MSCZO-508

M. Sc. II Semester

ENVIRONMENTAL BIOLOGY

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ENVIRONMENTAL BIOLOGY

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UNIT 1: ECOLOGY OF POPULATION

1.1 OBJECTIVES

After studying this topic, you shall be able to

- Understand the meaning of term "population" and various types of population in the nature.
- Learn about characteristics of a Population
- Population Growth Curve
- Life history strategies (R & K selection)
- Understand the Age structure Population

1.2 INTRODUCTION

The word population is derived from the Latin word "populous" which means people. Organisms in nature rarely grow as separate from each other. Each species in an ecosystem exist as a population. Ecologically, a population is an assemblage of individuals of a species which potentially interbreed and also occupying a particular space at the same time. For example, grasshopper in the field, deer population in the forest, pine trees in a forest etc. Sometimes individuals of some species live solitary but they interact with other members of the same species or others at different times in their lives. Clarke (1954) distinguished the population into two types.

1. Monospecific population: in which group of individuals belong to the same species.

2. Polyspecific population or mixed population: in which groups of individual belongs to different species. The term community is often used for the polyspecific population. The populations of species have numerous local populations or subpopulations known as demes. It

can be defined as a smallest collective unit of animal population which is able to interbreed. These individuals share a common gene pool. The gene flow between populations occurs through emigration and immigration. Thus genetic variation can occur at two levels, within subpopulations and among subpopulations. When genetic variation occurs among subpopulations of the same species, it is called genetic differentiation. The natural selection acts on individuals of a population which results in evolutionary process. The evolution can be defined as changes in the properties of populations of organisms over the course of generations. The evolution occurs because of alteration in gene frequency in several generations. More specifically, phenotypic evolution is the change in the mean of a phenotypic trait for several generations due to changes in allele frequencies. In favoring one phenotype over another, the process of natural selection acts directly on the phenotype. But in doing so, natural selection changes allele frequencies within the population. Changes in allele frequencies from parental to offspring generations are a product of differences in relative fitness of individuals in the parental generation.

1.3 CHARACTERISTIC OF POPULATION

The population ecologist Thomas Park expressed that a population has several characteristics or biological attributes which can be explained by the statistical functions. These statistical functions are applied only to the population but not to the individuals. Some of the population characteristics are density, mortality, natality, biotic potential, age distribution, dispersal, and dispersion and growth forms. These are explained as follow:

1.3.1 POPULATION DENSITY

It is number of individuals per unit area or per unit volume. The units of population density differ in different cases. For e.g. number of squirrel per square kilometer, the number of earthworms per acre and number of paramecium per liter of water. The population density varies with seasons, food supply and climatic conditions but has definite lower and upper limits. The lower limit of density is not clearly defined but the density is kept in the limits by homeostatic mechanisms. The upper limit to density is enforced by the organism’s size and its trophic level. If the animal is smaller, greater is its abundance per unit area. For example, large number of wood lice can be supported by a forest as compare to deer population. The density is one of the important characteristic of population which is dependent on various factors like resource availability, productivity of the population, energy flow, utilization, physiological stress and dispersal.

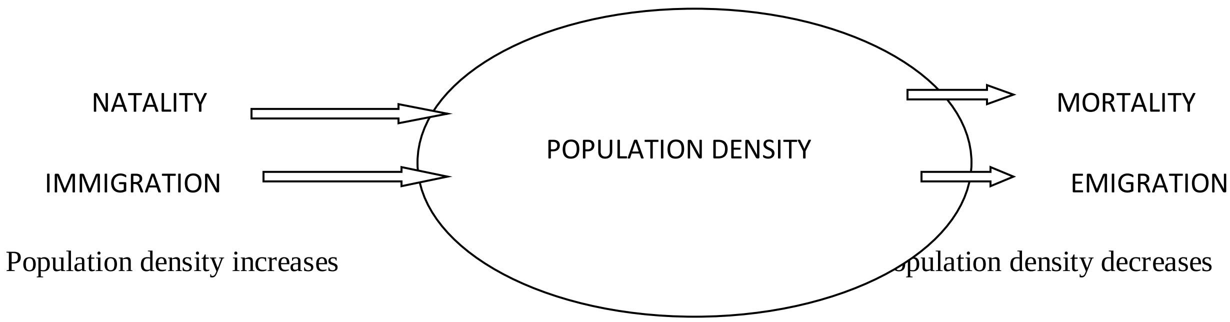


Fig.1.1Factors responsible for change in population density

Population density is categorized into two types:

1. CRUDE DENSITY: The crude density is total number of individuals per unit of total area. For e.g., the total number of Rhinoceros in Kaziranga National Park. The problem with the crude density is that individuals are not uniformly distributed over the geographic range of the population. The individuals do not occupy all the available space within the population's distribution, because not all areas are suitable for living. As a result, density can vary widely from one place to another place.

2. **ECOLOGICAL OR SPECIFIC DENSITY:** It is the number of individuals per unit of available living space. It is the available area actually colonized by the population. For e.g., Rhinoceros do not live in the whole Kaziranga national park but they try to avoid some part of the national park due to unavailability of food and shelter. So, the place where Rhinoceros actually live will be its ecological density. The contrast between crude density and ecological density was explained by Kahl in 1964, which was based on fish density in the pond (fig.1.1). As shown in the figure, the crude density of the fish in the area as a whole goes down as the water level declines during summer season but the ecological density in the contracting pond increases as the fish are crowded into smaller water area. Thus, with changing time, water level and total

number of fish, the two densities are different. So, now it becomes very easy for the predatory bird to catch fish when ecological density of the fish is highest.

METHODS OF MEASURING POPULATION DENSITY:

The following methods can be used to measure the population density:

1. Total counts: It is the total counts of all the organisms in a given area especially with large or conspicuous organisms. Eg. Conducting census of human population, whales in an area of sea etc. 2. Sampling methods: In this method, estimation of population is done by counting a small proportion of individuals of the population. The sampling is made by two different ways. i. Use of quadrate: In quadrate method, total number of individuals on several quadrates of known size is counted and then these samples are used to estimate the population density of the whole area. The shape and size of quadrate vary with type of organisms studied. It can be circular, triangular or square type. This method is mostly used to estimate the population density of plants and number of invertebrates.

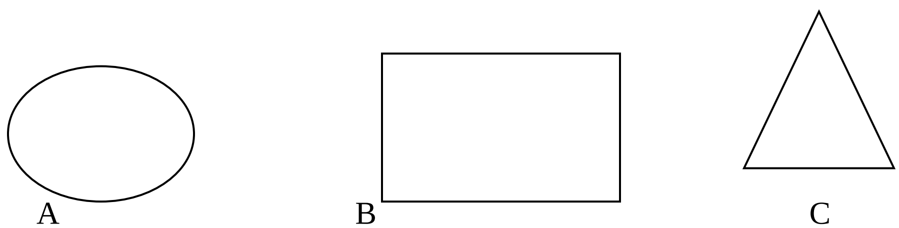


Figure 1.2: Types of Quadrate; A: Circular, B: Square, C: Triangle

ii. Capture- recapture method: the simple type of population method is known as Peterson method as it was developed by scientist C.G.J. Peterson in 1898. This method is used to count larger animals like birds, fish etc. In this method, the animals are first captured and then they are marked with tag and then they are again released into the environment. On subsequent day animals were recaptured to calculate the population density. The individuals when recaptured from the area, have both marked and unmarked population. Now the proportion of these marked individuals is used to find out the total population. For example suppose 100 fishes are captured, marked and released again into the pond. After some time again 120 fishes were captured this includes 30 marked fishes. The size of the population was counted by the formula:

$$\frac{\text{Marked animal in second sample}}{\text{Total caught in second sample}} = \frac{\text{marked animal in first sample}}{\text{Total population size}}$$

30/120= 100/N

Thus total population size estimated is 400. Sometime estimation of absolute density of a population is very difficult. So, it is simple to determine the relative density. The relative density never provides an estimate of density but it is rather an index of abundance that is more or less accurate. Relative density can be measured by the following methods: Trap: In addition to capture- recapture method, it is also used to determine relative density as the total number of individuals which are caught per day per trap. Number of fecal pellets: This method is used to calculate the index of population size in the given area by counting the number of fecal pellets of the individuals such as rabbits, deer etc. Vocalization frequency: By evaluating the voice of animals in particular time duration, index of population size can be determined. For example the number of pheasant calls/15 minutes during early morning. Feeding capacity: Population density can be counted by calculating the amount of food consumed by animals before and after treatment. For example the amount of bait consumed by rat/mice before and after poisoning and can be used to calculate an index of change in rat/mice density.

1.4 POPULATION GROWTH CURVE

Populations have a characteristic pattern of increase known as the growth forms. Two basic patterns are described on the basis of the shape of the growth curve namely

- “J’ shaped or exponential growth form
- “S‟ or sigmoid shaped or logistic growth form these two forms can be combined or modified or both in various ways depending on the characteristics of a population and environmental conditions following are the two growth forms of the populations:

  1. Exponential growth 2. Logistic growth

EXPONENTIAL POPULATION GROWTH

Exponential growth of a population was noted for the first time by Thomas Robert Malthus (1766- 1834) an economist. In 1798, he published his essay on “Principles of population” in which he proposed that the populations tend to increase faster than the means of their subsistence. He proposed that the populations increase in geometrical (2, 4, 8, 16, and so on) whereas, their food increases arithmetical (2, 4, 6, 8, and so on) progression. Using an exponential form of population growth, two fruit flies could produce enough offspring to fill the space between the Earth and the Sun in only one year, if all of the offspring survived. Exponential growth is one of two growth rates ecologists recognize in nature, but there are many other factors that keep the world from becoming overrun with any one population; may it be fruit flies or other organisms that show exponential growth.

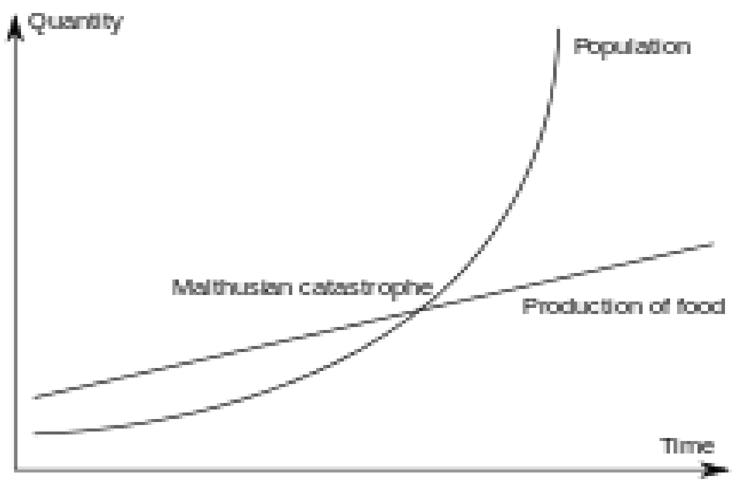


Fig 1.3 Malthusian growth

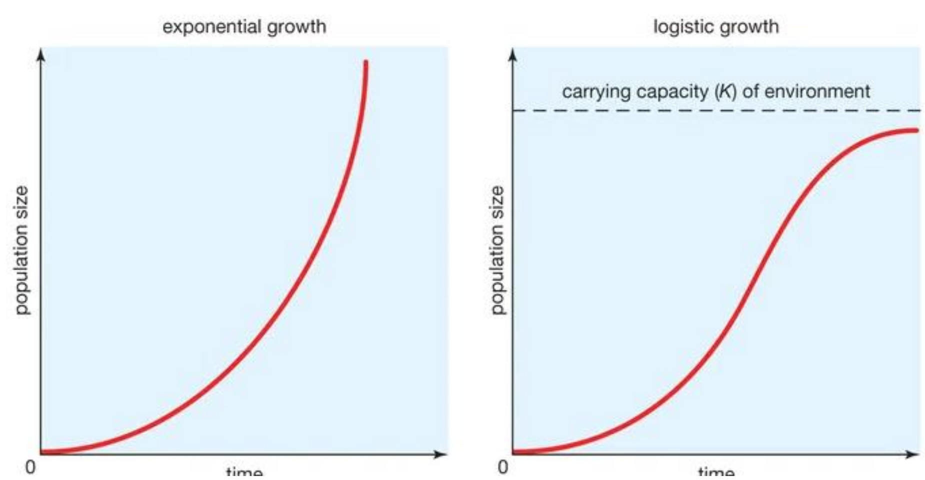


Fig.1.4 Exponential versus logistic population growth curve

2. LOGISTIC GROWTH

In1938 Verhulst (Pierre-François Verhulst (1804–1849) proposed that the populations grow in a much more systematic way than as proposed by Malthus. Growth pattern depends on the carrying capacity of a resource as well as the number of individuals (value of ‗N‘) at any given time. The growth is limited by resources as it gets consumed by the growing population (N) such as food and the exponential growth of the population begins to slow down. The competition for all resources increases with the increase in population with the increase in density and the growth rate eventually approaches to zero near the carrying capacity (K) for the environment and shows a plateau. This results in an S or Sigmoid Shape curve of population growth. It is also known as the logistic growth curve and can be plotted by applying the logistic growth equation. The logistic growth equation was independently proposed by Verhulst and Pearl, therefore it is named as Verhulst Pearl Growth Equation as given below:

$$\boldsymbol{dN/dt} = \boldsymbol{rN}\,\frac{(\boldsymbol{K}-\boldsymbol{N})}{K}$$

Where,

dN / dt = rate of increase of the population

r‘= Rate of pop growth per capita

N‘= the number of individuals of the population at the time‘t’

K‘= It is the constant upper limit of the population growth and is known as the carrying capacity of a place. It indicates the number of individuals that can be supported by a resource at which dN / dt equal to zero.

1.5 POPULATION REGULATION

Extrinsic Mechanisms:

These regulatory mechanisms are independent of population density and can lead to more drastic fluctuations in population

Intrinsic Mechanisms:

They are also called auto-regulatory feedback mechanism or density dependent factors as they are influenced by the population density. All populations have a tendency to evolve towards self-regulatory mechanisms. Another way of classifying the population regulatory mechanisms is:

A. BIOTIC:

Density dependent and density independent (interspecific interactions) mechanisms regulate the population density in large ecosystems with high biodiversity.

B. ABIOTIC: Physical and Climatic. Thirdly Peter Stiling has proposed a conceptual model to define population control describing the factors which are more important in determining the mortality in a population. They are classified into two systems A. Bottom-up Factors (or trophodynamics): These are related to the food chain based on Lindman‟s trophic dynamic model. This theory explains that the height of a trophic pyramidis the progressive attenuation of energy passing up the trophic levels from the producers through the primary consumers to secondary and tertiary. Since only 10 % energy is transferred between successive levels very little is left for the higher fourth or fifth trophic levels. This controls the population size. B. Top-down Factors: Hairstone, Smith and Stobodkin (1960) floated the idea that the earth appears green because of the abundance of vegetation on it. There is a little impact of herbivores on them as the population of herbivores is regulated by their predators leading to their increased mortality (usually referred to as HSS theory). The number of predators is limited by prey or resource availability. This theory emphasizes the various types of mortalities on the different trophic levels in varied ecosystems. Lauri Oksanon named this hypothesis as Ecosystem exploitation hypothesis (EEH).

Physical and Climatic Factors Ecosystems with low diversity and physically stressed or subjected to extrinsic perturbations populations tend to be regulated by physical components such as weather, Water currents, chemical limiting factors and pollution etc. Among the extrinsic factors the most important role is played by weather. Many seasonally breeding rodents and birds population sizes increase under favourable weather condition. Kangaroo rat in deserts can with stand dry and arid conditions but it reproduces in January after autumn rains. This is because rain stimulates the growth of herbaceous succulent plants that provide sufficient moisture and humid conditions required by kangaroo rat for reproduction. Similar behavior is observed in quails and weaver birds. Population growth rate increases during summer as long photoperiod and plenty of food is available for adults and their offspring. Weaver birds reproduce only during summer months when the days are long. Long photoperiod is required for the growth of testes and spermatogenesis in males (Laxmi Malhotra, et al 1979). Populations of dear in the Aderondack mountain (US) are sensitive to severe long winters of 50 to 60 days, the low growing winter food gets buried in snow and is unavailable to fawn and adults. It results in more than 80 % mortality of fawn. 3.2 Density Independent Factors There are positive, negative and neutral effects of various population interactions which affect the population size at a given time. Mutualism and commensalism are positive interactions and lead to increase in population size, whereas predation, parasitism, competition, and amensalism are population declining interactions.

1.6 LIFE HISTORY STRATEGIES (R & K SELECTION)

"K‟ selected populations live under more predictable environment, they are subjected to density related mortality, spend less energy on reproduction, favours efficient use of environment. Population growth is sigmoid shaped based on Verhulst Pearl logistic equation in "r"selected populations live under more harsh conditions and show exponential population growth. After attaining their maximum size may show a decline or complete population crash because the resources are completely exhausted.

Parameters	**"r" selection**	**"K" selection**
Climate conditions	Variable and unpredictable; uncertain	Fairly constant and predictable.
Mortality reasons	Often Catastrophic	More Directed
Survivorship curves	**Mostly Type III**	**Usually Types I and II**
Population size	1. Variable in Time, 2. Non-equilibrium well below carrying capacity of	1.Fairly Constant in Time 2. Equilibrium, at or near carrying capacity saturated

	environment; 3. Unsaturated communities or portions thereof ecologic vacuums; 4. Fast recolonization	communities 3. No recolonization
Intra- and Interspecific competition	**Variable, often negligent (lax)**	**Usually intense (keen)**
Selection favours	1. Rapid Development 2. High r max 3. Early reproduction 4. Small body size 5. Single reproduction (semelparous)	1. Slower Development 2. Greater competitive ability 3. Delayed reproduction 4. Larger body size 5. Repeated reproduction (Iteoparous)
Length of life	Short, usually less than a year	Longer, usually more than a year
Stage in succession	Early	Late, climax
Stage in succession	Short, usually less than a year	Longer, usually more than a year

1.7 AGE STRUCTURE POPULATION

It is the total number or percentage of individuals in a given population in different age group. The nature of a population is affected by its age structure. It influences mortality, natality and the ratio of different age groups in a population which specify its reproductive status. Age is generally expressed in days, months or years but it also considered in other categories such as pre-reproductive, reproductive and post reproductive. The age structure also determines the future population projections.

1. The population with high reproductive phase individuals than post reproductive phase shows an expanding population. However, some of the plants and animal including insects and fishes

etc do not have post reproductive phase. For example, bamboo shows mass flowering and subsequently die after producing seeds.

2. A population has more or less even distribution of post-reproductive and reproductive individuals showed stable population.

3. Populations which shows declining phase have large proportion of post reproductive individuals. Usually a population tries to make effort to keep a stable age distribution. The ratio of individuals of different age groups in a population specifies its current reproductive status. Usually, young to adult ratio in a relatively stable population is about 2: 1 of most animals. When a stable age distribution of a population is reached, the natality and mortality temporarily affect the population stability and it tries to come again to the stable condition at the earliest.

AGE PYRAMIDS:

The age distribution in a population can be characterized in the form age pyramids or polygons in which the number of individuals or the percentage in different age classes are shown by the relative width of the consecutive horizontal bars. Age pyramids are the snapshots of the age structure of a population at particular period of time which present an image of the relative sizes of different age groups in the population. The age structure of a population is a product of the age specific patterns of mortality and reproduction. When one or two age classes which are dominating in the population either die or removed, provide accessibility of resources to young age classes such as light, water, and nutrients so they can grow and develop.

1. Bell shaped pyramid having broad base represent an expanding population. It indicates a higher number of young individuals. In expanding population birth rate is high and population growth may be exponential like paramecium, bacteria, yeast etc.

2. Dome shaped pyramid represent a moderate proportion of young to old. As the proportion of prereproductive and reproductive age groups become equal, post reproductive age groups become smallest.

3. Urn shaped pyramid symbolize a declining population in which pre-reproductive individuals are less in number. If the birth rate is drastically reduced in the reproductive class, it results in drastic decline of proportion of pre-reproductive group than other two groups which indicates that population is dying off.

1.8 SUMMARY

A population is defined as a group of interacting organisms of the same species. A demographic structure of a population is how populations are often quantified. The total number of individuals in a population is defined as a population size, and how dense these individuals are is defined as population density. There is also a population's geographic range, which has limits that a species can tolerate (such as temperature).

Population size can be influenced by the per capita population growth rate (rate at which the population size changes per individual in the population.) Births, deaths, emigration, and immigration rates all play a significant role in growth rate. The maximum per capita growth rate for a population is known as the intrinsic rate of increase.

In a population, carrying capacity is known as the maximum population size of the species that the environment can sustain, which is determined by resources available. In many classic population models, r is represented as the intrinsic growth rate, where K is the carrying capacity, and N0 is the initial population size.

Term	Definition

Species population	All individuals of a species.
Metapopulation	A set of spatially disjunct populations, among which there is some migration.
Population	A group of conspecific individuals that is demographically, genetically, or spatially disjunct from other groups of individuals.
Aggregation	A spatially clustered group of individuals.
Deme	A group of individuals more genetically similar to each other than to other individuals, usually with some degree of spatial isolation as well.
Local population	A group of individuals within an investigator-delimited area smaller than the geographic range of the species and often within a population (as defined above). A local population could be a disjunct population as well.
Subpopulation	An arbitrary spatially delimited subset of individuals from within a population (as defined above).
Immigration	The number of individuals that join a population over time.
Emigration	The number of individuals that leave a population over time.

1.9 REFERENCES

1. M Ausloos and M Dirickx (eds.), *The logistic map and the route to chaos: From the beginnings to modern applications, Understanding Complex Systems* (Springer, Berlin, 2006).
2. J R Miner, Pierre-François Verhulst, the discoverer of the logistic curve, *Human Biology* **5** (1933), 673-689.
3. K Kint, D Constales and A Vanderbauwhede, Pierre-François Verhulst's final triumph, in *M Ausloos and M Dirickx* (*eds.*), *The logistic map and the route to chaos: From the beginnings to modern applications, Understanding Complex Systems* (Springer, Berlin, 2006), 13-28.
4. Dictionary of Scientific Biography.
5. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=2rAs1Puvga4LW93zMe83aA==
6. Sharma, P.D. (2003) Ecology and Environment. 7th Edition, Rastogi Publication, Meerut.
7. General book of Ecology by P.D.Sharma.

UNIT 2: POPULATION GROWTH

2.1 OBJECTIVES

After studying this Unit, you shall be able to know about:

- Growth of organism with non overlapping generation
- Stochastic and time lag model of population growth
- Exponential growth, Verhulst–Pearl logistic growth model
- Stable age distribution
- Population growth projection using Leslie Matrix

2.2 INTRODUCTION

Why Study Population Growth? Population ecology is **the study of how populations — of plants, animals, and other organisms — change over time and space and interact with their environment**. Populations are groups of organisms of the same species living in the same area at the same time.One of the important attribute of a population are to grow with time for the sustainability of a species and ecosystem balance. Depending on the size and reproductive strategies of organisms a population may grow in size from every minute, hour, days (bacteria and viruses and protozoan's), months or seasons (insects, fish and birds).The populations with long life span may breed once in several years (elephants and flowering plants like bamboo).

