PREFACE

In a bid to standardise higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses viz. *core, discipline specific, generic elective, ability* and *skill enhancement* for graduate students of all programmes at Honours level. This brings in the semester pattern, which finds efficacy in sync with credit system, credit transfer, comprehensive continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry acquired credits. I am happy to note that the University has been accredited by NAAC with grade ‘A’.

UGC (Open and Distance Learning Programmes and Online Learning Programmes) Regulations, 2020 have mandated compliance with CBCS for U.G. programmes for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the *six* semesters of the Programme.

Self Learning Materials (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English / Bengali. Eventually, the English version SLMs will be translated into Bengali too, for the benefit of learners. As always, all of our teaching faculties contributed in this process. In addition to this we have also requisitioned the services of best academics in each domain in preparation of the new SLMs. I am sure they will be of commendable academic support. We look forward to proactive feedback from all stakeholders who will participate in the teaching-learning based on these study materials. It has been a very challenging task well executed, and I congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

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Netaji Subhas Open University
Under Graduate Degree Programme
Choice Based Credit System (CBCS)
Subject : Honours in Zoology (HZO)
Course : Principles of Ecology
Course Code : CC-ZO-09

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Unit 1 ❑ Introduction to Ecology

Structure

1.0 Objectives

After studying this unit, the learners will be able to do the following—

- To have a general idea on ecology.
- To learn about different levels of ecological organisation.
- To know about different limiting factors of an environment.
- To know the laws proposed to explain the effect of different factors on organism.
- To understand about the physical factors of an environment.

1.1 Introduction

The scientific study of the interactions between organisms (biotic factors) and their environments (abiotic factors) is called ecology. Every organism is intricately linked to its surroundings and thus can't live in isolation, such as, an organism exchanges gases with the atmosphere. It acquires energy from autotrophs which in turn synthesizes organic food by assimilation of carbon dioxide from atmosphere in the presence of chlorophyll and sunlight. The waste products of an organism's metabolism are returned to the surrounding environment where they are recycled. It absorbs and radiates heat from and to the surrounding environment. It also competes with other organisms for limited resources (food and shelter). Most interestingly, organisms are either eat (predator) or being eaten (prey) by other organisms within an environment.

The environment in which organisms survive can be divided into two basic categories:

(1) **Abiotic factors:** It includes non-living chemical and physical factors of the environment, such as— light, temperature, pH, gravity, pressure, minerals, air etc.

(2) **Biotic factors:** It includes living factors such as—bacteria, protozoans, plants, fungi, animals etc.

1.2 Levels of ecological organization

The science of ecology is a broad and interdisciplinary aspect which can be subdivided into different levels of ecological organizations for simplicity in study and research. The levels of ecological organization are as follows:

a) **Organism:** The organisms form the basic unit of study in ecology. At each level, the biological unit has its own specific structure and function. At this level, the physiology, behaviour, distribution and adptations that enable individual organisms to survive in their environment are studied.

b) **Population:** The group of organisms belonging to same species that have the potential for interbreeding and produce fertile offspring are called population. At this level, population growth, density, interaction of animals are studied.

c) **Community:** The ecological organization that results from interdependence and interactions amongst population of different species in a habitat is called biotic community. This is an assemblage of populations of plants, animals, bacteria and fungi that live in an area and interact with each other. Each biotic community has a distinct structure and species composition.

d) **Ecosystem:** The ecosystems are parts of the nature where living organisms interact amongst themselves and with their physical environment. An ecosystem is 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 Arthur Tansley in 1935.

e) **Biome:** This is a large regional unit characterized by a major flora and associated fauna found in a specific climatic 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.

f) **Biosphere:** The entire inhabited part of the earth and its atmosphere including the living components is called biosphere. It is the highest ecological organization that constitutes all the earth's terrestrial biomes and aquatic ecosystems.

The global environment (abiotic factors) consists of the following three main sub-divisions:

a) **Hydrosphere:** It includes all the water components.

b) **Lithosphere:** It comprises the solid components of the earth's crust.

c) **Atmosphere:** It is the gaseous envelope around the earth.

1.3 Laws of limiting factors

The resources (nutrients, light, water, space etc.) necessary for the survival of an organism present in limited supply in the environment. Therefore, it affects the organism's life drastically. The importance of a physical or biological factor can be identified through a response of increased or shunted growth, abundance or distribution of a population, when the factor is altered in its quantity and quality.

A resource or environmental condition can be categorized as a limiting factor when it affects the growth of an organism or population within an ecosystem. Limiting factors are theorized under ***Liebig's Law of the Minimum,*** which states that "growth is not controlled by the total amount of resources available, but by the scarcest resource".

There are three laws proposed to explain the effect of different factors on organism:

1.3.1 Law of minimum / Liebig's law

According to this law, the growth is regulated by the limited factors *i.e*., resources in scarcity and not by the resources in abundance. This law was originated after studying and observing the crop and plant growth. The studies reveal that if we increase the supply of nutrients already present in enough amounts, it does not affect the growth of plants *i.e.*, no further growth happens. But when we provide the nutrients which are present in scarcity or in limited supply, growth improvements are detectable. Hence, it is the limiting factor that affects the growth of plants. The principles of Liebig's law conclude as a concept, where "the availability of nutrient in scarcity is the limiting factor which is equally important for plant growth as the nutrient in abundance". This law is applicable on natural resource management.

1.3.2 Blackman's law of limiting factor

Blackman was a plant physiologist and proposed the idea on limiting factor on plants photosynthesis system. He stated that a number of factors regulate the biological processes but the factors in different amount affect the process on the whole. For example, photosynthesis requires basic components like water, sunlight, chloroplast, temperature, carbon dioxide, chlorophyll present in certain required amount. Any of these factors, if present in scarcity will affect the rate of photosynthesis.

1.3.3 Law of tolerance / Shelford's law

Till now we are concentrating on the minimal limiting factors affecting the growth or rate of biological process. But Shelford's law states that it's not only the factor present in limits/scarcity but also the excess/ abundance of that same factor can affect the growth and development of organism or rate of biological process. For instance all nutrients required for the growth and development of organism are equally important but any nutrient in abundance may limit other nutrients absorption, thus indirectly restricting or limiting the growth of organism.

Thus, the law of tolerance by Shelford revealed that the growth and development of organism depends on the maximum and minimum limits of factors involved in the biological process.

Therefore, every factor has its own maximum and minimal limits in every organism and the tolerance is the range between these two limits.

1.4 Study of physical factors

The factor in the abiotic environment which influences the growth and development of organisms of biological communities is called physical factors. It includes:

a) **Sunlight:** Solar energy powers nearly all ecosystems. Since sunlight is such an important resource, many life-forms spend energy competing for it.

b) **Water:** Water is limited resource that life is very dependent upon. The amount of water on the ground, in the air, in the soil, and at different times of year influences the types of life-forms that are successful in different habitats. The ability to conserve water or get rid of excess water is some major adaptations has been observed in organisms.

c) **Temperature:** Temperature is highly important because of its influential role on metabolism. Most organisms operate optimally at between 32° F and 122° F. Above and below those temperatures, most organisms do not function well, partially due to the denaturing of enzymes and destruction of tissues and cells. However, some species are well adapted to extreme temperatures, including many desert species of plants and animals as well as some reptile and amphibian species that can withstand being completely frozen for several months each year. The ability to maintain internal temperature is a big hurdle facing living organisms and likewise, there are many adaptations (physiological, anatomical, and behavioral) that enable organism to survive in different habitats on Earth.

d) **Wind:** Wind has many effects upon organisms. Some groups that live on nutrient poor substrates depend on wind to blow in nutrients (*i.e.*, bacteria, protozoans & some insects). Many plants depend on wind to disperse their pollen (sperm) and seeds. Wind storms create patchiness in forest by blowing down trees. Wind also influences the rate of water loss by plants. Wind also plays important role in evaporative cooling which directly affects the internal temperature control of animals (mostly mammals). Wind chill can be a factor for organisms in temperate and arctic regions where any form of shelter serves as an important micro-habitat.

e) **Rocks and Soil:** The physical and chemical structure of rock and soil limit the distributions of plants and the animals that feed on plants. The chemical content of soil and rock impact the conditions of water sources (streams, rivers, and lakes).

f) **Disturbances:** Disturbances (*i.e.,* fires, hurricanes, tornadoes, volcanoes, drought, flood, grazing) can greatly impact biological communities and ecosystems. After a disturbance, the habitat begins to reemerge and is slowly re-structured. This process of disturbance and re-structuring is called succession and is a vital role in biological communities and ecosystems.

1.5 Summary

- The scientific stroy of the environment between biotic and abiotic factors is called ecology.

- The global environment consists of hydrosphere, lithosphere and atmosphere.
- There are three laws proposed to explain the effectes of different factors on organism.

1.6 Questions

i) Define ecology and ecosystem.

ii) Describe the major biotic and abiotic factors of an ecosystem.

iii) What do you know about the levels of ecological organization?

iv) Define population, community, biome and biosphere.

v) What are the laws of limiting factors?

vi) Describe the Liebig's law of minimum.

vii) Describe the Blackman's law of limiting factors.

viii) Why it is important to study the physical factors of an ecosystem?

ix) Discuss about the role of different physical factors on organisms.

x) Define photoperiod. How is it related to survival of organisms?

1.7 Suggested reading

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C., (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi, P.C. and Joshi, N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy, E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs, C. J. (2001). Ecology. Benjamin Cummings.
7. Odum, E. P. and Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith, T. M. and Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma, P. S. and Agarwal, V. K. (1993). Environmental Biology (Principles of Ecology). 4th Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 2 ❑ Population

Structure

2.0 Objectives

After studying this unit, the learners will be able to do the following—

- To know about population.
- To learn about various attributes of population.
- To understand about the characteristics of survivorship curves.

- To know tabout k-and r-selected species and their differences.
- To learn about different population growth forms.
- To know about density dependent and density independent factors.
- To learn about different tybes of population interactions.
- To know about lotka-voltera equation for competition.

2.1 Introduction

Population is a group of individuals of a particular species, which are found in a particular geographical area at a particular time. The population that occupies a very small area is called local population. A group of such a closely related local population is called meta-population. Population ecology is an important area of ecology as it links ecology to the population genetics and evolution. Natural selection operates at the levels of population to bring about evolution.

2.2 Population attributes

A population shows certain characteristic features/attributes which are discussed below.

There is a line of difference between a population and an organism. A population has certain characteristics / attributes that an individual organism does not have. The different attributes of a population can be summarized as birth (natality) and death (mortality) rates, sex ratio, age distribution (demography), population density, survivorship curve, life table etc. These attributes could be statistically measured for a population but not for an organism. Let us discuss the different attributes of a population one by one.

2.2.1 Natality or birth rate

Population increases by the addition of individuals in two ways, by birth and by immigration. On the other hand, individuals leave population by two ways, death and emigration. The birth of new individuals is referred to as natality.

Natality is a broad term and it covers the production of new individuals of any organisms, whether they are born, hatched, germinate or arise by division. The theoretical maximum production of new individuals under ideal conditions (in absence of any environmental stress) is said to be maximum natality that remains constant for a given population. The increase in population under an actual or specific environmental field condition is called ecological or realized natality which is not a constant. It is variable depending on the size and age composition of the population and with the physical environmental conditions. Natality is expressed as rate, that is as numbers in a given time. For example, if there are 320 births in a population during a year, then the natality rate is 320 per year.

The crude natality rate of population can be expressed as follows—

$$\text{Birth (natality) rate (b)} = \frac{\text{number of birth per unit time}}{\text{average population}}$$

$$\text{or, } b = \frac{DNa}{NDt}$$

Where, b = natality rate per unit time

D = entity that is changing

N = initial number of individuals in the population

Na = number of new individual added to the population by natality

t = time

Natality rate is of two types

1. Crude or absolute natality rate is obtained by dividing the number of new individuals produced in a specific unit of time.
2. Specific natality rate is obtained by dividing the number of new individuals per unit time by initial number of individuals in the population. It is also referred to as average rate of change per unit population.

Example

To illustrate the difference between crude and specific natality, let us consider a population of 1,000 fishes in a pond that has increased by reproduction to 3,500 in a year. The crude natality is (3,500 – 1,000) = 2,500 per year and the specific natality is 3,500 / 1,000 = 3.5 per year per individual.

2.2.2 Mortality

Morality or death value of individuals is more or less the opposite of natality.

The death rate is the number of individuals dying during a given time interval (deaths per unit time), or it can be expressed as a specific rate in terms of units of the total population.

The loss of individuals under a given environmental condition is referred to as ecological or realised mortality. Similar to ecological natality, it is also not a constant, but may vary with the size and age composition of the population and environmental conditions. However, the minimum loss under ideal or non-limiting conditions is a constant for a population and is referred to as minimum mortality.

The crude rate of death of a population can be calculated by the following equation:

$$\text{Death (d) rate (mortality)} = \frac{\text{number of deaths per unit time}}{\text{average population}}$$

$$\text{or, } d = \frac{DNa}{NDt}$$

Where, d = mortality rate per unit time.

D = entity that is changing.

N = initial number of individuals in the population.

Na = number of dead individuals excluded from the population by mortality.

t = time.

Scientists are interested not only why organisms die but also the reasons of their death at a given age. The opposite of mortality is survivals or longevity, which focuses on the age of death of individuals in a population. Often the survival rate is of great importance than the death rate.

Longevity can be of two types—

a) **Potential longevity**

The maximum life span attained by an individual of a particular species is said to be potential longevity. It depends upon the physiological condition of plants and animals (also referred to as physiological longevity) and the organisms die simply due to old age. Potential longevity can also be described as the average longevity of individuals living under optimum conditions. In nature. few organisms live in optimum conditions.

b) **Realised longevity**

It is the actual life span of an organism. It is the average longevity of the individuals of any population living under real environmental conditions. In nature, most animals and plants die from disease or are eaten by predators, or succumb to natural hazards. Thus, this longevity is measured in the field and is also referred to as ecological longevity.

Example

European robin has an average life expectancy of 1 year in the wild, whereas in captivity it can live at least 11 years.

2.2.3 Sex ratios and dispersal

The ratio of males to female organisms in a population is called sex ratio. Competitions often result in biased sex ratios. Female- biased sex ratios are formed due to competition among males for mates. On the other hand, sex ratios toward more males (male biased) take place when there is competition for resources, both among siblings and between offspring and parent. A stable sex ratio enables the population to reach optimum population growth.

Births often result in dispersal of offspring to avoid over-crowding. Young males of mammals and a few birds disperse far away from their birth places than do females. This phenomenon is called natal dispersal. Daughters have a tendency to remain near their mother and thus compete with her and among themselves for resources necessary for reproduction. This tendency to remain near their birth place is called philopatry (home-loving).

2.2.4 Survivorship curves

A graphical presentation of the proportion of individuals in a given species those are alive at different ages. Typically, the number of individuals of the population is plotted on the y-axis of the graph and the age of survivorship is plotted on the x-axis of the graph. Survivorship curves are hypothetically of three types: Types I, II and III, or better known as convex, diagonal and concave survivorship curves respectively (see figure 1).

a) **Convex or Type-I curve**

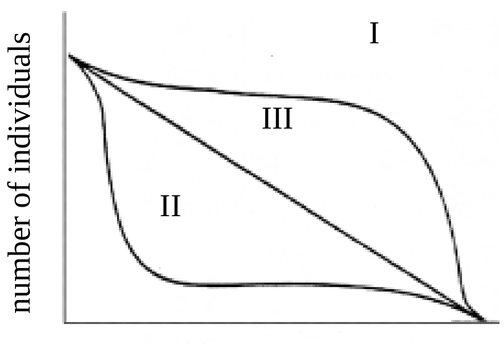
It indicates high survivorship or very low mortality among younger individuals up to a particular age, after which most of the population dies. This situation is characteristic of some human population, many species of large animals and Dali mountain sheep. Such a situation would happen if environmental factors were found to be unimportant and most of the organisms lived out their full physiological longevity. The abrupt drop in survivorship would depend on how variable the population was in genetic factors affecting length of life.

b) **Concave or Type-II curve**

It indicates high mortality rate during the young stages. This pattern is typical in the case of Oak trees, marine invertebrates (oysters), many fishes and some human population. Mortality is extremely high during the free-swimming larval stage or the acorn seedling stage. This results from such factors like inexperience in foraging and avoiding predators and lack of immunity to disease. Once an individual is well-established on a favourable substrate, life expectancy improves considerably.

c) **Diagonal or Type-III curve**

It indicates a constant probability of dying. It can be otherwise stated that a constant percentage of the population is lost in each time period. Probably no population in the natural world has a constant age-specific survival rate throughout its whole life span. However, a slightly concave curve, approaching a diagonal straight line on a semilog plot (Type II), is characteristic of many birds, mice, rabbit and deer. In these cases, the mortality rate is high in young but low and more nearly constant in the adults (1 year or older).



Total life span

Fig. 1: Different survivorship curves

The shape of survivorship curve is related to the following factors—

1) Shape related to the degree of parental care or other protection given to the young. For example, survivorship curve for honey bees, robins etc. who protect their young ones, are less concave than those occurring for grasshopper, sardines etc. who do not protect their young ones.

2) Shape related with the density of the population. For example, survivorship curves for two mule deer populations show a concave curve for denser population. This is due to deer living in the managed area where food supply is high, have a shorter life expectancy than deer living in unmanaged area. In the latter case, there is increased hunting pressure, intraspecific competition etc.

Humans also have greatly increased their own ecological longevity because of greater medical knowledge and facility, increased nutrition and adequate and proper sanitation. Thus, the curve depicting the survival rate of human beings approaches the sharp angled type I minimum normality curve.

2.2.5 Population density

The number of individuals (population size) of a species or population biomass per unit geographical area or volume at specific time is called population density.

For example, we can express the population size as 500 rabbits per square mile or 500 rabbits in a square block or 500 rabbits per hectare. The population density can be expressed as follows—

$$\text{Population density (PD)} = \frac{\text{Number of individuals in a region (N)}}{\text{Number of unit area in the region (S)}}; \ PD = \frac{N}{S}$$

In a particular habitat, the density of individuals of a particular species depends upon the intrinsic quality of their habitat, and on the net movement of individuals into that habitat from other habitats. It is obvious that individuals are numerous where resources are most abundant. Study of population density provides us with the following informations:

(i) The interaction of a population with its environment; and

(ii) Changes in density reflect changing local conditions.

