**FOREST ECOLOGY AND BIODIVERSITY**

**Class:- Ph.D (Forestry) Ist year**

**Course Teacher :- Dr Kundan Singh**

Theory

Basic concept of ecology - Study of Autecology and synecology - plant association and plant society - Ecosystem - components - plant succession - climax - Vegetational study - community characters – life and structural description - Ecological productivity - Efficiency of ecological production - Fire science - fire behaviour - Fires effect on vegetation structure and dynamics - fire Management. - Role of forest on global ecology - forest climate interaction - forest in global carbon cycle - forest and climate stabilization - Ecological modelling - components of modelling.

Biodiversity – Origin – Types – Biodiversity eastern and western ghats – Biodiversity conservation – Minimum viable population – *In situ* and *Ex situ* conservation – Sacred grooves – Biodiversity assessment.

Practical

Study of floristic composition - Forest productivity studies using bomb calorimeter, gas exchange methods, harvest method, chlorophyll estimation and studying plant succession - Measurement of light interception beneath different canopies - Quantification of nutrient return through litter fall - vegetation as site indicators - Effect of fire on regeneration - Fire Control – Fire safety measures.

Lecture Schedule

1. Ecology - definition - concept of ecology - Energy flow in ecosystem.
2. Autecology and synecology - plant association - plant society.
3. The Ecosystem - definition - components of ecosystem - Biotic interrelationship.
4. Movement in ecosystem - Food chain - Ecological Pyramids - Types of

pyramids.

1. The species concept - population characteristics - growth characteristics of populations - population interaction - population erosion - Genetic variation and genecology - selection pressure - Genecological differentiation.
2. Plant succession - primary and secondary succession - Causes of succession - primary causes.
3. Plant succession climax - Types of climax - theories of climax - Types of succession.
4. Vegetational study - Naming community - characters of community - Qualitative characters - life forms - biological spectrum - structural description - Quantitative character - Density - Frequency - Dominance.
5. Vegetative study - synthetic characters - methods of studying vegetation
   * Ecotone and diversity - species diversity index.
6. Production ecology - Biological production determination - Turnover - primary production process - Biological efficiencies - Ecological energetics - sources of energy - Law of energetics.
7. Productivity - biomass - biomass estimation - site quality - site estimation using environmental factors - forest productivity - productivity estimates of Indian forests.
8. Paterson's productivity index - FSI estimates of forest productivity - carbon budgeting in forest ecosystem - Ecosystem approach in forest management.
9. Decomposition and mineralisation - humus formation - effect of temperature and moisture.
10. Measurements of turnover in detrital layers - nutrient cycling - oxygen,

carbon cycling - Nitrogen, sulphur, phosphorus cycling - water cycle.

1. Nutrient cycling - Biogeo-chemistry – inter- and intra-system cycles - Ecosystem inputs - the atmosphere - Nitrogen fixation - Rock weathering
   * Hydraulic inputs.
2. Nutrient Accumulation - Biotic Accumulation - Ecosystem losses - loss by fire groundwater, forest harvest.
3. Mid Semester Examination
4. Forest disturbance - susceptibility and responses of forest to disturbing agents - pattern of mortality - effect of animals - general effect on reducing canopy area.
5. Host biochemistry and susceptibility - Biochemical defenses in plants - tissue quality and growth efficiency.
6. Fire science - principles of combustion - parameters of fire behaviour - Determination of fire intensity
7. Behaviour of different types of fire with special reference to head and backfires - factors influence fire behaviour - use of fire behaviour for ecosystem management.
8. Effect of fire on vegetation structure and dynamics - the grass/bush balance - season of burning - type and intensity of fire.
9. Fire management - fire danger rating system - principles and systems of fire control and suppression.
10. Role of forest on global ecology - forest climate interaction - Evidence of climate warming - interaction of forest and climate - forest in global carbon cycle - source / sink dynamics of global carbon cycle.
11. Global net primary production and the contribution of forests - Trace gas emission from forest - sustainability of global forest - future global wood supply - forest planting for climate stabilization and fuel replacement.
12. Ecological modeling - classes of mathematical models - components of models - Tentative modeling - procedure.
13. Biodiversity - definition - origin of diversity - speculation - the ecological role of biodiversity - diversity and niche structure - trophic diversity - human and species diversity.
14. Biodiversity – Biodiversity of Eastern Ghats and western ghats.
15. Endemism - categories of endemism. Rarity and Extinction of species - causes of extinction - Rarity of species - threat values of species - categories of existence.
16. Biodiversity conservation - co ncept of minimum viable population - population viability - Genetic drift - sexual reproduction - migration and gene flow.
17. *In situ* conservation - species that matters - species target for *in situ* conservation - forest trees - medicinal plants - National parks - sanctuaries - Biosphere reserves - reserved and protected forest - reserved trees.
18. *Ex situ* conservation - role of botanic gardens in conservation - issues in wild species conservation *ex situ*.
19. Sacred grooves – Role of sacred grooves on biodiversity conservation.
20. Biodiversity assessment – Modes and methods Practical Schedule
21. Studying and laying of quadrats
22. Vegetation analysis using transects.
23. Determination of relative density - abundance - frequency and Importance Value Index (IVI) calculation in forest.
24. Determination of Shannon Weiner Index.
25. Forest productivity - Bomb calorimeter - Harvest method.
26. Forest productivity - Gas exchange method - Radioisotope method
27. Forest productivity - LAI method - Chlorophyll estimation
28. Recording and monitoring plant succession through quadrats.
29. Recording light transmission in forest relative to open fields
30. Recording humidity and soil moisture inside forest and open fields.
31. Vegetation as site indicators - species in relation to different soils.
32. Recording litter fall, decomposition and soil microfauna.
33. Characterization of soil under different forest relative to openfields.
34. *Ex situ* conservation - visit to botanical garden.
35. *In situ* conservation - visit to Nilgiris biosphere reserve
36. Regeneration survey following mild fire in quadrats
37. Final Practical Examination Assignment
38. Qualitative characters of Vegetation
39. Population Ecology
40. Desert Ecosystem
41. Carbon Budgeting in Ecosystem
42. Production Ecology
43. Forest and Climate change
44. Forest Disturbances – Biotic and Abiotic factors
45. Fire Management
46. Ecological Modeling
47. Biodiversity Conservation – Old and modern methods
48. IUCN categories of species extinction

