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Principles of ecology
(B.Sc.- Zoology Sem. - I)

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Definition of Ecology:

Ecology is a Greek word which means the study of the habitation of living organisms (oikos=habitation, logos=discourse). The word ecology has been defined variously by different authors. Some prefer to define it as "scientific natural history" or "the science of community population" or the "the study of biotic communities".

The most comprehensive definition of ecology will be "a study of animals and plants in their relation to each other and to their environment".

The word 'ecology' was first proposed in the year 1869 by Ernst Haeckel, although many contributions to this subject was done much earlier. However, much later, in the 1900s ecology was recognised as a distinct field of science.

Initially it was rather sharply divided into plant and animal ecology, but later the understanding of the biotic community concept, the food chain, material cycling concept etc., helped to establish the basic theory for a unified field of general ecology.

Ecology till recently was considered in academic circles to be a branch of biology, which, along with molecular biology, genetics, developmental biology, evolution etc. was by no means always considered as one of the subjects of biological sciences only.

However, presently the emphasis has shifted to the study of environmental systems of the entire 'household', which in fact relates to its core meaning. Thus, ecology has grown from a subdivision of biological sciences to a major interdisciplinary science that links together the biological, physical and social sciences.

Study of Ecology:

Ecology is studied with particular reference to plants or to animals, hence the topics Plant ecology and Animal ecology. Since plants and animals are intimately interrelated, study of plant ecology or animal ecology alone is bound to be imperfect and inadequate.

So plant and animal ecology are to be given equal emphasis and it is better to study them under the term Bio-ecology. The term Synecology denotes ecological studies at the community level while the term Autecology denotes ecological studies at the species level.

History of Ecology:

In a sense ecology is the new name of 'Natural history'. Man's interest in natural history dates back to prehistoric times. The carving and pictures discovered in France and Spain speak on the observation of the cave-dwellers about the fauna and flora around them.

The writings of Romans and Greeks bear evidences of their interest in natural history. 'The Histories of Animals' of Aristotle (384-322 B.C.) is a famous contribution in this line.

The first naturalist to give a systemised knowledge about the relation existing between living organisms and environment was Buffon. In a series of work in 1749, he stressed on habits and adaptations. After this, outstanding advances were made in the study of natural history in the eighteenth and nineteenth centuries.

Darwin's Naturalistic voyage round the world, Wallace's Island of life and many other work stimulated the knowledge of Biology to a great extent. However, the term ecology was first coined by German Biologist, Haeckel in 1878.

The science of ecology after undergoing a several hundreds of years gestation period has emerged today as a matured, honoured and scholarly discipline in biological science.

Branches of Ecology:

Ecological studies focus on how various organisms interact with their environment. There are a number of fields within ecology, either focusing on specific areas of interest or using particular approaches to address ecological problems.

The sub-fields or branches of ecology are:

i. Behavioural Ecology:

It is concerned with explaining the patterns of behaviour in animals.

ii. Physiological Ecology or Eco-Physiology:

It deals with how organisms are adapted to respond to temperature, maintain proper water and salt balance, and balance levels of oxygen and carbon dioxide, or deals with other factors of their physical environment. Studies of eco-physiology play an important role in agriculture since crop yield is very much dependent on the performance of individual plants.

It also plays an important role in conservation studies. For example, the decline of migratory bird species focuses on how changes in the environment affect the physiological mechanisms that prepare birds for long-distance migration.

iii. Molecular Ecology:

The use of molecular biology to directly tackle ecological problems is the focus of molecular biology.

iv. Evolutionary Ecology:

Evolutionary ecology emphasises the impact of evolution on current patterns and human induced changes. It relates to how animals choose mates, determine the sex of their offspring, forage for food and live in groups, or how plants attract pollinators, disperse seeds, or allocate resources between growth and reproduction. Evolutionary ecologists are particularly interested in how form and function adapt organisms to their environment.

v. Ecosystem Ecology:

Organisms obtain energy either through photosynthesis or by consuming other organisms. These energy transformations are associated with the movements of materials within and between organisms and the physical environment.

Thus, the interaction between the biotic and abiotic components called an ecosystem is the sub-field of ecology called ecosystem ecology. Issues of interest at this level is how human activities affect food webs, energy flow and global cycling of nutrients.

vi. Population Ecology:

Population ecology constitutes organisms of the same species living in the same place and same time. It may comprise of the dynamics of a single population of any living thing (earthworm, fox, whale, pine tree etc.) or may focus on how two populations (predator and its prey or parasite and its host) interact with each other. At the level of population, evolutionary changes take place. It is also related directly to the management of fish and game populations, forestry and agriculture. Population ecology is also fundamental to our understanding of the dynamics of disease.

vii. Community Ecology:

Populations of many different organisms in a particular place are tied to one another by feeding relationships and other interactions. These relationships of interacting populations are called ecological communities and their study is under the purview of community ecology.

Community studies is principally on how biotic interactions such as predation, herbivory and competition influence the numbers and distributions of organisms. It has particular relevance in our understanding of the nature of biological diversity.

viii. Landscape Ecology:

These are of ecological fields whose study requires the synthesis of several other sub-fields of ecology. Landscape ecology is one that emphasizes the inter-connections among ecosystems of a region.

The values of landscape ecology are:

(a) It emphasises on larger land areas of interacting ecosystems, i.e., next higher level of organisation above the local ecosystem, and

(b) Its tendency to compartmentalize. We study a lake or forest ecosystem but landscape ecology considers the connections between them. For example, herons forage in the lake, nest in the forest and, thus, the herons move nutrients from water to land.

ix. Conservation Biology:

This sub- field of ecology blends the concepts of genetics with population and community ecology. It takes a landscape approach and is related to the maintenance of biodiversity and the preservation of endangered species.

x. Restoration Ecology:

It relates to the re-establishing of the integrity of natural systems that have been damaged by human activity.

xi. Ecotoxicology:

It is the study of the fate and action of human-made substances, such as pesticides and detergents, in the natural world. Ecotoxicology focuses on the way in which human-made substances affect human health. Eco-toxicologists often use other animals, such as fish or small invertebrates, as models for the action of the particular toxic substance under study.

Environmentalism, conservationism and preservationism are social or political movements and not branches of ecology. Roadside trash pickups and city tree planting drives are well-intentioned public beautification and cleanup activities, but such activities are not science. Although everyone applauds such civic responsibilities, they however, do not increase our understanding of the natural world.

The subfields of ecological studies provide ways to think about the various approaches in ecology. However, in many cases, individual ecologists conduct work that crosses boundaries of these subfields. The natural curiosity of most ecologists, along with the complexity of nature, often encourages broad approaches. Ecological study, thus, is an integrative science, one that requires great innovation, breadth and curiosity.

Scope of Ecology:

The solution of a particular ecological problem requires several lines of approach. None of this constitute an end in itself but each one of these makes important contribution in making the picture complete.

These various lines of approach towards the ecological problem can be translated as:

(a) Biotic

(b) Quantitative

(c) Climatic (both physical and chemical)

(d) Taxonomic

(e) Genetic and evolutionary.

Biotic factors are the direct outcome of the various types of activities amongst the animals. A competition for food and shelter always exists amongst the members of a community. This competition demands various types of activity amongst the animals.

Quantitative study includes an assessment of the population density in a given area and also an estimation of the number of members present in different communities. Information of this kind is of immense value in solving many problems like food availability and movement within a particular colony.