The factors that regulate population size can be classified as extrinsic and intrinsic. The population own response to density is said to be intrinsic, while the interaction with the rest of the community is said to be the extrinsic factor. Intrinsic factors include intraspecific competition, immigration, emigration and physiological and behavioral changes affecting reproduction and survival. Extrinsic factors are interspecific competition, predation, parasitism and disease.

Type of population density

1. Crude density: It is the number (or biomass) per unit of total geographical space.

2. Ecological density: Ecological density is the number (or biomass) per unit of habitat space (area or volume available that can be colonised by the population).

3. Relative abundance: It is used to denote changing (increasing or decreasing) population and is time relative. Example: the number of birds seen on a tree per hour.

Population density can be estimated either by direct counting of individuals or biomass or through a method called mark-recapture method. This method involves capturing of a fraction of the population and marking with tags, paint, radio collars etc. and releasing them back into the population. Enough time is allowed for the marked individuals to recover and mingle with the rest of the population. The ratio of the marked to unmarked is noted and the estimate of the population size can be calculated by the following equation:

$$X = nM/N \textit{ i.e., } N = nM/x$$

Where, x is the number of marked individuals recaptured;

n is the total number or size of the second sample;

M is the number of individuals marked initially (first sampling), N is the total size of the population.

2.2.6 Life tables

Population possesses a spatial as well as genetic structure. A third aspect is to do with the rates of births and deaths and the pattern of distribution of individuals among different age classes. Life table is a tabular accounting of the birth rates and probabilities of death for each age class in the population. It, thus, gives a statistical account of death and survival of a population by age. Pearl and Parker first introduced the life table into general biology, for a laboratory population of the fruit fly, *Drosophila melanogaster*.

The individuals from birth (born at approximately the same time) to the end of the life cycle, form a group known as a cohort and their investigation is turned as cohort analysis. To understand the construction of a life table, you must have knowledge of the age structure of the population. It comprises of different age classes and the number of individuals in each age class residing at the same time.

In a life table, age is designated by the symbol ×. The first or youngest age class is x = 0. Ages are depicted in years (for some organism it may even be months, days or hours). The age specific variables are indicated by the subscript x. In L_x survivorship (the number of individuals alive at the start) d_x is mortality, q_x is mortality rate (number dying divided by the number alive at the beginning of the time interval) and e_x is the life expectation (the average time left to an individual at the beginning of the interval).

Table shows the life table of Mckinley Murre population. At the start (age 0) 100 individuals were taken to be born at the beginning of the interval. Over one half (55) died during the first interval. The mortality was $^{55}/_{100} \times 100 = 55\%$. As in the first year 55 animals died, so 100 – 55 = 45 survived to begin the second year. During the second period (from age one to two), 30 died. Mortality rate in the second year was found to be slightly higher *i.e.,* $^{30}/_{45} \times 100 = 67\%$. The life expectation at birth was, on an average, just over one year (1.15). The number aged one year has a life expectation of slightly less than one year (0.94).

At age 0 life expectation is the same as mean natural longevity. Physiological longevity is another aspect of longevity which is the age reached by individuals dying of old age. Individuals living under conditions where death results due to predation, accident, poor nutrition and infection are not factors.

Limitation of life table construction

(1) It takes a long time to collect the data, and (2) It is difficult to apply to highly mobile animals.

Age x	Survivorship l_x	Mortality d_x	Mortality Rate q_x	Life Expectation e_x
0	100	55	0.55	1.15
1	45	30	0.67	0.94
2	15	10	0.67	0.83
3	5	5	1.00	0.50
4	0	—	—	—

Table-1 : Life table of Mekinley-Murre population

The r-and k-strategies

MacArthur and Wilson suggested another way of classifying evolutionary strategies, when they applied the terms r-selected and k-selected to populations. The initials r and k are taken from the logistic equation, used for describing the actual rate of growth of populations (R):$R = dN/dt = rN\ (1-N/K)$

Where, **r** is maximum rate of intrinsic increase of the population.

k is number of organisms that are able to live in the population, when it is in equilibrium; or, in other words, it is the carrying capacity of the population.

N is number of organisms in the population at time t.

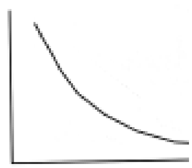
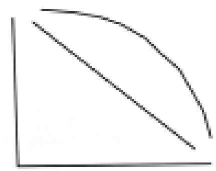
As we can observe from the above logistic equation, r-selected populations are ones where maximum rate of increase (r) is important. In temperate and arctic regions, populations undergo periodic reduction (irrespective of their genotypes) due to catastrophic weather conditions. These crashes in population are followed by longer period of rapid population increase.

A r-selected population has the ability to take advantage of these favorable situations through increased fecundity and earlier maturity. They have many offspring which under normal circumstances die before reaching maturity, but survives if circumstances change and are selected. Thus, r-selections are associated with the type-III of survivorship curve.

A k-selected population is associated with a steady carrying capacity. For example, in 'constant' tropical environments, where populations fluctuate little, populations remain near the limit imposed by resources (k). Adaptations that improve competitive ability and efficiency of resource utilization are selected. Thus k-selected populations are less able to take advantage of particular opportunities to expand (than r-selected populations). They are generally more stable and less likely to suffer high mortality. k-selected organisms usually have few and well-cared young. Thus, they are associated with type-I and II of survivorship curves.

Many ecologists have attempted to contrast genetic responses to r-selected and k-selected spectrums in laboratory populations. Francisco showed that when populations of *Drosophila* were maintained for long periods under crowded conditions, the numbers of adults per cage increased gradually. This was due to selection of traits that improved fecundity and survival at high densities. In another experiment, *Drosophila* populations were kept much below the carrying capacity by removing adults. The selective effects of low density with those of high mortality resulted. Similar experiments of bacteria and protozoans on laboratory populations have also given negative results.

Key differences between k-and r-selected species

Characters	r-selection	K-selection
Population size	Variable Usually below the carrying capacity Emigration common, reco-lonisation high	Constant Close to carrying capacity Recolonisation uncommon
Mortality	Variable and unpredictable Not density-dependent	More constant and predictable. Density-dependent
Intraspecific and inter-specitic competition	Variable, often weak	Usually strong
Survivorship curve (semilog plot)		
Selection favours	Rapid development, early reproduction, small body size. semelparity	Slow development, delayed reproduction, large body size, iteroparity
Lifespan	Usually shorter	Longer, usually more than one year
Leads to	High productivity	High efficiency

2.2.7 Population growth

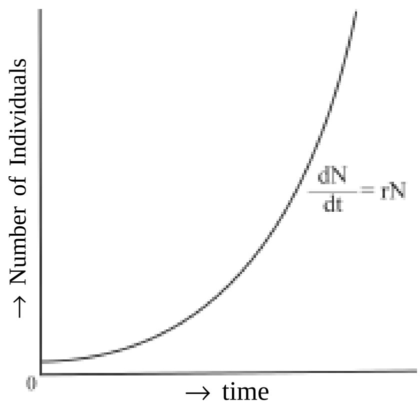
Living things undergo sexual maturity and have the ability to produce young ones of its own type. In other words, natural populations have the ability to grow. The capacity for populations to grow is enormous, particularly when they are introduced in new regions having suitable habitats. This rapid increase in numbers lead to the development of mathematical equations that predicts the growth of population and its regulation. The study of population growth is called demography. Reproduction provides an increase in population growth. But, in nature, populations do not explode. As the reproduction continues, but populations do not always grow. Darwin pointed that the sizes of populations are often regulated by environmental factors.

Population growth is of two types :

a) Exponential population growth (growth without regulation)

A small population living in a very large and favorable habitat has a growth rate that depends on two factors - the size of the population and the capacity of the population to increase (referred to as biotic potential or intrinsic rate of natural increase).

The important periodical production of offspring results in important differences in the way in which population grows. Young ones may be added to the population only at specific times of the year, *i.e.*, during discrete reproductive periods. Such populations are said to have geometric growth where the increment of increase is proportional to the number of individuals in the population at the beginning of the breeding season. Geometric growth is the typical pattern of population growth (see the figure in left).



There are some organisms which do not have distinct reproductive seasons, but instead add young at any time of the year. Such populations increase more or less continuously and are referred to as exponential growth. Exponential growth rate is the rate at which a population is growing at a particular time, expressed as a proportional increase per unit of time.

In exponential growth, the curve of numbers versus time becomes steeper and steeper. Growth depends on the biotic potential which does not change, and on the size of the population which changes continually growing larger and larger. As a result, the growth rate of the population increases steadily from a slow rate (when the population is low) to a faster rate (when the population is high).

Examples of exponential growth rate are many in laboratory studies, but in field conditions they are scarce as it requires hard work for accurate censuring. One such example is the ring-necked pheasant population introduced on Protection Island (off the coast of Washington).

The initial population of 8 birds reached to 1,898 in six breeding seasons. Another example is of a herd of tule elk introduced into Grizzly Island (northwest of San Francisco, California). This animal released in mid-1977, developed from 8 animals to a population of 150 by 1986.

If birth rate equals death rate, the rate of population growth is zero and the population is in a stable condition. If the population grows at a fairly constant rate (say 1%, 5% or less than 1%), the population size will increase exponentially.

However, if the population does not have a stable age distribution the growth rate is faster than predicted from the biotic potential. Subsequently, if growth persists at a constant rate a stable age distribution is quickly established.

Equation of exponential growth

The formula by which exponential growth occurs is $dN/dt = rN$

where, dN/dt is the population growth rate and refers to the change in numbers (dN) per time interval (dt). Biotic potential, (r), is the increase in number of individuals per time period per head (or per individual) and combines birth rate and death rate. N is the number of individuals in the population.

In the above formula, growth rate is higher in a population with a high r compared with one with a low r. Conversely, the growth rate also depends on N, with a slow growth rate when N is small and rapid growth rate when N is large.

The formula given above gives growth rate in a population growing exponentially. If, instead, the population size at various times during exponential population growth is to be noted then an equivalent expression is the integral equation $N_t = N_o e^{rt}$.

where, N_t is the number of individuals in the population after t unit of time; N_o is the number at time 0 (that is, at the beginning of the period being studied), r is the biotic potential and t is the time period being studied. The constant e is the base of the natural logarithm having a value of approximately 2.718. The term e^r is the factor by which the population increases during each time unit and is written as the lower case Greek lambda (λ); that is when t = 1. Then $Nt = N_0 e^{rt}$, or $Nt = N_0 \lambda$.

Example

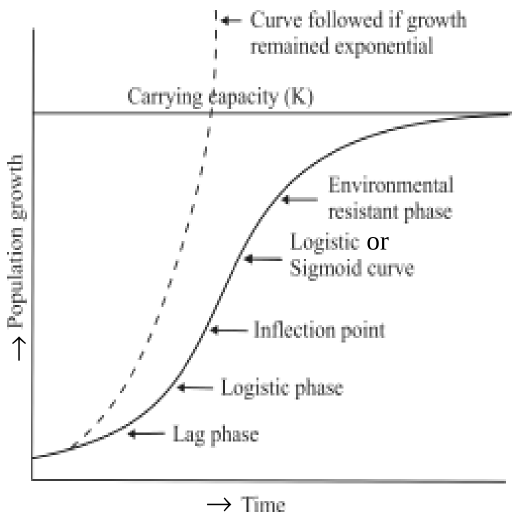
Suppose a population of 10 duckweeds grows for 4 days and r is 0.20 per day. Then $N_4 = 10 \times e^{(0.20 \times 4)} = 10 \times 2.22 = 22.2$

Thus, the population size at the end of 4 days is 22 or 23 duckweeds.

(b) Logistic population growth (simple population regulation)

As has been written earlier in exponential population growth when a population invades a new area where space and food are in plenty, the population undergoes exponential growth. However, the exponential population growth always seems ridiculous because the number of most organisms remain usually constant from year to year.

Thus, the population growth curve shows an exponential, or approximately so, at the beginning having initially a slower growth rate which subsequently gets faster and faster. The population then becomes medium sized and the growth rate begins to slow down until it finally reaches zero, when birth balances death. This type of growth curve looks like a flat S and is called the sigmoid growth curve.



The model depicting this type of growth is the logistic equation, introduced in ecology by Raymond Pearl and L. J. Reed in 1920. The logistic equation is defined as the mathematical expression for a particular sigmoid growth curve in which the percentage rate of increase/decreases in linear fashion as population size increases.

The growth rate of the population is determined by biotic potential and the size of the population is modified by the environmental resistance (by all the factors that control crowding). These factors may include lowered production due to mothers' poor nutrition, high rate of death because of predators or parasites, increased emigration etc.

Environmental resistance gradually increases as the size of the population gets closer to the carrying capacity (usually represented by K), which is the number of individuals in a population that the resources of a habitat can support.

Thus, the S-shaped or sigmoid growth curve comprises of population that increases slowly at first, then more rapidly, but it subsequently slows down as environmental resistance increases until equilibrium is reached and maintained. This can be represented by a simple logistic equation dN/dt = rN × K – N/K. K is the maximum carrying capacity.

The logistic growth curve, however, shows another basic pattern of growth, termed as the J- shaped growth curve. In the J-shaped growth curve, the density of the population increases rapidly in exponential manner. It frequently tends to overshoot the carrying capacity and then drops back rather sharply, as environmental resistance or other limiting factors become effective more or less suddenly. This curve can be presented by the simple model based on the experimental equation dN/dt = rN.

The equation given above for the J-shaped growth form is same as that of the exponential equation except that a limit is imposed on N. The unrestricted growth is suddenly halted when the population runs out of resources like food or space; when frost or heat wave or any other environmental factor intervenes; or when the reproductive season suddenly terminates.

When the population reaches the upper limit of N, it remains at this level for a while and then a sudden decline takes place. It thus produces a relaxation-oscillation (boom-and-bust) pattern in density. Such a pattern is the characteristic of many populations in nature, such as algal bloom, annual plants, zooplankton bloom, some insects and, perhaps, lemmings on the Tundra.

The S-shaped or sigmoid pattern of growth shows a gradual increasing action of detrimental factors (environmental resistance or negative feedback) as the density of the population increases. However, in the J-shaped population growth, negative feedback is delayed until right at the end when it goes beyond the carrying capacity.

The equation of the S-shaped curve differs from that of the J-shaped one, in the addition of one expression K - N/K or I - N/K, a measure of the portion of available limiting factors not used by the population.

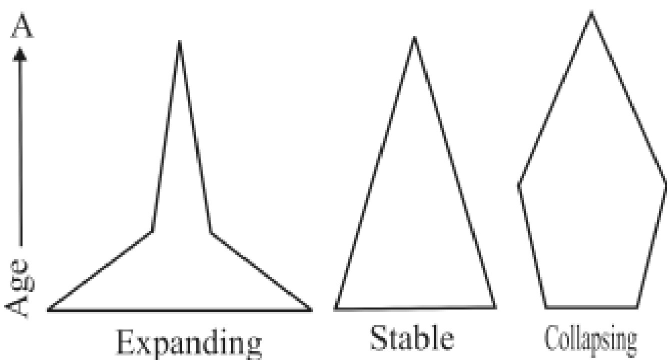
The S-shaped pattern of growth is followed by a great variety of populations represented by microorganisms, plants and animals, both in natural and laboratory populations. The S-shaped growth form includes two kinds of time lag: (1) the time needed for an organism to start increasing when conditions are favorable, and (2) the time required for organisms to react to unfavorable conditions by altering birth and death rates. The various phases seen in S-shaped curve are the lag, logistic growth, and point of inflection, environmental resistance and carrying capacity phases.

The lag phase is the time lag necessary for a population to become acclimated to its environment. The point of inflection is the maximum rate of increase. The environmental resistance phase is the slowing of population growth due to limiting resources. The population ultimately reaches the carrying capacity condition when the rate of population increase is zero and the population density is maximum. Globally the humans have yet to reach the carrying capacity condition.

2.2.8 Age structure

Another important attribute of population is age distribution or structure. Age structure of a population refers to the proportion of individuals of various ages. For most animals, the age of an individual is important in specifying its role in the population. Age distribution influences both natality and mortality. The reproductive status of a population is determined by the ratio of the various age groups.

It also indicates what may be expected in the future. A rapidly growing or expanding population generally will contain large number of young individuals; stable population will show an even distribution of age classes, while a decline or collapsing population will have large number of old individuals.



Percentge in age class

The population that is growing or declining at a constant rate, it is called stable age distribution. If the population is not changing and its growth or declining rate is zero, then it is called stationary age distribution. It can be calculated from the l_x column of the life table. It tends to have large number of older individuals than younger ones. However, real populations usually have an age structure quite different than the above two because of various events in its recent past.

It is evident that populations tend to go to a normal or stable age distribution. Once a stable age distribution is achieved, any unusual increase of natality or mortality will last for a short time and the population would spontaneously return to the stable condition.

As rapidly increasing pioneer population gradually reaches mature and stable condition having slow or zero growth, the percentage of younger age class individuals decreases. It has also been seen that the average age of individuals also increases in a stable population.

The changing age structure, with an increasing percentage of old individuals, has some strong impacts on life style and economical and sociological consequences. A greater proportion of our resources will have to be used for helping the elderly and a small proportion used for education and other child welfare services. However, the economic burden may not be greater as the dependency ratio (the number of workers compared to the number of non-workers) will not be too different.

Age structure also can be expressed in terms of three categories: pre-reproductive, reproductive and post-reproductive. In accordance to their lifespan, the relative duration of these ages varies greatly with different organisms. In case of humans, during recent times, the three age categories are relatively equal with a third of the human life falling in each class.

However, early humans had a much shorter post-reproductive period. Insects have extremely long pre-reproductive period, a very short reproductive period and no post-reproductive period. For example, mayflies require from one to several years to develop during the larval stage and adults emerge to live for only a few days.

In fish population that has a very high potential natality rate, a phenomenon called dominant age class has been observed. When in one year large survival of eggs and larval fish takes place, then in subsequent years reproduction is suppressed.

2.2.9 Patterns of distribution

Distribution or dispersion of individuals within a population describes their spacing with respect to one another.

In a population, individuals may be distributed according to four types of pattern—

a) Random

b) Regular

c) Clumped, and

d) Regular clumped.

All the above four types of distribution are found in nature.

a) Random distribution occurs in individuals that are distributed throughout a homogeneous area without regard to the presence of others. It takes place when the environment is uniform and there is no tendency to aggregate.