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2. [www.fbva.forvie.ac.at/inst3](http://www.fbva.forvie.ac.at/inst3)
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4. ces.iisc.ernet.in/hpg/cesmg

ECOLOGICAL ADAPTATIONS AND EVOLUTION (POPULATION ECOLOGY)

The Species Concept

Population is defined as a group of individuals of one species. This naturally leads us to discuss what constitutes a species. The term species could be defined either on morphological or on biological species may be defined as a group (of living organisms) whose constituent individuals show overall resemblance and have more characteristics in common with one another, than with a member of any other such group. To qualify as a species the group should also have some degree of persistence in time. However, this definition, though it may serve the objectives of a biological species which was defined as, groups of actually or potentially inter-breeding individuals which are reproductively isolated from other such groups, was evolved in the nineteen forties.

Population characteristics

The accent in the definition of a biological species is on the inter- breeding of the individuals, which form the species. The inter-breeding may be actual or potential. Thus, in theory, for example, all sal trees, whether they are growing in the sub-Himalayan belt of north India, or on the Maikal hills of the central India, would form one population. We cannot, however, take into account such a large population in any kind of analytical study.

In practice, therefore, a population is simply all of the organisms of the same species found occupying a given space (Odum, 1963). A population defined in such a manner has the following attributes:

1. Density, i.e. number of individuals that occupy an unit area
2. Natality, i.e. the rate at which new members are added to the population by reproduction
3. Mortality, i.e. the rate at which members are lost on account of death
4. Dispersal, i.e. the rate at which individuals immigrate into the population and emigrate out of the population. This attribute applies only to animals. Plants do not have this attribute as they are sessile organisms, not capable of movement
5. Population growth rate, i.e. the combined effect of mortality, natality and dispersal on population
6. Dispersion, i.e. the pattern of spatial distribution of individuals, three kinds of distribution are possible: (a) random distribution, i.e. there is no pattern in distribution of individuals, (b) uniform distribution, i.e. there is a more or less regular pattern of distribution, (c) clumped distribution,

i.e. individuals occur in a mass on some spots and do not occur at all on others. This kind of distribution mostly occurs in nature

1. Age distribution, i.e. population is divided into age classes, the proportion of various classes depending on the inherent character of the species as well as on the environment factors
2. Genetic characteristics, i.e., adaptedness, reproductive fitness and persistence of the species

Growth characteristic of populations

A population can grow in two ways. First, it may grow in exponential fashion, i.e. population X becomes X2 after the end of first interval, X3 after the second, X4 after the third and so on. This kind of growth is depicted by a J-

shaped curve. In this form the growth comes to an abrupt halt when some limit, like the depletion of a resource, is encountered. After the halt, population density usually declines until conditions for another phase of rapid growth come about.

In the second, if population density is plotted against time a ‘sigmoid’ or ‘logistic’ type of curves results. This curve has three distinct phases, the initial phase in which population size increases slowly, this phase corresponds to what is known as lapse time; the second phase, is associated with rapid exponential growth and is known as logarithmic phase; the third and the last phase indicates the gradual falling of population growth, till eventually the rate of fall becomes zero and the population density stabilizes.

It would be seen that the initial two phases both the growth forms are similar. The phase of exponential growth represents the biotic potential of the population. The biotic potential is the maximum capacity for growth exhibited by a population. The abrupt halt and decline in population in the first form of growth, and reaching of a steady state in second is caused by what is known as environmental resistance. Environmental resistance is the restriction of population growth through interaction of one of more environmental factors. Reaching of the steady state in the second form of population growth suggests that biotic potential is balanced by environmental resistance. The magnitude of the upper stable population level in this form of growth is called the carrying capacity, the maximum number of a given species that can be supported indefinitely by a particular environment. Factors that limit population growth may be density dependent which include competition and predation, etc., or density-independent which include adverse climatic or edaphic conditions.

Mathematical expression of biotic potential and environmental resistance Biotic potential of a population is reflected in its intrinsic rate of natural

increase, r, i.e., the instantaneous rate of increase per individual of a population under a given set of environmental conditions, assuming that the effect of changes in population size can be ignored. The intrinsic rate of natural increase is contained in the expression:

dN

-------- = rN (1)

dt

where N is population at time t, and the differential

dN

------ denotes the population growth rate dt

If the differential equation is integrated the form obtained is Nt = Noert (2)

where Nt – Number of individuals at time 5 No – Number of individuals at time zero

e – Base of natural logarithms, i.e. 2.718

The expression (1), in fact, is the equation for exponential growth and will be modified if the population growth becomes subject to some kind of environment resistance at some point of time. If environmental resistance factor is indicated by letter ‘K’, the rate of population will be given by the equation.

dN (1 – N)

------ = rN ----------

dt K

‘K’ in the equation is a constant indicating the population size at which some limiting substance or factor or a combination of the two prevents further increase in the population. ‘K’ in essence expresses the concept of carrying capacity.