Climatic factors include both physical and chemical conditions present in a habitat. These factors are ever changing in nature. Physical factors include mainly temperature, light and humidity. Chemical factors include acidity or salinity that are specially present in aquatic habitat. Some animals are so sensitive that a minute climatic change becomes fatal to them. Climatic factors play an important role in the distribution of animals.

Taxonomy means classification, naming and description of organisms. A mere naming of a large number of animals of a given area, as was done earlier in ecological surveys, is meaningless without a consideration of the circumstances that enable them to live there. Thus a complementary observation of the various ecological factors together with taxonomy is emphasized in ecology.

The genetic and evolutionary aspects have taken a rightful place in ecological problems. In recent years the knowledge of heredity and the mechanism of the operation of Natural Selection have increased to a considerable extent.

Evolution is no longer regarded as a thing of the past and it has been proved that evolution is a dynamic process though the progress is very slow. In certain circumstances it has become possible to detect and to measure the rate of evolution in wild population.

The above subdivisions form the backbone of the study of ecology. The inter-relationship existing between these subdivisions can be best understood with the help of an example. Let us assume that we want to study the ecology of a given species of edible fish inhabiting a large lake, with an object of establishing a new colony of these fishes to be started elsewhere.

In so doing, the first information that we need is that whether the food available in the new place is to be taken by these fishes. Our second enquiry would be to find out whether predators are present in the locality.

These two are included within the biotic factors. We will have to determine the number of fishes that are to be let loose in the new locality and the number is to be determined in such a way that they can live there without being overcrowded. Herein lies the involvement of the quantitative aspect. We will have to study the water itself and to find out the extent of the fluctuations in its constitution such as salt content, acidity or alkalinity in order to determine the tolerance of the fishes in the changing factors.

If the first lake is a very old one and the fish in question had been isolated there for a great period of time, it is possible that a subspecies or local race might evolve there. In such cases the taxonomist might come forward and help identifying the species. Such a situation opens up a case for the Geneticists and Evolutionists to find out how and at what rate the new forms have evolved.

Autecology & synecology

Autecology is the study of the environment in relation to only one species in contrast to synecology, which is the study of the environment affecting groups of species coexisting in the area.

Autecology primarily deals with the individual organism or species with the biotic and abiotic components of an ecosystem or environment. For instance, it aims to measure factors such as nutrient availability, light, and humidity in relation to the organism or species thriving in a particular environment.

Apart from autecology, another subfield of ecology that is closely related to it is synecology. The latter is concerned primarily with the studying groups of organisms associated as a unit or a community. While autecology attempts to understand the relationship between an organism and its environment synecology aims to understand the association of different groups of species in a community. Synecology is a subfield of ecology concerned with the relations between groups of organisms or coexisting biological communities. It encompasses distribution, abundance, demography and interactions between coexisting groups of organisms. For instance, interspecific interactions (e.g. predation) are dealt with in synecology.

Ecological levels of organization

Important levels of organization are:

1. Organisms

2. Population

3. Biological Community

4. Ecosystem

5. Landscape

6. Biome

7. Biosphere.

1. Organisms:

They make the basic unit of study in ecology. At each level, the biological unit has a specific structure and function. At this level, the form, physiology, behaviour, distribution and adaptations in relation to the environmental conditions are studied.

The organisms of the similar type have the potential for interbreeding, and produce fertile offspring, which are called species.

The organism performs all the life processes independently. However, parts of organism cannot exist independently of one another.

An organism is fully adapted to its environment. It has a definite life span including definite series of stages like birth, hatching, growth, maturity, senescence, aging and death.

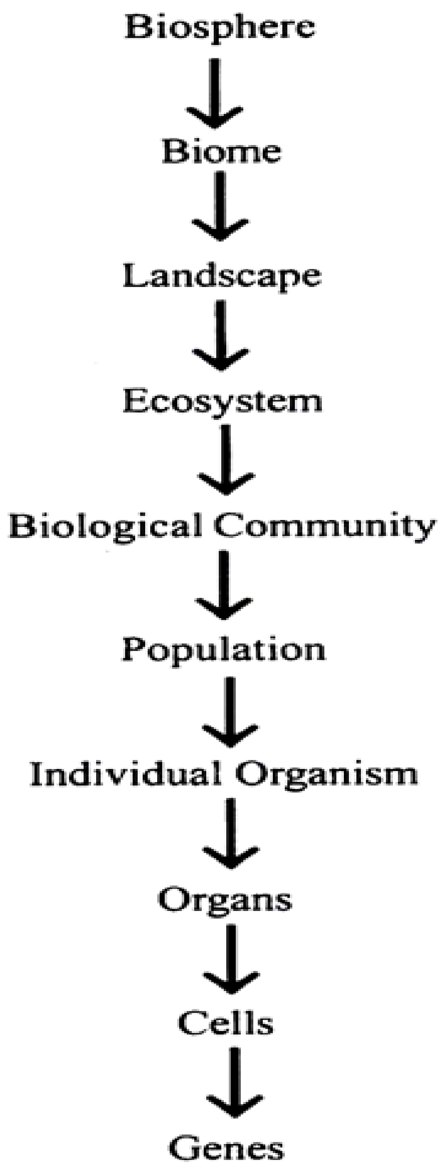
Competition, mutualism and predation are various types of interaction between organisms.

2. Population:

In ecology, a population is a group of individuals of the same species, inhabiting the same area, and functioning as a unit of biotic community.

For example, all individuals of the common grass, *Cynodon*, in a given area constitute its population. Similarly, the individuals of elephants or tigers in an area constitute their population.

The interaction between populations is generally studied. These interactions may be a predator and its prey, or a parasite with its host. Competition, mutualism, commensalism, parasitism, and predation are various types of interactions.



Levels of organization in ascending order

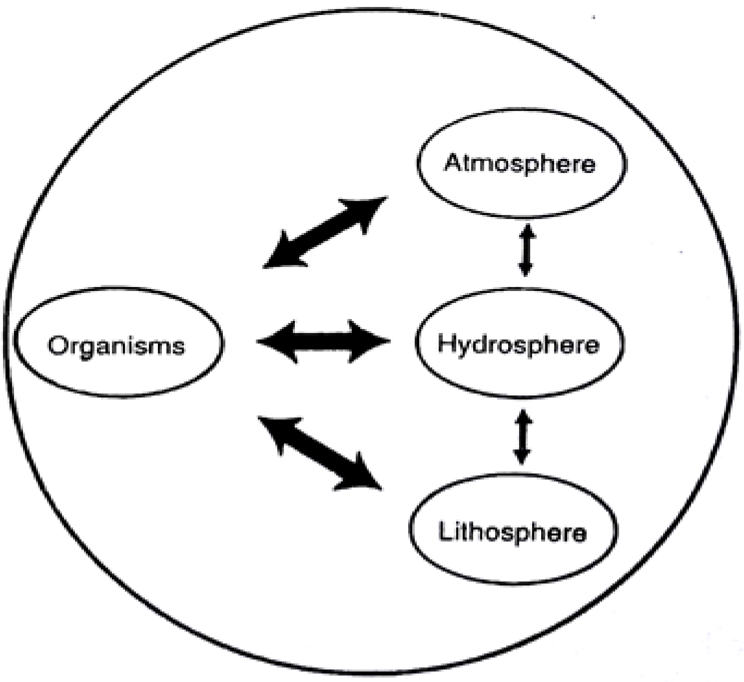
3. Biological Community:

Biotic community organization results from interdependence and interactions amongst population of different species in a habitat. This is an assemblage of populations of plants, animals, bacteria and fungi that live in an area and interact with each other.