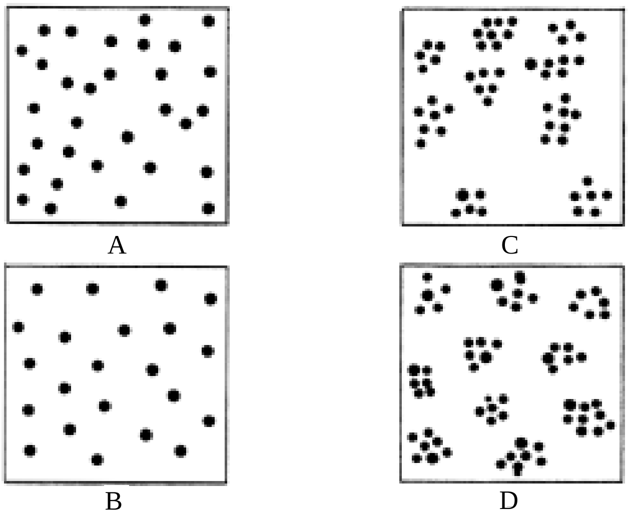


Fig: Types of distribution of individuals

(A : Random; B : Regular; C : Clumped; D : Regular Clumped)

Examples

Lone parasites or predators show a random distribution as they are often engaged in random searching behaviour for their host or prey.

b) In regular or uniform or spaced distribution, each individual maintains a minimum distance between itself and its neighbour. It may occur when competition between individuals is severe or when there is strong hostility, which eventually promotes even spacing.

Examples

Trees present in forests that have reached sufficient height to form a forest canopy show a regular uniform distribution due to competition for sunlight. Other examples are monoculture crops, orchard or pine plantation, desert shrubs etc. A similar regular pattern of distribution is seen in territorial animals.

(c) Clumped distribution takes place in individuals who maintain discrete groups. Clumping or aggregation, by far, is the most common pattern of distribution.

It may occur due to—

1) The social predisposition of individuals to form groups;

2) Clumped distribution of resources (the most common cause); or

3) Tendency of progeny to remain close to their parents.

Examples

Salamanders prefer to live in clumps under logs. Birds travel in large flocks. Trees form clumps of individuals through vegetative reproduction.

d) In regular clumped distribution individuals are clumped and are spaced out evenly from other similar clumps.

Examples

Herds of animals or vegetative clones in plants show either random or are clumped in a regular pattern. In the absence of hostility and mutual attraction, individuals may distribute themselves at random. Thus, in a population, the position of an individual is not influenced by the positions of other individuals. A random distribution pattern implies that spacing is not related to a biological process. It is often used as a model to compare it with an observed distribution. To determine the type of spacing and the degree of clumping, several methods have been suggested of which two are mentioned:

(i) To compare the actual frequency of occurrence of different sized groups obtained in a series of samples. If the occurrence of small sized and large sized groups is more frequent and the occurrence of mid-sized groups less frequent than expected, then the distribution is clumped. The reverse is seen in uniform distribution.

(ii) The distance between individuals are measured and the square root of the distance is plotted against frequency. The shape of the resulting polygon indicates the pattern of distribution. A symmetrical polygon (bell-shaped) indicates random distribution, a slanted polygon to the right indicates a uniform distribution, and one slanted to the left indicates a clumped distribution.

The pattern of dispersion for many species reflects the arrangement of habitat patches in the environment. For example, apple leaves are habitat patches for the mite. The pattern of dispersion for other species may be due to an interaction between the spatial arrangement of habitat patches and other ecological or behavioral processes.

For example, kangaroo rats, in order to construct their burrows, require certain soil characteristics. It may be assumed that individual kangaroo rats would simply aggregate within suitable habitat patches when they can easily construct burrows.

However, the aggregated dispersion in the population was not entirely due to habitat patchiness as banner tailed kangaroo rats have a tendency to leave the place of their birth. The movement of individuals may also influence the pattern of dispersion. For example, in case of plants, dispersal of seeds often depends on the action of other organisms.

2.2.10 Population regulation

Individuals are subjected to a number of environmental hazards which affects its growth and proliferation. Populations are made up of individuals and the size of the population depends upon the reproductive fitness and lifespan of those individuals. Thus, population size is affected by factors such as nutrients, flood, drought, predators, diseases etc.

The various limiting factors are—

(a) Factors those are constant

There are factors that are relatively constant and limits the population to a fairly constant size, as individuals has to compete for the resources. Plants, for example, compete for space and light, birds for nesting territories, heterotrophs for food etc. However, large changes in population are not produced.

(b) Factors those are variable

Although certain factors like seasonal drought or cold are variable however, they are predictable. Their presences are felt for some months or few days and may sometimes result in population crash. Evasive actions like migration or dropping of leaves (deciduous trees) may be taken to avoid such predictable factors.

(c) Factors that are unpredictable (density independent and density dependent)

Ecosystems are subjected to irregular or unpredictable extrinsic disturbances like weather, water currents, pollution etc. These physical factors often influence the population size. When there is low probability of physical stress such as storms or fire, populations tends to be biologically controlled and their density is self-regulatory.

Factors favourable or limiting to a population are either:

(i) Density-independent, that is, its effect on the population is independent of the population size, or

(ii) Density-dependent, if its effect is a function of population density, climactic factors often acts in a density-independent manner, while biotic factors act in a density-dependent manner. The J-shaped growth curve occurs in case of density-independent population whose growth slows down or stops. On the other hand, sigmoid growth curve occurs in density-dependent population where self-crowding and other factors regulate the population growth.

The primary differences between density- independent and density-dependent factors are:

1. Density-independent or extrinsic factors of the environment cause variations (sometimes drastic) in population density. This may cause shifting of carrying capacity levels (asymptotic). Density-dependent or intrinsic factors (such as competition) tend to maintain a stable population density.

2. In physically stressed ecosystem, density-independent environmental factors play a greater role. In favourable environment, density-dependent natality and mortality play an important role.

3. Density-independent factors involve interaction with the rest of the community. Density- dependent factors are the population's own response to density.

4. The main density-independent factors are predation, parasitism, disease and interspecific competition. Density-dependent factors include intra- specific competition, immigration, emigration and physical and behavioral changes that affects reproduction and survival.

For many organisms, intraspecific competition is one of the most important density dependent factors. Like animals, plants exhibit density-dependent population regulation mechanisms. At very high density, plant populations undergo a process termed self-thinning. When in an area seeds are sown at a high density, the emerging young plants compete with one another. As the seedlings grow, competition among them becomes tougher and tougher.

Many die leading to a gradual decline in the number of surviving plants. A similar condition occurs in over-populated caterpillars that tend to overshoot the carrying capacity conditions. Holling (1966), has emphasised the importance of behavioural characteristics, where a given insect parasite can effectively control the insect host at different densities.

Population studies generally depend upon the type of ecosystem of which it is a part. Physically controlled and self-regulatory ecosystems are arbitrary. It presents an oversimplified model. However, it is a relevant approach, as human efforts have been directed towards replacing selfmaintained ecosystems with monocultures and stressed systems. At the same time, the cost of physical and chemical control has risen due to the resistance of pest to pesticides and the toxic chemical by-products in food, water and air, have become a potential threat to mankind.

This has led to the increased implementation of integrative pest management (IPM). Evidences of the above are the generation of increased interest in a new frontier termed ecologically based pest management. This involves efforts to re-establish natural, density-dependent, ecosystem-level controls in agricultural and forest ecosystems.

2.2.11 Population interactions

Biological interactions are the effects that the organisms in a community have on one another. In the natural world no organism exists in absolute isolation, and thus every organism must interact with the environment and other organisms. Population of two species may interact in ways that correspond to combination of neutral, positive and negative Three of these combinations (+, +) (–, –) (+, –) are subdivided resulting in nine important interactions and relationships that are broadly classified under two categories.

Types of interactions

(a) Negative interactions

1. **Neutralism:** Neutralism describes the relationship between two species that interact but do not affect each other. Neither of the population is affected by interaction with each other. **Example:** Rabbits, deer, frogs, live together in grassland with no interaction between them.

2. **Direct interference:** It is the type of interaction where both populations actively inhibit each other. It occurs directly between individuals via aggression etc. when the individuals interfere with foraging, survival, reproduction of others. **Example:** Between the ant *Novomessor cockerelli* and red harvester ants, where the former interferes with the ability of the latter to forage by plugging the entrances to their colonies with small rocks.

3. **Competition for resource:** Competition is an interaction between organisms or species in which both the species are harmed. Limited supply of at least one resource used by both can be a factor in this type of interaction. Competition among members of the same species is known as intraspecific competition while competition between individuals of different species is known as interspecific competition. It is an antagonistic interspecific interaction in which one species is inhibited while other species is neither benefitted nor harmed. It is also called antibiosis and the affected species is called amensaland the affecting species is called inhibitor. **Example:** Roots of certain plants produce allochemic substances which check the growth of other plants to conserve resources, such as, *Convolvulus arvensis,* a weed that inhibits the germination and growth of wheat.

Competition always produces a winner and a loser. The winner is stronger in some or the other way, and hence, he wins. But when the competition is about life and death, you can say, it's the survival of the fittest and the smartest.

The competitive exclusion principle is also known as Gause's law of competitive exclusion. It states that the two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This is because, in a competition to survive, they try to consume as many resources as they can, not leaving anything for the opponent or competitor. The weaker species will either go extinct, or will adapt to some other resource and evolve, but it will be out of that competition sooner or later. Competition reduces the growth of other species. This means, in order to maintain the equilibrium, species that don't consume the same resources must coexist. 'Species' here will include all living things that depend on other living things for their food. Humans, animals (herbivores, carnivores), plants, microorganisms shows competition for resources. **Example:** Gray squirrels have replaced red squirrels in Britain. The population of red squirrels decreased substantially due to competitive exclusion, disappearance of hazelnuts, and diseases. Then, gray squirrels were introduced to Britain from 1876-1929, which easily adapted to the environment and slowly replaced the red squirrels.

Experimental basis of Gause's principle: Gause formulated the law of competitive exclusion based on laboratory competition experiments using two species of *Paramoecium, P. aurelia* and *P. caudatum.* The conditions were to add fresh water every day and input a constant flow of food. Although *P. caudatum* initially dominated, *P. aurelia* recovered and subsequently drove *P. caudatum* extinct *via* exploitative resource competition. However, Gause was able to let the *P. caudatum* survive by alteration of the environmental parameters (food, water). Thus, Gause's law is valid only if the ecological factors are constant.

Resource partitioning: It states that if two species compete for the same resource, they could avoid competition by choosing different times of feeding or different foraging patterns. In this relation, McArthur showed that five closely related species of warblers living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

Competitive release: It is a phenomenon, in which a species whose distribution is restricted to a small geographical area is found to expand its distributional range dramatically, when the competing species is experimentally removed.

4. **Amensalism:** It is a class of relationships between two organisms where one organism benefits from the other without affecting it. The commensal (the species that benefits from the association) may obtain nutrients, shelter, support, or locomotion from the host species, which is substantially unaffected. The commensal relation is often between a larger host and a smaller commensal; the host organism is unmodified, whereas the commensal species may show great structural adaptation consonant with its habits, as in the remoras that ride attached to sharks and other fishes.

5. **Parasitism:** Parasitism is a non-mutual symbiotic relationship between species, where one species, the parasite, benefits at the expense of the other, the host. Parasites can be micro parasites, which are typically smaller, such as protozoa, viruses, and bacteria. Examples of parasites include the plants mistletoe and cuscuta, and animals such as hookworms. Parasites typically do not kill their host, are generally much smaller than their host, and will often live in or on their host for an extended period.

6. **Predation:** It is a negative, direct food related interspecific interaction between two species of animals in which larger species called predator. Predator attacks, kills and feeds on the smaller species called prey. Predator population adversely affects the growth and survival of smaller prey population and therefore predation is considered as an antagonistic interaction. Example: Plant like *Nepenthes* (pitcher plant), *Drosera* (sundew), *Dionoeae* (Venus fly trap) etc. feed on insects to fulfill their nitrogen requirement. Some predators (such as frog) act as prey for others (snake) which in turn are prey to a higher carnivore (eagle).

Significance of predation

a) Local species diversity is directly related to the efficiency with which the predators prevent the monopolization of an environmental area by any species.

b) Predation keeps the prey population under check, so as to maintain an ecological balance. Weak and less efficient members in the prey population are removed.

c) Most important significance is in the practical utility of prey predator relationship on biological control of weeds and pests. Many insect pests are kept under check by introducing their predator into the area. Example: Opuntia which becomes a serious problem in Australia was brought under control by introducing its natural herbivore *Cactoblastis* (cochineal insects).

(b) Positive interaction

7. Commensalism: The term commensal was coined by P. J. Van Beneden (1876). It is a simple type of positive association and probably represents the first step toward the development of mutual beneficial relations. Commensals live on or around individuals of some other species (host) and derive benefit from the association. Example: (i) Vulture, a scavenger, feeds upon the leftovers of a kill of large carnivores (tiger, lion etc.). (ii) The fish, remora, has a suction cup on the top of its head. With its help it attaches itself to a shark and travels with it. It eats the leftovers of the bigger fish's meals, (iii) A number of communal fish, clams, polychaete worms and crabs live by snatching surplus or rejected food or waste materials from the host.

8. Proto-cooperation: It is a positive inter specific interaction in which both the partners are mutually benefitted and increase the chance of their survival. However, the interaction is not obligatory for their survival as both can live without this interaction. Example: Crocodile bird *(Pluvianus aegyptius*) enters the mouth of the crocodile and feed on parasitic leeches. By this the bird gets food and the crocodile gets rid of blood sucking parasites.

9. Mutualism: It is a positive interspecific interaction in which members of two different species favour the growth and survival each other and their association is obligatory. Both the partners are benefitted by this interaction. Mutualism is also referred as symbiosis or symbiotic interaction and the partners are referred as symbionts. Example: Termites (white ants) are not capable of digesting wood, which they ingest as food. A multi flagellate protozoan *Trichonympha campanula*, which lives in the intestine of white ant secretes cellulase enzyme to digest the cellulose of wood. In return, the ant provides food and shelter to the protozoan.

The following table will depict us about general nature of different types of interaction between two species (Species 1 and Species 2)

Sl. No.	Types of Interaction	Species 1	Species 2	General nature of Interaction
1.	Neutralism	0	0	Neither population is affected.
2.	Mutual inhibition competition type	—	—	Direct inhibition of each species by the other.
3.	Competition resource use type	—	—	Indirect inhibition when common resource is in short supply.
4.	Amensalism	—	0	One of the population inhibited, the other not affected.
5.	Parasitism	+	—	The parasite (smaller) gains at the expense of the host (larger).
6.	Predation	+	—	The predator is larger and gains at the expense of the prey which is smaller.
7.	Commensalism	+	0	The commensal (species 1) benefits while the host (species 2) is not affected.
8.	Protocooperation	+	+	Interaction favourable to both but not obligatory.
9.	Mutualism	+	+	Interaction favourable to both and is obligatory.

2.2.12 Lotka-Voltera equation for competition

The Lotka-Volterra equations are so termed because interspecific associations were proposed as models by Lotka (1925) and Volterra (1926) in separate publications. It comprises of a pair of differential equations useful for modeling predator-prey, parasite-host, competition or other two species interactions.

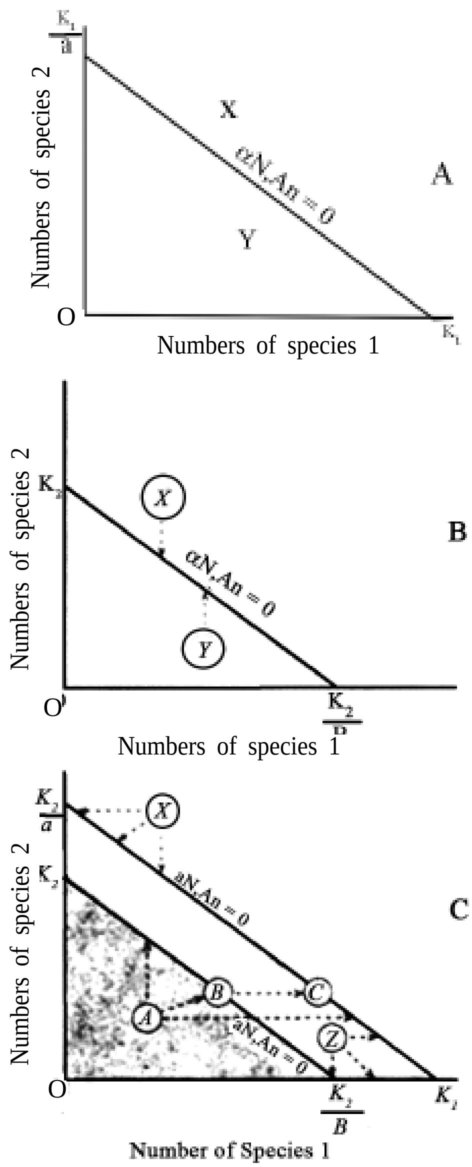
If one species is using some of the resources of the other, then the equations of growth for the two species are:

For species 1 = $$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha N_2}{K_1} \right)$$

For species 2 = $$\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \beta N_1}{K_2} \right)$$

Each population has a definite K or equilibrium level. The co-efficients α and β are competition factors indicating the effect of species 2 on 1 and the effect of species 1 on 2, respectively. N_1 and N_2 are the numbers of individuals of species 1 and 2, and r_1 and r_2 are the specific growth rate of species 1 and 2.

The inhibitory effect of one new individual of species 2 on the growth of species 1 is α/K_1 and the inhibitory effect of another individual on itself is $1/K_1$. The growth of any one of the competing species will stop when its carrying capacity has been reached which is the combination of its own numbers plus that of the other species.



Thus, species 1 stops growing when

$$N_1 + \alpha N_2 = K_1$$

Similarly, species 2 stops growing when

$$N_2 + \beta N_1 = K_2$$

The two species system will be at equilibrium only when the stoppage of growth coincides for the two species simultaneously, that is, when $dN_1/dt = dN_2/dt = 0$

The above equation can be best understood by wing graphs of zero population growth (ZPG). The graph shows a straight line that consists of all the mixes of species 1 and species 2 that add up to K. When N_2 is o then N_1 is equal to K_1.