Population interactions

The size and health of populations are controlled not only by abiotic factors of the environment, but also by interactions among the individuals of the population as well as by the interactions with members of other populations. The interactions may be negative or positive depending on whether they are harmful or beneficial to the interacting individuals belonging to two different populations, may either belong to the same trophic level or different trophic levels. However, whatever may be the kind of interaction, it contributes to evolutionary process as well as influences population dynamics, energy flow and diversity and stability of ecosystems.

Competition

Competition is the striving of two individuals for the same resource, which is not available in a quantity or manner so as to satisfy the needs of both. When the competition takes place among individuals of the same species, intraspecific competition, it serves the purpose of regulating the population density and preventing over-crowding. The individuals of relatively low vigour are eliminated. In a way, what is lost in quantity is made up in quality, as those surviving the competition are healthier and fitter than those who are eliminated. Intraspecific competition in plants takes place at all the stages: sapling, seedling, pole and tree. It may take place even before a seed sprouts.

The competition for scarce water or any other environmental factor may prevent the sprouting of many seeds. In arid zones, we find plants naturally widely spaced.

The interspecific competition has much more ecological significance. If the competition between two populations at the same trophic level is very intense, two situations are possible. First, one population decisively loses and may head for extinction, or, secondly, one or both are modified by selective adaptation so as to minimize the degree of competition between them.

Interspecific intense competitions are governed by what is known as the competitive exclusion principle. The principle states that strongly competing species cannot coexist indefinitely.

The concept of competitive exclusion may be understood from the differential equation for exponential growth of population given earlier:

dN

------ = rN

dt

We noted that exponential growth does not continue indefinitely and at some point of time some environmental factor intervenes and retards the growth rte. The environmental resistance factor, denoted K, the carrying capacity and representing shortage of some resource eventually reduces ‘r’ to zero.

If two species are dependent on the same resource, the losing species will reach the stage of zero growth before the other. If the winning species continues to increase its population, the growth rate of the losing species will attain a negative value and will, if the situation does not change, get extinct.

Predation

The predator can have three kinds of influences on the prey population:

1. It can have limiting effect on the prey population and in extreme cases reduce the prey population to the situation of extinction
2. It can have a regulatory effect on the prey population, and does not allow it to grow beyond the carrying capacity of the habitat
3. It can have an indifferent effect on the prey population, which is neither limiting, nor regulatory

Parasitism

Though in forest ecology, predation is more relevant in relation to animal population, and parasitism in relation to plants species, there are similarities in the two types of interactions. Like that of the predator on the prey population, the influence of the parasite on the host population could be either limiting, regulatory or relatively unimportant. No definite example of a parasite regulating the host population is known in Indian forestry. However, the beetle, *Hoplocerambyx spinicornis*, commonly known as sal heartwood borer, has had a nearly limiting effect on sal population in some localities. Sandal (*Santalum album*), the only important Indian tree species, which is parasitic on other plants, has a relatively insignificant effect on the host population.

Positive Interactions

Positive interspecific interaction can take three forms:

1. Commensalism in which one population benefits another, but is not itself significantly affected by the interaction. Orchids grow on trees, the former are benefited, while the latter are not seriously affected
2. Photocooperation in which two populations benefit each other, but do not play any significant role in each other’s existence
3. Mutualism in which association of two populations is vital for the existence of the either

Mutualism is not only most common, but also most significant in forest ecology. The mutualism between legumes and nitrogen fixing bacteria and between some conifers and mycorrhiza are the outstanding examples.

Population evolution

On this earth, the physical environment, i.e., climatic and edaphic conditions, varies enormously over space. To meet their needs of energy and matter from different environments organisms have to be different in their characteristics. The response of organisms to variation in physical environment accounts for diversity at the level of species, as well as below the level of species. Variation, however, either at the level of species or below the level of species, known as infraspecific variation, is not all accounted for by response of organisms to physical environment. It is substantially accounted for by what is known as biological evolution, which includes processes of natural selection, adaptation, reproductive isolation, and speciation, which we will define and discuss detail in the text to follow.

However, briefly, biological evolution is the change in the genetic makeup of a species or population over time. Biological evolution takes place, because all the individuals of a population, despite their overall similarity, are not cent per cent alike. They differ from each other in their genetic constitution (genotypes) and as a consequence, in their behavioural, physiological and morphological characteristics (phenotype). Different individuals in a population

have different capabilities to survive and reproduce in a given set of environmental conditions. This difference in survival and reproduction capabilities results from the genotypic variation in individuals. The genotypes that have the best survival and reproduction capabilities are obviously the best adapted to their environment and will make the large contribution to the next generation. If, however, the environmental change over time, the genotypes which were the best adapted and the fittest before the change, many not prove to be so after the change. Different genotypes will qualify as the fittest and the best adapted in the changed environment and these genotypes will produce the most off-spring. As a result, the genetic make-up of the population will change, or, in other words, evolution will take place.

The brief description we gave above, clearly indicates that evolution results from, first, natural selection, i.e. differential reproduction of genotypes resulting in preservation of some genotypes and elimination of others and secondly from adaptation, i.e. change in characteristics of organisms so that they become better suited to the environment.

Charles Darwin, the father of the evolutionary theory, used the expression descent with modification to describe evolution. The phrasels, indeed, the most succinct description of the evolutionary theory.

