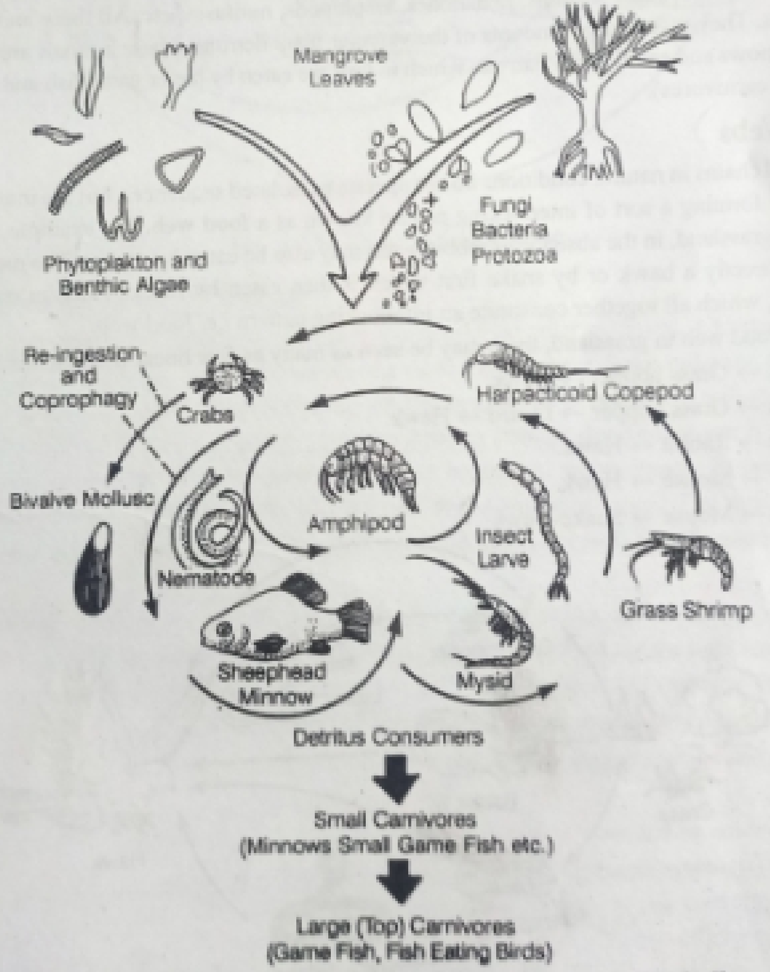

Fig. 5.8 : A detritus food chain based on mangroves leaves falling into shallow estuary waters

In nature we generally find two types of food chains : (1) Grazing food chain, and (2) Detritus food chain.

1. Grazing food chain : It starts from the green plants and goes to grazing herbivores, and on to carnivores (animal eaters). Ecosystems with such food chain are directly dependent on an influx of solar radiation. Most of the ecosystems in nature follow this type of food chain.

2. Detritus food chain : It goes from dead organic matter into micro-organisms and then to organisms feeding on detritus (detrivores) and their predators. Such ecosystems are less dependent on direct solar energy. These depend chiefly on the influx of organic matter produced in another system. For example, such 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). The fallen leaf fragments are eaten and re-eaten by small animals including crabs, cope pods, insect larvae, grass shrimps, nematodes, amphipods, molluscs, etc. All these animals are detritus consumers. They ingest large amounts of the vascular plant detritus. These animals are in turn eaten by some minnows and small game fish etc. which in turn are eaten by larger game fish and fish eating birds (large top carnivores).

Food Webs

Food chains in natural conditions do not operate as isolated sequences, but are interconnected with each other forming a sort of interlocking pattern known as a **food web.** 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 a hawk or by snake first which is then eaten by hawk. Thus, in nature there exist alternative, which all together constitute an interlocking pattern *i.e.* food web.

In a food web in grassland, there may be seen as many as five linear food chains :

1. Grass → Grass hopper → Hawk.
2. Grass → Grass hopper → Lizard → Hawk.
3. Grass → Rabbit → Hawk.
4. Grass → Mouse → Hawk.
5. Grass → Mouse → Snake-Hawk.

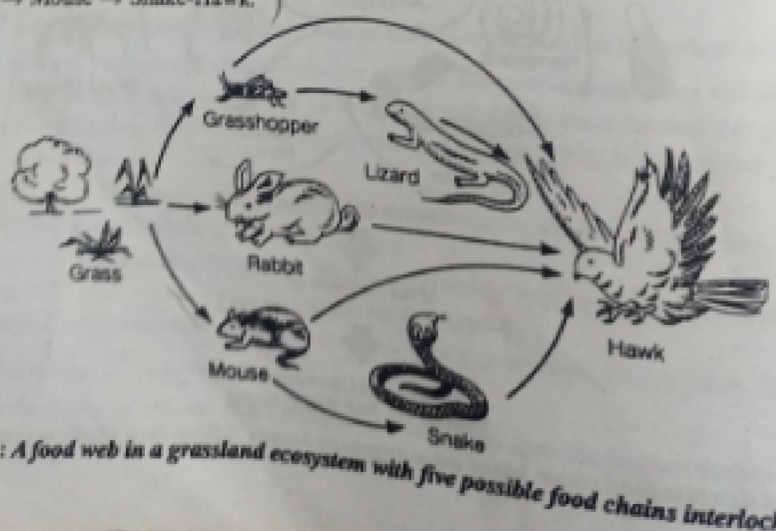

Fig. 5.9 : A food web in a grassland ecosystem with five possible food chains interlocked together

A similar food web in a pond, with different inter-linked food chains is shown in the following fig.

