UTTARAKHAND OPEN UNIVERSITY

Teenpani Bypass Road, Transport Nagar, Haldwani - 263 139

Phone No. : (05946) - 286002, 286022, 286001, 286000

Toll Free No. : 1800 180 4025

Fax No. : (05946) - 264232, email : <info@uou.ac.in>

http://www.uou.ac.in

FRN -102

Forest Ecology

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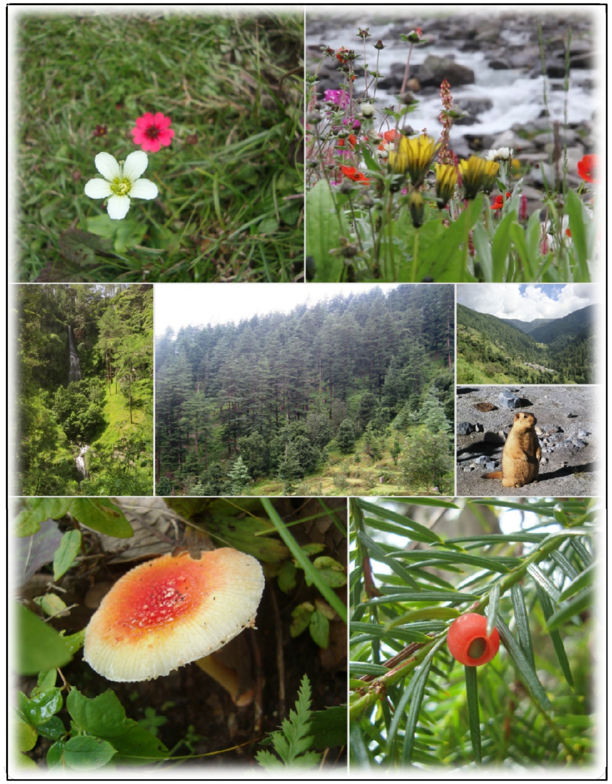

Department of Forestry and Environmental Science

School of Earth and Environmental Science

Uttarakhand Open University

Haldwani, Nainital (U.K.)

FRN – 102

Forest Ecology

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SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCE
University Road, Teenpani Bypass, Behind Transport Nagar, Haldwani - 263 139
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Toll Free No. : 1800 180 4025, Fax No. : (05946) - 264232,
e-mail: info@uou.ac.in, Website: http://www.uou.ac.in

Programme Coordinator

Dr. H.C. Joshi
Associate Professor
Department of Forestry and Environmental Science,
SoEES, Haldwani, Nainital (U.K.)

Units Written by	**Unit No.**
Adapted from different Open educational resources (OERs).	1-9
Dr. Beena Tewari Fulara, *Assistant Professor (AC),* Department of Forestry and Environmental Science, SoEES, Uttarakhand Open University, Haldwani	10,11,12,13,14

Cover Page Design and Format Editing

Dr. Krishna Kumar Tamta, Dr. H.C. Joshi,
Dr. Beena Tewari Fulara, and Dr. Neha Tiwari
Department of Forestry and Environmental Science, SoEES, Uttarakhand Open University, Haldwani

Title	:	Forest Ecology (FRN-102)
ISBN	:	XXXX-XXXX
Copyright	:	Uttarakhand Open University
Edition	:	2024 **(Restricted Distribution)**
Published By	:	Uttarakhand Open University, Haldwani, Nainital – 263139
Printed at	:	

Table of Contents

Unit 1: Definitions and Basic Concepts of Ecology

Unit Structure

1.0 Learning Objectives

After completing this unit you shall be able to:

- Discuss the basic concept of ecology
- Define ecology
- Discuss types of ecology
- Explain the significance of ecological studies
- Discuss the concepts of habitat and ecological niche

1.2 Introduction

Ecology is mainly concerned with the biological connections and processes of organisms, land, water etc. It can be referred as the scientific study of the interactions that determine the distribution and abundance of organism. The term ecology (oekologie) is derived from two Greek words "oikos" means 'house ` or place of live` and-logos means 'a discussion or study` Ecology is the study of organism at home in their native environment. The term was first of all introduced by Reiter in 1868, but because the German biologist Ernst Haeckel (1869) first of all fully defined ecology as the study of reciprocal relations between organism and environment.

Ecology is divided into the two main divisions:

1. Autecology: It is also called species ecology. It is concerned with the study of individual organism or the population of individual animals or plant species in relation to environment.

2. Synecology: The branch of ecology that studies about the relationship of various groups organism to their common environment.

1.3 Basic Concept of Ecology

The four basic concepts of ecology are Holism, ecosystem, succession, and conservation.

Holism

Ecology as a basic division of biology attempts to define and explain patterns within and among organisms, at each level of organization. The hierarchical levels at which we discus interacting units of ecology are, individual < population < community < ecosystem < biome < Biosphere. Each level of organization has characteristics peculiar to it that are not identifiable at the levels below. Each unit is a whole built up by the interactions of lower level wholes into a higher level whole in this kind of Hierarchy Williams Ophuls (1974) considered holism as the real base of ecology. It focuses on the system paradigm of interrelationships.

The term holism (from Greek word holon, meaning entity) was coined by the south African statesman, Jan Christian Smuts in his book Holism and evolution in 1926 to explain the process of evolution by the coming together of lesser wholes in order to create the universe.

Holism or the Holistic philosophy as one of the basic concepts of ecology explains the characteristics of units at successive higher level of organization of organisms.

Ecosystem

The concept of Ecosystem was first formulated by A.G.Tensley in 1935.An ecosystem is the whole biotic community in a given area plus its abiotic environment. It therefore includes the physical and chemical nature of the sediments, water and gases as well as all the organisms. Ecosystem ecology emphasizes the movements of energy and nutrients (chemical elements) among the biotic and abiotic components of ecosystem.

The biotic components of any ecosystem are linked as food chains. Food chains are interlinked to form complex food webs. Food webs are the basic units of ecosystem ecology. Thus ecology begins with populations and culminates in ecosystems. Food webs are basic units of ecosystem ecology the ecology begins with population and culminate in ecosystems Food webs are basic unit since it is around then that energy and nutrients transfers take place.

Succession

All living organisms and their environment are mutually reactive, affecting each other in various ways. Animal population, flora, and vegetation are interdependent through the environment and are mutually reactive.

Under natural condition, different kinds of population undergo succession. Ecosystems undergo an orderly process of change with time, passing from a less complex to a more complex state. This process involves not only change in species composition but also changes in the physical environment of a community. The terminal or stabilized state is known as climax.

Succession is thus an ecological phenomenon of replacement of an earlier ecosystem by a higher biomass-rich and tropically- diversified ecosystem. It is usually a longer term process taking centuries for a time-series procession of more resistant system of producer, consumer and decomposer organisms resulting into a stable system accompanying biotically transformed terrain or habit under a given climate.

1.3.1 Concept of Ecology

The world in which we live consists of living organisms and non-living structures. Often, relationships between organisms or between organisms and non-living structure are clearly visible. The science of ecology in its pure form studies the relationships of organisms with their environment. “Organisms” means all living entitles; this definition excludes relationships between non-living entities as a possible objects of study for ecology.

The term “environment” is meant in the sense of “the surrounding world,” i.e., all

entities, living or not, which surround a living entity.

Ecology is divided into the two main divisions:

Autecology: Autecology deals with the study of the individual organism or an individual species. It is also called species ecology. It is concerned with the study of individual organism or the population of individual animals or plant species in relation to environment.

Synecology: Synecology is the study of inter-relationship of the organisms, such as populations, biotic communities and ecosystem and ecosystems and there environment, which are associated together as unit (i.e., community).It can be differentiated into 5 types which are:

1. Organism (physiological and behavioral ecology): organism forms a basic unit of study in ecology. At the level of organism, we know to understand the form, physiology and behaviour, distribution and adaptations in relation to the environmental conditions.

2. Population Ecology: Population ecology is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study of how the population sizes of species change over time and space. The term population ecology is often used interchangeably with population biology or population dynamics.

A population is a group of interacting organisms of the same species, and contains stages: pre-reproductive juveniles and reproductive adults. Most populations have a mix of young and old individuals, and characterizing the numbers of individuals of each age or stage indicates the **demographic structure** of the population. In addition to demographic structure, populations vary in the number of individuals in the group, called **population size**, and how densely packed together those individuals are, called **population density**. A population’s **geographic range** has limits, or bounds, established by the encroachment of other species, by the physical limits that the organisms can tolerated, such as temperature or aridity.

3. Community Ecology: Community ecology is the study of the interactions between population and coexisting species. Community is made up of populations of different species, or animals, plants, fungi, and bacteria, living in the same area.

4. Ecosystem Ecology: Ecosystem ecology is the combined study of the physical and biological components of ecosystem. It focuses on how matter and energy flow through both organisms and the abiotic components of the environment.

Ecosystem ecology is the integrated study of living (biotic) and non-living (abiotic) components of ecosystems and their interactions within an ecosystem framework. This science examines how ecosystems work and relates this to their components such as chemicals, bedrock, soil, plants, and animal

5. Global ecology: A landscape is a unit of land with a natural boundary having a mosaic of patches. These patches generally represent different ecosystem. Global ecology is the study of the interactions among the Earth's ecosystems, land, atmosphere and oceans. Global ecology is very important because it is used to understand large scale interactions and how they influence the behavior of the entire planet, including the earth's responses to future changes.

1.3.2 Definition of Ecology

Ecology has been defined variously by different classical and modern ecologists with different viewpoints. The traditional definition of ecology is '*the study of an organism and its environment*` however, different ecologists have defined it variously.

Ernst Haeckel (1869): defined ecology as '*the total relation of the animal to both its organic and its inorganic environment*.

Taylor (1936) defined ecology as '*the science of all the relations of all organisms to all their environments.*

Charles Elton (1947) in his pioneer book Animal Ecology defined ecology as '*scientific natural history*.

Alleeet *all.*1949: Ecology may be defined broadly as '*the science of the inter-relation between living organism and their environments, including both the physical and biotic environments, and emphasizing interspecies as well as intra-species relations.*

G.L Clarke (1954): defined ecology as '*the study of inter-relations of plants and animals with their environment which may include the influences of other plants and animals present as well as those of the physical features'.*

Woodbury (1953): regarded ecology as 'the science which investigates organisms in relation to their environment: a philosophy in which the world of life is interpreted in terms of natural processes.'

Clarke (1954): Ecology is the study of inter-relations of plants and animals with their environment.

Kendeigh (1961): It is the study of animals and plants in their relations to each other and to their environment.

Odum (1963): Ecology is the study of the structure and function of nature.

Misra (1970): In a broad sence, ecology is the study of ecosystems.

C.J.Krebs: Ecology is the scientific study of the interactions that determine the distribution and abundance of organism.

1.3.3 Types of Ecology

1) Habitat ecology-It deals with the study of different habitats of the biosphere. According to the kind of habitat, ecology is subdivided into marine ecology, freshwater ecology, and terrestrial ecology. The terrestrial ecology too is further subdivided into forest ecology, cropland ecology, grassland ecology, etc.

2) Ecosystem ecology-It deals with the analysis of ecosystem from structural and functional point of view including the interrelationship of physical (abiotic) and biological (biotic) components of environment.

3) Community ecology–It deals with the study of the local distribution of animals in various habitats, the recognition and com-position of community units, and succession.

4) Conservation ecology- It deals with methods of proper management of natural resources such as land, water, forests, sea, mines, etc., for the benefit of human beings.

5) Production ecology- It is the modern subdivision of ecology which deals with the gross and net production of different ecosystems such as freshwater, sea water, crop-fields and tries to do proper management of these ecosystems so that maximum yield can be obtained from them.

6) Radiation ecology- It deals with the study of gross effects of radiations and radioactive substances over the environment and living organisms.

7) Taxonomic ecology- it is concerned with the ecology of different taxonomic groups and eventually includes sub division of ecology – plant ecology, insect ecology, invertebrate ecology, vertebrate ecology, microbial ecology and so on.

8) Human ecology-It deals with the study of relationship of man with his environment.

9) Space ecology- It is a modern subdivision of ecology which remains concerned with the development of partially or completely regenerating ecosystems for supporting life of man during long space flights or during extend exploration environments.

10) System ecology- The system ecology is the most modern branch of ecology which is concerned with the analysis and understanding of the function and structure of ecosystem by the use of applied mathematics such as advanced statistical techniques, mathematical models and computer science.

11) Palaeoecology- It is the study of environmental conditions, and life of the past ages, to which palynology, paleontology, and radioactive dating methods have made significant contribution.

12) Applied ecology- It deals with the application of ecological concepts to human needs and thus, it includes following applications of ecology: wild-life management, range management, forestry, conservation, insect control, epidemiology, animal husbandry, aquaculture, agriculture, horticulture, land use and pollution ecology.

13) Fire ecology- Studies the role of wild land fire in the environment (i.e, how it affects ecosystem processes, etc) and causes for these fires. Some species are fire-adapted while some are fire-dependent and require fire for part of their life cycle. The latter are pyrophytic plants. For instance, lodgepole pine requires the heat of fire to melt the resin on its cone, opening it up and disbursing its seeds. At my undergraduate institution (Humboldt State University) they had a fire lab to study fire ecology.

1.3.4 Significance of Ecology

Ecology is about the interactions between organisms, their habitat (home) in nature. And we are all part of the ecosystem, dependent on it for our survival, since in many ways we are just one more species. But we are also in the unique situation that we can change the ecosystem in many different ways. And understanding what all the effects of changing an ecosystem will be, is important in order to avoid our actions having unintended consequences (like the famine in the Sahel region of Africa being largely because of human changes to the ecosystem). But that is just the part of ecology that has direct consequences for us as humans.

If we want to conserve and protect nature in general and prevent the extinction of species, we need to know how they all fit together, what their habitat requirements are, how they influence each other, what the minimum population sizes are to ensure their survival, etc. So both for managing natural areas, as well as the sustainability of agriculture and our own continuous survival as a species, ecology is important. In the end, without a good knowledge of ecology, all the other fields of study will be useless… an extinct human species will no longer do any science at all.

1.4 Basic Concepts of Habitat

Habitat approach to nature is very important, as it aims to study organisms and non-living thing factors operating there. Thus we become well acquainted with organisms as they grow in different kinds of habitats in nature. Such an approach is mainly descriptive when we describe the environmental conditions and organisms present in different type of habitat. There are four major types of habitats in the biosphere- freshwater, marine, estuarine, and terrestrial. The terrestrial ecology too further subdivided into forest ecology, cropland ecology, grassland ecology, etc.

1.4.1 Fresh water Habitats

Fresh water habitats occupy a relatively small portion of earth's surface as compared to marine and terrestrial habitats. But the fresh water habitats are much importance to mankind. Such habitats are of two general types:

i) Standing water or (Lentic ecosystem) - Lentic habitats are represented by the ponds, lake swamps, bog etc.

ii) Running water or (lotic ecosystem)- Lotic habitats are those existing in relatively fast running streams, springs, rivers.

The classification of the freshwater environments is based on two conditions: currents and the ratio of the depth to surface area. However, temperature, light, currents, amount of respiratory gases, and concentration of biogenic salts are important limiting factors influencing the organisms of all freshwater.

Temperature in freshwater habitats does not show much range of variations, which is due to several unique thermal properties of water. Although temperature in such habitats shows less variations, it is a major limiting factor in distribution of organisms, as aquatic organisms generally have narrow tolerances i.e. are stenothermal. Temperature of water is measured with the instrument, thermistor. Turbidity of water depends upon the kind and amount of suspended materials, chiefly as silt clay particles and living organisms etc. Turbidity affects the penetration of light (transparency), and thus is important limiting factor in the distribution of organisms.

Transparency (that is directly related to turbidity) of water is generally measured with a very simple instrument called a secchi disk. Current action water, especially in streams, has direct very important effect on the organisms. The current generally affect the distribution of vital gases, salts, and small organisms. Concentrations of respiratory gases O_2 and CO_2 is often limiting factor in such habitats. Their concentration is measured in the terms of D.O.- dissolved oxygen, and B.O.D.-biological oxygen demand etc.

Lentic Community: Lentic waters are generally divided into three zones or sub-habitats: littoral, limnetic, and pro fungal. A small pond may consist entirely of littoral zone.

However, a deep lake with an abruptly sloping basin may possess an extremely reduced littoral zone.

Lake Zonation: The three major zones of a lake described as follows:

(a) Littoral zone: The littoral zone adjoins the shore (and is thus the home of rooted plants) and extends down to a point called the light compensation level, or the depth at which the rate of photosynthesis equals the rate of respiration. Within the littoral zone producers are of two main types: rooted or benthic plants, and phytoplankton (plant plankton) or floating green plants, which are mostly algae.

The littoral zone is the home of greater variety of consumers than are the other zones. The zooplankton (animal plankton) of the littoral zone is rather characteristic anddiffers from that of the limnetic zone in preponderance of heavier, less buoyant crustacean which often cling to plants or rest on the bottom when not actively moving their appendages. Important groups of littoral zooplankton are large, weak-swimming species of Daphnia and Simocephalus, some species of copepods, many families of ostracods and some rotifers.

The nekton of littoral zone is often rich in species and numbers. Adult and larval diving beetles and various adult Hemipetra are conspicuous. Various Diptera larvae and pupae remain suspended in

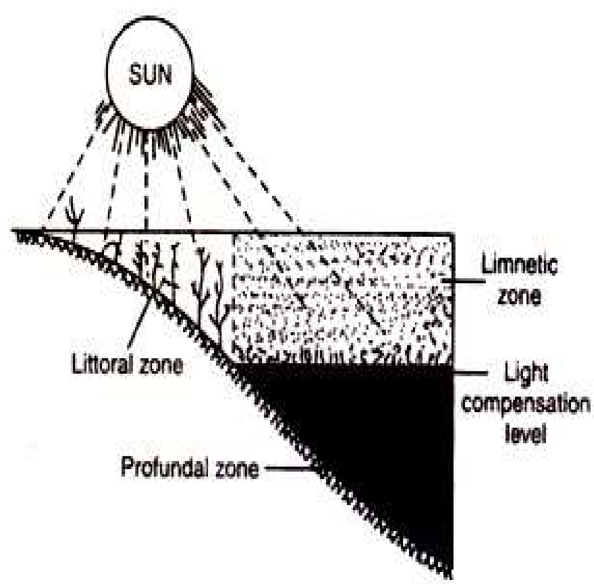

Fig: 1.1 Three Major zones of fresh water lake

the water, often near the surface. Pond fish, frogs, turtles, and water snakes are almost exclusively the members of the littoral zone community. Tadpoles of the frogs are important primary consumers, feeding on algae and other plant material.

Periphyton of the littoral zone exhibits a zonation paralleling that of the rooted plants, but many species occur almost throughout the littoral zone. Among the periphyton forms, for example, pond snails, damselfly nymphs and climbing dragonfly nymphs, rotifers, flatworms, bryozoa, hydra, and midge larvae rest on, or are attached to stems and leaves of the plants.

Another group containing both primary and secondary consumers may be found resting or moving on the bottom or beneath silt or plant debris— for example, sprawling odonata nymphs (which have flattened rather than cylindrical bodies), crayfish, isopods, and certain mayfly nymphs. Descending more deeply into the bottom mud are burrowing odonata and ephemeroptera, clams, true worms, snails, chironomids (midges), and other diptera larvae.

(b) Limnetic Zone: The limnetic zone includes all the waters beyond the littoral zone and down to the light compensation level. The limnetic zone derives its oxygen content from the photosynthetic activity of phytoplankton and from the atmosphere immediately over the lake's surface. The atmospheric source of oxygen becomes significant primarily when there is some surface disturbance of water caused by wind action or human activity. The community of the limnetic zone is composed only of plankton, nekton, and sometimes neuston (organisms resting or swimming on the surface).

Phytoplankton producers consist of diatoms, green algae, blue- green algae, and algae- like green flagellates, chiefly the dinoflagellates. The limnetic zooplankton consists of few species but the number of individuals may be large. Copepods, cladocerans, and rotifers are generally of first importance; but their species are largely different from those found in the littoral zone. The limnetic nekton consists almost entirely offish. In ponds, the fish of the limnetic zone are the same as those of the littoral zone, but in large bodies of water a few species may be restricted to the limnetic zone.

(C) Profundal Zone: The bottom and deep water area of a lake, which is beyond the depth of effective light penetration, is called the profundal zone. In north-temperate latitudes, where winters are long and severe, this zone has the warmest water (4°C) in the lake in winter and coldest water in summer.

The major community consists of bacteria and fungi and three groups of animal consumers:

(a) Blood worms, or hemoglobin containing chironomid larvae and annelids

(b) Small clams

(c) Phantom larvae, or Chaoborus (corethra)

The first two groups are benthic forms, the last are plankton that regularly move up into the limnetic zone at night and down to the bottom during the day. All the animals of the profundal zone are adapted to withstand periods of low oxygen concentration, whereas many bacteria are anaerobic. Large numbers of bacteria in the bottom ooze constantly bring about decomposition of the organic matter (plant debris, animal remains, and excreta) that accumulates on the bottom.

Eventually the organic sediments are mineralized and nitrogen and phosphorus are put back into circulation in the form of soluble salts. In this way, the profundal zone provides rejuvenated nutrients, which are carried by currents and swimming animals to other zones.

1.4.2 Marine Habitats

The marine habitat is the largest of all habitats. The seas, oceans and bays have occupied about 70% of the earth’s surface. The physical features of the marine habitat are relatively stable. All oceans are interconnected .Temperature salinity, and depths are the chief barriers to free movements of marine organisms.

In marine habitat, the most important physical factors as light, temperature, pressure, salinity, tides and currents.

Light: Light acts as a very important factor in the life of marine organisms due to its connection with photosynthesis, heating, radiation and vision. It is the amount of light available that determines plant life and in turn affects animal life. Penetration of light is affected by the angle of light rays. Only perpendicular rays reach deeper while slanting rays are reflected. Loss of light by reflection is about 10% and it is only the rest that penetrates.

Light determines diurnal migration of marine organisms. It also regulates color pattern of marine animals. Deep sea fauna exhibit either colorlessness or uniform coloration. It is also related with the development of visual sense organs.

Temperature: Ocean is the largest store house of the sun’s heat and it occupies much space. Stored heat of the ocean is able to regulate the temperature of the world. Thus it also regulates the terrestrial life. Large amounts of heat reserved by the sea are lost by evaporation and these vapors are condensed over the land masses. Likewise the various tributaries of rivers and streams that merge with the sea cause a variation in the temperature of the oceans.

Temperature gradually drops in seas as depth increases. At certain intermediate depths the fall in temperature exceeds that of the surface waters and deeper water. This is called thermocline and is supposed to occur between 50 and 150 meters depth. Life in the seas has been considerably influenced in the course of evolution by the thermal variation.

Pressure: Pressure in the ocean varies from one atmosphere at the surface to 1,000 atmospheres at the greatest depth. Pressure changes are many times greater in the sea than in terrestrial environments and have a pronounce defect on the distribution of life in seas.

Certain organisms are restricted to surface waters where the pressure is not so great, whereas certain organisms are adapted to live at great depths. Some marine organisms like sperm-whale and certain seals can dive to great depths and return to surface without difficulty.

Animals that have a great vertical range in the sea are called eurybathic like many pelycypods. *Natica* extends between 35-225 meters. On the hand animals which are limited to a narrow range of depth are called stenobathic animals. The fish Chimarea and the sanil Turris are Setnobathic.

Salinity: Salinity of sea water varies from place to place depending on the amount of inflow of fresh water rivers or melting glaciers or the amount that is concentrated by evaporation.

Salinity of the open ocean at about 300 meters depth is about 3.5%. The salinity in the Mediterranean is 3.95%, while in the Red sea it is 4.6%. Salinity of the sea is due to two elements, sodium and chlorine which account for 80% of the salts in sea. In the sea water cations and the anions are not balanced against each other. As a result sea water is weakly alkaline (pH 8 to 8.3) and strongly buffered. This factor is of much biological significant.

Animals absorb and utilize many substances like Ca, K, Na ,Mg, S, CI etc. they also use in many inorganic materials like Na, Mg, Ca and silica acid to build their bodies. A few animals even use and store rare elements. Strontium sulphate is utilized by some radiolarians. Bromine and iodine are stored by horny corals and vanadium by Ascidians.

1.4.3 Estuarine Habitats

Estuarine or Brackish zone is formed in those regions where a river meets a sea. The composition of water in this zone undergoes constant change. The concentration of dissolved substances in such habitats is unstable. At high tides such habitats experience maximum salinity. Salinity decreases during low tide and periods of heavy rain.

The rate of flow of the water or current varies greatly in different estuaries, also in various regions of any one. The constant turnover in the water of estuaries brings about considerable changes in temperature of comparatively short duration. Thus the conditions prevailing in different estuaries vary greatly depending upon topography and other factors.

1.4.4Terrestrial Habitats

Of the three major types of habitats, terrestrial habitat is the most variable. In altitude it ranges from below sea-level (Death-valley) to mountain peaks more than 28,000 feet in height. A considerable variation of temperature is encountered in terrestrial habitat.

The lowest recorded temperature is —60°C and the highest recorded temperature is 60°C in certain deserts. The chemical and physical nature of the soil, sand and surface rocks varies greatly. The amount of moisture or relative humidity and rate of precipitation are extremely variable in different- regions of the globe.

The major subdivisions of the terrestrial habitat are given below:

i) Tundra: The arctic region of North America, Europe and Asia is known as Tundra region. This treeless region is characterized by long-cold winter with no or little sunlight. The summer is cool, short and is with long daylight hours. Frosting is very common and may appear at any time in this region.

Soil is never thawed beyond a depth of few inches from the surface. Bogs, marshes and ponds are the common features of this region. Mosses, Lichens and low herbs are the common vegetation. Migrant birds, like water fowls make their summer nesting grounds in the region.

Resident birds of North America are Snowy owls and Ptarmigan. Amongst the mammals, Lemmings, Arctic hares, Arctic foxes, Caribou, Musk-oxen and Weasels live in this region.

The alpine community on the top of many high mountains of both temperate and tropical region resembles the tundra biomes in many respects. The plant and animal species of tundra and alpine regions are almost identical.

(ii) Taiga: The broad band just south of the tundra region of Eurasia and North America is known as taiga region. The taiga region in the southern hemisphere is poorly developed because of the absence of land mass. The region bears evergreen coniferous forests.

Climatic condition of this region is represented by bleak winter and cool summer. Precipitation is of moderate type. The summer lasts from three to six months. Red foxes, Lynx, Caribou, few reptiles and birds are found here. Spruce, Firs, Pines and Cedars are the common vegetation.

(iii) Temperate deciduous forest: This region is characterized by warm summer and cold winter. There is about 40 inches of rainfall throughout the year and the rainfall is uniform throughout the year. The dominant trees of this region bear broad leaves. The leaves are shed in summer and new leaves develop in the following spring.

Beech, Maples, Oaks, Walnuts are the common plants of this region. Deer, Gray foxes, Racoons, flying squirrels, many snakes and amphibia are the major vertebrates present in this region.

(iv) Grass lands: Large areas in both temperate and tropical regions do not support trees but remain covered with heavy growth of grass. This is because of lack of sufficient moisture. All the grass lands are ecologically similar in appearance.

These grass lands are also known as Steppes, Prairies, and Savannas etc. The rainfall in these regions is usually 12 to 40 inches per year. The rainfall is limited to few weeks in the year. Dominant plants of this region are Blue stem and Grama grasses. Characteristic grass land vertebrates are Bison, Pronghorn antelope, Coyotes, Prairie dogs, Rabbits, Larks, several snakes and lizards.

v) Deserts: Deserts occur both in temperate and tropical regions. Precipitation of moisture is the controlling factor in all deserts. The average rainfall in a desert is less than 10 inches per year and that too is very erratic with half or more than half of the annual rainfall occurring in one or two heavy downpour. Summer temperature is very high. The rate of evaporation too is very high.

The plants of the deserts are highly modified for the purpose of conservation of water. The leaves are reduced or absent or modified into thorns. The roots are long and go deep inside the soil. Many plants possess internally spongy tissue collect and store water obtained during rainy season.

Cacti, Yucca are the dominant plants. Kangaroo, rats, Foxes, Coyotes, many lizards, several snakes and toads are the common vertebrates present in the desert.

Deserts may be snowy too. The sage brush area of North America and the Sierra-Cascade mountain system are deserts of this type. The climate in these deserts is very dry. The deserts are hot in summer and cool in winter. Pronghorn antelope, Coyote, ground squirrels and many reptiles are found in these snowy deserts.

vi) Rain forests: Abundant rainfall in the tropics, subtropics and few regions in the temperate zone results in the formation of luxuriant vegetation of broad-leaved ever-green trees. Vines, Orchids and Epiphytes are plentiful in these regions. Characteristic vertebrates of these regions are: Monkeys, Sloths, Ant -eaters, Bats, many colourfull birds, frogs and salamanders, turtles and snakes.

A close similarity between terrestrial zonation and the zonations in mountains of high altitude is found. The zonation in a high mountain consists of a number of vegetational belts located various altitudes along a mountain slope. Temperature and rainfall play a role on the distribution of these vegetational belts. In a high mountain temperature decreases correspondingly at higher altitudes and thus produces communities of both animals and plants located along the slopes similar to more spacious biomes that occupy large areas within certain latitudes from the equator to the poles

1.5 Ecological Niche

An ecological niche is the role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment. Biotic factors are living things, while abiotic factors are nonliving things. It is advantageous for a species to occupy a unique niche in an ecosystem because it reduces the amount of competition for resources that species will encounter.

Summary

Ecology is a multidisciplinary science. Because of it focused on higher levels of the organization of life on earth and the interrelationship between organisms and their environment. Habitat is the natural abode or locality of an animal, plant or person. It includes all features of the environment in a given locality.

Adaptation: any feature of an organism that substantially improves its ability to survive and leave more offspring. Also, the process of a species' or a population's genetic variability changing due to natural selection in a manner that improves its viability.

Community: an integrated group of living organisms inhabiting a given part of an ecosystem.

Ecosystem: is a dynamic complex of plant, animal and microorganism communities and their abiotic environment, all interacting as a functional unit

Primary Production – The process of converting inorganic energy, suchasSun light, into biological energy, usually glucose.

Niche –A role or position that a creature can role within an ecosystem.

Nutrient cycling –The process through which different elements pass from organism to organism, and are used in different ways or returned to the environment.

Biosphere –The sum of all ecosystems on the planet, acting as one ecosystem.

Population- a group of individuals with common ancestry thatis much more likely to mate with one another than with individuals from another such group.

Organism-an individual plant or animal.

Habitat- the natural environment in which an organism normally lives.

1.7 Self-Assessment Question

1. Write short account of basic concepts of ecology.
2. Define the term ecology?
3. Write short notes on:

   1) Autecology 2) Synecology 3) Population ecology
4. What is the importance of the study of ecology?
5. Describe various kinds of lake and pond.
6. Write the difference on fresh water habitats and marine water habitats.
7. Write a note on Rain forest and Desert forest.
8. Write an essay on Terrestrial ecology.

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Unit 2: Ecosystem and its Structure

Unit Structure

2.0 Learning Objectives

After completing this unit you shall be able to:

- Define ecosystem
- Discuss the types of ecosystems
- Discuss the structure of an ecosystem
- Discuss the important ecosystems

2.2 Introduction

An ecosystem is defined as, "natural functional ecological unit comprising of living organism and their non-living environment that interact to form a stable self supporting system".

The term ecology was coined by Earnst Hackel in 1869 and derived from two Greek words "oikos" meaning house, habitation or place of living and "logos" meaning study.

Ecosystem is a collection of living and non-living entities, all biotic and abiotic organisms are inter dependent on each other for their survival i.e. living organisms cannot live isolated from their non-living environment because the later provides material and energy for the survival of the former. Natural ecosystem has evolved over millions of years manifesting a wide variety of life forms with complimentary interaction and dynamic equilibrium. Human being has manipulated the environment for his gain these manipulation has brought large changes in the ecosystem. It has deviated from natural trends and is losing the equilibrium through evolution and test of time. So, any interruption in the function of any of the factor may imbalance the ecosystem. So there must be a constant interaction between both of them to maintain the stability of ecosystem. Plants, animals and human beings live in association with a wide variety of other plants and animals. These communities of organisms are not only a collections of individuals or populations but they represent a highly ordered dynamic and complex organization. Such complex natural organization with their living and non-living an environment that controls them and from which the living organisms derive their sustenance are technically called as "ecosystem" or an "ecological system".

The interaction between living organisms and their environment is very much a two way process: organisms affect and are in turn affected by their surroundings. Professor A. Tansley, a British botanist, in 1935 proposed the term ecosystem and defined it as the "system resulting from the integration of all living and non-living factors of the environment". He regarded ecosystem as not only the organism complex but also the whole complex of physical factors forming the environment.

The concept of this interacting system has proved extremely valuable and the ecosystem is regarded as a basic unit for ecological studies.

2.3 Types Ecosystem

The kind of organism which can live in a particular ecosystem depends upon their physical and metabolic adaptations to the environment of that place of ecosystem and on certain aspects of the history of our planet, which has determined what organisms have been able to travel where. On earth, there are sets of ecosystems within a geographical region which are exposed to same climatic conditions and having dominant species with a similar life cycle, climatic adaptations and physical structure. This set of ecosystem is called Biome. In the biosphere, there are natural and artificial biomes (ecosystem).

1) Natural ecosystem (Biomes): Natural ecosystems operate by themselves under natural conditions without any interference by man. Natural ecosystems carry out many public service functions for us. Waste water from houses and industries is often converted to drinkable water by filtration through natural ecosystems, such as soil. Air pollutants from industries and automobiles are often trap on leaves or converted to harmless compound by forests. On the basis of particular type of habitat, they are further sub-divided as

a) Terrestrial Biomes: They are often classified by the vegetation type that dominates the community. The types of vegetation affect the climate and soil structure and that characterize the particular biome. Terrestrial vegetation has a rapid exchange of oxygen, water and carbon dioxide. The carbon dioxide concentration is affected by terrestrial vegetation seasonally and annually. Terrestrial biomes include tropical rain forests, grassland, deserts, cultivated land, etc.

b) Aquatic biomes: They fall into two categories, Fresh water and Marine. Fresh water biomes may be lotic (running water) such as streams, rivers and springs, or lentic (standing water)such as lakes, ponds and swamps, whereas, marine biomes include deep Sea and Oceans.

2) Artificial Ecosystem: They are maintained artificially by man. A pond constructed as a part of a waste water treatment plant is an example of artificial ecosystem, the management can vary over a wide range of actions. Agriculture can be thought of as partial management of certain kind of ecosystem. Here, natural balance is distributed regularly by addition of energy and panned manipulation. For e.g. Wheat maize and rice- fields etc, where man tries to control the biotic community as well as the physiochemical environment. The smallest artificial ecosystem that has been non to sustain a life over long period of time is 'Folsom bottles'. These materially closed ecosystems were created by Professor Claire Folsom of university of Hawaii by placing water algae, bacteria and sediment from Honolulu bay in a liter flask and sealing the top. The sealed bottles were placed near the window so that some energy is utilized by the biotic components during day time. Some of these have sustained life for nearly twenty years.

2.3.1 Types of ecosystem based on energy resources

Ecosystems are based on two major source of energy, the sun and chemical or nuclear fuels. So, on the basis of the major input, there can be solar powered and fuel powered ecosystems. On the basis of energy resources, the ecosystems are classified as:

1) Unsubsidized natural solar powered ecosystem: In these types of ecosystem, the only source of power/energy is solar energy. For e.g.: ocean, upland forest, grasslands etc.

These are unsubsidized in the sense that there is no auxiliary source of energy available to supplement solar radiation/energy.

2) Naturally subsidized solar powered ecosystem: In these types of ecosystems the main source of energy is sun, which is originated by natural non solar energy. As a result of which extra amount of energy is available to the system that can be used for the production of more organic matter that may be exported to other systems or stored in themselves. The auxiliary natural source of energy may be tides, waves and currents, wind, torrential rains etc.

3) Man subsidized solar powered ecosystem: In these types of ecosystems auxiliary fuels or other energy, like man and machine labor, is supplied by man. Here again, the main source of energy is sun. Examples of these types of ecosystems are agriculture and aquaculture. The power/energy input by man may be in the form of fertilizers, animal power, machine power, sprays etc.

4) Fuel powered ecosystems: In these ecosystems, the sun energy is replaced by highly concentrated potential energy of fuel, chemical or nuclear fuel. Examples of these systems are cities, suburds, industrial parks, etc. these systems are man's wealth generating and also pollution generating systems. In this system there is no limit of energy input.

2.4 Structure of Ecosystem

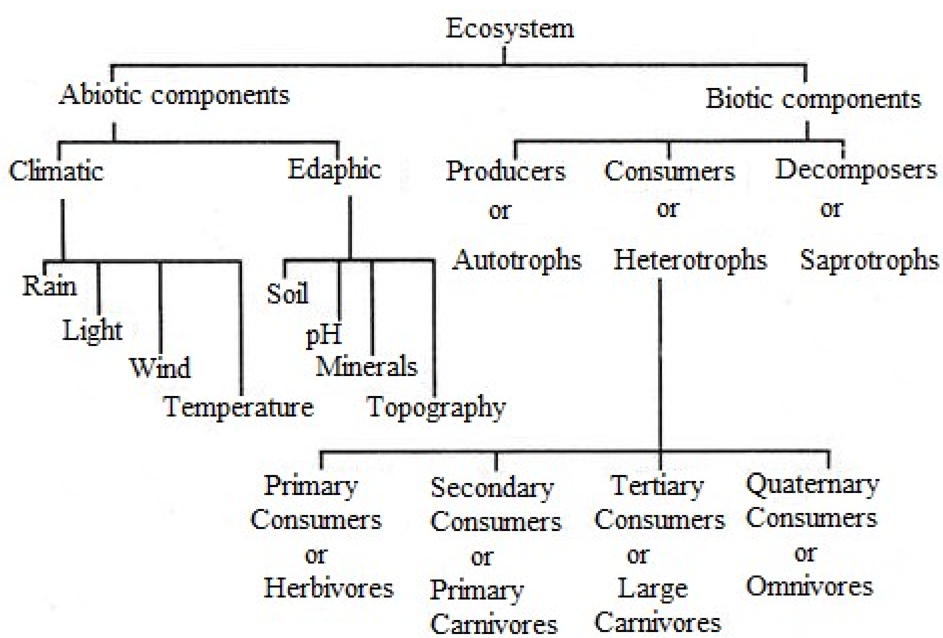
The structure of an ecosystem is basically a description of the organisms and physical features of environment including the amount of description of nutrients in a particular habitat. It also provides information regardingthe range of climatic conditions prevailing in the area.

Each ecosystem has two main components:

1. Abiotic components: The nonliving factory or the physical environment prevailing in an ecosystem from the abiotic components. They have a strong influence on the structure, distribution, behavior and inter-relationship of organisms. Abiotic components are mainly of two types - Climatic factors and edaphic factors

The functions of important factors in abiotic components are given below:

Soils are much more complex than simple sediments, they contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic matter, and living organism, soils provide nutrition's, water, a none and a structural organism medium for fragments and organisms. The vegetation found growing on top of a soil is closely linked to this component of an ecosystem through nutrient cycling. The atmosphere provides organism found within ecosystem with carbon dioxide for



photosynthesis and oxygen for respiration. The process of evaporation transpiration and precipitation cycle water b/w the atmosphere and the earth surface.

2) Biotic components: The living organisms including plants animals and microorganisms (bacteria and fungi) that are present in an ecosystem from the biotic components. On the basis of their role in the ecosystem the biotic component can be classified into three main groups

A. Producers: The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrate using simple inorganic compounds using namely water and carbon dioxide. This process is known as photosynthesis as the green plants manufactures their own food they are also known as autotrops. (i.e. auto= self, trophos= feeder).

The chemical energy stored by the producer is utilized partially by the producer for their own growth and survival and the remaining is stored in the plants parts for their future use.

B. Consumers: The animal lack chlorophyll and are unable to synthesis their own food. Therefore, they depend on the producers for their food. They are known as hetrotrops. (i.e. htros= other, trophos= feeder). The consumers are of four types, namely

i. Primary consumers or first order consumer or herbivores: these are the animal which feed on plants are the producers, they are called herbivores. Examples are rabbit, deer, goat etc.

ii. Secondary consumer or second order consumer or primary carnivores: the animal which feed on the herbivores is called the primary carnivores. Examples are cats, foxes, snakes etc.

iii. Tertiary consumers or third order consumers: these are large carnivores which feed on secondary consumers. Examples are wolves etc.

iv. Quaternary consumer or forth order consumer or omnivores: these are the largest carnivores which feed on the tertiary consumers and are not eaten by the any other animals. Examples are lions, tigers, etc.

C. Decomposers or reducers: Bacteria and fungi belong to this group. They break down the dead organic materials of producers (plants) and consumer (animals). For their food and release to the environment. The simple organic and inorganic substances produced as byproducts of their metabolisms. These simple substances are reused by the producers resulting in the cyclic exchange of materials b/w the biotic community and abiotic environment of ecosystem. The decomposers are known as saprotrophos (i.e. sparos= roftn, trophos= feeder).

2.5 Major Ecosystem

2.5.1 Freshwater Ecosystem

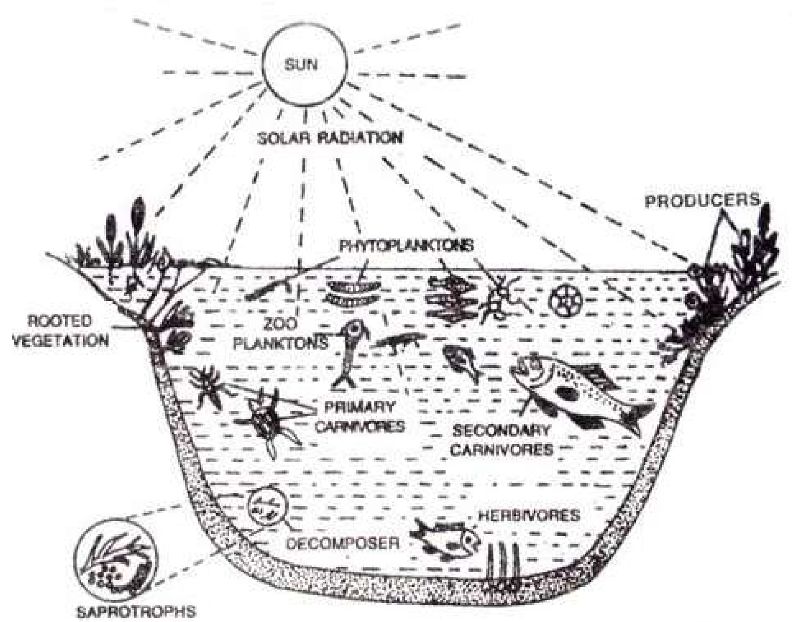
The freshwater pond represents a complete self-maintaining and self-regulating ecosystem. The pond can be defined as a body of shallow standing water characterized by relatively quiet water and abundant vegetation with thousands of micro-organism, large plant and animal. In the pond ecosystem all the four basic unit of an ecosystem are well represented these are:

A) **Abiotic substances:** These are non- living components of the pond eco system and include basic inorganic and organic compound such as water, carbon dioxide, oxygen, calcium, Nitrogen and phosphorus and their compound, amino and humus etc. Only a small amount of these vital nutrients is found in soluble state in the pond water, but much large proportion is held in reserve solid form especially in the bottom sediments, as well as in the organisms themselves. The rate of release of the nutrients from the solids, the solar input and cycle of temperature, day length and other climatic conditions regulate the rate of function of the entire ecosystem of pond on day-to-day basic.