2.3. GROWTH OF ORGANISM WITH NON OVERLAPPING GENERATION

In population genetics models, such as the Hardy–Weinberg model, it is assumed that species have no overlapping generations. In nature, however, many species do have overlapping generations. The overlapping generations are considered the norm rather than the exception.

Overlapping generations are found in species that live for many years, and reproduce many times. Many birds, for instance, have new nests every (couple of) year(s). Therefore, the offspring will, after they have matured, also have their own nests of offspring while the parent generation could be breeding again as well. An advantage of overlapping generations can be found in the different experience levels of generations in a population. The younger age group will be able to acquire social information from the older and more experienced age groups. Overlapping generations can, similarly, promote altruistic behavior.

Non-overlapping generations are found in species in which the adult generation dies after one breeding season. If a species for instance can only survive winter in the juvenile state the species will automatically consist of non-overlapping generations.

Fig 2.1

The group of species lacking overlapping generations mostly consists of univoltine insects, and some annual plants. One example of univoltine insects, only breeding once a year, is Dawson's burrowing bee, *Amegilla dawsoni*.

Although annual plants die after one season, not all annual plants truly lack overlapping generations. Many annual plants have seed banks containing dormant seeds that remain dormant for at least one year. This makes overlapping generations possible in annual plants.

Effects of Overlapping Generations

Genetic diversity

Whether a species has overlapping generations or not can influence the genetic diversity in the new generation. Changes in the genetic variance in populations due to genetic drift have been shown to been twice as great when they are overlapping generations as opposed to there being non-overlapping generations.

Assumptions in population genetic model

Effective population size is an essential concept in evolutionary biology and notoriously hard to estimate. In models estimating this figure, it is often assumed that the species has non-overlapping generations. This can bias the estimate of the effective population size, because temporal fluctuations in allele frequencies follow complicated patterns when generations overlap.

In the Neutral theory of molecular evolution, it is shown that the rate of evolution (substitution rate) in neutral genes is not influenced by fluctuations in population size. This, however, is only true for species having discrete generations. In this case, the substitution rate is equal to the mutation rate. When generation overlapping is incorporated in this model, the substitution rate does change with population size fluctuations. The substitution rate increases when the population size transits from small to large, with a high survival probability and when the population size transits from large to small, with a low survival probability.

Experimentation

In many experiments species are assumed to only consist of non-overlapping generations. For instance, when a scientist wants to look at genetic mutations in a strain of bacteria. He will look at all the offspring (F1) of the current generation (P). For a further look into genetic mutations in the strain he will then look at the next generation (F2) which consists only of offspring from generation F1 while the first generation P will not be used in the experiment any longer.

2.4 STOCHASTIC AND TIME LAG MODEL OF POPULATION GROWTH

Stochastic theory deals with random influences on populations and on the vital events experienced by their members. It builds on the deterministic mathematical theory of renewal processes and stable populations. Concentrating on structural and predictive models, it is distinct from statistical demography, which also deals with randomness but in the context of data analysis and inference under uncertainty. This entry treats macro demographic processes of population growth and structure first and micro demographic processes of individual experience second. Basic background for all these subjects is found in the classic textbooks by the demographer Nathan Keyfitz published in 1968 and 1985.

In theory, any kind of organism could take over the Earth just by reproducing. For instance, imagine that we started with a single pair of male and female rabbits. If these rabbits and their descendants reproduced at top speed ("like bunnies") for 777 years, without any deaths, we would have enough rabbits to cover the entire state of Rhode Island {1,2,3}1,2,3 start superscript, 1, comma, 2, comma, 3, end superscript. And that's not even so impressive – if we used *E. coli* bacteria instead, we could start with just one bacterium and have enough bacteria to cover the Earth with a 111-foot layer in just 363636 hours^44start superscript, 4, end superscript! As you've probably noticed, there isn't a 111-foot layer of bacteria covering the entire Earth (at least, not at my house), nor have bunnies taken possession of Rhode Island. Why, then, don't we see these populations getting as big as they theoretically could? *E. coli*, rabbits, and all living organisms need specific resources, such as nutrients and suitable environments, in order to survive and reproduce. These resources aren't unlimited, and a population can only reach a size that match the availability of resources in its local environment.

Population ecologists use a variety of mathematical methods to model **population dynamics** (how populations change in size and composition over time). Some of these models represent growth without environmental constraints, while others include "ceilings" determined by limited resources. Mathematical models of populations can be used to accurately describe changes occurring in a population and, importantly, to predict future changes.

Time–lag models attempt to create population growth forms which better reflect natural conditions because organisms rarely respond instantaneously to a change in the system. Introducing a time lag into a model can destabilize the model and cause dramatic fluctuations in population size, depending on the length of the time delay. The simplest time-lag model is a modification of the birth and death rate model.

2.5 EXPONENTIAL GROWTH, VERHULST–PEARL LOGISTIC GROWTH MODEL

Exponential growth of a population was noted for the first time by Thomas Robert Malthus (1766- 1834) an economist. In 1798, he published his essay on “Principles of population” in which he proposed that the populations tend to increase faster than the means of their subsistence. He proposed that the populations increase in geometrical (2, 4, 8, 16, and so on) whereas, their food increases arithmetical (2, 4, 6, 8, and so on) progression. Using an exponential form of population growth, two fruit flies could produce enough offspring to fill the space between the Earth and the Sun in only one year, if all of the offspring survived. Exponential growth is one of two growth rates ecologists recognize in nature, but there are many other factors that keep the world from becoming overrun with any one population; may it be fruit flies or other organisms that show exponential growth.

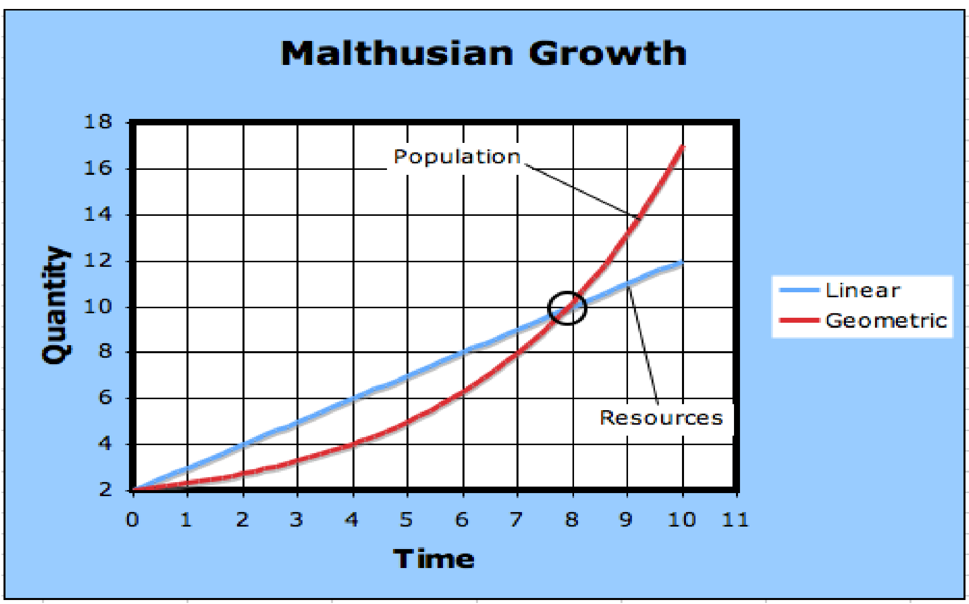


Figure 2.2 Malthusian *Growth*

SEMELPAROUS AND ITEROPAROUS REPRODUCTIVE STRATEGIES

The reproductive strategy of an organism can either be Semelparous or Iteroparous.

SEMELPAROUS:

A Semelparous species reproduces only once before it dies. A delay in the breeding season may exert a regulative effect on their population growth. If the adults breeding in one season rarely or never survive to breed in the next has an important effect on their dynamics. In discrete breeding species the population may breed only once at a specific time of the year. The word semelparity comes from the Latin word semel ' once or single time' and word pario' to beget' and was coined by evolutionary biologist Lamont Cole. As the single reproductive event of semelparous organisms is usually large as well as fatal, it is considered by some as "big bang" reproduction. Pacific salmon (Oncorhynchus spp.) is a classic example of a semelparous organism which lives for many years in the ocean before swimming to the freshwater stream of its birth, spawning, and dying. Other semelparous animals include some species of butterflies, cicadas, and mayflies, many arachnids, and some molluscs such as some species of squid and octopus. In plant kingdom an annual is a plant that completes its life cycle in a single season, and is usually semelparous.

ITEROPAROUS:

Iteroparous can reproduce more than once in its lifetime. The term iteroparity comes from the Latin itero, to repeat, and pario, to beget. Thus, there is two or more overlapping generation of organisms living at any one time. In other words one generation of young individuals coexist with one older generation in reproductively active state. Human is example of an iteroparous organism as humans are biologically capable of having offspring many times over the course of their lives. Iteroparous vertebrates include most fishes and reptiles, all birds and all mammals. Among invertebrates, most mollusca and many insects (for example, mosquitoes and cockroaches) are iteroparous. Most perennial plants are iteroparous.

EXPONENTIAL POPULATION GROWTH IN SEMELPAROUS SPECIES

In Semelparous life history, birth rate and the density of the organisms plays an important role in determining the growth pattern.

a) Multiplication rate remains constant (“Ro”Net reproductive rate or birth rate remains constant) b) Multiplication rate depends on population size (density Dependent) A. Multiplication Rate remains Constant: Consider a species with a single annual breeding season and a life span of one year. Let each female produce Ro female offspring on the average, that survive to breed the following year, then population numbers N in generations t = 0, 1, 2, ... is equal to:

VERHULST–PEARL LOGISTIC GROWTH MODEL

Verhulst Pearl Equation In1938 Verhulst (Pierre-François Verhulst (1804–1849) proposed that the populations grow in a much more systematic way than as proposed by Malthus. Growth pattern depends on the carrying capacity of a resource as well as the number of individuals (value of ‗N‘) at any given time. The growth is limited by resources as it gets consumed by the growing population (N) such as food and the exponential growth of the population begins to slow down. The competition for all resources increases with the increase in population with the increase in density and the growth rate eventually approaches to zero near the carrying capacity (K) for the environment and shows a plateau. This results in an S or Sigmoid Shape curve of population growth. It is also known as the logistic growth curve and can be plotted by applying the logistic growth equation. The logistic growth equation was independently proposed by Verhulst and Pearl, therefore it is named as Verhulst Pearl Growth Equation as given below:

$$\boldsymbol{dN/\ dt = rN\ (K - N)/\ K}$$

(Rate of population increase)= (Rate of pop growth per capita) x (Population Size) x (Unutilized opportunity for the population growth) Or the equation can be written as.

$$\boldsymbol{dN\ dt = rN\ (1 - N)/\ K}$$

Where, $dN\ dt$ = rate of increase of the population r‘= Rate of pop growth per capita ‗N‘= the number of individuals of the population at the time‘t’ K‘= It is the constant upper limit of the population growth and is known as the carrying capacity of a place. It indicates the number of individuals that can be supported by a resource at which dN / dt equal to zero.

2.6 STABLE AGE DISTRIBUTION

This age-structured growth model suggests a steady-state, or stable, age-structure and growth rate. Regardless of the initial population size, N_0, or age distribution, the population tends asymptotically to this age-structure and growth rate. It also returns to this state following perturbation. The Euler–Lotka equation provides a means of identifying the intrinsic growth rate. The stable age-structure is determined both by the growth rate and the survival function (i.e. the Leslie matrix). For example, a population with a large intrinsic growth rate will have a disproportionately "young" age-structure. A population with high mortality rates at all ages (i.e. low survival) will have a similar age-structure. Charles worth (1980) provides further details on the rate and form of convergence to the stable age-structure.

2.7 POPULATION GROWTH PROJECTION USING LESLIE MATRIX

There is a generalization of the population growth rate to when a Leslie matrix has random elements which may be correlated. When characterizing the disorder, or uncertainties, in vital parameters; a perturbative formalism has to be used to deal with linear non-negative random matrix difference equations. Then the non-trivial, effective eigen value which defines the long-term asymptotic dynamics of the mean-value population state vector can be presented as the effective growth rate. This eigen value and the associated mean-value invariant state vector can be calculated from the smallest positive root of a secular polynomial and the residue of the mean-valued Green function. Exact and perturbative results can thusly be analyzed for several models of disorder.

In applied mathematics, the **Leslie matrix** is a discrete, age-structured model of population growth that is very popular in population ecology. It was invented by and named after Patrick H.

Leslie. The Leslie matrix (also called the Leslie model) is one of the most well known ways to describe the growth of populations (and their projected age distribution), in which a population is closed to migration, growing in an unlimited environment, and where only one sex, usually the female, is considered.

The Leslie matrix is used in ecology to model the changes in a population of organisms over a period of time. In a Leslie model, the population is divided into groups based on age classes. A similar model which replaces age classes with ontogenetic stages is called a **Lefkovitch matrix**, whereby individuals can both remain in the same stage class or move on to the next one. At each time step, the population is represented by a vector with an element for each age class where each element indicates the number of individuals currently in that class.

The Leslie matrix is a square matrix with the same number of rows and columns as the population vector has elements. The $(i,j)^{th}$ cell in the matrix indicates how many individuals will be in the age class (*i*)at the next time step for each individual in stage (*j)*. At each time step, the population vector is multiplied by the Leslie matrix to generate the population vector for the subsequent time step.

To build a matrix, the following information must be known from the population:

- n_x the count of individuals (*n*) of each age class *x*
- $S_x$the fraction of individuals that survives from age class *x* to age class *x+1*,
- f_x fecundity, the per capita average number of female offspring reaching n_0 born from mother of the age class *x*. More precisely, it can be viewed as the number of offspring produced at the next age class b_{x+1} weighted by the probability of reaching the next age class. Therefore, $f_x=s_xb_{x+1}.$

2.8 SUMMARY

The two simplest models of population growth use deterministic equations (equations that do not account for random events) to describe the rate of change in the size of a population over time. The first of these models, exponential growth, describes theoretical populations that increase in numbers without any limits to their growth. The second model, logistic growth, introduces limits to reproductive growth that become more intense as the population size increases. Neither model adequately describes natural populations, but they provide points of comparison.

Charles Darwin, in developing his theory of natural selection, was influenced by the English clergyman Thomas Malthus. Malthus published his book in 1798 stating that populations with abundant natural resources grow very rapidly; however, they limit further growth by depleting their resources. The early pattern of accelerating population size is called exponential growth.

The best example of exponential growth in organisms is seen in bacteria. Bacteria are prokaryotes that reproduce largely by binary fission. This division takes about an hour for many bacterial species. If 1000 bacteria are placed in a large flask with an abundant supply of nutrients (so the nutrients will not become quickly depleted), the number of bacteria will have doubled from 1000 to 2000 after just an hour. In another hour, each of the 2000 bacteria will divide, producing 4000 bacteria. After the third hour, there should be 8000 bacteria in the flask. The important concept of exponential growth is that the growth rate—the number of organisms added in each reproductive generation—is itself increasing; that is, the population size is increasing at a greater and greater rate. After 24 of these cycles, the population would have increased from 1000 to more than 16 billion bacteria.

Extended exponential growth is possible only when infinite natural resources are available; this is not the case in the real world. Charles Darwin recognized this fact in his description of the "struggle for existence," which states that individuals will compete (with members of their own or other species) for limited resources. The successful ones are more likely to survive and pass on the traits that made them successful to the next generation at a greater rate (natural selection).

To model the reality of limited resources, population ecologists developed the logistic growth model.

2.9 TERMINAL QUESTIONS AND ANSWERS

Question No.1 Explain in Detail the Logistic and Exponential growth curve?

Question No.2 what do understand by stochastic and time lag model of population growth?

Question No.3 write short note on stable age distribution?

Question no.4 write short note on Verhulst–pearl logistic growth model?

2.10 REFERENCES

1. M Ausloos and M Dirickx (eds.), *The logistic map and the route to chaos: From the beginnings to modern applications*, *Understanding Complex Systems* (Springer, Berlin, 2006).
2. J R Miner, Pierre-François Verhulst, the discoverer of the logistic curve, *Human Biology* **5** (1933), 673-689.
3. K Kint, D Constales and A Vanderbauwhede, Pierre-François Verhulst's final triumph, in *M Ausloos and M Dirickx* (*eds.*), *The logistic map and the route to chaos: From the beginnings to modern applications, Understanding Complex Systems* (Springer, Berlin, 2006), 13-28.
4. Dictionary of Scientific Biography.
5. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=2rAs1Puvga4LW93zMe83aA==
6. Sharma, P.D. (2003) Ecology and Environment. 7th Edition, Rastogi Publication, Meerut.
7. General book of Ecology by P.D.Sharma.

UNIT 3: PREDATION

3.1 OBJECTIVES

After studying this module, you shall be able to

- Describes the models of predation
- Understand the prey-predator system
- Optimal foraging theory
- Role of predation in nature

3.2 INTRODUCTION

Different species interact with each other to compete for food or space through predation. Predation is called as biophagy and defined as one species feeding on other loving organisms. Moreover, it’s a broad term used for those species which not only eat other species but often involves in killing of other species. On Earth, as ecosystem, Humans are the major predators. It is an association where mostly stronger attacks the weaker organism. However, considered more broadly, predation can be distinguished into five specific types, namely: Herbivory, Parasitoidism, carnivory, cannibalism and parasitism. Herbivory is a type of predation where all type of grazing animals prey on plants. This type of prey predation association does not involves direct killing but plants, seeds or fruits eaten by animals causes damage to the green plants. Carnivory is a typical kind of predation where predator or stronger animal prey on other carnivores organisms or on herbivores. Another specific type of predation includes parasitoidism where an organism called parasitoids, generally these are insect parasitoids, predates on another insects called host insect by laying eggs near or on the host insects. These eggs, hatched into larva’s that feeds on tissues of host insect and subsequently killed and eaten by the insect parasitoid.

Parasitism is a type of predation where parasites (plants and animals) are the organisms that do not kill and consume the prey or hosts but depends on them for nutrients. A special form of predation is called cannibalism in which predator and prey belongs to same type of species.

Certain groups of tribal people show cannabilism where on death of any family member they eat their body parts. The predator does not interact with prey only but with other predator species through competition. The interaction mediated competition between predator species is indirect. When the prey of different or same species competes for food and space among themselves creates indirect competition between predators. Whereas when predators compete for same prey species i.e in short supply it causes indirect competition between predators.

3.3 MODELS OF PREY-PREDATION DYNAMICS

Organisms used two types of system called discrete generation and continuous generation systems by following two simple types of prey-predator models.

Model for organisms with Discrete Generation system

Discrete generation system is used to explore prey-predator interaction models. Several insect host act as prey and insect parasitoids acting as predator under seasonal environmental conditions have one generation per year and are described by following type of models. Logistic equation describes the increase in the prey population in the absence of predators and given as:

$$N_{t+1} = (1-B (N_t - N_{eq}) N_t$$

Where, N_t= population size; t= generation time; B=slope of reproductive curve; and (N_t-N_{eq}) = difference in the population size from equilibrium size of population in absence of predator. We must subtract a term related to the number of preys eaten by predators from the logistic equation of prey under the absence of predator. The logistic equation of prey in the presence of predator is represented as:

$$N_{t+1} = (1-B (N_t - N_{eq}) N_t - CN_tP_t$$

Where, P_t= in generation time t, the size of predator population; C= constant determining the predator efficiency. Assuming that the predator's reproduction rate depends on the population size of prey, the equation for predator population is given as:

$$P_{t+1} = QN_tP_t$$

Pt = predation population size; N = prey population size; t= generation time; and Q= constant determines the prey utilization efficiency of predation for its reproduction.

When these equations are put together and interpreted after calculating them over many generations resulted into a cycle of prey and predator numbers. There are form possible outcomes of these calculated equations:

a. A stable equilibrium without oscillation

b. Divergent oscillations, causing extinction of either prey or predator

c. Convergent oscillations, causing extinction of either prey or predator d. Stable oscillation

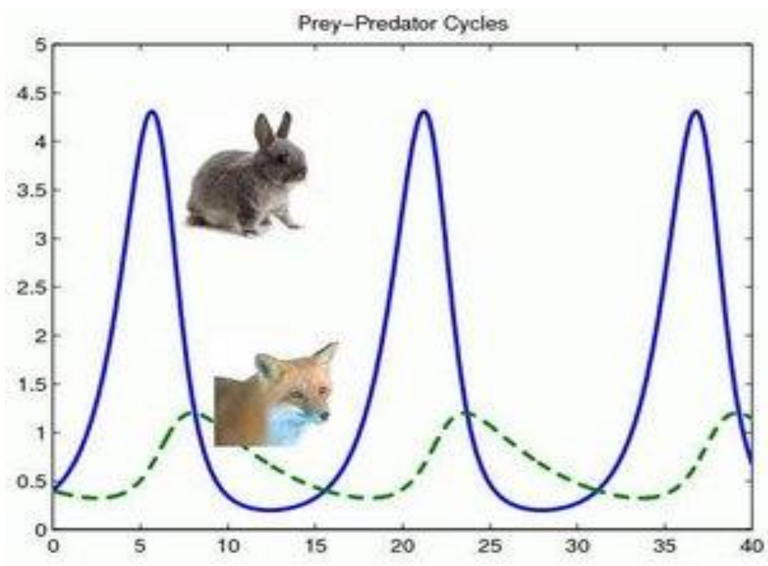


Fig.3.1 Periodic activity generated by the Predator-Prey model

Continuous generation system Organisms with continuously occurring births and deaths have overlapping generations such as several prey and vertebrate predators provide good examples. The continuous generation system used by the predator and prey interactions is described in an independently derived set of mathematical equations given by Lotka Voltera (1926).

Lotka Volterra Predation equations

In 1925, a physical scientist and mathematician, A. J. Lotka in his work “Elements of Physical Biology” suggested the early and very first model of predator-prey interaction system. Independently, A. Volterra developed a similar model of predator-prey interaction in 1926. The model assumed that the responses of predator population and prey population are proportional to the product of predator and prey population size. The Predator-prey equations given by Lotka-Volterra describe the interaction between prey and predation as a dynamic Biological system. The predator and prey populations follow a non-linear, first order differential equation and represented in pair of equation as:

$$\frac{dx}{dt} = \alpha x\text{-}\beta xy$$

$$\frac{dy}{dt} = \gamma xy\text{-}xy$$

- x is the number of prey (for example, rabbits)
- *y* is the number of some predator (for example, foxes);
- "dx/dt" or "dy/dt" represents the instantaneous growth rates of the two populations.
- *t* represents time
- *α*, *β*, *γ*, *δ* are positive real parameters describing the interaction of the two species.

