Unit

3 Ecosystems

■ CONCEPT OF ECOSYSTEM

Various kinds of life supporting systems like the forests, grasslands, oceans, lakes, rivers, mountains, deserts and estuaries show wide variations in their structural composition and functions. However, they all are alike in the fact that they consist of living entities interacting with their surroundings exchanging matter and energy. How do these different units like a hot desert, a dense evergreen forest, the Antarctic Sea or a shallow pond differ in the type of their flora and fauna, how do they derive their energy and nutrients to live together, how do they influence each other and regulate their stability are the questions that are answered by Ecology.

The term Ecology was coined by Earnst Haeckel in 1869. It is derived from the Greek words *Oikos*- home + *logos*- study. So **ecology deals with the study of organisms in their natural home interacting with their surroundings.** The surroundings or environment consists of other living organisms (biotic) and physical (abiotic) components. Modern ecologists believe that an adequate definition of ecology must specify some unit of study and one such basic unit described by Tansley (1935) was ecosystem. **An ecosystem is a group of biotic communities of species interacting with one another and with their non-living environment exchanging energy and matter. Now ecology is often defined as "the study of ecosystems"**.

An ecosystem is an integrated unit consisting of interacting plants, animals and microorganisms whose survival depends upon the maintenance and regulation of their biotic and abiotic structures and functions. The ecosystem is thus, a unit or a system which is composed of a number of subunits, that are all directly or indirectly linked with each other. They may be freely exchanging energy and matter from outside—an *open ecosystem* or may be isolated from outside—a *closed ecosystem*.

■ ECOSYSTEM CHARACTERISTICS

Ecosystems show large variations in their size, structure, composition etc. However, all the ecosystems are characterized by certain basic structural and functional features which are common.

■ STRUCTURAL FEATURES

Composition and organization of biological communities and abiotic components constitute the structure of an ecosystem.

I. Biotic Structure

The plants, animals and microorganisms present in an ecosystem form the biotic component. These organisms have different nutritional behaviour and status in the ecosystems and are accordingly known as *Producers* or *Consumers,* based on how do they get their food.

(*a*) **Producers:** They are mainly the green plants, which can synthesize their food themselves by making use of carbondioxide present in the air and water in the presence of sunlight by involving chlorophyll, the green pigment present in the leaves, through the process of **photosynthesis**. They are also known as **photo autotrophs** (auto=self; troph=food, photo=light).

There are some microorganisms also which can produce organic matter to some extent through oxidation of certain chemicals in the absence of sunlight. They are known as **chemosynthetic** organisms or **chemo-autotrophs**. For instance in the ocean depths, where there is no sunlight, chemoautotrophic sulphur bacteria make use of the heat generated by the decay of radioactive elements present in the earth's core and released in ocean's depths. They use this heat to convert dissolved hydrogen sulphide (H_2S) and carbon dioxide (CO_2) into organic compounds.

(*b*) **Consumers:** All organisms which get their organic food by feeding upon other organisms are called consumers, which are of the following types:

(*i*) ***Herbivores*** (plant eaters): They feed directly on producers and hence also known as *primary consumers*. e.g. rabbit, insect, man.

(*ii*) ***Carnivores*** (meat eaters): They feed on other consumers. If they feed on herbivores they are called *secondary consumers* (e.g. frog) and if they feed on other carnivores (snake, big fish etc.) they are known as *tertiary carnivores/consumers*.

(*iii*) ***Omnivores***: They feed on both plants and animals. e.g. humans, rat, fox, many birds.

(*iv*) ***Detritivores (Detritus feeders or Saprotrophs):*** They feed on the parts of dead organisms, wastes of living organisms, their cast-offs and partially decomposed matter e.g. beetles, termites, ants, crabs, earthworms etc.

(*c*) **Decomposers:** They derive their nutrition by breaking down the complex organic molecules to simpler organic compounds and ultimately into inorganic nutrients. Various bacteria and fungi are decomposers.

In all the ecosystems, this biotic structure prevails. However, in some, it is the primary producers which predominate (e.g. in forests, agroecosystems) while in others the decomposers predominate (e.g. deep ocean).

II. Abiotic Structure

The physical and chemical components of an ecosystem constitute its abiotic structure. It includes climatic factors, edaphic (soil) factors, geographical factors, energy, nutrients and toxic substances.

(*a*) ***Physical factors*****:** The sunlight and shade, intensity of solar flux, duration of sun hours, average temperature, maximum-minimum temperature, annual rainfall, wind, latitude and altitude, soil type, water availability, water currents etc. are some of the important physical features which have a strong influence on the ecosystem.

We can clearly see the striking differences in solar flux, temperature and precipitation (rainfall, snow etc.) pattern in a desert ecosystem, in a tropical rainforest and in tundra ecosystem.