B) **Biotic Component:** The biotic component of a pond ecosystem comprised the producers and variety of consumers. In a pond the produces organism are of following main types:-

   i) Phytoplankton's- These are minute floating plants usually algae, distributed throughout the pond as deep as light penetrates. When in abundance, phytoplankonts give a greenish colour to pond water. These are very important in the production of basic food for the ecosystem such as lakes, deep ponds and even oceans. The phytoplankton of a pond usually comprise of Eudorina, Volvox, Closterium, Mycrocystis, Anabaena, O

Pond ecosystem



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uglena, Ceratium and Malosira. The phytoplanktons are more important as producers in a pond ecosystem than the large plants.

ii) Filamentous algae:-These also occur floating in water and include Spirogyra, Oedogonium, Nitella and chara.

iii) Marginal and emergent plants- These are Ipomea, Jussiae which are found floating on the surface and Phragmities, Typha and Acorus, which are rooted plants or sedges.

iv) Sub-merged plants- These are Vallisneria, Potamogeton, Naias and Otelli, which are rooted to the bottom. Utriculariaand Ceratophyllum and rootless sub-merged plants.

v) **Surface**- floating plants- These are Pistia, lemnaea, wolffia and Ecichorina.

C) **Marco- consumers' organisms:** The macro -consumers represents animal fauna of a pond ecosystem. These are categorized as primary consumers or herbivores, secondary consumers or carnivores and the tertiary consumers. Then primary marco-consumers feed directly upon living plants plat remains and are of the following topics-

i) **Zooplanktons**- These animals drift on the water surface through the agencies of water current and include dinoflagellates, hellizoans and copepods.

ii) **Nektons**- These are free- swimming aquatic animals which swim independent of wave and current action. There for, these possess definite locomotory organs. Insecet and insect larvae which feed upon plants are included in this category.

iii) **Benthos**-These are bottom-dwelling forms found crawling or attached to the bottom. These include mollusks and annelids. The secondary consumers or carnivores are predaceous insects and tertiary consumers are game fish.

D) **Saprotophic or saprophytic organisms:** The fungi and saprophytic bacteria and flagellates are especially abundant in the mud water and bottoms of the ponds, where dead bodies of plants and animals are deposited. These decompose the dead bodies of the organisms and derive their nourishment. Decomposition is more rapid when temperature conditions are favorable.

2.5.2 Marine Ecosystem

Marine ecosystem is the biggest ecosystem, which cover around 71%of earth's surface and contain 97% of out planet's water. Water in Marine ecosystems features in high amounts minerals and salts dissolved in them. Each ocean indeed represents a very large and stable ecosystem. Marine environments as compared with fresh water appear to be more stable in their chemical composition due to being saline, and moreover other such physico-chemical as dissolved oxygen content, light and temperature are also different. The biotic components of an ocean ecosystem are of the following orders:

Producers: These are autotrophs and also designated as primary producers, since they are responsible for trapping the radiant energy of sun with the help of their pigments. Producers are mainly the phytoplankton, such as diatoms, dinoflagellates and some macroscopic algae. Besides them, a number of macroscopic seaweeds, as brown and red algae, also contribute significantly to primary production. These organism show a distinct zonation at different depths of water in the sea.

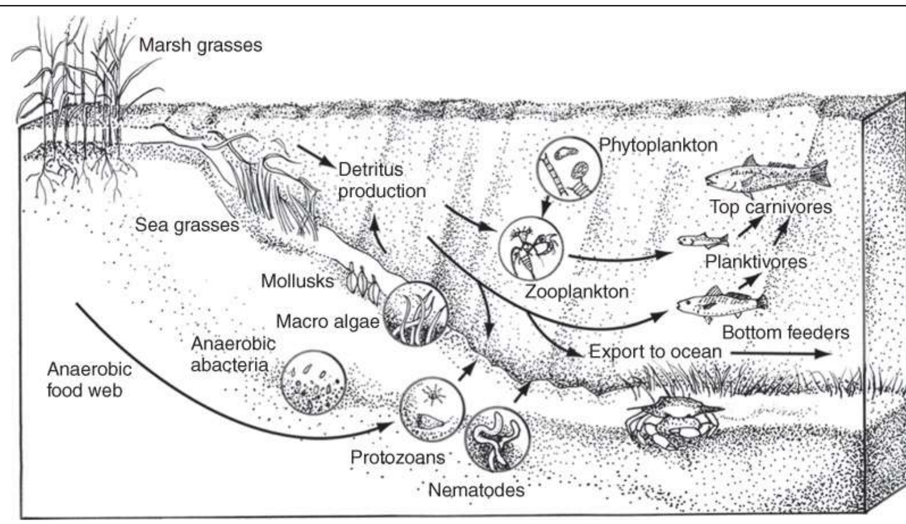
Consumers: These all are heterotrophic macro-consumers, being dependent for their nutrition on the primary producers.

Primary consumer: The primary consumers are the herbivores, that feed directly on producers, are chiefly crustaceans, mollusks Fish etc.

Secondary consumer: Secondary consumers which are carnivorous fish, as Herring, Shad, Mackerel etc., feeding on the herbivores.

Tertiary consumers: Tertiary consumers are other carnivorous fishes like cod haddock, Halibut etc. that feed on other carnivores of the secondary consumers level. Thus these are the top carnivores in the food chain.

Decomposers: Decomposers are mainly the microbes active in the decay of dead organic matter of producers and macro consumers are chiefly bacteria and some fungi.



Marine ecosystem

2.5.3 Forest Ecosystem

Forest occupy roughly 40%of the land in India, the forests occupy roughly one –tenth of the total land area. The different components of a forest ecosystem are abiotic and biotic component.

A) **Abiotic Component:** These are the inorganic as well as organic substances present in the soil and atmosphere. In addition to the minerals present in forests we find the dead organic debris-the litter accumulation chiefly in temperate climate. The light conditions are different due to complex stratification in the plant communities.

B) **Biotic component:** The living organisms present in the food chain occur in the following order:

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

   ii) **Consumers:** Consumers are categorized under the followings:

      a) **Primary consumers:** Primary consumers are the herbivores that include the animals feeding on trees leaves as ants, flies, beetles, leafhoppers, bugs and spiders Etc., and large animals grazing on shoots and/ or fruits of the producers the elephant, nigai, deer, moles, squirrels, shrews, flying foxes, fruit bats, mongooses etc.

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

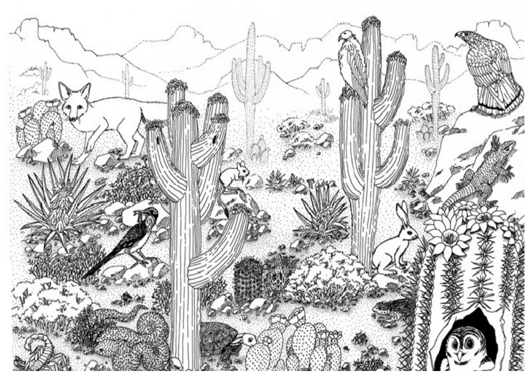
c) **Tertiary consumers:** Tertiary consumers are the top carnivores like lion, tiger etc. That eats carnivores of secondary consumers level.

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

2.5.4 Desert Ecosystem

The deserts ecosystem are located in regions that receive an annual rainfall less than 25%.They occupy about 17%of all the land on our planet. Due to extremes of temperature, the species composition of desert ecosystem is less varied and typical. The various components of a desert ecosystem are-

A) **Producers:** The shrubs, bushes, grass and some trees are the main producer in deserts. The shrubs have extensive and much branched root system with the stems and leaves variously modified. Some succulent cacti are also found in deserts. These store water in their stem to be used during the time of water scarcity. Some lower plants such as lichens, xerophytic mosses and blue green algae are also found there.



Desert Ecosystem

B) **Consumers:** Only a few animals are found in deserts. The most common animals are those reptiles and insects which are able to live under xeric conditions. Mammals are represented by a few species of nocturnal rodents. Some birds are also present. The camel, called the ship of desert, feeds on tender shoots of the plants and conserves large quantities of water in its stomach.

Summary

Abiotic components: The nonliving factory or the physical environment prevailing in an ecosystem from the abiotic components.

Biotic: Living; usually applied to the biological aspects of an organism's environment, i.e. the influence of other organisms (opposite of abiotic).

Community: The species that occur together in space and time; (see diversity and isotherms).

Ecosystem: All of the organisms of a given area and the encompassing physical environment.

Epidemic: The outbreak of a disease which affects a large number and/or proportion of individuals in a population at the same time.

Population: Any group of individuals, usually of a single species, occupying a given area at the same time; groups of organisms with homologue (same) alleles.

Organism (individual): Any individual living creature, either unicellular or multi-cellular.

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Self Assessment Question

A) Multiple Choice Questions

1) Natural ecosystem carries out many public service functions for us like –
a) Air pollutants from automobiles.
b) Wastewater from houses & industries is often converted to drinkable water through natural ecosystem,such as soil.
c) Both of them.
d) None of the above.

2) Which of the following statement are correct about ecosystem classification
On the basis of energy resources:
P: Naturally subsidized solar powered ecosystem.
Q: Fuel powered and radioactive ecosystem.
R: Unsubsidized natural and man subsidized solar powered ecosystem
S: Fuel powered and thermal powered ecosystem.
a) P,and R b) Q and S
c) P, Q and R d) P, R,and S

3)Chemosynthetic bacteria found around deep sea vents are example of
a) producers b) consumer
c) chemical cycling d) decompsers

4) Decomposers includes:
a) Fungi and bacteriophage b) Bacteria and virus

c) Fungi and algae d) Fungi and bacteria

5)Autotrophs are also known as –

a) producers only b) lithotrophs

c) lithotrophs and producers d) producers and osmotrophs

6) Which of the followings are correct for decomposers:

P: saprotrophs and osmotrophs .

Q: reducers and scavenger only.

R: saprotrophs and reducers.

S: scavengers and detritivores

a) P and R b) Q and S

c) R and Q d) P,Q,R, and S

B) Fill in the blanks

1) Set of ecosystems within geographical regions which are exposed to ……………

2)Aquatic biome falls into …….. categories.

3) Example of unsubsidized natural solar powered ecosystem are………………

Answer Keys:A)1. c, 2. d, 3. a, 4. d, 5. c, 6. a

B)1-Same Climatic Condition and Physical Structure, 2-Two, 3- Ocean, Upland forest, Grasslands,

C) Terminal Questions

a) Write short notes on the following:

1) Lithotrophs
2) Scavenger and Decomposers
3) Predator
4) Edaphic factor
5) Man subsidized solar powered ecosystem

b) Long answer type questions

1) Describe the categories of carnivores with suitable examples.

Unit 3: Ecosystem: Functions

Unit Structure

3.0 Learning Objectives

After completing this unit you shall be able to:

- Discuss the function of an ecosystem
- Discuss trophic levels
- Discuss energy flow and biogeochemical cycling of nutrients
- Discuss food chains and food webs, and their importance

3.1 Introduction

In the previous unit, you learnt that ecosystem has two main components- living and non-living components. Living components include may be categorized based on trophic levels i.e., herbivores, carnivores, omnivores and saprobes. These living components interact among themselves and with the non-living components for meeting their various requirements such as nutrients and energy for their growth and development. The nutrient and energy pass on from living beings of one level to another level as a result of eating and being eaten kind of relationship. Thus, ecosystems are interacting units and living components are associated with one another for performing certain functions such as flow of energy and cycling of nutrients. These are the main functions of ecosystems and these functions are performed through food chain or food web.

In this unit, we will discuss various trophic levels, cycling of nutrients and flow of energy through the various components of ecosystem in detail.

3.2 Function of Ecosystem

The function of the ecosystem is to allow flow of energy and cycling of materials which ensures stability of the system and continuity of life. These two ecological processes include interaction between the abiotic environment and the communities. For the sake of convenience, the ecosystem dynamics may be analyzed in terms of the following:

(i) food chains and food web
(ii) trophic levels
(iii) food pyramids,
(iv) energy flow,
(v) nutrient cycles,
(vi) development and evolution of ecosystem, and
(vii) homeostasis and stability of ecosystem

These are discussed in separate heads as below:

3.3 Food Chains and Food Web

3.3.1 Food Web

In an ecosystem the living organisms (biotic community) have a pattern of feeding. The producers are eaten by the herbivores. Herbivores in turn are eaten by carnivores. Carnivores may further be eaten by other larger carnivores. In this process the food energy is transferred from plants to herbivores to carnivores to larger carnivores who feed on them.

A food chain is a linear network of links in a food web starting from producer organics & ending at apex predator species, detritivores, or decomposer species.

Tertiary consumer	**Fourth trophic level (Top Carnivores)**	**Man, lion**
Secondary consumer	Third trophic level (Carnivore)	Birds, fishes wolf
Primary consumer	Second trophic level (Herbivores)	Zooplankton Grasshopper and cow
Producer	First trophic level	Phytoplankton grass, trees

Characteristics of food chain

1. In a food chain, there is a repeated eating in which each group eats the smaller one and is eaten by the larger are so a food chain involves a nutritive interaction between biotic components of an ecosystems.
2. The plants & animal which depend successively on one another from form the links of a food chain.
3. In a food chain there is a unidirectional flow of energy from sun to producers and then to a series of consumers of various types.
4. Usually there are 4 or 5 trophic level in the food chain shorter food chain will provide greater availability of energy and vice versa.
5. Omnivorous generally occupy more than are trophic level in the food chain.
6. Some organisms (e.g. man) occupy different trophic positions in different food chains.
7. The respiration cast increases along successive trophic levels of a food chain on an average, it is about 20% at producers level, about 30% at the level of herbivores, and as high as 60% at the level of carnivores. So the residual energy decreases at successive trophic levels.
8. A food chain consists of series of population which are related by eating & be eaten.
9. A food chain is generally straight.

10. The number of trophic levels is 3-6.
11. There is progressive reduction in available biomass energy & no. of individuals with the rise is trophic level.
12. In each trophic level a lot of biomass is consumed is liberating energy.
13. A major part of energy made available at each trophic level is lost as heat.
14. Some organisms like human operate at more than are trophic level.
15. Food chains are sustained by producers & decomposers.

Types of food chain

There are two basic types of food chain

1) Grazing food chain (GFC): It is a simple food chain that extends from producers to herbivores to carnivores. These types of food chains originate from plants and go to grazing animals and then on to animal eaters.

e.g., -Phytoplanktons → Zooplanktons → fish

Grass → rabbit → fox → lion

Producers (Primary consumer) → Herbivores (Secondary consumer) → Carnivores (Tertiary consumer)

The general characteristics of grazing food chain are as follows:

- There are directly dependent on solar radiation as the primary source of energy.
- Green plants (or producers) form the first trophic level of the food chain. These synthesize their plant biomass by the process of photo synthesis in which kinetic energy of color radiations in tropped in the presence of Mg++containing green pigment chlorophyll and is converted into potential energy of organic food (i.e glucose).
- Herbivores or primary consumers eat upon the producers and form the second trophic level.
- Herbivores are eaten up by carnivores which are of different categories.
- These always end at decomposer level.

e.g., Phytoplankton's → Zooplanktons → fish

Grass → rabbit → fox → lion

2) Detritus food chain: It begins with dead organisms or dead organic matter and passes through detritus feeding organisms in soil to organisms feeding on detritus feeders.

This type of food chain goes from dead organic matter into microorganisms to organisms feeding on detrivores & their predator. This system is thus less dependent on solar energy.

e.g.- Detritus → Earthworm → sparrow → Falcon

Frog → Snake → Peacock

The general characteristics of detritus food chain are:

- Primary energy source of detritus food chain is dead organic matter called detritus.
- Main source of dead organic matter are fallen leaves or dead animal bodies.
- Primary consumers are detritivores (detritus eating). These include protozoan's, bacteria, fungi etc. which food upon the detritus saprophytically.
- The detritivores, in term, are eaten by secondary consumers which include insect larvae, nematodes etc.
- There are generally shorter than grazing food chain.
- In nature, detritus food chain is indispensable as the dead organic matter of grazing food chains is acted upon by the detritivores to recycle the inorganic elements into the ecosystem.

3.3.2 Food Web

A food web (or food cycle) is the natural interconnection of food chains and generally a graphical representation of what – eats – what in an ecological community. Another same for food web is a consumer resource system. Examples are- gram or plants may be eaten by grass hoppers as well as rabbits, cattle and deers. Each of their herbivores may be eaten up by number at carnivores like frogs, birds, crakes and tiger depending on their food habits.

The general characteristics of food web are as follows:

- In an ecosystem, no food chain is independent and the linear arrangement of food chains hardly occurs.
- It is formed by interlinking of 3 types of food chains. e.g., predatory chains (proceeds from smaller to larger organisms), parasitic chains (proceed from larger to smaller organisms) and saprophytic chains (starting from dead organic matter).
- Food web provides the alternative pathways of food availability. e.g., if a particular crop is destroyed due to some disease, the herbivores are that areas do not perish as they can graze other type of crop or herbs. Similarly, dogs (secondary consumers) may feed on rats and mice in the event of decrease in the number of rabbits on which they feed.Greater number of thepathways result in more stable ecosystem.
- These also help in checking the overpopulation of some species of plants and animals.
- The age and size of the species and availability of food source are important factors in determining the position of an animal in a food web.
- Normally, a food web operates according to taste and food preferences of organisms at each trophic level for e.g. Tigers in Sunderbans eat fish and crab instead of their natural pray.
- Food web also helps in ecosystem developments time allows increasingly intimate associations and reciprocal adaptations between plants and animals.
- Food web is more real than food chain.
- It consists of a number of food chains interlinked at various trophic levels.
- Food web is not straight. The component food chains do not run parallel.
- Food backs checks operate in food webs that keep the population of different species rarely constant.
- It is essential for satiability of ecosystem.

3.4 Trophic Levels

In an ecosystem, the various biotic components remain in a kind or eating and being eaten kind of relationship with one another and forms what is known as food chains. If we group all the organisms in a food chain according to their general source of nutrition, we can assign them different trophic (feeding) levels. The producer organisms belong to **first trophic level**, primary consumers (herbivores) to the **second trophic level**, secondary consumers (carnivores) to the **third trophic level** and tertiary consumers (top carnivores) to the **fourth trophic level**. Man, who is an omnivore may belong to more than one trophic level.

There are usually four or five trophic levels, and seldom more than six levels in any ecosystem. This is because of the fact that at each level when energy is transferred a proportion of the food energy is lost as heat and subsequently at each level this amount is further reduced and finally after four or five levels the amount of energy becomes so low that further levels cannot be sustained. This is the reason why the number of trophic levels in a food chain I any ecosystem cannot be more than five and seldom six.

3.5 Ecological Pyramid

An Ecological Pyramid is graphical representation of the trophic structure and also trophic function. In ecological pyramid the first all producer level forms the base and successive level from the tier which make up apex.

The idea of ecological pyramid was developed by Charles Elton (1928). So the Ecological Pyramid are also called Eltonian Pyramid. An Ecological pyramid may be upright tapering towards the tip) or inverted (widen towards the tip) or spindle shaped (broader in the middle andnarrow above and below an upright ecological pyramid indicated that the producers outnumber or outweigh the herbivores which in turn, Outweigh or outnumber the carnivores.

On basis of Ecological Parameters there are three types of ecological pyramid

1) The Pyramid of number
2) The pyramid of biomass

3) The pyramid of Energy

3.5.1 Pyramid of number

It is graphic representation showing the arrangement of the number of individual organization at different level in an ecosystem is depicted. There are again of three types:

(a) Upright pyramid of Number.

(b) Partially Upright pyramid of Number.

(c) Inverted Pyramid of Number.

(a) Upright Pyramid of Number: This type of upright pyramid of number is found in grassland Ecosystem are band ecosystem the size of aquarium increase from the carnivore level while their no decrease in food chain.

(b) Partially Upright pyramid of Number: This type of pyramid is found in tree

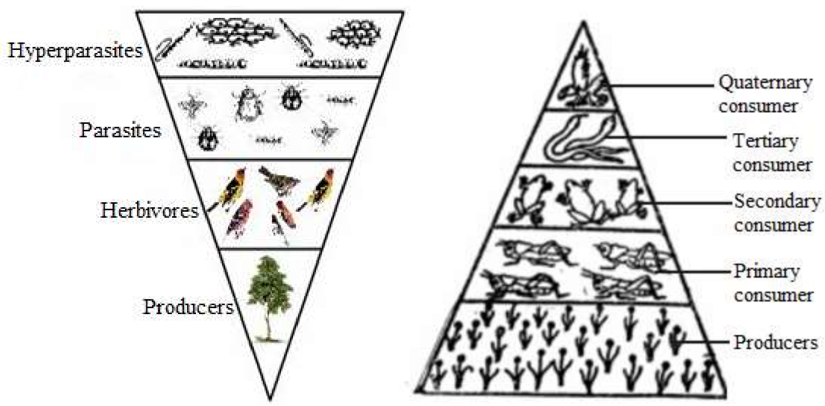


Fig. 1 Inverted pyramid of number Pyramid of numbers in a grassland

dominated Ecosystem single large size tree (T.) Is attacked by numerous minute plant eating and carnivorous insect (T3) which are further less by small sized (T4) and (T5).

(c) Inverted Pyramid of Number: In parasitic food chain e.g.:- an oak tree pyramid Number is an inverted pyramid in which single oak tree supports large no. of fruit eating birds and large no. of parasites. Hyper parasite like bacteria, fungi etc are the greatest in no. and occupy the top of inverted pyramid of number.

3.5.2 Pyramid of Biomass

It is a graphic representation of biomass (total amount of living or organic matters in an ecosystem at any time) present per unit area in different tropic levels. A typical pyramid of biomass is more fundamental as it shows the quantitative relationships of the standing crop. Pyramid of biomass may also be straight or inverted. In grassland and forest ecosystems, there is a gradual decrease in biomass of organisms at successive tropic levels from producers onwards to top carnivores (uprights or straight pyramid). In pond ecosystem, on the other hand, produces are the smallest organisms while carnivores are large in size. Consequently, there is a gradual increase in biomass of Aryanisms at successive tropic levels from producers onwards to top carnivores resulting in inverted pyramid. There the biomass of phytoplankton's will be smaller than that of zooplanktons; the biomass of zooplanktons will be lesser than of primary carnivores (E.g. Small fishes). In such an inverted pyramid of biomass a small standing crop of phytoplankton supports a large standing crop of zooplanktons.

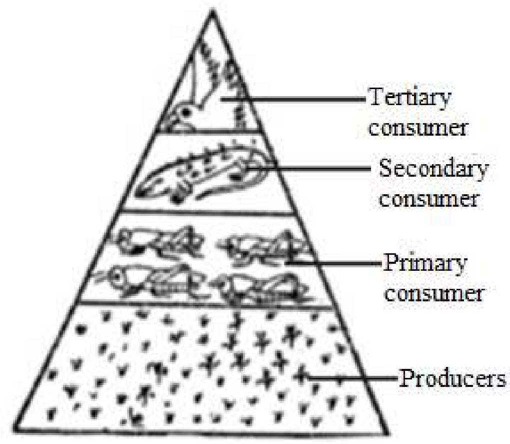


Fig. 2 Pyramid of Biomass in a grassland

3.5.3 Pyramid of Energy

"An energy pyramid is a graphical model of energy flow in community. The different levels represent different groups of organisms that might compose a food chain. From the bottom-up, they are as follow: producers bring energy from nonliving sources into the community". When, the production of a community is measured in terms of energy. We find that a pyramid is formed starting from each tropic level. Than that was put into it. Energy pyramid gives the best information on the nature of the states of passage of food mass through the food chain.

There is always a gradual decreasing the energy content at successive levels from the producers to consumers. The Source of energy for living being on earth is the sun. The energy that the sun emits at present is of 1366.75W/Mˆ2. When the studies of the capture of energy by the producer organisms (photosynthetic organisms) were made, the solar Irradiance (SI) was of 1365.45W/mˆ2.

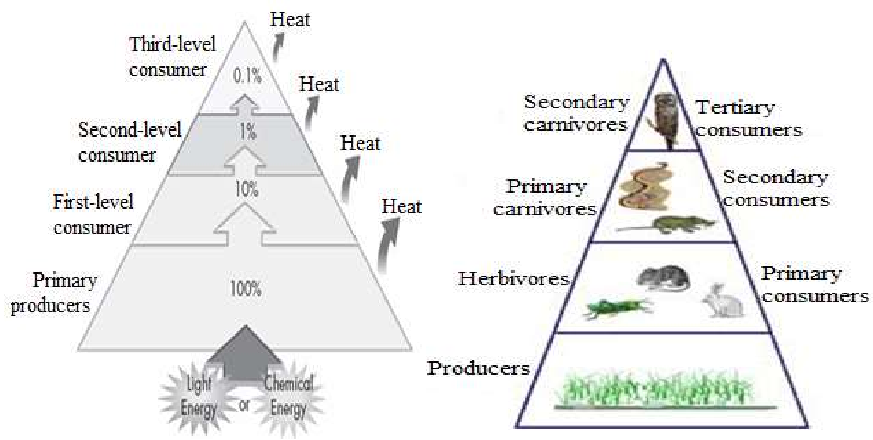


Fig. 3 Pyramid of Energy

The energy usable by photosynthetic organisms is 697.04W/mˆ2; never the less, the photosynthetic organisms take only 0.65W/mˆ2 and the rest of the incident energy on the surface is transferred to the biotic surroundings (oceans, soil, atmosphere, etc) and from there, the energy is emitted to the outer space and to the gravity field. The atmosphere absorbs 191.345W/mˆ2, maintaining the tropospheric temperature of earth in the hospitable 35.40oC (95.720F).

3.6 Energy Flow

Energy flow is the movement of energy through an ecosystem from the external environment through a series of organisms and back to the external environment.

Every ecosystem needs energy resources for its survival. The supply of energy has to be continuous to maintain the biotic structures and their function. The energy flow refers to a cyclic movement of energy comes from the environment which is external to the ecosystem, passes through a series of organism, and then return to same external environment from where it has come. The flow of energy through an ecosystem is very essential requirement. The quality and quantity of energy flow helps to tell or decide the richness or poorness and shortness of life. The Biosphere, the sun is ultimate source of energy.

In every ecosystem the energy flow provides a foundation for life and thus impure a limit on shortness and richness of life. The behaviour of energy on ecosystem can be termed energy flow due to unidirectional flow of energy. From energetic point of view it is essential to understand for an ecosystem.

- The efficiency of the producers in absorption and conversion of solar energy.
- The use of this converted chemical form of energy by the consumers.
- The total input of energy in form of food and its efficiency of assimilatory.
- The loss through respiration, heat, excretion etc
- The gross net production

Summarize in the flow of energy and inorganic nutrients through the ecosystem, a few generalizations can be made.

- The ultimate source of energy (for most ecosystem is the scene)
- The ultimate fate of energy in ecosystem is for it to be lost as heat.
- Energy and nutrients are passed from organism to organism. Through the food chain as one organism eat another.
- Decomposers remove the last energy from the remains of organism.
- Inorganic nutrients are yield energy.

Continuous and One way flow of energy

In different ecosystem the nutrients are low in a cyclic manner. The non energy yielding components like C, N, H_2O etc, also calculate from abiotic segment to biotic segments and vice versa. But the energy does not do so; it does not circulate rather flow unidirectional. The flow of energy is continuous and one way in every ecosystem. A

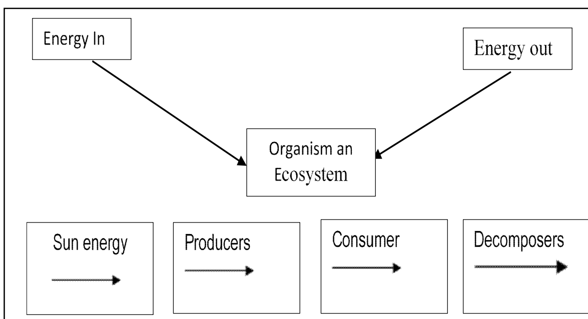


Fig. 4 Unidirectional flow of Energy

Unidirectional flow of energy from “sun” to decomposer is shown in Fig.4.

The energy transverse through producers and main consumers before reaching to decomposer. However it cannot flow in reverse direction. It is because of one way nature of energy flow.

Ecosystems maintain themselves by cycling energy and nutrients obtained from external sources. At the best tropic level, primary producers use solar energy to produce organic plant material through photosynthesis. Herbivore animals that feed solely on plant make up the second tropic level. Predators that eat herbivore compromise the third tropic level, if larger predators are present, they represent still higher trophic level and organisms that feed at survival tropic levels are classified as the highest on the trophic levels at which they feed. Decomposers which include Bacteria, fungi, worms and insects break down waste and dead organisms and return to the soil.

On average about 10 percent of energy production at one trophic level is passed on to the next level processes that reduce the energy transferred because consumers can conserve high quality food sources into new living tissue more efficiently than low quality food sources.

The low rate of energy transfers between trophic levels makes decomposers generally more important than producers in terms of energy blow. Decomposers process large amount of organic material and return.

How many trophic levels can an ecosystem support? The answer depends on served including the amount of energy entering the ecosystem, energy loss between trophic levels, and the formed structure and physiology of organism at each level. At higher trophic levels predators generally are physically layer and are able to utilize a fraction of the energy that was produced at level beneath them, so they have to over increasingly large area to meet their calorie needs.

Due to energy losses, most ecosystems have no more than five levels, and marine ecosystem is likely due to difference in the fundamental characteristics of land. Phytoplankton are small organisms with extremely simple structures so most of their primary production is consumed and used for energy by grazing organisms that feeds on them. In contrast, a large fraction of the bio mass that fund plant produce such as roots, trunks and branches cannot be used by herbivore for food. So proportionally less of the energy fixed through primary production travels up the food chain.

The simplest way to describe the fluxes of energy through ecosystem is as a food chain in which energy passes from the one trophic level to the next, without factoring In more complex relationship between individuals species some very simple ecosystem may consist of food chain with only a few tropic levels for example the ecosystem of the remove wind spot Taylor valley in Antarctica consist mainly of bacteria and algae that are eaten by nematodes warms more commonly, however producers and consumers are connected in intricate food wave with some consumers Breeding at several tropic levels.

Important consequences of the loose of energy between tropic levels that contaminants collect in an animal tissue a process called bioaccumulation

The insecticide DDT which was widely used in a USA from the 1940 s through the 1960s is a famous case of bioaccumulation. DDT build up in Eagle and other raptors to levels high enough to effect the reproduction, causing the birds to lay thin shelled Eggs that broke in their nests fortunately population have bound over nutrients to the ecosystem in a organic form which are then taken up again by primary producers. Energy is not recycled during decompositions but rather is released mostly as a heat.

An ecosystem is a gross primary productivity is the total amount of organic matter that is produces through photosynthesis net primary productivity describes the amount of energy that remains available for a plant to growth after subtracting the fraction that plant use for respiration productivity in land ecosystem generally rises with temperature upto 30`c after which is a declines and is positively corrected with moisture on land primary productivity thus is a highest in worm, wet zones in the tropics where tropical forest biomes on located in contrast desert have lowest productivity . In the oceans light and nutrients are important controlling factors for productivity. Photosynthesis occurs in surface and near surface water.

Bioaccumulation can threaten humans as well as animal. For example in the USA many federal and state agencies currently warn consumer to avoid or limit their consumption of large predatory fish that contain high level of Mercury such as shark, swordfish. To avoid resting neurological damage and birth defects.

Energy flow in Ecosystem

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

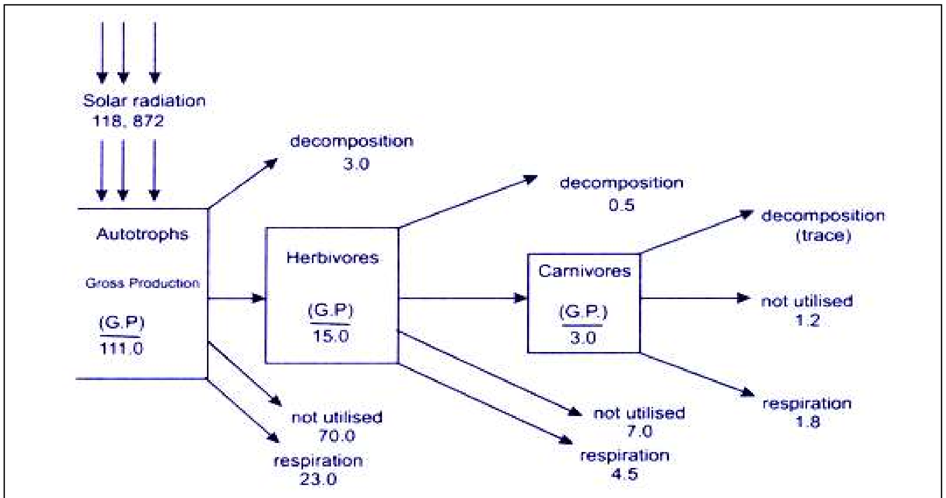


Fig. 5 Energy flow diagram for a lake (freshwater ecosystem) in g cal/cm2/yr

1-Single Channel Energy Flow Model: The flow of energy takes place in an unidirectional manner through a single channel of green plants or producers to herbivores and carnivores. From the energy flow model shown in Fig.5, two things are clear:

(i) There is unidirectional flow of energy. The energy captured by autotrophs does not revert back to solar input but passes to herbivores; and that which passes to herbivores does not go back to the autotrophs but passes to consumers. Due to one way flow of energy, the system would collapse if the primary sources of energy (i.e., sun) were cut off.

(ii) At each trophic level, there occurs progressive decrease in energy. This is accounted largely by the energy lost as heal in metabolic reactions (respiration) coupled with unutilized energy. The figure depicts a simplified energy flow model of three trophic levels. One can clearly note that the energy flow is greatly decreased at each successive trophic level starling from producers (autotrophs) to herbivores and then to carnivores. In the Figure, boxes represent the trophic levels and pipes represent the energy flow in and out of each level. Working of both the laws of thermodynamics is clearly seen as energy inflows balance outflows at each trophic level (as per first law of thermodynamics) and energy transfer is accompanied by dissipation of energy into unavailable heat i.e., respiration as per the second law of thermodynamics. Thus, of the total 3,000 kcal of light falling upon green plants, 1,500 kcal (50%) is absorbed level (first trophic level). 1% (15 kcal) is converted at autotroph level (first trophic level). Thus, net production is mearly 15 kcal. Secondary productivity (shown as P_2 and P_3 in Fig.5 tends to be about 10% at successive consumer levels i.e., at herbivore level and carnivore level. As has earlier been mentioned, there is successive decrease in energy flow at successive trophic levels. Therefore, shorter the food chain, greater would be the available food energy.

2- Y-Shaped or Double Channel Energy Flow Model: The Y-shaped energy flow models as pioneered by H.T. Odum in 1956, is shown in the figure. This model shows a common boundary, light and heat flows as well as the import, export and storage of organic matter. Decomposers are placed in a separate box as a means of partially separating the grazing and detritus food chains. In terms of energy levels, decomposers are, in fact, a mixed group. The significant part in Y-shaped model is that the two food chains are not isolated from each other.

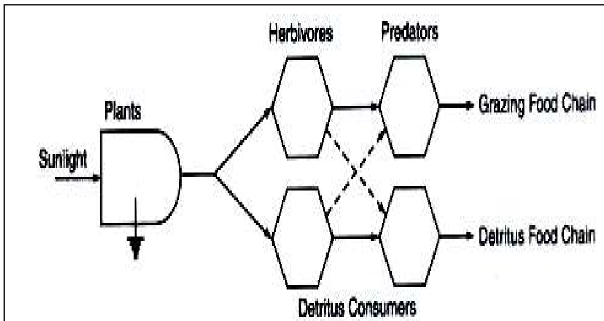


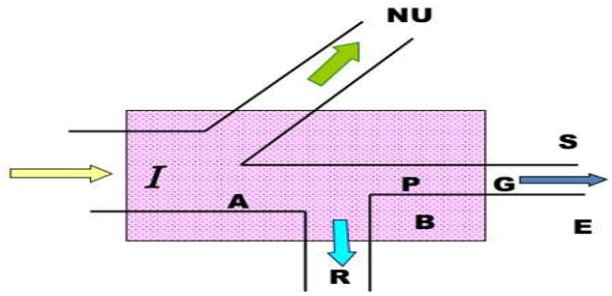
Fig. 6 Y-shaped energy flow model showing linkage between the grazing and detritus food chains

Y-shaped energy flow is more realistic and practical than the single-channel energy flow model because of following points:

- It conforms to the basic stratified structure of ecosystems.
- It separates the two chains i.e., grazing food chain and detritus food chain in both time and space.

- Micro consumers (e.g.. bacteria, fungi) and the macro consumers (animals) differ greatly in size-metabolism relations in two models.

3- Universal Energy Flow Model: E.P. Odum (1983) gave a generalized model by combining both single channel model and Y-shaped models which are both applicable to terrestrial and aquatic ecosystem and this combined model is known as Universal energy flow model. In this model I- Incident solar rays; A- Assimilated energy; P- net production; G- Growth; B-Biomass; R- Respiration; S-Stored energy; E-Excreted energy; NU-Unutilized energy. This model can be used in two ways as:



I=input or ingested energy; NU= not used; A= assimilated energy; P = production; R= respiration; B= biomass; G = growth; S= stored energy; E= excreted energy

Fig. 7 Components for a Universal model of energy flow

a) It can represent a species population in which case the appropriate energy inputs and links with other species would be shown as a conventional species oriented food levels and

b) The model can represent a discrete energy level in which case the biomass and energy channels represent many populations supported by the same energy source.

3.7 Productivity in an Ecosystem

The amount of food energy produced or obtained or stored by a particular tropic level per unit area, in a unit time is referred to as productivity. It is a rate function and is expressed in terms of dry matter and energy captured per unit area of land per unit time. It is generally expressed in terms of gm-2 year-1 or kcal m-2 year-1.

In ecology, productivity or production refers to the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for instance grams per square metre per day (gm-2d-2). The mass unit may relate to dry matter or to the mass of carbon generated. Productivity of autotrophs such as plants is called primary productivity, while that the hetrotrophs such as animals is called secondary productivity.

1. Primary productivity: It refers to rate at which sunlight is captured by producers for the synthesis of energy-rich organic compounds.

Primary production is the synthesis of new organic material from inorganic molecules such as H2O and CO2. It is dominated by the process of photosynthesis which uses sunlight to synthesize organic molecules such as sugar, although chemosynthesis represents a small fraction of primary production. Organisms responsible for primary production includes: land, plants, marine algae and some bacteria (including cyano-bacteria).

Primary production is the synthesis of organic compounds from atmospheric or aqueous carbon dioxide. It principal occurs through the process of photosynthesis, which uses light as it source of energy, but it also occurs through chemosynthesis, which uses the oxidation or reduction of inorganic chemical compounds as it source of energy. Almost all life on earth relies directly or indirectly on primary production. The organisms responsible for primary production are known as primary producers or autotrophs and form the base of food chain. In terrestrial eco regions, these are mainly plants, while in aquatic eco regions algae predominates in this role. Ecologists distinguish primary production as either net or gross, the former accounting for losses to processes such as cellular respiration, the latter not.

Under primary productivity it is again classified in two types:

(a) Gross primary productivity (G.P.P.) or Total photosynthesis: During the measurement period, the total photosynthesis including the amount of organic matter used up in respiration is called as gross primary productivity. It is defined as the total rate of photosynthesis during the measurement period. The rate of gross productivity is limited by the number and activity of producers and by the amount of solar energy available. It is associated with photosynthetic and chemosynthetic organisms. It includes green plants, phytoplanktons and bacteria. The rate of primary productivity is estimated in terms of either chlorophyll contents as chl/g dry weight/unit area, or photosynthetic number i.e., amount of CO2 fixed/g chl/hr.

(b) Net primary productivity (N.P.P.): It refers to gross production minus losses by way of respiration and decomposition (GPP- losses = NPP). It is called as apparent photosynthesis. It is defined as the rate of storage of organic matter in plants in excess of the organic matter used up in respiration during the period of measurement. Thus by

Table 1. Geographical Area, Mean Plant Biomass and Productivity in Major World System

Ecosystem	Area	Mean Plant Biomass	Mean net primary productivity
Tropical rain forest	17	440	20
Tropical deciduous forest	8	360	15
Temperate coniferous forest	12	200	8
Temperate deciduous forest	7	300	12
Savanna	15	40	9
Temperate grassland	9	20	5
Desert Shrub	18	10	0.7
T= ton= 1000kg **Ha= 10,000 meter square**			

definition it is the balance between total photosynthesis and respiration. It is also known as net assimilation. It is the energy which is potentially available to the next trophic level.

Net primary production is the rate at which all the plants in an ecosystem produce net useful chemical energy; it is equal to the difference between the rate at which the plants in an ecosystem produce useful chemical energy (GPP) and the rate at which they use some of that energy during respiration.

2. Secondary Productivity: The rate of energy storage at consumer's level is called secondary productivity. The total energy flow at heterotrophic levels, which is analogous to gross production of autotrophs should be distinguished as assimilation and not production.

This productivity is not static. The efficiency of any ecosystem greatly depends upon the production rates of its primary producers. Oceans from the largest ecosystem and their productivity vary in different regions. On the shares, the productivity may be 2 to 3.5 g/m2/day, and in deep seas only 0.5g. in highly productive lakes the productivity value may be 5 to 10 g/m2/day and reaches upto 50g in exceptionally favorable conditions. The net productivity of crop plants ranges from 0.25 to 1 kg or a little more for wheat and rice crops per m2/year. Sugarcane is one of the very efficient converters of solar energy and its NPP value ranges from 2 to 4 kg/m2/year or even more.

On the other hand, secondary productivity is associated with the heterotrophic and saprophytic types of nutrition and applies to all consumers and decomposers. The primary productivity remains laugely in situ, while the secondary productivity remains mobile and potential for dispersion.

3. Net Productivity: The amount of the food energy not utilized by heterotrophs per unit area time is referred to as net productivity.

N.P.P.- Consumption of heterotrophs = N.P.

3.8 Biogeochemical Cycles (Material Cycles)

The major plant nutrients derived from soil are nitrogen, phosphorus, potassium, because these are biologically available to plants, out of these three nutrients .

Nitrogen stands out as the most significant to microbial transformations as it builds up protein and many components of microorganisms, plants and animal .

Phosphorus is the 2nd to nitrogen which is required by both plants and microorganisms. It plays an important role in release of energy during metabolism.

Potassium is obtained from soil. In addition, there are many important chemicals present in plants, animals and microorganisms.

Principle: The nutrients flow from non living to living and they again return back to non living in the form of waste product or dead bodies' i.e., the nutrients are neither created nor destroyed.

Aspects of a Nutrient Cycle

Input of Nutrients: In this, an ecosystem receives the nutrients from external sources and stores them for their reutilization in the biological processes for the growth and development of living organisms.

Output of Nutrients: In this type of nutrients are mixed out of an ecosystem e.g loss of nutrients like calcium, magnesium etc through runoff water and soil erosion.

Internal cycling of nutrients

1. Regeneration of nutrients during decomposition of detritus by bacteria and fungi.

2. Nutrients absorption involves uptake of nutrients from soil by the plants.

3.8.1 Nitrogen Cycle

Nitrogen is found in the atmosphere in the concentration (78%)-gaseous state. It is an essential constituent of proteins and nucleic acid and chlorophyll found in organisms .Nitrogen is essential constituent of protoplasm.