Where "x" and "y" is the number of prey and predator population and "dx/dt" or "dy/dt" are the growth rates of prey and predator population in time "t". The symbols α, β, γ and δ denotes the real and positive parameters related to the interaction between prey and predator species. Lotka-Volterra predation equation is based on the assumptions: 1. Predator can eat limitless. 2. Supply of food resource (i.e. prey) depends on the prey population size. 3. The rate of change of population directly depends on its size. 4. Environment is constant, inconsequential genetic adaptations for both species. 5. All time unlimited food supply for prey. The equation is continuous and deterministic indicated continuous overlapping of prey and predator population. The rate of growth for predator population is given by equation:

$$\frac{dy}{dt} = \gamma xy\text{-}xy$$

The change in predator population equals to food supply mediated growth minus death of predators. The growth of predator population is represented as "δxy". "δ" is different from "β" as the rate of predator population growth is very much different from the rate of predation on prey. "γy" is the decay rate of predator either due to emigration or mortality. In the prey absence the predator follow an exponential decay.

The early models given by Lotka-Volterra provide insignificant biological realism and proved unrealistic and thus, replaced by other models, Berryman (1992).

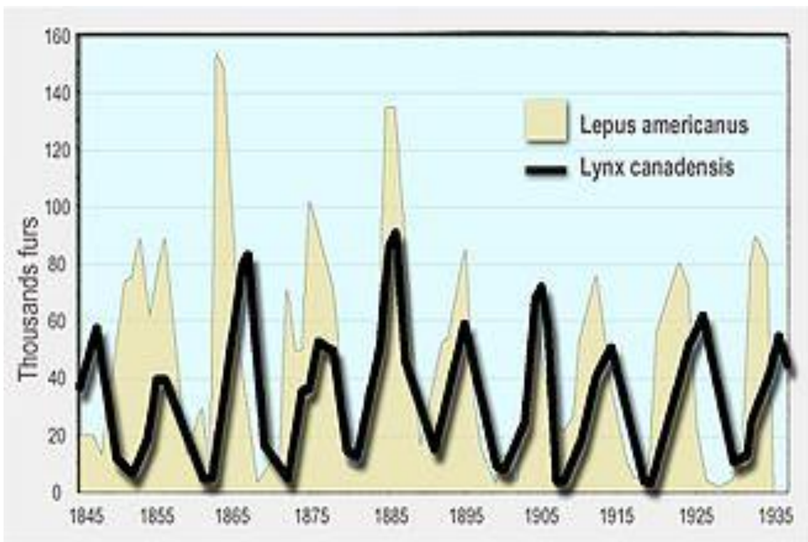


Fig.3.2 Numbers of snowshoe hare (yellow, background) and Canada lynx (black line, foreground) furs sold to the Hudson's Bay Company. Canada lynxes eat snowshoe hares.

PREDATION-PREY SYSTEM

The behaviour predictions of predator-prey system given by Lotka-Volterra model stimulated experimental investigations.

Laboratory studies In 1934, Gause, the Russian biologist under constant environment conditions reared together a predator and prey ciliates, Didinium nasutum and Paramecium caudatum, respectively. He performed two different types of experiments in a simple environment.

(i) In one experiment, he introduced predator in a test tube containing clear nutritive medium supporting a population of Paramecium (prey). Paramecium was unable to escape from the predatory ciliates Didinium, the prey succumbed to predation. On predation of complete prey population the predator, Didinium die due to starvation.(Thus, from his experiment, he discovered that the predator always exterminated the prey irrespective of prey and predator population size. Gause discovered that the predator population can be maintained only by periodically adding immigrants or prey to the medium.

(ii) In another experiment, Gause introduced predator into the test tube containing sediment at the bottom acting as a site for prey to refuge from predator. Following consumption of all the available prey the predators died from starvation. Meanwhile, prey that refuge in the sediments increase in number and eventually spread over the medium. By periodically introducing predator to the medium, Gause could be able to maintain both the population.

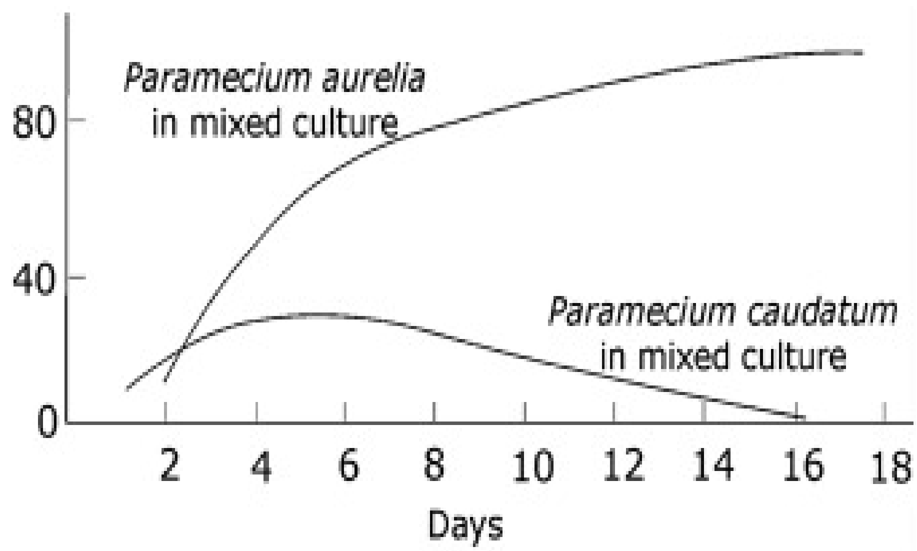


Fig.3.3 Compititive Exclusion in Paramecium

Gause’s experiments did not support Lotka-Volterra predation model and their predictions. Gause concluded in his model that predator-prey interaction cause overexploitation of prey population followed by decline in predator population and the predator-prey system could be maintained only by periodically introducing the immigrants. Inspired from the work of Gause, C. Huffaker (1958) established a complex laboratory environment to eliminate the possibility of self-extermination of predator-prey system. He introduced a mite, Typhlodromus occidentalis as preadtor and a six-spotted mite, Eotetranychus sexmacalatus as prey which feeds on oranges. Both predator and prey reproduces parthenogenetically. On trays, he established experimental population containing four rows with total 40 cells (10 cells each row), he placed rubber balls in some cells whereas oranges of same size in remaining cells and thus, regulate the pattern of food dispersion, total food availability, to control the distribution and size of prey population. From his experiments he concluded that:

(A) For prolonged time, the low population size of prey leads to collapse in predator population.
(B) The immigration of prey is essential to eliminate the occurrence of self-extermination in the predator-prey system.
(C) The intensity of predation has relatively low influence on the period of oscillation in respect to predator-searching for prey and prey dispersal complexity relationship along with the time required by prey to recover and repopulate followed by predation.

3.4 OPTIMAL FORAGING THEORY (OFT)

Optimal foraging theory (**OFT**) is a behavioral ecology model that helps predict how an animal behaves when searching for food. Although obtaining food provides the animal with energy, searching for and capturing the food require both energy and time. To maximize fitness, an animal adopts a foraging strategy that provides the most benefit (energy) for the lowest cost, maximizing the net energy gained. OFT helps predict the best strategy that an animal can use to achieve this goal.

OFT is an ecological application of the optimality model. This theory assumes that the most economically advantageous foraging pattern will be selected for in a species through natural selection. When using OFT to model foraging behavior, organisms are said to be maximizing a variable known as the **currency**, such as the most food per unit time. In addition, the **constraints** of the environment are other variables that must be considered. Constraints are defined as factors that can limit the forager's ability to maximize the currency. The **optimal decision rule**, or the organism's best foraging strategy, is defined as the decision that maximizes the currency under the constraints of the environment. Identifying the optimal decision rule is the primary goal of the OFT.

In nature, different biological factors such as intraspecific or interspecific interactions and physical factors such as landscape structure etc causes heterogeneous distribution of food. Therefore, keeping in mind this objective, sequence of optimal foraging theories was developed by several ecologists. The optimal foraging theories provide bases for interpreting complex predator prey interaction via testable hypotheses. The assumption made by the optimal foraging theories was that the predation activity is optimized to maximize the rate of net energy gain. Among various biological theories on animal behaviour, the most extensively developed optimization theory is the Optimal Foraging Theory (OFT). A patchy area is an area with high resources compared to average environment. Assume that the prey on which the predator feeds upon is distributed in the patchy area, then the predator spends its foraging time in searching and travelling between patches and rest in handling prey within these patches. Furthermore, while the predator searches for the prey, predator depletes the number of prey within the patches and gradually with time the benefit of staying in that patch declines. According to Optimal Foraging Theory, the predator may face four types of difficulties:

(a) The choice for optimal diet

(b) The choice for optimal patch (what type of patch should be searched?).

(c) Optimal departure time from the patch and

(d) Choice of optimal movement (movement between patches). In order to maximize the foraging efficiency of the predator, the predator should make decisions (assumed by the optimality approach) as per the optimal decision rules.

3.4.1 DIET

One classical version of the optimal foraging theory is the **optimal diet model**, which is also known as the prey choice model or the contingency model. In this model, the predator encounters different prey items and decides whether to eat what it has or search for a more profitable prey item. The model predicts that foragers should ignore low profitability prey items when more profitable items are present and abundant.

The profitability of a prey item is dependent on several ecological variables. **E** is the amount of energy (calories) that a prey item provides the predator. Handling time (**h**) is the amount of time it takes the predator to handle the food, beginning from the time the predator finds the prey item to the time the prey item is eaten. The profitability of a prey item is then defined as **E/h**. additionally, search time (**S**) is the amount of time it takes the predator to find a prey item and is dependent on the abundance of the food and the ease of locating it. In this model, the currency is energy intake per unit time and the constraints include the actual values of **E**, **h**, and **S**, as well as the fact that prey item are encountered sequentially.

3.5.2 PREY

Prey is a term used to describe organisms that predators kill for food. Predation is a biological interaction where one organism, the predator, kills and eats another organism, its prey. It is one of a family of common feeding behaviours that includes parasitism and micro predation (which usually do not kill the host) and parasitoidism (which always does, eventually). It is distinct from scavenging on dead prey, though many predators also scavenge; it overlaps with herbivory, as seed predators and destructive frugivores are predators.

Predators may actively search for or pursue prey or wait for it, often concealed. When prey is detected, the predator assesses whether to attack it. This may involve ambush or pursuit predation, sometimes after stalking the prey. If the attack is successful, the predator kills the prey, removes any inedible parts like the shell or spines, and eats it. Predation has a powerful selective effect on prey, and the prey develop antipredator adaptations such as warning coloration, alarm calls and other signals, camouflage, mimicry of well-defended species, and defensive spines and chemicals.

3.5.3 SELECTIVITY

Predators are often highly specialized in their diet and hunting behavior; for example, the Eurasian lynx only hunts small ungulates. Others such as leopards are more opportunistic generalists, preying on at least 100 species. The specialists may be highly adapted to capturing their preferred prey, whereas generalists may be better able to switch to other prey when a preferred target is scarce. When prey have a clumped (uneven) distribution, the optimal strategy for the predator is predicted to be more specialized as the prey are more conspicuous and can be found more quickly; this appears to be correct for predators of immobile prey, but is doubtful with mobile prey.

In size-selective predation, predators select prey of a certain size. Large prey may prove troublesome for a predator, while small prey might prove hard to find and in any case provide less of a reward. This has led to a correlation between the size of predators and their prey. Size may also act as a refuge for large prey. For example, adult elephants are relatively safe from predation by lions, but juveniles are vulnerable

.

3.5.4 FORAGING TIME

Foraging is searching for wild food resources. It affects an animal's fitness because it plays an important role in an animal's ability to survive and reproduce. Foraging theory is a branch of behavioral ecology that studies the foraging behavior of animals in response to the environment where the animal lives.

Behavioral ecologists use economic models and categories to understand foraging; many of these models are a type of optimal model. Thus foraging theory is discussed in terms of optimizing a payoff from a foraging decision. The payoff for many of these models is the amount of energy an animal receives per unit time, more specifically, the highest ratio of energetic gain to cost while foraging. Foraging theory predicts that the decisions that maximize energy per unit time and thus deliver the highest payoff will be selected for and persist. Key words used to describe foraging behavior include resources, the elements necessary for survival and reproduction which have a limited supply, predator, any organism that consumes others, prey, an organism that is eaten in part or whole by another, and patches, concentrations of resources.

3.5 ROLE OF PREDATION IN NATURE

In predation, one organism kills and consumes another. Predation provides energy to prolong the life and promote the reproduction of the organism that does the killing, the predator, to the detriment of the organism being consumed, the prey. Predation influences organisms at two ecological levels. At the level of the individual, the prey organism has an abrupt decline in fitness, as measured by its lifetime reproductive success, because it will never reproduce again. At the level of the community, predation reduces the number of individuals in the prey population.

The best-known examples of predation involve carnivorous interactions, in which one animal consumes another. Think of wolves hunting moose, owls hunting mice, or shrews hunting worms and insects. Less obvious carnivorous interactions involve many small individuals consuming a larger one. Such group predation is common among social carnivores such as lions, hyenas, and wolves. Group predation also occurs with ants and social spiders. This is, however, only part of the picture. Seed consumption can sometimes constitute predation. Seeds are considered organisms. Under ideal circumstances, seeds grow to become plants. However, consumption of a seed kills the plant before it can grow, making seed consumption an example of predation.

Not all predators are animals. Carnivorous plants, such as the Venus fly trap and the pitcher plant, consume insects. Pitcher plants catch their prey in a pool of water containing digestive enzymes, whereas the Venus fly trap captures an insect between the two lobes of a leaf and seals the insect inside with digestive enzymes. These plants absorb nutrients from the insects as they become available during digestion. On a microscopic scale, protozoa and bacteria also consume prey organisms. They play an important role in maintaining population sizes in microbial communities, which promotes the diversity of microorganisms and contributes to a stable community structure.

3.6 SUMMARY

When one organism consumes another living organism, the interaction is called as predation. It's a type of "+/-"relationship where one individual is benefitted at the expense of other. In the broadest manner the predation includes parasitism and herbivory. The predator-prey interactions of organism with discrete and continuous generation systems have been described by the mathematical models. The continuous generation model for predator-prey interactions is given by many ecologists. The very first but unrealistic model is given by Lotka-Volterra, followed by more realistic models given by Nicholson-Bailey, Rosenzweig MacArthur and Arditi-Berryman model. All these mathematical models in ecology predicted and concluded the oscillations of prey and predator population. The resulting oscillations from the interaction may be unstable, damped or stable. The predator-prey relationship causes two types of responses, namely functional response and numerical response. Predator may consume more number of preys on increase in density of prey population, called as functional response. Predator may increase in number in response to increase in prey population, called as numerical response. The functional response can be of three types, Type I, Type II, and Type III response. In Type I functional response the number of prey consumed per predator is directly proportional to the increase in prey density until it reaches maximum. In Type II functional responses, as the prey density increases, the number of prey consumed by the predator increases at a deaccelerating rate until reaches maximum. In Type III functional response, the predation rate increases slowly as the prey density increases, later following a sigmoid curve until reaches asymptote. Numerical response includes aggregative response in which as the prey density increases it attracts the influx of more number of predators to that area. Furthermore, numerical response also refers to increase in the rate of growth and development (natality and mortality rate alters) of predator population.

The food is distributed non uniformly in the habitat resulting into the patches where prey occurs, thus, in terms of profit relative to net energy gain, the predator spent time in hunting prey occurring in patches with more profit rather than patches with abundance of prey. This behavioral study of predators leads to development of concept of foraging theory. The optimal foraging theory (OFT) is a strategy adopted by the predator to consume its prey in such a manner that it should gain a maximum rate of energy. The optimal foraging theory includes the choice for optimal diet by the predator, the choice for optimal patch (what type of patch should be searched?); (c) optimal departure time from the patch; and (d) choice of optimal movement (movement between patches).

3.7 TERMINAL QUESTIONS AND ANSWERS

Question No. 1. Explain in detail the Lotka - Volterra Predation equations?

Question No. 2. Write a short note on Optimal foraging theory (OFT)?

Question No. 3. Explain the Models of prey-predation dynamics

Question No. 4. Explain the Role of predation in nature

Question No. 5. Write a short note on:

(a) Prey

(b) Selectivity

3.8 REFERENCES

1. General book of Ecology by P.D.Sharma.
2. Sharma, P.D. (2003) Ecology and Environment. 7th Edition, Rastogi Publication, Meerut.
3. M Ausloos and M Dirickx (eds.), *The logistic map and the route to chaos: From the beginnings to modern applications, Understanding Complex Systems* (Springer, Berlin, 2006).
4. J R Miner, Pierre-François Verhulst, the discoverer of the logistic curve, *Human Biology* **5** (1933), 673-689.
5. K Kint, D Constales and A Vanderbauwhede, Pierre-François Verhulst's final triumph, in *M Ausloos and M Dirickx* (*eds.*), *The logistic map and the route to chaos: From the beginnings to modern applications*, *Understanding Complex Systems* (Springer, Berlin, 2006), 13-28.
6. Dictionary of Scientific Biography.
7. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=2rAs1Puvga4LW93zMe83aA==

UNIT 4: COMPETITION AND NICHE THEORY

4.1 OBJECTIVES

Study of this unit will let the students to:

- Meaning of Competition in Nature
- Various level of competition at the level of intraspecific and interspecific.
- What is the concept and definition of ecological niche?
- How specifies interact with each other.
- Understand how the concept of niche evolved.
- Various Types of niche.
- What is Symbiosis?
- Various form of Symbiosis.
- Symbiosis in nature.

4.2 INTRODUCTION

Competition refers to group of flora and fauna competing for common limited resources like food, water, sunlight etc. for their survival. This competition can be within the same species or with different species.Over a period of time species have evolved a complex relationship within their species and with different species. These complex relationships have given rise to several concepts like predators, parasitism, and symbiosis etc.Some species have developed dependency on other species for food etc. Some have developed a relationship where both species are dependent on each other but they are both getting benefits for each other. Species have devised unique pattern, food habitat and various adaptations to support different species.American warbles birds have four species. These four species share the same resources like land, food (insect) but lives on different part of spruce tree. Thus they have undergone little physical modification in their body color, length etc. to suit with the new set of condition. Various flora and fauna have adapted themselves with the environment according to available resources. The flora and fauna have shown a remarkable adaptability to change with the environment factor just for their survival. The bear is a classic example how animals have changed for their survival. They are found from polar to tropical region. Their Body structure, behavior and food habitats have undergone changes drastically. Some of the animal have devised a unique combination of helping each other to overcome the threats from other species.

4.3 COMPETITION

Competition means the continuous process of compete (Fight out). This compete can be within the species or with species. They compete is for food, space, water and other factors needed for survival. The criteria which decide are power, few body adaptations like legs, head, teeth etc. These are the ones which decided whether the existing species can survive the onslaught of competition. Leopard, Lion, Cheetah, Hyena are fighting each other for same set of food, space etc. They can even kill each other just to reduce competition. This competition is not confine within species. The question of individuals in social status, right to breed etc. within the community, population also leads to compete within the individual of the same species. These compete sometimes can lead to death of individual. This competition has led to the development of complex relationship with in species and with species. The species have undergone drastic change in their behavior, body structure just because of competition. There are numerous examples like Giraffe and Babool tree, cheetah and impala deer etc. found in nature.

4.3.1 INTERSPECIFIC COMPETITION

Community comprises of all living organism that inhabits a particular area. It is an assemblage of population of different species that live together with mutual tolerance and interaction. Communities differ from each other in their species richness, composition, and size of each species and relative abundance of different species. This results in an interrelationship between these species and within these species. These interrelationships will be in the form of **neutralism, Competition, Predation, Herbivory, Symbiosis, Parasitism, Mutualism and Commensalism.**

We are going to discuss each of this behavior.

4.3.1.1NEUTRALISM:

This behavior where both the species are not gaining or losing by their association. Their interaction is of indirect nature or it may be just coincidental. For example Tarantulas and cacti. Their interaction is coincidental but their interaction neither results in loss and gain to any species.

4.3.1.2 COMPETITION:

This refers to interspecific competition where they compete for the same resource which is in short supply. This lead to an elimination of weaker species in a certain area. This was successfully demonstrated by Russian ecologist G.F.Gause in 1934. He used two species of paramecium namely *Paramecium aurelia* and *Paramecium caudatum* to show it. This experiment shows that *Paramecium aurelia* had eliminated the other species from the area. Further this concludes that *Paramecium aureli*a is the dominating species over *Paramecium caudatum*.

4.3.1.3 Predation:

The behavior in which one organism kills the other for its survival is refers to as Predation. In this behavior predator kills the host animal to be as its food. The predator mode is refers to as carnivorous. Predators have adaptation of teeth, fangs, claws, heat sensitive organs, speed and agility. For Example: A lion kills a deer, eagle feeds on fish, small birds, snake feeds on rat, sharks feed on seal and other fishes etc.

4.3.1.4 Herbivory:

The animals which feed on plants are called as herbivorous. These animals show adaptations in teeth and digestion system (to digest cellulose). For example deer, cow, elephant feed on plants for their survival.

4.3.1.5 Symbiosis:

Symbiosis is derived from two Latin word ‘Sym’ means ‘together’ and ‘biosis’ means ‘Living’.This refers to interspecies behavior which benefits both species. For example ant feed on acacia tree produced nectar and in return provide acacia tree free from spores and debris. Ant also allows no vegetation to grow near them. Thus allow no competition for acacia tree.

4.3.1.6 Parasitism:

This refers to interspecies behavior which benefits the one but harmful to others. For example Tape worm live inside the body of Human beings. It feeds on the host foods. This result in Host having the disease called Taeniasis.

4.3.1.7 Commensalism:

This refers to interspecies that benefits the one but nor helps or benefits the other. For example Flat worm eats the food of horseshoe crab by attaching themselves. These attachments neither benefits nor harm the crab.

4.3.1.8 Protocooperation:

They are also known as facultative cooperation. This association benefits both species but their association is not compulsory. For example Antis in search of some sugar substance in tree and shrub infested with honeydew secreting species. Ant gets the sugar by stimulating the Aphids. Aphids In return gets protection from predators.

Inter-relationship	**One species**	**Another species**
Neutralism	No Benefit, No Detrimental	No Benefit, No Detrimental
Amensalism	Detrimental	No Benefit, No Detrimental
Protocooperation	Beneficial	Beneficial
Competition	Can be Beneficial/ Detrimental	Can be Beneficial/ detrimental
Predation	Beneficial	Detrimental
Herbivory	Beneficial	Detrimental
Parasitism	Beneficial	Detrimental
Symbiosis	Beneficial	Beneficial
Commensalism	Beneficial	No Benefit, No Detrimental

Intraspecific competition:

This competition occurs within same species. This occurs when same species members compete for limited resources.

Cannibalism:

This refers to intra species interaction which feeds on its own species. Several species of shark and snake inhibits this strange behavior. Example King Cobra inhabiting in south India exhibits this strange behavior where they eats their own species members.

Competition for space, resources, right to breed:

Individual within the species fight with each other for better space (having right combination of abiotic and biotic), resources, right to continue their blood stream. In nearly every species males fight among them to get breeding rights. Each Species have unique characteristics like height, weight, fur, color etc. which differentiate it from individuals of its own species. These identify the dominant individual in a community. In some species it is done without fatality and in other it results in fatality. Example Lion fight with each other to control a group of population. Even they kill the kid of the previous individual to continue their blood stream.