(*b*) ***Chemical factors***: Availability of major essential nutrients like carbon, nitrogen, phosphorus, potassium, hydrogen, oxygen and sulphur, level of toxic substances, salts causing salinity and various organic substances present in the soil or water largely influence the functioning of the ecosystem.

All the biotic components of an ecosystem are influenced by the abiotic components and vice versa, and they are linked together through energy flow and matter cycling as shown diagrammatically in Fig. 3.1.

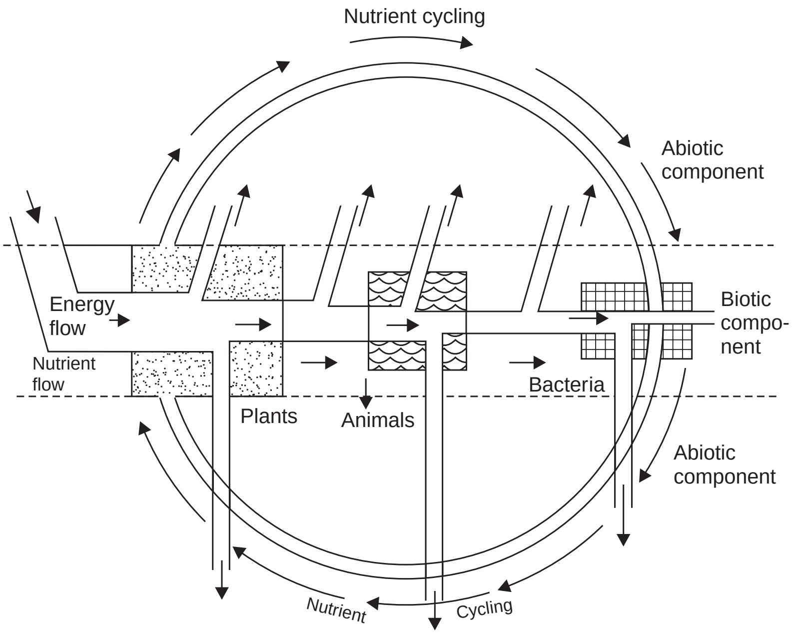

Fig. 3.1. Nutrient cycling and energy flow mediated through food-chain. The flow of energy is unidirectional while the nutrients move in a cyclic manner from the abiotic to biotic (food chain) to abiotic and so on.

■ FUNCTIONAL ATTRIBUTES

Every ecosystem performs under natural conditions in a systematic way. It receives energy from the sun and passes it on through various biotic components and in fact, all life depends upon this flow of energy. Besides energy, various nutrients and water are also required for life processes which are exchanged by the biotic components within themselves and with their abiotic components within or outside the ecosystem. The biotic components also regulate themselves in a very systematic manner and show mechanisms to encounter some degree of environmental stress. The major functional attributes of an ecosystems are as follows:

(*i*) Food chain, food webs and trophic structure
(*ii*) Energy flow
(*iii*) Cycling of nutrients (Biogeochemical cycles)
(*iv*) Primary and Secondary production
(*v*) Ecosystem development and regulation

TROPHIC STRUCTURE

The structure and functions of ecosystems are very closely related and influence each other so intimately that they need to be studied together. The flow of energy is mediated through a series of feeding relationships in a definite sequence or pattern which is known as **food chain**. Nutrients too move along the food chain. The producers and consumers are arranged in the ecosystem in a definite manner and their interaction along with population size are expressed together as **trophic structure**. Each food level is known as **trophic level** and the amount of living matter at each trophic level at a given time is known as **standing crop** or **standing biomass**.

Before we study about energy flow or nutrient cycling, we must learn about the food-chains, that provide the path through which the flow of energy and matter take place in ecosystem.

FOOD CHAINS

The sequence of eating and being eaten in an ecosystem is known as food chain. All organisms, living or dead, are potential food for some other organism and thus, there is essentially no waste in the functioning of a natural ecosystem. A caterpillar eats a plant leaf, a sparrow eats the caterpillar, a cat or a hawk eats the sparrow and when they all die, they are all consumed by microorganisms like bacteria or fungi (decomposers) which break down the organic matter and convert it into simple inorganic substances that can again be used by the plants-the primary producers.