Concentration of nitrogen in soil directly proportional to soil fertility is directly proportional to microbial activity. The nitrogen cycle can be further conveniently discussed under the following heads:

Nitrogen fixation: It is a process of conversion of gaseous form of nitrogen into combined forms i.e. ;ammonia or organic nitrogen by some bacteria and cyano bacteria .These are free living as well as symbiotic living organisms which fix N2 into proteins . The nitrogen –fixing, micro-organisms are called diazotrophs and the phenomenon of this activity is known as daizogtrophy. The nitrogen fixation is done by; Bacteria e.g.; Rhizobium, Cyanobacteria e.gAulosoria ,nostoc .

Industrial fixation: nitrogen and hydrogen combines to form ammonia industrially under extremely high temp of 400 and a high pressure of about 200 atmospheres

Ammonification: It is the decomposition of proteins, urea, uric acid etc by micro organisms like ammonifying bacteria, actinomyctes and fungi .They convert nitrogen presenting wastes dead wastes and decaying bodies into ammonia compounds. The process of conversion of organic nitrogenous compounds into ammonia ammonification

Ammonifying bacteria =*Baccilus remosur*, *B. vulgaris*

In this process, energy is also produced, so called as exothermic process

PROTIENS ⟹ AMINO ACIDS ⟹ AMMONIA

Nitrification: It involves the oxidation of ammonia or ammonium ions to nitrate ions in the presence of nitrifying bacteria is known as nitrification . The ammonium acts as the starting point for nitrification.

AMMONIA ⟹ Nitrosomonas nitrates ⟹ Nitrobacteria nitrates

These nitrates are absorbed by the plants from the soil

De-nitrification: It is a biological process by which ammonium compounds nitrates are reduced to molecular nitrogen .Nitrogen in the presence of de nitrifying bacteria like *Bacillus subtilis* etc. It reduces the soil fertility

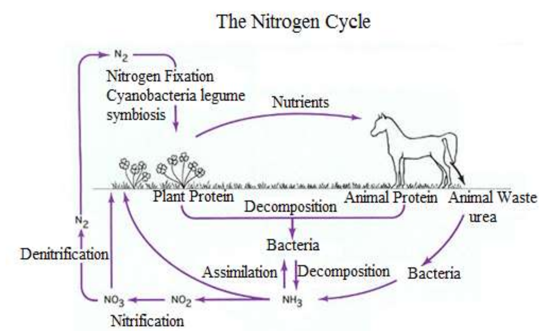


Fig. 8 Nitrogen cycle

It involves the following steps

NO_3----NO_2 (Nitrate)

NO_2---- NO (Nitric oxide)

NO ----N_20 (Nitrous Oxide)

N_20----N_2 (Nitrogen)

Free nitrogen refers to the atmospheric poor and nitrous and nitric oxides are taken up by the plants.

3.8.2 Oxygen Cycle

Sources of oxygen: Oxygen is the most abundant of all elements .It occurs in the free form as O2 and makes up to 21% by volume of the atmosphere. Oxygen makes up 46.6% by weight of the earth's crust. It combines 89% of weight of oceans .Oxygen occurs as ozone O3 in the upper atmosphere and is of great importance. Under normal conditions oxygen exists as gas organisms respire aerobically in the presence of oxygen .During respiration; it combines with hydrogen to form water.

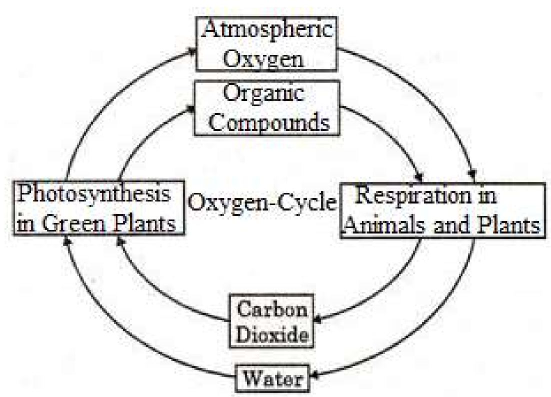


Fig. 9 Oxygen cycle

Oxygen Utilization: It enters the plants and animals through respiration during which carbohydrate is oxidized to form O_2 and water .It is also used in combustion of wood, coal, petroleum, etc to yield CO_2, SO_2 water etc .The oxygen in the atmosphere is in a state of dynamic equilibrium. Organisms get it from air or water for respiration.

Oxygen production: Oxygen is mainly produced during the proteolysis of water in the light phase of photosynthesis. Oxygen returns to the surroundings in the form of CO_2 and H_2O.It also enters the plant body as CO_2 or H_2O during photosynthesis and is released in the form of molecular as a big product in the same process for use in respiration. Thus the cycle is completed.

3.8.3 Carbon Cycle

Importance of carbon: Carbon is the most important element of the protoplasm .It is the major constituent of carbohydrates, proteins, fats and nucleic acid of the cells of an organism .so, carbon is generally considered as the basis of life. Carbon constitutes 49% of the dry weight of organisms.

Sources of carbon: In the biosphere there are four sources of carbon

1) As carbon in atmosphere and in water (oceans). They act as reservoirs of carbon. In atmosphere 0.034% carbon is present .It constituents about 1% of total global c.

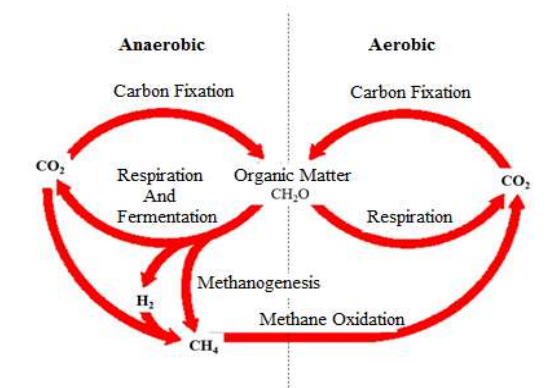


Fig. 10 Carbon Cycle

2) As carbon molecule in fossil fuels like coal is petroleum.

3) As carbonates in the rocks of earth's crust.

4) Oceans where it remains stored as bio carbonates as limestone and marble rocks.

Thus, the major reservoirs of carbon in the biosphere are atmosphere, oceans and fossil fuels.

Carbon utilization: carbon present in the atmosphere is the basic source that enters the organism through photo synthesis by plants or producers and then to herbivores to small and large carnivores and finally to decomposers. During photo synthesis O_2 is released as a byproduct.

Carbon production: CO_2 is returned back to atmosphere to various sources like:

1) During respiration plants and animals release carbon back to the surrounding medium as CO_2.
2) By decomposition of organic wastes and dead bodies by decomposers by the action of bacteria and fungi.
3) By burning of combustion of fossil fuels and wood.
4) Volcanic eruption and hot springs also release CO_2 in the atmosphere.
5) Weathering of carbonate contains rocks also add to CO_2 in atm.

Hence carbon cycling occurs through atmosphere occurs and living and dead organisms. The 'C' cycle is the perfect cycle in the sense that carbon is required to atm. as soon as it is required .The recycling of carbon is essentially a self regulating feedback system. However, human beings may upset the system by excessive use of fossil fuels and other activities like deforestation massive burning of fossil fuels etc. Carbon cycle is an example of one way cycle.

3.8.4 Sulfur cycle

Importance of Sulfur: It is an essential nutrient of plants and animals. Sulfur is a component of three amino acids (cystine, cystiene and methionine). So it is a component of most proteins some enzymes and vitamins.

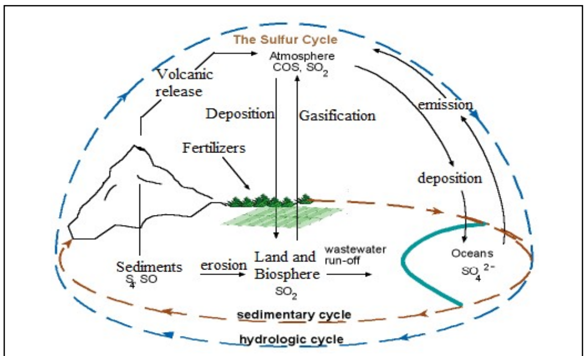


Fig. 11 Sulfur Cycle

Sources: It is the most abundant in the earth's crust in low concentration and is unavailable to plants. Sulfur is a sedimentary cycle as it is found in nature as element and also as sulphates in soil, water and rocks.

Organic and in organic forms of Sulfur compounds is micro biologically metabolized in soil through is different transformation process as given below.

1) Decomposition of organic Sulfur compounds by micro organisms into smaller units and finally into in organic compounds.
2) Assimilation of simple Sulfur compounds and their incorporation into bacterial fungi and actinomyctes cells
3) Inorganic ions or compounds such as sulfides thio sulfate and essential Sulfur.
4) Reaction of sulphate and other anions to sulfide.

Sulfur Utilization

1) Producers (green plants need Sulfur in the form of sulphates (SO_4) from soil or water (aquatic plants). some plants get their Sulfur in the form of amino acids.
2) Animals get Sulfur by feeding plants or animals
3) Animals get Sulfur through food chain.

Sulfur Production: After the death of plants and animals they are decomposed by aerobic microbes like *Aspergillus neurospora* and anaerobic microbes releasing hydrogen sulphide (H_2S).

1) A part of H_2S is obtained to soluble sulphates by Sulfur bacteria like thio bacillus while Beggiatoa (colorless, Sulfur, bacteria) oxidize a part of H_2S to essential Sulfur.
2) Many industries release SO_2 in the atmosphere. As the lichens are very sensitive to SO_2 they disappear in polluted air containing SO_2.
3) Fossil fuels in burning release SO_2 into the air.
4) Volcanic emissions also add sulphates to soil and air.

The filamentous fungi (e.g., species of as per genus penicillin, micro sperm), produce Sulfur from organic substances such as methonine and cysteine, etc.

Sulfur cycle is an perfect example as Sulfur has the potential for being bound under anaerobic conditions to cations like iron and calcium to form highly insoluble ferrous sulphide (FeS) ferricsulphide (Ferric) sulpide (Fe_2S_3)or calcium sulphate ($CaSO_4$).

SO_2 is a major source of air pollution atmospheric Sulfur in the form of elemental Sulfur or H_2S or SO_2 is oxidized to SO_3 which combines with water to form Sulfuric acid which comes from land acid rain.

3.8.5 Phosphorus Cycles

Importance of phosphorus cycle: It is an important constituent of protoplasm and for metabolism of all living organisms. It is the constituent of energy in rich compounds e.g. ADP, ATP, & GTP. It is also found in plasma membrane, bones and teeth. 'P' is also required for encoding of the information in genes as it is also the component of nucleotides of n.a.

Sources of Phosphorus: The major store house of the potassium is the rock deposits. Agriculture crops contain 0.05 to 0.5% of phosphorus in their tissue. In soil 15 to 85% of total 'P' is organic. Potassium cycle is an example of sedimentary cycle having its main reservoir in insoluble ferric and calcium phosphate as rocks. 'P' is usually used in phosphate form.

Phosphorus cycle Pathway: In the phosphorus cycle the main importance comes from the weathering. Weathering of phosphorus contains rocks and deposits. In soil potassium gets released from rocks and deposits from weathering. Some plants may be added to soil by man in the form of natural fertilizer. The plants get potassium from soil especially as ortho-phosphate PO_4 ions and are then transferred to consumers and decomposers as organic phosphate through food chain.

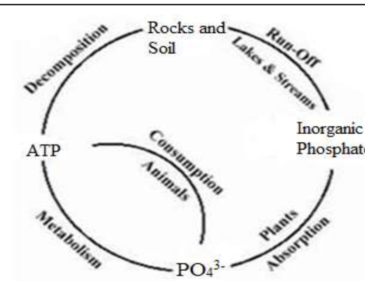


Fig 12 Phosphorus Cycle

Absorption of potassium by the higher plants is promoted by the presence of mycorhizae.

Decomposition: Potassium goes back to soil by decomposition of dead and decay organisms especially by phosphate- solubilizing bacteria.

'P' cycle is imperfect cycle as the biological process like teeth and bone formation and excretion account for considerable losses of phosphorus from the cycle.

High concentration of phosphorus in natural water causes eutrophication and pollution.

3.9 Ecosystem Control

Another important aspects of ecosystem functioning is ecosystem control, that is, how various activities I an ecosystem are well coordinated or how ecological balance is maintained in an ecosystem. It is clear now that an ecosystem is a dynamic system, wherein a lot of activities take place. For example, animals eat and in turn are eaten, moisture and nutrients flow in and out of the system, and weathers change. In spite of all these happenings the ecosystems persist and recover from the slight disturbances. This capacity of an ecosystem to self-regulate or self-maintain is called **homeostasis**. Consider grassland, when there is a drought, the growth is poor. The mice that eat the grass become malnourished. When this happens, their birth rate decreases. And also the hungry mice retreat to their burrows and sleep. By doing so, they need less food and are less exposed to predators, so their death rates decrease. Their behavior protects their own population balance as well as that of the grasses which are not being consumed while the mice hibernate. Such a mechanism is known as **feedback regulation** and is very important to maintain the ecological balance. It is the prime regulatory mechanism for the ecosystem as a whole. You may know that there are several kinds of organisms comprising an ecosystem. So all the organisms in an ecosystem are part of several different feedback loops. A feedback loop may be defined as relationship in which a change in some original rate, alters the rate of direction of further change. In the above example, we had deliberately taken a very small group of living beings that has primarily the mice and the plants. (Source: LSE Ecology 02, IGNOU)

Now we take up, another parameter of ecosystem balances. One factor that affects the stability or persistence of some ecosystems under small or moderate environmental stress is species diversity- the number of species and their relative abundance in a given ecosystem. High species diversity tends to increase long-term persistence of the ecosystem. It is because with so many different species and the linkages between them, risk is spread more widely. An ecosystem having a good variety of species has more ways available to respond to most environmental stresses. For example, the loss or drastic reduction of one species ip an ecosystem, with complex food web usually does not threaten the existence of others, because most consumers have several alternative food supplies. In contrast, the highly specialized agricultural ecosystem, planted with only one type of crop such as wheat or rice is highly vulnerable to destruction from a single plant disease or insects. Therefore, the essence of the whole discussion is that most balanced ecosystems contain many different species. The discussion so far, might have led you to conclude that the ecosystems have the ability to cope up with any disruption. You should realize that this ability is limited. Extremities like fires (destroy the landscape), over-exploitation (e.g., rampant, deforestation, mining) or excessive simplification, monoculture, plantation, crop fields) or too severe and prolonged stretch (like drought, pollution) seriously hamper the control mechanism, resulting in ecosystem degradation. The lesson is obvious. We should check and control our actions, so that, we do not overload the ecosystem.

Summary

Biogeochemical Cycle: The movement of chemical elements between organisms and non-living compartments of the atmosphere, lithosphere and hydrosphere.

Biogeography: The study of the geographical distribution of organisms.

Biomagnification: The increasing concentration of a compound in the tissues of organisms as the compound passes along a food chain

Biomass (organic matter): Total dry weight of all organisms in a particular population, sample or area; [J/m2];

Cycle: Biogeochemical cycles on a global and local scale.

Denitrification: The conversion of nitrate to gaseous nitrogen; carried out by a few genera of free-living soil bacteria.

Density: In relation to population, the number of individuals in a certain amount of space.

Disturbance: In community ecology, an event that removes organisms and opens up space which can be colonized by individuals of the same or different species.

Detritus:Primary energy source of detritus food chain is dead organic matter called detritus.

Food chain: A sequence of transfer of food energy from organism in one trophic level to those in other.

Food Web:A graphic depiction of the interrelationships by which organism consume other organism showing the complex and interlocking series of food chains.

Productivity: The rate at which biomass is produced per unit area by any class of organisms(see biomass).

Organic: Pertaining to living organisms in general, to compounds formed by living organisms, and to the chemistry of compounds containing carbon.

Organism (individual**)**: Any individual living creature, either unicellular or multi-cellular.

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Self Assessment Question

A) Multiple Choice Questions

1)Food web is a natural inter connection of food chains……….
a)on ecosystems b) in ecosystems
c) with in ecosystem d) at ecosystem
2)Which of the following trophic levels would have the largest number of individual
a) primary producers b) primary consumer
c) opoortunistic feeders d) scavenger

3)Productivity is generally expressed in terms of:

a) gm-2year-1 only
b) gm-2year-1 and tonnes per hectare
c) K cal m-2 year
d) both b and c

B) Fill in the blanks

1 Some organisms occupy …………………………….. in different food chain.

2) There is……………….reduction in available biomass,energy and no. of individual with the rise in trophic level.

3)…………….food chain begins with dead organism or dead organic matter.

4)The idea of ecological pyramid was developed by……………….in………

5)Partially upright pyramid of number is found in…………………………

6) The quality and quantity of energy flow helps to tell the…………….of life.

7) Process of nitrification involves the oxidation of ………………….into…………

Answer Keys:A) 1. c,2. a,3. d.

B)1) Different trophic Position, 2) Progressive, 3) Detritus, 4) Charls Elton, 1928, 5) Tree dominated Ecosystem, 6) Richness or Poorness and Shortness, 7) Ammonium Ion, Nitrite

C) Terminal Questions

a) Write short notes on the following:

1) Pyramids of biomass
2) Ammonification
3) Net primary product
4) Importance of phosphorous cycle
5) Basis of energy flow

b) Long answer type questions

1) What is the applicability of laws in biological energy flow?
2) What is pyramid? Elaborate its different types.
3) Describe the nitrogen cycle and also draw the daigram of this.
4) Define food chain and also differentiate between its two types.

Unit 4: Population Ecology

Unit Structure

4.0 Learning Objectives

After studying this unit, you would be able to explain:

- Demographic Parameters - Age structure, survivorship Curves, Life tables
- Types of Population

- Features of Population- size and density, dispersion
- Processes governing growth of population
- Growth Models and Time Lags
- Population Growth forms, carrying capacity and Growth Regulation

4.1 Introduction

In the previous units, you have come across with the various branches of ecology, structural and functional features of ecosystem etc. In any ecosystem, there are two components- Biotic component and abiotic component. In biotic component, we deal with different species in an ecosystem. It is not only species but number of individuals of species in ecosystem that influences the overall characteristics of the whole ecosystem. These individuals of one species form what we call population. So the population ecology is the study of populations of individual species and their characteristics in an ecosystem. The common tendency of living beings is to stay together in a suitable habitat and it is the basis of population ecology. Population ecology deals with various features of such groups. These aspects include properties of population, population's growth and regulation of population growth, each of which is essential to understand population's performance and status. Under population ecology, structure and dynamics of population are studied. Understanding population ecology is very important for planning conservation strategies. A population is a group of interbreeding individuals of a same species, occupying the same geographical area at a time. Berryman (2002) has modified this definition as "a group of individuals of the same species that live together in an area of sufficient size to permit normal dispersal and/or migration behavior and in which population changes are largely the results of birth and death processes"

4.2 Demography and demographic parameter

Demography is the study of population structure in relation to size, age, sex, natality, mortality, migration, age structure and survivorship. Population dynamics can vary drastically depending on the age structure of the population, ratio of male and females, addition of off springs through birth, deletion through death and so on. Demography is the study of the characteristics of populations. It incorporates statistical measurement of how these characteristics change over time. It is a useful tool for ecologists, economists and sociologists. In ecology it is applicable to all living beings while economists and sociologists make use of these studies only for human populations.

4.2.1. Demographic Parameters

4.2.1.1 Age Structure

Age structures define ratio or proportion of individuals in a population following under different age groups. These age groups are: Pre-reproductive, Reproductive, Post-reproductive which correspondingly can also be termed as young, adult and old. The age structure represents the population status and also helps in determining the future of the population.

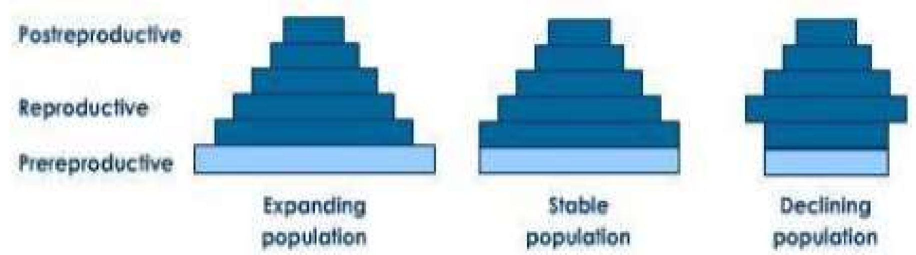

Fig.1 Different types of Age pyramids

Age structure is usually illustrated by an age pyramid, a graph in which horizontal bars represent the percentage of the population in each age group. Each age group is called a cohort. The longer a bar is, the greater the proportion of individuals in that age group. Age pyramids are useful for tracing the history of a population and for projecting future population trends. There are 3 forms of the age structure: according to which the populations can be (Fig. 1)

i. Expanding: The expanding population show higher ratios of pre-reproductive group of individual. More number of offsprings are produced than parents. It is pyramid shaped. It generally is found in lower organisms like algae, Bacteria and so on.

ii. Stable: The stable population on the other hand has almost same ratio of all the 3 age groups. Number of off springs is just equal to number of parents .The pyramid shows almost straight sides and is bell shaped.

iii. Diminishing: The ratio of pre-reproductive age group is minimum and of post reproductive is maximum in diminishing population. Number of offsprings produced is less than parents. The base of pyramid is narrow and is urn shaped.

The age structure also helps in judging the consequences of a typical type of population and if needed a strategy can be defined to take a remedial measure so that the population does not decrease.

In study of plant population demography, age structure has been included comparatively later. Determining age in plants is difficult plants show modular structure and asexual reproduction which is not dependent upon age .Uneven growth of same aged individuals also imposes difficulty, for example, trees of same age may not show exactly the same growth and at the same time, some may show same growth even if they are not of same age. Measuring girth of the stem, counting growth rings or taking account of the one cohort and then following it strictly are some parameters by which age structure in plant population is built up.

4.2.1.2 Survivorship Curves

Survivorship curves are graphical representation of a population growth form and they help in viewing the population future and status. The graph is plotted from the data of the life span and demarcating the different age groups, at different times during this life span.

The Survivorship curve is drawn by taking into account the percentage of living individuals at every age or life stage. The number of survivors (density) is plotted on vertical axis on a log scale. . Three types of graphs are obtained from different groups of plants and animals (Fig.2 &3):

Type I: It indicates high mortality rate at old age, most individuals of the population live their full life. Ex. Mammals especially human beings.

Type II: It indicates a steady mortality rate throughout the life span. Ex. Birds

Type III: It indicates high mortality in the young phase. Ex .Plants, insects and invertebrates The Survivorship curve helps in identifying the critical stage of the population or life cycle of the individuals at which mortality is high.

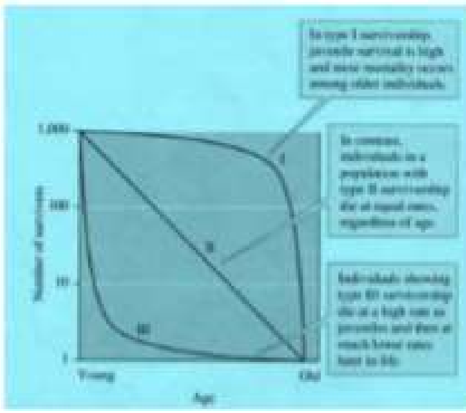

Fig.2a Types of survivorship curves with explanation

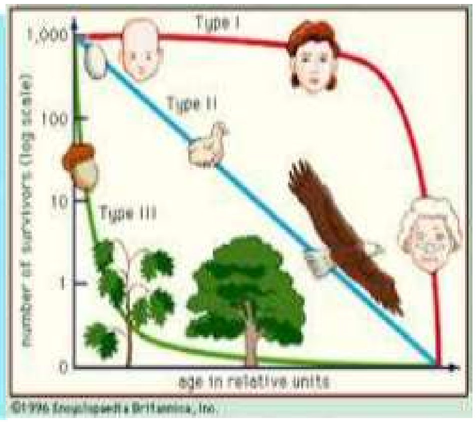

Fig.2 (b) Types of survivorship curves with examples

4.2.1.3 Life Tables

Life tables are useful devices to analyze probability of survival of individuals in a population at particular ages or to determine most vulnerable age to mortality. They are tabular form of survivorship curves and are used to determine mean expectancy of life. Life table data can provide much insight into the demographics of a population. Quantifying age-specific birth and death rates enables us to discern patterns and make predictions about the growth or decline of populations in the future. Life tables were first developed for human populations especially for life insurance companies. In ecology they were introduced by Deevey (1947). Tables are prepared by taking into account different features of the population like its age class and the proportion of the organism, surviving at a later stage, dying at a stage, total life span etc. The whole life span is divided into different segments and the number of individuals falling under that segments are termed as Cohort. The variables used to prepare a life table are:

Variables used to prepare life tables	
X	life stage or age class
nx	total number of individuals observed at start of each age class x
lx	proportion of original number of individuals surviving to the next stage or class; survivorship
dx	proportion of original number of individuals dying during each stage or class; mortality
qx	mortality rate for each stage or class
kx	"killing power;"
Fx	total fecundity, or reproductive output of entire population, for each stage or class
mx	individual fecundity, or mean reproductive output, for each stage or class
lxmx	number of offspring produced per original individual during each stage or class; product of survival and reproduction
R0	basic reproductive rate

Mainly there are 3 types of life tables. Horizontal, vertical and dynamic composite.

i. Horizontal / cohort / dynamic life tables: These are constructed by following a cohort of individuals, where all were born in short span of time, they are mostly used for short living species where generations are discrete.

ii. Vertical/time specific/Static life tables: These are constructed by sampling the population and incorporating the data on individuals all ages at a single point of time. This is not a very adaptable type because observations are short term observations.

iii. Dynamic Composite life table: This is constructed following the method of horizontal life table but the cohort is formed by accumulation of data for successive years. The dynamic life table is considered as most appropriate type.

Constructing life tables for plant populations is a difficult task. Determination of age is more difficult and it is difficult to identify separate individuals. While the "parent" plant may die, it also lives on through its propagule. Thus demographers have to deal with mortality on two levels-one for the individual plant (the genet), and one for the clones (the ramet).In case of plants, life table are helpful in studying population dynamics of plant modules such as leaves, buds and stem which shows age specific mortality. It also helps in studying the role of a particular module in the population growth. Regeneration or degeneration of these units as well as their longevity influences the performance of an individual, its competence and its productivity remarkably.

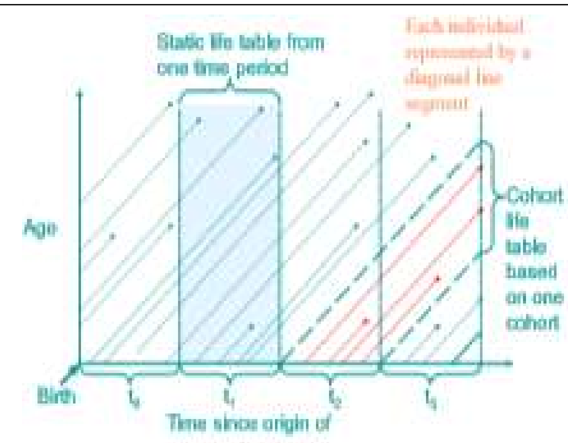

Fig 3. Diagrammatic illustration of dynamic versus static life

Life tables are important to be constructed especially when it is essential to estimate that how well a threatened or endangered species is doing. They can help in determining whether a population is able to maintain itself or whether individuals are dying and the species is going extinct.

4.3 Population and types of population

The common tendency of living beings to stay together in a suitable habitat is the basis of population ecology. Population ecology deals with various features of such groups. These aspects include properties of population, population's growth and regulation of population growth, each of which is essential to understand population's performance and status. Under population ecology, structure and dynamics of population are studied. Understanding population ecology is very important for planning conservation strategies. A population is a group of interbreeding individuals of a same species, occupying the same geographical area at a time. Berryman (2002) has modified this definition as "a group of individuals of the same species that live together in an area of sufficient size to permit normal dispersal and/or migration behavior and in which population changes are largely the results of birth and death processes"

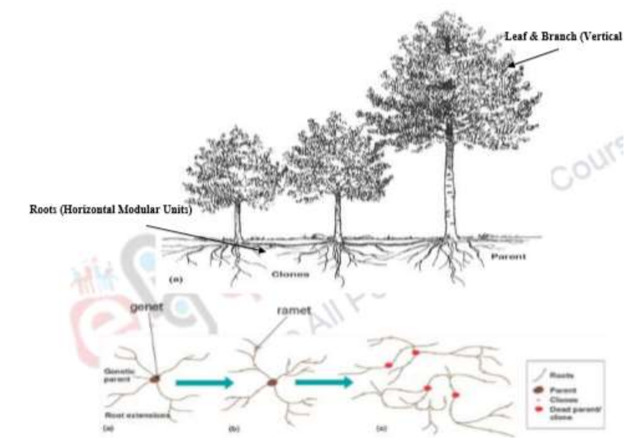

Fig.4 Horizontal and Vertical Modules of Plants (From:Smith& Smith 2001)

4.3.1 Types of Populations

Organisms which make the population may be unitary or modular depending on their reproductive pattern and thus populations are of two types:

i) Unitary Populations: In such populations, each individual are derived from zygote and thus are outcome of sexual reproduction.

Fig.5 Unitary Organisms

Identification and distinction of each individual of these populations is very easy, moreover the growth of these individuals is determinate and predictable. Most of the animal populations are unitary populations. For example, in a population of sheep it is very easy to identify and distinguish a sheep on the basis of its fixed morphological features like two legs, one head, two ears, its fur etc. and irrespective of age these features are constant and determinate.

ii) Modular Populations- In these populations single or few individuals arise from zygote and then produce other individuals/modules by asexual means. Individuals of these populations exhibit variation in their morphological features. Plants and few animal groups like sponges and corals are examples of modular population. In a plant population, no two individuals will have the same number of branches, leaves, flowers or fruits. The auxiliary buds or floral buds from where these plant parts developed are known as vertical modular units. Grasses and many plant species like pennywort are also examples of modular populations, which propagate vegetatively by means of horizontal stems or roots. Individuals which are produced by sexual reproduction are known as genets while the ones derived from genets are termed as ramet.

Fig. 6 Modular organisms

4.3.2. Features of Population

A population is a group of interbreeding individuals and thus the properties of a population are assessed as of a group, rather than that of an individual. These properties include:

4.3.2.1 Size and Density

Population size depends upon the geographical area/range occupied by the population and is the total number of individuals in that population. Density of a population is the number of its individuals per unit area. It is an important parameter of a population and is also one of the important indicators of species adaptability to that particular area. It varies with time at one area. Ecologists differentiate density in two types

4.3.2.2 Crude density

It describes the measure of density for the whole area under consideration, e.g. number of ferns in a rain forest

4.3.2.3 Ecological density

In measurement of ecological density only that area is considered which actually is occupied by the species like in previous example, most of the ferns grow on the forest floor, where humidity is abundant and only shade-tolerant plants can survive and in that case the density of ferns will be counted only for such areas and not for the other areas of forest where chances of their occurrence are nil. Ecological density concept is based on the assumption that the habitats are heterogeneous and populations do not occupy all the space of the available area, rather they occupy the area that is suitable to them. Though the ecological density measurement is ecologically realistic, in common practice measurements are done for crude density.

4.3.2.4Dispersion

It is defined as the placement of individuals and groups of individuals within the habitat they occupy and the process by which this is brought about. Dispersion includes species distribution as well as dispersal movements. Species distribution or dispersion is the pattern of distribution of individuals in a population over space (spatial) and time (temporal). Habitats consist of a spatial – temporal mosaic of many different elements. Exact location of an individual is a major determinant of its immediate fitness.

4.3.2.5 Spatial Distribution

It is distribution of individuals over a geographical area and can occur in three patterns:

- Random distribution
- Uniform or regular distribution
- Clumped distribution

A) Random distribution: It means position of each individual of a population is independent of the other and chances of occurrence of the individuals is anywhere in the given area and spacing between two individual is unpredictable. This type of dispersion is rare in nature. It can occur only where the environment is uniformly consistent and there is no strong attraction or repulsion among individuals of a population. Seed dispersal through wind may result in random distribution as chances of seed germination and seedling establishment are anywhere:

B) Uniform or regular distribution: In uniform distribution, individuals are equidistantly distributed. It generally occurs because of intraspecific competition. This competition may be for space or for a resource such as moisture or nutrients. For example, trees in a forest are spaced in a way that their canopies do not overlap aboveground and roots do not overlap belowground. Regular distribution may also occur because of allelopathy, the phenomenon in which toxic exudates released from an individual, do not allow other individual of the same or different species to grow near them. When the inhibition is towards same species, it is known as autotoxicity, alfalfa exhibits phenomenon of autotoxicity. Other example of allelopathy is black walnut; roots of black walnut produce a substance known as juglone which does not allow many plants such as tomato, potato, blueberry to grow within the root zone of this tree. Among animals, Penguins often exhibit uniform spacing by their territorial defense .Uniform distribution is rare in nature but is common in manmade systems like agricultural fields or planted forests.

C) Clumped distribution- In this type of distribution the individuals of a species are grouped in forms of patches or clumps. This distribution is also known as clustered, contagious or aggregated. It is the most common type of dispersion found in nature. It occurs because of common requirements of organism which are fulfilled at a common place/patch. It is distinctly visible in plant populations; aggregation in plants is affected by their propagative nature and their specific environmental requirements. Animal populations also show clumped distribution because of their reproductive pattern and social behavior. Co-operation, resource partitioning or protection also adds

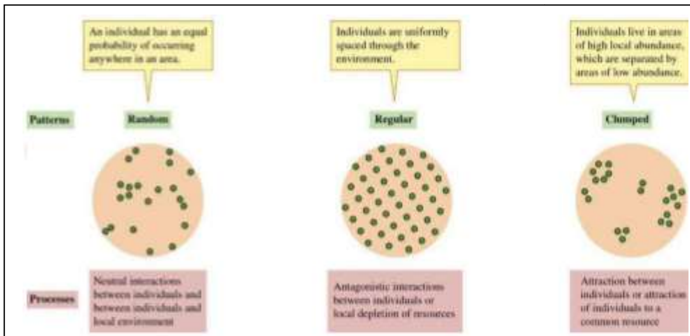

Fig 7. Distribution Patterns of Individuals in Population

to clumped distribution pattern. Clumping or aggregation increases group survival value. Clumped distribution can again be random, uniform or clumped.

The spatial distribution of plant populations is an important feature of population structure and it determines the population's ecological preferences, biological characteristics and relationships with environmental factors. In a population the distribution patterns are result of a long- term interaction between the population and environment (Gray and He 2009).

The distribution pattern of a population of a plant population differs among species, and the distribution pattern of a single species may vary in diverse habitats, it is scale dependent, for a species it may be clumped at one spatial scale and may be uniform or random at the other scale (Zhang et.al., 2012). Normally random distribution indicates homogenous environment while clumped pattern is indicative of heterogeneity and wide variation of microclimatic regions in a large scale.

The distribution pattern of species can be determined by using various methods. The Clark-Evans nearest neighbor method can be used to determine if a distribution is clumped, uniform or random. In this method the distance of an individual to its nearest neighbor is recorded for each individual in the sample, enough number (minimum 50) of distance measurements is recorded. The average distance between nearest neighbors is compared to the expected distance to get the ratio R. Values of R give idea about the distribution pattern if R=1the pattern is random, if R > 1 pattern is uniform and if R<1 the pattern is clumped.

The Variance/Mean ratio is also one such method, in this method, data is collected from several random samples of a given population. The number of individuals present in each sample is compared to the expected counts in the case of random distribution. The expected distribution can be found using Poisson distribution. If the V/M ratio = 1, the distribution is random. If V/M >1, it is clumped distribution and, if V/M<1, the population is evenly distributed. Test of significance has to be applied in both the methods. The point pattern analysis method of Ripley can also be used to study distribution pattern as well as interspecific relationships of populations at different scales ,it is especially important in plant population studies (Perry et.al,2006)

4.3.2.5 Temporal Distribution

It deals with pattern of population distribution over time. The scale of time may be a day, a season, a year or so on. The circadian movements of planktons, change in type of blooming flowers in an area and visit and return of migratory birds, are examples related to temporal dispersion. These examples clearly indicate that status of population at a place changes with time.

4.3.2.6 Dispersal

Dispersal includes movement of individuals or their offspring's/ propagules away from their originally occupied area to a new habitat. It is movement of organism beyond its distribution limit. Most of the organisms follow this process at some stage of their life. The process is important for their survival, growth and reproduction. It also helps in widening the distribution range of the species, as it leads to colonization of new areas. Lack of dispersal among populations impacts a species over a long time, if the species does not spread to newer areas chances of it becoming endemic rise. It is fundamental process of biogeography.

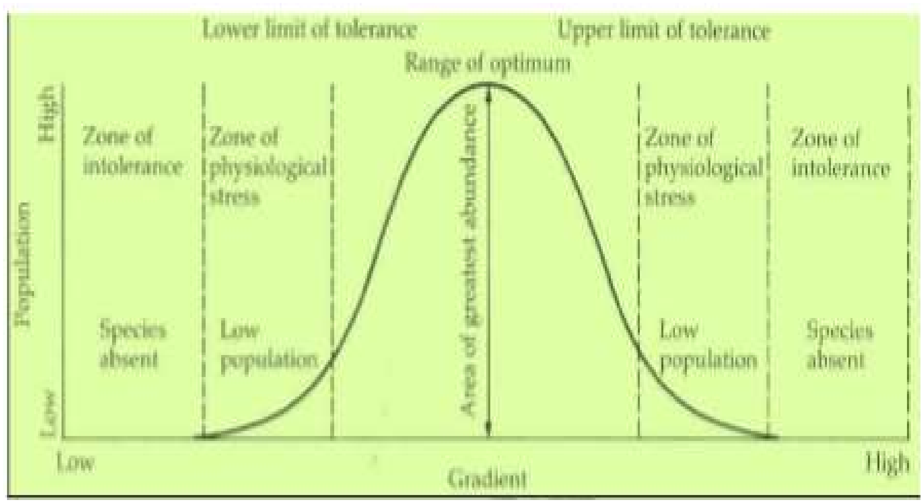

Fig. 8 Tolerance limits for species distribution

(From Smith & Smith 2001)

Dispersal, along with natality and mortality, regulates population growth, and plays an important role in evolution through mixing of genes between populations. Successful Dispersal depends on "long distance" transport, withstanding unfavorable conditions during travel and upon early arrival and establishing a viable population.

The distribution of species is ruled by Shelford's law of tolerance according to which first the presence and then the success of an organism depend on the completeness of a complex of conditions, each organism, whether the individual or the species population, is subject to an ecological minimum, maximum, and optimum for any specific environmental factor or complex of factors. The range from minimum to maximum represents the limits of tolerance for the factor or complex. Efficient dispersal and successful establishment decide the geographical distribution of species, consequently putting them into category of rare, endemic or ubiquitous species.

a) Dispersal movements: Movement of organisms or their propagules involves different ways viz.: Immigration - movement of new ones into a population leading to increase in population size. Emigration - movement of offspring's out of a population leading to decrease in population size. Migratio-periodic movement into or out of a population leading to temporary fluctuations in population size.

b) **Dispersal Mechanisms:** They are of two types active dispersal and passive dispersal.

- **Active Dispersal:** It is observed in mobile animals which have potential capacity to move to distant places, the degree of dispersal varies with species as well as with age within a species .These animals are known as vagile animals. Strong fliers like many species of birds, bats and large insects and large aquatic animals are examples of such vagile animals. The Monarch butterfly *(Danaus plexippus*) exhibits an ideal example of active dispersal, it is a highly vagile insect, capable of flying hundreds to thousands

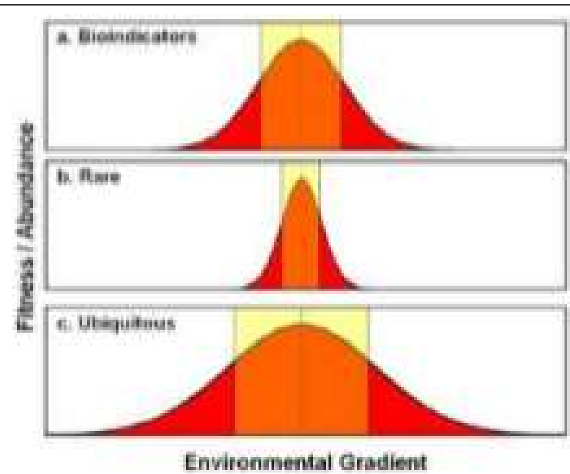

Fig. 9 Range depiction of Species

of kilometers moving from north to south America, in different seasons, in its journey it reproduces and the returning individuals are new offspring.

- **Passive Dispersal:** Plants and some animal groups like corals are not mobile and their dispersal is through their propagules (disseminules) ,these propagules in turn are dispersed by specific dispersal agents, , like wind, water, other animals etc. Such a dispersal is known as passive dispersal and the organisms as pagile.

Plants disperse through their fruits, seeds, spores etc. Special modifications are observed in these disseminules which help them to successfully disseminate via respective agent. Dispersal of winged fruits by wind and of hooked or sticky seeds via other animals are examples of this phenomenon. The major factors that influence dispersion patterns of population are :

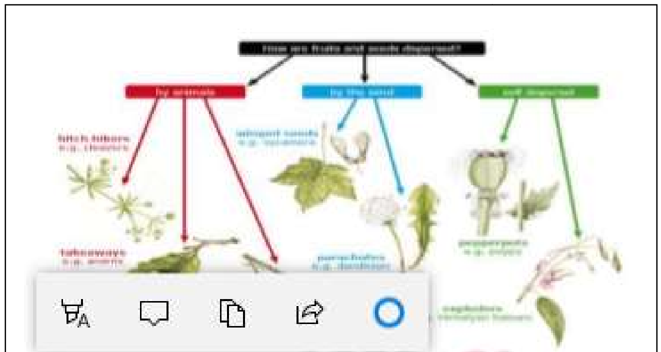

Fig. 10 Dispersal Adaptations in plants

1. Edaphic and climatic features of the habitat
2. Impact of intra- and interspecific competition
3. Reproductive pattern of the population
4. Social behavior and
5. Dispersal movements.

c) Barriers to Dispersion: Limitations are imposed on dispersal of a species by various types of barriers ,there are physical barriers like drastic change in nature of habitat (e.g. land to water),physiological barriers like change in temperature range to which a species is not accustomed or anthropogenic barriers like construction of buildings ,roads etc. which block the dispersal. Successful dispersal depends on efficient transport and successful establishment. These barriers modify the level of dispersal and consequently exert effects on population dynamics and genetic structure.

4.3.2.7 Cimate change and Dispersal

Dispersal processes are strongly affected by climate change and assessment of this is very essential for visualizing status of a species' population. It is the major decisive factor to decide the geographical range of a species because of its implications in the abilities of a species to cope with global environmental changes either in resisting reductions in available suitable conditions or in exploiting expansions in those conditions (Gaston, 2009).Climate change is posing a great impact on species range and ecologist are paying immense attention to it. Brooker et.al. (2007) have suggested that dispersal ability and species interactions are important biological processes useful in range modeling of a species.

4.4 Population Growth Regulations

Populations are dynamic entities, the properties of populations change all the time, and the rate of change can vary from very low to high. Even in populations that do not change in density, the individuals change and are replaced. They take birth, grow, reproduce and die. The changes taking place during life span of individuals are not same for all, the performance and behavior changes more, when they are in groups. The growth of a population is dependent on many such changes. Processes like natality, mortality immigration and emigration are direct causes for the changes in the population's dimensions, composition and dynamics. Studying changes in populations' dimensions helps in predicting future changes in population sizes and growth rates. As the response varies with species, these studies help in predicting future compositional changes in community structure. Population growth studies of invasive and pathogenic species help in their management and eradication. Population growth studies help in predicting size of population to be achieved in due course of time.