Genetic variation and genecology

Populations of a species which has a wide distribution, show spatial variation in their morphological and physiological characters, such as rate of growth in height and diameter, resistance to attack by insects and diseases, the number and size of branches, season of flowering and fruiting and periodicity of seed crops, etc. Much of this infraspecific variation (i.e. the variation between

the populations of the same species) can be correlated with habitat differences. The component, of variation, which is not due to plasticity, i.e., influenced by environment, is attributed to heritability, i.e. it is genetically controlled.

The branch of ecology which pertains to study of infraspecific variation of plants in relation to environment is called genecology, a term originally used by Tueresson (1923). Genecology is a synthetic discipline evolved from the disciplines of taxonomy, genetics and plant physiology. However, genetics is the component, which dominates genecology, as genecology is chiefly concerned with the action of natural selection in moulding locally adapted populations from the pool of genetical variation available to the species as a whole.

Basic genetic concepts

The genetic material in an organism may be described by four elements: deoxyribonucleic acid (DNA), codons, genes and chromosomes. DNA is the main carrier of genetic information. DNA molecule consists of two spiral strands, which are held loosely by hydrogen bonds. Each strand is composed of four organic bases, viz., cytosine, guanine, adenine and thymine and attached sugar radicals. One such organic base, and its attached sugar radical is called a nucleotide. The nucleotides in a strand are tightly held together by phosphate radicals.

Codon is a group of three nucleotides, it forms the unit of genetic code. Gene is the basic unit of heredity, which controls a particular inherited character. It occupies a fixed position on a chromosome and consists of a portion of DNA molecule.

Chromosomes are the carriers of genes. They are rod-like or thread-like structure, which in great majority of sexually reproduced organisms occurs, in

homologous (i.e., carrying the same kind, though not necessarily identical genes) pairs in the nucleus of animal and plant cells. Chromosomes are called so because of their affinity for particular colours. The organisms or cells having chromosomes in homologous paris are known as diploids, and the condition of being diploid is known as diploidy. Some species are polyploids even, i.e. they have three or more sets of chromosomes.

In simplest situations, two genes, located at similar positions in homologous chromosomes, control a character of an organism. A gene occupying a particular position on a chromosome may have two or more alternative forms. Any of such alternative forms of a gene is known as allele.

Genetic variation

The number of ways in which the sub-components of DNA may possibly combine to form genes is enormously large. The multiplicity of the ways in which the combination of DNA sub-components may occur, and the fact that genes may exist in two or more allelic forms, are the factors that brings about natural variation in populations. Various processes that may lead to variation in the genotypes are mutation, introgression, recombination and random genetic drift. They are briefly described below:

Mutation is a sudden heritable change in the genetic material. Most often the term refers to change in a single gene by duplication, replacement or depletion of a number of DNA pairs. Recombination is any process that gives rise to new combination of genes. Introgression is the spreading of genes of one species into the gene pool of another by hybridization and back crossing (a crossing between a hybrid and either of its parents).

Genetic drift is a change in gene frequency (the ratio of the occurrence of one allele of a gene in a population to the combined occurrence of other alleles of the same gene) and population characteristics due to chance rather than selection. It is usually most pronounced in small populations. Genetic drift removes genes from the population, but cannot add them and so the general result is loss in genetic variability.

Phenotypic vs. Genotypic Variation

We noted in an earlier paragraph that variation in populations has two component: first on account of plasticity, i.e. phenotypic variation and secondly on account of heritability, i.e. genotypic variation. Phenotypic variation is the variation in form, function and behaviour that results from the interplay of limiting factors on genotypes during the development of individuals. Much of the phenotypic variation is reversible, i.e. vanishes when the limiting factor that has caused the variation withdraws. Genotypic variation is irreversible.

Phenotypic variations in animals and plants do not form the basis for the systematic classification of biological diversity. Only genotypic variation, whether it is recognized or presumed, is taken into account in classifying biological diversity.

Infraspecific categories

In nature we often encounter the phenomenon that a local population exhibits genetic variation, which is only a portion of the whole range of variation exhibited by the species to which it belongs. Such local populations of a species, which are confined and adapted to particular and definable environmental conditions, are known as ecotypes. Tree species, which occur

across an environmental gradient with significant changes in some environmental factor, may be fragmented into ecotypes. Unlike different species which normally cannot interbreed, different ecotypes are capable of interbreeding. The resultant offspring are often more vigorous than either parent. The phenomenon is known as hybrid vigour.

A group of ecotypes constitute what is known as an ecospecies. An ecospecies is formally defined as a group of populations or ecotypes having capacity for free exchange of genetic material without loss of fertility or vigour, but having a lesser capacity for such exchanges with members of other ecospecies groups. The concept of an ecospecies leans as it does upon a genetical criterion, closely approximates that of a biological species.

The term race is often confused with ecotype. Race is a more general term than ecotype. Race is defined as an intraspecific category characterized by conspicuous physiological, biological, geographical or ecological properties. Ecological race is synonymous with ecotype. In plants another infraspecific category, known as cytotype, often occurs. Cytotype is a sub-specific variety that has chromosome compliment differing from the standard for species, either in chromosome number or structure. For example, the cytotype of diploid species may exhibit triploidy, i.e. may have three sets of homologous chromosomes. An important point about cytotypes is that different cytotype may or may not exhibit easily observable variation in physiological and morphological characters.

Infraspecific variation may be either continuous, i.e. change in character of a species takes place gradually along some environmental gradient, or

discontinuous i.e. changes take place abruptly. In 1939, J.W. Gregor suggested following definitions to the terms connected with infraspecific variation.