This Intraspecific competition is of two basic types namely:

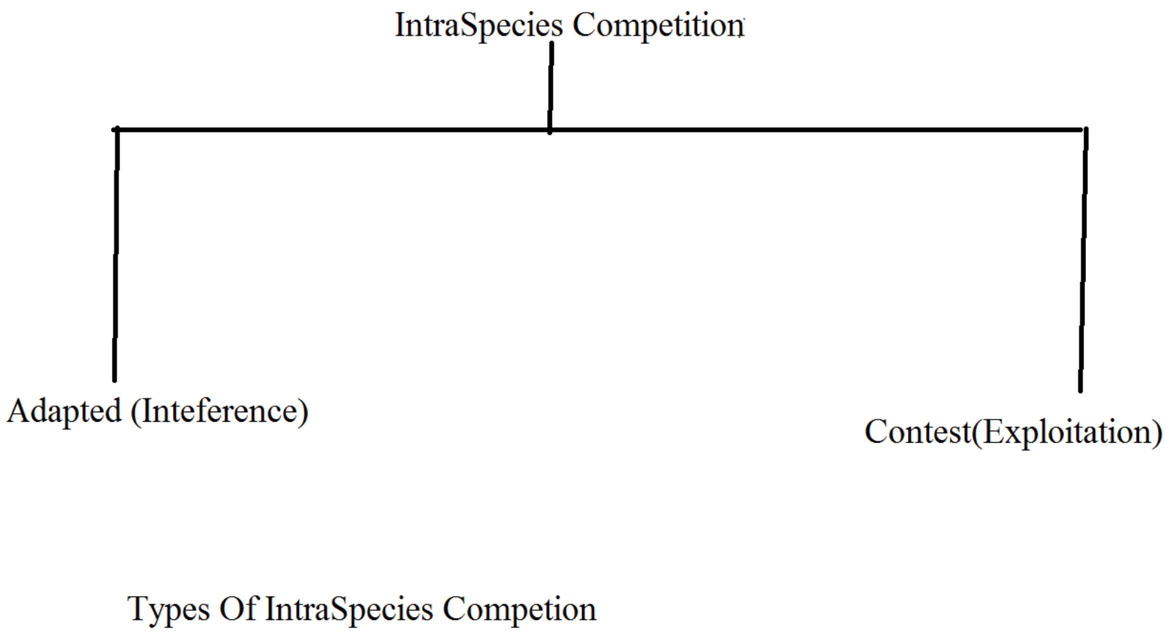


Fig 4.1 Types of Intra Species Competition

Interference (adapted):

this behavior is shown in those species that establish an order of hierarchy through aggressive behavior. This show of aggressive behavior makes one or more individual members dominant over others. This competition can be of territory, resources. , and breeding rights.

Exploitation (contest):

This behavior is shown between two individual where dominant individual deprive or reduce the resources to the other individual. This competition are generally of breeding nature where the dominant deprive the breeding right of the other individual.

4.4HISTORY OF NICHE CONCEPTS

Ecological niche have always been an important concepts in environment and ecology study. This concepts has positioned the Darwin evolution theory. This relationship between them is used to predict the species density and behavior in the future under a specific environment.

Ecological Niche history can be divided into three phases. They are namely:

1.Grinnellian and Eltonian Niche

2. Hutchinsonian niche

3. Modern Niche Theory

4.4.1. GRINNELLIAN AND ELTONIAN NICHE:

Grinnellian Niche:

The Term Niche was first used by Joseph Grinnel in 1917. He used niche as a subdivision of habitat. He brought about distribution of species which are structure similar but are different from each other in some characteristics. He included all abiotic components like climate, soil, humidity, rainfall and biotic components like food, competitor, predators, shelter etc. which affect the species existence at a particular location. He further brings out the relationship with populations density and evolution with environment.

Grinnel developed a hierarchy based on the distribution of biotic and abiotic factors. He also compare's community in different regions.

Further he concludes Niche as a complex which comprises of various environmental factors which in turn define how species will evolve and devoid of others.

Thus Grinnellian niche states that habitat and its accompanying behavioral adaptations define the niche. For example, bird California thrasher live in chaparral habitat. They live in underbrush. It is the place where they feed, breed and escapes from its predators. Its 'niche'(behavioral adaptation) are defined by the its suitable behavior and physical modification like camouflaging color, short wings, strong legs.

Eltonian Niche:

Charles Elton focuses on trophic relations. He identified four areas namely:

1. Food-chains and food cycle.

2. Relation between its size and its prey.

3. Animal place w.r.t to its food and its predators.

4. Number Pyramid.

He gives numerous examples occupying similar niche such as Arctic fox and spotted hyena. They both feed on eggs and carcasses' left after by top predators.

Thus Eltonian niche define the niche in terms of foods and enemy. He introduces the concept of species' response *to* and effect on the environment.

Elton state that besides resources availability, predators, climatic conditions, its behavior and food habits change with change in its availability. Example: Beavers require special resources to survive and reproduce in extreme environment. Dams have also alter its behavior by altering water flow in its niche. Change in beaver behavior effects the biotic and abiotic components of other species living in and near watershed.

Several ecologist like Whittaker, Ricklefs, Kerbs, Begon started to use Grinnell's and Elton's concepts, as "habitat niche" and "functional niche" respectively.

4.4.2 GEORGE HUTCHINSON AND THE COMPETITIVE EXCLUSION PRINCIPLE:

COMPETITION EXCLUSION PRINCIPLE:

In 1934,Georgyi Gause conducted an experiment on paramecium. He used two species of paramecium namely Paramecium aurelia and Paramecium caudatum to show the dynamics of population. This experiment shows that Paramecium aurelia had eliminated the other species from the area. Further Theoretical and experiment was performed by Hutchinson, Volterra and Lack lead to formulation of Competition Exclusion (Gause's Principle):

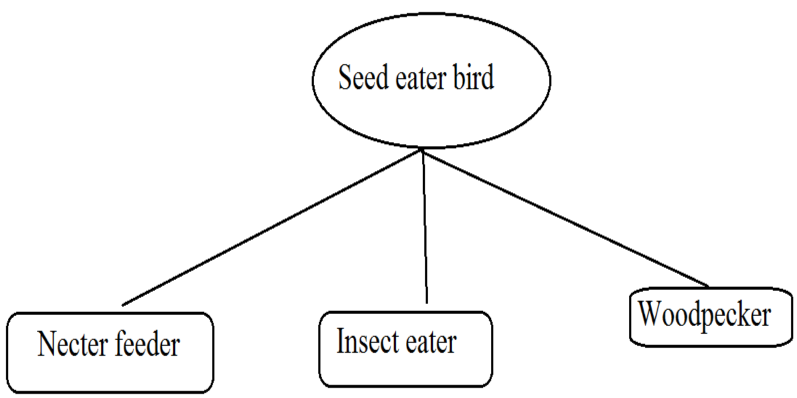
The principle of Competition Exclusion states that:

1. No two species can exists (survive) on the same limiting resources at the same time, all the time.

2. Species with identical resources requirements can't co-exist.

3. It leads to evolving new characteristics, Migration, Extinction and domination in Niche.

1. Creating New Niche:



Example:

Hawaiian Honey Creeper:

Niche concept was popularized by zoologist G. Evelyn Hutchinson. He wanted to know why there are so many types of organism in a habitat.

He formulated an Niche which is n dimensional hyper volume where the dimensional are environmental conditions and resources, that defines the requirements of an individual or a species to practice "its " way of life, more particularly, for its population to persist.

Hypervolume defines the multi-dimensional space of resources available to organisms. The volume were the various biotic and abiotic factors like Humidity, sunlight, temperature, wind exposure, food resources(insects, seeds, bacteria, soil nutrients), space requirements(breeding, hiding, shelter) etc. These finding were used by several scientists to formulate their own sets ofmodels. Statistics were introduced into these models by Robert MacArthur and Richard Levins.

These models bring out several new concepts namely: **Fundamental niche, Realized Niche, Niche breath, Niche partitioning and niche overlap.**

Fundamental niche:

It refers to an area which has all characteristic combinations required to live for an organism. It is the range in which species can survive.

- It is Larger
- Elaborate various rolesof species.
- Full niches of species.

Realized niche:

It refers to an area which has high chance of occurrence of an organism. Species doesn't use entire niche but are localized to a particular area.

- It is Small
- Elaborate the particular species.
- Elaborate a particular area.

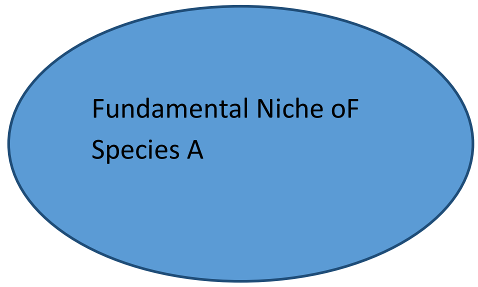


Fig 5.2 Fundamental Niche

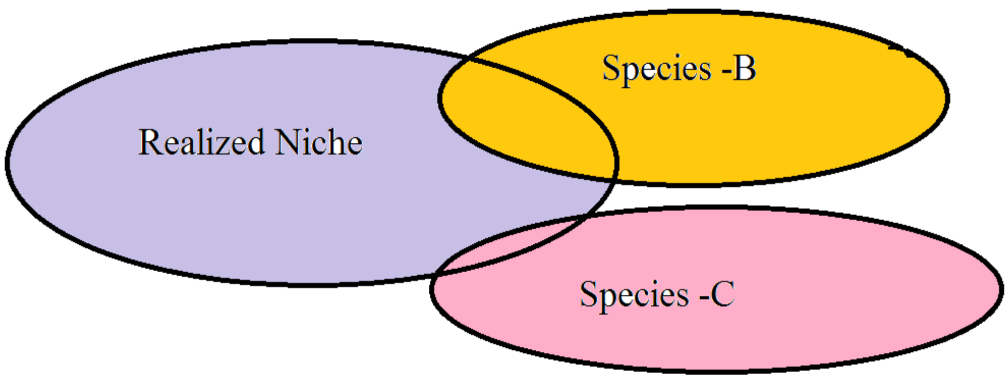


Fig 4.3 *Realized Niche*

Niche Partitioning:

Species coexist by using different types of resources or ranges of limiting resources it is called “Resource Partitioning” or “Niche Partitioning

Example: Anolis lizards in Cuba live in the same area but exploit different microhabitats. This resources partitioning is depicted in Serengeti grasslands where Zebra eats the upper section, wild beast eat the middle section and Impala deer eats the lower section of the same grass. It is also depicted with warbler bird who use different part of same tree.

Fig 4.4 Niche Partitioning

Niche overlap:

DifferentSpecies niche overlaps with each other's.It involves partial or complete sharing of resources. Example: Fish living in estuary share their niche with fresh and marine fish.

There are 5 types of niche overlap:

1. Included Niche: This niche is where the one species niche lay inside another species niche. Thus we can say that one niche is included in another niche. For example

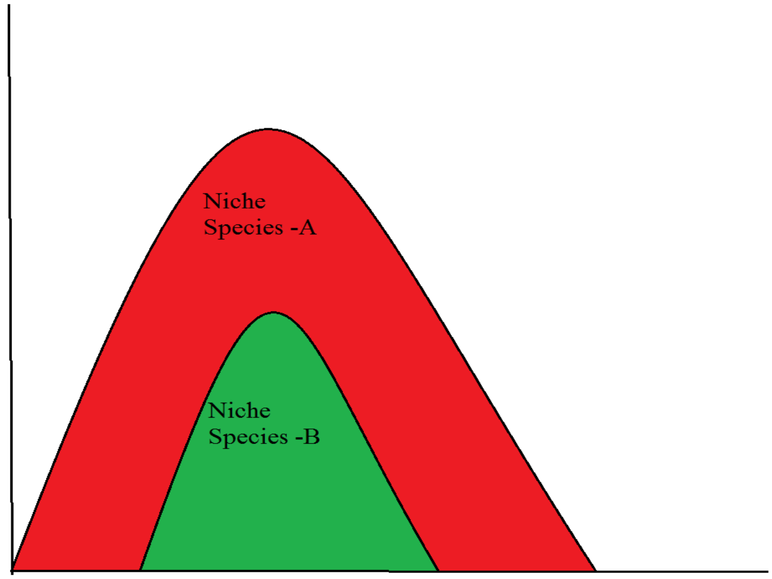


Fig 5.5 Included Niche Overlap

2. Overlapping niche of equal breadth: Partial overlapping where the two species share half of the niche with each other. Example Polar and Brown Bear share nearly half of the niche with each other.

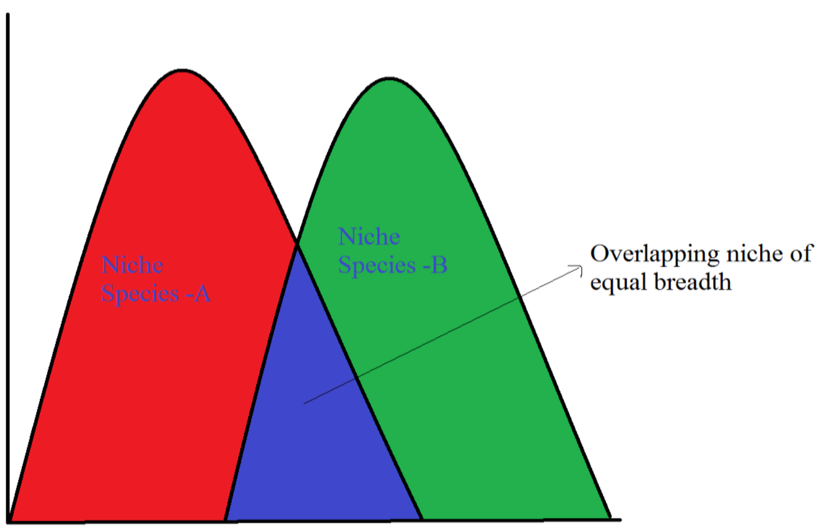


Fig 5.6 Niche Overlap of Equal Breadth

3. Overlapping niche of unequal breath: Partial overlapping where the two species share the niche of unequal breath. Example Niche of Tiger and Leopard overlap each other but there breath continuously changes.

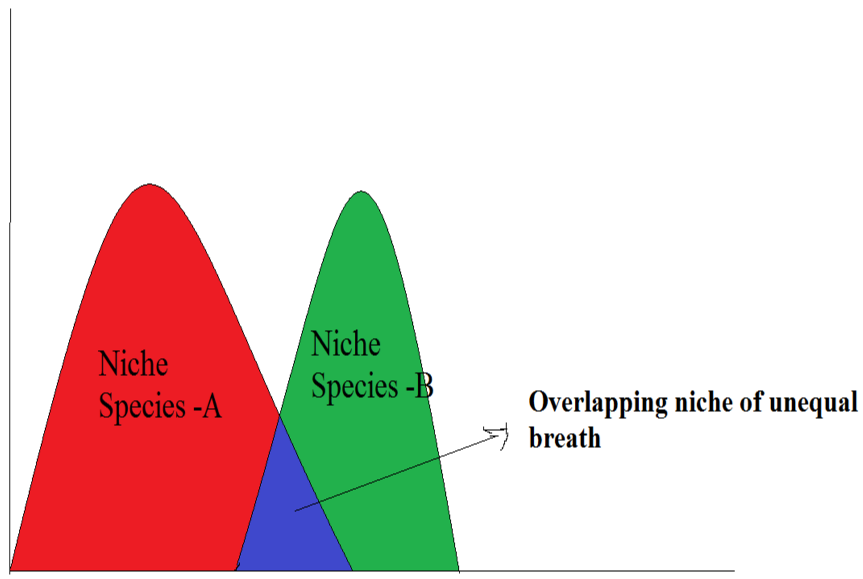


Fig 5.7 Niche Overlap of Unequal Breadth

4. Abutting Niche: A Partial Overlapping where the two species are next to each other. Example the niche of fresh aquatic fish and estuary fish are adjacent to each other.

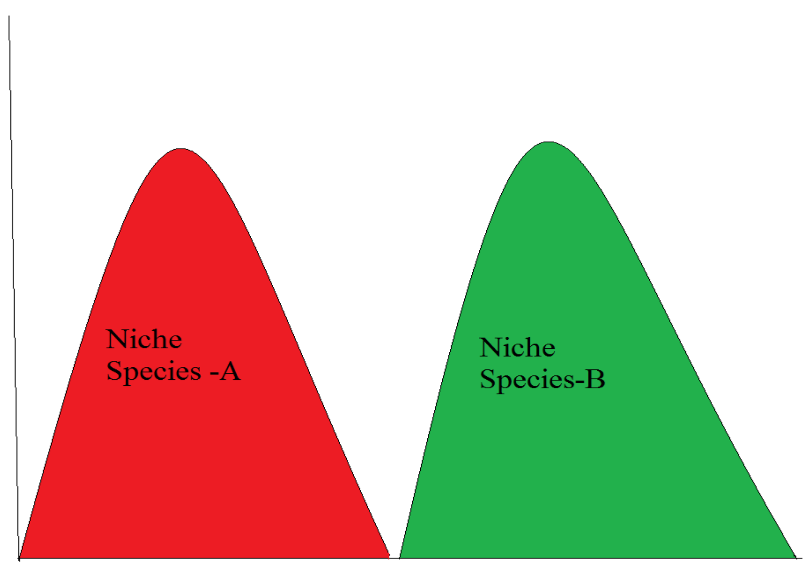


Fig 5.8 Abutting Niche

5. Disjoint Niche: It occurs when two species doesn't share any Niche with each other. Example Niche of Desert Animal and Tropical Rain Forest.

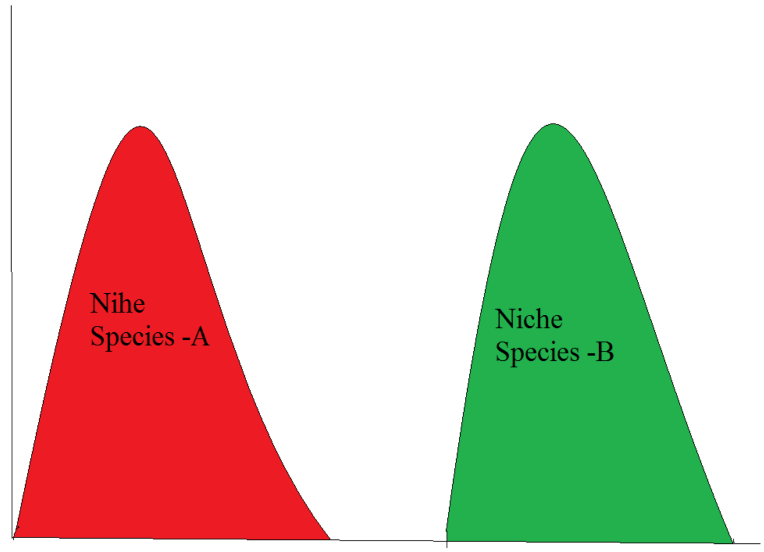


Fig 5.9 Disjoint Niche

What happens when two species niche overlaps:

This questions further lead to development of two concepts namely Niche Separation and Niche breath.

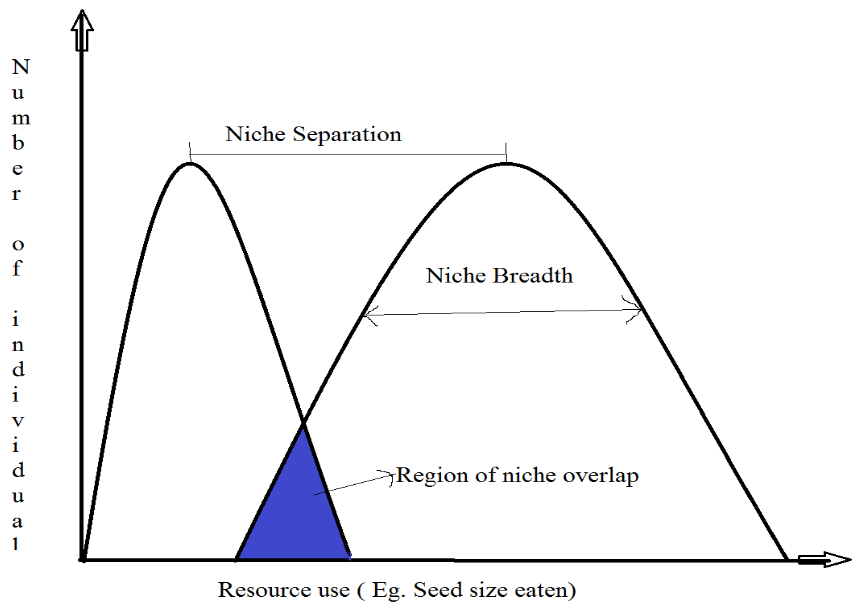


Fig 5.10 Competition: Two species niche overlap

Niche breath:

It refers to availability of range of resources which are required for an organism to live. Animal with Wide niche breath is called as Generalist, while with narrow niche breath are called as specialist. This hypothesis has led to the assumptions that wider niche organism show more dynamical behavior in environment tolerance, food habits or in morphological measurement. Specialist has evolved themselves with their geographical conditions.Giant Pandas have modified themselves by having a limited diet based on bamboos. They live solitary and their thumbs have been modified to climb bamboos tree.

It is distribution of individual organism within a set of resources.

Levins proposed to calculate Niche breath as

$B= 1/\sum p_j^2$

Or

$B = Y2/\sum N_j^2$

Where

B= Levin measure of niche breath

P_j = proposition of individual found in or using resources state.

N_j= Number of individual found in or using resources

Y = Total number of individual sampled.

Note: Specialist having narrow breadth have generally low score while generalist have high score. Typically specialist have a score of 1 or less than 1. Intermediate species have a score of between 1 and 3. Generalist have a score of 3 or greater than 3.

Suppose we observed three species of frog and quantified the food intake of 1000individuals in each species.

Prey for frog species	Ants	Mosquito	Larva	Grasshopper
Species 1	40	40	10	10
Species 2	50	10	30	10
Species 3	30	30	20	20

The niche breath is computed as

Species 1 = $1/ ((0.4)^2 +((0.4)^2 +(0.1)^2 +(0.1)^2)$

= 1/(0.16+0.16+0.01+0.01)

=1/0.34

= 2.94

Species 2 = $1/((0.5)^2 +((0.1)^2 +(0.3)^2 +(0.1)^2)$

= 1/(0.25+0.01+0.09+0.01)

=1/0.36

= 2.77

Species 3 = $1/((0.3)^2 +(0.3)^2 +(0.2)^2 +(0.2)^2)$

= 1/ (0.09+0.09+0.04+0.04)

=1/0.26

= 3.84

Thus niche breadth of species 3 is highest. As the species 3 food habits are more diverged as compared to other 2 species.

Niche Separation:

The process by which two species uses the same resources differently to helps each other coexist.

4.4.3. MODERN NICHE THEORY

Robert MacArthur, Richard Levins extended Hutchinson's approach of niche concept as an characteristic of the species to concepts of resource utilization distribution. The niche, defined was equivalent to the utilization of resource ordered on one or more dimensions. These were represented by a histogram. Each axes could be food(consumption pattern), space and time etc. Thus an inter-relationship and its level of dependency could be calculated.

Schoener gave niche as a utilization distribution as an "eminently operational concept". It was put to be used in many empirical studies .Vandermeer brings a new sets of models Schoener linked Niche theory with competition. He further explains the rules of coexistence of communities & degree of saturation and degree of similarity. The new Models of the niche theory are based on Lotka-Volterra's equations. MacArthur and Levins states that these models rely on assumption "overlap of utilization niches allow to calculate the coefficients of competition". These coefficients in a model are converted into resources utilizations properties. These are expressed as the ratio between the niche widths.