4.4.1 Processes governing growth of population

The growth depends upon four important processes which are: Natality, Mortality, Immigration and Emigration. Among the four governing processes of population growth, natality and mortality are related to life history strategies while immigration and emigration are dispersal movements.

4.4.2 Natality

It is the birth rate and is the prime factor leading to addition of new individuals to the population. It is also known as fecundity. The birth rate of the population is again influenced by various factors like type of species, environmental constraints or conditions and the number of reproducible individuals. It is an expression of the production of new individuals in the population. Natality is of two types:

i) Absolute/Potential/ Physiological natality: The maximum number of individuals that can be theoretically produced per individual under ideal environmental conditions is called as absolute natality. It is constant for a given population and expresses its biological limit. The absolute natality is calculated under conditions when there is no constraint upon the process; wild populations hardly reach this limit.

ii) Realized/ Ecological Natality: The amount of successful reproduction which actually takes place in due course of time is known as realized natality. It is influenced by environmental conditions, resource availability and density of population. The natality may also be expressed as specific natality that refers to population increase under specific conditions. It is not constant for a given population. Natality rate is expressed in two ways crude birth rate and specific birthrate. Crude birth rate expresses total population growth per unit time, while specific birth rate is in relation to a specific criterion. Specific birth rate is used in calculating natality rate in animal populations, where it is expressed as an age-specific schedule of births. This is done by counting number and age classes of females present in a population. By calculating specific birth rate, the results are seen in an age specific schedule of births i.e. the number of offspring produced per unit time by females in different age classes. It is also referred as fecundity in demographic studies. The expressions of natality are:

$\Delta Nn / \Delta t$= Absolute/ crude natality/birth rate

$\Delta Nn / N \Delta t$= specific natality/ birth rate i.e. the number of new Individuals added / unit time/ unit population

N = Total population or only the reproductive part of the population

Nn = New individuals added to the population

Δt = time lapsed during change in population

In plant populations determining natality is more difficult because various factors make it difficult to measure. Fluctuation in quantity of seed production, year to year and age class to age class are such factors, dormancy and unsuccessful germination also make it difficult to get a clear estimate of natality in plant populations.

4.4.3 Mortality

It refers to the death of individuals in a population and is responsible for decrease in size of population. It is also of two types:

i) Minimum / Physiological Mortality/ Physiological longevity: When the individuals of the species attain full maturity and die according to their life span, their mortality is described as physiological mortality.

ii) Ecological / Realized Mortality: When the death rate is influenced by various factors like unfavorable conditions, lack of resources, competition or any epidemic, the mortality rate may increase and it is known as realized mortality.

Natality and Mortality both are species specific but the ultimate outcome is influenced by other pressure also. There are intrinsic and extrinsic factors that control natural mortality rates and these factors are linked with individual metabolism (McCoy &Gillooly, 2008)

4.4.4 Immigration

It is the movement of new ones into a population leading to increase in population size.

4.4.4Emmigration

It is the movement of offspring's out of a population leading to decrease in population size. These processes are very dominant and can be easily calculated for animal populations while in case of plant populations these processes are not distinctly visible. In Plant Population seeds or propagule dispersal play an important role in these processes especially in emmigration.

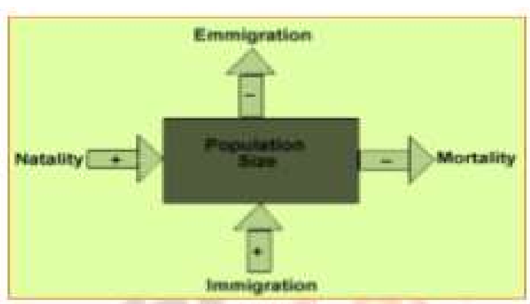

Fig. 11 Influence of natality, immigration, mortality and emigration on population

The Influence can be expressed as:

$Nt = N0 + B - D + I - E$

Where

N0 = the population size at some arbitrary starting time (time zero)

Nt = the population size at some future time *t*

B = Birth rate / Natality

D = Death rate/ Mortality

I = Immigration

E = Emigration

4.5 Growth Models

Two most significant models of population growth based on reproduction of organisms are exponential and logistic models .Former is for situation where resources are essentially unlimited and therefore individuals do not compete, later is for situations where there are limited resources and therefore members of the population must compete for these resources.

4.5.1 Exponential model

It is associated with the name of Thomas Robert Malthus (1766-1834) who first realized that any species can potentially increase in numbers according to a geometric series. Main parameters to be considered are:

N -- the population size

N0 -- the population size at starting time (time zero)

Nt -- the population size at some future time t (where t can have any positive value)

When the ratio of the population size in two adjacent time periods (for instance t =0 and t = 1) is taken, we obtain the factor by which the population increases during one unit of time, we call this factor λ. Thus:

$$\lambda = Nt/ N0$$

If a population increase is double in one unit of time then λ is 2; if tripled then λ is 3 and so on. When population remains stable λ = 1 that means Nt=N0, if increases λ > 1 and Nt>N0 and if decreases λ<1 and Nt< N0.When the rate of change of a population's size has to be calculated we can state that:

$\Delta N / \Delta t = B+I-D-E$

Where ΔN =Difference in population size in a time duration

Δt =Difference in time

If we assume that: I = E the equation will be

$\Delta N / \Delta t = B - E$

If B is replaced by b i.e. the birth rate for short time interval and D by d i.e. the death rate for a short time interval ,b and d will be instantaneous birth and death rates respectively which are determined as b=B/N and d=D/N. In situation where time interval is very short and instantaneous rates are to be calculated Δ is replaced by a derivative d and the equation will be modified as

$dN/dt = bN- dN =(b-d)*N$

in the equation (b-d) is net addition of individuals and indicates the instantaneous rate of increase (r), putting this value in it, the equation will be:

$$dN/dt = r N$$

When t is large and exponential growth has to be calculated the equation used is:

$$Nt = N0*exp(r-t) = N0^{ert}$$

There are three possible outcomes of this model viz.1. When r = 0, population will not change 2.when r>0,population will grow very fast and 3.when r < 0 population will decline suddenly. Exponential model assumes that all individuals of the population have same reproductive potential and there is no age structure, reproduction is continuous and resources are unlimited. There are different versions in which growth rates are expressed like

$rN = \Delta N / N \Delta t$ i.e. Specific Growth Rate

$rN = \Delta N / \Delta t \times 100$ i.e. Percentage Growth Rate

a version of r is r_o/r_{max} that is called as intrinsic rate of increase and is a measure of biotic potential of the population The difference between r_{max} and actual r gives measure of environmental resistance. The exponential growth is exhibited by short lived species like microbes, annual plants etc.

4.5.2 Logistic Model

The population growth is under influence of many factors and thus there are limitations on the population growth. The exponential equation is applicable till the situations are unlimited. e.g. r is constant (rate of growth) and N does not decrease, enrollment is same and there is no immigration and emigration, but in nature it is not possible and to predict growth of population under limitations Logistic model was developed by Belgian mathematician Pierre-Francois Verhulst in 1838, who suggested that the rate of population increase may be limited, by population density. An identical model was proposed by Raymond Pearl and I.J.Reed in 1920 the logistic model is now knowns as Verhulst – Pearl logistic model. The model proposes that when a population starts growing, resources are ample but as the density increases, competition for resources arise and gets intensified with further increase in density. As a result population growth rate declines with population numbers, N, and reaches 0 when N = K. Parameter K is the upper limit of population growth and it is called carrying capacity It is defined as the maximum number of individuals of a certain population that can survive in a given habitat. It is assumed that any number of individuals beyond K simply cannot survive -- either they die or they immigrate to a better place.The dynamics of the population under this situation is described by the logistic equation which is a differential equation:

$$dN/dt = rN(K-N/K) = rN(1-N/K)$$

The (1-N/K) is the unutilized opportunity for population growth. Logistic model has two equilibria: N = 0 and N = K. The first equilibrium is unstable because any small deviation from this equilibrium will lead to population growth. The second equilibrium is stable because after small disturbance the population returns to this equilibrium state. The two ecologically important processes, reproduction and competition are involved in the logistic model .Both of these processes are density dependent.This type of growth is exhibited by long lived species and is mostly observed in established systems.

4.6 Time Lags

The logistic equation suggests that the populations function as a system which is regulated by positive and negative feedback. The positive feedback is mostly by resources and they stimulate the growth while the negative feedback is brought about by competition as the N approaches K the density dependency works. Even these feedbacks do not work smoothly and many a times K is not achieved and this occurs because of certain lags. The two important lags are:

4.6.1 Reaction time lag ‘w’

This was denoted by Kreb 1985. It is the lag between environment change and corresponding change in the rate of population growth, including this in logistic equation the equation is modified as

$$dN/dt = rN\ (K- N\ (t-w)/K)$$

4.6.2 Reproductive time lag ‘g’

It is the lag between environment change and consecutive change in the derivation of reproductive maturity, incorporation of this in the equation modifies equation as

$$dN/dt = rNt-g\ \ (K- N\ (t-w) / K)$$

both these time lags result in fluctuation of population growth and bring rise and fall from K.

4.7 Population Growth Regulations

Population growth studies help scientists to understand what causes changes in population size and growth rates. Studying how and why populations grow or decline is important to know as it helps in predicting population’s fate in future. It also helps in understanding how organisms interact with each other and with their environments. Impact of changing environment can be assessed, once we know its influential role on the population growth. Understanding population growth is important for predicting, managing, monitoring, and eradicating pest and disease outbreaks, in biodiversity conservation and in knowing fate of an invasive species. Population growth forms, strategies and regulations are important aspects of population growth studies.

4.7.1 Carrying Capacity

What is carrying capacity? In ecology, the carrying capacity in a particular habitat or ecosystem refers to the maximum number of individuals (of that species) that the environment can carry and sustain under the available resources. In other words, it is the maximum load an environment can bear with. In this, the physical features present in the environment act as limiting factors (e.g. food, water, competition, etc.). Thus, the population size can be expected to depend on these factors. In essence, food availability is an important variable as it affects the population size of the species. It does so in such a way that if food demand is not met for over a given period of time the population size will eventually decrease until the resources become adequate. By contrast, when food supply exceeds the demand then the population size will soon increase and will stop increasing when the source is consequently depleted. Carrying capacity may also be defined as the population size at which the population growth rate equals zero.

4.7.2 Population growth modals

The growth of population is measured as increase in its size over a period of time and populations show characteristic patterns of growth with time. These patterns are known as population growth forms. There are two basic population growth forms:

J - shaped population growth form: In this growth form, the population grows exponentially and after attaining the peak value, crashes abruptly. (Fig.12)

The equation will be: $dN/dt = rN$; with the definite limit of N (the number of individual)

S -shaped population growth form: This form shows sigmoid growth curve, where population size changes against time, the population shows an initial gradual increase

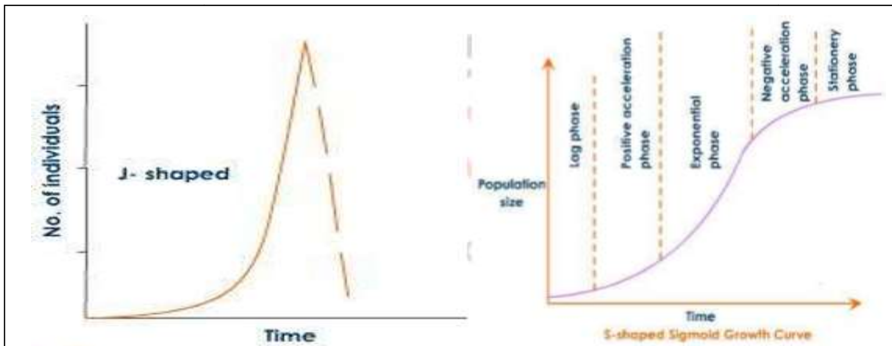

Fig. 12 J&S shaped curves

in population size, followed by an exponential increase and then a gradual decline to near constant level (Fig. 12). Sigmoid growth curve is formed of five phases:

i. Lag phase - Period where individuals adapt to the new environment.

ii. Positive acceleration phase - Period of slow increase in the population

iii. Logarithmic or exponential phase - Period of rapid rise in population due to availability of food and requirements in plenty and no competition. With abundance of resources the population expands exponentially into the habitat.

iv. Negative acceleration phase /Transition Phase - Period in which there is a slow rise in population as the environmental resistance increases. Resources are reduced and become limiting in the growth of the population. As the population grows, there will be increased competition between the individuals of that population for the same resources, resulting in survival of some and elimination of others, the rate of population increase is slow. Along with the reduced rate of population growth there will be selection (survival and reproduction) of those individuals within the population which are best suited to explore the resources.

v. Stationary phase/The Population plateau - where the population remains constant over considerable long time (may be for generations). Constancy in population growth indicates that Natality + Immigration = Mortality + Emigration. At this point in time the population size is determined by the carrying capacity (K) of the habitat.

4.7.3 Growth regulation

Populations experience many impositions during their growth which try to regulate or limit their growth. There are two basic categories of population regulating factors: Density dependent factors and Density independent factors.

a) Density dependent regulation

Density dependent effects influence a population in proportion to its size, as the size of the population increases, effect intensifies. This is due to the fact that individuals are competing for limited resources. Exhaustion of these resources by increasing density of population changes the carrying capacity, if resources increase and correspondingly the population size. Density can also increase the mortality rate when overcrowding leads to physiological stress and decreased natality. Both these processes try to bring back the population at equilibrium. Intra-specific competitions play very important role in growth regulation and are solely density dependent. In plant populations especially in tree stands, self-thinning is a common phenomenon. Clark (1990) demonstrated that even-aged stands show density dependent mortality and there is relationship between individual plant growth and population mortality.

b) Density independent influences

Density-independent factors are those that affect the population in the same proportion irrespective of the population size. Many natural disasters such as storms, hurricanes, droughts or floods affect the population equally. These factors affect but not regulate populations.

References

NOC:Forests and their management: A Project Funded by Ministry of Human resource Development, Govt. of India

Unit 5: Community Ecology

Unit Structure

5.0 Learning Objectives

After completing this unit you shall be able to:

- Define community and community ecology
- Discuss the concept of community ecology
- Explain species interaction
- Discuss the vegetation analysis
- Discuss biomass, productivity
- Explain the forest soil development

5.1 Introduction

In the previous units you have studied that every ecosystem has two main components – one biotic component (living beings) and another abiotic component (non-livings). Among the biotic components are included plants, animals, insects, microbes etc whereas in abiotic components are included all the mom-living materials such as gases, soil, minerals, water etc. In any ecosystem, species do not live in isolation but live in associations. In other words, we can say that individuals of many species live together and are dependent upon one another for many services or requirements. In other words many populations occupy the same space and remain in some sort of relationship with one another. These populations occupying same space form what is known as community. Communities in an ecosystem may be differentiated as plant communities, animal communities or microbial communities. The communities have certain characteristics and study of these characteristics forms what is known as community ecology.

In this unit, we will study bout community and characteristics of communities.

5.2 What is community?

In nature different kinds of organisms occur in association with each other, sharing the same space or habitat. In a field different kinds of grasses, insects, worms, birds and mammals interact in various ways. Grasses provide food for certain insects and mammals; insects provide food for birds; and birds prey on small mammals and worms. The various kinds of organisms in this field, thus, constitute an assemblage or groups known as community. Similarly a forest, desert, pond, marsh and stream are also examples of natural communities.

Like the concept of ecosystem that can be applied to any scale similarly a community can be large like a forest community or rotting log can have small communities of fungus or insects like termites or even mice. Similarly, a large number of microorganisms within the gut of termite that occurs in the rotting log of wood, also constitute a community or even in human intestine bacterial communities do occur.

5.3. Characteristics of Communities

All communities whether plant or animal have their own characteristics which are quite different than the characteristics of individual components of the communities.

The characteristics of the communities are broadly categorized in two categories:

- **Analytical characteristics**
- **Synthetic characteristics**

Among synthetic characters are included Presence and Constancy, Fidelity, Dominance, Physiognomy and Pattern, Frequency, Importance Value Index (IVI), Species Diversity.

5.4 Analytical characteristics

Analytical characteristics are those features of community which can be observed or measured directly in each aspect. Analytical characteristics are again subdivided into two sub-types as follows:

A) **Qualitative characters:** It includes composition, stratification of vegetation, periodicity (Phenology), vitality, vigour, life forms and sociability (gregariousness) and

B) **Quantitative characters:** It includes characters such as population density, cover, height and biomass.

It is easy to measure the quantitative characteristics whereas qualitative characteristics are difficult to measure.

5.4.1 Qualitative characteristics

Quantitative characteristics of a community are those which can be measured. The important quantitative characteristics of communities are as follows:

- Composition
- Stratification of Vegetation
- Periodicity (Phenology, Aspection)
- Vitality and Vigour
- Life Forms
- Sociability (Gregariousness)

i) **Composition:** One of the important qualitative characteristics of a plant community is its composition. This broadly refers to the kind of species occurring in a plant community. Here, we would like to make a point. Most communities are named after the dominant plant species that occur there.

ii) **Stratification**: Stratification of vegetation is another important feature of plant communities. By stratification is meant that plant species of different height occupy vertical space as if there are clear vertical layers. The composition of vertical strata is different in different plant communities. It usually occurs because of life forms such as trees, shrubs, herbs and mosses differ in their requirements and ecological amplitudes with regard to light intensity, temperature, moisture conditions, soil and biotic factors. In a tropical rain forest, vertical stratification is very clearly seen. In addition to the different layers described above, there are lianas and climbers that twine around the .trees. A forest with four or five strata can support a greater diversity of life forms as compared to a grassland with only two strata. Stratification is also seen in the underground plant parts, that is, the root and the rhizome systems. Root systems of different plant species tap moisture and nutrients from different soil depths. This enables them to avoid competition and too much exploitation of a particular soil layer.

iii) **Periodicity (Phenology)**: Periodicity refers to occurrence of more or less defined change over a period of time in the morphological appearance various plant species. It refers to the study of seasonal changes in the community, that is, the periodic phenomena of organisms in relation to their climate. Periodicity is a strongly fixed character in plants. Different species of plants have different periods of seed germination, vegetative growth, flowering and fruiting, leaf fall, seed and fruit dispersal, and dissemination of seeds. In other words, phenology is the calendar of events in the life history of a plant. The phenology of different species present in a community may differ from each other significantly. It is these phenological changes which give a definite look to a community.

iv) **Vitality and Vigour:** Vitality is related to the condition of a plant and its capacity to complete its life cycle, while vigor refers more specifically to the health or development within a certain stage. We can say that a seedling or a mature plant may be vigorous or it may be feeble or poorly developed. A number of criteria may be used in determining the vigour of plants such as the rate and total amount of growth especially in height; rapidity of growth renewal in spring or following mowing or grazing; area of foliage, colour and turgidity of leaves and stems; degree of damage caused by diseases or insects; time of appearance and number and height of flower stalks; rate of growth and extent of root system, appearance and development of new stems and leaves. For classification of vitality the following groups as given by Daubenmire (1968) are used :

V - Plants whose seedlings die

V2 - Seedlings grow, but unable to reproduce

V3 - Reproduce only vegetatively

V4 - Reproduce sexually, but are uncommon

V - Reproduce sexually and grow regularly

v) **Life Forms:** The form and structure of terrestrial communities are determined by the nature of vegetation. Vegetation may be classified according to growth form. The plants may be tall or short, herbaceous or woody, evergreen or deciduous. We might speak of trees, shrubs, and herbs, and then further sub-divide these categories into needle-leaved evergreens, broad-leaved evergreens, broad-leaved deciduous, shrubs, ferns, grasses and so on and so forth. A more useful system was proposed by a Danish botanist, Christen Raunkiaer in the year 1903. In this system, instead of considering plants' growth form, he classified plants by life form, the relation of their height above ground to their perennating organ. A perennating organ is one that survives from one growth season to the next, remaining inactive over winter or dry periods. Perennating tissue is the embryonic or meristeimatic tissue of buds, bulbs, tubers, roots and seeds. Raunkiaerrecognised five principal life forms that we shall discuss below :

a) Phanerophytes,

b) Chamaephytes,

c) Hemicryptophytes,

d) Cryptophytes, and

e) Therophytes

a) Phanerophytes (Phaneros= visible): The phanerophytes, the perennating buds are present on erect, negatively geotropic shoots, much above the ground. These buds are naked or least protected and are exposed to varying climatic conditions. These life forms include trees, shrubs and climbers. These are I generally common in tropical climates, and their number progressively decreases when we move from tropics to Polar Regions.

b) Chamaephytes (Chamai= on the ground): The perennating buds and organs are borne on shoots close to but just above the ground. The buds receive protection from fallen leaves and snow cover. These life forms include creepy, woody plants and herbs. These plants are typical of cool dry climate that is the arctic and alpine regions.

C) Hemicryptophytes (hemi =partly; kryptos= hidden): Here the perennating buds or organs are situated at the soil surface where they are protected by soil and fallen leaves. These include herbs growing in rosettes and tussocks. These plants are found in cold, temperate zones, where aerial parts die at the onset of unfavorable conditions. Most of the biennial and perennial herbs come under this category.

d) Cryptophytes (kryptos= hidden): Perennating buds or shoot apices are buried in the ground at a distance from the soil surface that varies in different species. The buds are buried where they are protected from freezing or drying. Examples are tuberous and bulbous herbs. Many of these are found in arid zones. Hydrophytes are the cjptophytes whose buds are found below the water surface.

e) Therophytes (theros=summer): These are annual plants of the summer season or of the favourable season. They complete their life cycles in a single favorable season and overwinter as seeds, which remain dormant during the unfavorable periods. These plants complete their life cycle within few months only and occur commonly in deserts and grasslands.

The relative proportion of different life forms in vegetation, tells us about the geo-climatic conditions. For example phanerophytes comprise about 60-90% of the flora of humid tropics, Chameophytes are characteristic of arctic and alpine regions, and hemicryptophytes (more than 50% species) make a major part of cool temperate regions.

vi) Sociability (Gregariousness): Sociability refers to the nature of grouping of individual plants, that is, whether they grow singly, in patches, in colonies or evenly intermixed. This is dependent upon the life form and vigor of the plants, habitat conditions, and competitive and other relations between the individuals. Sociability expresses the degree of association between species. The five sociability groups given below are used for rating the sociability of species:

S1 - Plant (stems) found quite separately from each other, thus growing singly

S2 - A groups of 4-6 plants at one place

S3 - Many smaller groups at one place

S4 - Several bigger groups of many plants at one place

S5 –A large group occupying large area

5.4.2 Quantitative Characters

Among the quantitative characters are included those characters which can be counted or quantified by some formula. Among the important quantitative characters are:

- Population Density
- Cover (area occupied)
- Height of Plant
- Biomass of Plants

i) **Population Density:** Density denotes the average number of individuals of a particular species in a unit area. In other words, it represents the numerical strength of a species in a community. A study of density makes it possible to have accurate and direct comparisons of the abundance of species between different areas. Density also gives an idea of the degree of competition between the members of the same species as well as of one species with the other. It is calculated as follows:

$$Density = \frac{\text{Total number of individuals of a species in all the sampling units}}{\text{Total number of sampling units studied}}$$

The value thus obtained is expressed as number of individuals per unit area.

ii) **Cover:** Cover or specifically herbage cover refers primarily to the area of ground occupied by the leaves, stems and inflorescence i.e. the above-ground parts of the plants, as viewed from above. Each layer of vegetation is considered separately, since overlapping usually occurs, so that a tall plant is rated apart from one growing under it. Basal area, refers to the ground actually penetrated by the stems. This can be readily seen when the leaves and stems are clipped at the ground surface. Herbage area or vegetation cover is an important aspect of vegetation study in understanding the nature of a community particularly in evaluating quantitative relationship between species. When the herbage covers of individual plants are in lateral contact and form a continuous cover, the vegetation is said to be closed. When the vegetation cover has gaps, which could be colonized by other individuals, it is said to be open, and if the amount of space is much greater than that occupied by plants the term sparse is used. Periodic record of herbage cover provides extremely valuable information in determining the nature and trend of changes in a community. It shows the basal area over a considerable period of time changes.

iii) **Height of Plants:** The height of a plant is a very good indicator of their general performance and therefore, can be employed as a criterion of the success of a species in various habitats. It can also be used as a measure of favourable environment and is much used by foresters as an index of site quality for various species of trees.

iv) **Biomass of Plants:** Weight is one of the most important quantitative characteristics of plants. Quantitatively growth is best measured on the basis of dry weight, since it expresses the total mass of the vegetation or the biomass. Biomass of plants can be measured separately for the above ground plant parts and for underground parts, i.e., by drying them at 80°C in an oven. The data from such studies provide us valuable information about the yield of that species. For example evaluation of the above ground plant parts that are useful provide an accurate idea about the availability of forage in a community.

5.5 Synthetic characters

Among the synthetic character of community are included following:

- Presence and Constancy
- Fidelity
- Dominance
- Physiognomy and Pattern
- Frequency
- Importance Value Index (IVI)
- Species Diversity

i) Presence and Constancy: Presence and constancy refer to how uniformly a species occurs in different stands in a community. For example, when a species is found in 15 out of the 20 stands in a community the presence or constancy is 75 per cent. The terms presence and constancy are used in more or less in the same sense but they are however not synonyms. The term constancy is used when equal, measured sample areas are used for study, and presence is used when the area of sampling unit varies from stand to stand and especially when it is not measured. Many times, the sampling units do not have the same area, because of the nature of vegetation, as for example, small gular stands in rock crevices or on sand deposits along a stream.

Species in a community can be classified into five classes of constancy, according to the percentage of occurrence in sampling units or stands. These classes are:

Class I - 1-20% of the sampling units of a community

Class II - 21-40% of the sampling units of a community

Class III - 41-60% of the sampling units of a community

Class IV - 61-80% of the sampling units of a community

Class V - 81-100% of the sampling units of a community

The species that occur in over 80-90% or in more sampling units are called constant species. These species are important as they characterize and help to distinguish a community type.

ii) Fidelity: Fidelity refers to the degree to which a species is restricted in its occurrence to a particular kind of community. The species with low fidelity occur in a number of different communities, and species with high fidelity are restricted to few or only one community. The following five fidelity classes can be recognized:

A) Characteristic species (Character, faithful species)

Fidelity 5 - Exclusive, completely or almost completely restricted to one kind of community **Fidelity 4 -** Selective, occurring most frequently in one kind of community, but also, though rarely, in **Fidelity 3** other kinds

- Preferential, occur in more or less abundantly in several kinds of communities but with optimum conditions for abundance and vitality in one kind of community.

B) Companion Species

Fidelity 2 - Indifferent, occurring without pronounced affinity or preference for any particular kind of community

C) Accidental Species

Fidelity 1 - Strange, rare and accidental intruders from another community or relicts from an earlier stage of succession

You have seen that some species cannot grow or are not found in other communities, because species differ in their ecological amplitude or in their capacity to tolerate a wide range of ecological conditions. Some species are able to associate with others, whereas others are not.

Fidelity and constancy are independent characteristics. Fidelity being concerned with the occurrence of a species in different kinds of community types, constancy with various stands in the same community. Fidelity is primarily a sociological quality. A species which has high fidelity or belonging to class 5 is known as indicator species

iii) Dominance: It is a characteristic of vegetation which expresses the predominating influences of one or more species in a stand so that the population of other species is more or less repressed, or is reduced in number and vitality. Dominants are those species which are highly successful in a particular habitat. Cover and population density are the chief qualities determining dominance, but parameters like frequency, height, life form and vitality are also important. The dominants exercise a controlling influence in the habitat while modifying the microhabitat which permits the growth of many different species which otherwise cannot survive in the absence of dominants.

iv) Physiognomy and Pattern: Physiognomy is the general appearance of vegetation as determined by the growth form of dominant species. It may be considered a synthetic character because the appearance is based on a number of qualitative characteristics such as the kind of dominant species, life form, population density, cover, height, sociability, stratification, and association of species. For example, if we look at a community where large trees are dominant and some shrubs are also present we would immediately say that it is a forest. Similarly on the basis of appearance one can identify a community as grassland or desert community.

Pattern refers to whether the vegetation occurs in the form of groups or clumps of individuals or in any other non-random arrangement

v) Frequency: This term refers to the degree of dispersion of individual species in an area, and is usually expressed in terms of percentage. Frequency can be studied by sampling the study area at several places at random or in a desired pattern, so that the site is covered adequately and the names of the species that occur in each sampling unit are recorded. Let us now see how frequency of a species is determined. Consider a species that occurs in five sampling units out of a total of 20 sampling units, then its frequency (F) is 25%. It is calculated by the following formula:

$$Frequency = \frac{No.of\ sampling\ units\ having\ the\ species\ X\ 100}{Total\ number\ of\ sampling\ units\ studied}$$

A species most abundantly spread all over the area will have chance of occurring in all the sampling units, and therefore, its frequency will be 100%. A poorly dispersed species, with large number of individuals aggregated in one place will have a chance of occurrence in only a few sampling units and its frequency value will be low. Thus, a high frequency value shows a greater uniformity of its dispersion. It is important to note that in determining the frequency, the presence or absence of a species in the sampling units is needed and not the number of individuals of each species. This is how it can be differentiated with density where the number of individuals per unit area are needed. Frequency of a species relative to other species in a community is called relative frequency. It is calculated as:

$$Relative = \frac{\text{Frequency oi a species } X\ 100}{\text{Total frequencies of all species}}$$

vi) Importance Value Index (IVI)

In any study of community, the quantitative value of each of the frequency, density and cover has its own importance. But the total picture of ecological importance cannot be obtained by any one of these alone. For instance, frequency gives an idea as to how a species is dispersed in an area but we do not get any idea about its number or the area covered. Density gives an idea about the numerical strength and so on. To have an overall picture of ecological importance of a species with respect to the community structure, the percentage values of the relative frequency, relative density and dominance are added together and this value out of 300 is called the Importance Value Index (or IVI) of the species.

vii) Species Diversity: It is one of the most important and basic characteristics of a community. There are various ways of measuring species diversity; the simplest is to enumerate the number of species present in a given area. This is relatively easy to achieve for plants, and large or sedentary animals but it is generally difficult to enumerate the various insect species accurately. For large areas such as forests, islands etc., it may take many years to prepare a reasonable estimate of species numbers. To determine species diversity, the most widely used index is Shannon's Index of Diversity (H') and it is calculated as below:

$$H' = \sum_{k=0}^{i=s} \text{Pi Log e Pi}$$

H' = Index of species diversity

S = Number of species

p = Proportion of the total sample belonging to the i^{th} species (in rank), which is calculated by dividing the number of individuals in species i by the total number of individuals in the sample.

e = base of natural logarithms (log, pi = 2.302 x $\log_{10} P_i$)

Summary

In this unit you have learnt some aspects of nature and structure of community. So far you have learnt that

- Communities are made up of populations of organisms, occupying and interacting in a given area. They constitute the biotic component of ecosystems.
- Communities have several group characteristics which are not exhibited by either its individuals or populations.
- The size of community may vary. Just like an ecosystem, a bigger community too may be sub-divided into smaller communities.
- Based on the source of energy, a community may be autotrophic or heterotrophic.
- Rarely, can different communities be sharply delimited, because they blend together to form a continuum along some environmental gradient. Sometimes, because of severe environmental disturbance(s), sharp boundaries between the communities can be seen.
- The area where two communities blend is an ecotone. This zone has a high species richness. It not only supports the species of the adjoining two communities, but also a few species found exclusively in this zone.

- To get a complete picture of a community, a study of its analytic and synthetic characters is necessary.
- Qualitative analytic characters include : floristic composition - kinds of species occurring in a community; stratification - layering of vegetation, that influences the nature and distribution of animal life; periodicity - periodic changes in a community in a year; vitality and vigour - the rate and amount of growth; life form - the location of perennating tissue in plants; sociability - nature of grouping of plants.
- Quantitative analytic characters include: Population density - the number of individuals of a species within a unit area; Cover-area of ground covered by the above-ground plant parts (herbage cover), and the area of ground actually covered by stem (basal area); height of plants; weight of plants - measured as biomass.
- The synthetic characters are: presence and constancy - the uniformity with which a species occurs in different stands in a community; fidelity - degree to which a species is restricted in a particular community; dominance - the ecological success of species in a community, and influencing the occurrence of other species in thecommunity: physiognomy and pattern - the general appearance of vegetation based on a number of qualitative and quantitative characters; frequency - the degree of dispersion of species in an area; Importance Value Index - complete picture of sociological structure of a species in a community; species diversity - number and kind of species in a community.

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Unit 6: Ecological Succession

Unit Structure

6.0 Learning Objectives

After studying this unit, you would be able to:

- define succession
- recognize differences between primary and secondary succession
- contrast autogenic and allogenic succession
- compare autotrophic and heterotrophic succession

- describe the basic processes involved in succession
- describe the process and various stages of succession in aquatic and terrestrial habitats, and explain why animal life changes with seral stages
- describe the facilitation, inhibition and cyclic models of succession
- describe the characteristics and trends in succession

6.1 Introduction

From the previous knowhow, you know that the ecosystems are dynamic systems. The living and nonliving components of an ecosystem keep on changing with time. The changes may be small or large. Small changes may be brought about by natural causes or by human actions. One of the examples of small-scale changes is a stream, in which some sewage is accidentally dumped. In such a case there would be an Increase in the organic and inorganic chemicals in the water. The organic molecules are consumed by bacteria. With the increased availability of organic matter, the number of bacteria would increase. Bacteria use up oxygen as they consume organic materials, thus, the level of oxygen in the streams usually drops. This can kill the fishes and other organisms or cause them to migrate to the new areas. In due course of time, the stream will return to normal. The bacteria will die if the level of organic matter falls off, and dissolved oxygen will return to normal, thus allowing fish to return. This example clearly shows that the biotic community of an ecosystem may be temporarily affected by the small scale changes.

On the other hand, there are certain long-term changes in the ecosystem which can permanently change the organization and composition of biotic communities. These long-term changes may be caused by factors like volcanic eruptions, landslides, earthquakes, floods, hurricanes, and of course human interventions such as mining and deforestation. All these disturbances change the habitat considerably. A variety of species invade the changed or disturbed site, and eventually over a period of time, a new community develops there. This process continues in which one community replaces another community, until a stable, mature community develops.

In this unit, we shall focus our attention, primarily on the large-scale changes in a community. Such large-scale changes are collectively known as ecological succession. We shall discuss the basic processes involved in succession. Then we shall take up two specific examples to explain how succession takes place in nature. Subsequently you would study, models of succession. We shall also talk about the characteristics and trends in succession.

6.2 Succession

As we have discussed in the previous section those factors like fire, floods and human interventions affect an ecosystem considerably. They often lead to the depletion or stripping off of original vegetation of an area. The eventual result is the formation of bare ground or area. But this bare area does not remain devoid of life for long. It is rapidly colonized by a variety of species that subsequently modify one or more environmental factors. This modification of the environment may in turn allow additional species to become established. So, a biotic community destroyed by natural or human causes is gradually replaced in a series of changes, until a mature or climax community is reached. The process of community development, through a series of intermediate successional stages leading to climax community is known as seral stage and all such intermediate stages from bare area to climax community are collectively referred as 'seres'.

Succession is a universal process of directional change in vegetation, on an ecological time scale. If said in another way, succession is a progressive series of changes which leads to the establishment of a relatively stable climax community.

6.3 Processes in Succession

Whether succession is primary or secondary, in terrestrial or aquatic ecosystems, the basic processes involved in succession are similar. There are a number of sequential steps in succession. In this section, we shall discuss them in detail. These steps or processes are:

- Nudation
- Invasion or Migration
- Ecesis
- Aggregation
- Competition
- Reaction
- Stabilization
- Climax

6.3.1 Nudation

The first step or requirement is the availability of the right kind of habitat, primary succession takes place in a bare area, that is, without any life form; and secondary succession occurs in area where soil is already formed, but the vegetation is destroyed. The bare area may develop due to several causes, some of them are:

i) **Topographic factors** like soil erosion by gravity, water or wind, may destroy the existing vegetation thus creating a bare area. Other topographic causes include deposition of sand, landslide and volcanic activity.

ii) Climatic - glaciation, long dry periods, hails and storm, frost and fire are the agents that destroy vegetation.

iii) Blotic - One important agent is man that causes destruction of forests, grasslands and other stretches of vegetation for agriculture, industry, housing and several other purposes. Overgrazing by animals, diseases caused by organisms like bacteria, fungi and insects too destroy vegetation of an area to produce bare areas.

6.3.2 Invasion or Migration

When a habitat is changed, it can be a potential site for the establishment of many organisms. Many species actually invade or reach this new site from any other area. The seeds, spores or other propagules of the plant species reach this area. This process is known as migration, and is generally brought about by air, water and various other agents.

6.3.3 Competition

The aggregation of individuals in an area leads to inter-specific and intra-specific competition. The competition is usually for

i) Water, particularly when there is shortage of water;

ii) Nutrients, particularly when they are in short supply;

iii) Radiant energy, if one plant grows in the shade of another plant;

iv) Carbon dioxide;

v) Oxygen, and

vi) Space.

Success of a species during competition depends on several features, e.g., strong and efficient root system, capability to trap nutrients, endurance to drought and poor soil aeration, and efficiency of reproduction of the plant.

6.3.4 Reaction

This is the most important stage in succession. The mechanism of modification of environment, through the influence of living organisms on it is known as reaction. As a result of reaction, changes take place in soil, water, light conditions, temperature and many other factors of the environment. The environment thus gets modified, and becomes unsuitable for the existing community, and is eventually replaced by another community. The old occupants are ousted and fresh migrants establish themselves. Thus, through a series of invasions, a sequence of plant communities marked by changes from lower to higher forms establish themselves in the course of time. Each stage of succession plays some part in reducing the extreme conditions in which the sere began. Thus, gradually the conditions of the area are modified by the seral communities to suit the growth of a wider range of species.

6.3.5 Stabilization - Climax

The whole process of succession results in stabilization of the vegetation which is now in complete harmony with the environmental complex of that place. And it is likely to persist as long as the climatic and physiographic conditions remain unchanged. The soil is fully occupied by plants and the community is closed. Only those species, which are capable of completing their life cycles, despite the intense competition, establish themselves, the homeostasis is thus attained. This final community is not replaced, and is known as climax community and the stage as climax stage.

The kind of succession that takes place from simple, few forms to complex, several kinds of forms are known as progressive succession. In some cases, reverse situation is seen, that is, the process of succession, instead of being progressive becomes retrogressive. This may be due to the destructive effects of organisms. For example, a forest changing into a grassland community is an example of retrogressive succession.

6.4 Kinds of succession

There are different approaches for classifying succession. These are as follows:

6.4.1 Primary and Secondary Succession

Succession occurring in bare areas where no community existed before is called Primzry Succession. For instance, primary succession would take place on new, volcanic flows, islands, deltas, dunes, bare rocks and in newly formed lakes. Secondary Succession occurs at a site from where an already developed community has been destroyed by some natural catastrophe such as fire or flooding; or by human activity (such as deforestation, ploughing, grazing etc. and a series of communities subsequently develop at the site. Secondary succession also occurs on abandoned farmlands, in overgrazed areas and construction projects. -

In primary succession on a terrestrial site takes place in the new site with first colonization by a few hardy pioneer species, those are often microbes, lichens and mosses. The pioneers over a few generations alter the habitat conditions by their growth and development. These new conditions may be conducive to the establishment of additional organisms that may subsequently arrive at the site. The pioneers through their death any decay leave patches of organic matter in which protists and small animals can live. 'The organic matter produced by these pioneer species produce organic acids during decomposition that dissolve and etch the substratum releasing nutrients to the substratum. Organic debris accumulates in pockets and crevices, providing soil in which seeds can become lodged and grow. As the community of organisms continues to develop, it becomes more diverse and competitions increases, but at the same time new niche opportunities develop. The pioneer species disappear as the habitat conditions change and invasion of new species progresses, leading to the replacement of the preceding community. Similarly, primary succession in aquatic habitat also develops through a number of seral communities.

Secondary succession is the sequential development of biotic communities after the complete or partial destruction of the existing community. A mature or intermediate community may be destroyed by natural events such as floods, droughts, fires, or storms or by human interventions such as deforestation, agriculture, overgrazing, etc. Let us look briefly at an example of secondary succession occurring on an abandoned agricultural farm where soil has been already formed before cultivation started.

This abandoned farmland is first invaded by hardy species of grasses that can survive in bare, sun baked soil. These grasses may be soon joined by tall grasses and herbaceous plants. These dominate the ecosystem for some years along with mice, rabbits, insects and seed-eating birds. Eventually, some trees may come up in this area, skeds of which may be brought by wind or animals. And over the years, a forest community develops. Thus are, abandoned farmland over a period say 30 to 40 years becomes dominated by trees and is transformed into a forest.

When talk about the differences between primary and secondary succession, one obvious difference between the two is that the secondary succession starts on a well-developed soil already formed at the site. Thus secondary succession is relatively faster as compared to primary succession which may often require hundreds of years.

6.4.2 Autogenic and Allogenic Succession

In many cases the living beings of an ecosystem, modify their environment considerably by their growth, death and decay. The changed conditions lead to the establishment of new kinds of species in that area. The whole process goes on and on, that is, there is replacement of one kind of community with another. Such a succession process is called autogenic succession. To sum up, autogenic succession results because of the changes brought about in the habitat by the members of the community themselves.

In some cases, the changes brought about in the habitat are caused by external agencies and not by the existing vegetation itself. This is called as allogenic succession. Such a succession may occur in a highly disturbed or eroded area or in ponds where nutrients and pollutants enter from outside and modify the environment and in turn the communities.

6.4.3 Autotrophic and Heterotrophic Succession

The succession where initially the green plants are much greater in quantity than the animals is known as autotrophic succession. Such a succession takes place in a medium rich in inorganic substances. Since there are green plants, there is gradual increase in the organic matter content and energy flow in the ecosystem. On the other hand, in heterotrophic succession, the populations of heterotrophic organisms, like bacteria, actinomycetes, and fungi are present in greater quantity in the initial stages.

Such a succession begins in a medium rich in organic matter such as the rivers and streams which are polluted heavily with sewage, or in small pools receiving leaf litter in large quantities. As indicated earlier, it begins, prominently in organic environment, and there is a progressive decline in the energy content.

6.4.4 Kinds of Succession based on nature of the habitat

The ecological succession can be broadly classified into two kinds, on the basis of the nature of the habitat.

A) Hydrarch - When succession takes place in a wet area, that is, succession progresses from hydric to mesic conditions. This can be further subdivided as:

- **i) hydrosere** - when succession starts in fresh water ecosystems like ponds, pools, lakes and marshes;
- **ii) halosere** -when succession starts in saline water ecosystems, e.g., mangroves, coral reefs, estuaries.

B) Xerarch - When the succession takes place in drier area, i.e., the succession progresses from xeric to mesic conditions. It is further subdivided as :

- **i) Lithosere** - when it takes place on bare rocks;
- **ii) Psammosere** - when succession takes place in a sandy area, like sand dunes.

6.5 Hydrarch succession

Its various stage are well studied in ecosystem like ponds, pools and lakes. In this subsection, we shall discuss, succession in a pond. Since pond is a fresh water ecosystem, the succession in it is also referred to as hydrosere. Succession in pond, begins by colonization by the pioneers like the phytoplankton's, and finally terminates into a forest which is a climax community. As succession progresses, changes take place in the kind of vegetation as well the associated animal life. The whole process of succession or the hydrosere is further subdivided into a number of stages depending on the kind of organism(s) dominating a stage. We shall now discuss these stages one by one, in detail.