A biotic community is a higher ecological category next to population. These are three types of biotic community, they are: animals, plants and decomposers (i.e., bacteria and fungi). A biotic community has a distinct species composition and structure.

4. Ecosystem:

The ecosystems are parts of nature where living organisms interact amongst themselves and with their physical environment. An ecosystem in composed of a biotic community, integrated with its physical environment through the exchange of energy and recycling of the nutrients. The term ecosystem was coined by Sir Arthur Tansley in 1935.



The interaction of organisms with atmosphere

Ecosystems can be recognized as self- regulating and self-sustaining units of landscape, e.g., a pond or a forest.

An ecosystem has two basic components:

(i) Abiotic (non-living), and

(ii) Biotic (living organisms).

Abiotic components comprise inorganic materials, such as carbon, nitrogen, oxygen, CO_2, water etc., while biotic components include producers, consumers and decomposers.

5. Landscape:

A landscape is a unit of land with a natural boundary having a mosaic of patches, which generally represent different ecosystems.

6. Biome:

This is a large regional unit characterized by a major vegetation type and associated fauna found in a specific climate zone. The biome includes all associated developing and modified communities occurring within the same climatic region, e.g., forest biomes, grassland and savanna biomes, desert biome, etc.

On a global scale, all the earth's terrestrial biomes and aquatic systems constitute the biosphere.

7. Biosphere:

The entire inhabited part of the earth and its atmosphere including the living components is called the biosphere.

The global environment consists of three main sub-divisions:

(i) The hydrosphere which includes all the water components,

(ii) The lithosphere comprises the solid components of the earth's crust, and

(iii) The atmosphere formed of the gaseous envelope of the earth. The biosphere consists of the lower atmosphere, the land and the oceans, rivers and lakes, where living beings are found.

Limiting factor in biology refers to any of the factors (variables) in an environment capable of limiting a process, such as growth, abundance, or distribution of a population of organisms in an ecosystem.

The principles or laws that help explicate limiting factors in an ecosystem are **Liebig's *law of the minimum*, Blackman's *law of limiting factor*, and Shelford's *law of tolerance***.

In *law of minimum*, the growth of population could be regulated by the scarcest resource, not by the resources in abundance.

In *law of limiting factor*, a biological or an ecological process that depends on multiple factors will tend to have a rate limited by the slowest factor.

In *law of tolerance*, the survival success of an organism is suggested to depend on a complex set of environmental factors.

- Limiting factors may be density-dependent or density-independent. Those that are density-dependent tend to limit growth, abundance, or distribution of a population depending on how dense a population is. Conversely, a density-independent limiting factor is capable of limiting population growth, abundance, or distribution irrespective of population density.
- Limiting factors may also be *single-limiting*, i.e. when only one factor limits the system. When a factor causes an indirect restrictive effect or increases the effect of a direct limiting factor, it is termed as a *co-limiting factor*. Examples of limiting factors that could limit the size of a population are food, nutrients, shelter, and mate. These resources are limited in the ecosystem, and as a result, they could drive living things to compete for them.

Limiting factor

Different limiting factors affect the ecosystem.

They are

(1) keystone species,

(2) predators,

(3) energy,

(4) available space, and

(5) food supply.

In biology, the term *limiting factor* is defined as an environmental factor or variable that has the capacity to restrict growth, abundance, or distribution of a population in an ecosystem. These factors are present in limited supply. Thus, organisms tend to compete for their limited availability in the ecosystem.

Etymology

The term *limiting factor* comes from Latin *limitare*, meaning "to bound" and from Latin *factor*, meaning "a doer", "performer"), from *factus*, meaning "done" or "made".

Liebig's *law of the minimum*

Law of the minimum was originally developed by Carl Sprengel and then later popularized by Justus von Liebig.

This law states that the growth is regulated by a limiting factor, i.e. the scarcest resource, rather than by the total resources available. In biology and ecology, this means that the growth of a population is restricted by the factors that are scarcest and not by the factors that are abundant. This was based on the observation of crop growth. Accordingly, the addition of nutrients in abundance did not result in increased growth. Conversely, the addition of nutrients that are scarce, which in this case is the limiting factor, did lead to increased crop growth. This means that even if some of the nutrients in the soil are abundant but if the other nutrients are limiting or relatively fewer then crop growth will not increase. Applying this principle to other biological populations, this implicates growth occurring only as dictated by the most limiting factor. This principle was used by William

Cumming Rose as a basis in identifying the amino acids that were labelled as *essential*.

Blackman's *law of limiting factor*

The law of limiting factor was proposed in 1905 by the British plant physiologist, Frederick Frost Blackman.

According to this law, a process that depends on multiple factors will have a rate limited by the pace of the slowest factor. Photosynthesis, for example, is a biological process that depends on multiple factors. The general chemical reaction of photosynthesis is

$6CO_2+12H_2O+energy=C_6H_{12}O_6+6O_2+6H_2O$.

Based on this equation, CO_2, H_2O, and light energy (sunlight) are the limiting factors of this reaction. If any of them become accessible at a pace slower or lower than the usual, the rate of photosynthesis is expected to become slow based on the pace of the slowest factor. For example, if CO_2 concentration becomes scarce (e.g. due to closure of stomatal openings in response to elevated temperatures in the environment), the rate of photosynthesis becomes slow even if H_2O and light energy levels are amply available. The same result will occur if light energy becomes less available or less intense, the rate of photosynthesis will be slower despite the abundance of CO_2 and H_2O. Light becomes a limiting factor in photosynthesis when the plant is unable to collect light, for instance, due to shade resulting from the dense population of plants.

Shelford's *law of tolerance*

The *law of tolerance* was developed in 1913 by American zoologist Victor Ernest Shelford. It states that the success of an organism depends on a complex set of environmental conditions (environmental factors). And that organism would have definite *minimum*, *maximum*, and *optimum* environmental factors that determine success. These signify the limit of tolerance of that organism. However, the tolerance ranges may vary within the same organism, for example depending on the life stage (larval vs. adult).

Types of limiting factors

Density-dependent limiting factor definition

Density-dependent limiting factor refers to the factor restricting the size of a population based on density. A large, dense population are more strongly affected than a small or less dense population. For example, a dense population would have higher demands for food and water compared to a small population. In this case, food and water supply is the limiting factor and it depends on density. Disease as a factor is also density-dependent. It spreads faster in dense population than small ones.

Density-independent limiting factor definition

Density-independent limiting factor refers to the limiting factor that is not dependent on density. The limiting factor can restrict population size independent of how dense the population is. For example, a catastrophic event, such as an earthquake or a volcanic eruption, could cause a population decline regardless of population density.

Single-limiting and co-limiting

A *single-limiting factor* is when there is one factor that limits the system. A *co-limiting factor* is when a factor affects the population of organisms in an ecosystem indirectly but increases the limitation of the factor directly affecting the population.