Roughgarden and Case state that these niche models deals with niche properties such as its position of mode, width & distance/width ratio. After Hutchinson's publication on the 4/3 size ratios, many studies were conducted on dimension (i.e. size) to determine whether, niches can be non-randomly spaced – with both positive and negative results .

In 1980s several ecologist like Simberloff and Strong showed that patterns of competition did not involve adequate null hypotheses. So niche theory importance and validity was questioned. Niche theory was also questioned as new treatment produced unexpected results, which did not fit with the theory. Empirical ecologists were now skeptical about the usefulness of the theory. They just focus on testing very basic hypotheses with rigorous null models. These results force studies to be done in studies of local interactions, instead of large spatial scales.

In late 1990 Jonathan Chase and Matthew Leibold, showed that, within the ecology of an organism, we must distinguish the impacts of a given ecological factor on this organism. They give a niche as the niche as the union of the responses of the organism and its impacts. They presented a range of ecological factors based on the impacts types, positive, null or negative, according to organism. These factors were emphasized as resources, predators and stresses. They were able to free niche theory from the focus on competition and local interactions. Their theory was put to use in understanding exploration of multi-scale heterogeneous processes, such as habitat degradation, extinctions, invasions, etc.

4.5 SYMBIOSIS

Introduction:

Symbiosis is derived from two Latin word Sym means together and biosis means living. This refers to interspecies behavior where both interacting species live together and benefiting each other's. For example Corals and Algae. Algae create food through photosynthesis. This food is consumed by corals. Corals emit ammonia form of waste. This waste is used by algae as nutrient.

Evolutionary origins:

Symbiotic relationship between corals and algae began nearly 210 million years ago. This interrelationship has made the nutrient recyclable. This symbiotic association led to massive expansible of corals worldwide. Further corals deposit calcium carbonate on the surface. This calcium carbonate has form reefs. Today Reefs host nearly 25 % of marine life. Coral have been the major source of food which host the marine life. Thus Corals and algae relationship had transforms the entire ocean. Ocean hosts more life, diversity and species richness compared to land.

Relationship between plants and animal was initiated between legumes plant species and nitrogen fixing nodules bacteria. This interrelationship was developed nearly 100 million years ago. This symbiosis plays a major role in biogeochemical cycle. This cooperative relationship brought about the drastic change in land landscape. Today it is mainstay of our agriculture and food security.

Symbiosis evolves through the process of natural selection. In natural selection some individuals in a population have some special characteristics. These special characteristics are passed over generations. In later generation, it becomes a permanent feature. Thus evolving into a new species. These interrelationships must have started as facultative. In a few generations the species must have developed new characteristics which forced them to obligate relationship. Finally symbiosis became a source of shelter, food etc. For example clown fish and sea anemone. Clown fish has developed resistance against sea anemone sting. This resistance must have been spread over several generation evolutions.

Thus symbiosis is an interrelationship which is actually a source of life.

4.5.3 SYMBIOSIS CLASSIFICATION:

Symbiosis have been divided into two part based on degree of dependence.

Symbiosis

Obligate

(Exclusive Mutualisms)

Faculative

(Generalist Mutualisms)

Symbiosis have been divided into two part based on degree of dependence.

1. Obligate Symbiosis: In this symbiosis relationship one species is dependent on other species for its survival. These both species cannot survive in the absence of another.This symbiotic relationship is also known as Exclusive mutualisms. Example: Termites and Flagellates. Acacia Tree and Ant.

2. Faculative Symbiosis : In this symbiosis relationship one species survival is not dependent on other species. These both species can survive in the absence of another. Their interaction is just coincidental. This symbiotic relationship is also known as Generalist Mutualisms. Example: honeybees and flower, corals and the algae.

Some species show both Obligate and Faculative Symbiosis behavior. Example Flowering Plants and pollinators, Humans and domestic animals etc.

Symbiosis

Trophic **Defensive** **Dispersive**

(Resource- resource Benefits) **(Resource- Service Benefits)** **(Service- service Benefits)**

Symbiosis have been divided into three parts based on type of benefits.

1. Trophic Mutualism: both interacting species works together to obtain energy and nutrients from each other's.

For example: Cow and bacteria

Plant cellulose can't be digested by herbivorous animals.Herbivorous animal lumen has the presence of bacteria. This bacterium helps in digestion of cellulose. In this both species gets foods and energy.

2. Defensive Mutualism:in this relationship one partner receives food and shelter and other receive the protection from its predators or parasites.

For example: Aphids and ants:

Ants require sugar (honeydew) for their living. This sugar is with the Aphids. So, in nights aphids are carried to their nest by the ants. So aphids are saved from predators and weather. Next morning these aphids are carried back to the plants.

3. Dispersive mutualism: In this relationship one species receive foods another helps flower in transferring their pollen.

For example: Honey bee and flower.

Honey bee prepares honey from nectar obtained from flower. They travel from one flower to another in search of nectar. In this process pollen are transferred from one plant to another.Plants are benefitted by the pollination.

4.6 SUMMARY

Competition had been a core of evolution. This competition for food,space etc. had forced various organismsto develop complex relationship with and within species. They have developed various associations like neutralism, Competition, Predation, Herbivory, Symbiosis, Parasitism, Mutualism, and Commensalism. Symbiosis has been one of the relation where both interacting species are benefiting. They are classified according to the level of dependence and services. The level of dependence can be permanent or temporary which are called as Obligate (Exclusive Mutualisms) and Faculative (Generalist Mutualisms) respectively. This permanent feature have reached a stage where the both interacting species can’t survive without each other. They have been classified into 3 type namely Trophic (Resource- resource Benefits),Defensive (Resource- Service Benefits) and Dispersive (Service- Service Benefits).

Individuals within species are competing for space (having best combination of biotic and abiotic component),food social domination and right to continue their race shows several behavior like cannibalism and death of individual .This study of Competition had resulted in bringing the concepts of Niche. This Niche concept has undergone a drastic change since its first introduce by

Joseph Grinnel in 1917. He state Niche as a complex which comprises of various environmental factors which in turn define how species will evolve and devoid of others.

Charles Elton added the concept of trophic relations. He defined the niche in terms of foods and enemy. He introduces the concept of species' response to and effect on the environment. Russian ecologist Georgyi Gause used two species of paramecium to show the dynamics of population. His findings were performed by other ecologist Hutchinson, Volterra and Lack on other organism lead to formulation of Competition Exclusion (Gause's Principle).This principle make the leading cause for developing new characteristics, Migration, Extinction and domination.

Niche concept was popularized by zoologist G. Evelyn Hutchinson. He formulated an Niche which is n dimensional hyper volume where the dimensional are environmental conditions and resources, that defines the requirements of an individual or a species to practice "its " way of life, more particularly, for its population to persist.The volume were the various biotic and abiotic factors like Humidity, sunlight, temperature, wind exposure, food resources(insects, seeds, bacteria, soil nutrients), space requirements(breeding, hiding, shelter) etc. These finding were used by several scientists to formulate their own sets of models. These models bring out several new concepts namely: Fundamental niche, Realized Niche, Niche breath, Niche partitioning and niche overlap.

RobertMacArthur, Richard Levins extended Hutchinson's approach of niche concept as an characteristic of the species to concepts of resource utilization distribution. Schoener gave niche as a utilization distribution as an "eminently operational concept". Schoener linked Niche theory with competition. MacArthur and Levins states that these models rely on assumption "overlap of utilization niches allow to calculate the coefficients of competition". These coefficients in a model are converted into resources utilizations properties. These are expressed as the ratio between the niche widths.

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In late 1990 Jonathan Chase and Matthew Leibold, showed that, within the ecology of an organism, we must distinguish the impacts of a given ecological factor on this organism. They give a niche as the niche as the union of the responses of the organism and its impacts. They presented a range of ecological factors based on the impacts types, positive, null or negative, according to organism. These factors were emphasized as resources, predators and stresses. They were able to free niche theory from the focus on competition and local interactions. Their theory was put to use in understanding exploration of multi-scale heterogeneous processes, such as habitat degradation, extinctions, invasions, etc.

The niche concept has been used in evolutionary biology, and the stem cell niche in cell biology.

4.7 SELF ASSESSMENT QUESTION

1. The relationship between termite and Trichonymph is

a. Mutualism b. Symbiosis

c. Obligatory Symbiosis d. Generalist Mutualisms

2.The relationship between sea anemone and Hermit Crab is

a. Mutualism b. Commensalism

c. Proto Co-operation d. Generalist Mutualisms

3. One species is inhibits while other species remains unaffected. This type of relationship is refers as:

a. Paratism b. Symbiosis

c. Amensalism d. Predation

4. Ecological Niche

a. is same for all animalb. varies from individual to individual

c. Is same for species.d. space occupied by individual.

5. In ecological succession, pioneers are

a. Autotrophs b. Heterotrophs

c. Plants d. Micro-organism

6. Species become niche specialists because

a. Less vulnerableb. Reduced inter species competition

c. Reduced intra species competition. d. Fewer resource available

7. Giant Pandas are niche specialist because

a. They are found in a particular region. bvery limited diet.

c. Live solitary. d. All of above.

8. Species with wide niche breath are called

a. Generalist b. Specialist

c. Naturalist d. None of them

9. Species with narrow niche breath are called

a. Generalist b. Specialist

c. Naturalist d. None of them

10. Which one of the following has highest chance of finding?

a. Fundamental niche b.Realized niche

c. Niche Breath d. Niche Partitioning

11. Abundance of species population within a habitat is known as

a. Absolute density b. niche density

c. Niche richness d. relative density

12. Niche of species means

a. habitat of species b. specific function of species

c. place where organism live d. both a & b

13. Which of the following association is knowns as oldest association.

a. Symbiosis b. Paratism

c. Cannibalism d. Commensalism

1(c) 2(c) 3(c) 4(d) 5(a) 6(b) 7(a) 8(a) 9(b) 10(b)11(b) 12(d) 13(a)

4.8REFERENCES

1. Environmental biology (principle of ecology) by Verma P.S, Agarwal V.K S.Chand publication second edition reprint 2013.
2. Ecology and environment by Sharma P.D Rastogi Publication eleventh revised edition 2012.

3. Fundamental Of Ecology by Dash Madhab Chandra, Dash Satya Prakash The Mc Graw Hill Edition 3rd Edition 2009.
4. https://www.researchgate.net/publication/273695790 The Ecological Niche: History and Recent Controversies Chapter · January 2015 Arnaud Pocheville the University of Sydney.

4.9 SUGGESTED READING

1. Environmental Studies by Basak Anindita Pearson Publication 1st edition 2014.
2. Fundamentals of Ecology by E.P Odum, G.W Barrett Cengage publication 5th Edition 15th Indian Reprint 2017.

4.10 TERMINAL QUESTION AND ANSWERS

Question No.1. What is the difference between Commensalism and Amensalism?

In Commensalism one species is benefited and other species is not affected.

In Amensalism one species is detrimental and other species is not affected.

2. What is the difference between Mutualism and Proto cooperation?

In both Mutualism and Proto-Cooperation bothinteracting species benefits. But Mutualism is obligatory and Proto-Cooperation is not obligatory.

3. How Hutchinson concept of niche differs from Grinnel and Elton concepts.

Hutchinson state niche as n dimensional hyper volume with each volume be a factor of biotic and abiotic. Grinnel state only various environmental factors and Elton in terms of foods and enemy.

4. How migration differs from immigration.

Migration involves moving complete population from one locality to another. Immigration involves moving a part of population from one locality to another.

5. Grinnell's and Elton's concepts are known as

They are known as "habitat niche" and "functional niche" respectively.

6. **Russian ecologist Georgyi Gause famous paramecium experiment leads to formulation of which concepts:**

Competition Exclusion Principle.

7. **Why Symbiosis is referred as "source of life".**

Symbiosis is oldest association. Coral and algae symbiosis is the reason for spread of life in sea. Further Life come to Land from sea. There are many symbiotic association existing on land and ocean.

8.**Why animal use only a part of Fundamental Niche.**

Animal are generally found in Niche where the perfect combination of biotic and abiotic component needed for its survival is found.

4.11GLOSSARY

Amensalism: An inter species relationship where one species is affected and another species is not effected.

Cannibalism: An intra species behavior which feed on its own species.

Commensalism: An inter species relationship where one species is benefitted and another species is not affected.

Competition: An act or condition to gain or dominate.

Facultative Symbiosis: The symbiotic relationship where two species can survive without each other.

Fundamental niche: the place which has all the necessary condition of biotic and abiotic needed by particular species to survive.

Herbivory:A Group of animal who feed on plants.

Migration: Shifting of all individual of a species from one niche to another.

Neutralism: The interrelationship where two species are neither beneficial nor detrimental.

Niche breath:availability of range of resources which are required for an organism to survive.

Niche overlap:A location in which two species niche overlaps.

Niche partitioning: Dividing a niche within several species.

Niche: A location for an organism which has required component for a particular organism to survive.

Obligate Symbiosis: The symbiotic relationship where two species can’t survive without each other.

Paratism: The relationship in which one species live inside the another species. It is detrimental for host while beneficial for another.

Proto Co-operation: Association which benefits both species but that is not compulsory

Realized niche: An area within Fundamental niche which has high chance of occurrence of an organism.

Symbiotic: A relationship which benefits both species.

UNIT 5: COMMUNITY ECOLOGY AND ECOLOGICAL SUCCESSION

5.1 OBJECTIVES

Study of this unit will let the students to:

- Understand the meaning of community.
- What is Behavior of Community
- What is Structure of a community
- What is significance of species diversity
- Methods to calculate species diversity
- How Complex is a Community
- Concepts of Edges and Ecotones
- Concept of Ecological Succession
- Types of Ecological Succession
- Concepts of Climax

5.2 INTRODUCTION

Community ecology is the study of a community interrelationship between biotic and abiotic components in a particular area. Community comprises of a sum of the entire living component found in a particular area. These also include several population (group of same species) group which share a common resources like food, shelter and abiotic component. A community has its own behavior based on its composition, species diversity, growth forms, dominance of certain species and succession plan. Nature of Community has always been a bone of contention. This has leads us to development of different thought regarding its nature. Accordingly its structure has been used in distinguishing the diverse communities. The structure is dependents upon functional inter-relationship between organisms. Further they have leads us to introduce new concepts like edges and ecotones. Edges and Ecotones come into area where one community mixed with another community. A change in abiotic component in a period of time leads to change in biotic component or community which has evolve into a new concepts known as ecological succession.Ecological succession undergoes in 2 phases namely primary and secondary succession. This evolving finally results in maturing the community biotic component. This maturation is known as the stage of climax. Climax is a stage where the community has matured in terms of its composition of flora and fauna, inter-relationship between species and their inter dependence.

5.3 NATURE OF COMMUNITY

Community comprises of all living organism that inhabits a particular area. It is an assemblage of population of different species that live together with mutual tolerance and interaction. Communities differ from each other in their species richness, composition, size of each species and relative abundance of different species. This has resulted in development of 2 different thought regarding nature of community: These two are opposing to each other. They are the organismic school and the individualistic school.

6.3.1 THE ORGANISMIC SCHOOL:

This school thought was also known as Holistic Theory. It was given by Frederic Clements in 1916. It was supported by ecologist Daubenmire, Langford and Buell. He stress on species inhabiting in a community are generally independent from each other. Community is regarded as top of living world. The hierarchy order was from:

cell tissue organs system organism population community

Though community comprises of several population but their characteristic and function differs from each other. Species distribution and abundance depends on interaction with other species in same community.

6.3.2 THE INDIVIDUALISTIC SCHOOL:

This approach was put forward by Henry A. Gleason in 1926. It was further enhanced by Curtis, McIntosh and Whittaker. This school put up the species as the essential unit in analysis and distribution of population in a community. Species responds independently according to biotic and abiotic component found in a community. Any change in biotic or abiotic component is bound to effect a particular population rather than whole community. The amount of effect varies with scale of change of particular factors on which a particular population depends that also on how much. Whenever a particular species population is plotted against an environmental gradient, resulting graph is in a normal or bell shaped curve. This school regards a collection of population of a particular species as a unit living in a same condition. Community comprises of sum of all these unit in a continuous manner,not integrated one.

Smith in 1977 proposed that both school to be partial true. He suggest that though species responds individually to change in biotic and abiotic factors, still community works as functional unit in respect to energy flow and nutrient recycling.

5.4COMMUNITY STRUCTURE

6.4.1 Introduction:

Community structure refers to composition of various species and their relative numbersoccurring in a community. It also includes all types of interaction between species. A community structure is made up of species richness and species diversity. Species richness is a measure of number of species present in community while species diversity is a measure of species richness and species relative numbers. Species richness and species diversity depends upon many factor including abiotic factors. They depend upon climate, soil, rainfall, species interaction and levels of disturbance. Foundation species and Key stone species play a critical role in determining community structure.

6.4.2 MEASURING COMMUNITY STRUCTURE:

There are two major measure of measuring community structure namely species richness and species diversity.

6.4.2.1 SPECIES RICHNESS:

It refers to number of different species found in a community. The community which has the highest number of species is said to high in species richness. Species richness is depends upon several abiotic component and location. These abiotic components are availability of solar energy, temperature, rainfall and seasonal variation. Equatorial communities have high availability of solar energy, warm temperature, large amount of rainfall and no seasonal variation. These factors make up ideal condition for high species richness. Polar communities have the lowest species diversity as they have low availability of solar energy, cold temperature, little or no rain and lot of seasonal variation.

6.4.2.2 SPECIES DIVERSITY:

it refers to mix of species richness and their relative abundance known as species abundance. Community which has larger number of species and abundance of species is said to be high in species diversity.

6.4.3 WHICH FACTORS SHAPE COMMUNITY STRUCTURE?

Community Structure is influenced by a combination of abiotic and biotic components. They are

1. **Location:**Community structure is a lot influence by the location where it is located. Amazon rain forests are located in an area which has a lot of sunshine. This sunshine provides enough energy to support high primary productivity.
2. **Climatic pattern:**Several local climatic patterns are created due to certain geographical pattern like mountain range, water bodies and valley. These pattern creates favorable environment for biotic community. Thus they have larger species diversity and to allow flora and species richness as compare to it near community.
3. **Global Climatic change:**Global climatic change has brought a lot of change in abiotic component. Frequent drought, higher frequency of flash floods, infrequent patterns of rainfall had led to loss of species. This had altered the species richness and species diversity.
4. **Heterogeneity in community:**A community having variation in its environment will allow for greater species diversity. Grassland with mountain will have species of mountain and grasslands.

5. **Frequency of disruptive events:** Disruptive events like wildfire, storms, and landslides have a great influence on the structure of community. Frequent occurrence of disruptive events will result in less species diversity.
6. **Species interactions:** Community structure richness also depends upon the way in which individual within same species and how species interact with each other. These interactions will be in the form of predator, competition and symbiosis. Species have change their food habitats as to avoid competitors with other species. Ecological niche has been a part of how to use aresources without competition within their species.

5.4.4 HOW TO MEASURE COMMUNITY STRUCTURE:

There are several technique to measure community structure. Among them is a diversity index.

Diversity Index: It is quantitative measure that reflects different speciesin a dataset (a community), further how individuals are distributed. They provide information about rarity and commonness of species in a community.

1. **Shannon Wiener Diversity Index:**
   1. **Introduction:**

   Shannon wiener diversity index is one of the most commonly used to calculate species richness and diversity among the various index. They are also known as Shannon Weaver Index.
2. **Assumptions:**
   1. All individuals are randomly sampled.
   2. Population is infinite.
   3. All Species are represented.

3. Calculation:

Shannon-Wiener Index is defined and given by the following function:

$H = -\sum[(p_i)\times\ln(p_i)]$ where ln =log base to 2

Where:

- p_i = proportion of total sample represented by species i.
- S = number of species,

- H_{max}=ln(S)
- H_{max}=ln(S) = Maximum diversity possible
- E = Evenness = H/H_{max}

Eveness is used to determine the deviation from maximal eveness and diversity.

E will always be between 0 and 1.

H_{max} = maximum diversity if all species are equally abundant.

Example

Problem Statement:

The samples of 4 species are 12,562,8,1. Calculate the Shannon diversity index and Evenness for these sample values.

Sample Values (S) = 12,562,8,1. Number of species (N) = 4

First, let us calculate the sum of the given values.

Sum = (12+562+8+1) = 583.

Species	Sample Size(S)	$p_{i=}$ S_i/∑S	ln(p_i)	(p_i) (ln(p_i))
1	12	0.020583	-3.88328	-0.07993
2	562	0.963979	-0.03669	-0.03536
3	8	0.013722	-4.28875	-0.05885
4	1	0.001715	-6.36819	-0.01092
ln(S_{max})	∑S= 583			Sum = -0.18507

H= 0.18507

H_{max} = ln(S) = ln(4)= 1.386294

E_h= H/H_{max} = 0.18507/1.386294 =0.1335

2. **Simpson index:**

   Introduction: This index was introduced by Edward H. Simpson. It is used to measure the community diversity. .

   Assumption :

Their value vary between 0 and 1

Higher values indicate high diversity

Calculation:

Simpson Diversity Index is calculated from the following function:

D= N(n-1)/ ∑n(n-1)

Where

D = Diversity Index

N= Total number of organism

n= Number of individual in each particular species.

Example:

Species	Number of individual	n-1	n(n-1)
1	81	80	6480
2	2	1	2
3	2	1	2
4	2	1	2
5	2	1	2
	89		6488

Step 1:

Calculate n(n-1) = 89(81-1) = 7832

Step 2:

Calculate n(n-1) = 6488

Step 3:

Calculate D for species 1= (6488/7832)=0.83

Calculate D for species 2= 89/7832 = 0.011

3. **Margalef Diversity Index:**

Introduction:

It is used to find out the diversity of species.

Assumption:

1. All species are uniformly distributed.
2. Species abundance were ordered.

Calculation:

Margalef Diversity Index is calculated from the following function:

D_a= (S-1)/ ln (N)

Where

D_a = Margalef Index

S= Total number of species

N = Total number of individuals

ln = log to base 2

Example:

Calculate Margalef Index for the given data 9 species, 274 individuals

Da= (9-1)/ln(274)

= 8/5.6

=1.42

6.4.5: EFFECT OF KEYSTONE SPECIES ON COMMUNITY STRUCTURE:

Keystone species are those species which have a significant large effect on the community structure. They keystone species are generally top predators and act in a variety of way to sustain the community. These keystone species effect have been listed with an example. The sea star *Pisaster ochraceus found in* America was removed from intertidal region in an experiment. This resulted in exponential rise of mussel (their prey).This further altered the species composition and species diversity giving rise to change in community structure. There were nearly 2.5 lakh species of barnacles and algae at the time of sea star. These 2.5 lakh variety got vanished away by increased population of mussels. This large variety were sustained as sea star use to control the population of mussels.