6.5.1 Phytoplankton Stage

In this initial stage, the pond water is poor in nutrients and is devoid of much life. At this stage, the water is incapable of supporting larger life forms. So, in such situations, phytoplankton's consisting of microscopic algae, begin to multiply and they quickly become the pioneer colonizers. As the phytoplankton's and the dependent animal population dies, decomposer organisms like bacteria and fungi increase in number and bring about decomposition of the organic material. Decomposition results in the release of minerals and enrichment of aquatic habitats. Besides this, some silt may be brought to the pond, by the rain water from the surrounding land. By now the pond becomes shallower, and the mud at its bottom is rich in nutrients. Now it can support some rooted hydrophytes, thus initiating the next stage.

6.5.2 Submerged Stage

This habitat which is now shallower and is richer in nutrients and where light is available up to a certain depth, becomes suitable for the growth of rooted, submerged hydrophytes like *Myriophyllum, Elodea, Hydrilla, Potamogeton, Vallisneria, Utricularia* and *Ceratophyllum.* These grow at various depths, mostly rooted in the muddy or sandy bottom depending on the species, and also on the clearness or turbidity of water. Year after year, this vegetation expands and covers large areas, and brings about marked changes in the habitat. Materials eroded by streams, rainwater or surface runoff are brought to the pond, and some of it are deposited on the plants because they form a direct obstacle in its advance, and especially because they slow down the currents, when the plants and the associated animals die, they sink to the bottom, where because of the insufficient oxidation, this organic matter is partially decomposed. Thus humus is formed which cements the mucky soil together making it firmer. The result of these reactions is the building up of substratum and shallowing of lake. Obviously, this process is disadvantageous to the present occupants and these are eventually replaced by another type of plants, which are of floating type.

6.5.3 Floating Stage

The pond is now colonised by plant species which are rooted in mud but their leaves reach water surface and float. These are species of Nelumbo, Nymphaea, Trapa, Monochoria. Some free-floating species that are not fixed in the mud, also make their appearance. Examples are *Lemna, Wolffia, Pistia, Salvinia, Azolla* and *Eichhornia*. Due to the growth, and death and decay of these organisms, the water level by now becomes very much decreased, making the pond much shallower. Evaporation of water, along with the addition of silt from the adjacent area also contributes in making the pond shallower. The pond now does not remain suitable for this kind of plants and the next stage appears.

6.5.4 Reed-Swamp Stage

This stage is also known as amphibious stage, as the plants of the community are rooted but most parts of their shoots remain exposed to air. Species of *Typha, Sagittaria* and *Phragmites* are some examples of this stage. These plants have well developed root system and they form dense patches of vegetation. The reaction of the reed-swamp plants is not only to shade the surface of the water but also to build up the pond margins by retaining the sedimentary materials washed into the lake and by the very rapid accumulation of plant remains. Not only is the plant population much denser than before but also mechanical tissues, which resist decay, are much more highly developed in plants with aerial organs. After the invasion and activities of these plants, the water level is very much reduced, and finally it becomes unsuitable for these plants also.

6.5.5 Sedge-Meadow Stage

Favoured by an increasing amount of light, as the former occupants disappear, they gradually change the reed swamp into a sedge meadow and now species of Cyperaceae and Gramineae such as *Carex, Juncus, Cyperus* and *Eleocharis* colonise the area. They form mat-like vegetation with the help of their much branched rhizomatous systems. At1 these react upon the habitat by binding water-carried and wind-borne soil, accumulating plant debris and transpiring enormous quantities of water. There is much rapid loss of water, and sooner or later the mud is exposed to air. As a result nutrients like ammonia, sulphides become oxidised to nitrates and sulphates. Thus the conditions in the area gradually change from marshy to mesic, and the marshy vegetation shows a decline. Upto the end of sedge-meadow stage, the climate of the region has no control over the succession because the water content of soil is high, irrespective of rainfall and climate of the region. At the end of this stage, the soil becomes dry and its water content will henceforth be dependent upon rainfall and climate of the region. The plants which succeed the sedge-meadow stage are therefore controlled by the climate to a very large extent. In dry climates the next stage may be grassland or some other xeric climax but in more moist climates it is woodland.

6.5.6 Woodland Stage

When the lowland has been built upto an extent where the soil is saturated perhaps only in spring and early summer, certain species of shrubs and trees may appear. Those that can tolerate waterlogged soil around their roots will be - the pioneers. Various species of *Salix, Cornus, Cephalanthus, Alnus and Populus* may form the dense thickets. Some shade-tolerant herbs may also grow among the trees and shrubs. These woody plants react upon the habitat by producing shade and by lowering the water table both by further building up the soil and by vigorous transpiration. By this time of succession there is much accumulation of humus wit rich flora of microorganisms like bacteria, fungi and others. Thus mineralization o the soil favours the arrival of new tree species in the area leading to climax stage.

6.5.7 Climax Stage

A variety of trees invade the woodland community, which soon develop into the climax community. The nature of the climax is dependent upon the climate of the region. In tropical region, where rainfall is high, dense rain forests develop, and in temperate regions, mixed forests of trees like *Quercus, Ulmus, Acer* may develop. In regions of moderate rainfall the climax stage consists of deciduous forests or monsoon forests.

Thus, in the hydrosere, stage (I) is the pioneer community stage, stage (VII) is the climax community, and stages falling between these i.e., stage II to VI, are regarded as the seral communities or seral stage.

Successive changes in animal life during Hydrosere so far, we have discussed the successive changes in plant communities in the different seral communities of a hydrosere. The question arises, is there any change in the animal life along with the different seres. There are certainly changes in the animal life also, but these may not be as obvious as in case of plant community. In an aquatic ecosystem like this, protozoans Like Paramecium, Amoeba, Euglena and many others are the pioneers. When the planktonic growth forms are very rich, then animals like blue gill fish, sun fish, largemouth bass etc. start appearing. Some caddisflies are also found. In the second stage, that is, the submerged stage, the caddisflies are replaced by other animals that may creep over the submerged vegetation. Thus dragonflies, mayflies and some crustaceans as *Asellas, Gammarus, Daphnia, Cypris, Cyclops* inhabit the pond at this stage. At the floating stage, the animal life is chiefly represented by Hydra spp., gill breathing snails, frogs, salamanders, diving beetles, and other insects. There also appear some turtles and snakes.

At the reed-swamp stage, the pond becomes shallower, and the bottom starts becoming exposed. The floating animals are replaced by different species of mayflies and dragonflies, whose nymphs remain, attached to submerged parts of the vegetation, and adults present on the surfaces of exposed parts of vegetation. Gill-breathing animals like snails are replaced by lung breathers as *Lymnea, Physa* and *Gyraulus*. Among insects, water scorpion, giant water bug, scavenger beetles etc. are present at this stage. The bottom of the pond is now inhabited by some annelids, mud pickrel and bull-heads. Red-winged black birds, kingfisher, great blue heron, swamp sparrow, ducks, musk rats, and beavers become common in the area.

At the sedge-meadow stage, the animals like snails as *Anodonta, Psidium* become common. Finally, at the woodland stage, under terrestrial conditions, most of the terrestrial forms of animal life appear in the area.

6.6 Xerarch Successions

It is initiated on bare rock, wind-blown sand, rocky talus slopes, or other situations where there is an extreme deficiency of water are termed xerarch. Here, we shall discuss the example of a bare rock. It is not only deficient in water but also lacks any organic matter, having only minerals in disintegrated, unweathered state. The pioneers to colonize this primitive substratum are crustose type of lichens, and through a series of successive seral stages, the succession finally terminates into a forest which constitutes the climax community. As in the hydrarch, successive changes take place in both plants as well as animals, but changes in plants are more obvious than animals. Now, we shall take up the various stages of xerosere for discussion.

6.6.1 Crustose Lichen Stage

On bare rocks, conditions are inhospitable for life, as there is extreme deficiency of water and nutrients, great exposure to sun, and extremes of temperature. Crustose lichens alone are usually able to grow in such situations. Some examples of these pioneering species are, Rhizocarpon, Rhinodina, Lecidea and Lecanora. These plants flourish during periods of wet weather and remain in a state of desiccation for very long periods during drought. During the wet weather they rapidly absorb moisture by their sponge-like action. Mineral nutrients are obtained by the secretion of carbon dioxide which, with water forms a weak acid that slowly eats into the rock into which the rhizoids sometimes penetrate for a distance of several millimeters. Nitrogen is brought by rain or by wind-blown dust. Thus all the life requirements of this simple, crust-like species is met with. Thus, lichens help corrode and decompose the rock, supplementing the other forces of weathering. And by mixing the rock particles with their own remains, make conditions favourable for growth of other organisms. Thus, a thin layer of soil is formed. The rapidity with which a small amount of soil is formed is controlled largely by the nature of the rock and by the climate. On quartzite or basalt rocks in a dry climate, the crustose-lichen stage might persist for hundreds of years. But on limestone or sandstone in a moist climate, sufficient changes permit the invasion of foliose lichens, and all this may occur within a life time.

6.6.2 Foliose Lichen Stage

As mentioned earlier, the weathering of the rocks and the decaying of the crustose lichens results in the formation of soil on the otherwise bare rocks. The foliose lichens make their appearance on such spots on the rocks which have accumulated some soil. These lichens include *Dermatocarpon, Parmelia and Umbilicaria*. These lichens have large, leaf-like thalli, which overlap the crustose lichens. The latter are thus cut-off from direct light. This results in death and decay of the crustose lichens. The mass of foliaceous lichens can absorb and retain more water to some extent. Wind and water-borne dust particles are trapped by these lichens. This helps in the further building up of substratum. All these processes result in the accumulation of more and more humus. The rocks are weathered by the acids secreted by the living and the decaying plants. The weathering of the rocks and the rapid addition of humus to it result in the increase in thickness of soil layer. Thus, a considerable change in habitat is brought about.

6.6.3 Moss Stage

The accumulation of soil, particularly in the crevices and depressions of rock favours the growth of certain xerophytic mosses. i.e., species of *Polytrichum, Tortula* and *Grimmia*. The spores of these mosses are brought by the blowing wind. They have more or less the same power of withstanding desiccation as that of foliose lichens. The lichens and mosses grow together and compete 'with one another. The rhizoids of mosses and foliose lichens compete for water and nutrients, and the stems of the former attain greater height than the latter. The plants in the lower strata, i.e., the lichens die, and the mosses grow. The mosses form cushion-like structure, that may be a few centimeters in thickness. The substratum is thus gradually built up and is widened. The foliose lichens gradually give way to mosses that overtop the lichens. Many times, all three stages may be found on a single rock surface, the pioneers occupying the most exposed places.

6.6.4 Herb Stage

The Soil-forming and soil-holding reactions of the mosses are so pronounced that the seeds of various xerophytic herbs, especially short-lived annuals: are soon able to germinate and grow. The plants mature, although the first generations, because of the drought and sterility of the soil, may make only a stunted growth. Their roots continue the process of corroding the rock, and each year the humus from their decaying remains enriches the soil. Gradually, biennials and perennials begin to invade the area and with the habitat becoming more and more favourable, their numbers also increase.

The processes of rock disintegration and humus and nutrient accumulations are greatly increased, as the tangled network of roots increases and the soil becomes shaded. Evaporation and temperature extremes are decreased, humidity is slightly increased, and drought periods are shortened. The bacterial, fungal and animal populations of the soil increase and conditions gradually become less xeric. Upto now, some xerophilous, shallow rooted grasses like *Aristida, Festuca* and *Poa* were growing. As the conditions improve, then some drought-enduring species like *Potentilla, Solidago* and many others invade the area. As a result of growth of the herbs, the smaller plants like mosses and lichens do not get enough light. So these conditions are detrimental for their growth, they gradually start perishing.

6.6.5 Shrub Stage

Sufficient soil is formed in the herbs stage, for supporting the woody plants or the shrubs. They migrate with the help of seeds or rhizomes from the adjacent areas. Examples are species of *Rhus* and *Phytocarpus*. The shrubs soon develop into dense vegetation. The habitat is considerably modified. The herbs are shaded by the overgrowing shrubs. They no longer find it possible to thrive in such a situation and are, therefore, completely replaced by the shrubs. The shrubby vegetation adds a lot of organic matter to the soil, through leaves and other plant parts. The soil is thus enriched with considerable amount of humus. The huge mass of roots of the shrubs corrodes the rocks. The enriched soil attains greater capacity for holding water. The soil is shaded, and, therefore, evaporation of water is considerably reduced. The humidity is increased over such areas. All these favour the growth of seedlings of trees which start invading the area.

6.6.6 Climax Forest

First, some xerophytic species of trees, establish in this area. They are sparsely distributed and are stunted because the conditions are still not very congenial for them. With passage of time, the rocks are further weathered and a deep layer of soil is formed. This favours vigorous growth of a much larger number of trees. The moisture in the soil is conserved because of the shading of soil. The climax forest is thus developed. The vegetation becomes more and more mesophytic with the accumulation of humus. Thus, in the xerosere, as in the hydrosere the habitat has changed from one extreme condition to a medium situation which permits the development of a mesophytic type of vegetation

Changes in Animal Life During Xerosere- Just like the hydrosere, there occurred successive changes in animal life during the B xerosere. A few mites are usually found associated with the lichens. Initially, the fauna is sparse in terms of species composition. There are a-few ants or a few spiders present in the cracks and crevices of rock. These pioneer animals are exposed to harsh environment particularly the thermal extremes. As succession progresses, the mites become more varied in terms of species and small spiders, springtails as well as tradigrades become associated with the mosses. At later stage of succession, when grasses start appearing, the fauna increases markedly, both in qualitative and quantitative terms. Nematodes, larval insects, collembola, ants, spiders and mites appear in this new environment. With the development of forest climax community, there develops a rich fauna consisting of invertebrates as well as vertebrates. These include springtails, mices, squirrels, shrews, and mammals like fox, chipmunk, mouse and mole, birds, reptiles like turtles, snakes, and amphibians like salamanders and frogs.

Summary

- Succession occurs when a series of communities replace one another, as each community changes the environment to make conditions favourable for a subsequent community, and unfavourable for itself. The first plants to colonize an area make up the pioneer community. The final stage of succession is called the climax community. The stages leading to the climax community are called successional stages or seres.
- Primary succession occurs when plants colonize bare rocks or other areas where there is no soil. Secondary succession occurs when plants recolonize an area in which the climax community has been disturbed.
- When succession is brought about by living inhabitants, the process is called autogenic succession, while change brought about by outside forces is known as allogenic succession.
- Succession in which, initially the green plants are much greater is quantity is known as autotrophic succession; and the ones in which the heterotrophs are greater in quantity is known Bs heterotrophic succession.
- The basic processes of succession are more or less the same for any kind of succession. These processes are; nudation, invasion or migration, ecesis, aggregation, competition and reaction, andstabilization (climax).
- Succession in aquatic ecosystems like pond begins with increased nutrient sediments, encroachment by shore plants, and a general increase in both numbers and kinds of organisms. The continued trend results in the pond filling in and later F blending in with the surrounding terrestrial community.
- Succession in xeric habitat like a bare rock begins by pioneer plants. These establish on the substratum with hostile conditions, like deficiency of water, too c much exposure to sun. By the activity of the pioneers, some soil is formed on the bare area. This area is subsequently colonized by various kinds of plants, and a considerable amount of soil builds. The overall xeric conditions change to mesic conditions.

Unit 7: Classification of forest and Forest types of India

Unit Structure

7.0 Learning Objectives

- After studying this unit, you would be able to:
- Forest Cover of India
- Main forest types of India
- Distribution of different Forest types
- Characteristics and composition of Forests

7.1 Introduction

Forests in India are very diverse in their composition with a long evolutionary and geological history, occurring under diverse climatic and edaphic conditions. The forests represent a very unique assemblage of both Indo-Malayan and Australian species indicating the geological and paleo-botanical value of these forests. The forest types of India were classified for the first time in 1936 by Sir HG Champion and compiled his monumental work 'Preliminary Survey of Forest Type of India and Burma' (Champion 1936). Champion and Seth classified India's forests into 16 major types and about 221 sub-type groups; published 'A Revised Survey of the Forest type of India' in 1968. The detailed classification of forest types in India is based on climate, physiognomy, species composition, phenology, topography, soil factors, altitude, aspect, and biotic factors (Champion and Seth, 1968). The forests have been classified into six "major groups ", ranging from tropical to alpine These major groups have been further classified into 16 sub-groups on the basis of temperature and moisture regimes, and more than 200‘group categories’(see, Singh and Chaturvedi, 2017).

7.2 Major Forest Types

At the beginning of the 20th century about 30% of land in India was covered with forests. But by the year 2015 the forest cover has been reduced to 21.34%. In 2015, of the existing forests, about 2.61% are very dense forests (canopy cover 70% or more), 9.59% moderately dense forests (canopy cover 40% or more but less than 70%), 9.14% open forests (canopy cover 10% or more but less than 40%), and 1.26% scrub forests (canopy cover less than 10%) (FSI 2015). Mizoram, with 88.93 % of forest cover has the highest forest cover in percentage terms, followed by Lakshadweep (84.56%). Madhya Pradesh is having largest total forest cover (77, 462 km2) in India, followed by Arunachal Pradesh (67,248 km2) and Chhattisgarh (55,586 km2) (FSI 2015).

The forest types of India have been described on the basis of Champion and Seth (1968). The major forest types are given in Table 7.1.

Table 7.1 The major forest types of India (based on Champion and Seth, 1968)

Major Forest Groups	Forest Groups
I. Moist Tropical forests	Group1: Tropical Wet Evergreen Forests
	Group 2: Tropical Semi-evergreen Forests
	Group 3: Tropical Moist Deciduous Forests
	Group 4: Littoral and Swamp Forests
II. Dry Tropical forests	Group 5: Tropical dry deciduous forest
	Group 6: Tropical thorn forests
	Group 7: Tropical dry evergreen forests
III. Montane Subtropical Forests	Group 8: Subtropical broad-leaved hill forests
	Group 9: Subtropical pine forest
	Group 10: Subtropical dry evergreen forests
IV. Montane Temperate Forests	Group 11: Montane wet temperate forests
	Group 12: Himalayan moist temperate forests
	Group 13: Himalayan dry temperate forests
V. Sub alpine forests	Group 14 Sub alpine forests
VI. Alpine Forests	Group 15: Moist-Alpine Scrub
	Group 16: Dry-Alpine Scrub

I. MOIST TROPICAL FORESTS

(i) Group 1: Tropical Wet Evergreen Forest

These forests are dense and show 30-45m tall canopy structure with four or five strata, generally found in regions having rainfall in the range of 2000 to > 3000 mm per year. The diversity of tree species is high in these forests. The forests are discontinuously distributed mainly along the Western Ghats, north-eastern India and Andaman and Nicobar. The northern and southern wet tropical evergreen forests are described in Table 7.2.

Table. 7.2 The northern and southern wet tropical evergreen forests of India

Southern wet tropical evergreen forests	**Northern wet tropical evergreen forests**
The southern tropical wet evergreen forests occur in the Western Ghats, and Andaman and Nicobar; the most widely distributed genera are *Dipterocarpus* and *Hopea*. In the Western Ghats, rainfall ranges from 1500 to 5000mm; altitude varies from 250 to 1200m. (i). The variations in climatic conditions results in a large variety of plant formations and high species richness (Pascal et al., 2004). (ii). The evergreen forests of the Western Ghats have a very high percentage of species endemic to the region. (iii). The Western Ghats are considered as one of the biodiversity hot spots of the world (Myers et al., 2000). The **Nilgiri Biosphere** Reserve in the Western Ghats was the first biosphere reserve in India established in the year 1986. *(iv).* The evergreen forests of Wayanad, Kerala are characterized by high proportion of *Mesua ferrea, Palaquium ellipticum, Cullenia sp.,* and *Calophyllum elatum.*	The northern wet tropical forests occur in upper Assam, northern Bengal and Arunachal Pradesh, dominated by trees of the family Dipterocarpaceae. Bamboos are usually present. Climbers are abundant, palms and canes generally present; abundance of epiphytes, ground cover is mainly composed of evergreen shrubs. Some salient features of these forests are: (i). The upper Assam valley tropical wet evergreen forests- *Dipterocarpus*, *Mesua ferrea*, *Dysoxylum* spp, *Echinocarpus*, and *Canarium* spp. *(ii).* The giant *Dipterocarpus macrocarpus*(Hollong) and *Shorea assamica* in Assam valley occur in patches, attain high girths up to seven meter and height up to 50m. (iii). The Cachar Tropical Evergreen Forest occur in lower hills and hill slopes of Cachar hills, and the Khasi and Jaintia hills around the Surma valley. The forest is *Mesua-Dipterocarpus-Palaquium* formation.

(ii) Group 2: Tropical Semi-Evergreen Forest

These forests occur in areas adjoining tropical wet evergreen, and form a transition between the evergreen and moist deciduous forests. Lower canopy is evergreen, whereas canopy species are deciduous for short periods during the dry seasons. Tropical Semi-evergreen Forest type comprises 13.79% of the Indian forest types.

(a) These are dense, multi-strata, 24-36m in height.

(b) Rainfall ranges from 1500-2500mm per year.

(c) The canopies are not continuous and species richness lower as compared to evergreen forests.

(d) Buttressed stems occur in the case of both evergreen and deciduous trees (e.g. *Elaeocarpus* sp, and *Salmalia* sp)

(e) Bamboos, canes, ferns, climbers are common. Epiphytes are abundant including many ferns and orchids.

(f) These are not climate climax formations, but occur as edaphic sub climax on shallow poor soils.

The northern and southern tropical Semi-evergreen forests are described in Table7.3.

Table 7.3. The northern and southern tropical Semi-evergreen forests of India.

Southern Tropical Semi-evergreen Forest	**Northern Tropical Semi-evergreen Forest**
Distributed in Western Ghats where rainfall gradient is steep, north of Bombay, near Goa, and South of Cochin; Andaman (in the main valley), Tiruneveli (eastern slopes of the southern Western Ghats). (i). The forests are composed of both evergreen and deciduous species in the top storey. (ii). Upper canopy composed of *Xylia, Terminalia, Dipterocarpus, Balanocarpus,* and *Hopea* spp. (iii). Middle canopy trees belong to family Myrtaceae, Lauraceae, (iv). Ground-floor is composed of evergreen shrubs belonging to Rubiaceae and Acanthaceae.	These type of forests occur in moderate to heavy rainfall areas of Assam, West Bengal, and Odisha, include the following types: (i). Assam valley and alluvial plains Semi- evergreen Forest (ii). Eastern submontane Semi-evergreen Forest: *Schima-Bauhinia* association (iii). Sub-Himalayan light alluvial Semi-evergreen Forest : *Terminalia- Phoebe* association (iv). Cachahar semi-evergreen forest– Assam: mixed semi-deciduous type; Manipur: *Tectona, Dipterocarpus hylium.* (v). Odisha tropical semi evergreen forest: occur on the Odisha hills at about 800m and in lower permanently moist valleys. Composed of *Artocarpus, Mesua ferrea, Terminalia* spp, *Michelia* sp, *Phoebe* spp, and *Litsea* sp.

(iii) Group 3: Tropical Moist Deciduous Forest

These forests are common in areas where rainfall is 1000 to 2000 mm with a dry season of three to four months. Dominant trees are deciduous, lower storey trees are usually evergreen. The trees shed their leaves in winter months, again become flushed in March-April. These forests comprise 19.73% of India's forest types (FSI 2011). These forests are widely distributed covering both in southern and northern states including Tamil Nadu, Arunachal Pradesh, Assam, Meghalaya, Mizoram, Bihar, West Bengal, Odisha, and Uttarakhand.

These forests are usually 2 to 3 strata with a much lower number of species as compared with the tropical evergreen and semi evergreen forests. The canopy trees are light demanding, middle ones are shade tolerant species of shrubs and young trees, and on ground floor are present herbs and saplings. Climbers are abundant. The northern and southern tropical moist deciduous forests are described in Table 7.4.

Table 7.4 The northern and southern tropical Moist Deciduous forests of India

Southern Moist Deciduous Forests	**Northern Moist Deciduous Forests**
These forests are distributed in Maharashtra, Mysore, Tamil Nadu, and Arunachal Pradesh. *Tectona grandis* is dominant in the southern Moist Deciduous Forests with the following variations: (i). Very moist teak forests occur in Kerala and Tamil Nadu in high rainfall areas over 2500mm on deep alluvial soils. (ii). Moist –teak bearing forests, southern moist mixed deciduous forest and southern secondary moist mixed Deciduous Forest. (iii). Moist teak forests are associated with *Terminalia* spp, *Pterocarpus* spp, *Adina*, and *Dalbergia latifolia*. Bamboos are quite common. *Bambusa arundinacea* and *Dendrocalamus strictus* are the most common bamboo.	The northern moist deciduous Forests are dominated by *Shorea robusta* with the following variations: (i). Very moist sal –bearing forests occur in Sikkim, West Bengal, the Garo, Khasi hills, and Jaintia hills, Assam and Meghalaya. These forests are composed of *Shorea robusta, Schima wallichii, Stereospermum personatum.* (ii). Moist Siwalik sal forests occur on Nahan Sandstones, whereas sandy alluvium soil with dry subsoil. (iii). Moist peninsular sal forests also occur in Madhya Pradesh, and Odisha; common associates being *Pterocarpus marsupium*, *Anogeissus latifolia, Syzygium cumini*, *Phoenix acaulis* etc. (iv). Moist mixed deciduous forests occur in Siwalik Hills of Uttarakhand. In eastern Himalaya in Bengal and Assam.

(iv) Group 4: Littoral and Swamp Forests

These forests consist of evergreen species of varying densities and height, usually associated with mesic habitats. These forests are mostly in their developmental stage and are seral in nature.

(i). The littoral forests occur along the coast in the Andaman and Nicobar, Andhra Pradesh, Odisha, and Tamil Nadu. The most characteristic species is tall and evergreen *Casuarina* on sandy beaches and dunes along the sea face. In Andaman, the forests are dominated by *Manilkara littoralis*.

(ii). The tidal and swamp forests (mangrove scrub) are dominated by several evergreen and semi- evergreen species in deltas of the Ganga and the Brahmaputra rivers.

(iii). Mangroves are found along the east and west coasts of India, the Andaman and Nicobar Islands, the Gulf of Kachchh and Khambat (Gujarat). Sundarban (40% in West Bengal) is the largest mangrove in the world. Mangrove forests are generally dominated by trees of the genera – *Rhizophora, Avicennia, Sonneratia, Bruguiera,* and *Ceriops*. Some genera like *Heritiera* and *Xylocarpus.* On the drier areas within the salt water mangrove scrub/forest are found palm swamp.

(iv). Tropical fresh water swamps such as *Myristica* swamp forest occur in Travancore, Kerala, contain species such as *Myristica* spp., *Lagerstroemia speciosa.*

(v). The species like *Baringtonia* spp, and *Syzygium cumini*, are found in swamps forests of UP and West Bengal.

II. DRY TROPICAL FORESTS

(i) Group 5: Tropical Dry Deciduous Forests

These are largest forest type of India covering about 38.2% of the forest area of the country. Tropical dry forests occur in climates exhibiting a marked seasonality in rainfall and prolonged drought period over the annual cycle. These forests consist of trees less than 25m high, with a light demanding canopy consisting of deciduous trees. These forests occur from Kanyakumari to the foothills of the Himalaya in low rainfall areas of 800 to 1200mm; large areas of these forests are suitable habitats for wildlife.

Dry teak and dry sal communities predominate in the southern and northern regions, respectively. In some areas a mixture of trees like *Anogeissus pendula*, *Boswellia serrata*, *Hardwickia binata*,*Acacia nilotica*, *Madhuca indica*, and *Butea monosperma* occupy the area. *Acacia catechu* and *Dalbergia sissoo* are conspicuously present on newly formed soils. The northern and southern tropical Dry Deciduous forests are described in Table 7.5.

Table 7.5 The northern and southern tropical Dry Deciduous forests of India.

Southern Tropical Dry Deciduous Forest	Northern Tropical Dry Deciduous Forest
Occupy whole of peninsular India (except coastal Karnataka). These forests are distributed in Maharashtra, Karnataka, Andhra Pradesh, MP, and Tamil Nadu. The main climax types include: (i). Dry Teak bearing forest: *Tectona grandis*, *Boswellia serrata*, *Anogeissus latifolia*, *Sterculia* sp., and *Acacia catechu*. (ii). Dry red sanders bearing forest: *Pterocarpus santalinus* predominates forming pure associations over extensive areas, and teak is absent.. (iii). Southern dry mixed deciduous forest: *Boswellia serrata* is conspicuous, distributed throughout peninsular India;common trees are *Anogeissus latifolia*, *Terminalia tomentosa*, and *Hardwickia binata*. *(iv).* Dry mixed forest with *Tectona grandis* (v). Sandal (*Santalum album*) bearing scrub forest.	Occur in Bihar, Bengal, Odisha, Gujarat, UP, , Haryana. *Shorea robusta* is of low quality in these forests. These are of following types : (i). Dry Siwalik sal forest are dominated by *Shorea robusta*, *Anogeissus sp*., *Buchnania lanzan*, whereas dry plains sal forests are composed of Shorea robusta, Terminalia tomentosa , Madhuca india , and Diaspyros sp. (ii). In Kalesar reserve forest in Haryana, the forests are mainly composed of dry Siwalik Shorea robusta forest, dry plains Shorea robusta forest (Fig.7.1) , northern dry mixed deciduous forests, and the dry tropical riverine forests. (iii). Dry peninsular sal forest: Occur in regions of Bihar, MP (*Pachmarhi plateau*), Odisha, UP, west Bengal, Chhattisgarh (Amarkantak); Shorea robusta mixed with Boswellia serrata. (iv). Northern Dry mixed Deciduous Forest: Main trees are *Anogeissus latifolia*, *Boswellia serrata*. (v). The dry deciduous scrub is distributed throughout the dry deciduous forest zone of India. (vi). The edaphic climax types in dry deciduous forests occur in some regions of Rajasthan.

Fig. 7.1. A view of the (a) dry Siwalik *Shorea robusta* forest, and (b) dry plains *Shorea robusta* forest at Kalesar National Park in Haryana, northern India (Photo SR Gupta).

(ii) Group 6: Tropical Thorn Forests

These forests are found in low rainfall areas (200 to 800mm) of northern India, peninsular India and central India. Moisture availability is limiting for plant growth. The trees experience prolonged dry periods. The tree height ranges from six to nine meters.

Southern Tropical Thorn Forests Occur in Maharashtra, Tamil Nadu and AP. In south India, important species are *Acacia chundra* , *Acacia planifrons* and *Acacia catechu*..

Northern Tropical Thorn Forests occur in **s**emiarid regions of Rajasthan, Punjab, Haryana, northern Gujarat, MP, UP, and Delhi.

(i). These forests are open, consisting of short trees, generally belonging to thorny tree species. The desert thorn type consist of *Acacia senegal*, *Prosopis spicigera, Prosopis cineraria*, *Acacia leucophloea*, *Acacia nilotica*, *Ziziphus* spp, and *Salvadora* spp. *Acacia tortilis* and *Prosopis chilensis* have been widely planted in this region.

(ii). The desert dune scrub are very open, irregular formations of stunted trees and bushes, these are sparse and thorny. The main species are *Acacia senegal, Prosopis spicigera, Acacia Arabica, Tamarix aphylla, Salvadora oleoides*.

(iii) Group 7: Tropical Dry Evergreen Forests

The forests are restricted in distribution to Karnataka coast, also reported from the east coast in AP. These are low growing forests; trees are of 9-12 m height, and form a complete canopy. Most conspicuous trees are *Manilkara hexandra*, *Memecylon edule* along with *Diaspyros*, *Eugenia*, *Chloroxylon*, *Albizzia amara*. There is a high diversity of trees, shrubs and herbs in these forests.

III. MONTANE SUBTROPICAL FORESTS

(i) Group 8: Subtropical Broad Leaved Hill Forests

These forests are of the following types:

(a) Southern Subtropical Broad Leaved Hill Forests

In south India, these forests are found in the hill slopes and tops at about 1000 to 1700m height in Nilgiri, Palani, **Tirunelveli**, and Mercara hills. Main trees are *Calophyllum elatum*, *Eugenia* spp., *Dalbergia latifolia*, *Anogeissus latifolia*, *Emblica officinalis*, *Olea dioca*, and *Phoenix humilis.*

(b) Central Indian Subtropical Hill Forests

Hill top forests occur above 1200m in Madhya Pradesh (Pachmarhi), Bihar, Odisha. In Pachmarhi hills, *Manilkara hexandra, Mangifera, Syzygium cumini* are conspicuous trees.

(c) Northern Subtropical Broad Leaved Hill Forests

Occur in Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Nagaland Sikkim, and west Bengal represented by east Himalayan subtropical wet hill forest, Altitude 1000-to 2000m, Occur in Khasi, Jainti and adjacent hills, dense evergreen forests , rarely exceeding 20m height. Important tree species are *Quercus*, *Castanopsis, Alnus*, *Prunus*, *Betula* and *Schima*. There is heavy growth of epiphytic mosses, ferns and phanerogams. Subtropical broad leaved hill forest dominated by *Quercus serrata*, *Eugenia praecox*, *Schima wallichii*,*Rhus succidanea* located located at Imphal, Manipur is shown in Fig.7.2.

Fig.7.2. Subtropical broad leaved hill forest dominated by *Quercus serrata*, *Eugenia praecox*, *Schima wallichii*, *Rhus* sp located at 24^{0}50’ N latitude and 93^{0}48’ E longitude at an altitude of 796 m above mean sea level near Imphal in Manipur (Photo: Dr Amrabati Thokchom).

(ii) Group 9: Sub-Tropical Pine Forests

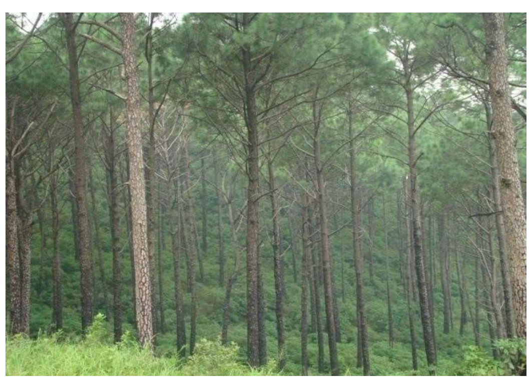

Fig7.3. A view of Sub-tropical Chir Pine (Pinus roxburghii) forest in Morni hills in north-east Haryana, northern India (Photo S. R. Gupta)

Sub-tropical chir pine (*Pinus roxburghii*) forests occur throughout the central and western Himalaya between 1000 to 1800m; distributed in Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Uttarakhand. *Pinus roxburghii* along with broad leaved species is the main characteristics of these forests. Climbers and bamboos are absent. A view of Sub-tropical chir pine (*Pinus roxburghii*) forest in Morni hills in north-east Haryana is shown in Fig.7.3. The forests of *Pinus keysia* along with *Schima wallichii* occur in Khasi and Naga Hills, and Manipur hills, in eastern Himalaya (Fig 7.4). *Pinus kesiya* is often a pioneer in deforested secondary vegetation, especially if fire has been a factor in the disturbance.

Fig.7.4. A view of Sub-tropical (*Pinus keysia*) forest in Manipur in north-east India (Photo: Dr Amrabati Thokchom).

(iii) Group 10: Sub-Tropical Dry Evergreen Forests

These forests are distributed in Bhabar tract, Shiwalik hills, and the foothills of western Himalaya. In Punjab, Uttrakhand, and Himachal Pradesh, *Olea cuspidata* is found on alluvial ground of wider valleys. In Jammu and Kashmir, the dominant species of these scrub forests are *Olea cuspidate, Acacia modesta,* and *Dodonaea viscose.*

IV. MONTANE TEMPERATE FORESTS

(i) Group 11: Montane Wet Temperate Forest

The southern Montane wet temperate forests are closed evergreen forest, trees are mostly short boled (not exceeding 6m), and highly branched. The branches are clothed with mosses, ferns and other epiphytes, woody climbers are common. The northern Montane wet temperate forests are a characteristic feature of the eastern Himalaya and are found between 1800 m and 3000 m elevation in high rainfall areas (>2000mm rainfall); The northern and southern Montane wet temperate forests of India are described in Table7.6.

Table 7.6. The northern and southern Montane wet temperate forests of India

The southern Montane wet temperate forests	Northern Montane wet temperate forests
(i). These forests are found in patches (Sholas) in the more sheltered sites on rolling grasslands. Occur in high hills of Tamil Nadu and Kerala on the, Anamalai, Palni and Tirunelveli hills from about 1,500 m upwards. (ii). In the southern Indian hills, important species belong to *Syzygium* spp , *Eurya*, *Michelia nilagirica*, and *Ternstroemia*. *Rhododendron nilagiricum* is important components. (iii). The forests are luxuriant with dense undergrowth, epiphytes, and woody climbers. Southern Indian wet grasslands occur over large areas on the rolling downs.	(i). These forests occur in Bengal, Sikkim, Assam, Manipur are closed evergreen high forests of large girth class, medium height (~ 25m), oak forests with *Quercus lamellosa*, *Castanopsis*, *Machilus*, and *Rhododendron*. *Acer, Prunus*, *Ulmus*, and other deciduous genera are present. (ii). Northern Montane Wet temperate forest at the Ukhrul district of Manipur, dominated by *Rhododendron arboreum* and *Quercus* sp. located at an altitude of 1900m msl is shown in Fig.7.5. (iii). In higher hills along the Assam/Burma border, these forests occur at an altitude of 1800-2500m and composed of *Alnus nepalensis*, *Betula alnoides*, *Acer, Prunus* and *Pyrus*.

Fig. 7.5 Northern Montane Wet temperate forests at the Ukhrul district of Manipur, dominated by *Rhododendron arboreum* and *Quercus* sp. located at an altitude of 1900 msl. (Photo: Dr Amrabati Thokchom).

(ii) Group 12: Himalayan Moist Temperate Forests

These forests extend the whole length of the Himalayan region between the sub-tropical pine forest and sub-alpine forests. Altitude ranges from 1500m to 3300m. These are concentrated in the central and western Himalaya, except in areas where rainfall is below 1000 mm. Distributed in Kashmir, Himachal Pradesh, Punjab, Uttrakhand, Darjeeling district of west Bengal, Assam, and Sikkim.

(a) Several species of oak predominate in the temperate forests including *Quercus leucotrichophora*, *Quercus. Floribunda*, *Quercus incana*, *Quercus semecarpifolia*, *Quercus dilatata*, *Q. larginosa*. All oak species in Himalayan region are evergreen showing leaf fall in summer, but are never leafless. There are four strata, 25-30m height, tree canopy is dense, herbaceous layer not well developed, grasses generally lacking, and rich in epiphytes. A view of temperate oak forest at Munsiyari Pithoragarh, Uttarakhand in Kumaun Himalaya is shown in Fig.7.6.

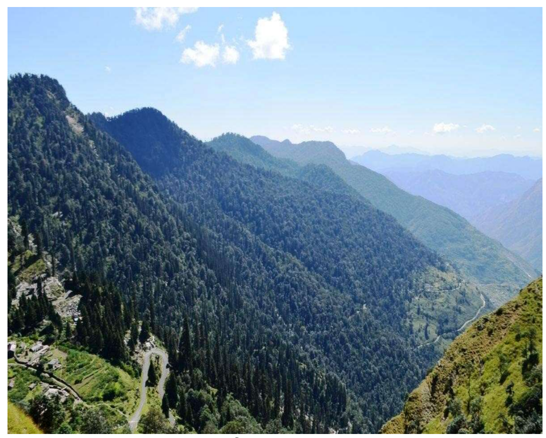

Fig. 7.6 Temperate oak forest at Munsiyari, Pithoragarh in Kumaun Himalaya (Photo courtesy Dr Balkar Singh)

Fig. 7.7 The evergreen Cedrus deodara forest surrounding the Khajjiar lake located at 1920 m above mean sea level in Khajjair, Chamba district, Himachal Pradesh in western Himalaya. (Photo SR Gupta)

(b) Most *Cedrus deodara* forests form pure stands, canopy is fairly complete, boles are straight and tall (30-40m), There are scattered oaks and *Rhododendron* under the conifers. The evergreen *Cedrus deodara* forest surrounding the

Khajjiar Lake located at 1920 m above mean sea level in Khajjair, Chamba district, Himachal Pradesh in western Himalaya is shown in Fig.7.7.

(c) As the altitude increases, the upper form consisting of *Abies pindrow*, *Picea smithiana*, and *Quercus semecarpifolia* becomes dominant.

(d) The eastern Himalayan hills are occupied by *Quercus. lineata*, *Quercus lamellosa*, *Quercus pachyphylla*, *Rhododendron* spp., *Tsuga dumosa*, *Picea spinulosa* and *Abies densa*.

(e) *Cupressus torulosa* is a conspicuous species found on limestone rocks from Chamba (Himachal Pradesh) to the Aka hills at 1800 to 2800 m.

(iii) Group 13: Himalayan Dry Temperate Forests

Conifers predominate, distributed on 1700 to 3000m altitude, in the inner ranges of Himalaya, rainfall usually less than 1000mm mostly received as snow in winter months, distributed in Kashmir, Ladhakh, Lahaul, Chamba, inner Garhwal, and Sikkim.

(a) Coniferous forests are tall (30-35m) and have evergreen canopy.

(b) These forests consist of both coniferous and broad-leaved species.

(c) In the western Himalaya, the characteristic species are Pinus gerardiana, Cedrus deodara and Juniperus. At higher elevation, Abies pindrow, and Pinus wallichiana are found.

(d) In the eastern Himalaya, the common species are from Abies and Picea.

(e) In higher hills, Juniperus wallichiana is common.

(f) Locally, between 2500 and 4000 m elevation, a few other species like Larix griffithiana, Populus eupheretica, Salix spp., Hippophoe spp. and Myricaria spp. also occur.

V. SUB-ALPINE FORESTS

(i) Group 14: Sub-Alpine Forests

The subalpine forests occur throughout the Himalaya above 3000 m elevation up to the tree limit, rainfall 83-600mm. The forests are mainly evergreen, *Rhododendron* is common constituent. Tall trees are conifers; *Betula utilis* is present as the largest deciduous tree and associated with genera like *Quercus semecarpifolia, Sorbus,* and *Rhododendron* sp.

(a) Western Himalaya sub-alpine forests reported from Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. In the western Himalaya, there are two types of forests (i) *Abies spectabilis* and *Betula utilis* , (ii) west Himalayan sub-alpine birch/fir forest.

(b) In the eastern Himalaya, these forests occur above 3000m. These forests are distributed in Arunachal Pradesh, Sikkim, and west Bengal. There is predominance of *Abies densa* and *Betula utilis*, and *Rhododendron* spp. These are climax formations, self generating with marked resilience.

VI. ALPINE FORESTS

(i) Group 15: Moist- Alpine Scrub

Moist Alpine Scrub occurs throughout Himalaya, above timber line to 5,500m altitude, composed entirely of species of *Rhododendron* with some birch (*Betula*) and other deciduous trees. The tree trunks are short and highly branched, moss and ferns cover the ground. A thick layer of humus is present and soil is generally wet.

(a) In Kumaun, Uttarakhand, Betula utilis and Rhododendron campanulatum scrub forest occur.
(b) Rhododendron- Lonicera association occurs in Uttarakhand, in inner Himalaya.
(c) In eastern Himalaya, dense Rhododendron thickets occur at 3350-4600m altitude. These forests are reported from Arunachal Pradesh, Sikkim and west Bengal.