When N_1 is o then N_2 is equal to K_1/α. The straight line represents all the combinations of numbers at which species 1 will stop growing. Ni will decrease if there is a mix of N_1 and N_2 as shown by the arrow at X. Similarly, N_1 will increase at a mix up at Y as shown by the arrow. Figure shows another graph for species 2 like that in species 1.

When the lines for the two species are put together on the same graph it would be possible to determine how the densities of the two species will change from any point by drawing arrows for each species. We can see that any point (A) below line K_2-K_2/β, both species will be able to increase their numbers.

When the mix of species forms a point (Z) between the two lines K_2-K_2/β and K_1/α-K_1, represented by the shaded area, species 1 will continue to increase but species 2 will decline. If species 2 remains the same but species 1 grows in number, the point B will slide horizontally towards C, thereby the numbers of species 2 will start to decline.

In the area (X) above the line K_1/α-K_1 both species 1 and 2 will decline. In this graph the invariable result will be the extinction of species 2. Similar sort of graphs are possible to show three other relationships-extinction of species 1, extinction of one species or the other and coexistence of the two species.

The Lotka-Volterra predator-prey model

The Lotka-Volterra predator-prey model is a simple but valuable one. This model presumes that the numbers of a predator (increase in birth rate) depends upon the prey population. For example, in a paddy field, if the mouse population is high, the foxes would eat a lot of mice and would have a lot of babies. If the mouse population falls to zero, the foxes will not breed.

Conversely, the numbers of a prey would depend on the predator population, as it would act on the prey death rate. For example, most mouse babies would grow if the fox population is low. Even the old mice would live for a longer time. Therefore, prey are predator limited and predators are food-limited.

The Lotka-Volterra predation model can be best represented in a graph (see figure at previous page) for the predator. The predator population shows neither growth nor decline (dN predator/dt = 0) at any point on line C. Any point to the left will result in decline of the predator population because of lack of food.

A similar graph can be drawn for the prey population, when any point on the line D, the prey population will neither grow nor decline (dN prey/dt = 0).

The probable happenings of the system are in accordance to the deep arrows forming a circle around E. At the quadrant marked by A, both the populations would increase and the system would move to the upper right quadrant. Here, the tendency would be towards further increase of predator population while the prey population would decline. The system would then move towards the upper left quadrant where both populations would decline. The system would eventually return back to A. From this Lotka-Volterra model, if the numbers of predator and prey were plotted against time, a cyclic fluctuation could be observed of the two populations. A classic example of such a cycle can be illustrated by the Canadian lynx *(Lynx canadensis)* and the snowshoe hare *(Lepus americanus)* as shown in the Figure. High lynx numbers reduce the snowshoe hare population. This, in turn, causes a reduction in the number of lynx in subsequent years. This would allow the hare population to rise again and the cycle continues.

2.3 Summary

- Population is a group of individuals of a particular species, which are found in a particular geographical area at a particular time.
- The population shows different characteristics like natality, mortality, sex ratio, survivorship curve, population density, life tables, population growth.
- The lotka— voltera model presumes that the number of predator depends upon the prey population.

2.4 Questions

i) What is population?

ii) What are population attributes?

iii) What is population density? Describe the types of population density.

iv) What is natality and mortality? Mention its types. How the natality and mortality rates are calculated?

v) What is life table? With the help of an example describe its significance.

vi) What is survivorship curve? Describe type I, II and III survivorship curve.

vii) What is demographic curve? Mention its types.

viii) What are the different types of population dispersal?

ix) Describe the exponential and logistic growth curves of a population with suitable equations.

x) Discuss the Gause's principle of population exclusion.

xi) Discuss the Lotka-Voterra equation for competition.

2.5 Suggested reading

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C. (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi. P.C. & Joshi. N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy. E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs. C. J. (2001). Ecology. Benjamin Cummings.
7. Odum. E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith. T M & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma P. S. & Agarwal V. K. (1993). Environmental Biology (Principles of Ecology). 4^{th} Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 3 ❑ Community

Structure

3.0 Objectives

After studying this unit, the learners will be able to do the following—

- To know about community.
- To learn about different types of communities.
- To know about keystone species.

- To know about keystone species.
- To know about ecotone and edge effect.
- To have an idea about ecological succession.
- To know about habitat and niche concept.

3.1 Introduction

It is now a known fact that individuals of a species together constitute a population. Various places of earth are shared by many coexisting populations and such association is called a community. A generalized definition of community is any assemblage of populations of living organisms in a prescribed area or habitat. According to A. G. Tansley (1935), community plus its habitat constitutes an ecosystem. In the ecosystem, thus, community and habitat are bounded together by action and reaction. The biotic communities represents a higher order of biological organisation than populations, yet, since communities refers only to living organism, they are not as inclusive as ecosystem.

3.2 Types of communities

Kendeigh (1974) divided the biotic community into two types - major and minor communities. Major communities are those that along with their habitats form near complete and self-sustaining units or ecosystems. However, the indispensable input of solar energy is not taken into account. Minor communities or societies, are not completely independent units as far as circulation of energy is concerned. They are, however, secondary aggregates within a major community. In this text, major communities are generally referred to as communities. .

3.3 Characteristics of communities

Communities, like populations, are characterized by a number of unique properties which are referred to as community structure and community function. Community structure comprises of species richness (types of species and their relative abundances), physical characteristics of the vegetation and the trophic relationships among the interacting populations in the community. Community function comprises of rates of energy flow, community resilience to troubles and productivity. The structure and function of a community are the manifestation of a complex array of interactions, directly or indirectly tying all the numbers of a community together into an intricate web. The characteristic features of a community are described below.

3.3.1 Species composition

A community is a heterogeneous assemblage of plants, animals and microbes. In ecosystem, virtually every organisms of a community, including the most insignificant microbes, plays some role or the other in determining its nature. The species in a community may be closely or distantly related but they are interdependent and are interacting with each other in several ways.

3.3.2 Species richness

The number of variety of species represented in an ecological community, landscape or geographical region is called species richness. It is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions. Species diversity takes into account both species richness and species evenness. Species richness is used to evaluate the relative conservation values of habitats or landscapes. However, species richness is blind to the identity of the species. An area with many endemic or rare species is generally considered to have higher conservation value than another area where species richness is similar, but all the species are common and widespread.

3.3.3 Species diversity

Species diversity is defined as the number of species and abundance of each species that live in a particular location. Species diversity is of immense importance. Each species has a role in the ecosystem. For example, bees are primary pollinators for flowering plants. Imagine what would happen if bees went extinct? Fruits and vegetables could be next, and subsequently the animals that feed off them - this chain links all the way to humans. Various species provide us not only with food but also contribute to clean water, breathable air, fertile soils, climate stability, pollution, absorption, building materials for our homes, prevention of disease outbreaks, medicinal resources, and more.

3.3.4 Species abundance

Species abundance is a component of biodiversity and refers to how common or rare a species is relative to other species in a defined location or community. Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area.

3.3.5 Species dominance

All the species of a community are not equally important. There are a few overtopping or dominant species who, by their bulk and growth, modify the habitat. They also control the growth of other species of the community, thus forming a sort of nucleus in the community.

Some communities have a single dominant species and are thus named after that species, such as sphagnum bog community, deciduous forest community etc. Other communities may have more than one dominant species, for example, oak-hickory forest community.

a) Keystone species

There are species upon whom several species depend and whose removal would lead to a collapse of the structure and ultimate disappearance of these other species. Such species are referred to as keystone species. The term keystone species was coined by Paine in 1966. These species may exert their keystone role in several ways. The beaver is one example whose ponds provide homes for many organisms from pond weeds to black ducks.

Paine through his classic experiments showed that predators and herbivores can manipulate relationships among species at lower trophic levels and, thereby, control the structure of the community. Such predator species are called Keystone predators as their removal can tumble the community. Paine's work on the star fish, *Pisaster ochraceus,* is a classic example of keystone predator that feeds primarily on barnacles and mussles (*Mytitus*). After removal of this star fish from the experimental areas on the coast of Washington, Paine observed that the mussels spread very rapidly. They crowded other organisms out of the experimental plots, thereby reducing the diversity and complexity of local food webs. Similarly, removal of the herbivore sea urchin, *Strongylocentrotus,* allowed a small number of competitive macro algae to form healthy beds and crowding out limpets, chitons and other bottom-dwelling invertebrates.

b) Bio-indicator

An indicator species (bio-indicator) is any species or group of species whose function, population, or status signify the qualitative status of the environment. For example, copepods and other small water crustaceans that are present in many water bodies can be monitored for changes (biochemical, physiological, or behavioral) that may indicate a problem within their ecosystem. Bio-indicator species also indicates the presence of the pollutant and also attempt to provide additional information about the amount and intensity of the exposure. A classic example of indicator species is lichen whose population shows a reciprocal relationship with the SO_2 present in the atmosphere.

3.3.6 Vertical stratification

Community structure can become stratified both vertically and horizontally during the process of succession as species become adapted to their habitat. Gradations in environmental factors such as light, temperature, or water are responsible for this fractionation. The vertical stratification that occurs within forests results from the varying degrees of light that the different strata receive; the taller the plant and the more foliage it produces, the more light it can intercept. Three or more vertical strata of plants: A herb layer, a shrub layer, a small tree layer, and a canopy tree layer, often are found in a forest. Animals are affected by this stratification of plant life. Although they can move from one layer to another quite easily, they often adhere closely to a specific layer for foraging, breeding, or other activities.

3.3.7 Ecotone and edge effect

Communities generally have their boundaries well-defined. The intermediate zone lying between two adjacent communities are called ecotones. The border between a forest and grassland, the bank of a stream running through a meadow, an estuary (the junction where the river meets the sea), the transition between aquatic and terrestrial communities, between distinct soil types, are a few examples of ecotone. Even the transition between north-facing and south-facing slopes of mountains is ecotones where the transition between communities is abrupt and obvious. The ecotone may be as broad as 100 kms or as narrow as 1 km. Species are distributed at random in respect to one another giving an open structure.

The environmental condition in an ecotone is variable, intermediate between the two adjacent communities. Boundaries between grassland and scrubland or between grassland and forest have sharp changes in surface temperature, soil moisture, light intensity and fire frequency. This results in replacement of many species. Grasses prevent the growth of shrub seedlings by reducing the moisture content of the surface layer of soil. Shrubs, on the other hand, depress the growth of grass seedlings by shedding them. The edge between prairies and forests in mid western United States is maintained by fire. Perennial grass resists fire damage to tree seedlings. Ecotone generally offers an abundance of food and shelter. It contains organisms from both the communities. As a rule, ecotone contains more species and often a denser population than the two concerned communities. This is called edge effect. There are certain species which are entirely restricted to the ecotone and are called edge species. However, it must be made clear at this point that the concept of ecotone is not restricted to the interaction among communities, nor to the transition in the number of species. Ecotone may be viewed as a surface forming common boundary between populations, or between ecosystems, as well as between communities. Eeotone transitions will include fluxes of materials as well as transition in number of species.

To have a knowledge about ecotone a diagram of the species distribution across a transition zone of ecosystem between two communities have been presented in Figure below.

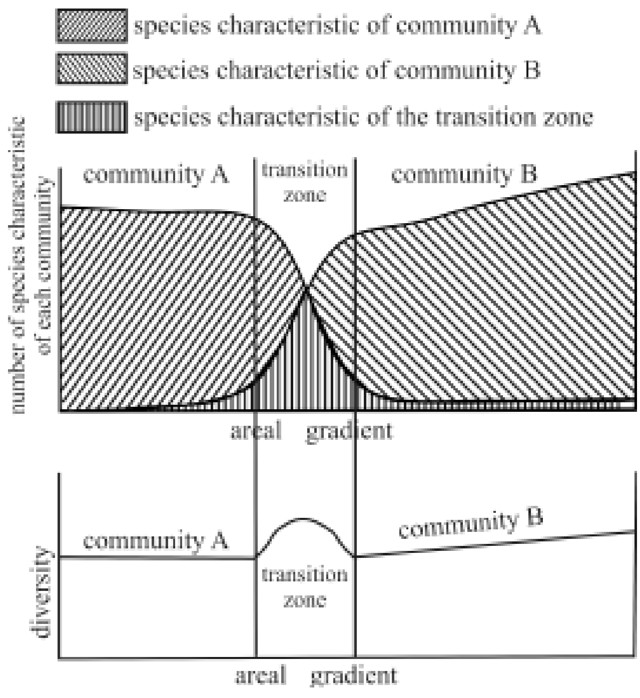


Fig. Diagram of the species distribution across a transition zone or ecotone between two communities, labelled A and B (after Clapham, Jr., 1973).

3.3.8 Habitat and ecological niche

The word habitat is used to denote where an organism lives, or the place where one would go to find it. The word habitat is a Latin word which literally means 'it inhabits' or 'it dwells'. It was first used in the eighteenth century to describe the natural place of growth or occurrence of a species. For example, the lowland gorilla (*Gorilla gorilla*) has as its habitat lowland tropical secondary forest.

Some species, like the tiger *(Panthera tigris*), have several habitats. It includes tropical rain forest, snow-covered coniferous and deciduous forests and mangrove swamps. The habitat of some smaller organisms is highly specialized. Certain species of leaf miners live only in the upper photosynthetic layer of leaves, while other species live in the lower cell layer in certain plant species. Thus, the habitat of the two species is different and such divisions of the environment are called microhabitats. Any one environment is divided up into many possibly thousands of microhabitats. The specific environmental variables in the microhabitat of a population are called micro-environment or microclimate.

The term niche is used by ecologists to express the relationship of individuals or populations to all aspects of their environment. Niche, thus, is the ecological role of a species in the community. It represents the range of conditions and resource qualities within which an individual or species can survive and reproduce. Niche is multidimensional in nature.

Difference between habitat and niche

The words habitat and niche are often misunderstood. Therefore, a clear line difference between the two is required.

Habitat	Niche
A habitat is an area, where a species lives and interact with the other factors.	A niche is an address where organisms survive or shows its functional attributes in the provided environmental conditions.
Habitat consists of numerous niches	Niche does not contain such components.
Desrets, oceans, forest, rivers, mountains, etc. are examples of habitat.	It is a part of habitat only, where shelter for living being can be furnished.
Habitat supports numerous species at a time.	Niche supports a single species at a time.
Habitat is a physical place.	Niche is an activity performed by organisms.
Habitat is not species specific.	Niche is species specific.

3.4 Ecological succession

Ecological succession is the gradual and sequential replacement of one community by the other in an area over a period of time. According to E.P. Odum (1971), the ecological succession is an orderly process of community change in a unit area. It is the process of change in species composition in an ecosystem over time. In simpler terms, it is the process of Ecosystem Development in nature. The different types of ecological succession exist during different phases of an ecosystem, and depend on how developed that ecosystem is? In the concept of ecological succession, ecosystems advance until they reach a climax community. In the climax community, all of the resources are efficiently used and the total mass of vegetation maxes out. Many forests that have not been disturbed in many years are examples of a climax community.

3.4.1 Types of ecological succession

a) Primary succession: When the planet first formed, there was no soil. Hot magma and cold water make hard rocks, as seen by newly formed islands. Primary ecological succession is the process of small organisms and erosion breaking down these rocks into soil. Soil is then the foundation for higher forms of plant life. These higher forms can produce food for animals, which can then populate the area as well. Eventually, a barren landscape of rocks will progress through primary ecological succession to become a climax community. After years and years, the soil layer increases in thickness and harbors many nutrients and beneficial bacteria that are required to support advanced plant life. If this primary ecosystem is disturbed and wiped out, secondary succession can take place.

b) Secondary succession: When a climex community is destroyed by a fire and the fire does not burn hot enough to destroy the soil and the organisms it harbors, secondary ecological succession takes place. Small plants will come back first. After they create a solid layer of vegetation, larger plants will be able to take root and become established. At first, small shrubs and trees will dominate. As the trees grow, they will begin to block the light from most of the ground, which will change the structure of the species below the canopy. Eventually the ecosystem will arrive at a climax community, which may or may not be the similar to the original community. It all depends on which species colonize the area, and which seeds are able to germinate and thrive.

c) Cyclic succession: Cyclic ecological succession happens within established communities and is merely a changing of the structure of the ecosystem on a cyclical basis. Some plants thrive at certain times of the year, and lay dormant the rest. Other organism, like cicadas, lay dormant for many years and emerge all at once, drastically changing the ecosystem. .

3.4.2 Process of ecosystem succession

The ecological succession is a complex process and it may take thousands of years. Frederic Clements in 1916 for the first time proposed the sequential phases of an ecological succession. The process of succession is completed through a series of sequential steps as given below:

a) **Nudation:** It is the development of a bare area (an area without any life form). It is the first step in ecological succession. The causes of nudation are: (i) Topographic: Soil or topography related causes such as soil erosion, sand deposit, landslide and volcanic activity results in the formation of a bare area; (ii) Climatic: Destruction of the community due to glaciers, dry period and storm; (iii) Biotic: It includes forest destruction, agriculture and disease epidemics which results in the total destruction of the population in an area.

b) **Invasion:** It is the successful establishment of a species in the bare area. It is the second step in ecological succession. A new species reaches the newly created bare area and they try to establish there. The process of invasion is completed in 3 steps: (i) Migration ((Dispersal): Seeds, spores, propagules of a species reach the bare area due to migration. The migration can be achieved through air or water medium, (ii) Ecesis: It is the process of successful establishment of a species in the bare area. The seeds or spores that reached the new area due to migration will germinate, grow and reproduce. Only a few progenies will survive due to the harsh environmental condition prevailing in the area, (iii) Aggregation: Following the process of ecesis, the individuals of a species increase their number and they stay close to each other. This process is called aggregation.

c) **Competition and coaction:** Aggregation results in the increase of the number of species within a limited space. This results in competition between individuals for food and space. The competition may be intra-specific (individuals within a species) or inter-specific (individuals between species). Individuals of a species affect each other's life in various ways and this is called coaction. Competition and coaction results the survival of fit individuals and the elimination of unfit individuals from the ecosystem. A species with wide reproductive capacity and ecological amplitude only will survive

d) **Reaction:** Reaction is the most important stage in the ecological succession. It is the modification of the environment through the influence of living organism present on it. Reaction cause change in soil, water, light and temperature of the area. Due to these modifications, the present community becomes unsuitable for the existing environmental conditions. Such communities will be quickly replaced by another communities. The whole sequence of communities that replaces one another in the given area is called sere (sera).

e) **Stabilization (Climax):** It is the last stage in ecological succession. The final or terminal community becomes more or less stabilized for longer period of time. This community can maintain its equilibrium with the climate of the area. This final community is called the Climax Community (climax stage). The climax community is not immediately replaced by other communities. Climax community is determined by the climate of the region. Example of climax community: Forest, Grassland, Coral Reef etc.