Cline –any gradation in measurable characters

Ecocline – a cline apparently correlated with an observable ecological gradient.

Ecotype – a particular range on an ecocline

However, in general usage, term ecoclinal refers to continuous variation and ecotypic to discontinuous variation. In nature, a species may exhibit genetical variation over space in any of the following forms:

1. The species may be differentiated into ecotypes associated with different kinds of habitats within its zone of distribution and within an ecotype there may be an ecoclinal variation adaptive to gradually varying environmental factors
2. The species may exhibit an overall pattern of ecoclinal variation, but have local variation of ecotypic kind
3. Conversely, the species which exhibits an overall pattern of ecotypic variation, may have local variation of ecoclinal nature
4. The overall pattern of variation in the species may be either of ecotypic or ecoclinal pattern, and the local variation may be ecoclinal in general ecotypic pattern and ecotypic in ecoclinal pattern

Selection pressure

In a population, nature tends to favour the reproduction of those genotypes who are best adapted to the existing environmental conditions. Genotypes not well adapted to the environment are eliminated. The process that brings about non-random (i.e. not associated with chance) and differential

reproduction of genotypes which results in preserving favourable variants and eliminating less favourable variants, is known as natural selection. An environmental factor that forces natural selection is called a selection pressure. The expression, selection pressure is also used to denote the intensity of natural selection, intensity being measured as the degree of alteration of the genetic composition of a population in passage from one generation to the next.

If a population is not subject to any selection pressure, a state of constant gene frequencies is likely to be maintained. Gene frequency, as we defined earlier, is the proportion of any allele to the total of all alleles at the same locus (position of a gene on a chromosome) in the gene pool of the population. The situation of constant gene frequencies is known as Hardy- Weinberg equilibrium. The maintenance of Hardy-Weinberg equilibrium in absence of any selection pressure or mutations is explained by the fact that each alternative form of a gene which we call an allele, has arisen in the past by mutation and unless further mutations are taking place or selection is increasing or lowering the representation of particular alleles in successive generations the gene frequency for any particular allele will remain unchanged. A situation contrary to Hardy-Weiberg equilibrium indicates occurrence of mutations, or selection pressure or both.

The operation of natural selection on a population may result in one of the following situations: new patterns of variation may be created, and/or the diversity of genotypes may be reduced. Whatever may be result, however, natural selection always leads to more fitness.

Types of selection

The process of natural selection may be of three types stabilizing, directional and disruptive. Stabilizing selection takes place when physical environmental conditions remain stable. In this kind of selection, genotypes giving rise to mean or intermediate phenotypes, which are obviously the optimum type in the prevailing environmental conditions, are selected and peripheral variants are eliminated. This kind of selection reduces the range of genetic variation in the population.

Directional selection occurs in changing conditions of physical environment. It is directed towards finding the genotype, which may develop into the phenotype optimally adjusted to the new environmental conditions. This kind of selection leads to a directional shift in gene frequencies of the character most relevant to the attainment of the optimally of the population in the changed conditions of environment.

Disruptive selection may be considered as a process opposite to that of stabilizing selection, as it tends to enhance the range of genotypic variation in a population. In this kind of selection genotypes giving rise to extreme phenotypes are favoured for retention and those developing into intermediate phenotypes are eliminated.

In a forest ecosystem competition from other tree populations promotes stabilizing selection, which reduces the variety of genotypes by favouring the most competitive ones. On the other hand, spatial variation in physical factors in a locality normally leads to disruptive selection, which increases the number of genotypes in a local population. In summary, we may state that natural

selection is the process, which leads to systematic differences in survival and reproduction and takes place on account of the following:

1. There is morphological and physiological (and behavioural also in case of animal populations) variation in individuals comprising a population. Much of the variation is inherited
2. Populations have the potential to grow exponentially, but on account of limitations imposed by their biotic and abiotic environment, they do not grow indefinitely. All the individuals which are born do not survive and some die prematurely
3. Some inherited characters enhance the chances of survival and reproduction of individuals. As a result, the descendants of these individuals, because they too have these characters, make progressively increasing proportion of the population in future generations

Genecological differentiation

Having discussed selection, we might define the term genecological differentiation, which is often used as a synonym for infraspecific or inter- population variation. Inter-population variation in a plant species may arise from three major sources: (i) plastic modification of individuals, (ii) genetical divergence as a result of selection and (iii) genetical divergence resulting from some fortuitous event. The variation arising from (ii) is referred to as genecological differentiation. We may summarize the subject of infraspecific or inter-population variation with the help of the following diagram:

Genetic

Non-random (Resulting from selection)

Infraspecific variation

Adaptation

Plastic

(non-genetic)

Fortuitous

The process of selection, whatever be its type, stabilizing directional or disruptive, leads to what is known as adaptation. Adaptation may be defined as a genotypic change in a population, which improves the chances of its survival and growth.

The term adaptation is often incorrectly used to describe those changes which take place within the lifetime of individuals in response to changes in physical environment. The term acclimation, and not adaptation, should be used to describe changes, which are not inherited. The term adaptation should be used to describe only permanent and inherited changes, which have arisen in a population over long periods of time by means of natural selection.

In general, adaptive changes in a population depend upon the cumulative effect of minor genetic changes, mutations, under the directive action of selection. In adaptive changes, a compromise takes place between fitness for the existing environment ad flexibility, which will allow further adaptive changes. Fitness is achieved by reproduction of genotypes best suited to prevailing environmental conditions and flexibility, by continuous creation of

new genotypes some of which may be optimal for environment to be encountered in future.