(ii) Group 16: Dry- Alpine Scrub

It is a xerophytic formation, having predominance of dwarf shrubs; rainfall < 370mm per year. Characteristic plants are *Juniperus wallichiana*, *Lonicera* spp, *Potentilla* spp. Vegetation along the streams is composed of *Salix*, *Myricaria*, and *Hippophae rhamnoides*. These scrub forests are distributed in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Arunachal Pradesh. In eastern Himalaya, *Juniperus recurva* and *Juniperus wallichiana* occur at an altitude ranging from 3000 to 4600m.

7.3 New Classification of Forest Types of India

Recently, the new classification of forest types has been proposed reflecting the present ecological, climatic, bio-geographic and edaphic influences on the vegetation composition and stand formation (see ICFRE 2013; Bahuguna et al. 2016). India's forest types are very diverse in their compositions with a long evolutionary and geological history, occurring under many climatic and edaphic conditions. They have been undergoing significant changes in the composition of forests since the forest types were revised by Champion and Seth, (1968).

The revised classification of forests has been based on the field survey covering more than 200 forest types and subtypes representing very diverse climatic and edaphic conditions throughout the country. Data were collected from the field surveys in terms of forest types, basal area, importance value index, stem density and diversity indexes including similarity indexes. Impact of climate change on the vegetation has been critically examined. The new classification of forest types reflects the present ecological, climatic, bio-geographic and edaphic influences on the vegetation composition and stand formation. In the proposed new classification, 10 major groups and 48 sub-groups have been were identified (ICFRE 2013; Bahuguna et al. 2016). The study has reported many changes occurring at species and forest subtypes levels. There are some positive and negative changes in different forest types. Some trends in the new classification of forest types are summarized as follows:

- **(i)** The species level changes were observed largely in *Shorea robusta* (Sal), *Tectona grandis* (Teak) and Bamboo forests with regard to their distribution and species density. The study has revealed that teak is found absent from very moist and moist teak sub-type, and occurrence of many moist deciduous and semi-evergreen species.
- **(ii)** In central India, the decline of *Shorea robusta* (Sal) and occurrence of dry deciduous species, fragmentation and changes in the species composition due to anthropogenic and climate changes.
- **(iii)** The vegetation composition, particularly on the alpine flora is experiencing the effect of climate change.
- **(iv)** There are changes in species composition of *Shola* forests and evergreen forests.
- **(v)** The forests in Andhra Pradesh, Karnataka and Gujarat have shown positive changes in the forest composition and density.
- **(vi)** Analysis based on national level data showed change in temperature and rainfall patterns reveal that many forests are moving towards drier conditions,

particularly the temperate forests. There are changes in the pattern of distributions of Oaks and Conifers.

(vii) The blue pine (*Pinus wallichiana*) found in the higher elevations up to 1700 m is now found in still higher elevations up to 2700 m showing a the shift in the tree lines towards higher elevations.

7.4 Forest Types of Uttarakhand

Different forest types of Uttarakhand as per the Champion & Seth classification (1968) are swon in table 7.7. Forest Type Maps of 2011 have been refined in the recently completed exercise by FSI. Percentage area under different forest types of Uttarakhand as per the Champion & Seth classification (1968), according to the latest exercise are presented in table 7.8.

Table 7.7 Different Forest Type Groups of Uttarakhand

S. No.	Forest Type Groups
1.	Group 3- Tropical Moist Deciduous Forests
2.	Group 5- Tropical Dry Deciduous Forests
3.	Group 9- Subtropical Pine Forests
4.	Group 12- Himalayan Moist Temperate Forests
5.	Group 13- Himalayan Dry Temperate Forests
6.	Group 14- Sub Alpine Forests
7.	Group 15 - Moist Alpine Scrub
8.	Group 16- Dry Alpine Scrub

Table 7.8 Percentage area under different forest types of Uttarakhand

S. No.	Forest Type	Forest cover (%)
1.	3C/C2a Moist Siwalik Sal Forest	14.05
2.	3C/C2c Moist Tarai Sal Forest	1.56
3.	3C/C2d (i) Western Light Alluvium Plains Sal Forest	0.62
4.	3C/DS1 Moist Sal Savannah	0.02
5.	3C/C3a West Gangatic Moist Mixed Deciduous Forest	4.04
6.	4C/FS2 Submontane Hill-Valley Swamp Forest	0.00
7.	5B/C1a Dry Siwalik Sal Forest	1.57
8.	5B/C1b Dry Plains Sal Forest	0.04

9.	5B/C2 Northern Dry Mixed Deciduous Forest	3.59
10.	5/DS1 Dry Deciduous Scrub	0.16
11.	5/1S2 Khair-Sissu Forest	0.97
12.	9/C1a Lower Or Siwalik Chir Pine Forest	0.18
13.	9/C1b Upper Or Himalayan Chir Pine Forest	27.97
14.	9/DS1 Himalayan Subtropical Scrub	1.61
15.	9/DS2 Subtropical Euphorbia Scrub	0.11
16.	12/C1a Ban Oak Forest *(Q.incana)*	13.86
17.	12/C1b Moru Oak Forest *(Q.dilatata)*	0.47
18.	12/C1c Moist Deodar Forest *(Cedrus)*	1.55
19.	12/C1d Western Mixed Coniferous Forest (Spruce, Blue Pine, Silver Fir)	5.01
20.	12/C1e Moist Temperate Deciduous Forest	0.79
21.	12/C1f Low-Level Blue Pine Forest *(P. wallichiana)*	0.09
22.	12/C1/DS1 Oak Scrub	0.14
23.	12/C1/DS2 Himalayan Temperate Secondary Scrub	0.06
24.	12/C2a Kharsu Oak Forest *(Q. semecarpifolia)*	3.08
25.	12/C2b West Himalayan Upper Oak/Fir Forest	5.49
26.	12/C2c (Moist Temperate Deciduous Forest)	0.79
27.	12/DS2 Himalayan Temperate Parkland	0.03
28.	12/DS3 Himalayan Temperate Pastures	0.16
29.	12/1S1 Alder Forest	0.03
30.	12/2S1 Low Level Blue Pine Forest	0.09
31.	13/C2b Dry Deodar Forest *(Cedrus)*	0.73
32.	13/C5 West Himalayan Dry Juniper Forest *(J. macropoda)*	0.02
33.	13/1S1 Hippophae / Myricaria Scrub	0.26
34.	14/C1a West Himalayan Sub-Alpine Birch/Fir Forest *(Betula/Abies)*	0.71
35.	14/C1b West Himalayan Sub-Alpine Fir Forest	2.06
36.	14/1S1 Hippophae / Myricaria Brakes	0.08
37.	14/1S2 Deciduous Sub-Alpine Scrub	0.16
38.	14/DS1 Sub-Alpine Pastures	0.82
39.	15/C1 Birch/*Rhododendron* Scrub Forest	0.45

Summary

- ✓ Champion and Seth (1968) gave the detailed classification of forest types in India based on climate, physiognomy, species composition, phenology, topography, soil factors, altitude, aspect, and biotic factors.

- ✓ The forests have been classified into six major forest types and 16 major groups on the basis of temperature and moisture regimes.
- ✓ The tropical wet evergreen forests are dense and show 30-45m tall canopy structure with four or five strata, generally found in the Western Ghats, north-eastern India and Andaman and Nicobar having rainfall in the range of 2000 to > 3000 mm.
- ✓ The tropical semi-evergreen forests occur in areas adjoining tropical wet evergreen, and form a transition between evergreen and moist deciduous forests.
- ✓ Tropical Moist Deciduous Forests are common in areas where rainfall is 1000 to 2000 mm with a dry season of three to four months, widely distributed covering both southern and northern states.
- ✓ Mangroves are found along the east and west coasts of India, the Andaman and Nicobar Islands. Sundarban (is the largest mangrove in the world).
- ✓ Tropical Dry Deciduous Forests are largest forest type of India covering about 40% of the forest area of the country, dry teak (*Tectona grandis*)and dry sal (S*horea robusta*) forests predominate in the southern and northern regions of India, respectively.
- ✓ Tropical thorn forests are found in low rainfall areas of northern India, peninsular India and central India, moisture availability is limiting for plant growth, the trees experience prolonged dry periods.
- ✓ Subtropical Broad Leaved Hill Forests occur in the hill slopes and tops at about 1000 to 1700m height in south India and northern India.
- ✓ Sub-tropical chir pine (*Pinus roxburghii*) forests occur throughout the central and western Himalaya between 1000 to 1800m. The forests of *Pinus keysia* occur in Khasi and Naga Hills and Manipur hills in eastern Himalaya.
- ✓ The southern Montane wet temperate forests Occur in high hills of Tamil Nadu and Kerala on the, Anamalai, Palni and Tiruneveli hills from about 1,500 m upwards. Tiruneveli
- ✓ Northern Montane wet temperate forests are a characteristic feature of the eastern Himalaya and are found between 1800 m and 3000 m elevation in high rainfall areas (>2000mm rainfall).

- ✓ Himalayan Moist Temperate Forests are distributed in northern India at altitude ranging from 1500m to 3300m. Several species of oak predominate in the temperate forests
- ✓ The Himalayan Dry Temperate Forest: Conifers predominate, 1700 to 3000m altitude, in the inner ranges of Himalaya, rainfall usually less than 1000mm.
- ✓ Sub-Alpine Forests occur throughout the Himalaya above 3000 m elevation up to the tree limit.
- ✓ The new classification of forest types has been proposed reflecting the present ecological, climatic, bio-geographic and edaphic influences on the vegetation composition and stand formation.

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Unit 8: Biodiversity

Unit Structure

8.0 Learning Objectives

After completing this unit you shall be able to:

- Define biodiversity
- Explain the importance of biodiversity
- Discuss levels of biodiversity
- Know the measurement of diversity and various diversity indices
- Discuss hot spots of biodiversity
- Enlist red list categories

8.1 Introduction

In the present time biodiversity of the organism is the main issue regarding their utility as well as conservation. Diversity of animals, plants and microbial life has been evolving billions of years. As more and more forms of life evolve, replacing some and helping the development of others, the networking of life becomes more encompassing and complicated. The evolving nature of natural organism was the resultant of their diversification. In the same way biodiversity spans the whole spectrum of life from microorganism to plants and animals. In present time there are many causes which are directly or indirectly responsible for the loss of biological organism in order to their flora and fauna. Exact number of exiting species on earth is still unknown. The estimated global species diversity contains approximately 13-14 million species. In which 1.75 species are described so far and many more still being discovered. Today need to focus on this aspect of life science and in the same way a lot of conservational programmers and resource management is necessary for the benefit of flora.

8.2 Basic Concept of Biodiversity

8.2.1 Definition of Biodiversity

Variability of biological organism is called biodiversity. Bio- diversity is interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment. In present time biodiversity of the organism is the main issue regarding their utility as well as conservation. Diversity of animals, plants and microbial life has been evolving billions of years. As more and more forms of life evolve, replacing some and helping the development of others, the networking of life becomes more encompassing and complicated. The evolving nature of natural organism was the resultant of their diversification. In the same way biodiversity spans the whole spectrum of life from microorganism to plants and animals. In fishes morphological variations are the resultant of either environment or genetic or the combination of both. Biological diversity is the fundamental interest of biology in which intraspecific diversity is considered as a component of biological diversity. Biodiversity can be measured in term of species, genes ecosystem. Species diversity can be classified into two type's i.e. interspecific and intraspecific diversity. According to the article 2 of conventions of biodiversity, *Biological diversity"* means the variability among living organisms from all sources including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems. *"Biological resources'* includes genetic resources, organisms or parts of their populations, or any other biotic component of ecosystems with actual or potential use or value for humanity.

8.2.2 Types of Biodiversity (Genetic, Species & Ecosystem Biodiversity)

Biodiversity can exemplify in term of species, level of genes and at broad level ecosystems.

1) Species diversity is the combination of the different species, as well as the differences within and between different species.
2) Genetic diversity is all the different genes contained in all the living species, including individual plants, animals, fungi, and microorganisms
3) Ecosystem diversity is all the different habitats, biological communities and ecological processes, as well as variation within individual ecosystems.

8.2.3 Genetic Diversity

Simply Genes are the segments of DNA, but their complexity is increases from prokaryotes to eukaryotes. In prokaryotes a set of genes are regulated by single promoters and operator's on the other hand eukaryotic gene is regulated by each promoter and operator. Genes regulated the overall process of organism including morphological traits, physiological traits in combination with the environmental plasticity. Genetic polymorphism has important implications for the conservation and evolution of species. Genetic diversity is blue print of the species in order to their single nucleotide (SNPs) variation. The number of genes is variable in the organism which exhibit by the genome of the organisms. Genetic diversity retains a variety of genetic information of all the individual plants, animals and microorganisms.

Fig 1. Genetic diversity within a population

Simply it is the variation of genes in their promoter region as well as in the coding sequence, with in species and populations. Species evolution is driven by a number of different factors, including migration and settlement in different environments, genetic mutation, natural selection, and genetic drift. The product of these different forces is genetic diversity within a population. The genetic variability in the organism is driven by the many factors as fig2. These factors are crossing over which is the primary source of variation for evolution while the mutation is the ultimate source of evolution. The other factors such as independent segregation of alleles (alleles are the alternative forms of genes), random fertilization. These factors lead to the sexual recombination as resultant genetic reshuffling occurs.

Genetic Variation can be measured by Several Methods

Genetic variation can be measured by the different markers such as single nucleotide polymorphism(SNPs) are the preferred markers for measuring genetic variation, other markers also have been used for the quantification of genetic variation including microsatellites. These are variable number tandem repeat (VNTR) sequences in the genome. VNTRs can be “short” (involving two to five nucleotide repeats) or “long” (involving more substantial repeat sequences). VNTRs are still used in studies today and are especially useful where the candidate gene is known or a specific region is being scanned. Earlier studies used restriction enzymes to identify different VNTRs and SNPs. To determine VNTR genotypes, one or more restriction enzymes that cut the DNA sequence above and below the region encoding the VNTR sequences can be used and DNA fragments of different sizes can be obtained. After digestion with the appropriate enzyme(s), the DNA sample can be run by electrophoresis on either an agarose gel or a polyacrylamide gel to reveal the size(s) of the fragments and thus the number of sequence repeats in each individual sample. Genotypes can be assigned based on the pattern obtained on the gel. This method is known as restriction fragment length polymorphism (RFLP) analysis. RFLP analysis was also used to detect SNPs where the differences in the DNA sequence can be detected by use of restriction enzymes that cut the DNA at a particular sequence encoded by one allele, but not the other. Multiple enzymes were often used when genotyping SNPs in order to obtain readable accurate results. Different enzymes are used to detect different polymorphisms. Later studies substituted RFLP genotyping for more reliable polymerase chain reaction (PCR) genotyping using primers specific for the gene sequence of interest. This method uses a polymerase enzyme purified from the hot-springs “thermophilic” bacteria Thermusaquaticus to amplify multiple copies of the gene sequence. These amplified sequences are then run out on a gel using the same process as that used with RFLP fragments and genotypes can be assigned from the specific banding patterns obtained for each sample.

8.2.4 Species Diversity

Diversification of species is known as species diversity. Species diversity can be measured as either within the species or between the species. Species diversity and genetic diversity are influenced by a complex set of processes across a range of spatial and temporal scales (Huston 1994; Rosenzweig 1995; Hedrick 2000; Frankham et al. 2002) Species diversity can be classified into two types: i.e. Intraspecific and Interspecific diversity. Species diversity also described by the following ways,

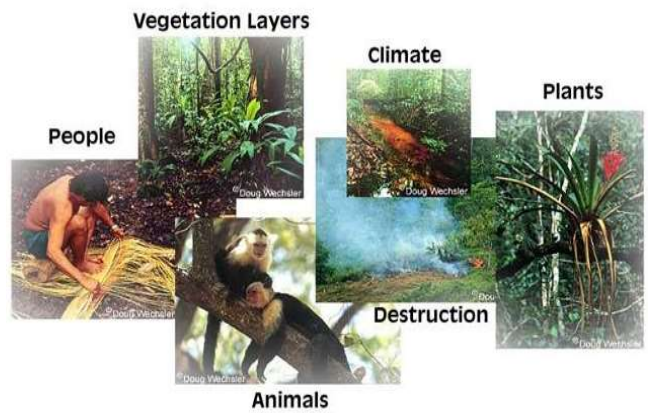

Fig. 2 Species diversity

Species Richness – Species richness may defined as the total numbers of species defined in area. Various indices are used including the Mangalet and Menhink index. This refers to the total count/number of species in a defined area. Various indices are used including the Mangalet index and Menhink index.

Species Abundance: Species abundance may be defined as the relative numbers among species. If all the species have the same equal abundance, this means that the variation is high hence high diversity,

Taxonomic or phylogenetic diversity- This considers the genetic relationships between the different groups of species. The measures are based on analysis, resulting into a hierarchical classification representing the phylogenetic evolution of the taxa concerned.

8.2.5 Ecosystem Diversity

Ecosystem is the unit of environment. Diversity of organism in relation to ecosystem is considered as ecosystem diversity. This relates to the variety of habitats, biotic communities and ecological processes in the biosphere. The variety of ecosystem found on Earth- the forest, desert, lakes, costal coral and other ecosystem. “Ecosystem“ i.e., a dynamic complex of plant, animal and micro-organismal communities and their non-living environment interacting as a functional unit. (Article 2 of the Convention on Biological Diversity).The Ecosystem Approach is the primary framework for action under the Convention on Biological Diversity and is defined as a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. This approach will be implemented over time in management practices in relation to key ecosystems.

India has very diverse terrestrial and aquatic ecosystems ranging from ice-capped Himalayas to deserts, from arid scrub to grassland to wetlands and tropical rainforests, from coral reefs to the deep sea. Each of these comprises a great variety of habitats and interactions between and within biotic and abiotic components. The most diversity-rich are Western-Ghats and the north-eastern region. A very large number of species found in these ecosystems are **endemic** or found in these areas only in India i.e., they are found nowhere else except in India. The endemics are concentrated mainly in north-east, Western-Ghats, north-west Himalaya, and Andaman and Nicobar Islands. About33% of the flowering plants recorded in India are endemic to our country. Indian region is also notable for endemic fauna. For example, out of recorded vertebrates, 53% freshwater fish, 60% amphibians, 36% reptiles and 10% mammalian fauna are endemic.

8.3 Importance of Biodiversity

Biodiversity has a great importance because it includes a variety of plant, animal life and microorganisms, and the variety of these types of Earth's ecosystems supports life. It supports the survival strategy of human either directly or indirectly. Biodiversity is the very stuff that supports the evolution and differentiation among the varying species. Resource management is an important aspect for proper utilization of resources and energy transfer across the ecosystem. Biodiversity contained ecosystems of forest, grassland, desert marine lake, river, and pond even our aquarium also which retains and supports many organism in term of shelter and food .Nature and its natural things has a great importance. Biodiversity has a direct value in food, agriculture, medicine and in industry also. Biodiversity maintains an ecological balance and continues as evolutionary process.

8.4 Hot Spots of Biodiversity

The constant diversity of organism is not throughout across the green planet. Certain regions of the earth are very rich in biodiversity; such biodiversity rich regions are called “mega diversity zones According to him, the hot spots are the richest and the most threatened reservoirs of biodiversity on the earth. The criteria for determining a hot spot are:

- The area should support >1500 endemic species
- It must have lost over 70 % of the original habitat

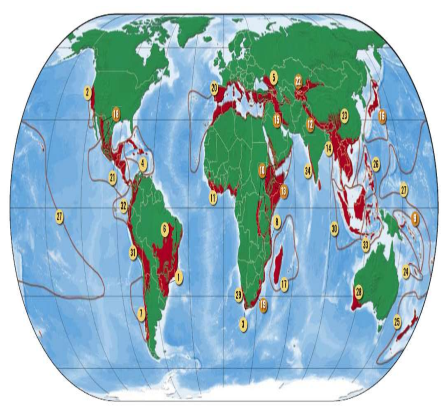

Fig. 3 Hot –spot area around the world

There are thirty four identified hot spots of the world in which four are found in India. These four are Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaban. The endemic species are those species which are confined in a specific geographic area or aparticular area. The hotpots of the worlds are shown in the fig3.

1) Atlantic Forest
2) California Floristic Province
3) Cape Floristic Region
4) Carribbean Islands
5) Caucasus
6) Cerrado
7) Chilean Winter Rainfall
8) Valdivian Forest
9) Coastal Forest of Eastern Africa
10) East Melanesian Islands
11) Eastern Afromontane
12) Guinean Forests of W. Africa
13) Eastern Himalaya
14) Horn of Africa
15) Indo Burma
16) Irano Anatolian
17) Japan
18) Madagascar & Indian Ocean Islands
19) Maderan Pine-oak woodlands
20) Maputaland-Pondoland Albany
21) Mediterranean Basin
22) Mesoamerica
23) Mountains of central Asia
24) Mountains of SW China
25) Wallace
26) New celedonia
27) New Zealand
28) Philippines
29) Polynesisa Micronesia
30) Southwest Australia
31) Succulent caro
32) Sunderland
33) Tropical Andes
34) Southwest Australia

Thirty four biodiversity hot spots have been identified in the world. These hot spots are characterized by posing exceptionally high biodiversity. For example the total area of these 25 hot spots cover 1.4% of the total land area, support 44% of plant and 35% terrestrial vertebrates. Among the 25 hot spots of the world, 2 are found in India namely Western Ghats and the eastern Himalayas. These two areas of the country are exceptionally rich in flowering plants, reptiles, amphibians, butterflies and some species of mammals. The eastern Himalayan hot spot extends to the north – eastern India and Bhutan. The temperate forests are found at an altitude of 1780 to 3500 m. Many deep and semi isolated valleys are exceptionally rich in endemic plant species. The Western Ghat region lies parallel to the western coast of Indian peninsula for almost 1600 km, in Maharashtra, Karnataka, Tamil Nadu and Kerala. These forests at low elevation (500 m above mean sea level) are mostly evergreen, while those at 500- 1500 m height are generally semi-evergreen forests.

8.4.1 Biodiversity hotspots

The important biodiversity hotspots are:

- Himalaya
- Indo-Burma
- Sunderland
- Western Ghats and Sri Lanka

1) **Himalaya**: It includes the entire Indian Himalayan region. The Himalaya Hotspot is the home of the world's highest mountains, including Mt. Everest. The mountains rise abruptly, resulting in a diversity of ecosystems that range from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line. Vascular plants have even been recorded at more than 6,000 m. The hotspot is home to important populations of numerous large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffalo.

2) **Indo-Burma:** Includes entire North-eastern India, except Assam and Andaman group ofIslands (and Myanmar, Thailand, Vietnam, Laos, Cambodia and southern China). Encompassing more than 2 million km² of tropical Asia, Indo-Burma is still revealing its biological treasures. Six large mammal species have been discovered in the last 12 years: the large-antlered muntjac, the Annamitemuntjac, the grey-shanked douc, the Annamite striped rabbit, the leaf deer, and the saola. This hotspot also holds remarkable endemism in freshwater turtle species, most of which are threatened with extinction, due to over-harvesting and extensive habitat loss. Bird life in Indo- Burma is also incredibly diverse, holding almost 1,300 different bird species, including the threatened white-eared night-heron, the grey-crowned crocias, and the orange-necked partridge.

3) **Sunderaland:** It includes Nicobar group of Islands and Indonesia, Malaysia, Singapore, Brunei, Philippines. The spectacular flora and fauna of the Sunderland Hotspot are succumbing to the explosive growth of industrial forestry in these islands and to the international animal trade that claims tigers, monkeys, and turtle species for food and medicine in other countries. Populations of the orang-utan, found only in this hotspot, are in dramatic decline. Some of the last refuges of two Southeast Asia rhino species

are also found on the islands of Java and Sumatra. Like many tropical areas, the forests are being cleared for commercial uses. Rubber, oil palm, and pulp production are three of the most detrimental forces facing biodiversity in the Sunderland Hotspot

4) **Western Ghats and Sri Lanka:** Includes entire Western Ghats (and Sri Lanka). Faced with tremendous population pressure, the forests of the Western Ghats and Sri Lanka have been dramatically impacted by the demands for timber and agricultural land. Remaining forests of the Western Ghats are heavily fragmented; in Sri Lanka, only 1.5% of the original forest remains. Population levels are also applying increased stress on the fringes of protected areas where many farms, loggers, and poachers use the resources illegally. Due in part to the varying effect of the yearly monsoons and the high mountain regions, this hotspot is home to a rich endemic assemblage of plants, reptiles, and amphibians. Sir Lanka alone may be home to as many as 140 endemic species of amphibians. The region also houses important populations of Asian Elephants, Indian Tigers, and the Endangered Lion-tailed Macaque. Freshwater fish endemism is extremely high as well, with over 140 native species.

8.4.2 Threats to Biodiversity

Biodiversity has many benefits which humans use for a variety of purposes. The over increasing population and consequently development processes has resulted into over-exploitation of natural resources including biodiversity. Today's threats to species and ecosystems are the greatest recorded in recent history and virtually all of them are caused by human mismanagement of biological resources often stimulated by misguided economic policies and faulty institutions. There are many threats to our natural resources particularly biodiversity. A threat by definition refers to any process or event whether natural or human induced that is likely to cause adverse effects upon the status or sustainable use of any component of biological diversity. Important threats include:

- Habitat loss
- Over exploitation
- Invasive alien species
- Increase in pollution and
- Global climate change

Habitat alteration / destruction Increased insatiable demand for resources results to land use changes hence loss to genetic diversity, species reduction and increased ecosystem changes such as random population changes, disease outcrops, habitat fragmentation among others resulting in biodiversity losses.

Overharvesting/over-exploitation of biological resources means using of individuals of a particular species at a higher rate than can be sustained by the natural reproductive capacity of the population being harvested. This can be through hunting, fishing, trade, food gathering etc. Overharvesting will lead to extinction of resources or the biological resources, eventually leading to loss of species.

Introduced species / biological invasions is another factor responsible for biodiversity loss. This can be intentional or accidental. Species introduced in an ecosystem will cause changes in the ecosystem. Introduced species are organisms arising in areas/ habitats in which they were previously not native. Such introduced species are usually referred to as biological pollutants. Some of the ecological impacts of the invasion include hybridization, out competition, disruption of original ecosystem, plant pathogenic influences, disease transmission, and disruption of food webs and to some situations extinction. Species may be introduced intentionally for Ornamental concerns; Agriculture; Hunting and spotting activities; Biotechnology for scientific research.

Pollution is a threat to biodiversity as the species in habitats / ecosystem are increasingly being harmed by industrial activities and pollution from excessive use of agro-chemicals such as DDT, oil spills, acid precipitation etc.

This is of great concern especially when global CO2 increases in the atmosphere resulting to global warming. Most species originate within a very narrow physiological limit; hence nature has a range of tolerance maintained for ecosystem stability. Changes may be gradual or abrupt such that if the limit is exceeded the upper or lower species suffers extinction.

Population is the root cause of As the human population is increasing; there exists insatiable demand for raw materials which is bound to cause changes in biodiversity. It is therefore vital to control human population which will result in biodiversity conservation. Some institutions are created to manage biological resources. However, the institutions/policy fail to internalize the values of biodiversity within the decision making process of their Nations and individuals. Such institutions/policies in place should have a holistic approach towards biodiversity conservation rather than part conservation.

8.4.3 IUCN Red List Categories

According to IUCN (1995), six categories of threatened species have been identified as below:

i) Extinct (Ex)

ii) Extinct in the Wild (EW)

iii) Critically Endangered (CR)

iv) Endangered (EN)

v) Vulnerable (VU)

vi) Lower Risk (LR)

   a. Conservation Dependent (cd)

   b. Near Threatened (nt)

   c. Least Concern (lc)

vii) Data Deficient (DD)

A taxon is said to be **Extinct** when there is no reasonable doubt that the last individual has died.

A taxon is **Extinct in the wild (EW)**when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed extinct in the wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

A taxon is **Critically Endangered**(CR) when it is facing an extremely high risk of extinction in the wild in the immediate future.

A taxon is **Endangered (EN)**when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.

A taxon is **Vulnerable(VU)** when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

A taxon is **Lower Risk (LR)**when it has been evaluated, does not satisfy the criteria for any of the categories Critically Endangered, Endangered or Vulnerable. Taxa included in the Lower Risk category can be separated into three subcategories:

A taxon **is Data Deficient (DD)** when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution is lacking. Data Deficient is therefore not a category of threat or Lower Risk. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

Summary

- The estimated global species diversity contains approximately 13-14 million species. In which 1.75 species are described so far and many more still being discovered.
- Variability of biological organism is called biodiversity. Bio- diversity is interrelatedness of genes, species, and ecosystems and in turn, their interactions with the environment.
- Biological diversity is the fundamental interest of biology in which intraspecific diversity is considered as a component of biological diversity. Biodiversity can be measured in term of species, genes ecosystem.
- species diversity can be classified into two type's i.e. interspecific and intraspecific diversity.
- Biodiversity has three levels of study i.e., Species diversity, Genetic diversity and ecosystem diversity
- Biodiversity has a great importance because it includes a variety of plant, animal life and microorganisms, and the variety of ecosystems supporting life. It supports the survival strategy of human either directly or indirectly. Many of requirements

and benefits are derived from these resources including edibles, vegetables, medicinal plants etc.

- The diversity of organism is not constant. Certain regions of the earth are very rich in biodiversity; which are called “mega diversity zones”.
- Certain areas high diversity of endemic species are known as, “hot spot”. The criteria for the purpose are - the area should support >1500 endemic species and it must have lost over 70 % of the original habitats.
- There are thirty four identified hot spots around the world. Four of these identified in our country. These four are Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaban.
- The over increasing population and consequently development processes has resulted into over-exploitation of natural resources including biodiversity. Today’s threats to species and ecosystems are the greatest recorded in recent history and virtually all of them are caused by human mismanagement of biological resources often stimulated by misguided economic policies and faulty institutions. A threat by definition refers to “any process or event whether natural or human induced that is likely to cause adverse effects upon the status or sustainable use of any component of biological diversity”. Important threats to biodiversity include: Habitat loss, Over exploitation, Invasive alien species, Increase in pollution and Global climate change.
- IUCN has defined certain criteria to categorize the species according to their threat status into seven categories. These are - Extinct (Ex), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Lower Risk (LR). There is one more category called as Data Deficient (DD) although species falling in this category cannot be regarded as a threat category.

References

1. Presented at Short Course IV on Exploration for Geothermal Resources, organized by UNU-GTP, KenGen and GDC, at Lake Naivasha, Kenya, November 1-22, 2009.
2. Kenya Electricity Generating Co., Ltd. GEOTHERMAL TRAINING PROGRAMME Geothermal Development Company BIODIVERSITY CONSERVATION Thecla M.
3. Mutia Geothermal Development Company Limited P.O. Box 100746-00101, Nairobi KENYRelated Links

Unit 9: Biodiversity Conservation

Unit Structure

9.0 Learning Objectives

After completing this unit you shall be able to:

- Define biodiversity
- Explain the importance of biodiversity
- Discuss levels of biodiversity
- Know the measurement of diversity and various diversity indices
- Discuss hot spots of biodiversity
- Enlist red list categories

9.1 Introduction

In the present time biodiversity of the organism is the main issue regarding their utility as well as conservation. Diversity of animals, plants and microbial life has been evolving billions of years. As more and more forms of life evolve, replacing some and helping the development of others, the networking of life becomes more encompassing and complicated. The evolving nature of natural organism was the resultant of their diversification. In the same way biodiversity spans the whole spectrum of life from microorganism to plants and animals. In present time there are many causes which are directly or indirectly responsible for the loss of biological organism in order to their flora and fauna. Exact number of exiting species on earth is still unknown. The estimated global species diversity contains approximately 13-14 million species. In which 1.75 species are described so far and many more still being discovered. Today's need to focus on conservational programmers and resource management is necessary for the benefit of flora.

9.2 Conservation of Biodiversity

We know that ecosystems are undergoing change due to pollution, invasive species, overexploitation by humans, and climate change. Most people are beginning to recognize that diversity at all levels - gene pool, species and biotic community is important and needs to be conserved. We should not deprive the future generations from the economic and aesthetic benefits that they can derive from biodiversity. The decisions we make now, as individuals and as a society, will determine the diversity of genes, species and ecosystems that remain in future. We may appreciate the fact that the most effective and efficient mechanism for conserving biodiversity is to prevent further destruction or degradation of habitats by us. We require more knowledge to conserve biodiversity in reduced space and under increased pressure of human activities. There are two basic strategies of biodiversity conservation

- in situ (on site) conservation
- ex situ (off site) conservation

9.2.1 In situ Conservation Strategies

The in situ strategy emphasizes protection of total ecosystems. The in situ approach includes protection of a group of typical ecosystems through a network of protected areas. Protected areas are the areas of land and/or sea especially dedicated to the protection and maintenance of biological

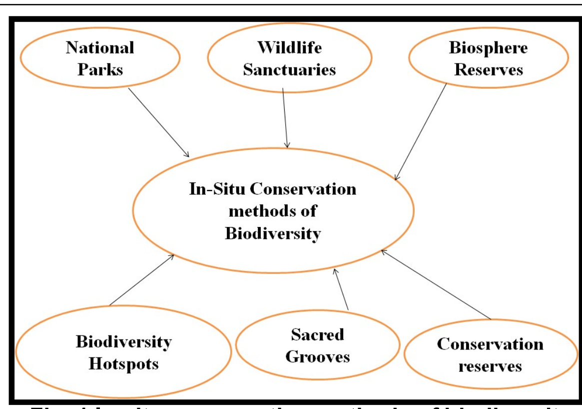

Fig. 1 In-situ conservation methods of biodiversity

diversity, and of natural and associated cultural resources. These are managed through legal or other effective means.

Protected areas are areas or locations which receive protection because of their recognized natural, ecological values. There are several kinds of protected areas such as **National Parks, Wildlife Sanctuaries, Biosphere reserves, and conservation sites** etc. which vary by level of protection depending on the permitting laws of each country or the regulations of the international organizations. Examples of protected areas are National Parks, and Wildlife Sanctuaries. Protected areas are essential for biological diversity conservation, often providing habitat and protection from hunting and poaching. Protection helps maintain ecological processes within ecosystems.

World Conservation Monitoring Centre has recognized 37000 protected areas around the world. As of September 2002, India has 581 protected areas (89 National Parks and 492 Wildlife Sanctuaries), covering 4.7% of the land surface as against 10% internationally suggested norm. The Jim Corbett National Park was the first National Park established in India.

According to International Union for Conservation of Nature (IUCN) Protected area may defined as "Protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values".

Protected areas provide various social, environmental and economic benefits to people and communities at local and global level. Protected areas are very important to react to present environmental problems and these areas provide food and water security, human health and welfare, disaster risk reduction and climate change.

As you now that the world continues to develop at a rapid speed consequently, pressure on ecosystems and natural resources increases. Protected areas, when administered and managed properly and embedded in development strategies, may provide nature-based solutions to this pressure. Protected areas are important in following terms:

- These protected areas provide habitat to wildlife
- Protected areas provide drinking water to communities.
- Store the same amount of carbon as the tropical rainforests,

- Protected areas keep human being and wildlife healthy by being the source of clean air and water.
- Protected areas protect endangered plants and animals in their habitats.
- Protected areas help to reduce the risks and consequences of extreme events such as floods, storm-surges, and drought
- Protected areas Provide homes, jobs and livelihoods to millions of people around the world.
- Maintaining viable populations of all native species and subspecies;
- Maintaining the number and distribution of communities and habitats, and conserving the genetic diversity of all the present species;
- Preventing human-caused introductions of alien species; and
- Making it possible for species/habitats to shift in response to environmental changes.

A) Biosphere Reserves: Biosphere reserves are protected area established by different countries and recognized under Man and Biosphere Programme of United Nations Educational, Scientific and Cultural Organization (UNESCO). Biosphere Reserves are excellent locations to examine how to implement the sustainable development Goals. Three zones are characteristic of Biosphere reserve, the core area(s) and sometimes buffer zone(s) of all biosphere reserves which are protected areas as recognized by IUCN.

Biosphere reserves are a special category of protected areas of land and/or coastal environments, wherein people are an integral component of the system. These are representative examples of natural biomes and contain unique biological communities. The concept of Biosphere Reserves was launched in 1975 as a part of the UNESCO's Man and Biosphere Programme dealing with the conservation of ecosystems and the genetic resources contained therein.

The main functions of biosphere reserves are:

- **Conservation:** to ensure the conservation of landscapes, ecosystems, species and genetic resources. It also encourages traditional resource use.
- **Development:** to promote economic development, this is culturally, socially and ecologically sustainable.

- **Scientific research, monitoring and education:** the aim is to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development

A Biosphere Reserve usually consists of three zones i.e., core, buffer and transition zones. These are described below:

i) **The core Zone/area:** The natural or core zone comprises an undisturbed and legally protected ecosystem. It is long term protected area and it act as a reference point of biosphere reserve. This area is indication of biosphere reserve. It is strictly protected area that contributes to conservation of landscape, species and genetic variation.

ii) **Buffer Zone/Area:** The buffer zone surrounds the core area, and is managed to accommodate a greater variety of resource use strategies, and research and educational activities.

iii) **Transition Zone:** Transition zone is part of biosphere reserve where maximum human activities are allowed. Such activities may for fostering economic and human development that is socio-culturally and ecologically sustainable. It is an area of active cooperation between reserve management and the local people, wherein activities like settlements, cropping, forestry and recreation and other economic uses continue in harmony with conservation goals.

At present, there are 669 Biosphere reserves around the world. There are eighteen (18) Biosphere reserves are established in India. One biosphere reserve established in Uttarakhand which is described below:

Nanda Devi Biosphere Reserve: The Nanda Devi Biosphere Reserve is an important protected area of Uttarakhand. It was established in 1988 NDBR Its name was named after famous peak of that area i. Nanda Devi (7817 m) which is second highest peak of India. The total area of this biosphere reserve is about 6384.49 sq. km. The Nanda Devi biosphere reserve has divided in to three zones: Core zone (National Parks), Buffer Zone and transition zone. There, are two core zone in Nanda Devi Biosphere Reserve, these are Core zone 1 of Nanda National Park and core zone-2 of Valley of Flower National Park. Both the core zones of this biosphere reserve are declared as world heritage sites of UNESCO. Common flora of this biosphere reserve are include fir, birch, rhododendron, and juniper, ramani, alpine, prone mosses and lichens. Common fauna of this biosphere reserve are Leopards, Himalayan Musk deer, Himalayan tahr, rhesus macaque, brown bear, snow leopards, barking deer etc. Total of 114 bird species are recognized from this biosphere reserve

B) National Parks and Wildlife Sanctuaries

An area dedicated by statute for all time, to conserve the scenery and natural and historical objects of national significance, to conserve wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations, with such modifications a local conditions may demand". (IBWL 1952). NPs are very important protected areas which are declared by IUCN. These National parks provides habitat to wildlife and very few human activities are allowed in the buffer zone of National park. The plantation, cultivation, grazing, hunting and predating of animals, destruction of flowers are highly prohibited in National Parks. International Union of Conservation of Nature (IUCN) has declared National Parks in Category II of the protected areas. IUCN is global authority which works for conservation of Nature. It was established in 1948 in France. There are six National parks in the State of Uttarakhand (Gangotri National Park, Govind Pashu Vihar National Park and Sanctuary, Jim Corbett National Park, Nanda Devi National Park, Valley of Flower National Park, Rajaji National Park). A brief description of these is as follows:

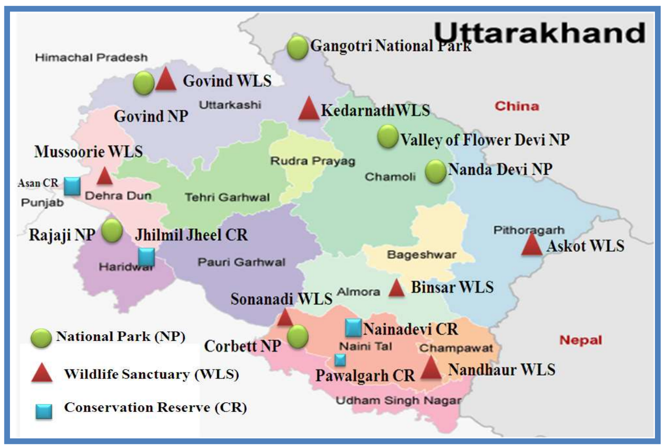

Fig. 2 Protected area network in Uttarakhand

Gangotri National Park: This National Park is located in the District Uttarkashi of Uttarakhand. It has area about 2,390.02 sq. km. It was established in the year 1989. This National park is home to floral diversity such as: Alpine shrubs, meadows, chirpine, deodar, rhododendrons and oak and fauna like snow leopard, tahr, Himalayan barbet, pheasant birds, pigeons etc. According to scientists about 15 species of mammals and 150 bird species have discovered in this park.

Govind Pashu vihar National park and Sanctuary: This is also located in Uttarkashi district of Uttarakhand. It was established initially as a wildlife sanctuary in 1955, and later converted into a national park. It has an area about 958 Sq.km. It is named after a renowned Indian freedom fighter and politician Govind Ballabh Pant, who became Home Minister in 1950 and is remembered for his achievement in establishing Hindi as an official language. This NP is home to various flora like chir, pine, deodar, oak, conifers, rhododendrons etc. This National Park is home to Snow leopard species which categorized as endangered under IUCN category. Other mammals found in the NP/sanctuary include the musk deer, bharal, brown bear, Himalayan tahr, porcupine, wild boar etc. Birds found here include several endangered species such as the golden eagle, black eagle, monal, finches cuckoos, parakeets, bulbul etc.

Jim Corbett National Park: It is is the first national park of India which established in the year 1936 as Hailey National Park to protect the endangered Bengal tiger. It is located in district Nainital and was named after Jim Corbett who played a key role in establishment of this National park. Corbett National Park comprises 520.8 sq.km area of hills, riverine belts, marshy depressions, grasslands and a large lake. A total of 488 different species of plants have been recorded in the park. About 586 species of resident and migratory birds, 33 species of reptiles, 07 species of amphibians, seven species of fish and 36 species of dragon flies have also been recorded from this National Park. Bengal tigers, leopards, jungle cats, fishing cat, otters, owls, barking deer, sambhar deer, langur, Elephant, python etc are common fauna of this National Park.

Nanda Devi National Park: It was established in 1988 in the district Chamoli of Uttarakhand. it is a situated around the peak of Nanda Devi (goddess of hindu religion). This is world heritage site by UNESCO. The national park has an area about 624.60 sq. km in Nanda Devi biosphere reserve. This NP is home to a wide variety of flora such as fir, birch, rhododendron, and juniper. Common fauna of national park are Himalayan Musk Deer, Snow Leopard, Himalayan Black Bear, and Brown Bear etc.