In the following diagram figure a diagramatic representation of the interactions between various aspects of the ecosystem as the mechanism for ecological succession has been presented.

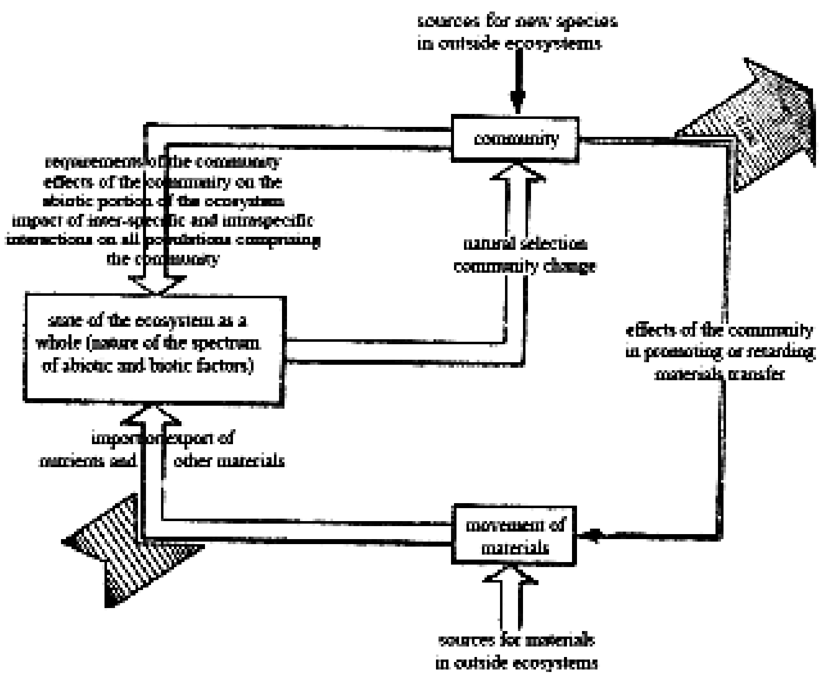


Fig. Diagrammatic representation of the interactions between various aspects of the ecosystem as the mechanism for ecological succession (after Clapham, Jr., 1973).

Characteristics of a climax community

The climax community in a succession shows the following characteristics:

i) The vegetation of the climax community will have high ecological amplitude.

ii) They possess high tolerance towards the environmental conditions.

iii) They show rich diversity in species composition.

iv) The species composition remains constant for many years.

v) The community possesses a complex food chain system.

vi) The ecosystem will be balanced and self-sustainable.

vii) There will be equilibrium between gross primary productivity and respiration.

viii) The energy used from the sunlight and energy released after decomposition will be balanced.

ix) The uptake of nutrients from the soil and the release of nutrients back to the soil by decomposition will be in equilibrium.

x) The individuals of the community lost by its death are replaced by the individuals of the same species.

xi) The climax community is considered as the manifestation of the climate prevailed in the area.

3.5 Summary

- Communities are characterised by a number of unique properties which are referred to as community structure and community function.
- The characteristic features of communities are

  (i) Species composition; (ii) Species richness; (iii) species diversity; (iv) species abundance; (v) species dominance.
- There are species whose removal from any ecosystem lead to a collapse of the structure and ultimate disappearence of other structure and ultimate disappearence of other species is known as keystone species.
- They intermediate zone lying between two adjacent communities is known as ecotone.
- Ecological succession is the gradual and sequential replacement of one community by the other in an area over a period of time.

3.6 Questions

i) What is community? Describe briefly the characteristic features of a community.

ii) What is species richness and species diversity?

iii) Define keystone species and bioindicator species.

iv) Differentiate between habitat and niche.

v) What is vertical stratification of a community? Give example.

vi) What are the types of ecological succession?

vii) Define sere, pioneer and climax community.

viii) Describe the process of ecological succession.

ix) What is hydrarch and xerarch succession?

x) What are the characteristic features of a climax community?

3.7 Suggested readings

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C. (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi. P.C. & Joshi. N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy. E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs. C. J. (2001). Ecology. Benjamin Cummings.
7. Odum. E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith. T M & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma P. S. & Agarwal V. K. (1993). Environmental Biology (Principles of Ecology). 4^{th} Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 4 ❑ Ecosystem

Structure

4.0 Objectives

After studying this unit, the learners will be able to do the following—

- To have an idea about ecosystem and its types.
- To know about food chain, food web and food pyramid.
- To learn about energy flow in ecosystem.
- To know about ecological efficiency.
- To know about biogeochemic cycle with the example of nitrogen cycle.

4.1 Introduction

An ecosystem is a dynamic process that consists of community of living organisms in association with the abiotic components of their environment (air, water and mineral soil), interacting as a system. These biotic and abiotic components are linked together through nutrient cycles and energy flows. As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment, they can be of any size but usually encompass specific, limited geographical location. For instance, in an ecosystem where there are both deer and lion, these two creatures are in a relationship where the lion eats the deer in order to survive. This relationship has a effect with the other creatures and plants that live in the same or similar areas. For instance, the more deer that lion eat, the more the plants may start to thrive because there are fewer deer to eat them.

4.2 Types of ecosystems

There are different types of ecosystems according to the environment. These are the following:

4.2.1 Aquatic ecosystems

These can then be broken up into smaller ecosystems. For instance:

(i) **Pond ecosystems:** These are usually relatively small water bodies. It includes various types of plants, amphibians and insects. Sometimes they include fish, but as these cannot move around as easily as amphibians and insects, it is less likely, and most of the time fish are artificially introduced to these environments by humans.

(ii) **River ecosystems:** As rivers always link to the sea, they are more likely to contain fish along side the usual plants, amphibians and insects. These sorts of ecosystems can also include birds, because birds often hunt in and around water for small fish or insects.

(iii) **Wetland:** It is a zone of flat lands that has groundwater of shallow depth and that ascend to the surface in determined periods, forming lagoons and marshes, until where they come to live hundreds of species. There are five classes of wetlands: marine, estuarine, lake, rivarian and marshy.

(iv) **Mangrove:** It is a grouping of semi-submerged trees that have been flooded with water, with high levels of salinity and therefore they develop and survive in coastal lands. The trees grow on long roots, which like stilts raise the trunks above the level of the waters. To reproduce, they quickly retain the seeds in the branches until they are about to develop. When the tide goes down they are able, within a few hours, to root and begin to grow before being again underwater.

(v) **Coral reef:** It is one of the richest aquatic ecosystems of the planet, product of the great amount of species that inhabit in them (fish, snails, corals and algae). The reef structure consists of large colonies of corals, accumulations of sediments and calcareous sands. They are found mainly in tropical regions and there are two types of coral, *i.e.,* hard and soft.

According to different habitats of aquatic organism, aquatic ecosystems are various kinds and divided into the following:

(i) **Benthic:** These are located at the bottom of aquatic ecosystems. In those that are not very deep, the main inhabitants are algae. In the deeper ones, the majority are consumers.

(ii) **Nectonic:** These animals move freely, thanks to their means of locomotion can adapt to water currents.

(iii) **Planktonic:** These living beings floated in the terrestrial or marine water and are dragged by the water currents. They do not move by their own movements.

(iv) **Neustonie:** These live floating on the surface of the water.

4.2.2 Terrestrial ecosystems

They are regions where organisms (animals, plants, etc.) live and develop in the soil and air that surround a certain terrestrial space. Terrestrial ecosystems are part of other larger ecosystems, called biomass or ecological regions. These zones are delimited by latitude, climate, temperature and the level of precipitations. Depending on the abiotic factors of each ecosystem, there are different types of terrestrial habitats: deserts, grasslands and forests.

(i) **Tropical forests:** It is usually having extremely dense ecosystems because there are so many different types of animals and they all live in a very small area. They have a high biodiversity in plants and animals; is also one of the oldest ecosystems of the planet and they are below the 1200 meters of height; the temperature and light remain constant throughout the year.

(ii) **Temperate forest:** Those who have a good number of trees like mosses and ferns are for them. Temperate forests exist in regions where the climate changes significantly from summer to winter. Summers and winters are clearly defined and trees lose their leaves during the winter months.

(iii) **Swamp:** Situated just before the arctic regions, swamp is defined by evergreen conifers. The temperature is below zero degrees for almost half a year, the rest of the months, is full of migratory birds and insects.

(iv) **Tundra:** It has an extremely cold climate. The ground remains frozen for much of the year. Its rainfall is very low, so it reduces the growth of living organisms. There are no large trees, only small plants (mosses, lichens and other tree species) remain present in this region.

(v) **Desert:** Found in regions that receive annual rainfall of less than 25%. They occupy about 17% of all the land on our planet. Due to the high temperatures, low availability of water and intense sunlight, the fauna and flora are scarce and underdeveloped.

(vi) **Savanna:** Tropical meadows are seasonally dry and have few individual trees. They support a large number of predators and herbivores.

(vii) **Grassland:** The temperate of grassland are completely devoid of large shrubs and trees. Grasslands could be categorized as mixed grass, tall grass and grassy meadows.

(viii) **Mountain:** Offers a dispersed and diverse matrix of habitats where a large number of animals and plants can be found. The harsh environmental conditions that normally prevail at higher altitudes, the alpine vegetation can only survive. The animals that live there have thick fur coats for preventing cold and hibernation in the winter months.

(ix) **Deserts:** Quite the opposite of tundra in many ways, but still harsh, more animals live in the extreme heat.

(x) **Savannas:** These differ from deserts because of the amount of rain that they get each year. Whereas deserts get only a tiny amount of precipitation every tea, savannas tend to be a bit wetter which is better for supporting more life.

(xi) **Forests:** There are many different types of forests all over the world including deciduous forests and coniferous forests. These can support a lot of life and can have very complex ecosystems.

(xii) **Grasslands:** Grasslands support a wide variety of life and can have very complex and involved ecosystems.

4.2.3 Ocean ecosystems

It is the earth's largest salt water ecosystem that contains millions of species. There are different types of ocean ecosystems:

i) **Shallow water:** Some tiny fish and coral only live in the shallow waters close to land.

ii) **Deep water:** Big and even gigantic creatures can live deep in the waters of the oceans. Some of the strongest creatures in the world live right at the bottom of the sea.

iii) **Warm water:** Warmer waters, such as those of the Pacific Ocean, contain some of the most impressive and intricate ecosystems in the world.

iv) **Cold water:** Less diverse, cold waters still support relatively complex ecosystems. Plankton usually form the base of the food chain, following by small fish that are either eaten by bigger fish or by other creatures such as seals or penguins.

4.2.4 Ecosystems according to the degree of human intervention

1. **Natural ecosystems:** Man has not intervened in their formation, such as forests, lakes, deserts.

2. **Artificial ecosystems:** Man actively participates in its formation, such as dams, parks, gardens.

4.3 Detailed description of a typical ecosystem - pond ecosystem

A pond is a quiet body of water that is too small for wave action and too shallow for major temperature differences from top to bottom. It usually has a muddy or silty bottom with aquatic plants around the edges and throughout. However, it is often difficult to classify the differences between a pond and a lake, since the two terms are artificial and the ecosystems really exist on a continuum. Generally, in a pond, the temperature changes with the air temperature and is relatively uniform. Lakes are similar to ponds, but because they are larger, temperature layering or stratification takes place in summer and winter, and these layers turnover in spring. Ponds get their energy from the sun. As with other ecosystems, plants are the primary producers. The chlorophyll in aquatic plants captures energy from the sun for converting carbon dioxide and water to organic compounds and released oxygen through the process of photosynthesis. Nitrogen and phosphorus are important nutrients for plants. The addition of these substances may increase primary productivity. However, too many nutrients can cause algal blooms, leading to eutrophication.

4.3.1 Abiotic components of pond ecosystem

The abiotic substances of pond ecosystem are formed as a result of the mixture of some organic and inorganic materials. The basic components are water, oxygen, carbon dioxide, salts of calcium and nitrogen etc. Only a small amount of these elements are present in soluble state in pond water, but a large amount is held in reserve solid form in the bottom sediments as well as within the organisms. Various organisms get their nourishment from these abiotic substances. The rate of release of reserve nutrients, the solar input and the cycle of temperature, day length and other climatic conditions regulate the function of the Pond ecosystem.

4.3.2 Biotic components of pond ecosystem

The biotic components of pond ecosystem consists of the followings:

a) Producers: The producres are of two types— (i) Macrophytes: larger rooted and floating vegetations; and (ii) Phytoplanktons: microscopic floating plants. Phytoplanktons are available upto the depth of water where light penetrates. The phytoplanktons are filamentous alga like *Ulothrix, Oedogonium, Spirogyra, Anabena, Oscillatoria* and minute floating plants like *Microcystis, Gloeotrichina, volvox* etc.

The macrophytes include marginal emergent plants like *Typha, Acerus, Ipomea* submerged plants like *Hydrilla, Utricularia, Trapa, Nymphrea* etc; surface floating plants like *Pistea, Lemna, Wolffia, Eichhornia, Salvinia* etc.

b) **Consumers:** Consumers of pond ecosystem are heterotrophs which depends for their nutrition on other organisms. Zooplanktons form primary consumers, include *Brachionus, Asplanchna, Lechane* (all rotifers) *Colops, Dilepteus, Cyclops, Stenocypris* (crustacean) ,who feed on phytoplankton. Nectic animals like insects, beetles, fishes form secondary consumers as they feed on zooplanktons. Benthic animals like snakes, big fishes live on nectic animals and are termed tertiary consumers.

c) **Decomposers:** Most of the decomposers of pond ecosystem are saprophytes but some parasites are also found. Bacteria, fungi like *Aspergillus cladosporium, Rhizopus, Alternaria, Fusarium, Saprolegnia* etc. are decomposers.

Generally the decomposers either live in the soil layer beneath water or in the mud. They act on dead and decayed organic matter of plants and animals and supply raw materials to the producers.

4.3.3 Energy flow in pond ecosystem

Phytoplanktons are the producers of pond ecosystem along with other floating plants. The energy produced by the autotrophs is passed through **"eat and being eaten chain".** In pond, the larvae of insects consume autotrophs as food. According to law of energy flow the larvae assimilate energy from autotrophs. So larvae are primary consumers. These primary consumers are taken as food by prawns, small carnivorous fishes etc. and so they collect energy from larvae. They are, therefore secondary consumers. Large fishes consume secondary consumers, and are tertiary consumers.

4.4 Food chain

The transfer of energy and nutrients from the source in plants through a series of organisms with repeated processes of eating and being eaten is called food chain.

Example: Grass (Primary producers) → Cow (Primary consume)→Tiger (Secondary consumer)

Wheat Seed (Primary Producers) → Mouse (Primary consumers) → Cat (Secondary consumers)

Significance of food chain:

i) The studies of food chain help to understand the feeding relationship and the interaction between organisms in any ecosystem.

ii) They also help us to appreciate the energy flow mechanism and matter circulation in ecosystem and understand the movement of toxic substances in the ecosystem.

iii) The study of food chain helps us to understand the problems of bio-magnifications.

4.4.1 Types of food chain

Food chains are classified into two basic types:

a) **Grazing food chain:** A food chain that always starts with green plants moves to grazing herbivores and on to carnivores is called grazing food chain. The total energy assimilated by primary carnivore is derived entirely from the herbivore. Thus, the grazing food chain is more effective as most of the primary production is passed on through different trophic levels and only a small fraction goes to the decomposer system. Therefore, grazing food chain can be represented as:

Autotroph→Herbivore→Primary carnivore→Secondary carnivore→Tertiary camivore→Decomposer.

Grazing food chain can be of two types:

(i) Predator food chain: where the sequence of organisms are generally from smaller to larger.

(ii) Parasitic food chain: where organisms tend to decrease in size from lower to higher trophic levels.

b) **Detritus food chain:** The food chain that always starts with the dead, decaying organic matter or organic wastes (metabolic wastes and extrudates) is called detritus food chain. It is first handed over to microorganisms and finally to detritus feeding organisms known as detritivore. The energy stored in detritus serves as a source of energy for detritivore. This type of food chain is less efficient as the major portion of energy is lost to the ecosystem without being properly used.

4.5 Energy flow in an ecosystem

The process of transfer of energy through various trophic levels of the food chain is known as flow of energy. Producers (green plants) capture energy from the sun by the process of photosynthesis and use it to make food. Most of this energy is used to carry on the plant's life activities. The rest of the energy is passed on as food to the next level of the food chain (consumers). At each level of the food chain, about 90% of the energy is lost in the form of heat. The total energy passed from one level to the next is only about one-tenth of the energy received from the previous organism. Therefore, as you move up the food chain, there is less energy available. Animals located at the top of the food chain need a lot more food to meet their energy needs. The flow of energy and inorganic nutrients through the ecosystem can be summarized as follows:

i) The ultimate source of energy (for most ecosystems) is the sun.

ii) The ultimate fate of energy in ecosystems is for it to be lost as heat.

iii) Energy and nutrients are passed from organism to organism through the food chain as one organism eats another.

iv) Decomposers remove the last energy from the remains of organisms. The behavior of energy in ecosystem can be termed energy flow due to unidirectional flow of energy. Two models have been proposed for energy flow:

a) **Single-channel/ Linear energy model:** This model is proposed where the nutritional availability of the energy source in high, and transfer efficiencies can be much higher. Both plants and animals produce enzymes to digest organic matter (cellulose, lignin chitin) together with chemical inhibitors, the average transfers between whole trophic levels average twenty percent or less. This model suggests one-way flow of energy, and there is progressive decrease in energy level at each trophic level.

A simplified energy flow diagram depicting three trophic levels (boxes numbered 1,2,3) in a linear food chain is presented in the following figure. I-total energy input; LA-light absorbed by plant cover; PG-gross primary productivity; A-total assimilation; PN-net primary production; P-secondary (consumer) production; NU-energy nor used (stored or exported); NA-energy not assimilated by consumers (egested); R-respiration. Bottom line in the diagram shows the order of the magnitude of energy losses expected at major transfer point, starting with a solar input of 3,000Kcal per square meter per day.