Some common examples of simple food chains are:

- Grass → grasshopper → Frog → Snake → Hawk (Grassland ecosystem)
- Phytoplanktons → water fleas → small fish → Tuna (Pond ecosystem)
- Lichens → reindeer → Man (Arctic tundra)

Each organism in the ecosystem is assigned a feeding level or trophic level depending on its nutritional status. Thus, in the grassland food chain, grasshopper occupies the Ist trophic level, frog the IInd and snake and hawk occupy the IIIrd and the IVth trophic levels, respectively. The decomposers consume the dead matter of all these trophic levels. In nature, we come across two major types of food chains:

I. Grazing food chain: It starts with green plants (primary producers) and culminates in carnivores. All the examples cited above show this type of food chain. Another example could be

Grass → Rabbit → Fox

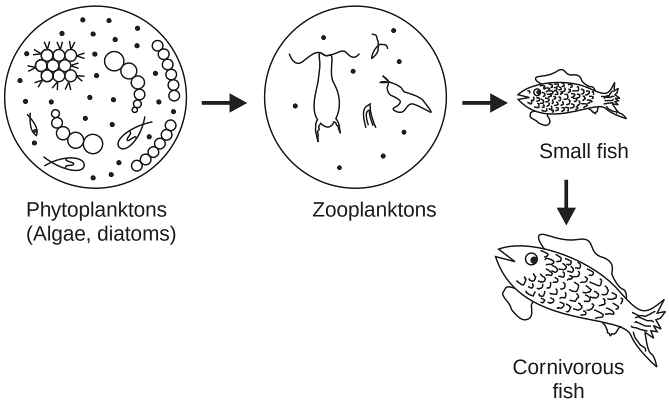

Fig. 3.2. A grazing food chain in a pond ecosystem.

II. Detritus food chain: It starts with dead organic matter which the detritivores and decomposers consume. Partially decomposed dead organic matter and even the decomposers are consumed by detritivores and their predators. An example of the detritus food chain is seen in a Mangrove (estuary).

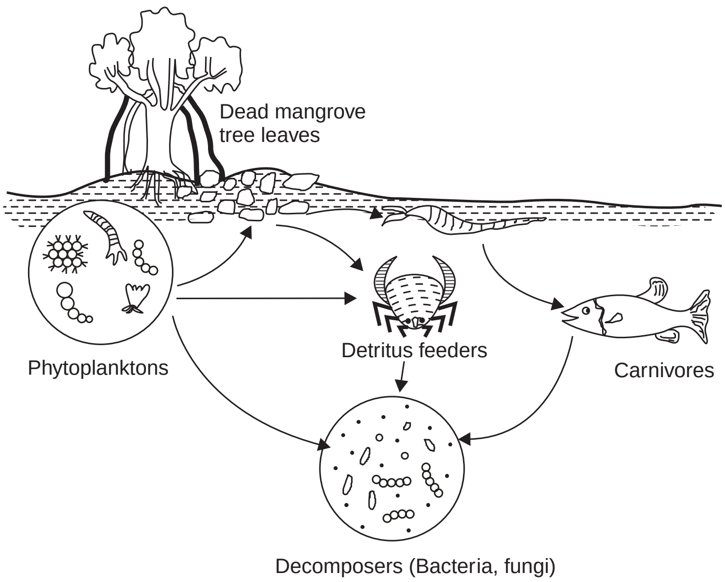

Fig. 3.3. A detritus food chain in an estuary based on dead leaves of mangrove trees.

Here, a large quantity of leaf material falls in the form of litter into the water. The leaf fragments are eaten by **saprotrophs.** (Saprotrophs are those organisms which feed on dead organic matter). These fallen leaves are colonized by small algae, which are also consumed by the saprotrophs or detritivores consisting of crabs, mollusks, shrimps, insect larvae, nematodes and fishes. The detritivores are eaten by small carnivorous fishes, which is turn are eaten by large carnivorous fishes.

Leaf litter → algae → crabs → small carnivorous fish → large carnivorous fish (Mangrove ecosystem)

Dead organic matter → fungi → bacteria (Forest ecosystem)

Thus the grazing food chain derives its energy basically from plant energy while in the detritus food chain it is obtained primarily from plant biomass, secondarily from microbial biomass and tertiarily from carnivores. Both the food chains occur together in natural ecosystems, but grazing food chain usually predominates.

■ FOOD WEB

Food chains in ecosystems are rarely found to operate as isolated linear sequences. Rather, they are found to be interconnected and usually form a complex network with several linkages and are known as food webs. Thus, **food web is a network of food chains where different types of organisms are connected at different trophic levels, so that there are a number of options of eating and being eaten at each trophic level.**

Fig. 3.4 illustrates an example of a food-web in the unique Antarctic Ecosystem. This is representing the total ecosystem including the Antarctic sea and the continental land. The land does not show any higher life forms of plants. The only species are that of some algae, lichens and mosses. The animals include penguins and snow petrel which depend upon the aquatic chain for their food energy.

In a tropical region, on the other hand, the ecosystems are much more complex. They have a rich species diversity and therefore, the food webs are much more complex.

Why nature has evolved food webs in ecosystems instead of simple linear food chains? This is because food webs give greater stability to the ecosystem. In a linear food chain, if one species becomes extinct or one species suffers then the species in the subsequent trophic levels are also affected. In a food web, on the other hand, there are a number of options available at each trophic level. So if one species is affected, it does not affect other trophic levels so seriously.