Valley of Flowers National Park: It was established in the year 1982 in the District Chamoli of Uttarakhand. It has an area about 87.50 $sq.km^2$. This National Park and

Nanda Devi National Park are lies under the Nanda Devi Biosphere reserve. We will discuss Nanda Devi Biosphere reserve in later. This National park is famous for different flowers like orchids, poppies, marigold etc. Common flora of National parks are *Abies pindrow*, *Betula utilis*, and *Rhododendron campanulatum*, *Taxus wallichiana*, *Syringa emodi*, *Arisaema jacquemontii*, *Boschniakia himalaica*, *Corydalis cashmeriana*, *Polemonium caerulium*, *Polygonum polystachyum*, *Impatiens sulcata*, *Geranium wallichianum*, *Galium aparine*, *Morina longifolia*, *Inula grandiflora*. The common fauna of this park are *Semnopithecus entellus* (langur), *Petaurista petaurista (*flying squirrel*)*, *Ursus thibetanus (*Himalayan black bear) *Vulpes vulpes (*red fox*)*, *Mustela sibirica (*Himalayan weasel*)*, and *Martes flavigula* (Himalayan yellow-throated marten), *Naemorhedus goral* (Himalayan goral), *Moschus leucogaster* (Himalayan musk deer), *Moschiola indica* (Indian chevrotain), *Hemitragus jemlahicus a*nd serow *Capricornis sumatraensis*.

Rajaji National Park: This National Park is spread over 820 sq. km. in the area of three districts namely Haridwar, Dehradun and Pauri Garhwal. It was established in 1983, when three wildlife sanctuaries (Chill, Motichur and Rajaji) merged in to one. It has been named after C. Rajagopalachari, a prominent leader of the Freedom Struggle and first recipients of India's highest civilian award Bharat Ratna in 1954. Rajaji National Park declared as tiger reserve in 2015. Rajaji National Park is home to various plant species such as *Cassia fistula* (amaltash), *Shorea robusta* (sal), *Butea monosperma* (palash), *Terminalia arjuna* (arjun), *Aegle marmelos* (bel) etc. Common fauna of National parks are elephant, tiger, chital, leopard,sambhar, jackal, barking deer, Indian porcupine, Himalayan black bear, striped hyena, monitor lizard, python, pea fowl, kingfisher, great pied hornbill etc.

C) Wildlife Sanctuaries

Wildlife makes the primary natural heritage, all around the world. Constant industrialization and deforestation, has been threat of extinction to the wildlife. International Union of Conservation of Nature grouped wildlife sanctuaries in Category IV of protected areas. Wildlife sanctuary refers to an area which provides protection and favourable living conditions to the wild animals. Wildlife Sanctuary, as the name imply, is the place that is reserved exclusively for the wildlife protection. It provides habitat and safe living conditions to the wild animals especially to the endangered. For proper management of the sanctuary, rangers or guards are appointed to patrol the region. Governments ensure the safety of animals, from poaching, predating or harassing.

Wildlife sanctuaries are the areas where killing and capturing of any species of birds or animals is prohibited except under orders of competent authority and whole boundaries and characteristics should be sacrosanct (free from outrage) as far as possible". (IBWL 1952).

WLS	Location	Year of Establishment	Total Area (Sq.km)
Askot WLS	Pithoragarh	1986	599.93
Binsar WLS	Almora	1988	45.59
Kedarnath WLS	Chamoli and Rudraprayag	1972	975.20
Nandhaur WLS	Nainital, Champawat	2012	269.96
Sonanadi WLS	Nainital	1987	301.18
Benog Mussoorie WLS	Dehradun	1993	3.39

Wildlife Sanctuaries of Uttarakhand

Wildlife Sanctuaries of Uttarakhand are described below:

Askot Wildlife Sanctuary: This sanctuary was established in the year 1986 with objective of conserving Himalayan Musk deer (*Moschus leucogaster*). As you know that, poaching of musk deer is very common in hilly states of India. Intensive efforts have been initiated to conserve this rare species. Therefore, this sanctuary is also called Askot Musk deer Sanctuary. It has an area about 600 sq. km. Beside, musk deer this sanctuary is home to Bengal tiger, Indian leopard, Jungle cat, Himalayan brown bear etc. Religious spots under the sanctuary are Chota Kailash, Bhanar etc. The famous peaks of area are Panchchuli, Neodhura, Chiplakot etc.

Binsar Wildlife Sanctuary: It is located in the Almora district of Uttarakhand and 33 km north of the Almora. It has an area about 45.59 sq. km. It was established in 1988 for the conservation and protection of the oak forests of the Central Himalayan region, and it has over 200 bird species. The fauna of sanctuary include Himalayan goral, leopard, chital, musk deer, Jungle cat, red fox, forktail bird, woodpecker, monal, parakeet etc. It is also home to many reptiles and a wide range of butterflies

Kedarnath Wildlife Sanctuary: It is also called the Kedarnath Musk Deer Sanctuary established in 1972 for the protection of Himalayan Musk deer. It consists of an area of 975 sq. km. The sanctuary takes its name from the famous Hindu Shrine Kedarnath which is just outside its northern border. The whole route (14km) from Gauri Kund to Kedarnath Temple lies under this wildlife sanctuary. Flora of sanctuary includes high-altitude bugyal dense forests of Chir pine, oak, rhododendron. Common fauna of sanctuary are Himalayan Musk deer, Red fox, snow leopard, flying squirrel, rhesus mazaque, langur, Himalayan Monal, pheasants, grey cheeked warbler, Himalayan pit viper etc.

Nandhaur wildlife sanctuary: It is located in the district nainital and champawat and was established in 2012. it lies between gola river and sharda river in haldwani forest division. It has an area about 269.96 sq. km. nandhaur wls is important for the protection of tigers. Main floras of this sanctuary are shisham, bamboo and chir pine. forest department of Uttarakhand found a tree in this sanctuary, which is called “king of trees”.This tree is expected 200 year with 54 feet wide and 120 feet height.This sanctuary is also home to about 25 species of mammals, 250 species of birds, 15 species of reptiles and 20 species of fishes. The major mammalian species include leopards, asian elephants, tigers and sloth bears.

Sonanadi Wildlife sanctuary: It is spread in district Nainital of Uttarakhand State. It has an area about 301.18 sq. km. It is an undisturbed wildlife haven, tucked between the Corbett and Rajaji national parks. It was established in 1987 to protect the biodiversity-rich region between these important wildlife conservation destinations. Main flora of sanctuary are Sal, Shisham, Khair, Asna and bamboo species. Fauna of this sanctuary are Asiatic Elephant, tiger, leopard, Ibar, cheetal, sambar, ghariyal, king Cobra and otter. This wildlife sanctuary is also famous for bird population that includes about 550 avian species like Pied Hornbill, Hawk Eagle, Kaleej Pheasant and Fishing Eagle.

Benog Mussoorie Wildlife sanctuary: It is part of famous Rajaji National Park and was established in the year 1993. It has an area about 3.39sq.km. The sanctuary is home to several species of exotic birds such as White Capped Water Redstart and Red Billed Blue Magpie to name a few. The Mountain Quail (Pahari Bater) was spotted in this sanctuary in 1876, but now considered extinct. Common fauna of sanctuary are Himalayan goat, panther, leopard, deer and bear. Flora of this sanctuary includes pine trees, several medicinal plants.

Table 1 Difference between Wildlife sanctuary and National Park

Base of Comparison	National Park (NP)	Wildlife Sanctuary (WLS)
Category In IUCN	Category II	Category IV
Meaning	National park is the protected area, which is established by the government, to conserve wildlife and also develop them. It also protects natural habitats, cultural and heritage sites.	Wildlife Sanctuary is a natural habitat, owned by the government or private agency that protects particular species of animal.
Preservation	Flora, fauna, landscape, historic objects, etc.	Animals, birds, insects, reptiles, etc.
Aim/Objective	To protect the natural and historic objects and wildlife of an area.	To maintain population of the wildlife and their habitats.
Restriction	Highly restricted, random access to people is not allowed.	Restrictions are less and it is open to public.
Permission to visit	Required for Officials	Not required
Boundaries	Fixed by legislation	Not fixed
Human activity	Not allowed at all.	Allowed but up to a certain limit.

D) Conservation Reserves In Uttarakhand

Table 2 Conservation reserves in Uttarakhand

Name of Conservation Reserve	Location	Establishment Year	Total Area (Sq.km)
Naina Devi Himalayan bird conservation reserve	Nainital	2015	111.9
Jhilmil Jeel conservation reserve	Haridwar	2005	37.84
Asan wetland conservation reserve	Dehradun	2005	4.44
Pawalgarh Conservation reserve	Nainital	2012	58.24

Conservation reserves are the protected areas for the protection of animals and their habitats. There are four conservation reserves namely: Naina Devi Himalayan bird conservation reserve, Jhilmil Jeel conservation reserve, Asan wetland conservation reserve, Pawalgarh Conservation reserve in Uttarakhand. These are briefly described below:

Naina Devi Himalayan bird conservation reserve: It was established in 2015 in the District Nainital of Uttarakhand. It spread in area of 111.95 sq.km. This conservation reserve is home to temperate broad-leaf forests to alpine grasslands to rhododendron shrubberies. Common fauna of Naina Devi Conservation reserve are Koklas pheasants, Kalij pheasants, black throated tit, bearded vulture, Himalayan goral etc.

Jhilmil Jeel conservation Reserve: It is little known marshy grassland just near the Rajaji National Park at Haridwar district of Uttarakhand. It has an area about 37.84 sq. km. It is located between Haridwar-Najibabad Highway. It was declared a Conservation Reserve in the year 2005 on order from renowned scientist and former President Dr. Abdul kalam. Jhilmil Jheel conservation Reserve is rich in fauna and flora diversity including five species of deer as Chital, Sambar, Barking deer, Hog deer and Swamp deer, Elephant, Nilgai, leopard and tiger are also seen in the area. This conservation was established under Sec 36 (a) of Wildlife (Protection) Act, 1972.

Asan wetland conservation Reserve: It is located in Dehradun district is first conservation reserve of India established in 2005. It has an area of 4.44 sq km, this wetland is at the confluence of the Asan and Yamuna Rivers. The conservation reserve supports more than 250 species of birds. Its proximity to Dehradun and the ease of seeing birds makes it a great bird tourism destination. Some of the bird species of Asan conservation reserve are Black francolin, Grey francolin, Ruddy shelduck, Gadwall, Mallard, Northen pintail, Bear's pochard, Common goldeneye, Little Grebe, Glossy ibis, Black-necked stork, Eurasian spoonbill, Indian pond heron, Grey heron, Great cormorant, Osprey, White-tailed fish, Himalayan vulture etc. This conservation was established under Sec 36 (a) of Wildlife (Protection) Act, 1972.

Pawalgarh Conservation Reserve: It is located in the Nainital District of Uttarakhand state and established on 14 Dec, 2012. It has an area about 58.24 sq.km. Pawalgarh conservation reserve is a network of forest, grassland and riverine ecosystems which provide habitats to many floral and faunal species. The common fauna of conservation reserve are tiger, leopard, spotted deer, nilgai, kakad (goat like deer), hares, langures. It has over 350 species of birds and every year many tourists visit here for bird watching. Great slaty woodpeckers, varieties of hornbills are main attractive birds of this conservation reserve.

C) Sacred forests and sacred lakes: A traditional strategy for the protection of biodiversity has been in practice in India and some other Asian countries in the form of sacred forests. These are forest patches of varying dimensions protected by tribal communities due to religious sanctity accorded to these forest patches. The sacred forests represent islands of pristine forests (most undisturbed forests without any human impact) and have been free from all disturbances; though these are frequently surrounded by highly degraded landscapes. In India sacred forests are located in several parts, e.g. Karnataka, Maharashtra, Kerala, Meghalaya, etc., and are serving as refugia for a number of rare, endangered and endemic taxa. Similarly, several water bodies (e.g. Khecheopalri Lake in Sikkim) have been declared sacred by the people leading to protection of aquatic flora and fauna.

Table 3 Important Sacred Groves in Uttarakhand

District	Location	Name of the Deity	Name of the Grove (Surrounding forest)
Almora	Chamarkhan	Golu Devta	Chir pine (Pinus roxburghii)
Nainital	Ghorakhal		Banj oak (Quercus leucotrichophora)
Chamoli	Badheth		Ghanteyal ki cheevi, Devika mandi Ghandiyal Devataka van Laxmivan, Nandaaur Ghantakaran Ki Phulwari
Pithoragarh	Ganglihat tehsil	Mahakali Shaktipith	Haat Kali
Pithoragarh	Berinag tehsil	Kokilamata	Lohathal

As you know that Uttarakhand is also called Dev bhoomi means land of God and Goddess. State has variety of religious and traditional beliefs, cultural and practices and these play a crucial role in the conservation of environment and biodiversity. According to Hughes and Chandran sacred groves are defined as "segments of landscape containing vegetation, life forms and geographical features, delimited and protected by human societies under the belief that to keep them in a relatively undisturbed state is expression of an important relationship of humans with the divine or with nature.

According to Environmental Education Centre, Chennai which ii body of Ministry of Environmental, Forest and Climate change "sacred groves in Uttarakhand are

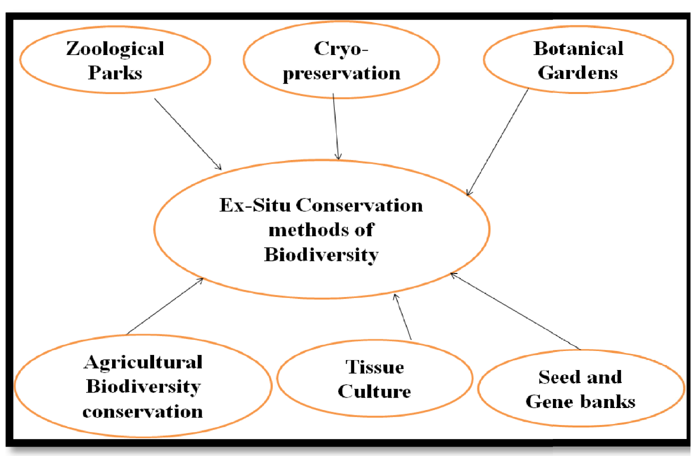

Fig. 3 Different Ex-situ conservation methods of biodiversity

locally known as Deo Bhumi and Bugyal (sacred alpine meadows and 126 sacred groves have been documented in the state. Uttarakhand has an age-old tradition of protected temple forests near villages, where different God and Goddess are worshipped in these sacred groves. The trees which are growing in these groves are not allowed to destroy and as it is believed that these trees are associated with God and Goddess. Local communities conserve these sacred grooves and sometimes dried parts are seed by them. Communities believe that sudden falling of trees or plants of these sacred grooves are said to be indicator of misfortune or disaster for the villagers. These types of believe in these sacred grooves helped conservation of biodiversity of area. areas. It is expected that many more sacred grooves are found in Uttarakhand. Some important sacred grooves in Uttrakhand are given below:

9.2.2 Ex-situ Conservation Strategies

The ex-situ conservation strategies include botanical gardens, zoos, conservation stands, and gene, pollen, seed, seedling, tissue culture and DNA banks. Seed gene banks are the easiest way to store germplasm of wild and cultivated plants at low temperature in cold rooms. Preservation of genetic resources is carried out in field gene banks under normal growing conditions. In vitro conservation, especially by cryopreservation in liquid nitrogen at a temperature of -196^0C, is particularly useful for conserving vegetatively propagated crops like potato. Cryopreservation is the storage of material at ultra-low temperature either by very rapid cooling (used for storing seeds) or by gradual cooling and simultaneous dehydration at low temperature (used for tissue culture). The material can be stored for a long period of time in compact, low maintenance refrigeration units. Conservation of biological diversity in botanical gardens is already in practice. There are more than 1500 botanical gardens and arboreta (botanical gardens where specific tree and shrub species are cultivated) in the world containing more than 80,000 species. Many of these now have seed banks, tissue culture facilities and other *ex situ* technologies. Similarly there are more than 800 professionally managed zoos around the world with about 3000 species of mammals, birds, reptiles and amphibians. Many of these zoos have well-developed captive breeding programmes.

The conservation of wild relatives of crop plants and the off-site conservation of crop varieties or cultures of microorganisms provide breeders and genetic engineers with a ready source of genetic material. Plants and animals conserved in botanical gardens, arboreta, zoos and aquaria can be used to restore degraded land, reintroduce species into wild, and restock depleted populations.

9.2.3 International efforts for conserving biodiversity

The Earth Summit held in 1992 at Rio de Janeiro resulted into a Convention on Biodiversity, which came into force on 29 December 1993. The convention on Biodiversity has three key objectives:

(1) Conservation of biological diversity,

(2) Sustainable use of biodiversity, and

(3) Fair and equitable sharing of benefits arising out of the utilization of genetic resources.

The World Conservation Union and the World Wide Fund for Nature (WWF) support projects worldwide to promote conservation and appropriate development of Biosphere Reserves.

9.2.4 Biodiversity conservation in India

Indian region has contributed significantly to the global biodiversity. India is a homeland of 167 cultivated species and 320 wild relatives of crop plants. It is the centre of diversity of animal species (zebu, mithun, chicken, water buffalo, camel); crop plants (rice, sugarcane, banana, tea, millet); fruit plants and vegetables (mango, jackfruit, cucurbits), edible diascoreas, alocasia, colocasia; spices and condiments (cardamom, black pepper, ginger, turmeric); bamboos, brassicas, and tree cotton. India also represents a secondary centre of domestication for some animals (horse, goat, sheep, cattle, yak, and donkey) and plants (tobacco, potato and maize).

The Ministry of Environment and Forests is carrying out the in situ conservation of biodiversity through Biosphere Reserves, National Parks, Wildlife Sanctuaries and other protected areas. The joint forest management systems involve forest departments and local communities. This enables the tribal people and local communities to have access to non-wood forest products and at the same time protect the forest resources.

The National Bureau of Plant, Animal and Fish Genetic Resources has a number of programmes to collect and conserve the germplasm of plants and animals in seed gene banks, and field gene banks for in vitro conservation. Botanical and zoological gardens have large collections of plant and animal species in different climatic regions of India the land races and diverse food and medicinal plants are also being conserved successfully by the tribal people and women working individually or with various non-governmental agencies. The women particularly have an important role in the conservation of agro biodiversity. In India, a programme is underway to develop a system of community registers of local informal innovations related to the genetic resources as well as natural resource management in general.

9.3 Endangered Species of Uttarakhand

Endangered fauna are that species of animals which has been categorized as likely to become extinct in near future. Endangered (EN), as categorized by the IUCN, Red List is second most severe category after critically endangered. Biodiversity extinction is commonly due to habitat destruction, *poaching*, pollution, introduction of exotic (invasive) species, use of insecticides and pesticides. There are many endangered fauna are found in Uttarakhand which are given below:

Table: 4: Table Showing Endangered Fauna of Uttarakhand State

Scientific Name	Common/Vernacular/Local Name	IUCN Category
Endangered Birds		
Gyps bengalensis	White-rumped Vulture, Asian White-backed, Vulture, Oriental White-backed Vulture, Whitebacked Vulture	Critically Endangered
Sarcogyps calvus	The Red-headed Vulture, Asian King Vulture, Indian Black Vulture	Critically Endangered
Vanellus gregarius	Grey-headed Lapwing	Critically Endangered
Tragopan melanocephalus	Western Tragopan	Vulnerable
Tragopan satyra	Satyr Tragopan	Near Threatened
Ophrysia superciliosa	Himalayan Quail (Chota Kala Teetar)	Critically Endangered
Endangered Mammals		
Moschus leucogaster	Himalayan Musk Deer (Kasturi Mrig)	Endangered
Uncia uncial	Snow leopard	Endangered
Ursus arctos isabellinus	Himalayan brown bear (Lal bhalu orBurra bhalu)	Least Concern
Cervus duvaucelii	Barasingha	Vulnerable
Melursus ursinus	Sloth bear (Reech).	Vulnerable
Murina grisea	Peter’s tube nosed bat	Endangered

Amblonyx cinereus	Asian small clawed otter	Vulnerable
Panthera tigris tigris	Royal Bengal Tiger	Endangered
Hyaena hyaena	Striped Hyena	Near Threatened

(Source: Uttarakhand Biodiversity Board)

Summary

Biodiversity or Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. Different Governments of countries established protected area for the protection of habitats and animals and plants there are various protected areas such as National Parks, Wildlife sanctuaries, biosphere reserves, sacred grooves etc have established for the protection of wildlife and their habitats. Generally conservation of biodiversity has done with the help of two methods. First is In-situ conservation method of biodiversity in which species conserve in their own habitats. National parks, Wildlife sanctuaries, biosphere reserves, conservation reserves are the examples of In-situ conservation. Another method is called Ex-situ conservation method in which species conserve out site of the original habitats. Zoological Parks, botanical gardens, seed banks, gene banks, cryopreservation etc are the common examples of Ex-situ conservation methods of biodiversity. Uttarakhand is fully blessed with variety of natural resources and biodiversity. The state animals of Uttarakhand is Himalayan Musk deer, state flower is Brahmakamal, state fruit is Kaphal, state tree is burans and state bird is monal. Uttarakhand being a part of Indian Himalayan Region is home to vast variety and unique range of floral and faunal diversity of India. According to studies, the diversity under 1503 genera and 213 families of flowering plants, including 93 endemic species is harbored in various vegetation types, ranging from sub-tropical forests in upper Gangetic plain and Shiwaliks zone in the south to arctic-alpine vegetation of trans-Himalayan cold desert in the north in Uttarakhand. Uttarakhand houses the faunal biodiversity of 3748 species belonging to 1848 genera and 427 families of both vertebrates and invertebrates. To be precise, there are 499 genera with 1060 vertebrates and 1349 genera with 2688 species of invertebrates found in Uttarakhand 743 species of birds, 72 species of reptiles and about 439 species of butterflies. Protected areas of Uttrakhand comprises in 6 National parks (Gangotri National Park, Govind Pashu Vihar National Park and

Sanctuary, Jim Corbett National Park, Nanda Devi National Park, Rajaji National Park, Valley of Flower National Park) 7 wildlife sanctuaries (Askot Wildlife Sanctuary, Binsar Wildlife Sanctuary, Kedarnath Wildlife Sanctuary, Nandhaur Wildlife Sanctuary, Sonanadi Wildlife sanctuary and Benog Mussoorie Wildlife sanctuary, Govind Pashu Vihar National Park and Sanctuary), 1 biosphere reserve (Nanda Devi biosphere reserve) and 4 conservation sites (Naina Devi Himalayan bird conservation reserve, Jhilmil Jeel conservation reserve, Asan wetland conservation reserve, Pawalgarh conservation reserve) are established in Uttarakhand.

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Glossary

Protected area: Areas or locations which have developed for the protection due to their recognized natural, ecological values.

Geography: Science devoted to the study of the lands, features, inhabitants, and the phenomena of Earth.

In-situ conservation: This is the method of biodiversity conservation in which species are protected in their natural or own habitats.

Ex-situ conservation: This is the method of biodiversity conservation in which species are protected outside their natural or own habitats**.**

Biodiversity: Biological diversity means the variability among living organisms from all sources.

Fauna: All the animal species are collectively called fauna.

Flora: All the plants species are collectively called flora.

National Park: Protected areas which declared by IUCN declared National Park in Category II

Wildlife Sanctuary: Protected areas which declared by IUCN declared in Category VI

Biosphere Reserves: Protected areas which recognized by Man and Biosphere Programme by UNESCO.

Extinct: Species or organism which is not present in this time in any habitat.

Critically Endangered: Species or organism which are verge to extinction

Endangered: Species or organisms which are verge to Critically Endangered

Core Zone: It is long term protected area and it act as a reference point of biosphere reserve. This area is indication of biosphere reserve. It is strictly protected area that contributes to conservation of landscape, species and genetic variation.

Buffer Zone: This zone is adjoining area of core area and may used for several activities such as scientific research, monitoring, training and education.

Transition Zone: Transition zone is part of biosphere reserve where maximum human activities are allowed. Such activities may for fostering economic and human development that is socio-culturally and ecologically sustainable.

Self-Assessment Questions and Possible Answers

Multiple Choice Questions

1. Total area of Uttarakhand is hilly or mountainous:
   (a) 65461 sq. km (b) **46035 sq. km**
   (c) 21872 sq. km (d) 12547 sq. km
2. State tree of Uttarakhand is:
   (a) *Emlica officinalis* (b) Acacia catechu
   (c) ***Rhododendron arboreum*** (d) *Mangifera indica*
3. How many biosphere reserve/s are located in Uttarakhand?
   (a) Two (b) Eight
   (c) **One** (d) Six
4. State animal of Uttarakhand is:
   (a) ***Moschus leucogaster*** (b) *Panthera uncia*
   (c) *Panthera tigiris tigiris* (d) *Axis axis*
5. Rajaji National Park is located in which districts of Uttarakhand?
   (a) **Haridwar, Dehradun, Pauri Garhwal** (b)Haridwar, Dehradun, Chamoli
   (c) Haridwar, Dehradun, Tehri Garhwal (d) Nainital, Almora, US Nagar
6. Askot Wildlife sanctuary was established for the protection of
   (a) Himalayan Quail (b) **Himalayan Musk Deer**
   (c) Tiger (d) snow leopard
7. Which one of the following is first National park of India?
   (a) Rajaji National Park (b) Valley of Flower National Park
   (c) **Corbett National Park** (d) Nanda Devi National Park
8. Scientific name of snow leopard is:
   (a) *Panthera tigiris* (b) ***Panthera uncia***
   (c) *Panthera leopardis* (d) *Panthera indica*
9. IUCN is stands for:
   (a) International Union for Conservation of Nature
   (b) International Union for Consumption of Nature
   (c) International Union for Commercial utilization of Nature
   (d) Indian Union of Conservation of Nature
10. Which one of the following is ex-situ method of biodiversity conservation?
    (a) National Park (b) Wildlife Sanctuary
    (c) Cryopreservation (d) Biosphere reserve

11. Which of the following Wildlife Sanctuary is not established in Uttarakhand?
    (a) Askot wildlife Sanctuary
    (b) Nandhaur Wildlife Sanctuary
    (c) **Kishanpur Wildlife Sanctuary**
    (d) Sonanadi Wildlife Sanctuary
12. Valley of flower National Park is located in the district:
    (a) Chamoli (b) Champawat
    (c) Uttarkashi (d) Pithoragarh
13. Asan conservation reserve is located in the district?
    (a) Pauri Garhwal (b) Nainital
    (c) Dehradun (d) Pithoragarh
14. Govind Pashu Vihar National Park and Sanctuary is located in the district?
    (a) Pithoragarh (b) Almora
    (c) Nanital (d) **Uttarkashi**
15. Total area of Corbett National Park is about?
    (a) 87.56 sq. km **(b) 520.82 sq. km**
    (c) 120.25 sq. km (d) 872.32 sq. km

<u>Very Short Questions</u>

1. Variety and Variability among living species is called as -
2. The conservation methods in which species are protected within their natural or own habitat is called as
3. Give the common and scientific name of state fruit of Uttarakhand ?
4. Total geographical area of Uttarakhand is about……………..?
5. The conservation methods in which species are protected outside their natural habitat is called…………..?
6. Give the common and scientific name of state bird of Uttarakhand ?
7. Give the Expanded form of UNESCO ?
8. Give the name of National Parks which lies in the area of Nanda Devi Biosphere reserve?
9. Binsar Wildlife Sanctuary is located in which district of Uttarakhand?
10. Give the name of the that zone (Biosphere Reserve zone) which is used for several activities such as scientific research, monitoring, training and education ?
11. Jhilmil Jheel conservation reserve was created through which Act?
12. Religious spots like Chota Kailash, bhanar are located in the periphery of this Wildlife sanctuary.
13. Give the name of three wildlife sanctuary of Uttarakhand
14. Give the name of three National Parks of Uttarakhand

Answers

1.(b); 2.(c); 3.(c); 4.(a); 5.(a); 6.(b); 7.(c); 8.(b); 9.(a); 10.(c); 11.(c); 12.(a); 13.(c); 14.(d); 15.(b)

1. Biodiversity 2. In-situ-conservation method 3. Kaphal, Myrica esculenta 4. 53483 sq.km 5. Ex-situ conservation method 6. Monal, LOPHOPHORUS IMPEJANUS 7. UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION 8. Nanda Devi NP and Valley of Flower NP 9. Almora 10. Buffer Zone 11. Wildlife (Protection) Act, 1972 12. Askot Wildlife Sanctuary 13. Askot Wildlife Sanctuary, Kedarnath Wildlife Sanctuary, Sonanadi Wildlife Sanctuary, Binsar Wildlife Sanctuary, Nandhaur Wildlife Sanctuary, Benof Mussorrie Wildlife Sanctuary 14. Gangotri NP, Corbett NP, Nanda Devi NP, Rajaji NP, Valley of Flower NP.

Unit10. Size of Sample

Unit Structure

10.0. Learning Objectives

After you have studied this unit, you should be able:

- To determine the minimum size of quadrat by species curve method.

10.1 Introduction

Vegetation includes all plants of an area i.e. tree, shrub and herbs, climbers. It is made-up of small groups of populations which forms a community. Study of entire plant community or segment thereof cannot be measured, even if it is small. Therefore, we have to depend on samples, based on sampling methods drawn from a community to approximate the structure of entire community. So we have to select the samples cautiously in such a way that the data so generated could be utilized to estimate the nearly true value as accurately as possible. The minimum size and minimum number of samples are determined to get the accuracy of data and to avoid the waste of energy of the worker involved in analysis. Mainly three types of sampling methods are used for vegetation study. These are: Quadrat, Transect and Point methods. Of these, quadrat method is commonly used for vegetation sampling.

Ecosystem: Ecosystem is the basic unit of ecology. Species and populations are the basic structural units of ecological organization.

Species: A species consists of all the organisms potentially able to interbreed under natural conditions and to produce fertile offspring.

Population: A population consists of all the members of a single species occupying a common geographical area at the same time.

Community: An ecological community is composed of a number of populations that lie and interact in a specific region.

An entire plant community or a segment thereof cannot be measured, even if it were small and easily accessible. Therefore we have to depend on sample drawn from the community to approximate the structure of the entire community.

Quadrat: Quadrats are sampling units of various forms and sizes that are chosen for their convenience and usefulness. It could be rectangular, round, or square. Compared to rectangular and circular quadrats, square quadrats are preferred. Though square quadrats are commonly employed, rectangular quadrats are also preferable since most plant distributions are clumped, and a rectangle can best accommodate patches of diverse species. However, a rectangular quadrat should not be more than two to four times as long as it is wide; as the length to width ratio increases, so does the number of border relatives to area, resulting in increased error from edge effects (in general, too many individuals near the border are counted) (Singh et al. 2006). A quadrat can be of either type:

(i) **List** (for listing of allspeciespresent),
(ii) **Count**(for determining the individualsof species),
(iii) **Cover**(fordetermining basal area or canopy of species),
(iv) **Chart** (for mapping the plants within thequadrat),
(v) **Clip or Harvest** (for determining biomass or the weight of plants) and,
(vi) **Denuded quadrat**(for determining the sequence or development of vegetation overtime,followingatreatment.

The size of quadrat varies in accordance with the size of plants to be sampled. Commonly used quadrats for density measurements are: 10 x 10 m for tree layer, 5 x 5 m for woody under growth upto 3.0 m height, and 1 x 1 m or less for herb layer (Oosting 1956). The number of quadrats should be such as to sample about 20 per cent of the vegetation of an area.

The minimal size of quadrat for a given region is the one with the greatest number of species variety. Similarly, the number of quadrats in which the greatest diversity of species can be recorded is known as the minimal number of quadrats for a given area.

10.2. Sampling Approaches

For describing the vegetation of an area, first it is surveyed to select representative stands or segments of vegetation cover and then within them, sample(quadrats) are placed to record data on Parameters related to vegetation and species. There are several approaches to sampling of vegetation. They could be completely subjective, completely objective (random sampling) or have various combinations of regular and random distribution of samples.

10.3. Minimum size of Sample

Sample: Sample is a small group or portion of a population selected using a suitable method so that it can be regarded as representative of the entire population and can be used for investigating its properties.

Researchers want to find out some specific features about a population, but it is not possible to study single individual in the population. They select a small number of individuals from the population, study them and use that information to draw conclusions about the whole population. This is called population.

Sampling: Sampling is the process in which enumeration is to be done only in a representative portion of the whole.

- In Sampling, the information is obtained only from a part of the population assuming that it is the representative of the whole. A part is studied and on that basis, the conclusion is drawn for the entire population.
- For example, a forest area may be of 10,000 ha out of which only 1000 ha have been selected for enumeration and estimate of the whole population of 10000 ha is made, it is called sampling.

Sampling unit: The population is divided into suitable units for the purpose of sampling.

Types of sampling units in forest surveys are:

- ✓ Compartments,
- ✓ Topographical sections,
- ✓ Strips of a fixed width,
- ✓ Plots of definite shape and size etc.

Sampling frame: The list of sampling units from which the sample units are to be selected is called sampling frame.

Sampling Intensity (SI): The ratio of sample to the whole population which is expressed on a percentage

SI=samplearea/Totalareax100

Size of the sample

The number of sample units in the sample is known as sample size. Factors affecting the size of sample

- ✓ Nature of population
- ✓ Number of classes
- ✓ Nature of Study
- ✓ Types of sampling
- ✓ Standard of accuracy/precision required, and
- ✓ Other considerations

Scope of sampling

- ✓ Less time
- ✓ Reduced cost
- ✓ Administrative convenience
- ✓ Better supervision
- ✓ Check result of census method
- ✓ Suitable for infinite/hypothetical population
- ✓ Suitable for destructing sampling

Limitations of sampling

Sampling is better over complete census only if

- ✓ The sampling units are drawn in a scientific manner.
- ✓ Appropriate sampling technique is used, and
- ✓ the sample size is adequate.

Sampling theory has its own limitations and problems, which are:

- ✓ Proper care should be taken in the planning and execution of the sample survey; otherwise the results obtained might be inaccurate and misleading
- ✓ Sampling theory requires the services of trained and qualified personnel and sophisticated equipment for its planning, execution and analysis. In the absence of these, the results of the sample survey are not reliable.
- ✓ If the information is required about each and every unit of the universe, there is no way but to resort to complete enumeration.

10.4. Experiments to determine Minimum size of the sample

Exercise 1

Objective: To determine minimum size of the sample by species area curve in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: It is important to determine minimal size of the sample which can be representing the maximum species of the forest. The minimal size of the sample may be determined by the species area curve. The curve is developed by placing larger and larger quadrats in a forest stand in such a way that each larger quadrat encompasses all the smaller quadrats. Such an arrangement is called nested sampling (fig. 1)

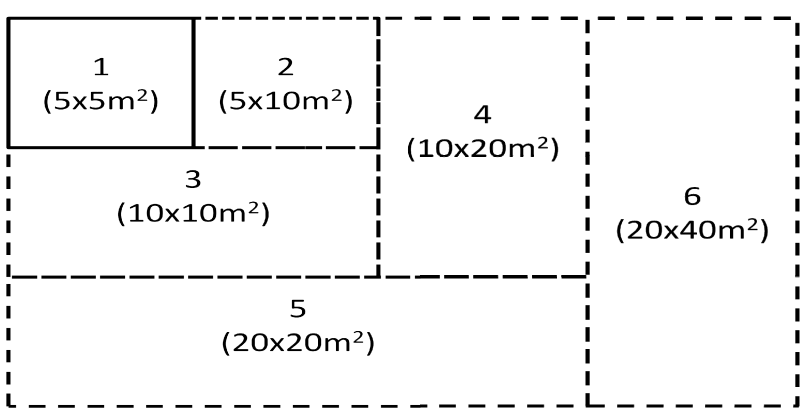


Fig. 1. Arrangement of Sampling

Sampling Method: Place a 5x5m quadrat in a forest and count the number of species occurring within it. The size of the sample is increased to 5x10m and additional species encountered in the sample is counted. Similarly, enlarge the size of the sample to 10x10m and count the additional species present in the sample. This process will be continued till the number of species becomes constant or only few additional species are encountered. The presence or absence of species is recorded as follows (Table 1):

Table 1: Occurrence of species ("+" presence, "-" absence)

Species	**5x5m**	**5x10m**	**10x10m**	**10x20m**	**20x20m**	**20x40m**
Quercus leucotrichophora	+	+	+	+	+	+
Cedrus deodara	+	+	+	+	+	+
Cupressus torulosa		+	+	+	+	+
Toona ciliata			+	+	+	+
Quercus floribunda				+	+	+
Acer oblangum					+	+
Total	**02**	**03**	**04**	**05**	**06**	**06**

Results: Draw a graph with number of species on Y-axis and size of quadrat (sample) on X axis (fig 2). Mark the point from where the curve becomes horizontal to x-axis and this will be minimal size of the sample.

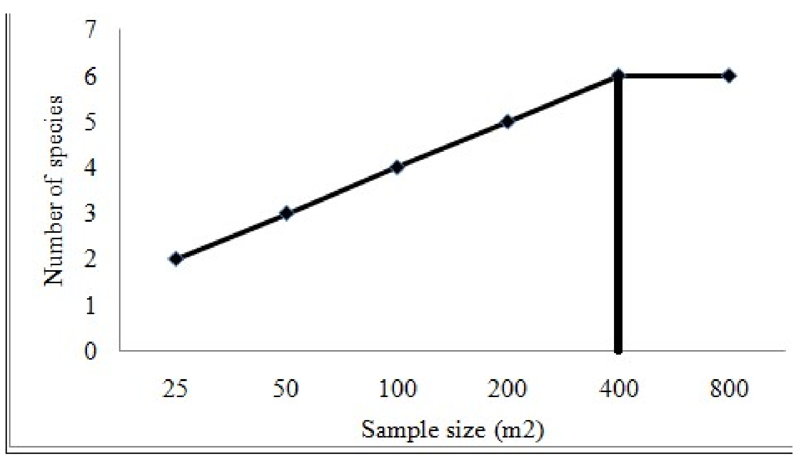


Fig. 2.Relationship between Sample size (m2) and number of species

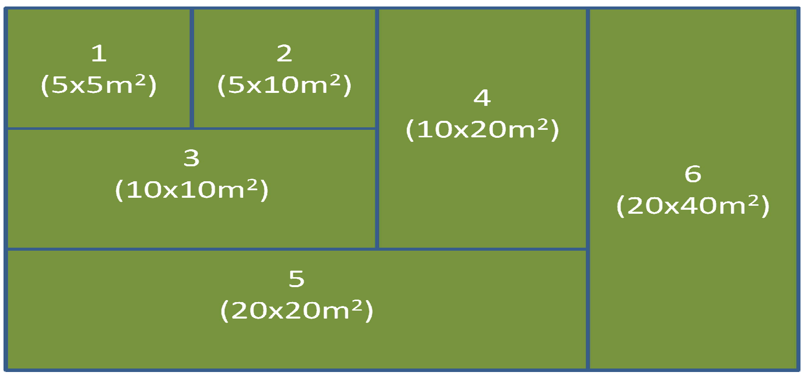
Conclusion: The minimal size of the sample from the above example is 20x20m.

Exercise 2

Objective: To determine minimum size of the sample by species area curve in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: It is important to determine minimal size of the sample which can be representing the maximum species of the forest. The minimal size of the sample may be determined by the species area curve. The curve is developed by placing larger and larger quadrats in a forest stand in such a way that each larger quadrat encompasses all the smaller quadrats. Such an arrangement is called nested sampling (fig. 3).



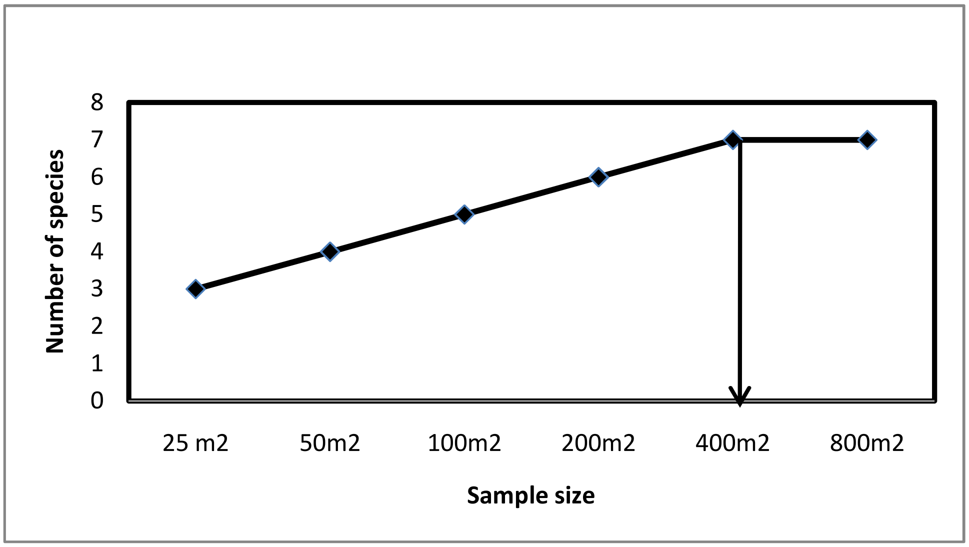
Sampling Method: Place a 5x5m quadrat in a forest and count the number of species occurring within it. The size of the sample is increased to 5x10m and additional species encountered in the sample is counted. Similarly, enlarge the size of the sample to 10x10m and count the additional species present in the sample. This process will be continued till the number of species becomes constant or only few additional species are encountered. The presence or absence of species is recorded as follows (Table 2):

Table 2: Occurrence of species ("+" presence, "-" absence)

Species	5x5	5x10	10x10	10x20	20x20	20x40
Quercus leucotrichophora	+	+	+	+	+	+
Quercus floribunda	+	+	+	+	+	+
Quercus semecarpifolia		+	+	+	+	+
Toona pictum			+	+	+	+
Toona ciliata				+	+	+
Acer oblangum					+	+
Total	**03**	**04**	**05**	**06**	**07**	**07**

Results: Draw a graph with number of species on Y-axis and size of quadrat (sample) on X axis (fig 4). Mark the point from where the curve becomes horizontal to x-axis and this will be minimal size of the sample.

Conclusion: The minimal size of the sample from the above example is 400m^2.



10.5. Terminal Question

Q1. Determine minimum size of the sample by species area curve in a given forest of 10 ha. area.

10.6. Summary

Sample is a small group or portion of a population selected using a suitable method so that it can be regarded as representative of the entire population and can be used for investigating its properties. Sampling is the process in which enumeration is to be done only in a representative portion of the whole.

Reference:

- Oosting, H.J. 1956. The Study of Plant Communities: An Introduction to Plant Ecology, Second Edition, W.H. Freeman, San Francisco.
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Unit 11: Phytosociological analysis of species

Unit Structure

11.0. Learning Objectives

After you have studied this unit, you should be able:

- To have basic understanding of valuation and value addition

11.1 Introduction

The dynamics of forest structure and function are influenced by various abiotic and biotic parameters (Chawla et al., 2008). The nature of forest communities largely depends on the ecological characteristics of sites, species richness, diversity, distribution, abundance, and regeneration status of species (Pandita et al., 2019). The population structure expressed in terms of tree girth class distribution provides valuable information on the reproductive capacity of any given stand (Joshi & Chandra, 2020; Sinha et al., 2018). Besides, an assessment of species diversity indices expresses the stability and sustainability of forest communities (Sarkar & Devi, 2014).

Phytosociological analysis of a plant community is the first and foremost basis of the ecological study of any piece of vegetation and this study is important to understand the functioning of any community. Oosting (1956) suggested the importance of phytosociological parameters for spatial problems in sociological behaviour of plants.