In controlling and improving adaptations to the environment, diploidy is a big advantage to plants and animals. In enables them to test mutations, which as a rule appear as recessive (non-expressed) traits to begin with. They can be carried through many generations as a “genetic load” before they are eventually eliminated, or taken by the whole population, if instead of being harmful, they become beneficial in some new environmental situation.

Genetic tree improvement programmes are in fact attempts to induce adaptations. These programmes in a way mimic natural selection of stabilizing kind and produce a population of very similar, well adapted genotypes which under conditions to which they are adapted, will grow, compete and reproduce successfully. But if environmental conditions were to change suddenly and become unfavourable to these very similar genotypes, they will all be eliminated. It is, therefore, not only desirable, but also necessary that certain degree of variability is aimed at in man-induced adaptations.

In an earlier parameter we discussed interbreeding of different ecotypes. Hybrid populations normally have more variation than do the parent populations. On account of enhanced variability, the possibilities of selecting new and fitter combinations of alleles are increased. Hybridization, therefore, increases the potential for adaptation and consequent evolution.

Speciation

If the physical environment of a particular ecosystem is subject to rapid changes, new forms evolve by adaptation, which have often to be classified as new species. In other words, adaptation leads to speciation, which is defined as

the process by which new species are formed. Two kinds of speciation take place: branched speciation and graduation. Branched speciation is the process by which a single species branches down to form two or more new species. Graduation is the process by which a species changes gradually over time.

Isolation

It is held that selection pressures and consequent changes in the gene frequencies of particular populations are by themselves incapable of bringing about speciation. For speciation to take place some degree of isolation is also necessary. Isolation means the separation of two populations so that they are prevented from interbreeding. The most pronounced from of isolation is that brought about by geographical barriers between the allopatric (inhabiting separate areas) segments of once sympatric (inhabiting the same area) populations.

However, sympatric fragmentation of a species cannot be obviously explained by geographical separation. Various mechanisms (morphological, phonetic, physiological and cytological) have been suggested to explain sympatric fragmentation of a species. Two examples of the isolating mechanism are given below:

Polyploidy – A tetraploid can cross with a diploid to produce triploid. Triploids are normally sterile and do not form pathways by which tetraploids and diploid plants can exchange genes.

Differences in flowering time – If some kind of mutation produces early flowering genes in one part of the population and late flowering genes in the other part, after several generations the difference in flowering time may be big enough to prevent interbreeding in the two parts of the population.

Evolution

Evolution is the adaptive modification of organisms through successive generations. It involves a change in gene frequencies with time. The mechanism by which evolution occurs is basically natural selection. The steps that lead to evolution are: change in abiotic or biotic environment of organisms, selection, adaptation and finally evolution. Individuals vary. Some have characteristics, which suit the existing environment; others do not. Those individuals, which are best, suited, contribute most to the next generation, because they survive longer and reproduce most. Thus, the percentage of individuals with favourable characteristics will increase with every succeeding generation and the percentage of individuals with unfavourable traits will decrease. Evolution, therefore, to put it simply, is a change with time in the proportion of individuals in a population, possessing some favourable hereditary factor, or gene.

It should be noted however, that evolution is a process associated with populations. Individuals do not evolve. They, depending on their genetic constitution, only live a long or short age, and produce more or less offspring.

Evolution is not brought about only by abiotic factors of environment. Living organisms also cause environmental differences, and thus influence natural selection. Shade tolerant plant species evolved only on account of the existence of shade causing trees.

Intraspecific and interspecific competitions have also played an important role in evolution. To illustrate the point, we may consider the example of herbivores and plants they eat. Some plant species will be more palatable and nutritious to herbivores than the others. The less palatable ones

will have a greater chance of survival and reproduction. Thus, over generations, there will be considerable increase in vegetation, which is not suitable for herbivores. This in turn, however, may cause selection pressure on herbivores, leading to increase of those genotypes in them, which can survive on unpalatable vegetation. Thus selection pressures will be alternately felt by plant and animal population. This alternating evolution of two species in face of mutual selection pressures in known as coevolution. Coevolution is an important phenomenon. This has led to many organisms in an ecosystem becoming so dependent on each other that the survival of one depends on the existence of the other. The mycorrhizal association of trees and fungus is an excellent example.

The rate at which evolution can take place is highly variable and largely depends on the frequency and abundance of sexual reproduction of the populations concerned. An insect population with a dozen generations a year will genetically change much faster than a tree population, which may have just one population in a century. Human intervention acts as a powerful agent in accelerating the rates of evolution. Use of pesticides places selection pressures on pest species. As a result pests frequently evolve new genotypes, which are resistant to the chemicals used as pesticides.

Two theories

There are two theories about evolution, one of gradualism and the other of punctuated equilibria. The theory of gradualism holds that evolution takes place in small steps, while that of punctuated equilibria suggests that evolution occurs in a series of rapid steps broken by long periods of little or no change. Most commonly, however, as Darwin envisaged, evolution occurs in small

stages and in particular directions. When these stages tend to reduce the diversity shown by populations, within a community, they are known as convergent evolution and when they lead to greater diversity, they are called adaptive radiation. An example of convergent evolution may be cited from desert ecosystems where most of the flowering plants are succulent in nature. Relatively large monkey species in tropical rain forests is an example of adaptive radiation.