Limiting factors examples

In the law of the size of a population, a population will grow exponentially as long as the environment from where all individuals in that population are exposed to remains constant.Thus, if the environmental conditions are kept the same, the population is expected to grow. However, there will come a time when the population will reach the maximum at which the environment can sustain. This is called the *carrying capacity*, the maximum load of the environment. Carrying capacity is the number of individuals that an environment can sustain without ending in damage or destruction to the organisms and the environment. Thus, population size may increase until carrying capacity is met. Above this capacity, the population size will eventually decrease. The determiners of carrying capacity are limiting factors. The common limiting factors in an ecosystem are food, water, habitat, and mate. The availability of these factors will affect the carrying capacity of an environment.

As population increases, food demand increases as well. Since food is a limited resource, organisms will begin competing for it. The same thing goes for space, nutrients, and mate. Since these resources are available for a limited amount over a given period of time, inhabitants of a particular ecosystem will compete, possibly against the same species (intraspecific competition) or against other group of species (interspecific competition). In the wild, another predominant symbiosis is the predator-and-prey relationship. The deer populations, for instance, could decline if predation is high. If the number of wolves is relatively greater than the number of deer as their prey, the number of deer could drop. However, with the dwindling number of deer, the number of wolves could also eventually decline. This predator-prey factor is an example of a biotic factor in an ecosystem.

While a biotic factor includes the activities of a living component of an ecosystem, an *abiotic factor* includes the various physico-chemical factors in an ecosystem. These physico-chemical factors include sunlight, humidity, temperature, atmosphere, soil, geology of the land, and water resources. Temperature, for instance, is a major limiting factor primarily due to the fact it affects the effectiveness of enzymes and catalysts, which are essential in an efficient system, both biological and chemical.

Unit II

Population and its characteristics

A population is defined as a group of individuals of the same species living and interbreeding within a given area. Members of a population often rely on the same resources, are subject to similar environmental constraints, and depend on the availability of other members to persist over time.

As a tool for objectively studying populations, population ecologists rely on a series of statistical measures, known as demographic parameters, to describe that population (Lebreton *et al*. 1992). The field of science interested in collecting and analyzing these numbers is termed population demographics, also known as demography.

Demography

Demography is the study of the characteristics of populations. It provides a mathematical description of how those characteristics change over time. Demographics can include any statistical factors that influence population growth or decline, but several parameters are particularly important: population size, density, age structure, fecundity (birth rates), mortality (death rates), and sex ratio (Dodge 2006).

Population Size

The most fundamental demographic parameter is the number of individuals within a population (Lebreton *et al*. 1992). Population size is defined as the number of individuals present in a subjectively designated geographic range. Despite the simplicity in its concept, locating all individuals during a census (a full count of every individual) is nearly impossible, so ecologists usually estimate population size by counting individuals within a small sample area and extrapolating that sample to the larger population. Regardless of the challenges in measuring population size, it is an important characteristic of a population with significant implications for the dynamics of the population as a whole (Lebreton *et al*. 1992).

Populations display distinctive behaviours based on their size. Small populations face a greater risk of extinction (Caughley 1994). Individuals in these populations can have a hard time finding quality mates so, fewer individuals mate and those that do risk inbreeding (Hamilton 1967). Additionally, individuals in small population are more susceptible to random deaths. Events like fire, floods, and disease have a greater chance of killing all individuals in the population.

Large populations experience their own problems. As they approach the maximum sustainable population size, known as carrying capacity, large populations show characteristic behaviour. Populations nearing their carrying capacity experience greater competition for resources, shifts in predator-prey relationships, and lowered fecundity. If the population grows too large, it may begin to exceed the carrying capacity of the environment and degrade available habitat.

Population Density

A more complete description of a population's size includes the population density — the size of a population in relation to the amount of space that it occupies. Density is usually expressed as the number of individuals per unit area or volume (Lebreton *et al*. 1992). For example: the number of crows per square kilometer or the number of plankton per liter (Andren 1992, Sterner 1986).

Like all population properties, density is a dynamic characteristic that changes over time as individuals are added to or removed from the population. Birth and immigration — the influx of new individuals from other areas — can increase a population's density, while death and emigration — the movement of individuals out of a population to other areas — can decrease its density (Lebreton *et al*. 1992).

Similar to population size, population density displays distinctive characteristics at both high and low values.

Density-dependent factors, including competition, predation, migration and disease, intensify within populations as density increases. In contrast, density-independent factors, such as weather, fire regimes, and flooding, impact populations regardless of their specific densities (Lebreton *et al*. 1992).

Age Structure

Not all individuals contribute equally to a population. Occasionally, researchers find it useful to characterize the different contributions made by different individuals. First, individuals are sorted into age-specific categories called **cohorts**, such as "juveniles" or "sub-adults" (Dodge 2006). Researchers then create a profile of the size and age structures of the cohorts to determine the reproductive potential of that population, in order to estimate current and future growth. Usually, a rapidly expanding population will have larger reproductive cohorts, stable populations show a more even distribution of age classes, and rapidly declining populations have large older cohorts (Lebreton *et al*. 1992).

Age structure can be represented graphically with a population pyramid. Although a population's age structure is not always pyramidal in shape, most populations have younger cohorts that are larger than older cohorts. For example, Sherman and Morton's studies of the Tioga Pass Belding's ground squirrels revealed birth cohorts larger than 300 individuals and less than 10 individuals in cohorts over the age of six (Sherman & Morton 1984).

Fecundity

As age structure suggests, some individuals within a population have a greater impact on population-level processes, such as growth. Fecundity describes the number of offspring an individual or a population is able to produce during a given period of time (Martin 1995).

In demographic studies, fecundity is calculated in age-specific birth rates, which may be expressed as the number of births per unit of time, the number of births per female per unit of time, or the number of births per 1,000 individuals per unit of time. Maximum (or physiological) fecundity is the theoretical maximum number of offspring produced in a population assuming no ecological constraints. However, since every **ecosystem** implements constraints on its populations, ecologists prefer to measure realized (or ecological) fecundity, which is the observed number of offspring produced in a population under actual environmental conditions.

While maximum fecundity is a constant for populations, realized fecundity varies over time based on the size, density, and age structure of the population. External conditions, such as food and habitat availability, can also influence fecundity. **Density-dependent regulation** provides a negative feedback if the population grows too large, by reducing birth rates and halting population growth through a host of mechanisms (Lebreton *et al*. 1992). In white-footed mice, for example, populations regulate their reproductive rate via a **stress hormone**. As population densities increase, so do aggressive interactions between individuals (even when food and shelter are unlimited). High population densities lead to frequent aggressive encounters, triggering a stress syndrome in which hormonal changes delay **sexual maturation**, cause **reproductive organs** to shrink, and depress the immune system (Krohne 1984).

Mortality

Another individual trait that affects population growth is mortality. Mortality is the measure of individual deaths in a population and serves as the counterbalance to fecundity. Like fecundity, mortality is measured in **rates**, usually expressed as the number of individuals that die in a given period (deaths per unit time) or the proportion of the population that dies in a given period (percent deaths per unit time). A population theoretically has a **minimum mortality** — the theoretically minimum number of deaths in a population assuming no ecological constraints. The minimum mortality is always lower than the **realized** (or **ecological**) **mortality**, which is the observed number of losses in a population under actual environmental conditions. Much like realized fecundity, realized mortality varies over time based on dynamics internal and external to the population (Benrey & Denno 1997).