11.2. Density

Density is the number of individuals in a unit area. Density per unit area is expressed as the number of individuals per unit area (eg. Trees/ha) and calculated as:

$$\textbf{Density} = \frac{\textbf{No. of individuals of a species in all quadrats}}{\textbf{Total number of quadrats studied}}$$

EXERICSE 2

Objective: To determine the tree density in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: Density calculated as:

$$\textbf{Density} = \frac{\textbf{No. of individuals of a species in all quadrats}}{\textbf{Total number of quadrats studied}}$$

Methods: Select a forest for determination of trees density. Place ten quadrats of appropriate size randomly in the forest. The best quadrat size is to use depends on the items to be measured. The recommended quadrat size for tree vegetation is 100 m^2 (10x10m). Count the number of individuals of different species and record as follows:

Table 2: Number of individuals of a species in different quadrats

Species	**Quadrats**										**Total number of Individuals in all quadrats**	**Density**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		**(trees /100 m^2)**
Quercus leucotrichophora	4	4	3	2	6	5	3	4	3	4	38	38/10=3.8
Quercus floribunda			2	4	2	2	2	2	2	4	20	20/10=2
Quercus semecarpifolia	1		2			1	3	2			9	9/10=0.9
Cedrus deodara	2	2		2		2			3	2	13	13/10=1.3
Cupressus torulosa		2				3		3			8	8/10=0.8
Pinus roxburghii	1				3		2	1		2	9	9/10=0.9
Total												**9.7**

Calculations: Density is calculated as:

$$\textbf{Density} = \frac{\textbf{No. ofindividualsofaspeciesinallquadrats}}{\textbf{Totalnumberofquadratsstudied}}$$

Results: The density is calculated as described above. The density of species *Quercus leucotrichophora*is 3.8 trees/100m^2, *Quercus floribunda is* 2 trees/100m^2, *Quercus semecarpifolia* 0.9, *Cedrus deodara*1.3, *Cupressus torulosa*0.8 and *Pinus roxburghii* 0.9 trees/100m^2 .

Conclusion: The total density of a forest is 9**.7 trees/ unit area**. The highest density trees/unit area is shown by ***Quercus leucotrichophora*** species and lowest trees/unit area by ***Cupressus torulosa***species in the forest.

11.3. Frequency

It is either the percentage of quadrats in which a species is present or the number of sampling units (as %) in which the particular species exists. The frequency varies with the size of the quadrat. Frequency refers to the homogeneity of distribution of different species in a stand. If a species is found in greater abundance throughout the area, it has a better chance of appearing in all samples/quadrats. As a result, this species will be present in all populations. Species that occur seldom (even when several individuals of the same species occur at the same location) will have a chance of appearing in only a few samples/quadrats. In that instance, the species' frequency would be minimal. A high frequency value indicates a more uniform incidence or dispersion.

It can be stated that frequency represents the degree of dispersion of individuals in an area and is expressed as a percentage occurrence.

$$\textbf{Frequency} = \frac{\textbf{Totalnumberquadratsinwhichspeciesoccured}}{\textbf{Totalnumberofquadratsstudied}}\textbf{x100}$$

Frequencyclass: Amongtheearlyplantecologists,C.Raunkiaer(1934)concentratedon plant frequencies. Raunkiaer‘s law of frequency includes five frequency classes based on frequency value (20% interval) as follows:

Class A	1-20 % frequency value
Class B	21-40 % frequency value
Class C	41-60 % frequency value
Class D	61-80 % frequency value
Class E	81-100 % frequency value

Accordingly the frequency law suggested:

A>B>C=D<E

In general, higher values of classes B, C and D indicate heterogeneity of the stand, and greater value of class E shows homogeneity of the stand. If the value of the ratio (E+D)/(B+C) is < 1.0, the stand is heterogeneous, whereas the stand is homogenous if the value is > 1.0.

On the basis of the study of large samples (some 8087 frequency percentages), Raunkiaer prepared a Normal Frequency Diagram shown in Fig. 11.1.

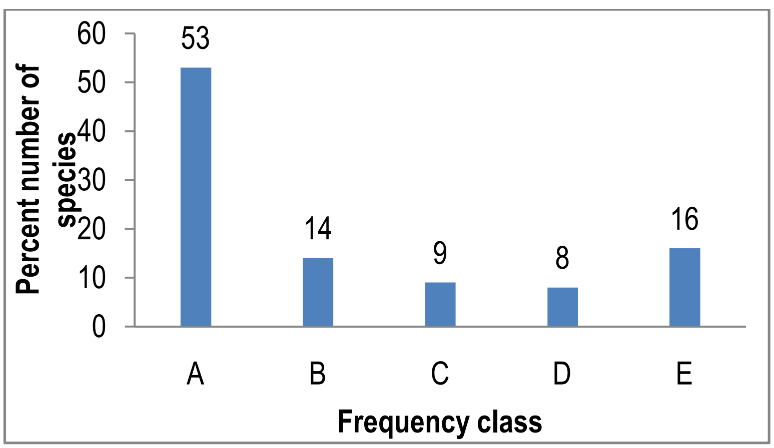

Fig.11.1. Raunkiaer'snormalfrequency diagram

After examining the frequency of various species in a locally available stand, students can give a frequency class to each species by calculating the percentage of each class specified by Raunkiaer, and then compare it to Raunkiaer's normal frequency diagram, which can be drawn on the graph sheet.

Exercise 3

Objective: To determine the tree frequency in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: Frequency is the degree of dispersion of a species in a forest. Individuals of some species are sparsely distributed while others are found in clumps. Frequency is expressed in terms of per cent value (%) as:

$$\mathbf{Frequency} = \frac{\mathbf{Totalnumberquadratsinwhichspeciesoccured}}{\mathbf{Totalnumberofquadratsstudied}}\mathbf{x100}$$

Methods: Select a forest for the determined of frequency. Place 10 quadarts of appropriate size randomly in the forest. The best quadrat size is to use depends on the items to be measured. The recommended quadrat size for tree vegetation is 100 m^2. The presence or absence of the species is marked by the plus (+) or minus (-) signs, respectively and is recorded as follows:

Table 3: Occurrence of species in different quadrats

Species	**Quadrats**										**Total number quadrats in which species occurs**	**Frequency (%)**
	1	2	3	4	5	6	7	8	9	10		
Quercus leucotrichophora	3	4	1	2	4	5	3	4	2	1	10	$\frac{10}{10}$x100= 100
Quercus floribunda			2	5	1	1	2	2	1	2	8	$\frac{8}{10}$x100=80
Quercus semecarpifolia	1	1	1			1	2	1			6	$\frac{6}{10}$x100=60
Cedrus deodara	2	1		1		1		1	2	1	7	$\frac{7}{10}$x100=70
Cupressus torulosa		1			1	3			1	1	5	$\frac{5}{10}$x100=50
Pinus roxburghii	1			1	2		1	2		1	6	$\frac{6}{10}$x100=60

The frequency is calculated as:

$$\mathbf{Frequency} = \frac{\mathbf{Totalnumberquadratsinwhichspeciesoccured}}{\mathbf{Totalnumberofquadratsstudied}}\mathbf{x100}$$

Results: The frequency of species A is 100%, B is 80% ,C, F is 60% and D is 70%and E is 50% in the forest.

Conclusion: The maximum frequency is shown by **A** species and minimum by **E** species. The higher frequency shows even dispersion of individuals and the lower frequency indicates the poor dispersion of the species.

11.4. Abundance

Abundance is simply the number of individuals of a species. It refers actually to the density of population in those quadrats in which a given species occurs. It is expressed as tree per unit area. The abundance is expressed as:

$$\textbf{Abundance} = \frac{\textbf{Totalnumberofindividualsofaspeciesinallquadrats}}{\textbf{Totalnumberquadratsinwhichspeciesoccured}}$$

EXERCISE 4

Objective: To determine species abundance in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: Abundanceis expressed as:

$$\textbf{Abundance} = \frac{\textbf{Totalnumberofindividualsofaspeciesinallquadrats}}{\textbf{Totalnumberquadratsinwhichspeciesoccured}}$$

Methods: Select a forest for the determination of abundance. Place 10 quadrats of appropriate size randomly in the forest. Count the individuals of species and record as follows:

Table 4: Individuals of a species in different quadrats

Species	**Quadrats**										Total number of Individuals	Total no. of quadrats in which species occurs	Abundance (Trees/100m^2)
	1	2	3	4	5	6	7	8	9	10			
Quercus leucotrichoph	3	2	1		6	5		5	2	1	25	8	3.1

ora													
Quercus floribunda			2	2	1	1		2	1		9	6	1.5
Quercus semecarpifolia	1		2			1	2	1			7	5	1.4
Cedrus deodara	2			1					2	1	6	4	1.5
Cupressus torulosa		1				3					4	2	2
Pinus roxburghii	1				2		1	1		1	6	5	1.2

The abundance is calculated as:

$$\frac{\textbf{Totalnumberofindividualsofaspeciesinallquadrats}}{\textbf{Totalnumberquadratsinwhichspeciesoccured}}$$

Results: The abundance of species A is 3.1 ind./unit area, B=1.5 ind./unit area C=1.4 ind./unit …D= 1.5 ind./unit... E= 2 ind./unit and F=1.2 tress/unit area.

Conclusion: The highest abundance is shown by **A** Species and lowest by **F** species.

11.5. A/F ratio

Abundance/frequency ratio (A/F ratio) is also calculated to show the distribution of different species in the forest. The A/F ratio indicated distribution pattern (Curtis and cottan 1956).

A/F ratio	**Distribution pattern**
<0.025	Regular distribution
0.025-0.05	Random distribution
>0.05	Contagious distribution

The A/F ratio determined from above frequency and abundance data are given in table 5.

Table 5: Frequency, Abundance and A/F ratio of the species.

Species	Frequency of a species (%)	Abundance of a species (Trees/100m^2)	A/F ratio
Quercus leucotrichophora	100	3.1	0.031
Quercus floribunda	80	1.5	0.019
Quercus semecarpifolia	60	1.4	0.028
Cedrus deodara	70	1.5	0.025
Cupressus torulosa	50	2	0.100
Pinus roxburghii	60	1.2	0.024

Results: The A/F ratio of species *Quercus leucotrichophora* is 0.031, *Quercus floribunda*=0.019, *Quercussemecarpifolia*=0.028, *Cedrus deodara*= 0.025, *Cupressus torulosa*= 0.100 and *Pinus roxburghii*=0.024.

Conclusion: *Pinus roxburghii* showed regular distribution and all other species are randomly distributed in the forest.

11.6. Terminal Question

1. *What do you understand by density? Explain with example.*
2. *What do you understand by Frequency? Explain with example.*
3. *Explain Frequency distribution Classes?*

11.4. Summary

The community is defined by species variety, various growth forms, and successional stages. Several parameters are considered when studying a community or stand. These are then utilised to convey the qualities of a community. Any community can be researched by analysing a variety of characteristics, which might be qualitative or quantitative. Quantitative characteristics include density, frequency, abundance , A/F ratio cover, and basal area, with the first four described in this chapter.

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Unit 12: Importance Value Index (IVI)

Unit Structure

12.0. Learning Objectives

After you have studied this unit, you should be able:

- To have basic understanding of valuation and value addition

12.1 Introduction

A plant species' cover refers to how much ground area it occupies. It is expressed in two ways:

- Canopy cover or crown cover: This term refers to the ground area covered by a species aboveground portions (crownor canopy) when projected vertically.
- Basal area or cover: This refers to the ground area actually penetrated by a species, stem or shoot.

Cover is considered more ecologically significant than density estimates because it provides a more accurate indication of plant biomass. It is also the most appropriate way to note the change in a stand. Basal cover or area indicates species dominance. Thus, a higher basal area indicates dominance of a species. The grassland species are completely distinct from the woody species. As a result, techniques for calculating basal area (cover) for each species are described separately as follows:

12.2. Basal Area

Basal area is the cross sectional area of the tree stem at breast height (1.37m). It is regarded as an index of dominance.

Basal area is measured either 2.5cm above ground or actually on the ground for herbaceous vegetation. In case of grassland 8-10 stems of a species are clipped at the ground level or 2.5cm above the ground and diameter of each individual at its base is measured with the help of Vernier caliper or Screw guage and average diameter of one stem can be obtained. This value is divided by two (2) to get the value of radius. This procedure is repeated for each species present in the grassland where the study is being conducted. The basal area of each species present in the grassland can be obtained as follows:

The tree basal area is expressed as:

Basal area = πr^2

cbh = 2 π r or π d, r = cbh/ 2 π or r = d/2

Where, π = 3.142 and r = radius of a cross section or

The basal area is directly calculated by cbh as: (cbh) 2 /4 π

Total Basal area or cover = Mean basal area X Density

EXERCISE 12.1

Objective: To determine mean and total basal area for different tree species in a given forest.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: Basal area is the cross sectional area of the tree stem at breast height (1.37m). It is regarded as an index of dominance. The tree basal area is expressed as:

Basal area: $= \boldsymbol{\pi r^2}$

cbh = 2 πr or πd, r = cbh/ 2π or r = d/2

Where, π= 3.142 and r = radius of a cross section or

$$\textbf{Mean basal area of a species} = \frac{(\mathbf{cbh})2}{4\pi}$$

The unit of mean basal area is cm^2 / individual or cm^2 / unit area, or m^2 / unit area (multiplying by the conversion factor).

Methods : Select a forest for the determination of basal area. Measure circumference at breast height (cbh) or diameter at breast height (dbh) for several individual of a species. Similarly, cbh or dbh will be measured for individuals of others species present in the forest and are recorded as:

Table 5: Circumference or diameter (cm) at breast height of different individuals of a species:

Species	Individuals										Total	Average cbh or dbh	MBA (cm^2)
	1	2	3	4	5	6	7	8	9	10	cbh or dbh		
A	110	80	90	120		60	90	80	80	120	830	92.2	676.82
B	130		70	120	130	60		90	60	40	700	87.5	609.57
C	140		80			110	80			80	490	98	764.65
D	80	90		130	150		90	90	70	40	740	92.5	681.23
E	140	110	90		110		120				570	114	1034.71

Total basal area of a species = Mean basal area X density of that species.

Total basal area of a forest = Sum of total basal area of all the species

Results:

Species	Total	Average cbh or dbh	MBA (m2)	Density	TBA
A	8.3	0.922	0.068	0.900	0.061
B	7	0.875	0.061	0.800	0.049
C	4.9	0.980	0.076	0.500	0.038
D	7.4	0.925	0.068	0.800	0.054
E	5.7	1.140	0.103	0.500	0.052
TBA of forest			**0.377**		**0.254**

The mean tree basal area for species A is 0.068, B=0.061, C=0.076, D=0.068 and E=0.103 m^2 / individual and total basal area **0.377 m^2 / 100m^2.**

Conclusion: Total basal area of different species ranged between 0.038 and 0.061m^2 / unit area. The total basal area of the forest is **0.254 m^2 / 100m^2**.

12.3. Relative density, Relative Frequency and Relative Dominance

Relative density: The proportional density of a species in the forest is referred to as relative density (RD). It is expressed as:

$$\textbf{Relative Density (RD)} = \frac{\text{Total individuals of a species in all quadrats}}{\text{Total individuals of all species}} \times 100$$

or

Density of a species/ Density of all species

Relative Frequency: The dispersion of a species in relation to that of all species is termed as relative frequency (RF).It is expressed as:

$$\textbf{Relative Frequency (RF)} = \frac{\text{Occurrence of a species}}{\text{Total occurrence of all species}} \times 100$$

or

Frequency of a species / Frequency of all species

Relative Dominance: The relative dominance (RDo) is the proportion of the basal area or cover of a species to the total basal area or cover of all species. It is expressed as:

$$\textbf{Relative Dominance (RDo)} = \frac{\text{basal area or cover of a species}}{\text{total basal area or cover of all species}} \times 100$$

or

Cover of a species/ Cover of all species

EXERCISE 12.2

Objective: To determine tree relative density, relative frequency, relative dominance and importance value index (IVI) in a given forest by quadrat method.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: The proportional density of a species in the forest is referred to as relative density (RD) and dispersion of a species in relation to that of all species is termed as relative frequency (RF). The relative dominance (RDo) is the proportion of the basal area or cover of a species to the total basal area or cover of all species. The relative values of different vegetation parameters are expressed as:

$$\textbf{Relative Density (RD)} = \frac{\text{Total individuals of a species in all quadrats}}{\text{Total individuals of all species}} \times 100$$

or

Density of a species/ Density of all species

$$\textbf{Relative Frequency (RF)} = \frac{\text{Occurrence of a species}}{\text{Total occurrence of all species}} \times 100$$

or

Frequency of a species / Frequency of all species

$$\textbf{Relative Dominance (RDo)} = \frac{\text{basal area or cover of a species}}{\text{total basal area or cover of all species}} \times 100$$

or

Cover of a species/ Cover of all species

Importance value index (IVI) of a species is the relative contribution of a species to the whole forest. Curtis and McIntosh (1951) defined IVI as a sum of relative density, relative frequency and relative dominance as:

IVI = RD + RF + RDo

Methods: Select a forest for the determination of relative and importance value of different species. Place 10 or 20 quadrats of appropriate size (determined with the help of species area curve) randomly in the forest. The number and cbh for individuals of a species is recorded as follows:

Table 7: Circumference at breast height (cbh) (m^2) of individuals of different species.

Species	Quadrats										Total circumference
	1	2	3	4	5	6	7	8	9	10	
A	1.8	1.1	-	0.8	-	1.5	-	1.9	0.6	0.55	8.25
B	0.8	1.6	1.12		0.9	0.65	0.85	1.45	-	1.6	8.97
C	0.6	0.7	-	0.55	-		0.95	0.65	0.45	-	3.9
D	1.45	1.5	0.46	0.65	-	2.55	-		0.75	0.65	8.01
E	1.1		1.6	0.9	0.65	-	0.75	-	1.85	-	6.85
F	-	0.9	1.7	0.87	1.1	0.85	0.65	0.55	-	0.67	7.29

$$\textbf{Mean cbh of a species} = \frac{\text{Total cbh of individuals species}}{\text{Total number of individuals}}$$

$$\textbf{Basal area} = \frac{(\text{cbh})2}{4\pi}$$

$$\textbf{Relative Density (RD)} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of individuals of all species}} \times 100$$

$$\textbf{Relative Frequency (RF)} = \frac{\text{Presence of a species}}{\text{presence of all species}} \times 100$$

$$\textbf{Relative Dominance (RDo)} = \frac{\text{basal area or cover of a species}}{\text{total basal area or cover of all species}} \times 100$$

Results: The value of all relative importance is given in the table 8 as:

Table 8: The relative values and IVI of different species in the forest.

Species	Relative density	Relative frequency	Relative dominance	IVI
A	18.5	16.7	18.1	53.2
B	20.4	19.0	17.6	57.1
C	11.1	14.3	11.2	36.6
D	18.5	16.7	17.0	52.2
E	14.8	14.3	19.5	48.6
F	16.7	19.0	17.4	53.1
	100.0	100.0	100.8	300.8

Conclusion : The relative density was higher for B species and lowest for D species. The relative frequency was higher for B and F species and lowest for C and E species, Species E is most dominant in the forest while C Species is least dominant in the forest. B is the most dominant species and C is the least dominant species in the forest.

12.4. Importance Value Index

Importance value index (IVI) of a species is the relative contribution of a species to the whole forest. Curtis and McIntosh (1951) defined IVI as a sum of relative density, relative frequency and relative dominance as:

IVI = RD + RF + RDo

<u>EXCERSICE 12.3</u>

Objective: To determine the tree relative density, relative frequency, relative dominance and importance value index (IVI) in a forest by point centered quarter method.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: The point centered quarter method is used for measurement of distance from randomly chosen points to the nearest tree. Cottam and Curtis (1956) described the method as:

$$\text{Density} = \frac{\text{Relative density of a species}}{100} \text{X total density of all species}$$

$$\text{Relative Density (RD)} = \frac{\text{individuals of a species}}{\text{Total individuals of all species}} \text{X 100}$$

The frequency is calculated as:

$$\text{Frequency} = \frac{\text{Number of points at which a species is present}}{\text{Total number of points studied}} \text{x100}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \text{X 100}$$

The dominance of a species is calculated from the basal area or cover of the species:
Dominance = Average basal area of a species x density of that species

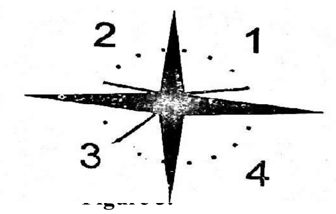
$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \text{X 100}$$

IVI = RD + RF + RDo

Methods: Select several random points in a forest for the determination of various vegetation parameters. At each point, the surrounding area is divided into four parts at right angles. In each part, the nearest tree is marked. Record its distance from the point, the cbh/diameter of the tree and species (fig. 3) for the determination of basal area. Thus the data are obtained for four trees at each point. The average distance of point to plant is determined as:

Average distance = total distance /number of distances

Square the distance to obtain the mean area covered by per plant. The total density is calculated as:



Total Density of trees = $\frac{\textbf{Unit area}}{\textbf{average distance}}$

Unit area = size of the area e.g. 1 ha area, it will be $\frac{\mathbf{1000}}{(\mathbf{Averagedistance})\mathbf{2}}$

Table 9: Nearest tree distance from different points

Species	**Points**										**Total Distance**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
A											
B											
C											
D											
E											

Results: The various vegetational parameters for difference species are calculated as give above and tabulated as follows:

Table 10: The relative values and IVI of different species.

Species	**Relative density**	**Relative frequency**	**Relative dominance**	**IVI**
A				
B				
C				
D				
E				

F				

The highest relative density is for ....species and lowest for ....species while highest relative frequency is for ....species and lowest for ....species. highest relative dominance is shown by ....species and lowest by ....species. ..... Species was dominant in the forest and........ species was least dominant in the forest.

Conclusion : The highest IVI is for …… species and lowest for …… species. The most dominant species is ------------ in the community and the least dominant species .... in the forest.

12.5. Terminal Question

1. Give a short note on Basal Area.

2. What do you understand by Relative density, Relative frequency and Relative dominance?

3. Determine mean and total basal area for different tree species in a given forest.

4. Determine tree relative density, relative frequency, relative dominance and importance value index (IVI) in a given forest by quadrat method.

12.6. Summary

Dominance described under quantitative characters. On the basis of density, frequency and dominance (cover) values there has been proposed the idea of Importance value Index (IVI). IVI of a species in the community gives the idea of its relative importance.

Unit 13: Species Diversity

Unit Structure

13.0. Learning Objectives

After you have studied this unit, you should be able:

- To understand Species richness, Species Diversity and Concentration of dominance.

13.1. Species Richness

Species richness refers to the number of various species present in an ecological community, landscape, or region (Colwell 2009). Species richness is basically a count of species; it does not consider species abundances or relative abundance distributions. Species richness is sometimes used interchangeably with species diversity, however the formal measure species diversity considers both species richness and species evenness.Species richness is frequently used to compare the biodiversity of different biological communities, the number of species within a specific taxonomic category (such as birds or mammals) at different places, and to track changes in a biological community over time.It is calculated by following formula:

$$\text{species richness} = \left(\frac{\text{S} - 1}{\text{Log N}}\right)$$

where S = total number of species

N = total number of individuals of all species.

EXERCISE 13.1

Objective: To determine species richness of a given forest.

Requirement: Measuring tape, collection file, data sheet, pen etc.

Principle:

Species richness: species richness is the number of different species represented in an ecological community or region. It is calculated by following formula:

$$\textbf{species richness} = \left(\frac{\mathbf{S-1}}{\mathbf{Log\ N}}\right)$$

where S= total number of species

N= total number of individuals of all species.

Methods: Select a forest stand for the measurement of species richness. Place the sample of appropriate size and estimate the individuals of different species present in the forest stand.

Results:

The species richness and evenness indexes are determined from the following data.

Species	**Number of individuals**		
	Stand 1	Stand 2	Stand 3
Q. leucotrichophora	12	7	-
Q, floribunda	10	-	5
C. deodara	4	10	-
C. torulosa	6	4	6
A.pictum	3	10	8
P roxburghii	8	2	3
Total number of individuals (N)	**43**	**33**	**22**
Total number of species (S)	6	5	4

1. **Species richness**

Species richness (Stand 1) $=\frac{(S-1)}{\text{Log N}}= \frac{(6-1)}{\text{Log } 43} = \frac{(5)}{1.63} =$ 3.06

Species richness (Stand 2) $=\frac{(S-1)}{\text{Log N}}= \frac{(5-1)}{\text{Log } 33} = \frac{(4)}{1.51} = 2.63$

Species richness (Stand 3) $=\frac{(S-1)}{\text{Log N}}= \frac{(4-1)}{\text{Log 22}} = \frac{(3)}{1.34}=2.23$

All the above parameters for all three stands are calculated and presented hereunder:

Stand	Species richness
1	3.06
2	2.63
3	2.23

Conclusion: Species richness is higher for stand 1 as compared to other stands.

13.2. Species Diversity

Species diversity refers to the number of species found in a specific location (which could include habitats, biomes, or the entire biosphere) as well as the relative abundance of each species. Species diversity refers to the quantity and relative abundance of different species in a given location. The area under consideration could be a habitat, a biome, or the entire biosphere. Areas with minimal species diversity, such as Antarctic glaciers, yet have a diverse range of living organisms, whereas tropical rainforest diversity is so high that it is impossible to quantify adequately.

The key components of biological diversity are:

- ✓ **Species diversity** refers to the number of distinct species represented in a given community.
- ✓ **Ecosystem diversity** refers to the diversity of ecosystems within a given geographic area, as well as their overall impact on human life and the environment.
- ✓ **Genetic variety** refers to the numerous hereditary qualities within a species.

Environmental factors have a considerable impact on species diversity. Locations near the equator have greater diversity of species than locations near the poles. One possible explanation is that habitats and ecological niches are more abundant towards the equator.

Species diversity calculated using the Shannon-Wiener Index and Simpson's Diversity Index.

Shannon-Wiener Index

This index helps ecologists study the diversity in environments and can provide useful information about a given community. It takes into account the number of species in an environment as well as their relative abundance. The Shannon-Wiener information index is also widely used index of diversity (Shannon and Wiener, 1963). It is represented as:

$$\mathbf{H} = -\Sigma\left(\frac{\mathbf{Ni}}{\mathbf{N}}\right)\mathbf{\log 2}\ (\frac{\mathbf{Ni}}{\mathbf{N}})$$

Σ = Sum of species, Ni = number of individuals of ith species

N = Total number of individuals of all species

log 2 is 3.322 log10, then for calculation of the index, the equation used is:

$$\mathbf{H = 3.322\ (log10N - 1/N\ \Sigma Ni\ \ log10Ni)}$$

With a higher value of H comes an increase in the diversity of species in a specific community. Values can range between 0 and 5 but specifically between 1.5 and 3.5.

EXERCISE 13.2

Objective: To determine the Index of diversity of a forest by Shannon-Weiner informationIndex.

Field equipment: Measuring tape, collection file, data sheet, pen etc.

Principle: Species diversity is a function of the number of species present in a given area and the distribution of individuals among the species. The Shannon-Wiener information index is also widely used index of diversity (Shannon and Wiener, 1963). It is represented as:

$$\mathbf{H} = -\Sigma\left(\frac{\mathbf{Ni}}{\mathbf{N}}\right)\mathbf{\log 2}\ (\frac{\mathbf{Ni}}{\mathbf{N}})$$

Σ = Sum of species, Ni = number of individuals of i^{th} species

N = Total number of individuals of all species

Sampling method: Select a forest stand for the measurement of diversity index. The diversity of different species is determined through IVI or density or dominance value. The zero diversity index is for the single species (pure stand) and higher value for the many species. The Density or dominance or IVI is calculated from the recorded field data and tabulated as:

Table 12: Density or IVI for different species

Species	Density or dominance or IVI	H
A	101	-0.53
B	69	-0.49
C	65	-0.48
D	45	-0.41
E	20	-0.26
Total	**300**	**2.17**

Results: The diversity index for the forest is 2.17.
Conclusion: The index of the diversity of the forest is 2.17.

13.3. Concentration of dominance

The species diversity is also calculated by the Simpson's index (Simpson 1949) The Simpson's index of diversity includes the number of species, the total number of individuals and the proportion of the total. This formula actually gives dominance and represented as:

$$\textbf{Concentration of dominance (CD)} = \sum\left(\frac{ni}{N}\right)^2$$

Σ = Sum of species, ni = number of individuals of ith species and N is the total number of individuals of all species in the sample.

EXERCISE 13.3

Objective: To determine Concentrationof dominance of a given forest.

Requirement: Measuring tape, collection file, data sheet, pen etc.

Principle: The species diversity is also calculated by the Simpson's index (Simpson 1949) The Simpson's index of diversity includes the number of species, the total number of individuals and the proportion of the total. This formula actually gives dominance and represented as:

$$\textbf{Concentration of dominance (CD)} = \sum\left(\frac{ni}{N}\right)^2$$

Σ = Sum of species, ni = number of individuals of i^{th} species and N is the total number of individuals of all species in the sample.

Methods: Select a forest stand for the measurement of concentration of dominance and diversity. The diversity of different species is determined through IVI or density or dominance value. Index of dominance and diversity index are calculated by the following formula:

Table 12: Density or IVI for different species

Species	Density or dominance or IVI	CD
A	101	0.11
B	69	0.05
C	65	0.05
D	45	0.02
E	20	0.00
Total	**300**	**0.24**

Results: The Concentration of dominance for the forest is 0.24.

Conclusion: The index of the dominance of the forest is 0.24.

EXERCISE 13.4

Objective: Todetermine the Shannon-Weiner Index of diversity and concentration of dominance:

Table 13: Number of individuals of different tree species.

species	Number of individuals			Density		
	Stand 1	Stand 2	Stand 3	Stand 1	Stand 2	Stand 3
Q. leucotrichophora	10	5	-	1	0.5	0
Q, floribunda	8	-	2	0.8	0	0.2
C. deodara	2	8	-	0.2	0.8	0
C. torulosa	5	4	4	0.5	0.4	0.4
A.pictum	2	8	6	0.2	0.8	0.6
P roxburghii	6	2	1	0.6	0.2	0.1
Total number of individuals (N)	**33**	**27**	**13**	**3.3**	**2.7**	**1.3**
Total number of species (S)	6	5	4			

The various vegetation parameters calculated as givenin table 14.

Table 14. Density, Diversity (H) and CD for different species

Species	Diversity (H)			Index of dominance (CD)		
	Stand 1	Stand 2	Stand 3	Stand 1	Stand 2	Stand 3
Q. leucotrichophora	0.52	0.45		0.09	0.03	0.00
Q, floribunda	0.50		0.42	0.06	0.00	0.02
C. deodara	0.25	0.52		0.004	0.09	0.00
C. torulosa	0.41	0.41	0.52	0.02	0.02	0.09
A.pictum	0.25	0.52	0.51	0.004	0.09	0.21
P roxburghii	0.45	0.28	0.28	0.03	0.01	0.01
	2.37	**2.18**	**1.74**	**0.21**	**0.24**	**0.34**

Results:

Shannon wiener index: $(H) = -3.322 * \left(\frac{ni}{n}\right) * \log 10\left(\frac{ni}{n}\right)$

$$=\sum -3.322 * \left(\frac{1}{3.3}\right) * \log 10 \left(\frac{1}{3.3}\right) = 0.52$$

Stand 1: 0.52+0.50+0.25+0.41+0.25+0.45= **2.37**

Stand 2: 0.45+0.52+0.41+0.52+0.28= **2.18**

Stand 3: 0.42+0.52+0.51+0.28= **1.74**

Index of dominance (CD)

$$(\text{Stand 1}) = \sum\left(\frac{ni}{n}\right)^2 = \sum \left(\frac{1}{3.3}\right)^2 + \left(\frac{0.8}{3.3}\right)^2 + \left(\frac{0.2}{3.3}\right)^2 + \left(\frac{0.5}{3.3}\right)^2 + \left(\frac{0.2}{3.3}\right)^2 + \left(\frac{0.6}{3.3}\right)^2 =$$

(Stand 1) = 0.09+0.06+0.004+0.02+0.004+0.03= **0.21**

Index of dominance (CD) (Stand 2)= 0.03+0.00+0.09+0.02+0.09+0.01= **0.24**

Index of dominance (CD) (Stand 3)= 0.02+0.00+0.09+0.21+0.01= **0.34**

Conclusion: For Shannon –wiener index higher the value more is the diversity thus in present case stand number 1 is most diverse followed by stand 2. The higher value of Index of dominance is reflects that one species is dominating more than that of other species.

13.4. Terminal Question

1. Write a short note on Species Diversity?

2. What do you understand by Shannon-Wiener information index? Explain with suitable example.

3. Determine the Shannon-Weiner Index of diversity and concentration of dominance of a given sample:

species	**Number of individuals**		
	Stand	**Stand 2**	**Stand 3**
Q. leucotrichophora	15	8	4
Q, floribunda	6	2	-
C. deodara	4	6	1
P roxburghii	8	2	-

13.5. Summary

Species diversity is an important feature of biodiversity that helps maintain ecosystems balanced. The restoration and preservation of our species' diversity ensures that all life on our planet can cohabit peacefully.

References:

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Unit 14: Assessment of Biodiversity

Unit Structure

14.0. Learning Objectives

After you have studied this unit, you should be able:

- To have basic understanding α, β and γ diversity.

14.1 Introduction

Over thousands of years, the diverse range of life on Earth has met the needs of humans. The diversity of living organisms serves as a support system for each civilization's growth and development. Those who used the "bounty of nature" wisely and sustainably lived. Those who overused or abused it disintegrated. For more than a century, scientists have attempted to describe and categories nature's diversity. This has helped us understand how it is organized into plant and animal communities. This information has aided in the utilization of the earth's biological resources for the benefit of humanity, and it is an essential component of the 'development' process.The diversity of life on Earth is so immense that if we use it sustainably, we can continue to develop new goods based on biodiversity for many generations. To achieve this goal, we must treat biodiversity as a valuable resource and prevent species extinction.

14.2. Biodiversity

Biodiversity (or biological diversity) refers to the variety and variability of life on Earth. It can be measured at several levels. Examples include genetic variety, species diversity, environmental diversity, and phylogenetic diversity (Faith, 1992). Diversity is not evenly distributed on Earth. It is greater in the tropics due to the warm environment and high primary productivity near the equator. Tropical forest ecosystems encompass less than one-fifth of the planet's land area and are home to around half of all species (Pillay et. al. 2022). There are latitudinal gradients in species diversity for both marine and terrestrial species (Hillebrand 2004).

14.3. Assessment of α, β and γ diversity

Diversity can be defined as the number of species present in a community. It is "a single statistic in which the number of species and evenness are compounded". Many approaches for calculating diversity have been proposed, combining these two forms of data. Mathematical indexes of biodiversity have also been constructed to connect species diversity at different geographical scales as follows:

a) Alpha diversity

b) Beta β diversity

c) Gamma diversity

14.3.1. Alpha (α) diversity

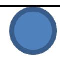
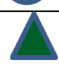
This refers to number of species in a single community. This diversity comes closest to the popular concept of species richness and can be used to compare the number of species in different ecosystem types.

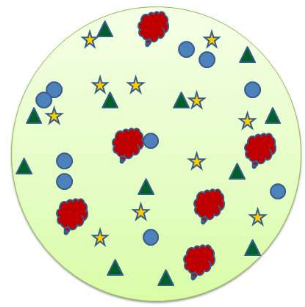
In ecology, alpha diversity (α-diversity) refers to the average species variety of a site on a small scale. R. H. Whittaker (1960, 1972) coined the phrase along with β-diversity and γ-diversity. Whittaker proposed that the total species diversity in a landscape (gamma diversity) is influenced by two factors: the mean species diversity in sites on a smaller scale (alpha diversity) and the differentiation between those sites (beta diversity).

How do you calculate alpha diversity?

Alpha diversity is a measure of the diversity of species found in a specific region, community, or ecosystem. It is calculated by determining the number of taxa present in a specific location. Consider a mountain slope. This hillside will include an assortment of woodland and grassland regions. Each of these zones will contain a different number of taxa. The alpha diversity of the entire hillside would equal the sum of the diversity of each individual location.

Alpha-diversity is a measure of the observed richness (number of taxa) or evenness (relative abundances of those taxa) of a typical sample within a habitat.

Species	Number of individuals
A 	6
B 	10
C 	12
D 	11
Total	39
Alpha (α) diversity : 4	

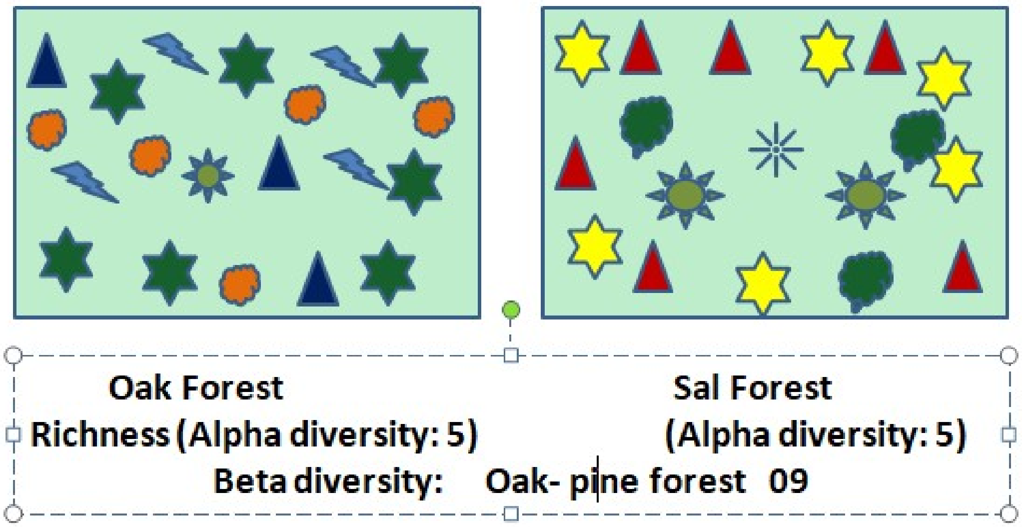


14.3.2. Beta (β) diversity

Beta-diversity is a measure of the variability in community composition (the identity of taxa observed) among samples within a habitat. Beta diversity can be used to measure the turnover of species between sites, or the change in species composition from one site to another. It can also be used to compare the species composition of two regions, or to compare the diversity of different regions. Whittaker's proposal is a way to summarize beta diversity as the ratio of two inventory diversities measured at different scales. This can be helpful in understanding the overall biodiversity of an area.

This refers to the degree to which species composition changes along an environmental gradient. Beta diversity is high for example, if the species composition of moss communities changes at successively higher elevations on amountain slope, but is low if the same species occupy the whole mountain side.

Beta diversity is the ratio between regional and local species diversity. The term was introduced by R H Whittaker together with the terms alpha diversity (α-diversity) and gamma diversity (γ-diversity).



How do you calculate beta diversity?

Beta diversity is the ratio of the difference in species composition between two sites to the average species composition of those two sites. The concept of beta diversity was originally proposed by Whittaker (1972) as the ratio of gamma diversity (the total number of species in a region) to alpha diversity (the number of species at a single site.

14.3.3. Gamma diversity

This applies to larger geographical scales and defined as "the rate at which additional species are encountered as geographical replacements within a habitat type in different localities. Thus gamma diversity is a species turnover rate with distance between sites of similar habitat or with expanding geographic areas".

Species	**Open canopy**	**Moderate canopy**	**Close canopy**
Quercus leucotrichophora	5		
Pinus roxburghii	3		
Myrica esculanta	2		
Cedrus deodara	1	5	
Cupressus torulosa	2	2	
Prunus ceresoides	3	1	2
Quercus floribunda		4	3
Acer pictum		4	1
Acer oblungum			2

Alpha diversity	**6**	**5**	**4**
Beta Diversity	**Open/Moderate canopy: 5**	**Moderate/ close canopy: 3**	**Open/ Close canopy: 8**
Gamma diversity	**9**		

Example: Calculate alpha , beta and gamma diversity from the given data:

Species	**Oak Forest**	**Pine Forest**	**Sal Forest**
Quercus leucotrichophora	12		
Quercus floribunda	6	3	
Pinus roxburghii		10	2
Myrica esculanta		8	
Cedrus deodara		4	
Cupressus torulosa	5	2	
Prunus ceresoides		2	
Quercus semecarpifolia	3		
Acer pictum	2	2	
Acer oblungum	1	1	
Populus deltoides			6
Toona ciliata		3	4
Mallotus philippensis			5
Acacia catechu			2
Bombac ceiba			4
Shorea robusta			2
Alpha diversity	**6**	**9**	**7**
Beta Diversity	**Oak-Pine: 5**	**Pine-Sal: 12**	**Sal-Oak: 13**
Gamma diversity	**16**		

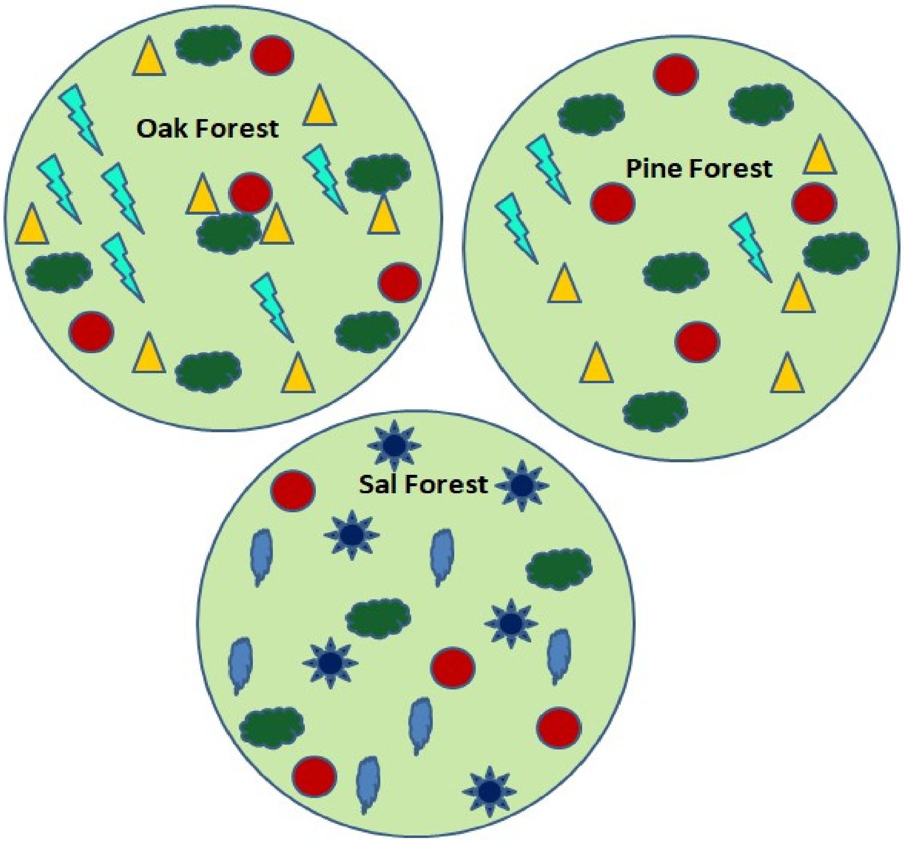
Results: **Alpha diversity:**

Oak Forest: 6
Pine Forest: 9
Sal Forest: 7

Beta diversity:

Oak-Pine Forest: 5
Pine-Sal Forest: 12
Sal-Oak Forest: 13

Gamma diversity: 16



14.4. Terminal Question

1. Calculate alpha , beta and gamma diversity from the given data.

Species	Oak Forest	Pine Forest	Sal Forest
Quercus leucotrichophora	12		
Quercus floribunda	6	3	
Pinus roxburghii		10	2
Cupressus torulosa	5	2	
Prunus ceresoides		2	4
Quercus semecarpifolia	3		
Acer pictum	2	2	
Populus deltoides			6
Toona ciliata		3	4

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