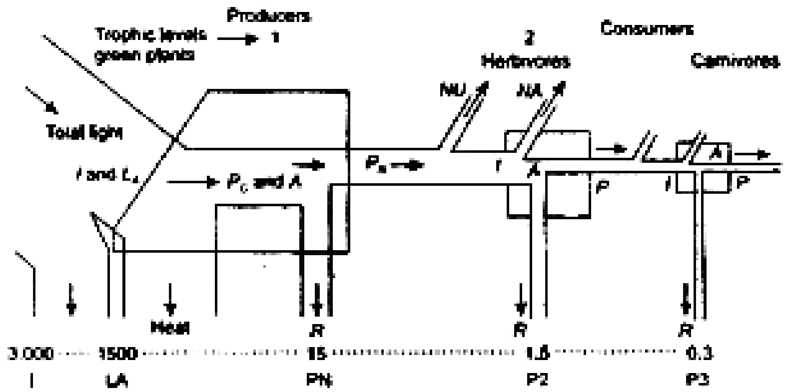


Fig.: Energy flow model (After E.P. Odum, 1983)

b) **Y-shaped energy flow model:** In Y-shaped energy flow model, one arm represents the herbivore food chain, and the other, the decomposer (detritus) food chain. The two arms differ fundamentally in which they can influence primary producers. This model is more realistic than the single-channel model because it conforms to the basic stratified structure of ecosystem, direct consumption of living plants and utilization of dead organic matter and macro consumers (phagotrophic animals) and micro consumers differ greatly in size of metabolic relations.

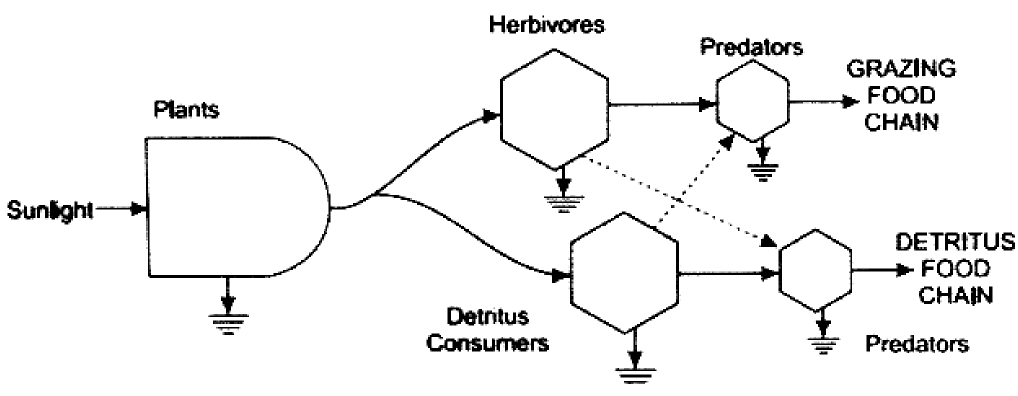
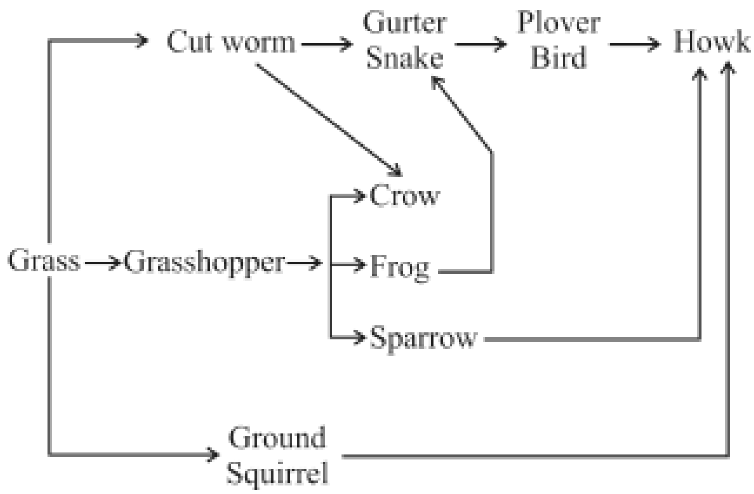


Fig.: The Y-shaped energy flow model showing linkage between the grazing and detritus food chains. (After E.P. Odum, 1983)

4.6 Food web

Food chains in the ecosystem are not linear rather they are interconnected with one another. A network of food chains which are interconnected at various trophic levels so as to form a network of feeding connections in a community called a food web.

In the following a food web from the Pairy grassland has been demonstrated as an example.



4.7 Ecological / Eltonian pyramid

The amount of living matter at any given time in an ecosystem is called standing crop. It can be expressed in terms of biomass, number or total amount of energy fixed at each step of the food chain. It gives a definite trophic structure to the ecosystem. Graphically it is represented with the producers at the base and the subsequent trophic levels as the tiers. This gives a gradually sloping pyramidal shape as the biomass, number and energy is reducing at each trophic level. This graphical representation of the standing crop expressed as number, biomass or energy is called ecological pyramid.

a) **Pyramid of number:** For example in grassland, you have observed that the number of grasses is more than the total number of herbivores (grasshoppers and hare) that feed on them and the number of herbivores is more than the number of snakes and birds (carnivores). When an ecological pyramid is constructed on the basis of the number of individuals at each trophic level it is called a pyramid of number. The pyramid of number is a result of three phenomenon—(i) Geometrical - many small units are required to build up one big unit (units are organisms); (ii) Entropy -due to entropy at each step many small organisms are required to support a few large organisms, which is a basic principle of food chains; (iii) Inverse size metabolism pattern - smaller organism have higher metabolic rate than the larger organisms. Sometimes the pyramid of number is inverted. For example many caterpillars and insects feed on one plant/ tree. In this case, the number of herbivore is more than the number of autotroph. Similarly the number of phytoplankton is less than the herbivorous zooplankton in English Channel. This is because of the high turnover rate of phytoplankton in it.

b) **Pyramid of biomass:** This is the graphical representation of biomass at each trophic level. For instance the total biomass of trees in the forests is greater than the total biomass of the herbivores supported by them. At the level of top carnivore in a community very little biomass is left to support any further trophic level. Pyramid of biomass can also be inverted like the pyramid of number. In a channel of water or a canal where the producers have short life cycles and are replaced rapidly by the new plants (high turnover rate), the biomass of producers is less than consumers who have longer life span like fishes. Pyramid of biomass is expressed as dry weight per unit area.

c) **Pyramid of energy:** The pyramid of energy represent the total amount of energy fixed at each trophic level. These give the true functional structures to the ecosystem. They are never inverted and most informative. Energy is expressed in terms of rate such as kcal / unit area / unit time or cal / unit area / unit time. In a lake ecosystem, if the energy at producers level is 20,810, then in herbivore is 3,308 primary carnivore is 383 and secondary carnivore is 21 kcal/ m^2/ year. Energy pyramid provides a more suitable index for comparing any or all components of an ecosystem. The pyramid of number over emphasizes the smaller individuals, biomass gives more importance to the larger individuals and therefore, both cannot be used as reliable tools for comparing the functional role of the populations that differ widely in size and metabolism.

The following figure demonsostrate different kinds of ecological pyramids.

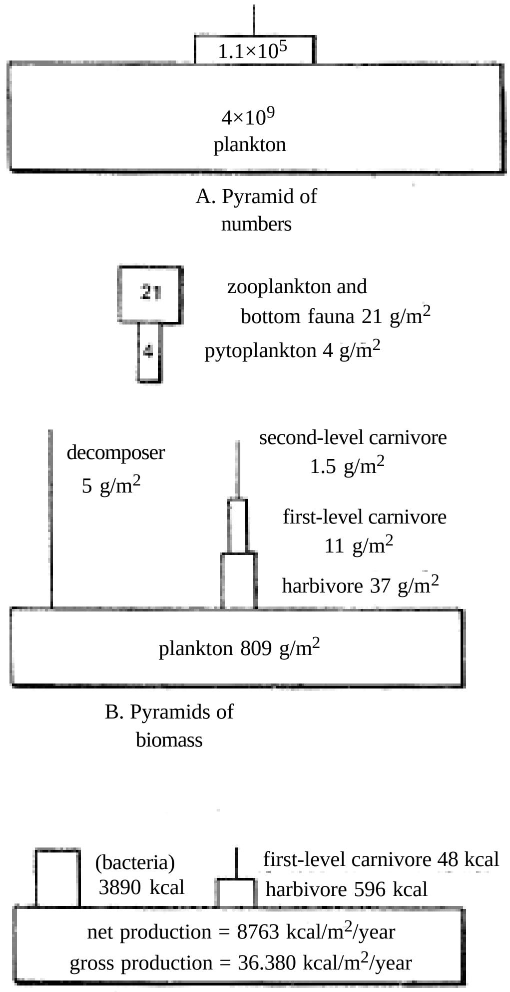


Fig.: Different kinds of ecological pyramids (after Smith, 1977)

4.8 Ecological efficiency

The percentage ratio of the energy flow at different points along the food chain is called ecological efficiencies. Commonly if a poultry man speaks of 30 % efficiency in his poultry farm then the efficiency for him is the percentage ratio of input (feed) to the output in chicken (biomass). The ecological efficiency can be given in terms of various parameters such as growth, production and assimilation. Lindeman (1942) defined these ecological efficiencies for the first time and proposed 10% rule as discussed in energy flow model. However, there are slight variations to this law in different ecosystem and ecological efficiencies may range from 5 to 35%.

Ecological efficiency is also called Lindeman's Efficiency and can be represented as: Production efficiency = P = production / assimilation × 100 (Similarly assimilation efficiency is percentage conversion of food into protoplasm). In the above mentioned example, if 10 gm food is given to the chicken its biomass would increase by 3 gm. Therefore, 3 × 100 = 30 % is the production efficiency. This is an example of human modified system and also it is assumed that all the food is assimilated in the body of chicken. In natural ecosystems this efficiency will be much less. Ecological efficiency increases at higher trophic levels. Ecological efficiency can be given as production efficiency, assimilation efficiency, growth efficiency or tissue growth efficiency.

4.9 Biogeochemical cycle

In ecosystem, flow of energy is linear but that of nutrients is cyclic. This is because energy flows downhill *i.e.,* it is utilized or lost as heat as it flows forward. The nutrients on the other hand cycle from dead remains of organisms released back into the soil by detritivores which are absorbed again i.e., nutrient absorbed from soil by the root of green plants are passed on to herbivores and then carnivores. The nutrients locked in the dead remains of organisms and released back into the soil by detritivores and decomposers. This recycling of the nutrients is called biogeochemical or nutrient cycle (Bio = living; geo = rock; chemical = element). There are more than 40 elements required for the various life processes by plants and animals. The entire earth or biosphere is a closed system *i.e.,* nutrients are neither imported nor exported from the biosphere.

There are two important components of a biogeochemical cycle

(1) Reservoir pool: Atmosphere or rock, which stores large amounts of nutrients.

(2) Cycling pool or compartments of cycle: They are relatively short storages of carbon in the form of plants and animals.

Biogeochemical cycles connect living things to the earth. The four chemicals that make up 95% of biomolecules are: carbon, hydrogen, oxygen and nitrogen. These elements are constantly being cycled through living and non-living organic matter.

4.9.1 Nitrogen cycle

Nitrogen is an essential component of protein and required by all living organisms including human beings. Our atmosphere contains nearly 79% of nitrogen but it cannot be used directly by the majority of living organisms. Broadly like corbon dioxide, nitrogen also cycles from gaseous phase to solid phase then back to gaseous phase through the activity of a wide variety of organisms. Cycling of nitrogen is vitally important for all living organisms. There are five main processes which essential for nitrogen cycle are elaborated below.

(a) **Nitrogen fixation:** This process involves conversion of gaseous nitrogen into ammonia, a form in which it can be used by plants. Atmospheric nitrogen can be fixed by the following three methods:-

(i) Atmospheric fixation: Lightening, combustion and volcanic activity help in the fixation of nitrogen.

(ii) Industrial fixation: At high temperature (400°C) and high pressure (200 atm.), molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.

(iii) Bacterial fixation: There are two types of bacteria:

1. **Symbiotic bacteria:** e.g. Rhizobium in the root nodules of leguminous plants.
2. **Freeliving or symbiotic:** e.g. Nostoc, Azobacter, Cyanobacteria can combine atmospheric or dissolved nitrogen with hydrogen to form ammonia.

(b) **Nitrification:** It is a process by which ammonia is converted into nitrates or nitrites by *Nitrosomonas* and *Nitrococcus* bacteria respectively. Another soil bacterium *Nitrobacter* can covert nitrate into nitrite.

(c) **Assimilation:** In this process nitrogen fixed by plants is converted into organic molecules such as proteins, DNA, RNA etc. These molecules make the plant and animal tissue.

(d) **Ammonification:** Living organisms produce nitrogenous waste products such as urea and uric acid. These waste products as well as dead remains of organisms are converted back into inorganic ammonia by the bacteria. This process is called ammonification. Ammonifying bacteria help in this process.

(e) **Denitrification:** Conversion of nitrates back into gaseous nitrogen is called denitrification. Denitrifying bacteria live deep in soil near the water table as they like to live in oxygen free medium. Denitrification is reverse of nitrogen fixation.

This following figure will give an overall idea about the nitrogen cycle within the environment.

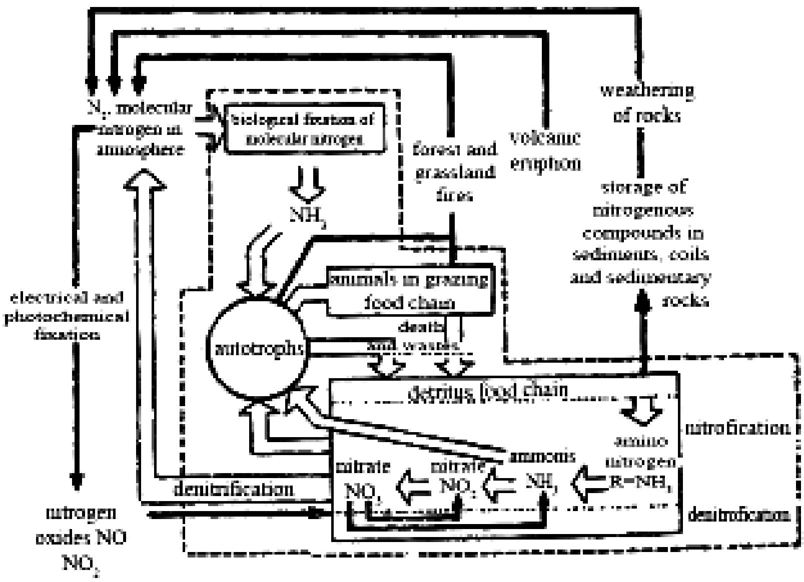


Fig.: **Nitrogen cycle Organic phase is within broken lines (after Clapham, Jr., 1973).**

4.10 Summary

- An ecosystem is a dynamic process that consists of community of living organisms in association with the abiotic components of their environment.
- The transfer of energy and nutients from the source in plants through a series of organisms with repeated processes of eating and being eaten is called food chain.
- The ultimate source of energy is the sun.
- The flow of energy in the ecosystem is unidirectional.
- Food chain in the ecosystem is not linear rather they are interconnected with one another
- The percentage ratio of the energy flow at different points along the food chain is called ecological efficiences.

4.11 Model questions

i) Define ecosystem.

ii) What are the types of ecosystem according to prevailing environment?

iii) What are the types of ecosystem based on human intervention?

iv) Differentiate between food chain and food web.

v) Differentiate between detritus and grazing food chain.

vi) Describe the significance of food chain.

vii) Describe the structure of an ecosystem in detail.

viii) What is biogeochemical cycle? Describe nitrogen cycle in detail.

ix) What is ecological pyramid? Describe the upright and inverted pyramids of number and biomass respectively.

x) Why the pyramid of energy is always upright?

xi) What are ecological efficiencies?

xii) Describe the linear and Y-shaped model of energy transfer in an ecosystem.

4.12 Suggested reading

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C., (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi, P.C. & Joshi. N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy, E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs, C. J. (2001). Ecology. Benjamin Cummings.
7. Odum, E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith, T M & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma, P. S. & Agarwal, V. K. (1993). Environmental Biology (Principles of Ecology). 4^{th} Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 5 ❑ Wildlife conservation

Structure

5.0 Objectives

After studying this unit, the learners will be able to do the following—

- To know about the aim and strategies of wild life conservation.
- To know about different types of conservation, i.e., *in-situ* and *ex-situ* conservation.
- To learn about tiger conservation.

- To know about protective laws for wild life conservation.

5.1 Introduction

As the human population increases, more and more lands are brought under its control and, as a result, the amount of natural vegetation has diminished considerably and so also the habitat of various species. The vast expanses of tropical forest and its inhabiting species have become increasingly threatened in the last few decades. Even in the oceans, fishing is so intensive that fish populations are diminishing rapidly. We have become too efficient as predators. Sometimes we hunt species for luxury items! For example, the elephants for their tusk, the rhinoceroses for their horns etc. Sometimes we capture exotic species such as various birds, coral reef fishes etc. for the pet trade. Thus, we have become a species which is no longer in co-evolved balance with its environment.

5.2 Strategies for wild life conservation

a) Protection of natural habitats.

b) Maintenance of the viable number of species in protected areas.

c) Establishment of biosphere reserves.

d) Protection through legislation.

e) Imposing restriction on export of rare plant and animal species and their products.

f) Improving the existing conditions of protected areas.

g) Mass education.

h) To declare some animals, trees, flowers as national and state symbol.

5.3 Types of conservation

Conservation can broadly be divided into two types:

5.3.1 *In-situ* conservation

In-situ conservation, which is also known as “on-site conservation”, refers to the conservation of wild species in their natural habitats and environment. It aims to conserve the natural habitats of the living creatures and maintain to recover wild species, especially the endangered species. The national parks, wildlife sanctuaries and biosphere reserve are some of the examples of *in-situ* conservation. This method of conservation allows animals flourish in their natural habitat and food chain and offers more mobility to the animals. It is suitable for the conservation of animals that are found in abundance.

Example: National parks, wildlife sanctuaries, biosphere reserves etc.