To visualize mortality and fecundity within a population, ecologists create **life tables** to display **age-specific** statistical summaries of a population's survival patterns. First developed by Roman actuaries, life tables were used to estimate how long individuals of a particular age category were expected to live in order to value life insurance products (Trenerry 1926). Raymond Pearl (1928) first introduced the life table to biology when he applied it to laboratory studies of the fruit fly, *Drosophila*. Life tables are particularly useful for species with **discrete developmental stages** and mortality rates that vary widely from one stage to the next.

Sex Ratio

Sexually reproducing organisms must find mates in order to produce offspring. Without comparable numbers of males and females, mating opportunities may be limited and population growth stunted. Thus, ecologists measure the number of males and females within a population to construct a sex ratio, which can help researchers predict population growth or decline. Much like population size, sex ratio is a simple concept with major implications for population dynamics. For example, stable populations may maintain a 1:1 sex ratio and therefore keep their growth rate constant, whereas declining populations may develop a 3:1 sex ratio favoring females, resulting in an increased **growth rate**. In species where males contribute significantly to offspring **rearing**, populations may instead maintain a ratio skewed towards males (Hamilton 1967).

Interestingly, sex ratio is not always random but can be manipulated at birth by environmental or **physiological** mechanisms. All crocodiles and many reptiles utilize a strategy called environmental sex determination, wherein incubation temperature determines the sex of each individual (Delmas *et al*. 2008). For example, low temperatures will produce males and high temperatures will produce females. In times of limited resources or high population densities, females can manipulate the sex ratios of their **clutch** by spending more or less time incubating their eggs (Girondot *et al*. 2004).

Unit III

Characteristics of a Community

The features within communities are highly variable, and there are a number of characteristics that can be used as descriptors to distinguish them.

1. **Trophic Organization**

Each organism within a community can be categorized within a specific *trophic level*, which relates to the way which it obtains nutrition. These trophic levels can be divided into three main groups:

i) primary producers (also known as *autotrophs*) manufacture their own food using energy from the sun to perform *photosynthesis*. Primary producers are usually green plants and algae.

ii) Consumers, or *heterotrophs* must obtain their nutrition from other organisms. Primary consumers, or *herbivores* eat the plant material while secondary and tertiary consumers, *carnivores* or *omnivores*, eat the primary consumers.

iii) Decomposers (which are also heterotrophs) consume dead plant and animal material, recycling the nutrients back in to the earth.

For example, in a grassland community, the grass (primary producer) is consumed by a mouse (primary consumer), which is consumed by a snake (secondary consumer), and subsequently an eagle (tertiary consumer). The dead body of the eagle may be consumed by fungus (decomposer).

Dominance

There are usually one or two species at each trophic level, which exert a more dominant influence over the function and structure of the community than others. This may be due to their physical size, population numbers, or activities that have an impact upon other organisms or the environment. These so called '*ecological dominants'*, can have a major effect on the nature of the community.

Plants usually dominate land communities, and so the name of the community is often based on the ecologically dominant vegetation, for example Douglas-fir Woodland or Rocky Mountain Maple Forest.

Interdependence

Communities are not just a random mixture of plants, animals and microbes; each of the organisms within a community has a fundamental dependence on at least one other, although most organisms will engage in multiple interactions.

There are three main forms of interdependence.

a) **Nutritional interdependence** describes the transfer of energy and nutrients through feeding. Certain organisms may be more reliant on the presence of others to fulfil their nutritional requirements, for example insects that can feed only from one species of plant.

b) **Reproductive independence** can take several forms. A common example is that of pollination, which is present within most communities. Whilst for the pollinator the interaction provides a food source of nectar, for the plant, the interaction is essential to its reproductive success. Certain species may only be able to reproduce on a particular plant or substrate and are therefore dependent on the presence of this within the community. Other reproductive independences involve *parasitic* interactions, for example cuckoos, which lay their own eggs in the nests of other birds.

c) **Protective interdependence** is the third main interaction. Most organisms require a level of shelter, and may rely on other organisms within the community for this. For example, insects living on a tree are dependent on the leaves and branches to shelter them from predation by birds.

Interactions between community members are not always linear and can involve several highly complex interactions. Many of such interactions may take place only under precise environmental conditions. An example of this is the *symbiosis* between corals and the photosynthetic algae which live within their body structures. The interaction supplies the coral with energy and the algae with nutrients; however, the algae only remain within the body under certain temperatures.

Community Structure

Descriptions of the community structure relate to both the *species richness*, which is the total number of species, and the *species diversity*, a community complexity measurement which takes in the species richness as well as their relative abundances (i.e. 5 individuals rather than 100 individuals). Communities in which species exhibit higher species richness and evenness (the numbers of individuals in each species present are more equal) are considered to be more diverse.

The structure of a community may be determined by its natural history, i.e. the chance colonization event of a population onto an island, by (non-living) *abiotic* *factors* such as the climatic patterns, the geography and the habitat location, or by (living) *biotic factors* such as the presence of other organisms which exert pressures such as predation or competition.

Communities at tropical latitudes tend to display high species richness and diversity, due to the high productivity of plants, which receive large amounts of solar energy, and have year-round climatic stability. Alternatively, community structure in habitats such as arctic tundra are very different – usually displaying lower species richness as a result of fewer basic resources such as sunlight and nutrients.

As a general rule, communities that have more species diversity are more resilient against ecosystem damage.

Growth Form & Succession

A community can be described by major categories of its growth form. For example mosses, herbaceous plants, shrubs or trees.

Communities may also be characterized by their *successional stage*. *Ecological succession* is the progressive and predictable replacement of one type of community by another, over time. *Primary succession* is the initial colonization of a bare landscape which has not previously been occupied, often following a significant ecological disturbance such as a volcanic eruption. *Secondary succession* occurs where a community has existed previously but has been removed from a landscape, for example, an area of deforestation or an abandoned cropland. In this case the nutrients within the soil are already present, and conditions for growth are favorable and so secondary succession happens much more rapidly than primary succession.

Pioneer species are the first to make up the community within a bare landscape once their seeds or spores migrate from surrounding areas and successfully germinate. These *pioneer communities* consist of fast growing, hardy plants with a short lifespan and low biomass, requiring very little nutrients. The roots of pioneer species contain nitrogen-fixing bacteria, which are important for the formation of soil and other organic material.

Seral communities develop in the area after the pioneer community. These transitional communities consist of intermediate sized species such as shrubs and heaths, which have high biomass and high nutritional content. These species further build the soil and nutrients with *biogeochemical cycling*.

The *climax community* is the stable, self-regulating biotic community, which establishes after many years. It contains longer-lived and larger species with high *niche* specialization, complex food webs and mature interdependent relationships. Diversity is highest within climax communities and the community is at equilibrium with the habitat and climate.

Stratification

Natural climax communities usually exhibit some form of stratification, by which the populations that make up the community are distributed into defined vertical or horizontal strata.

For example, the bottom-up stratification of a forest community could be divided into:

- The subterranean layer
- The forest floor
- The herbaceous vegetation
- The shrub layer
- The canopy layer

Organisms may not occupy only one stratum, moving between the layers often on a diurnal basis. For example, a bird that feeds on the forest floor during the day but roosts within the canopy.

A community may occur along a horizontal stratification where there is transition between successional stages and ecotones.

Communities occur in a range of different sizes, and the boundaries of each are often not well defined. An *ecotone* is the transitional area between two *biomes*, where communities meet and may integrate.