6.5 LEVEL OF SPECIES DIVERSITY

6.5.1 Introduction:

Species Diversity is the sum of all type of different species in an area. It is used to calculate the different number of species found in an ecosystem. It is also used to figure out the health of an ecosystem, greater its value, better its health. Species diversity is made up of three components: species richness, taxonomic or phylogenetic diversity and species evenness

Species richness is just a count of total number of species, taxonomic or phylogenetic diversity is the how a species is genetically related with other species: species evenness specify how abundance is that species. It is one of the approach to find biodiversity.

The species diversity is more in rainforest than temperate forest. There are close to 1.8 million species known to us. Each year new set of species are added to this list. By conservative approach it has been estimated between 10 to 30 million species.

6.5.2 IMPORTANCE OF SPECIES DIVERSITY:

Species richness is the index of health of ecology. Each species has a unique role in ecosystem. Species have interdependence on other species for their survival. If one species become extinct then it is bound to have effect on its dependent species. This in turn affects the whole ecosystem. Overall species diversity is bound to get on lower side. Species diversity is more in lower chordate and invertebrates than the higher order. Species diversity helps in reducing the use of fertilizer and pesticides by controlling pest population, controlling disease causing parasites like malaria, dengue etc. Thus species diversity can helps us economically, medical science etc.Some species also help us by clean the ecosystem by providing clean water, clean air, fertile soil etc.

Thus we can summed up as:

Its s provides us with:

- Protection of water resources
- Soil formation and protection

- Nutrient storage and its recycling
- Nutrient breakdown and absorption
- Climatic stability
- Ecosystem maintenance
- Food
- Medicinal resources and drugs formulation
- Wood products
- Ornamental plants
- Population reservoirs of plants and animal
- Gene, species diversity
- Prevention and minimizing the effect of natural disaster

6.5.3 LEVEL OF DIVERSITY:

There are three level of diversity:

1. Genetic Diversity: Diversity in terms of genetic component within a species. It is an approach to find how a population has changed with changing environment. Example Domestic Dogs. Dogs have been sourced from common source, distinct breed of dogs with distinct traits have been created by human through selective breeding.

2. Species Diversity: Diversity in a species with in a community. Species diversity is made up of 3 components: Species Richness, Species Evenness and taxonomic diversity. Example: Sharks There are many types of sharks found in corals each with unique traits like Hammerhead Shark, Sand Sharks, Mackerel Sharks, Thresher Sharks, Saw Sharks, Catshark, Angel shark etc.

3. Ecosystem/Community Diversity:variation of habitat diversity in a given area. It includes all biotic and abiotic components. Example: Diversity in Forests and Coral reefs.

6.5.4 MEASUREMENT OF BIOLOGICAL DIVERSITY:

It is measured by two components: Species Richness and Species Evenness.

1. Species Richness: There are three levels namely alpha, beta and gamma. These three levels were introduced by R.H.Whittaker.

There are 3 levels of species diversity

1. Local diversity where different communities exist in different latitude in a particular area.(Alpha Level).
2. Regional diversity within different communities in a particular area.(Beta Level). It is a sort of comparison between communities.
3. Total diversity in an area of interest (Gamma Level). It has both alpha and beta diversity as its component. It is an overall diversity.

2. Species Evenness: It measures the proportion of species at a given site. Calculation of Species Evenness is already been discussed in section 6.4.4

6.5.4 HOW THEY ARE CALCULATED:

Suppose that we have three site A, B and C.

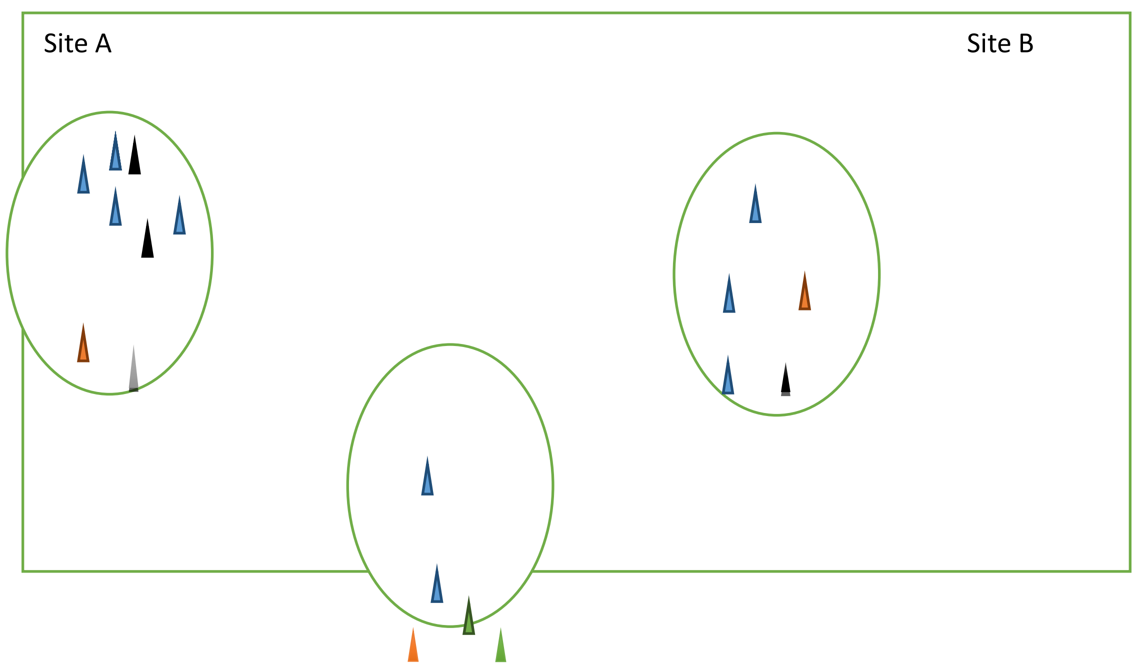

Fig 6.1 Species Diversity

lpha Diversity refers to number of species found in a community. A,B and C have 4 , 3, 3 different types of species respectively.

So Alpha diversity of A, B and C is 4, 3 and 3 respectively

Beta diversity refers to the total number of species which are common in between two communities. It is computed as
= (Total number of species found in first community – Total number of species which are distinct from first community) + (Total number of species found in second community – Total number of species which are distinct from second)

So Beta diversity of A and C is (4-2) +(3-2)= 2 + 1 =3
So, Beta diversity of A and B is (4-2)+(3-2) = 2 +1 =3

Alpha diversity refers to the total number of species found in an area. So the total number of species found in A,B and C is 6.
So, Alpha diversity of A, B and C is 6.

6.5.5 WHICH FACTORS AFFECTING SPECIES DIVERSITY:

Beside the above factors discuss in section 6.4.3. There are other factors which are significant: They are.

Speciation: It is the evolutionary process of generating new species. This occurs when gene flow is interrupted by a mechanism. They have 4 modes namely:

1. **Allopatric:** Species found in different ecosystem but separated by a natural barrier like mountain, water bodies etc. Example South East Asia alligator from American Alligator.
2. **Parapatric:**it occur when a part of certain Species adapted in new niche. It can be in same area or different area. Example: Tennessee cave salamanders (Gyrinophilus palleucus) and Tennessee spring salamander(Gyrinophilus porphyriticus).

3. **Peripatric:**Species whose habitat are adjacent but never cross each other. Example brown bear and polar bear. They habitat are adjacent found in closely found in boreal and tundra region. This occur's when few polar bear migrate to brown bear original habitat periphery.
4. **Sympatric:** Species which have same or overlapping area in ecosystem. Example divergence of Rhagoletis pomeonella, maggot fly in northeastern U.S.A

The other reason are:

ii)Geographic Isolation: Geographic Isolation has resulted in evolution of new species which are not found anywhere in the world. Example: Marsupials species have developed separately and localized to Australia.

iii)Extinction:A lot of species diversity is lost due to several human activities like hunting, overexploitation, invasive, destruction of habitat,pollution and global environment change. It has been estimated that nearly 40 % of vertebrates and 60 % of invertebrates have been extinct or close to extinction. Example several species like Dodo,

iv)Migration: A massive migration is seen in mammals, birds spreading over thousands of Km in presence of food, climate etc. This allow exchange of genetic material temporary with the native species.

v) Immigration: Immigration refers to certain population moving from one community to another for better living condition. This allows a new set of genetic material to inherit in native community.

vi) Emigration: Emigration refers to entire population of a species moving from one community to another. It is due to certain castotrophic like earthquake, fire, floods etc. which make the community unable to sustain. Example: Sahara Desert was once a marshyland with rich diversity of flora and fauna. But due to natural castrophic, Today is a desert with spare vegetation and population.

Total Number of species Known in world:

Species	Living Species	% of Total Species
Fungi	69000	4.8
Algae	26900	1.9
Higher Plants	248000	17.55
Monera	4800	0.33
Animals	281000	19.89
Virus	1000	0.07
Protozoa	30800	2.18
Insects	751000	53.16
Total Number of Species Known	1412500	100

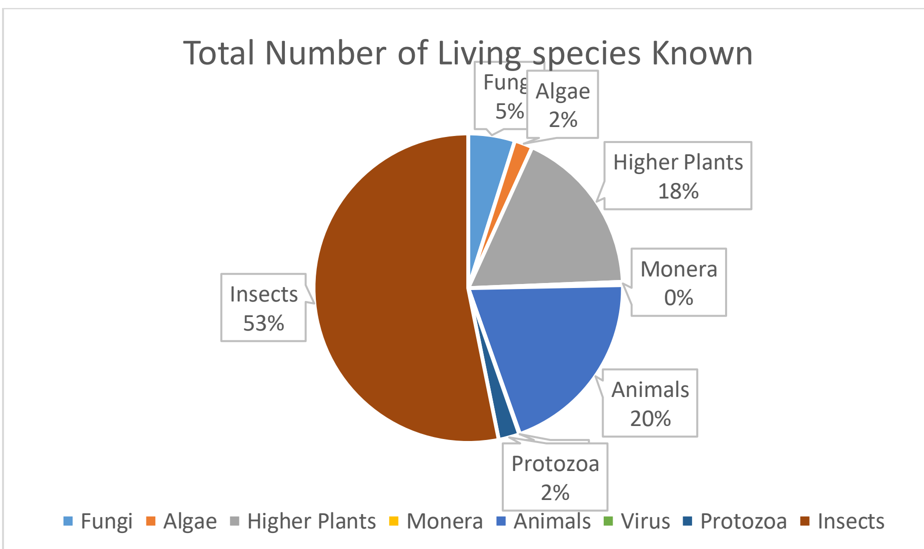

Fig 6.2

6.6 EDGES AND ECOTONES

6.6.1 ECOTONE:

6.6.1.1 Introduction: The word ecotone is made up of two words eco+ tone. The word eco stands for ecology, tone is derived from Greekword tonos meaning tension. In other word ecotone stands for a place where ecology is in tension. Tension occurs when two biomes meet and integrate. This transition can be narrow or broad. An area between field and forest, forest and grassland, river and estuary salt marshes and riparian zones are all example of it.

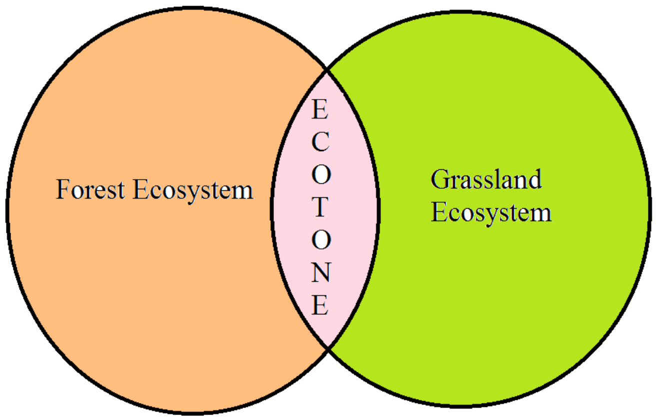

Fig.6.4 Ecotone

6.6.1.2 CHARACTERISTICS:

1. A sharp change in vegetation cover with unique property like color, plant life etc.
2. A clear demarcation line between two biome.
3. A change in physical appearance of plant species.
4. Unique variety of animal species inhabits
5. An abundance of life form as compared to adjoining biome.
6. They have diverse ecosystem.

6.6.2 EDGES :

6.6.2.1 INTRODUCTION:

The edges refer to those zone where a rapid change in species abundance and community structure occurs. It is at the intersection of two biome. The species which has higher density in a ecotone as compared to other zone is refers to as edge species. This concept of higher density of species is refers to as Edges Effect. Species dominating in edge region are knows as Edge Species. Birds living on the border of forest, sea are example of edges effect.

6.6.2.2 Types of Edges:

Edges are divided into 5 different types based upon its formation depending on its types of barrier and shape.

They are classified as:

Classification On Criteria	**Edges Types**
Based on barrier	Inherent, Induced
Based upon shape	Narrow, Wide , Convoluted

6.6.2.2.1 CLASSIFICATION BASED UPON BARRIER:

Inherent: – The edges formed by nature where certain Natural features acts as border.

Induced: – The edges which are forced upon by natural disturbances (flood, fire) and human related activities like clearing of forest over a period of time.

6.6.2.2.2 CLASSIFICATION BASED UPON SHAPE

Narrow – A narrow stretch divides one habitat from another (e.g., an agricultural field.)
Wide (ecotone) –: A wide stretch divides one habitat from another. Habitats are clearly marked with purely defined set of flora and fauna based upon their physical conditions and vegetation.

Convoluted – The demarcated line is non-linear.

6.6.3 IMPORTANCE OF ECOTONE AND EDGES IN COMMUNITY ECOLOGY

Ecotone are areas of great importance as it is considered a habitat of greater genetic diversity and "gene flow" from one population to another. Further they act as a "buffer-zone" protecting the neighboring ecosystem from possible environmental damage. Ecotone acts as an indicator of global change. Any change in biome boundaries is due to climate change. Similarly edge found in Ecotone is the barometer to changes to the local environment. The local environment changes will be first felt by those inhabiting species. Edges also changes species interaction.

6.6.4 HUMAN ACTIVITY EFFECTING ECOTONES AND ECOLOGY:

Human activity has redefined the ecosystem to satisfy their need. This has forced to have a new boundary line for ecotone and edges. Their activity have creates more edges than ecotone. The various Examples of human activities are:

1. **Introduction of exotic variety:** Introduction of camels in Australia. In few years their population has become a dominant species destroying a large tract of vegetation in already sparse environment.
2. **Use of Fires to have a fodder for cattle's.:** Wild fires in Himalaya.Wild fire used to burn the vegetation. Thus loose the soil leading to landslides.
3. **Introduction of pets:** Introduction of dogs and cats. In Guam dogs and cats have led to extinct of several birds species namely Dodo etc.
4. **Pollution:** Pollution has led to loss of several species in lower order.
5. **Loss of foraging habitats:** Land use change pattern like forest to fields etc. make certain species vulnerable, even some of them have become extinct.

6.7 TYPES OF ECOLOGICAL SUCCESSION

6.7.1 INTRODUCTION:

Community dynamics change with change in climatic, physiological and change in interaction of species over a period of time. The Process of moderate changes in environmental changes also led to replacement of older species. This process goes on till equilibrium is reached. This process is known as Ecological succession. It is an ecological development that happens by means of autogenic process.

Ecological succession has the following characteristics.

- It is slow and systematic process that involves change in community structure and their relative numbers.
- The changes are of more dynamics and complex with function of time.
- These new changes are predictable. This process is biological feasible.
- Changes in physical environment and species population are the major characteristics.
- Population explosion leads to realign the structure of community.

6.7.2 CAUSES OF ECOLOGICAL SUCCESSION:

Ecological Succession is due to cumulative of several factors: They are classified as Initial causes and continuing factors:

1. Initial causes:-

Primary Succession are set in when land is ready. It is due to Climatic **s**uch asfire,wind,erosion, deposits etc.

Activities of organism: Organism activities allow new species to develop new interaction among themselves. Besides they are also responsible for destruction of existing habitat and inhabitationthe barren area.

2. Continuing causes:-

- Migration, Emigration for basic needs for survival.
- Moving to new area to get away from competition.

3. **Stabilizing causes:-**

Ecological Succession at the end leads to Stabilizing in Community.This stabilizing depends upon various factors. They are as follows-

- Combination of Abiotic and biotic component in Community.
- Location of Community.

6.7.3 PROCESS OF SUCCESSION:

Succession is complex and slow process which is divided into 5 stages namely

- **Nudation**
- **Invasion**
- **Competitionand Co-action**
- **Reaction**
- **Stabilisation**

Nudation: It's refers to development of barren lands without living things. It can be due to landslide, volcano eruption, fire etc.

Invasion: This comes after nudation. It's involves establishment of some living things on barren land. It occurs in 3 stages namely

- **Migration**
- **Eceris**
- **Aggregation**

Migration: Some living organism shifts from one place to another in search of food, shelter etc. Generally seeds, spores are populated.

Eceris: Thiscomes after Migration. This involves adjustment with new set of condition.

Aggregation: This comes after Eceris. It involves existing species multiplication.

Stabilisation. This is the ultimate stage of succession where species bring about an equilibrium in their behavior, food habits and their species interaction and intra action.

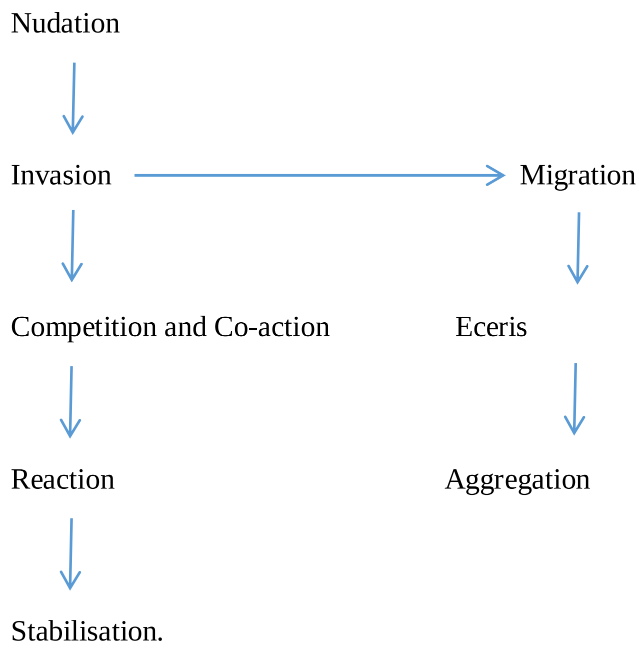

Fig 6.5 Diagram Showing Flow of Succession.

6.7.4 BASICS TYPES OF ECOLOGICAL SUCCESSION:

Ecological succession can be classified in several ways. They are broadly classified as:

1. Primary Succession and Secondary Succession.
2. Autogenic Succession and Allogenic Succession
3. Autotrophic Succession and Heterotrophic Succession.

6.7.4.1 PRIMARY AND SECONDARY SUCCESSION

6.7.4.1.1 PRIMARY SUCCESSION:

This is the initial stage of development of an ecosystem. It begins with the creation (birth) of a community (species) on such a location which was previously unoccupied by any living organism. Such location may be water, soil, land, a new island, a newly created body of water, a new volcanic flow etc.

Example:

1. Formation of certain types of forests on dried lava of a new volcanic flow.
2. Development of vegetation on a retreating glacier.

6.7.4.1.2 SECONDARY SUCCESSION:

This is a re-establishment stage of the development of ecosystem, which existed earlier but was destroyed due to natural calamity or man-made reasons. Such re-establishment occurs due to the presence of seeds and organic matters of biological community in the soil. These seeds transform into plants on getting favorable conditions of climate, weather water etc.

Examples:

1. Forests, which were destroyed due to fire, take rebirth on abandoned land.
2. Vegetation that existed earlier, but was destroyed due to some nature activities like fire, flood, Landslide etc. Grows once again.
3. Crops which were harvested, grow again as some seeds of earlier crops remain buried under soil.Bushes grow on an abandoned mining site.

6.7.4.2 AUTOGENIC AND ALLOGENIC SUCCESSION:

Autogenic succession is self-driven adaptation where organism inhabiting that community bring their change when environment and their interaction changes. Allogenic succession refers to where individual are made to change because of some change are made by outsider of that community.

6.7.4.3 AUTOTROPHIC AND HETEROTROPHIC SUCCESSION:

Autotrophic succession is the stage where plants dominate in a community. Whereas heterotrophic succession is the stage where the bacteria and heterotrophic dominates.

6.7.5 EXAMPLE OF SUCCESSION:

Hydrosere and Xerosere are the two succession found naturally. They involves conversion of pond into land community and succession in rock surface. They are shown as

Succession In Hydrosere:

Pond Ecosystem

↓

Phytoplankton

↓

Rooted Aquatic Plants

↓

Free Floating Aquatic Plants

↓

Reeds & Sedges

↓

Mesic Communities

↓

Terrestrial Communities.

Succession In Xerosere :

Bare Rock

↓

Crustose Lichen Stage

↓

Foliose Lichen Stage

↓

Moss Stage

↓

Herb Stage

↓

Shrub Stage

↓

Forest Stage

6.8 CONCEPT OF CLIMAX

6.8.1 Introduction:

The concept of Climax was first coined by Frederic Clements in 1916. He describes it as the idealized endpoint of succession. At this point succession stop, as it attain a steady state with physical and biotic environment. The community is stable and self-replication except any major disturbance.

6.8.2 Characteristics:

1. Tolerant to environmental condition.
2. Complex food chains and drained spatial structure.
3. Ecosystem is balanced.
4. Species composition remains same where individuals are replaced by same kind of species.
5. It is an index regarding climate of area.

6.8.3 Classification:

There are classified into 6 types namely:

1. **Climatic Climax**
2. **Edaphic Climax**
3. **Catastrophic Climax**

4. **Disclimax**
5. **Pre-climax**
6. **Post –Climax**

6.8.3.1 Climatic Climax: Climatic climax refers to a community which has only a single climax that depending upon climate. For example maple beech in Ohio, U.S.A. Maple beech forest has American beech and sugar maple tree co-dominating the area

6.8.3.2 Edaphic Climax: Edaphic climax refers to a community which has more than one climax modified by local conditions such as soil moisture, soil nutrients, and climatic changes. For example

6.8.3.3 Catastrophic Climax: Catastrophic Climax refers to a community which has climatic climax but get effected by some Catastrophic like wild fire etc. This result in loss of mature vegetation. A new vegetation starts to grow until it reach its climax. For example California forest.

6.8.3.4 Disclimax: Disclimax is refers to as disturbance climax. This stable community is neither climatic nor edaphic but maintain by man or domestic animal. For example overgrazing will destroy the farmland, but can be maintained by local climate.

6.8.3.5 Pre-climax: Any community which has less life form than the expected one under same climatic condition. It is generally found in less moist and hot areas.

6.8.3.6 Post –climax: Any community which has more life form than the expected one under same climatic condition. It is generally found in moist and cooler areas.

6.8.4 MODELS REGARDING CLIMAX:

There are three theory suggested while explaining climax. They are:

1. **Monoclimax Theory**
2. **Polyclimax Theory**
3. **Climax Pattern Theory**

6.8.4.1 Monoclimax Theory: This theory was given by Clements in 1916. He recognized only one climax which in turn depends only on climate. He further stressed that ecological succession overcome change in abiotic component. The concept of sub climax, post climax and sub climax were introduced.