5.3.2 *Ex-situ* conservation

Ex-situ conservation, which is also known as "off-site conservation", refers to the conservation of endangered species in the artificial or man-made habitats that imitate their natural habitats, e.g. zoo, aquarium, botanical garden etc. It offers less mobility to the animals as it is smaller in area than the area of *in-situ* conservation. This method of conservation is suitable for the animals which are not found in abundance. It provides protection to animals against predators, unfavourable climatic conditions and other hostile factors. Furthermore, proper food and care is provided under good supervision.

Example: Botanical gardens, zoos etc.

Advantages of *ex-situ* preservation

a. It is useful for declining population of species.

b. Endangered animals on the verge of extinction are successfully breed.

c. Threatened species are breed in captivity and then released in the natural habitats.

d. *Ex-situ* centers offer the possibilities of observing wild animals, which is otherwise not possible.

e. It is extremely useful for conducting research and scientific work on different species.

The key differences between *in-situ* and *ex-situ* conservation are as follows:

***In-situ* Conservation**	***Ex-situ* Conservation**
It means onsite conservation.	It means offsite conservation.
It is the conservation of wild species in their natural habitats in order to maintain and recover endangered species.	It is conservation of species in the man-made habitats that imitate the natural habitats of species.

***In-situ* Conservation**	***Ex-situ* Conservation**
It is more dynamic as it involves natural habitats of organisms.	It is less dynamic as it involves man-made habitats.
It provides protection to endangered species against predators.	It provides protection against all hostile factors.
It is suitable for animals that are found in abundance.	It is suitable for animals that are not found in abundance.
It is not suitable in the event of a rapid decline in the number of a species due to environmental, genetic or any other factor.	It is an ideal option in case of rapid decline in the number of a species due to environmental or any other reason.
Wildlife and livestock conservation involve *in-situ* conservation.	It can be used to conserve crops and their wild relatives.
Examples include national parks, wildlife sanctuaries, biospheres reserve etc.	Examples include zoo, aquarium and botanical garden.
It involves designation, management and monitoring of the target species in their natural habitat.	It involves sampling, storage and transfer of target species from their natural habitats to man-made habitats.
It helps to maintain the ongoing process of evolution and adaptation within the natural environment of the species.	It separates the animals form the ongoing process of evolution and adaptations within their natural environment.

5.4 Tiger conservation

Tiger conservation programme was launched in April 1973 by the Government of India at Jim Corbet National Park. The main aims of project tiger were:

a) To reduce factors that lead to the reduction of tiger habitats and to mitigate them by suitable management. The damages done to the habitat were to be rectified so as to facilitate the recovery of the ecosystem to the maximum possible extent.

b) To ensure a viable tiger population for economic, scientific, cultural, aesthetic and ecological values.

The formation of tiger reserves in the country were based on the ‘core-buffer’ strategy:

a) **Core area:** The core areas are free of all human activities. It has the legal status of a national park or wildlife sanctuary. It is kept free of biotic disturbances and forestry operations like collection of minor forest produce, grazing, and other human disturbances are not allowed within core area.

b) **Buffer areas:** The buffer areas are subjected to ‘conservation-oriented land use’. They comprise forest and non-forest land. It is a multi-purpose use area with twin objectives of providing habitat supplement to spillover population of wild animals from core conservation unit and to provide site specific co-developmental inputs to surrounding villages for relieving their impact on core area.

The important thrust areas for the Tiger project are:

i) Setting up networking surveillance of tigers.

ii) Voluntary relocation of people from core/critical tiger habitat.

iii) Use of information technology in wildlife crime prevention.

iv) Developing a national respirator of camera trap tiger photographs.

v) Strengthening the regional offices of the National Tiger Conservation Authority.

vi) Creation of new tiger reserves.

vii) Elimination of all forms of human exploitation and biotic disturbance from the core area.

5.5 Protection laws for wildlife conservation

It is a general conception that India does not have strong wildlife conservation laws. On the contrary, we have some of the most stringent legislations to protect wildlife and habitats. The Government of India has introduced various types of legislation in response to the growing destruction of wildlife and forests. These are:

5.5.1 The Wildlife Protection Act, 1972

The Wildlife Protection Act (WLPA), 1972 is an important statute that provides a powerful legal framework for:

* Prohibition of hunting.

* Protection and management of wildlife habitats.
* Establishment of protected areas.
* Regulation and control of trade in parts and products derived from wildlife.
* Management of zoos.

National parks and Tiger Reserves are by law more strictly protected, allowing no human activity except that which is in the interest of wildlife conservation. The amended WLPA does not allow for any commercial exploitation of forest produce in both national parks and wildlife sanctuaries, and local communities can collect forest produce only for their bonafide needs. The statute prohibits the destruction or diversion of wildlife and its habitat by any method unless it is for improvement or better management and this is decided by the State Government in consultation with the National and State Boards for Wildlife. The WLPA provides for investigation and prosecution of offences in a court of law by authorized officers of the forest department and police officers.

5.5.2 The Indian Forest Act (1927)

The main objective of the Indian Forest Act (1927) was to secure exclusive state control over forests to meet the demand for timber. Most of these untitled lands had traditionally belonged to the forest dwelling communities. The Act defined state ownership, regulated its use, and appropriated the power to substitute or extinguish customary rights. The Act facilitates three categories of forests, namely, (i) reserved forests; (ii) village forests; (iii) protected forests. Reserved forests are the most protected within these categories. No rights can be acquired in reserved forests except by succession or under a grant or contract with the Government. Felling trees, grazing cattle, removing forest products, quarrying, fishing, and huhting are punishable with a fine or imprisonment. Although the Indian Forest Act is a federal act, many states have enacted similar forest acts but with some modifications.

5.5.3 The Forest Conservation Act (1980)

In order to check rapid deforestation due to forestlands being released by state Governments for agriculture, industry and other development projects (allowed under the Indian Forest Act) the federal Government enacted the Forest Conservation Act in 1980 with an amendment in 1988. The Act made the prior approval of the federal

Government necessary for de-reservation of reserved forests, logging and for use of forestland for non- forest purposes.

5.5.4 The Environment (Protection) Act (1986)

The Environment Protection Act is an important legislation that provides for coordination of activities of the various regulatory agencies, creation of authorities with adequate powers for environmental protection, regulation of the discharge of environmental pollutants, handling of hazardous substances, etc. The Act provided an opportunity to extend legal protection to nonforest habitats ('Ecologically Sensitive Areas') such as grasslands, wetlands and coastal zones.

5.5.5 The Biological Diversity Act (2002)

India is a party to the United Nations Convention on Biological Diversity. The provisions of the Biological Diversity Act are in addition to and not in derogation of the provisions in any other law relating to forests or wildlife.

5.5.6 National Wildlife Action Plan (2002-2016)

It replaces the earlier plan adopted in 1983 and was introduced in response to the need for a change in priorities given the increased commercial use of natural resources, continued growth of human and livestock populations, and changes in consumption patterns. The plan most closely represents an actual policy on protection of wildlife. It focuses on strengthening and enhancing the protected area network, on the conservation of endangered wildlife and their habitats, on controlling trade in wildlife products and on research, education, and training.

5.5.7 National Forest Policy (1998)

The National Forest Policy (NFP), 1988, is primarily concerned with the sustainable use and conservation of forests, and further strengthens the Forest Conservation Act (1980). It marked a significant departure from earlier forest policies, which gave primacy to meeting Government interests and industrial requirements for forest products at the expense of local subsistence requirements. The NFP prioritizes the maintenance of ecological balance through the conservation of biological diversity, soil and water management, increase of tree cover, efficient use of forest produce, substitution of wood, and ensuring peoples' involvement in achieving these objectives.

5.6 Questions

i) Why there is need to conserve wildlife?

ii) Differentiate between the *ex-situ* and *in-situ* conservation.

iii) What is tiger project? Describe the management strategies for tiger conservation.

iv) Write a short note on the protection laws for wildlife conservation.

v) Mention the advantages of *ex-situ* and *in-situ* conservation.

5.7 Suggested reading

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.

2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.

3. Dash, M. C. (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.

4. Joshi. P.C. & Joshi. N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.

5. Kormondy. E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.

6. Krebs. C. J. (2001). Ecology. Benjamin Cummings.

7. Odum, E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.

8. Smith. T. M. & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.

9. Verma, P. S. & Agarwal, V. K. (1993). Environmental Biology (Principles of Ecology). 4^{th} Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 6 ❑ Ecological, Faunal and Floral Characteristics

Structure

6.0 Objectives

After studying this unit, the learner will be able to do the following—

- To know about tropical rain forest.
- To learn about mangrove ecosystem.
- To know about different floral and faunel characteristics of island ecosystem.
- To know about desert ecosystem.

6.0 Introduction

The group of ecosystems sharing the same characteristics and are well adapted to the prevailing abiotic factors are called biomes. Any earth surface that has got a very large ecological system characterized by dominant forms of plant and animal life forms adapted to the prevailing climate and other environmental factors is termed as a biome. Biomes include both the abiotic and biotic factors. The climate and geography of a region determines what type of biome can exist in that region. Major biomes include deserts, forests, grasslands, tundra, and several types of aquatic environments. Each biome consists of many ecosystems whose communities have adapted to the small differences in climate and the environment inside the biome. In this unit we will study the ecological, faunal and floral characteristics of some selected ecosystems.

6.2 Tropical rain forest

The tropical rainforest is a hot, moist biome found near Earth's equator. There are two types of rainforests, tropical and temperate. Tropical rainforests are found closer to the equator where the environment is warm. Temperate rainforests are found near the cooler coastal areas further north or south of the equator. The world's largest tropical rainforests are in South America, Africa, and Southeast Asia. Tropical rainforests receive from 60 to 160 inches of precipitation that is fairly evenly distributed throughout the year. The combination of constant warmth and abundant moisture makes the tropical rainforest a suitable environment for many plants and animals. Tropical rainforests contain the greatest biodiversity in the world. Over 15 million species of plants and animals live within this biome. The hot and humid conditions make tropical rainforests an ideal environment for bacteria and other microorganisms. Because these organisms remain active throughout the year, they quickly decompose matter on the forest floor. In other biomes, such as the deciduous forest, the decomposition of leaf litter adds nutrients to the soil. But in the tropical rainforest, plants grow so fast that they rapidly consume the nutrients from the decomposed leaf litter. As a result, most of the nutrients are contained in the trees and other plants rather than in the soil. Most nutrients that are absorbed into the soil are leached out by the abundant rainfall, which leaves the soil infertile and acidic.

6.2.1 Floral characteristics

Although tropical rainforests receive 12 hours of sunlight daily, less than 2% of that sunlight ever reaches the ground. The tropical rainforest has dense vegetation, often forming three different layers—the canopy, the understory, and the ground layer. Frequently, people think of the tropical rainforest as a "jungle" where plant growth is dense even at ground level. However, the canopy created by the tall trees (100-120 feet) and the understory, prevents sunlight from reaching the ground. The soil is, therefore, always shaded, and very little vegetation is able to survive at ground level.

Vegetation can become dense at ground level near riverbanks and on hillsides. Hillsides have more plant growth because the angle of the growing surface allows sunlight to reach lower layers of the forest. Riverbeds break up the forest canopy so that smaller plants can get the needed sunlight. Plant survival in a tropical rainforest depends on the plant's ability to tolerate constant shade or to adapt strategies to reach sunlight. Fungus is a good example of a plant that flourishes in warm, dark places created by the forest canopy and understory.

Competition for sunlight by plants is sometimes deadly. The strangler fig needs sunlight to grow and reproduce. Seeds falling to the ground quickly die in the deep shade and infertile soil of the tropical rainforest. So it has adapted. Its seeds are deposited on branches of host trees by birds and small animals that have eaten the fruit of the strangler fig. The seeds sprout and send a long root to the ground. This root rapidly increases in diameter and successfully competes for the water and nutrients in the soil. As the strangler fig matures, branches and leaves grow upwards creating a canopy that blocks sunlight from the host tree. Additional roots are sent out and wrap around the host tree, forming a massive network of roots that strangle and eventually kill the host.

6.2.2 Faunal characteristics

Tropical rainforests support a greater number and variety of animals than any other biome. One of the reasons for this great variety of animals is the constant warmth. Tropical rainforests also provide a nearly constant supply of water and a wide variety of food for the animals. Small animals, including monkeys, birds, snakes, rodents, frogs, and lizards are common in the tropical rainforest. Many of these animals and a multitude of insects never set foot on the ground. The animals use the tall trees and understory for shelter, hiding places from their predators, and a source of food. Because there are so many animals competing for food, many animals have adapted by learning to eat a particular food eaten by no other animal. Toucans have adapted by developing long, large bill. This adaptation allows this bird to reach fruit on branches that are too small to support the bird's weight. The bill also is used to cut the fruit from the tree.

The Sloth uses a behavioral adaptation and camouflage to survive in the rainforest.

It moves very, very slowly and spends most of its time hanging upside down from trees. Blue-green algae grow on its fur giving the Sloth a greenish color and making it more difficult for predators to spot.

6.3 Mangrove ecosystem

A Mangrove swamp is a coastal, wetland ecosystem that is made up of small halophytic trees and is found in tropical and subtropical areas. The term “mangrove” refers to a tidally influenced wetland ecosystem within the intertidal zone of tropical and subtropical latitudes. Mangrove also designates the marine tidal forest that includes trees, shrubs, palms, epiphytes and ferns. The distinctive community of plants and animals associated with mangroves is sometimes referred to as the ‘mangal’. Mangrove ecosystems are heterogeneous habitats with an unusual variety of animals and plants adapted to the environmental conditions of highly saline, frequently inundated, soft-bottomed anaerobic mud. Plants that are confined to the mangrove are called true mangroves; plants that can also occur elsewhere are called mangrove associates. Mangrove associates never grow in true mangrove communities and may occur in terrestrial vegetation. The mangrove fauna includes terrestrial, marine, temporary and permanent animal species, all of which have different adaptations to cope with the mangrove environment. The diversity of mangroves is high, but the variety of mangrove ecosystems also makes it difficult to produce general guidelines for conservation and management of mangroves because each system is unique.

6.3.1 Floral and faunal characteristics

Mangroves support unique ecosystems, especially on their intricate root systems. The mesh of mangrove roots produces a quiet marine region for many young organisms. In areas where roots are permanently submerged, they may host a wide variety of organisms, including algae, barnacles, oysters, sponges, and bryozoans, which all require a hard substratum for anchoring while they filter feed. Shrimps and mud lobsters use the muddy bottom as their home. Mangrove crabs improve the nutritional quality of the mangal muds for other bottom feeders by mulching the mangrove leaves. In at least some cases, export of carbon fixed in mangroves is important in coastal food webs. The habitats also host several commercially important species of fish and crustaceans. The coastal horseshoe crab, *Tachypleus gigas,* Oriental pied-hombill, *Anthracoceros albirostris,* Malayan water monitor, *Varanus salvator* (and other species of monitor lizards), Nipah palm, *Nypa fruticans*, mangrove plant. Mudskipper, fiddler crabs are some commonly found organisms in mangrove ecosystem.

6.4 Island ecosystem

An island is an area of land that is surrounded by water. Islands and their surrounding waters cover around one sixth of Earth's surface. Islands have played an important role in our understanding of ecology and evolution, with the most famous example being the exploration of the Galapagos Islands by English naturalist Charles Darwin (1809-1882). Islands have long been of interest to ecologists. Their isolation from the mainland means that species tend to live undisturbed by invasion from non-native plants and animals. Over time, they evolve to adapt to their environment, creating an ecosystem unique to that island. Island ecosystems are vulnerable, particularly if they are small and remote. Limited resources means that species are more likely to become extinct on an island than they are on the mainland. Therefore, islands are home to many of the world's endangered species. An island is sometimes colonized by new species dispersing there, especially if it is not far from the mainland. There are many conservation projects underway around the world that supports island ecologies by monitoring the health of species and protecting their habitats.

6.4.1 Floral and faunal characteristics

The islands are home to the richest butterfly diversity in the world and the islands are home to some of the largest butterflies globally. The islands are also a bird watching hot spot with hundreds of species of birds. Some most important birds are wood pigeon, hornbill scops owl, the blue-eared kingfisher and the fulvous breasted woodpecker. Different species of wild boars, elephants, sea turtles and wild salt water crocodiles make the islands a wildlife hotspot.

6.5 Desert ecosystem

Desert ecosystems are defined by scarcity of water, heat stress and limitations of food and nutrients resources. Desert regions are found globally in the subtropical high pressure belts, in the rain shadow of mountain ranges or the continental interior, and bordering cold ocean currents. Even though primary productivity by plants and microorganisms is relatively low, species richness and taxonomical diversity can be fairly high. Taxonomically different organisms evolved traits to cope with water stress and often similar life forms arose due to convergent evolution. Typical desert organisms show traits that allow them to avoid periods of extreme aridity in inactive stages and/ or to store water for use during drought; a few organisms evolved traits to tolerate the lack of water altogether. Microbial decomposition in deserts is limited due to aridity and the energy flow in desert ecosystems is dominated by detritivores that form the base of the food chain. Humans show adaptations to hot desert climates and a number of cultural practices arose that enable human populations to live near or in deserts.

6.5.1 Floral and faunal characteristics

Most desert species have found remarkable ways to survive by evading drought. Desert succulents, such as cacti or rock plants for example, survive dry spells by accumulating moisture in their fleshy tissues. They have an extensive system of shallow roots to capture soil water only a few hours after it has rained. Additionally, many cacti and other stem-succulent plants of hot deserts present columnar growth, with leafless, vertically- erect, green trunks that maximize light interception during the early and late hours of the day, but avoid the midday sun, when excessive heat may damage plant tissues. One of the most effective drought-survival adaptations for many species is the evolution of an ephemeral life-cycle. An ephemeral life cycle is characterized by a short life and the capacity to leave behind very hardy forms of propagation. This ability is found not only in plants but also in many invertebrates. Desert ephemerals are amazingly rapid growers capable of reproducing at a remarkably high rate during good seasons.

Birds and large mammals can escape critical dry spells by migrating along the desert plains or up into the mountains. Smaller animals cannot migrate but regulate their environment by seeking out cool or shady places. In addition to flying to other habitats during the dry season, birds can reduce heat by soaring. Many rodents, invertebrates, and snakes avoid heat by spending the day in caves and burrows searching out food during the night. Animals active in the day reduce their activities by resting in the shade during the hotter hours.