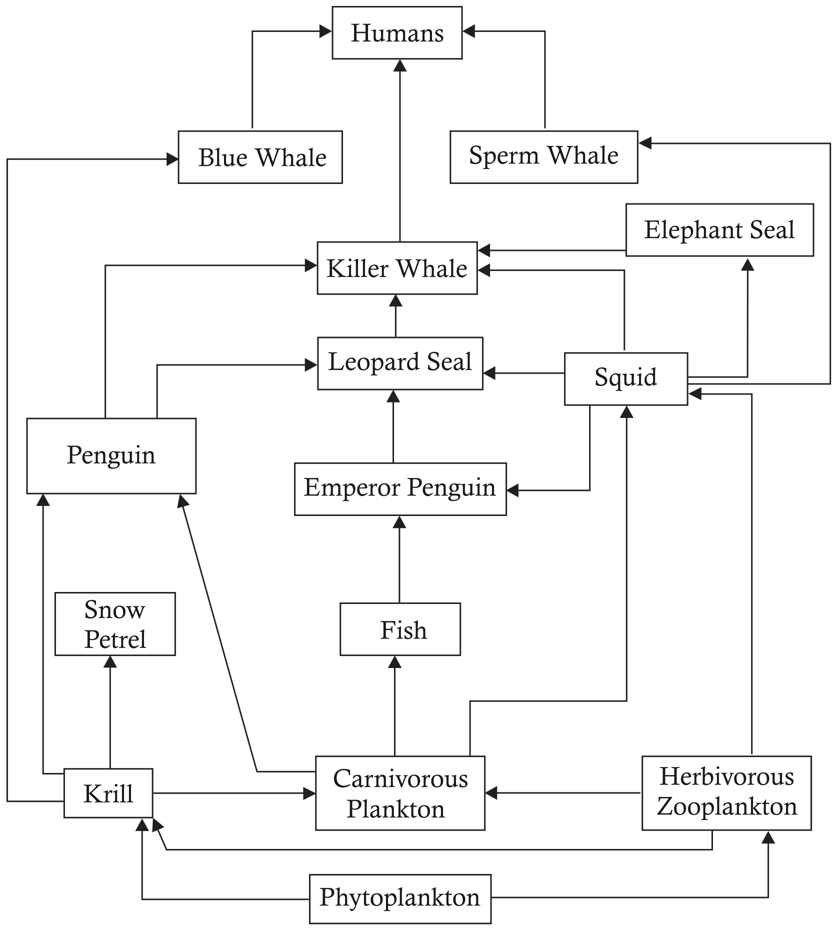

Fig. 3.4. A simplified food web in Antarctic ecosystem.

Just consider the simple food chains of arctic tundra ecosystem:

Cladonia → Reindeer → Man

Grass → Caribou → Wolf

If due to some stress, the population of reindeer or Caribou falls, it will leave little option for man or wolf to eat from the ecosystem. Had there been more biodiversity, it would have led to complex food web giving the ecosystem more stability.

Significance of food chains and food webs

- Food chains and food webs play a very significant role in the ecosystem because the two most important functions of ***energy flow and nutrient cycling take place through them.***

- The food chains also help in maintaining and regulating the population size of different animals and thus, help maintain the ***ecological balance*.**
- Food chains show a unique property of **biological magnification** of some chemicals. There are several pesticides, heavy metals and other chemicals which are non-biodegradable in nature. Such chemicals are not decomposed by microorganisms and they keep on passing from one trophic level to another. And, at each successive trophic level, they keep on increasing in concentration. This phenomenon is known as biomagnification or biological magnification.

CASE STUDY

A **build-up of DDT concentration :** A striking case of biomagnification of DDT (a broad range insecticide) was observed when some birds like Osprey were found to suffer a sharp decline in their population. The young ones of these birds were found to hatch out in premature condition leading to their death. This was later found to be due to bio-magnification of DDT through the food chain. DDT sprayed for pest control was in very low concentration, but its concentration increased along the food chain through phytoplanktons to zooplanktons and then to fish which was eaten by the birds. The concentration of DDT was magnified several thousand times in the birds which caused thinning of shells in the birds' eggs, causing death of the young ones.

It becomes very clear from the above instance that the animals occupying the higher trophic levels are at a greater risk of biomagnification of toxic chemicals. Human beings consuming milk, eggs and meat are at a higher trophic level. So, we have to stop indiscriminate use of pesticides and heavy metals if we wish to save ourselves from their biologically magnified toxic levels.

■ ECOLOGICAL PYRAMIDS

Graphic representation of trophic structure and function of an ecosystem, starting with producers at the base and successive trophic levels forming the apex is knows as an ecological pyramid. Ecological pyramids are of three types:

Pyramid of numbers: It represents the number of individual organisms at each trophic level. We may have *upright* or *inverted* pyramid