Many organisms may be part of several different communities because they have various geographic ranges, and density peaks; if these boundaries are wide, it is known as an *open community*. A community in which the species all have similar geographic ranges and density peaks, resulting in a discrete unit where the boundaries are well defined, is called a *closed community*.

Open communities tend to occur where there is a long environmental gradient, such as that of soil moisture content or the altitudinal slope of a mountain. Organisms with different tolerances to the conditions occur at different spatial scales along the gradients.

Closed communities occur where there is a sharp change in the vegetative structure or the physical environment, for example, an area of a beach, which separates the water from the land.

Ecotones are generally very hard to define because within an ecosystem there are usually organisms, which can disperse between both open and closed communities.

UNIT IV

Ecosystem

Ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others" – Woodbury.

Types of ecosystem

Organisms and environment are two non-separable factors. Organisms interact with each other and also with the physical conditions that are present in their habitats.

"The organisms and the physical features of the habitat form an ecological complex or more briefly an ecosystem." (Clarke, 1954).

The concept of ecosystem was first put forth by A.G. Tansley (1935). Ecosystem is the major ecological unit. It has both structure and functions. The structure is related to species diversity. The more complex is the structure the greater is the diversity of the species in the ecosystem. The functions of ecosystem are related to the flow of energy and cycling of materials through structural components of the ecosystem.

According to Woodbury (1954), ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others.

According to E.P. Odum, the ecosystem is the basic functional unit of organisms and their environment interacting with each other and with their own components. An ecosystem may be conceived and studied in the habitats of various sizes, e.g., one square metre of grassland, a pool, a large lake, a large tract of forest, balanced aquarium, a certain area of river and ocean.

All the ecosystems of the earth are connected to one another, e.g., river ecosystem is connected with the ecosystem of ocean, and a small ecosystem of dead logs is a part of large ecosystem of a forest. A complete self-sufficient ecosystem is rarely found in nature but situations approaching self-sufficiency may occur.

Structure of Ecosystem:

The structure of an ecosystem is basically a description of the organisms and physical features of environment including the amount and distribution of nutrients in a particular habitat. It also provides information regarding the range of climatic conditions prevailing in the area.

Ecosystems consist of the following basic components:

1. Abiotic components
2. Biotic components

1. Abiotic Components:

Ecological relationships are manifested in physicochemical environment. Abiotic component of ecosystem includes basic inorganic elements and compounds, such as soil, water, oxygen, calcium carbonates, phosphates and a variety of organic compounds (by-products of organic activities or death).

It also includes such physical factors and ingredients as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant energy source for any ecosystem. The amount of non-living components, such as carbon, phosphorus, nitrogen, etc. that are present at any given time is known as standing state or standing quantity.

2. Biotic Components:

The biotic components include all living organisms present in the environmental system.

From nutrition point of view, the biotic components can be grouped into two basic components:

(i) Autotrophic components, and

(ii) Heterotrophic components

The autotrophic components include all green plants which fix the radiant energy of sun and manufacture food from inorganic substances. The heterotrophic components include non-green plants and all animals which take food from autotrophs.

So biotic components of an ecosystem can be described under the following three heads:

1. Producers (Autotrophic components),
2. Consumers, and
3. Decomposers or reducers and transformers

The amount of biomass at any time in an ecosystem is known as standing crop which is usually expressed as fresh weight, dry weight or as free energy in terms of calories/metre.

Producers (Autotrophic elements):

The producers are the autotrophic elements—chiefly green plants. They use radiant energy of sun in photosynthetic process whereby carbon dioxide is assimilated and the light energy is converted into chemical energy. The chemical energy is actually locked up in the energy rich carbon compounds. Oxygen is evolved as by-product in the photosynthesis.

This is used in respiration by all living things. Algae and other hydrophytes of a pond, grasses of the field, and trees of the forests are examples of producers. Chemosynthetic bacteria and carotenoid bearing purple bacteria that also assimilate CO_2 with the energy of sunlight but only in the presence of organic compounds also belong to this category.

The term producer is misleading one because in an energy context, producers produce carbohydrate and not energy. Since they convert or transduce the radiant energy into chemical form, E.J. Kormondy suggests better alternative terms 'converters' or 'transducers' because of wide use the term producer is still retained.

Consumers:

Those living members of ecosystem which consume the food synthesized by producers are called consumers. Under this category are included all kinds of animals that are found in an ecosystem.

There are different classes or categories of consumers, such as:

(a) Consumers of the first order or primary consumers,

(b) Consumers of the second order or secondary consumers,

(c) Consumers of the third order or tertiary consumers, and

(d) Parasites, scavengers and saprobes.

(a) Primary consumers:

These are purely herbivorous animals that are dependent for their food on producers or green plants. Insects, rodents, rabbit, deer, cow, buffalo, goat are some of the common herbivores in the terrestrial ecosystem, and small crustaceans, molluscs, etc. in the aquatic habitat. Elton (1939) named herbivores of ecosystem as "key industry animals". The herbivores serve as the chief food source for carnivores.

(b) Secondary consumers:

These are carnivores and omnivores. Carnivores are flesh eating animals and the omnivores are the animals that are adapted to consume herbivores as well as plants as their food. Examples of secondary consumers are sparrow, crow, fox, wolves, dogs, cats, snakes, etc.

(c) Tertiary consumers:

These are the top carnivores which prey upon other carnivores, omnivores and herbivores. Lions, tigers, hawk, vulture, etc. are considered as tertiary or top consumers.

(d) Besides different classes of consumers, the parasites, scavengers and saprobes are also included in the consumers. The parasitic plants and animals utilize the living tissues of different plants and animals. The scavengers and saprobes utilize dead remains of animals and plants as their food.

Decomposers and transformers:

Decomposers and transformers are the living components of the ecosystem and they are fungi and bacteria. Decomposers attack the dead remains of producers and consumers and degrade the complex organic substances into simpler compounds. The simple organic matters are then attacked by another kind of bacteria, the transformers which change these organic compounds into the inorganic forms that are suitable for reuse by producers or green plants. The decomposers and transformers play very important role in maintaining the dynamic nature of ecosystems.

Function of Ecosystem:

An ecosystem is a discrete structural, functional and life sustaining environmental system. The environmental system consists of biotic and abiotic components in a habitat. Biotic component of the ecosystem includes the living organisms; plants, animals and microbes whereas the abiotic component includes inorganic matter and energy.

Abiotic components provide the matrix for the synthesis and perpetuation of organic components (protoplasm). The synthesis and perpetuation processes involve energy exchange and this energy comes from the sun in the form of light or solar energy.

Thus, in any ecosystem we have the following functional components:

(i) Inorganic constituents (air, water and mineral salts)

(ii) Organisms (plants, animals and microbes), and

(iii) Energy input which enters from outside (the sun).

These three interact and form an environmental system. Inorganic constituents are synthesized into organic structures by the green plants (primary producers) through photosynthesis and the solar energy is utilized in the process. Green plants become the source of energy for renewals (herbivores) which, in turn become source of energy for the flesh-eating animals (carnivores). Animals of all types grow and add organic matter to their body weight and their source of energy is complex organic compound taken as food.

They are known as secondary producers. All the living organisms whether plants or animals in an ecosystem have a definite life span after which they die. The dead organic remains of plants and animals provide food for saprophytic microbes, such as bacteria, fungi and many other animals. The saprobes ultimately decompose the organic structure and break the complex molecules and liberate the inorganic components into their environment.