6.6 Questions

i) Describe the ecological conditions, faunal and floral characteristics of tropical rain forest.

ii) Discuss the adaptations of flora and fauna of tropical rain forest.

iii) Describe the ecological conditions, faunal and floral characteristics of Mangrove ecosystem.

iv) Discuss the floral adaptations of Mangrove ecosystem.

v) Describe the ecological conditions, faunal and floral characteristics of Island ecosystem.

vi) Describe the ecological conditions, faunal and floral characteristics of desert ecosystem.

vii) Discuss the adaptations of flora and fauna of desert ecosystem.

6.7 Suggested reading

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C. (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi, P.C. & Joshi, N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy, E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs, C. J. (2001). Ecology. Benjamin Cummings.
7. Odum, E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith, T. M. & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma, P. S. & Agarwal, V. K. (1993). Environmental Biology (Principles of Ecology). 4^{th} Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055

Unit 7 ❑ Zoogeography

Structure

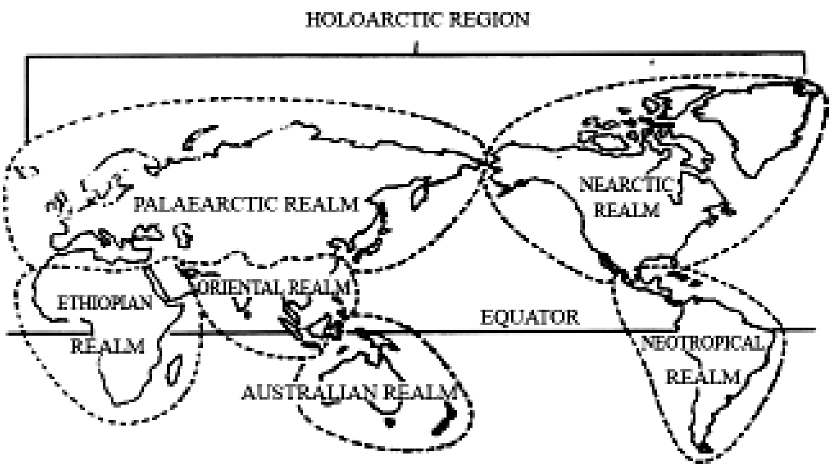
7.0 Objectives

After studying this unit, the learners will be able to do the following—

- To know the basic idea of zoogeography.
- To know what is Wallaces line.
- To have a basic idea about zoogeographical realm.
- To know about geography, climate, ecology and fauna of different zoogeographical realm.
- To know about the theories pertaining to distribution of animals.

7.1 Introduction

The distribution of plants (flora) and animals (fauna) throughout the earth shows a differential pattern. This difference is based on the adaptation of organisms to its immediate environmental conditions. Therefore, based on the geographic distribution (presence and absence of several organisms), the earth can be divided into some regions called realms. Several scientists proposed several scheme of realms. Sclater (1857), on the basis of the distribution of birds divided the geographical areas of the Earth into six parts. After that, Alfred Russel Wallace in 1876 published a paper on zoogeographical realms. He retained the 'six area concept' of Sclater, but included in his study all the terrestrial vertebrates and invertebrates. The only change, he made was in renaming the Indian region of Sclater to Oriental region. The realms, which they described were all separated by distinctive barriers from each other. The scheme of division proposed by Wallace is presented here and the realms are separated by dotted lines on world map, which are known as Wallace's line.



7.2 Zoogeographical realms

In this section we will discuss about the geographical boundary, climatic and ecological cotulitions and characteristic faunal composition of six zoogeographical realms in detail.

7.2.1 Palaearctic realm

Geographical boundary: Geographically this realm consists of whole of Europe, Northern part of Africa and Asian Himalaya and Nan ling range of China.

Sub-divisions: This realm is further divided into four sub-divisions by Wallace.

(i) European sub-region: Northern and Central Europe, Black Kokesus.

(ii) Mediterranean sub-region: Part of Africa, Asia, Europe, Arab, Afghanistan and Baluchistan. .

(iii) Siberian sub-region: Northern part of Himalaya, i.e., Northern Asia.

(iv) Manchurian kub-region: Mongolia, Korea, Manchuria, Japan.

Climatic condition: Extreme cold of Siberia and extreme hot of Sahara desert are characteristic climate of this region.

Ecological condition: Deciduous forest, large grassland, coniferous forest and mixed forest. Tundra area is also present in this region.

Characteristic vertebrate fauna:

(i) Fish: Carp, *Salmon*, *Pike*, Sticklebacks are common in freshwater of this region

(ii) Amphibia: European Salamander, *Proteius*, *Hynobius*, *Bombinator*, *Alytes*, *Didocus* etc.

(iii) Reptiles: Sand boa, lizard - *Trigonophis* and *Alligator*.

(iv) Birds: Arctic tern, Pheasant, *Wrens*, *Finches*, *Warblers*, *Geese* etc.

(v) Mammals: Among 39 families of characteristic mammals, family - Seluinidae and Ailuropodie are endemic. Other mammals are porcupine, dog, wild ass, European bison, polar cat, deer, etc. .

7.2.2 Nearctic realm

Geographical boundary: This region consists, on its north the entire of North America, in south up to Mexico, in East Greenland and in west Aleutian islands.

Sub-divisions: It is also sub-divided into four sub-regions.

(i) Californian sub-region: Vancouver Island part of British Colombia, Nevada and some part f of Cascade hill region are the areas of this region. It is commonly known as the low biodiversity area.

(ii) Rocky mountain sub-region: Eastern side of California has a high and rocky mountain range. This region contains a rich zoo-diversity among Nearctic region.

(iii) Allegheny sub-region: This sub-region is situated at the eastern side of the rocky mountain sub-region. Its northern part is bounded by Great lakes. This sub-region is with moderate zoo property.

(iv) Canadian sub-region: This sub-region consists of North America and Greenland and is not renowned for its animal contents.

Climatic condition: Like Palaearctic region this region also has extreme cold and hot climate.

Ecological condition: Deciduous forest range, huge grassland, coniferous forest, dry land and Tundra regions are prominent ecological zonations.

Characteristic vertebrate fauna

(i) **Fishes:** *Lepisosteus*, *Polydon*, *Acipenser* and varieties of perches.

(ii) **Amphibia:** *Siren*, *Amphiuma*, *Cryptobranchus*, *Ambystoma*, *Ascaphys* and Axolotl larva. Most of them belong to caudata.

(iii) **Reptiles:** *Conophis*, *Chilomeniscus*, *Pituophis*, *Farancia* are prominent snakes. *Phrynosoma*, *Uta* are lizards and *Aromochelys* and *Chelydra* are turtles.

(iv) **Birds:** Turkey, pelican, crow, cuckoo, pigeon, saras, swan, kite, rel, owl, hawk, etc. Most of them are migratory birds.

(v) **Mammals:** *Didelphis*, *Armadillo*, *Caribou*, *pronghorn*, srew, mole, bear, wolf, monkey, deer, bat, goat, mask ox, bison, etc. The mammalian family Aplodontidae and Pronghorn are endemic.

7.2.3 Neo-tropical realm

Geographical Boundary: South and central America lower Mexico and West Indies are the constituents of this region. This region is connected with Nearctic region by central American isthmus and other parts are bordered by the sea.

Sub-divisions: This is also sub-divided into four sub-regions:

(i) **Chilean sub-region:** Western part of South America, Peru, Bolivia and Andes mountain range are the different parts of this region. It is not so rich in faunal content.

(ii) **Brazilian sub-region:** It covers whole of Brazil and extends up to the Panama canal. It is very rich in faunal composition.

(iii) **Mexican sub-region:** This sub-region is situated within North and South America, i.e., northern side of the Panama isthmus. It contains some important fauna.

(iv) **Antillean sub-region:** Entire West Indies except Trinidad and Tobago is included in this sub-region. Very few animal content is the characteristics of this sub-region.

Climatic condition: Most parts of this region is covered by tropical dry lands. Only southern part of America experiences temperate climate.

Ecological condition: In the Amazon valley there is tropical rain forest. Temperate region consists of Savannah and grassland. Western part of South America is dry and has desert like ecosystem. Argentina comprises mostly of grassland.

Characteristic vertebrate fauna

(i) **Fishes:** 120 genus of the three families (Polycentridae, Gymnotidae and Trigonidae) are present in this region. The prominent fishes are *Lepidosiren*, eel, catfish, etc.

(ii) **Amphibia:** *Caecilia*, *Siphonopsis*, *Hyla*, *Salamander*, frog, toad, etc.

(iii) **Reptiles:** *Dromicus*, *Boa*, *Epicrates*, *Snakes*, *Gecko*, *Alligator*, *Chelys*, etc.

(iv) **Birds:** Total 700 genus of birds are recorded in this region. Among these *rea*, *tenemus*, *screamus*, *whatgin*, to wean, *thrush*, *parakeet*.

(v) **Mammals:** Total 32 families are recorded of which *Opossum*, *Caenolestes*, *Sloth*, *Armadillo*, rodents, American tapir, bat, spider monkey, *lama*, etc. are important.

7.2.4 Ethiopian realm

Geographical boundary: It consists of southern part of the Tropic of cancer, most of the African mainland, southern part of Arabia and Madagascar.

Sub-divisions: It is also sub-divided into four sub-regions.

(i) **East African sub-region:** Hot and dry region of Africa and Arabia are included in this sub-region.

(ii) **West African sub-region:** Western part of the Ethiopian region is extended up to Kongo in this sub-region.

(iii) **South African sub-region:** Whole of the southern part of Africa is included in this sub-region.

(iv) **Malagasy:** Whole of Madagascar is included in this sub-region.

Climatic condition: Mainly temperate in most of the areas, but remains hot during most time of the year.

Ecological condition: The areas on the equinoctial line and West Africa possess rain forest along the sides of large rivers. Most of the other parts are dry deciduous forest. Northern and Southern parts of the region are transformed into desert.

Characteristic of vertebrate fauna:

(i) **Fishes:** Cat fishes, lung fishes (*Protopterus*, *Polypterus*) and several fresh water fishes are present.

(ii) **Amphibia:** *Xenopus* and several species of *caecilians* are present. The group caudata is completely absent.

(iii) **Reptiles:** Among snakes, *Leptorhynchus*, *Ramnophis*, etc.; among lizards, *Monotrophis*, *Cordylus*, *Agama*, *Chameleon*, etc. are prominent species.

(iv) **Birds:** 67 families of Aves are recorded. Some important species, are *ostrich*, *cuckoo*, *parakeet*, *eagle*, *kite*, *pigeon*, *hombill* etc.

(v) **Mammals:** The recorded families are 51 of which 15 are endemic. The remarkable species are Zebra, *Gorilla*, *Antilope*, *Leopard*, two homed *Rhinoceros*, *Hippopotamus*, *Lemur*, *Gnu*, *Beboon*, *Lion*, *Giraffe*, *Chimpanzee*, *Loxodonta* etc.

7.2.5 Oriental realm

Geographical boundary: Most of the Asian countries which are situated at the southern side of Himalaya are included in this realm. India, Burma, Indo-China, Malay, Sumatra, Java, Bali, Borneo and Filipines, etc. are within this realm.

Sub-divisions: It is composed of four sub-regions.

(i) **Indian sub-region:** From the base of Himalaya the whole of the Indian subcontinent is under this sub-region. Indian sub-region was separated on the basis of distribution of molluscs, reptiles, birds and mammals by Wallace (1876).

(ii) **Ceylonese sub-region:** Part of the Indian peninsula and Sri Lanka are covered under this sub-region.

(iii) **Indo-Chinese sub-rcgion:** South China, Burma, Thailand and Indochina fall within the border of this sub-region.

(iv) **Indo-Malayan sub-region:** This is eastern part of the oriental realm. Malay and East-Indies islands are included in this sub-region.

Climatic condition: Most part experience temperate atmosphere. Annual rainfall more than 1500 mm.

Ecological condition: Eastern part contains dense rain forest. Western part possess a desert. Other parts are having moderate forest.

Characteristic vertebrate fauna:

(i) **Fishes:** Different types of carp, catfish, notopteridae, osteoglocid, cipriniformes, etc.

(ii) **Amphibians:** Varieties of anurans, some salamanders and caecilians are present.

(iii) **Reptiles:** Various types of snakes like, *Viper*, *Pit Viper*, *Kraits*, etc.; lizards-like, *Gekko*, *Aagamid*, *Varanus*, *Chamellion*, *Crocodiles*, *Gavialis*. Platystemidae family of turtles are present.

(iv) **Birds:** *Pigeons*, *Owls*, *Finches*, *Phesants*, *Peacock*, *Saras*, etc., are present.

(v) **Mammals:** Srew, rabbit, dog, cat, boar, rodents, flying lemur, elephants, ox, tiger, orangutan, gibbon, tapir, pangolin, *Rhinoceros unicorns*, etc., are important members. Out of 30 families only 4 are endemic.

7.2.6 Australian realm

Geographical boundary: Australia, New Zealand, New Guinea, Tasmania and some islands of adjacent areas are included in this realm.

Sub-divisions: This is divided into four sub-regions.

(i) **Austro-Malayan sub-regions:** Malay archipelago including New Guinea, Moluccas and Solomon island are covering this sub-region.

(ii) **Australian sub-region:** Tasmania and Australia are the parts of this sub-region.

(iii) **Polynesian sub-region:** Polynesia and Sand-wick islands are included in this sub-region.

(iv) **New Zealand sub-region:** New Zealand, Norfolk island, Auckland, Campbell and Macquarie islands comprises this sub-region.

Climatic condition: Hot and temperate, both types of climate are present here. Average rainfall in a year is 75 mm.

Ecological condition: Rain forest, grassland, eucalyptus forest are prominent ecological characters.

Characteristic vertebrate fauna

(i) **Fishes:** *Neoceratodus* (Lung fish), *Osteoglocidos*, *Gadopcidae*, etc.

(ii) **Amphibia:** Xenorhinidae family is present in New Guinea only. *Helioporus*, *Pelodyrus* are other important members. Total 11 families are recorded.

(iii) **Reptiles:** Important snake families are Phithonidae and Elapidae: *Pizopidae*, *Apracidae*, *Liadidae* are prominent lizards. Sphenodon of Rhynchocephalidae family is the famous relict of reptiles present in New Zealand.

(iv) **Birds:** Casuary, liar bird, magpie, emu, kiwi, scrab, bawar are important members of this region. Nine hundred and six species of birds are recorded from this region.

(v) **Mammals:** *Omithorhynchus* (a marsupial), *Tachyglossus* (ant eater), Kangaroo, *Dendrolagus* (climbing kangaroo), *Petaurus* (flying opossum), wolf are the remarkable members. For simplicity in understanding you may go through the table below that describes the six zoogeographical realms in short:

Realms	Geography	Climate	Ecology	Some important vertebrates
Palaearctic	Whole of Europe, North of Africa, Asian Himalayas	Extreme cold of Siberia and hot of Sahara	Deciduous, Tundra, Coniferous and mixed forest	*Myogale*, Hyrax, Shrew, Civet, Yak, Mole, Phaco, Upupa, Pastor
Nearctic	Entire North America, Mexico, Greenland, Aleutian island	Extreme cold and hot	Deciduous, Tundra, Coniferous forest and huge grass land	Vampire, Free-tailed bat, Bison, Heloderma, Mole, Parrot, Polar bear, Rain deer
Neo-tropical	South and central America, Lower Mexico and West Indies	Tropical dry lands and temperate	Tropical rain forest, Savannah grass land and desert like	Rhea, Oil birds, Lama, Vampire bat, Armadillo, Cavis, American Monkey
Ethiopian	Southern part of Tropic of Cancer of Africa, Arabia and Madagascar	Temperate but most of the time is hot	Rain forest, Deciduous forest and desert	*Rhinoceros bicornis*, Giraffe, Zebra, Gorilla, Chimpanzee, Flying Squirrel, Ostrich, Lemur
Oriental	Most of Asia	Temperate, annual rainfall more than 1500 mm	Eastern dense rain forest, Western desert and other part with moderate forest	Sloth, Black buck, Antilope, Spring rat, Panda, Flying Lemur, Rhino, Frog, *Rhinoceros unicornis*
Australian	Australia, New Zealand, New Guinea, Tasmania	Hot to temperate, Rainfall 75 mm	Rain forest, Grassland, Eucalyptus forest	Crowned pigeon, Turtle, Emu, Kangaroo, Duckbill, Bat, Frog, Toad, Parrot, kiwi, *Sphenodon*

7.3 Theories pertaining to distribution of animals

Basically two theories explain the spreading of animals all over the globe:

7.3.1. Continental drift hypothesis

Proposed by Wagner and according to him the earth was one whole mass when it was originated, but about 135 million years ago (Cretaceous Period) the land mass fragmented in to continents. With the fragmentation of land mass animals were also distributed in their respective continents.

7.3.2 Centre of origin hypothesis:

According to this theory the individuals of a species spread out from the center of their origin because of their high reproductive capacity.

7.4 Questions

i) What is zoogeography?

ii) What are the zoogeographical realms? What is Wallace line?

iii) Describe the distribution, ecological conditions, flora and faunal characteristics of the zoogeographical realms.

iv) Write a short note on the theories pertaining to distribution of animals.

v) Discuss continental drift hypothesis.

7.5 Suggested readings

1. Basu, R.N. (2004). A Compendium of Terms in Ecology and Environment. Naya Udyog.
2. Chapman, R. L. and Reiss, M. J. (2000). Ecology - Principles & Application. Cambridge University Press.
3. Dash, M. C., (2001). Fundamental of Ecology. 2nd Ed. Tata McGraw-Hill Company.
4. Joshi, P.C. & Joshi, N. (2009). A Text Book of Ecology and Environment. Himalaya Publishing House.
5. Kormondy, E. J. (2002). Concepts of Ecology. 4th Indian Reprint, Pearson Education.
6. Krebs, C. J. (2001). Ecology. Benjamin Cummings.
7. Odum, E. P. & Barret, G. W. (2005). Fundamentals of Ecology. 5th Ed. Thompson Brooks Cole.
8. Smith, T. M. & Smith, R. L. (2006). Elements of Ecology. 6th Ed. Pearson Education.
9. Verma, P. S. & Agarwal, V. K. (1993). Environmental Biology (Principles of Ecology). 4th Ed. (Reprinted). S. Chand & Company Ltd., New Delhi-110055