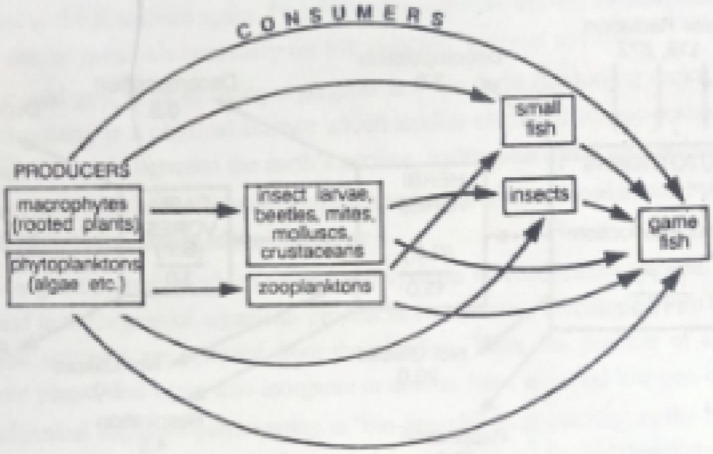

Fig. 5.10 : Food web in a pond

Energy Flow in an Eco-System

The energy used for all plant life processes is derived from solar radiation. A fraction *i.e.* about ½ billionth part of the total solar radiation reaches the earth's atmosphere. Solar radiation travels through the space in the form of waves. Most radiations are lost in space by processes of reflection, absorption and through scattering. Its energy is greatly altered as it passes through cloud cover, water and vegetation. The daily input of sunlight to autotrophic layer of an ecosystem varies mostly between 100-800 to 300-400 gcal per cm^2 (= 3000 to 4000 kcal per m^2) in the temperate zone. The total radiation flux within different strata of ecosystem varies from season to season as well as with nature of the earth's surface.

The energy reaching the earth's surface is transformed and/or absorbed by plants and other organisms. It is used by the green plants during photosynthesis by converting the light energy to chemical energy and making it available to other organisms as food. **Lindeman** (1942) was the first to study such energy transfers along the food chain. He stated that the functions of an ecosystem could be explained in terms of energy by two attributes of each trophic level—the level of energy storage and the efficiency of energy transfer.

The behaviour of energy in ecosystem can be termed energy flow due to unidirectional flow of energy. From energetics point of view it is essential to understand for an ecosystem (*i*) the efficiency of the producers in absorption and conversion of solar energy, (*ii*) the use of this converted chemical form of energy by the consumers, (*iii*) the total input of energy in form of food and its efficiency of assimilation, (*iv*) the loss through respiration, heat, excretion etc. and (*v*) the gross net production.

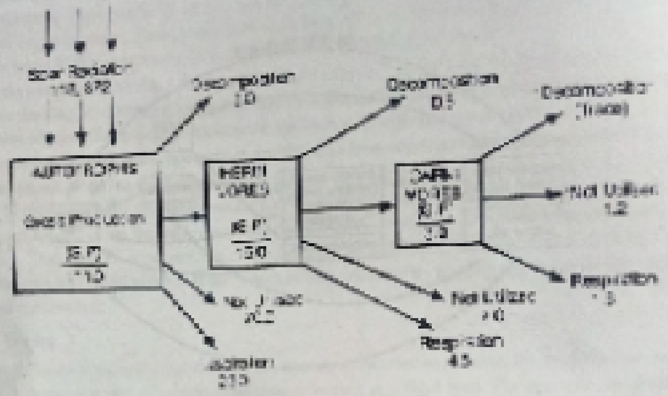

Fig. 5.11 : Energy flow in a lake (fresh water ecosystem) in gcal/cm²/yr
(modified from Lindeman, 1942)

As shown in Fig. 5.11 out of the total incoming solar radiation (118,872 gcal/cm²/yr), 118,761 gcal/cm²/yr remain unutilised, and the gross production (net production plus respiration) by autotrophs is 111 gcal/cm²/yr with an efficiency of energy capture of 0.10 per cent. It may also be noted that 21 per cent of this energy, or 23 gcal/cm²/yr is consumed in metabolic reactions of autotrophs for their growth, development, maintenance and reproduction. It may be seen further that 15 gcal/cm²/yr are consumed by herbivores that graze or feed on autotrophs — this amounts to 17 per cent of net autotroph production. Decomposition (3 gcal/cm²/yr) accounts for about 3.4 per cent of net production. The remainder of the plant material, 70.0 gcal/cm²/yr or 79.6 per cent of net production, is not utilised at all but becomes part of the accumulating sediments. It is obvious, then, that much more energy is available for herbivory than is consumed. It may also be noted that various pathways of loss are equivalent to and account for total energy capture of the autotrophs i.e. gross production.

From the energy flow diagram, two things become clear. Firstly, there is one-way street along which energy moves (unidirectional flow of energy). The energy that is captured by the autotrophs does not revert back to solar input; that which passes to the herbivores does not pass back to the autotrophs. As it moves progressively through the various trophic levels it is no longer available to the previous level. Thus, due to one-way flow of energy, the system would collapse if the primary source, the sun, were cut off. Secondly, there occurs a progressive decrease in energy level at each trophic level. This is accounted largely by the energy dissipated as heat in metabolic activities and measured here as respiration coupled with unutilised energy.