ECOLOGY IN RESOURCE MANAGEMENT

Origin of ecology

The father of the world ‘ecology’ was Ernst Haeckel, a German zoologist. He derived it from the Greek words ‘oikos’ and ‘logos’ and spelt it Oecology. ‘Oikos’ means house and ‘logos’ study of. Ecology thus means the study of the house or the habitat of an organism, a living animal or plant. The term ‘animal’ very much includes man.

There is uncertainty about the year Haeckel first used the word, ecology. Five different years are mentioned in literature. They are 1866, 1870, 1873 and 1896. They year of the birth of the term is, however, irrelevant; what is relevant is the ‘definition’ Haeckel gave to the term. He defined ecology ‘as the science that treats reciprocal relations of organism and the external world’. The Concise Oxford Dictionary defines ecology as “the branch of biology dealing with organisms” relation to one another and to their surroundings. Today, it is no longer valid that ecology is a branch of biology, though it developed as such. Currently, ecology is an integrated discipline covering much more of a field than

biology does. We shall revert to this later. At the moment we shall look at some other definitions of ecology.

Definition

Elton (1927) defined ecology as “the study of animals and plants in relation to their habits and habitats”. Odum (1971) defined it as the “scientific study of the structure and function of nature”. The latest definition has come from Krebs (1978). He defines ecology “as the scientific study of interactions that determine the distribution and abundance of organisms”.

Prima-facie, the definition given by Odum, is a little vague, as the word ‘nature’ does not have a precise meaning. However, he makes his intension very clear when he states: “it is understood that mankind is a part of nature” and picks a definition of ecology from Wester’s Unabridged Dictionary. The dictionary definition he quotes is ”the totality of pattern of relations between organisms and environment”. By nature, Odum means all kind of life and that part of earth where life is possible. Perhaps the most comprehensive definition of ecology is that given by Kimmins. He defines ecology as “the branch of biological science concerned with the distribution, abundance and productivity of organisms and their interactions with each other and their environment”.

Thus it is obvious that the key word in the definition of ecology is relationships or interactions and the discipline of ecology involves an integrative rather than a reductionist approach in its theory and practice. Most of the sciences adopt a reductionist approach for the simple reason that nearly all the situations in the real word are so complex and diverse that it virtually becomes impossible to make an enquiry about the whole and studies are mostly made in relation to the parts. Unfortunately the sum of the parts does not make the

whole and a holistic approach becomes a must if the enquiry is directed towards phenomena, which occur as a single system.

The word system implies an aggregation of parts or occurrences which are linked together in such a way as to form a functional unit or a unified whole. In a system any change in one of its parts will have its effect on the other parts also. Biosphere, i.e. the part of the earth where life is possible, works as a system. It is the biggest system and is at the top of a hierarchy of biosystems (i.e. systems which have both living and non-living components).

Hierarchy of biosystems

An understanding of the hierarchy of biosystems is necessary to appreciate fully the scope of ecology. However, before we draw the hierarchical chart we might introduce the terms used in ecology to describe various levels of biological organizations.

Level Description

Organism An individual plant or animal Population A group of individuals of one species

Community The sum of populations of different species within a given area

Ecosystem The sum of the communities & the non-living environment Biosphere The sum of all ecosystems

Table. Levels of biological organization

|  |  |  |  |
| --- | --- | --- | --- |
| Living (Bio) component (+) | N O N  L I V I N G  E N V I R O N M E N T  (GEO) | (=) Resultant Biosystem | Discipline  concerned with the enquiry |
| Genes | Genetic Systems | Genetics |
| Cells | Cell Systems | Cytology |
| Tissues | Tissue Systems | Histology |
| Organs | Organ Systems | Anatomy |
|  |  | Physiology |
| Organisms | Organismic Systems |  |
| Populations | Population Systems | Ecology |
| Communities | Ecosystems |  |

The interactions between biological units of various levels with their non- living surroundings or environment result in a hierarchy of biosystems. The situation is elaborated in the following table. The table also indicates various disciplines concerned with scientific enquiries at various levels of biological organization

The table makes it obvious that ecology is concerned with organisms, populations and communities. Biological organizations lower than the level of organism are dealt wit by other sciences.

Sub-divisions

The science of ecology has many sub-divisions and each sub-division is related to a different level of biological organization:

Autecology : Study of an individual organism, life history of the

organism and it response to the environment

Population ecology : Study of abundance, distribution and/or dynamics of a group of organisms of same kind

Synecology (community ecology)

: Study of properties of a community, i.e. a natural assemblage of different species of organisms

Ecosystem ecology : Study of an ecosystem, biotic community and its

abiotic environment

However, there has been a lot of flexibility in the use of the four terms. The term ‘autecology’ is very often used to cover population ecology also. If unqualified, ecology may mean either synecology or ecosystem ecology. Further, many a modern ecologist believes that the division of ecology into autecology and synecology is not very valid. They would like to separate ecology into such sub-disciplines as population ecology, community ecology, evolutionary ecology, environmental ecology, behavioural ecology, marine ecology and human ecology. The latest of the sub-disciplines identified is radiation ecology or radioecology.

In addition to the two approaches to sub-division of ecology given above, another approach is possible, which is perhaps, more basic in nature. Three basic kinds of biosystems are those related to land, fresh water and oceans. In each of three kinds, living systems can be studied under the sub-disciplines of microbiological ecology, botanical ecology and zoological ecology. Thus there would be nine sub-disciplines in all. The situation is summed up in the following chart:

Microbiological ecology

Land

Botanical ecology Zoological ecology Microbiological ecology

EARTH Fresh Wate~~r~~

Botanical ecology Zoological ecology Microbiological ecology

Ocean

Botanical ecology Zoological ecology

Relation to economics and other sciences

Ecology links together the physical, biological and social sciences. Ecology has close relations with economics also. Primafacie, ecology is as different from economics as agriculture from aeronautics. In reality it is not so. The term economics has the same root as the word ecology. The parentage of the term economics also is traced to the Greek word ‘oikos’. Literally, economics would mean house keeping or distribution of resources in the household. Thus, if ecology relates to the functioning of the household of man, i.e. this earth, economics deals with the production (availability) and distribution of the resources in the household.