These organisms are known as decomposers. During the process of decomposition of organic molecules, the energy which kept the inorganic components bound together in the form of organic molecules gets liberated and dissipated into the environment as heat energy. Thus, in an ecosystem energy from the sun, the input is fixed by plants and transferred to animal components.

Nutrients are withdrawn from the substrate, deposited in the tissues of the plants and animals, cycled from one feeding group to another, released by decomposition to the soil, water and air and then recycled. The ecosystems operating in different habitats, such as deserts, forests, grasslands and seas are interdependent on one another. The energy and nutrients of one ecosystem may find their way into another so that ultimately all parts of the earth are interrelated, each comprising a part of the total system that keeps the biosphere functioning.

Thus, the principal steps in the operation of ecosystem are as follows:

(1) Reception of radiant energy of sun,

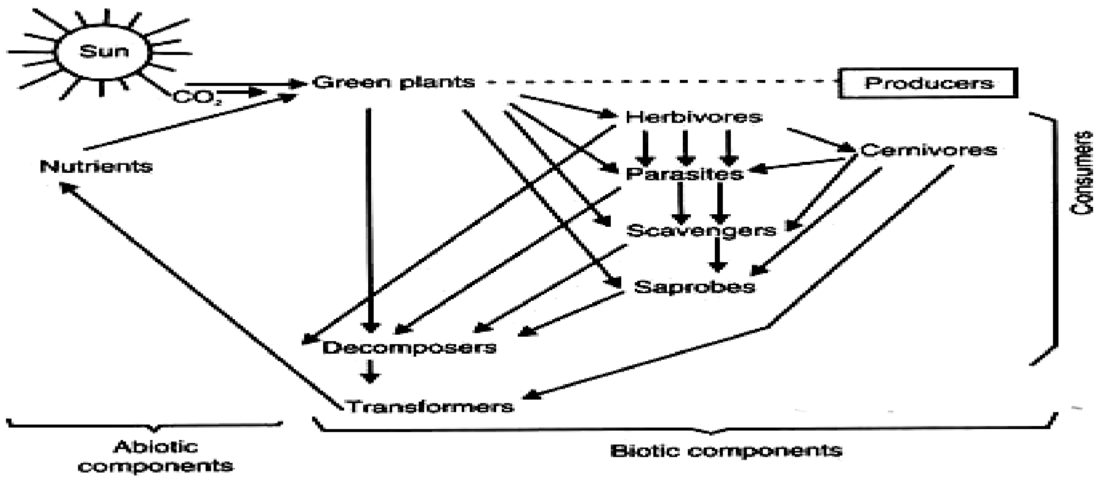
(2) Manufacture of organic materials from inorganic ones by producers,

(3) Consumption of producers by consumers and further elaboration of consumed materials; and.

(4) After the death of producers and consumers, complex organic compounds are degraded and finally converted by decomposers and converters into such forms as are suitable for reutilization by producers.

The principal steps in the operation of ecosystem not only involve the production, growth and death of living components but also influence the abiotic aspects of habitat. It is now clear that there is transfer of both energy and nutrients from producers to consumers and finally to decomposers and transformers levels. In this transfer there is a progressive decrease of energy but nutrient component is not diminished and it shows cycling from abiotic to biotic and vice versa.

The flow of energy is unidirectional. The two ecological processes—energy flow and mineral cycling which involve interaction between biotic and abiotic components lie at the heart of ecosystem dynamics. The principal steps and components of ecosystem are explained below.



Fresh water ecosystems

Pond and lake are fresh water ecosystems in which, like other ecosystems, there are two main components:

(A) Abiotic component

(B) Biotic component

(A) Abiotic component:

Abiotic component of pond consists of water, dissolved minerals, oxygen and carbon dioxide. Solar radiations are the main source of energy.

(B) Biotic component:

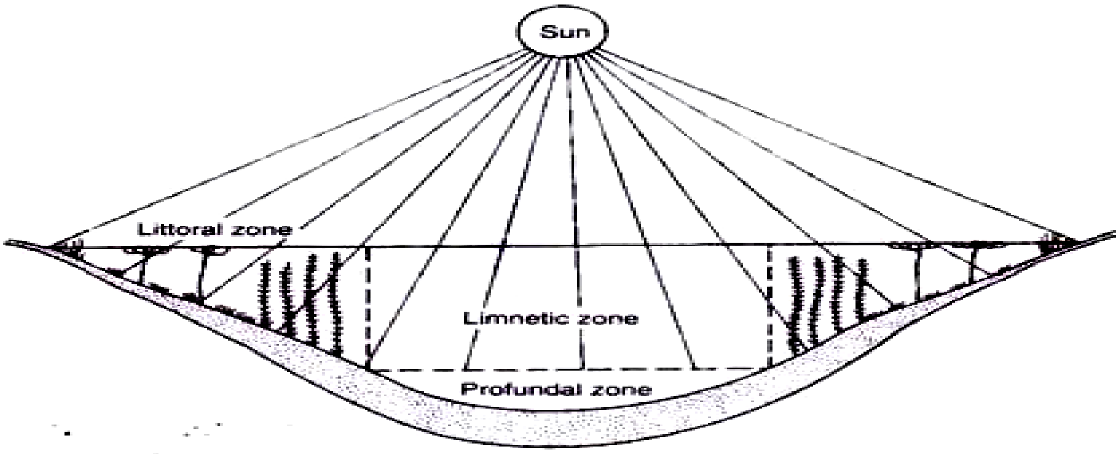
It includes the following:

(i) Producers

(ii) Consumers

(iii) Decomposers and transformers.

On the basis of water depth and types of vegetation and animals there may be three zones in a lake or pond littoral, limnetic and pro-fundal. The littoral zone is the shallow water region which is usually occupied by rooted plants. The limnetic-zone ranges from the shallow to the depth of effective light penetration and associated organisms are small crustaceans, rotifers, insects, and their larvae and algae. The pro-fundal zone is the deep-water parts where there is no effective light penetration. The associated organisms are snails, mussels, crabs and worms.



(i) Producers:

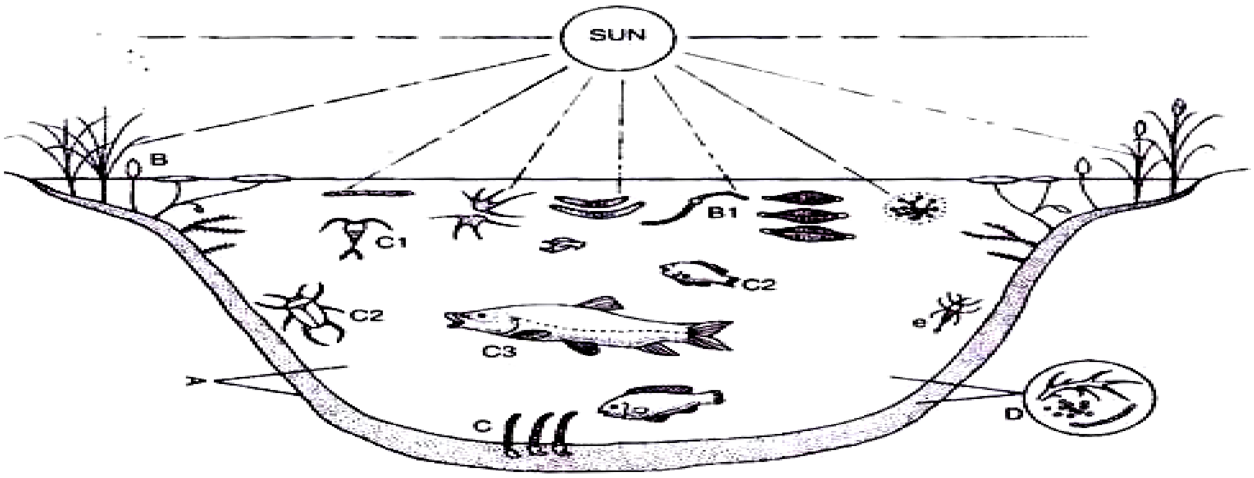
The main producers in pond or lake ecosystem are algae and other aquatic plants, such as *Azolla*, *Hydrilla*, *Potamogeton*, *Pistia*, *Wolffia*, *Lemna*, *Eichhornia*, *Nymphaea*, *Jussiaea*, etc. These are either floating or suspended or rooted at the bottom. The green plants convert the radiant energy into chemical energy through photosynthesis. The chemical energy stored in the form of food is utilized by all the organisms. Oxygen evolved by producers in photosynthesis is utilized by all the living organisms in respiration.

(ii) Consumers:

In a pond ecosystem, the primary consumers are tadpole larvae of frogs, fishes and other aquatic animals which consume green plants and algae as their food. These herbivorous aquatic animals are the food of secondary consumers. Frogs, big fishes, water snakes, crabs are secondary consumers. In the pond, besides the secondary consumers, there are consumers of highest order, such as water-birds, turtles, etc.

(iii) Decomposers and Transformers:

When aquatic plants and animals die, a large number of bacteria and fungi attack their dead bodies and convert the complex organic substances into simpler inorganic compounds and elements. These micro-organisms are called decomposers, chemical elements liberated by decomposers are again utilized by green plants in their nutrition.



Biogeochemical Cycles

The term bio-geochemical is derived from **"bio"** meaning **biosphere**, **"geo"** meaning the **geological components** and "**chemical**" meaning the **elements that move through a cycle**. The matter on Earth is conserved and present in the form of atoms. Since matter can neither be created nor destroyed, it is recycled in the earth's system in various forms.

The earth obtains energy from the sun which is radiated back as heat, rest all other elements are present in a closed system. The major elements include:

- Carbon
- Hydrogen
- Nitrogen
- Oxygen
- Phosphorus
- Sulphur

These elements are recycled through the biotic and abiotic components of the ecosystem. The atmosphere, hydrosphere and lithosphere are the abiotic components of the ecosystem.

Types of Biogeochemical Cycles

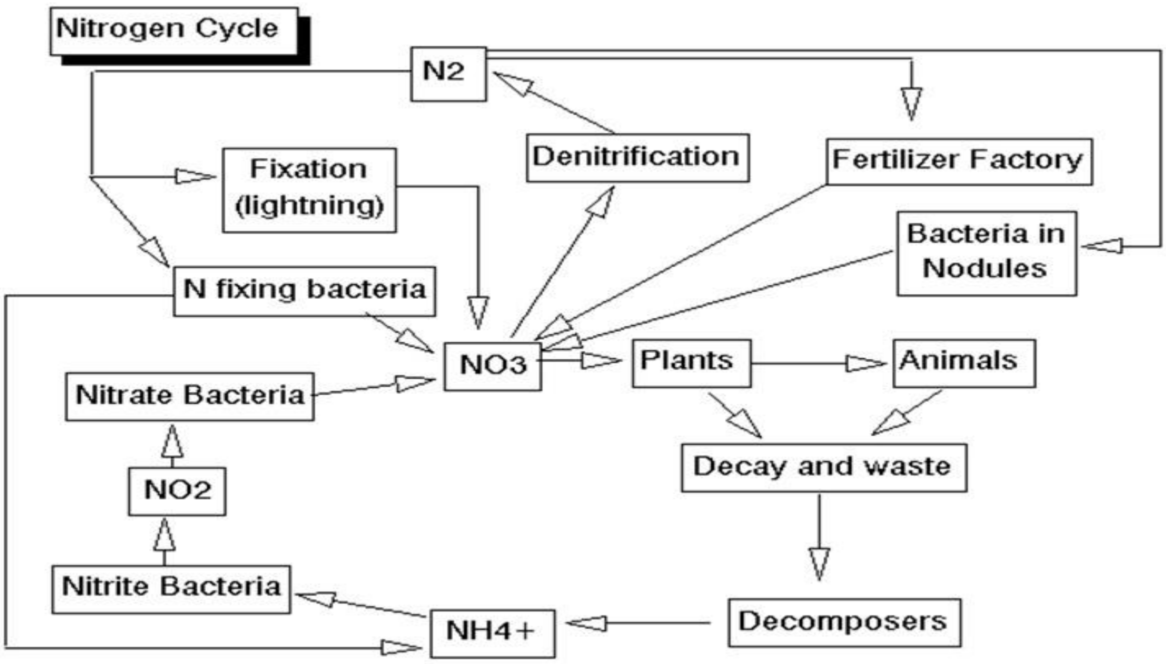
Biogeochemical cycles are basically divided into two types:

- **Gaseous cycles** – Includes Carbon, Oxygen, Nitrogen, and the Water cycle.
- **Sedimentary cycles** – Includes Sulphur, Phosphorus, Rock cycle, etc.

Nitrogen Cycle

It is the biogeochemical cycle by which nitrogen is converted into several forms as it circulates through the atmosphere, terrestrial and marine ecosystems.

Nitrogen is an essential element of life. The nitrogen in the atmosphere is fixed by the nitrogen-fixing bacteria present in the root nodules of the leguminous plants and made available to the soil and plants.



The bacteria present in the roots of the plants convert this nitrogen gas into a usable compound called ammonia. Ammonia is also supplied to plants in the form of fertilizers. This ammonia is converted into nitrites and nitrates. The denitrifying bacteria reduce the nitrates into nitrogen and return it into the atmosphere.

Unit V

Wildlife:

Wildlife conservation and forest conservation are very closely related. When deforestation is done wild animal run here and there as they lost their habitat.

Hunting of animals for food, skin, bones, horns and ivory is responsible for reduction in the number of wild animals. Some animals are gun down only for fun and sports which is very cruel activity. Due to the illegal trade of hides, large number of tigers, leopards, deer snakes and crocodiles are killed. Indian rhinoceros, great Indian bustard, musk deer, blue whale are endangered species.

Indian egg-eating snake, olive ridley turtle, Indian pied hornbill and golden cat are rare species. Hunters and poachers disturb food chain in nature and also balance of environment. For example, killing of snakes which feed on rats and mice, increase the number of these pests and damage of crops is increased.

Conservation of wildlife:

1. Hunting should be discouraged.
2. Deforestation should be prevented.
3. Natural habitat of animals should be protected and maintained.
4. Articles made by hides, fur, ivory and horns should be boycotted.
5. Laws against hunting should be implemented effectively.
6. Poachers should be arrested immediately and should be kept behind the bars.
7. More National parks and bird sanctuaries should be established
8. Indian public should be educated by films, T.V. shows, popular articles in newspapers and magazines regarding the significance of Indian wildlife.

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