6.8.4.2 Polyclimax Theory: This theory was given by Tansley in 1935. He emphasize that there are more than one climax in a community that also depends upon soil moisture and its nutrients, topography, natural disaster and animal activity

6.8.4.3 Climax Pattern Theory: This theory was given by Whittaker in 1953. He stated that community develops in accordance with all biotic and abiotic conditions. The concepts of multiple climax holds in community. Climax vegetation changes as environmental patterns changes.

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6.9 SUMMARY

Community ecology comprise of inter-relationship between biotic and abiotic component in an community. Composition and structure of each community is dependent upon species diversity and its relative number. Higher the species diversity, better is the health of the community. Species diversity depends upon the climate, location, global environment, species interaction and seasonal variation etc.Community Nature has always been an issue to ecologist. Two view have been developed namely Organismic and individualistic. Organismicstress on species inhabiting in a community are generally independent from each other. While individualistic put up the species as the essential unit in analysis and distribution of population in a community. Health of the community has been found in species richness (No of total species found in a community) and species diversity (relative abundant). Diversity Index are used to calculated the health of community. Shannon Weiner, Simpson Index and Margalef Diversity Index are mainly used. These index figures out the total number of species and their relative number in a community and the deviation between maximum diversity possible to the actual diversity. Diversity is also used to find out at levels namely in a local, regional and totally in a particular area. These are named as alpha, beta and gamma levels of species diversity. These levels provide us with the total number of species in a community to the total number of species found in a particular area.Further community diversity have also given rise to new term namely edges and Ecotones. Ecotones are those Area's where one community ends and another start. These intermediate area are the area of high species diversity having species found in both community. Edges play a significant role in studying the ecology. These ecotones are divided according to shape and patterns in which one community differs from another. There are area within a community which have a higher density of a certain species. Those species are refers to as edges. Few significant species namely edges species are also called as Keystone species play a key role in managing the community. Species have evolved themselves with the changing environment and adapted themselves with change in their surroundings. Their food habits, behavior and other characteristics have undergone drastic change so much their sub species have developed distinct niche. The constant evolutions of new species have led to succession in an community. The order of succession is First succession give rise to secondary succession. Finally communities reach a stage of saturation. This saturation stage is refers to a Climax. Climax is the state when species diversity and their relative number have reached their peak. There is no scope for new set of species to a part of climax community.

6.10 SELF ASSESMENT QUESTION

1. Species Richness is

a. number of different species b. Total number of population

c. relative population d. None of these.

2. Mono Climax Theory was given by

a. Tansley b. Whittakar

c. Clements d. Simpson

3. Climax refers to an community which has only a single climax

a. Climatic Climax b. Edaphic Climax

c. Catastrophic Climax d. Disclimax

4. Ecological succession is ______development

a. Ecological b. Self driven

c. Biotic d. Abiotic

5. Presence of which of the following tend to decrease species diversity.

a. Competitive Exclusion. b. Predators of Keystone

c. Disturbed environment. d. Speciation.

6. Keystone species are the ones which

a. prey heavily on a particular species. b. vulnerable to extinction.

c. found in a selected area.d. Influence the functioning and Structure of community.

7. In which of the following stage of succession, flora and fauna remain unchanged, until destroyed by external factor.

a. Primary Succession b. Secondary Succession

c. Climax d. Tertiary Succession

8. The Process of succession which starts at barren place is called as:

a. Primary Succession b. Secondary Succession

c. Climax d. Tertiary Succession

9. Animal variation in community is called

a. Species Diversity b. Species Richness

c. Species Pyramid d. Species Abundance

10. Species which become abundant in Ecotone are called:

a. Keystone Species b. Edges Species

c. Endemic Species d. In-situ Species

11. Which of the following has most complex structure?

a. Sub Tropical rainforests b. Coniferous Forest

c. Tropical Forest d. Deciduous forest

12. Which of the following levels are arranged in correct sequence?

a. ecosystem, community, population, individual.

b. community ecosystem, individual, population.

c. ecosystem, population, individual, community.

d. community, individual, population, ecosystem.

13. The first species to live on new land formed by volcanic eruption are called.

a. climax species b. keystone species

c. foundation species d, pioneer species.

14. When a certain species population has reached a level where it can grow any larger , then we say that it has reached.

a. climax b. carrying capacity

c. limiting factor d. minimum size.

15. Species richness refer to

a. population of species b. total number of species

c. number of edge species d. total number of different communities.

16 Which of the following is at the highest level of species diversity

a) Alpha b) Beta

c) Gamma d) None of them.

17. Which of the following doesn't supports Organismic school

a**.** Frederic Clements b) Daubenmire,

c. Langford d. Gleason.

18. Man made climax are called as

a. artificial climax b . Polyclimax

c. Monoclimax d. Plagioclimax

1(a) 2(c) 3(a) 4(a) 5(b) 6(d) 7(c) 8(a) 9(a) 10(b) 11(c) 12(a) 13(c) 14(b) 15(b) 16(c) 17(d) 18(d)

6.11 REFERENCES

- Environmental biology (principle of ecology) by Verma P.S, Agarwal V.K S.Chand publication second edition reprint 2013.
- Ecology and environment by Sharma P.D Rastogi Publication eleventh revised edition 2012.
- Fundamental Of Ecology by Dash Madhab Chandra, Dash Satya Prakash The Mc Graw Hill Edition 3rd Edition 2009.

6.12 SUGGESTED READING

- Environmental Studies by Basak Anindita Pearson Publication 1st edition 2014.
- Fundamentals of Ecology by E.P Odum, G.W Barrett cengage publication 5th Edition 15th Indian Reprint 2017.

5.13 TERMINAL QUESTION AND ANSWERS

1 .How keystones species differs from edges species?

Key stones are the species which affects the structure and composition of community. Removal of key stone species brings a drastic fall in species diversity. Edges species are those dominant species found in edge region. There effects are not as key stone species. They are generally endemic in nature.

2. In Recent years the rate of extinction of species has increased significantly. Can you suggest the reason?

Human actions have resulted in loss of habitat. Climatic change hasaffected the abiotic component. These two factors cumulatively have resulted in increased rate of loss of species.

3. Climax is the last stage of succession. Can you suggest me when that climax can be disturbed?

1. Elimination of species sitting at top of food chain.
2. Introduction of new invasive species.

4. Why ecotones are of great significance in ecology?

Ecotones have species found in both adjacent communities. These area are also homes to Several endemic species which are found only in those area.

5. What is the need to preserve and conserve ecology?

To get clean air, water and medicine.

6.14 GLOSSARY

Climax: final stage of succession. A stable community that maintain itself in equilibrium over a period of time.

Community: Group of organism found naturally in common environment

Diversity Index: it is an index of richness of community, depicting the ratio between number of species and their relative number.

Ecesis: A process of species settling in a new environment.

Ecotones:A transition zone between two or more community

Ecology: Science that deals with living beings relations with environment.

Ecosystem:A Collection of interacting living beings with their environment.

Edges: Dominant species in Ecotones.

Endemic: Confine to certain area.

KeyStone Species:specie that effect the nature and structure of community.

Primary Succession: A succession that starts from barren land to some organic matter.

Secondary Succession: A succession which starts from some organic matter

Species: Related individuals that can inter breed and physical similar.

Succession: A natural process in which species evolved and settle their relationship in community.

UNIT 6: APPLIED ECOLOGY AND CONSERVATION BIOLOGY

6.1 OBJECTIVES

Study of this unit will let the students to:

- What is pollution?
- What are the various types of pollution?
- Understanding the factors which promote environmental change.
- How Human action have led to loss of species diversity.
- How Global change is affecting the flora and fauna
- Understanding the need of conservation.
- What are the major factors for diversity change?
- Elucidate the how conservation is reducing the impact of pollution.

6.2 INTRODUCTION

Industrial revolution has started a race for industry and exploitation of Natural Resources. This race had produced a lot of pollutant which are disposed into air, water, soil. This disposal has results in changing the physical, chemical properties of them. This alteration has affected flora and fauna surviving of those ecosystems. This effect is refers to as Pollution. The scale of pollution has been so huge that it has started to change global environment. Global community has started to realize that environment change will bring a lot of social, economic and political stress on their community. Global temperature have risen, weather change, unpredictable rainfall, increased natural calamities etc. are few of the initial sign of change in global weather. These consequences with human action like hunting of meat, overfishing etc. These have led a lot of species i.e. flora and fauna to threatened or extinct level. These factors are refers to as drivers. These drivers may be different for each ecosystem. The need start to work for conservation. Global leader have meet and have agreed on few critical issue like Greenhouse gas limit, CGC Gas emission, adoption of convenient sources etc.

6.3 Environmental Pollution:

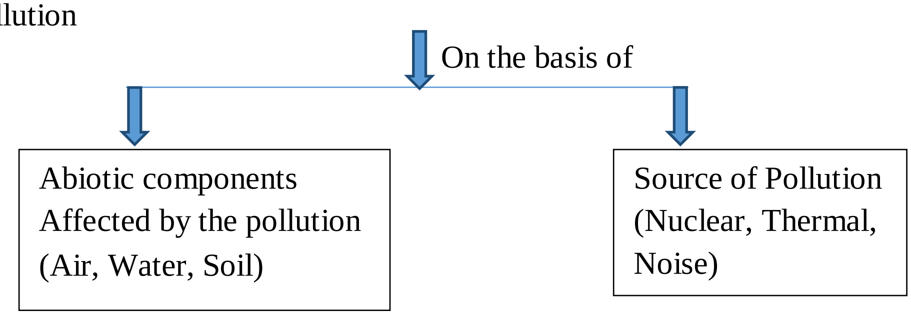
6.3.1 Introduction:

Pollution is the addition of a substance to environment which is or will be toxic to all living organism. This introduction results in undesirable change in abiotic component of environment. This abiotic can be air, water, soil or some abnormal activity like noise etc. The toxic substance introduced is known as pollutants. Theses pollutants can be solid, liquid or gases. It can be a chemical, geochemical, nuclear radiation or some electromagnetic patterns like noise etc.

6.3.2 Types of Pollution:

Pollution can be classified on the basis of

Pollution



6.3.2.1 Effect on which abiotic component are effect:

Introduction: It is been classified according to the component in which pollutants have an effect. The components are air, water, soil. They have been taken in detail:

Air Pollution:

Introduction of greenhouse gases like oxide of oxygen, nitrogen, CFC and dust particle have resulted in altering the structure of atmosphere. This alteration has resulted in directly harming the local and global environment. Air pollution has resulted in altering basic parameter of the earth like energy flow, sunlight, heat, rainfall etc.

Causes of Air Pollution:

Human development has resulted in release of gases in the environment. Transportation, Industrial activity have been the prime contributor for deterioration of air quality. Varieties of compounds are released into atmosphere namely:

1. **Oxide of Carbon, Nitrogen and Sulphur:** These are mainly CO_2, CO, NO, NO_2, HNO_3, SO_2, H_2S and H_2SO_4. These gases are released by burning of fossil fuel and industrial activity mainly metallurgy and refinery.
2. **Release of CFCs:** CFCs compounds rises to stratosphere levels and reacts with ozone. This reaction leaves the layers without ozone protection often known as ozone hole.
3. **Fluoride Compounds:** Fertilizer industries are major contributor with fluoride compounds as discharge in air.
4. **Metallurgy:** Several oxide of heavy metal like lead, nickel, arsenic, tin, cadmium etc. are released in air during metal extraction process.
5. **Hydrocarbon:** Several hydrocarbon like benzene etc. and unburned hydrocarbon are released by automobile and industry.
6. **Particulate matter (SPM):** Several particulate matter less than size of 50 micron are released by thermal power station and stone crusher.

Effects of Air Pollution:

Air pollution effects all living organisms, but their effect varies from human, flora and fauna. Accounts of the effect are summarized as:

Effect on human:

Human is affected in the following way:

1. **Irritation of skin, nose, eye and throat:** This lead to infection in these sensitive organs. Several skin diseases, eye redness, throat soreness are the effect of air infection.
2. **SPM affects the respiration system:** The suspension of very small particle in air allows their passage to lungs through nose. These particles get settled in trachea resulting in Asthma.

3. **Fumes of Automobile fuel contains lead particle:** Lead is known to effect nervous system leading to convulsion, coma.
4. **Fumes of cadmium:** Cadmium has been found to effect cardio vascular, kidney and liver damage. This is discharge during metal extraction.
5. **Fumes of Mercury:** Mercury fumes are released during some industrial process. These fumes effect nervous and kidney.
6. **Global Temperature:** Global Temperature had leads to melting of glacier which results raise in ocean levels. All Coastal areas are of center of economic activities. They are under threat of being drown.
7. **Global Climate change:** Climatic change like excessive temperature, excessive or scanty rains have resulted in increasing the misery of human.

Effect on flora:

Flora is affected in the following way:

1. **Ozone damage:** Ozone damages leaves. It react with leaves to turn them pale.
2. **Oxide of Nitrogen:** Oxide of Nitrogen brings premature fall of leaves. This inhibits the plants growth.
3. **Oxide of Sulphur:** Oxide of Sulphur change the green leaves to yellow and loss of chlorophyll.
4. **Heavy metal discharge:** Certain heavy metal reduce the leafy vegetable growth, some even bringing premature fall of leaves, premature fall of sepals and flower. This significantly reduces their yields.

Effect on fauna:

Fauna is affected in the following way:

1. **Feed with heavy metals:** Feeding on feed contaminated with heavy metal result in organ damage and having several disease like bronchitis etc.
2. **Pre mature Death:** Losses of Appetite and in certain case premature death have been resulted.

Control measure

Air pollution can be minimized by applying modern technology to clear Particulate matter from discharged gas, increasing the fuel efficiency, improving the fuel quality etc. There are several techniques available to remove Particulate matter from the polluted gas. They are Electrostatic Precipitators, Cyclone Separator, Spray Tower, and Fabric Filters. They work on principle of electrostatic, centrifugal force, spraying of water and use of fabric as a filter respectively.

The imposition of certain standard like EURO, BS has forced the refinery to reduce the contents of Sulphur beyond a certain limit. Further it specifies to increase the octane number of petroleum product by reducing the content of unburned carbon compounds. Automobile manufactures have been forced to design vehicle which can run on new standards fuel.

The adoption of new technology and process which reduce the smog generated at each process of industrial production are the way to control the menace of air pollution.

6.3.2.1.2 Water

Introduction:

Introduction of impurities and substance which reduces the quality of water and make it unfit to be used. This is refers to as Water Pollution. Water has been graded as fit for drinking, fit for bath according to these impurities dissolved contents.

Causes:

Water has been contaminated from the various sources. They are

1. **Industrial waste:** A lot of untreated industrial waste contaminated with heavy metal is discharged into water sources like ponds, rivers etc. They come from power station, chemical industry, tanneries, paper industry, metallurgy etc.
2. **Sewage Waste:** Untreated sewage is directly discharged into water sources. It originates from home, animal and food processing industry.
3. **Agricultural Discharge:** Fertilizer, Pesticides, herbicides sprayed on fields finds its way to water sources by natural forces like rainfall etc.

Effects:

Water is the vital resource needed for sustaining the living organism. Pollutants bring a lot of physical and chemical change in water. If the polluted water is consumed, then effects are bound to come. Major effects are been mentioned:

1. **Industrial waste:** Industrial waste contains very poisonous compounds of arsenic, lead, mercury etc. These compounds kill aquatic animals. Human get contaminated by consuming those aquatic animal or consuming water.
2. **Agriculture disposal:** Fertilizer, detergents contain nitrate and phosphate compounds. These compounds reduce dissolved oxygen in surface water by promoting algae growth. This results in loss of aquatic animals.
3. **Infection of water bodies:** Several water borne disease like typhoid, cholera, dysentery is caused due to ingestion of contaminated water.

Control measure

The main objective of controlling water pollution is to remove those impurities from the water. According to types of impurities different control measures are done. These methods are done in a step wise method as:

Sedimentation → Filtration → Disinfection of water → softening of water

Sedimentation involves the separation of suspended particle.

Filtration involves getting away from color, taste, bacteria.

Disinfection involves killing bacteria.

Softness involves removing hardness.

6.3.2.1.3 Soil

Introduction:

Introduction of Impurities which reduce the productivity of soil is known as soil pollution. These impurities are chemicals, fertilizer, plastic goods, radioactive waste, solid waste etc.

Causes:

Land has been contaminated by various sources. They are

1. **Waste disposal:** sewage, industrial waste, domestic waste and agricultural waste are disposing on the land.
2. **Fertilizer:** Use of Fertilizer has resulted in decreasing the natural yield of soil.
3. **Soil Erosion:** These leads to the loss of top soil cover due to nature and human activities.
4. **Radioactive Disposal:** Dispose of radioactive waste under the soil lead to radioactivity in soil.
5. **Acid rain:** Industrial activity leads us to acid rain. This change the basic character of soil.

Effects:

Human, Plants and Animal directly or indirectly consumed foods which are grown on soil. Food grown on contaminated soil is bound to be contaminated. In this way flora and fauna also get contaminated with impurities. The effects have been summed as:

1. **Sewage disposal:** Sewage disposal leads to growth of microorganism which causes disease.
2. **Soil Fertility:** Urban solid waste disposal also reduce the soil fertility.
3. **Agriculture disposal:** Pesticides, Fertilizer, Insecticide sweep through soil. These contaminate the ground water.
4. **Transfer of Nutrient from soil:** Fertilizer leave residue in soil. This residual reach fauna through flora. These affect normal metabolism.

Control measure:

The soil pollution is minimized by

1. Minimization of generated solid waste.
2. Promotion of recycle of industrial waste, solid material.
3. Minimizing use of fertilizer and Promotion of Organic manure.
4. Scientific management of sewage, agricultural waste.

Type of source: The classification based upon the source of pollution. They are classified as nuclear, Thermal, Noise, Solid waste and industrial waste pollution.

6.3.2.2.1 Nuclear Pollution

Introduction:

Contamination of air, water and soil by radioactive material is known as nuclear pollution. They are released from nuclear reaction like fission and fusion. These reactions can be naturally or men made. Various electro-magnetic waves like α rays, β rays and gamma rays are released. Exposure to these waves brings several diseases like genetic disorder, etc.

Causes:

Main source of electromagnetic waves are:

1. **Cosmic waves from outer surface:** Cosmic waves coming from heavily body effects our health.
2. **Radiations naturally coming from radioactive substance:** There are several place where radioactive substance are found. Their community is effect by their emission.
3. **Nuclear Reactors:** Nuclear reactor power plants are the one of source of electromagnetic waves.
4. **Radioactive Isotopes:** Several Isotopes are used in health and research activities. There emissions are continuous source of radiation.

Effects:

There are various hazards of nuclear pollution.

1. **Cancer:** Cancer, Tumor and genetic change are associated with nuclear pollution.
2. **Death :** This can lead to death in case of high dose
3. **Organ Disruption:** Disruption in Organ functioning in case of low dose.

Control measure:

Exposure to these electromagnetic waves can be curtained by

1. Use of laboratory hoods, air filters, and exhaust system:
2. Proper management of radioactive solid and liquid waste.

7.3.2.2.2 Noise Pollution

Introduction: The generation of unpleasant and annoying sound is known as Noise Pollution. Noise levels between range 75 dB - 80 dB are refer to as noise.

Causes:

There are various source of noise pollution:

1. **Industrial Factory:** Factory machine emits a lot of noise
2. **Transportation:** Transportation vehicle like truck, bus, automobile emit a lot of noise while burning fossil fuel in engine.
3. **House Holds Application:** Several Households application like mixer, television, Music system are big source of noise.

Effects:

1. Loss of Hearing: Continuous expose to high pit noise can make our ear to loose sensitivity to sound wave. The permanent loss of sensitivity results in loss of hearing.

2. Physiological effects: Physiological effects such as headache, heart pain, nervous breakdown are associated with noise pollution.

3. **Psychological effects:** Psychological effects such as depression, fatigue, sleep disorder are associated with noise pollution

Control measure:

1. **Use of aids to reduce noise intake:** It involves the use of ear buds to reduce the intake of sounds into ear.

2. Suppression of noise: It involves a scientific approach like proper lubrication of machine, using silencers, designing, fabricating quieter machine, using acoustic to suppress the noise. This will involves a noise development of less dB to generates and enter into our ear.

3. Creating silence zone: It involves creating silence zone on certain location, based on certain time. It also involves restriction on generation of sound having high dB generation in a residential area, school, hospitals etc.

4. Plantation: Plant is known to be a good absorbent of sound wave. The tree reduces the sound level drastically.

5. Legislative Framework: Legislative framework is require to impose restriction on usage, time etc. like pressure horn are banned, no use of D.J. beyond 10 PM

6.3.2.2.3 Solid Waste Pollution

Introduction:

Introduction of solid pollutants which are unfit for human and animal consumption. These include construction material, Fly ash, rubber, plastic etc.

Causes:

Solid wastes are mainly generated from consumable goods, disposable items, packaging items and construction material.

Effects:

Solid waste has become a paradise for diseases carrying host and carriers to live.

1. **Rats live in dumping site:** They cause plague, salmonellosis and typhus diseases.
2. **Disease micro-organism in dumping site:** Various bacteria, virus disease like typhoid, cholera, dysentery, polio, hepatitis have their source found in these dumping sites.
3. **Water logging:** These wastes choke the drains resulting in water logging. This becomes the breeding ground for mosquito.
4. **Smell:** Odour's of waste pollute the air.
5. **Percolation of chemical:** Percolations of few chemical or metal oxides contaminate the water and soil.
6. **Plastics Effect:** Plastics can stop percolate of rain water. This will affect the soil fertility.

Control measure:

Solid waste Control measure comprises of:

1. Reducing the generation of solid waste.
2. Proper segregation of waste into degradable, non-degradable, medical waste. A separate process will be taken for their disposal.

6.3.2.2.4 Industrial Waste Pollution:

Introduction:

Various compounds of organic and inorganic compounds are generated as waste by industries. A significant portion of these chemical are not biodegradable. Their effect is felt over several generations.

Effects:

The Industrial waste compounds effects the following way:

1. **Percolation in soil:** Metallic compounds percolate the soil and kill beneficial bacteria.
2. **Toxic compound in food chain:** These toxic metallic compounds enter the food chain affecting all component of community.
3. **Emergence of Disease:** Industrial waste leads to several soil and water borne disease.
4. **Radioactive substance:** Ingestion of water expose to radioactive industrial pollution leads to organs working disorder.

Control measure:

Several techniques like anaerobic digestion, deionization, incineration, lagooning, vacuum filtration, screening, filtration etc. are used to segregate industrial waste.

6.4 Global Environmental Changes

Introduction:

Global environment means earth's environment. It is a sum of all ecosystem, community, and biosphere. Global environment deals with how various factors effect each ecosystem, how each ecosystem is related with another, how events in one ecosystem effect all other ecosystem.

Climate and environmental change:

Climate and environment change have brought significant change on all living beings. These changes have forced the living beings to evolve new tools, methods to sustain themselves. Some species have started to take advantage of the environment change but others don't. Those unchanged species are on threatened list. We have gone through its cause and its effect on ecosystem.

Cause of climate and environmental change:

There are various cause of climatic change.

1. **Increase in greenhouse gases emission:** Greenhouse gases like CO_2, Methane etc. emission have increase significantly.
2. **Increase in Human populations.** World Population has increased from 2.6 billion in 1950 to nearly 8 billion. Basics ingredient required for survival i.e. Food, Water & Air. This has prompt to grow more food, have more water at their disposal.
3. **Increase in per capital income.** The gross world product per capita has increased from $ 2,000 in 1950 to $ 6,500 in 2010. This has allow indispensable resources at consumer end. This has increase spending in consumable item. It has lead into solid waste generation.
4. **Increase in Food Requirement.** Human population has nearly become 4 times in last 5 decades. This has increase need of food to satisfy the human appetite.
5. **Increase in Forest Product requirement:** Need of forest product like timber, wood etc. have increased for various activities like Construction, heating, and other activities.

Effect of climate and environmental change:

Climate and environmental change have resulted in the following change:

1. **Global Temperature have risen:** The Global temperature has risen by 1ºC since 1950. This has altered the all physical component of ecosystem. Similarly abiotic component have undergone change in physical and chemical properties. This has effect on flora and fauna living in ecosystem.
2. **Frequent Climatic Change:** Change in flow of heat, air has resulted in frequent climate change. The temperature gradient of day, season has undergone significant change in these 5 decade. This has altered the duration of season.
3. **Loss of species diversity:** It is estimated that nearly 40% of vertebrate, 60% of Invertebrate have been lost in last 100 years. Several human action like conversion of forest into fields, introduction of invasive species, taking out exotic species from community, hunting of animals for food, hide and ornamental purpose etc. have resulted in loss of species diversity. Above them conversion of land use and climate change have led to loss of animal who can't adjust with change in ecosystem.
4. **Large Incidence of Natural disaster:** Global climate will increase the rate of occurrence of natural disaster. The frequency and intensity of the disaster have increased significantly. Nearly 50% of earth surface is prone to one or more natural disaster.
5. **New Types of Disease:** Global climate has forced the flora and fauna to adjust themselves with the changing ecosystem. Changes in land use have altered the structure, complexity and biological composition of community. Climate change have bring change in temperature, rainfall, soil moisture, and biogeochemical cycles. Thus a combination of both have resulted in change of the range and breeding habitat of numerous vectors, hosts and pathogens. We expect change in behavior of disease.

A chart is been drawn how change in land use habits have increased malaria.

Land Use Change	**Examples**
Deforestation	In Peru, biting rates of Anopheles darlingi have increased 300 times than in intact forest. In Sub-Saharan Africa and Asia, It has been found that deforestation favors some vectors. This has leads to increased transmission.
Dams	In Ethiopia concentration of anopheles vector have increased, malaria case have increased 7 folds.
Irrigation projects	Irrigation projects in India provided an ideal ground for breeding of Anopheles culcifacies which leads us to endemic malaria.
Agricultural Development	Cultivation of cassava and sugarcane in the same field reduced the density of Anopheles dirus but it created widespread breeding grounds for Anopheles. minimus. .

6. **Lacking of fresh air and water:** Air and water pollution will make fresh air and water a luxury. Their inhalation or ingestion will impact functioning of organs. In worst case death is inevitable.
7. **Man and animal conflicts:** Decrease in soil fertility with increased population will lead human to clear more forest land. This will force more man and animal conflict.
8. **Spread of Cancer:** Exposure of Radioactive substance through water and air will leads us to more genetic mutations. Child will be born physically, mentally impaired. The

Ozone depletion will increase the skin cancer. Thus a sum of these factors will lead us to cancer.

9. **Ocean are becoming more acidic:** Nearly 60% of total CO_2 gas emission are absorbed by ocean. If their gas emission increase's then more CO_2 will be absorbed by ocean. This absorption will make ocean more acidic.

6.4.2.3 Global Environmental Change: The Threat to Human Health:

Human activities are responsible for change of earth physical and biological system. It has been realized that environmental change affects human health on a larger scale. The environment has become a key factor in determining human health.

It is the last 50 years that entire ecosphere has been modified extensively by human beings. We have controlled more than 50% of nitrogen cycle, converted near 40% of earth surface into crop fields, reduced 7 to 11 million square kilometer of forest, fished fish beyond their sustainable limit, build 45,000 large dam, 8,00,000 minor dam to regulate water flow are testimony to change in our ecosystem.

Industry revolution has led to increase in greenhouse gas emission. These greenhouse gas emissions have gone up by 30 % from pre-industrial level. Carbon dioxide concentration has shot up from 310 ppm to 395 ppm. This has led to increase the global earth temperature by 1^oC. This is bound to threaten human beings in the following ways:

1. **Human health will suffer from numerous health issues:** Air pollution will led to increase incidence of asthma, water and soil pollution to bacteria disease. Global climate will also alter the behavior of micro-organism. This will altered exposure to infectious disease. Radio Active waste will lead us to new mutation and various form of cancer. Ozone depletion in stratosphere layer will allow Ultra-Violet radiation to enter earth surface. This U.V will led us to more case of cancer mainly skin cancer.
2. **Exposure to heat waves:** Global environment have started to get warmer. Warmer area are getting warmer, even colder place are getting warmer. Exposure to heat wave results

in dizziness, headache, fainting and even death. Hundreds of People died due to heat wave in east, southern part of India, and even in south Europe.

3. **Exposure to frequent disaster:** Global environment will disrupt the natural flow of heat, air across the globe. This will force the increased incident of landslide (due to increased temp gradient), cyclone (due to disruption of heat flow), floods & famine (due to disruption of heat flow) etc. U.S.A has started to have more category 3 or higher hurricane, Sub Sahara region have frequent drought.
4. **Climatic disruption:** Global environment has led to change in climate of globe. Earth temperature have risen, Polar region have started to become warmer. Glaciers are melting at alarming rate. Ocean are getting warmer, Equilibrium in Flow of warm and cold current is getting disrupted. This disruption is making Rainfall pattern unpredictable. Ocean are getting warmer
5. **Food availability:** Global environment will make irregular temperature, heat, rain and alter all abiotic components. This will make flora and fauna susceptible. Soil won't be fertile. Various staple food varieties are on the verge of higher risk. If temperature rise by 1 to 2^{o}C, Rice and Wheat cultivation won't be viable. Thus Food availability will be less.
6. **Unavailability of Fresh Air & Water:** Water and Air Pollution will make water and air polluted. Changing climate will make rain an irregular pattern. Thus water will become merge community for ever increasing population.
7. **Inundating of Coastal Area:** Glacier melting will lead to rise of sea level. Major city of globe are situated on sea coast. These areas are under constant threat of inundate. There will be forced migration in large numbers. This will increased instability and strife.

7.4.5 Control measure:

Several steps are required to control the global change:

1. **Reduce the Greenhouse Gas Emission:** We need to reduce the emission level of greenhouse gas to reduce the rate of rise of global temperature. Several change are due to effect of greenhouse gas in a community, ecosystem.
2. **Reduction of Chloro Fluro Carbon compounds emission:** CFCs gas have resulted in creation of black hole. These black hole allow the emission of U.V. rays to our earth. This U.V increase the chance of cancer.

3. **Development of Protected Area:** Protected areas like National Park, Forest Reserve are needed to conserve species diversity, air and water purification. These protected area absorb a lot of greenhouse gas and convert into a food.
4. **Sustainable Forest Management:** A sustainable forest management is required to maintain flora and fauna species diversity, re-habituating the threatened species with the human development.
5. **Sustainable land Management:** This refers to maximizing use of land in a scientific way so that human need can be maximized.
6. **Safe disposal of Hazard Chemicals:** Disposal of toxic chemicals in such a way they don't become a part of the food chain.
7. **Adaptation to Climate Change:** We have to start a mitigation plan of how to survive in a changing environment.
8. **Adoption of Conventional Energy Source:** Adoption of conventional energy source like water, air, solar, geothermal in a large scale to reduce the burning of non- conventional energy source like coal, petroleum. This will stop a bulk of greenhouse gases.
9. **Integrated water Management:** This refers to a scientific use of water in such a way that human need can be maximized use.

6.5 Principle of Conservation

6.5.1 What is Conservation?

The word conservation is derived from a combination of two Latin word con + servare. Con meaning together, servare meaning guard. Thus conservation means to guard together. Conservation means preservation of resources. It also includes how existing resources can be used efficiently. Conservation generally refers with biodiversity, environment and natural resources. This conservation has been done by human since pre historical days. This has taken a new look by apply modern outlook from natural and social science. This outlook has given rise to conservation biology.

6.5.2 What is Conservation Biology?

Conservation biology is an interdisciplinary subject drawn from natural and social science, with the sole objective of applying natural resource management techniques for protecting flora, fauna, their habitats from extinction and conservation of biotic component.

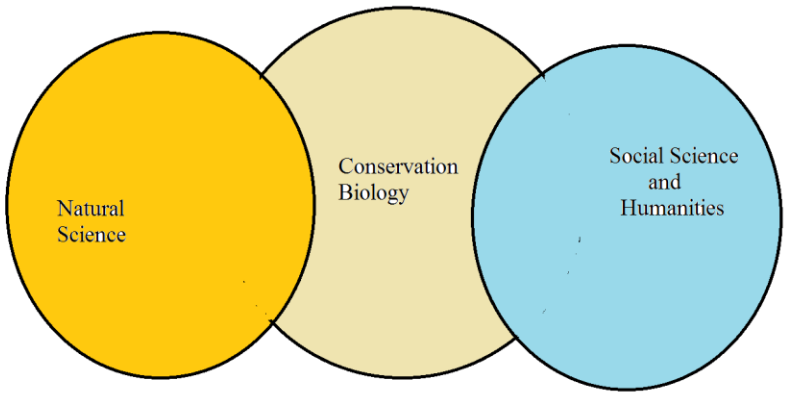


Fig 6.1 Conservation Biology as an Interdisciplinary subject

Some of the definition given by various Scientist is as follows:

M.Soule(1986) has defined as The science of scarcity and diversity

M.Hunter (1996,2002) had defined as "The applied science of maintaining the earth's biological diversity" or more simply "biology" as applied to conservation issues."

R.Primack(2006) : "Conservation biology is the new, multidisciplinary science that has been developed to deal with the crisis confronting biological diversity" R.Primack(2006)

6.5.3 Goal of Conservation biology:

The main objectives of Conservative biology are:

1. Document the whole of biological diversity.
2. Figure out the human effect on the species diversity, genetic variation.
3. Figure out human effect on whole ecosystem.

4. Design and develop natural resources management techniques which will prevent extinction of species, maintain genetic diversity within species and restoring biological communities.

6.5.4 Need of conservation Biology:

Human actions have affected the abiotic and biotic component of the community, ecosystem. Their actions have started to harm their own species. So the need arise is to have a pre-study of the consequence before the actual action can be done. This biology deals with documentation of all biodiversity, its effect on their populations in a community. Finally working out a plan how to re habitat their population in that affected communities. The need of having sustainable development has necessitated the requirement of E. I. A. (Environmental Investigation Agency) to prepare a report on effect in a community. It is also a jobs, how to mitigate those effect using scientific knowledge. The question arise is why to conserve ecosystem. This is because biodiversity provides:

1. Provide food, fuel, fiber and shelter.
2. Purifies air and water.
3. Detoxifies and decompose waste.
4. Stabilizes climate.
5. Moderates floods, drought and temperature.
6. Cycle nutrients.
7. Controls pest and disease.
8. Maintains genetic resources.
9. Provides cultural and aesthetic benefits.

Human cannot function without these biodiversity benefits. So Conservation biologists are conducting research in saving endangered species, protecting their habitats, restoring population. This also helps in restoring natural ecosystem.

6.5.5 Principle of Conservation biology:

Conservation biology is guided by two principle namely guiding & Ethical.

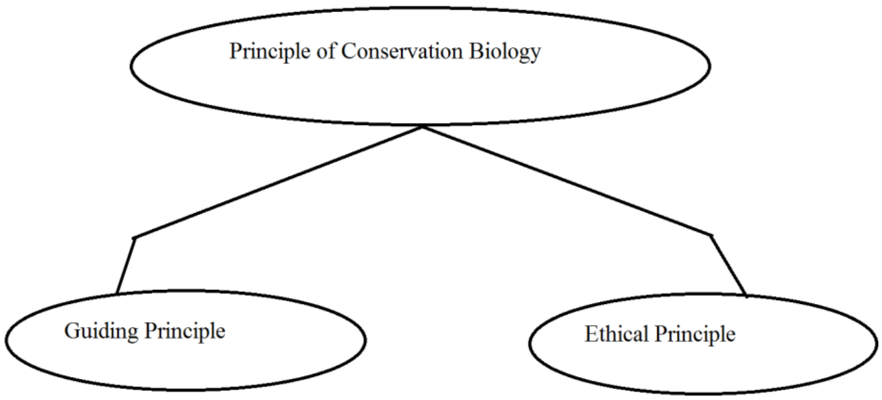


Fig 6.2 Classification of Principle Of Conservation Biology

6.5.5.1 The Guiding Principle of conservation biology:

This principle are given by Meffe and Carol in 1994. It has evolved from several fields namely Ecology, Physiology, Molecular Biology, Genetics and Evolutionary biology. It is a combination of three principle namely:

Principle 1: Evolution is the basic axiom that unites all of biology: Evolution is the theme which forces the development of new species, change in physiology, new Genetics combination over a period of time. This change is refers to as adaptation.

Principle 2: Ecological world is dynamic and largely non-equilibria.: The way in which ecosystem works is quite complex, some concepts have been documented, understand while some are still quite despair to human. Further the diversity in all ecosystems is not the same.

Principle 3: Human Presence must be included in conservation planning. Conservation can't be possible until human support come for it.

7.5.5.2 Ethical Principles of Conservation Biology:

This principle was given by Primack in 2010. It emphasize on ethical side of conservation. It is a combination of 5 Principle:

Principle 1: The diversity of species and biological communities should be preserved. This is the main concept behind conservation that species diversity and communities should be maintained. Every efforts should be made like protected area, national park etc. to preserve it in a natural way.

Principle 2: The ultimate extinction of populations and species should be prevented. Conservation biology goal is to converse the species before the population become extinct.

Principle 3: Ecological complexity should be maintained: Species diversity should be maintained. More the species, more the complexity.

Principle 4: Evolution should continue (Red queen Hypothesis): This is the hypothesis that biotic component continue to adapt themselves with the changing environment. Thus evolution continues.

Principle 5: Biological diversity has intrinsic values: Cultural and social value are deeply related with the environment. Several plants and animals have special meaning in the communities. These values are intrinsic in nature.

Steps of conserving environment in environmental biology:

The following are the steps in diagnosis and treatment of declining populations:

1. Confirm the species is declining which was earlier more dominant.
2. Figure out species environmental requirements
3. Determine all possible reason for decline
4. List the hypothesis for various factors responsible for decline.
5. Test the most likely hypothesis for major factors responsible for decline.
6. Apply results to Diagnosis of threatened species.

6.6 Major Drivers of Diversity Changes

6.6.1 Introduction:

Drivers are set of factors which have led various species into extinction. Industry revolution has increased the rate at which species are been threatened, endangered and extinct. These factors can be natural or mankind.

The set of drivers vary for each ecosystem like:

1. Terrestrial ecosystems are land use change, climate change, eutrophication and biotic exchange.
2. Freshwater ecosystems are habitat degradation, pollution and biotic exchange.
3. Marine ecosystems are climate change, overfishing, habitat degradation acidification and pollution.

6.6.2 Classification of drivers: Drivers have been classified into two parts namely Direct and Indirect Factors:

Drivers

Direct Factors
(Land use change,
Climate change etc.)

Indirect Factors
(Change in Human Population,
Economic activity etc.)

6.6.2.1 Direct Drivers: They comprises of those factors which directly affect the ecosystem.These include land use change, climate change, invasive species, overexploitation, and pollution. We are going to take each of them:

- **Land use change:** land use change (such as marshy land into fields) forces species who are surviving in that ecosystem to migrate or get extinct.
- **Climate change:** Climatic change is forcing a lot of change in abiotic component of ecosystem. This lead a lot of species to adapt or get extinct. A lot of flora and fauna are sensitive to temperature, moisture, sunlight & heat.
- **Invasive species:** The introduction of alien species beyond their normal boundaries. This has created havoc by threatening the host variety to extinct level. Several species like Dodo, Large Marsupial have got extinct due to this introduction. New Zealand & everglade forest are fighting from these effects.

- **Over Exploitation:** Over Exploration has been a serious issue affecting nearly every ecosystem. Marine Fish, Fresh Water Fish, Tree are been exploited beyond their levels leading some to threatened or extinct. Several species like bush meat have been so much hunted for meat beyond their replacement level.
- **Pollution:** Air, Water, Soil and other pollution have brought a lot of change in ecosystem. This change is leaving lot of species to perish. ,

6.6.2.2 Indirect Drivers: They comprises of those factors which indirectly affect the ecosystem. These include changes in human population, economic activity and socio-political factors, cultural and religious factors & use of science & technology. We are going to take each of them:

- **Change in human population:** World population has thrice in last 50 years. This has increased a lot of demand for food, energy putting pressure on ecosystem.
- **Economic activity:** Global economy has become nearly 10 times than in last 40 years. Economic activities have increased human movement and industrial activity. This has increased interdependence among people and country, leading to pollution.
- **Socio-Political factors:** socio and political are characterizing how environment resources need to be managed.
- **Cultural and Religious factors:** Individual Culture and religious belief brings their perceptions. It is the perception that affects the ecosystem.
- **Use of Science and Technology:** Advancement in science and technology decided how the resources can be used more efficiently.

6.7 Summary

Human actions have brought a lot of change to environment. Industrial revolutions have increased the requirement and need of human beings. This spurt along with increase in human population has increased the demand of resources. This has led to increased exploitation of natural resources, some over-exploitation. Exploitation has resulted in pollution, loss of forest, conversion of land use, loss of species diversity etc. The pollution is due to addition of pollutant in the ecosystem. This addition can be in land, air & water or depending upon the source like noise, nuclear, solid waste and industrial waste. Pollution has drastically affected the flora and fauna surviving on those ecosystems. This pollution has increased the rate of global weather change. Human action like emission of greenhouse gas, land use conversion, urbanization, hunting of animals, introduction of invasive species have altered the delicate balance of food flow, energy flow etc. This flow alteration has effect abiotic component of ecosystem like rainfall, temperature, soil characteristics etc. overall flora and fauna have been affected. Some dominant species have started too been threatened, even some have extinct, as they couldn't adjust with changing environment. It has been estimated that nearly 40 % of vertebrates and 60 % of invertebrates have been lost in 200 Years. Factors responsible for each ecosystem may be different, but the result is almost the same. These changes have started to affect the human beings. Thus the need arise is how to live with the changing environment. There are two ways namely reducing the rate of global environment change or how to live in new set of condition. Reducing the rate means conservation. This includes decrease the amount of greenhouse gas, emission of CFG, rejuvenation of forest, water bodies, lesser amount of solid waste etc. Global leader have started to come together to a platform where they can discuss and adopt new green technologies and customized with their need and requirement, without the need of human development. Thus the future need is of sustainable development with the nature.

6.8 Terminal Questions and answer

1. How environmental biology different from ecology.

Ecology deals with species interaction in ecosystem while environmental biology deals with ecosystem effects caused by human action and its influence on biotic component.

2. How Dam effects the ecosystem.

Dam obstruct natural flow of water. It stops the flow of nutrient from upper stream to lower, stop migration of aquatic animals.

6.9 Self-Assessment Question

1. Behavioral disorders, development of destructive nature and neurotic traits in later stage are outcome of:

a. Thermal Pollution b. Noise Pollution

c. Nuclear Pollution d. Soil Pollution.

2. The noise is refereed to sound other than

a. 75 dB to 80 dB b. 60 dB to 70 dB.

c.) 70 dB to 80 dB d 70 dB to 75 dB.

3. Main discharge of thermal power plant is

a. Smog b. Dust particle

c. Fly ash d. Smoke

4. Acid rain has pH

a. Below 5.4 b. Above 5.4

c. 5.4d. 7

5. the most emissive greenhouse gas is

a. Carbon dioxide b. methane

c. Sulphur dioxide d. carbon monoxide.

6. Global environment change has __________ rate of species extinction.

a. Decrease b. Increase

c. No change d. depends on situation.

7. Major threats to biodiversity is due to

a. Habitat destruction b. Human action

c. introduction of invasive species d. Pollution

8. Extinction of weaker species by introducing alien species is due to

a. Endemism b. Domino effect

c. Habitat Loss d. Mutualism

9. Which of the following is most important for ecosystem

a. Food Cycle b. Energy Cycle

c. Material Flow d. Rainfall

10. Wildlife Sanctuary, National Parks are created for

a. Conservation b. Enjoy Wild Life

c. Research d. None of these

11. Ganga Action Plan has been formulated for:

a. To keep Water Pollution Free b. To Increase Fish Cultivation

c. To Promote Tourism d. To make sustainable development

12. Main source of energy in ecosystem is:

a. Sugar in Plants b. Sun

c. Energy released during transpiration d. None of these.

13. Famine is the result of

a. Deforestation b. Weather Change

c. Excess use of ground water d. Mining

14. Which of the following is a clean energy source

a. Thermal Power b. Hydel Power

c. Nuclear Power d. Diesel Handsets.

1(b) 2(a) 3(c) 4(c) 5(a) 6(b) 7(b) 8(b) 9(b) 10(a) 11(a) 12(b) 13(b) 14(b)

6.10 References

1. Environmental Biology (Principle of ecology) by Verma P.S, Agarwal V.K S.Chand Publication Second Edition Reprint 2013.
2. Ecology and Environment by Sharma P.D Rastogi Publication Eleventh Revised Edition 2012.
3. Fundamental Of Ecology by Dash Madhab Chandra, Dash Satya Prakash The McGraw Hill Edition 3rd Edition 2009.

6.11 Suggested Reading

1. Environmental Studies by Basak Anindita Pearson Publication 1st edition 2014.
2. Fundamentals of Ecology by E.P Odum, G.W Barrett Cengage publication 5th Edition 15th Indian Reprint 2017.
3. https://enviroliteracy.org/ecosystems/drivers-of-biodiversity-loss/

6.12 Glossary

Abiotic: Non Living component of a region like soil, rainfall etc.

Bio Degradable: Organic substance which are broken down by micro-organism.

Biotic: Living component of a region.

Community: Group of organism found naturally in common environment.

Detoxifies: Process to remove the toxicant.

Ecology: Science that deals with living beings relations with environment.

Endangered: Species which are under threat to being extinction.

Ecosystem: A Collection of interacting living beings with their environment.

Eutrophication: Sudden increase in algae in water due to influx of organic compounds.

Evolutionary Biology: A field of biology which deals with how species have evolved.

Extinct: Species which have beings lost forever.

Genetics: Science which deals with heredity and variation.

Greenhouse gas: Gas which increase the rate of absorption of sunlight.

Molecular Biology: A field of biology which deal with macromolecules structure and function.

Non-Biodegradable: Substance which can't be broken down by micro-organism.

Physiology: A field of biology which deal with living organism function and theirs's parts.

Pollutant: Thing which pollutes environment.

Pollution: Addition of pollutant in surrounding.

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