Not only are the fields of enquiry of the two disciplines intimately linked, the moral of the resultant findings is also the same. The household functions as a system. The various components of the household are interdependent. If one component is damaged, the other will not function properly too. Indeed, the importance of both ecology and economics lies in their integrative approach.

And the integrative approach draws its vitality from what is formally known as the principle of integrative levels.

Principle of integrative levels

Odum stated the principle as follows: “as components combine to produce larger functional wholes in a hierarchical series, new properties emerge”. The principle is not based on any new concept. The principles is only re-stating of the old sayings that the “whole is more than a sum of the parts” and a “forest is more than a collection of trees”. A good example of the principle of integrative levels is the formation of glucose (C6H12O6) by the combining of atoms of carbon, hydrogen and oxygen. The properties of glucose are totally different from any of the constituting elements.

From natural phenomena, the example of tropical rain forests is very striking in the context of the principle of integrative levels. Soils, which support tropical rain forests, are themselves poor, but their interaction with vegetation enables them to support luxuriant many storeyed forests. Many a people learnt the hard way that conversion of tropical rain forests into agricultural lands is an enormous folly. Without forest vegetation, those soils are poor and cannot sustain permanent agriculture. A harmless insect turning into a pest, and a useful plant turning into a weed when removed from their natural habitats, can only be explained by the principle of integrative levels. In their natural environments the insect of the plant was a part of the system and there were mechanisms in the system, which controlled its behaviour. In the absence of controlling mechanisms in the new environment it turned harmful. *Lantana camara* is a good example. It is a dreaded weed in India but a harmless population in its native Latin America.

Development of ecology

Ecology in its latest form as a study of living systems is of relatively recent origin. The earlier studies were either experimental, or observational and analytical in their approach. Moreover, in the earlier stages, ecological studies had proceeded on two divergent channels. One channel was animal ecology which adopted an experimental approach and was concerned with the effect of environmental factors on animal populations. This channel eventually grew into the sub-discipline now known as autecology.

Strangely, about the middle of this century the two channels began to converge. Plant ecologists gave up their observational and analytical approach and animal ecologists, their experimental approach. They both began to adopt the systems approach in their studies. It was, perhaps, the change in approach of ecologists that prompted Odum to define ecology as the study of ecosystems.

A systems approach in essence lies in formulating models, i.e. simplified versions of the situations in the real world. In models, less important attributes of the real world are omitted; only the most important properties and functions are included. Models which may be verbal or graphic, help in understanding the complex phenomena of the real world, and enable the ecologists to make predictions about a particular intervention in a natural system.

Importance of ecology

Beginning from the late fifties, ecology has rapidly grown into importance chiefly on account of three reasons: first, population explosion resulting in over taxation of natural resources, both renewable and non-renewable; secondly, march of technology which often ignored biological laws and finally, emergence of an extravagant pattern of consumption which allowed littler or more-cycling

of waste products. The three factors enumerated above led to the scarcity of natural resources, decrease in productivity of biological systems, which sustain man and his domesticated animals, deterioration of climate, and pollution of soil, water and air.

The environmental degradation made man realize with some degree of panic than with his advanced technology he has not made his species an exception and achieved any special exemption from the biological laws, which govern other species. This realization made him search for the natural laws which he had to comprehend and follow if he desired to survive on the earth. The search led him to the field of ecology. With the help of the science of ecology, man came to appreciate than in the use of living systems with interdependent components he could not afford to take a fragmented view. He could not sustain the use of a living resource if he managed it on the basis of the knowledge of some part or parts only. For example, effective and proper management of forests cannot be achieved if it were to be based on the knowledge of tree populations. For good management, a forest is to be studied as an ecosystem.

Growing human population has also warranted that increasing biological production is obtained from smaller areas. This requires management of the highest quality, which can take place only if it is based on a comprehensive understanding of the ecological relationships that govern a biological system.

Modern dilemma of ecology

Panic caused by rapid environmental degradation in recent decades, has led many a people to enlarge the scope of ecology beyond reasonable proportion. Ecology began to be used as synonym for the environment itself, let alone that

for environmental science. People began to assume that ecology was the theoretical Messiah, which would deliver them from all environmental ills. They began to believe that political and socio-economic decisions should be entirely based on ecology.

Indeed, socio-economic decisions should seriously take ecology into account. But ecology is certainly not the only source of information for good socio-economic decisions. For a good socio-economic decision, information in regard to three major areas is required. The areas are: first, natural processes, both physical and biological, that operate in the world; second, the role that technology plays in modern human society and the effect it has on the natural processes; third, the social and economic processes that govern human activity. Ecology is the science that gives information on the first area and partly on the second. The rest of the information has to come from other sciences.

It should be specifically emphasized that ecology is not a base for value judgements. A favourable decision on an activity should be made not only on its ecological soundness, but also on its social acceptability, economic viability and technical feasibility.

Forest and forest ecology

The word, forest is derived from the Lain ‘foris’, which means ‘out of doors’. The Shorter Oxford English Dictionary defines forest “as an extensive tract of land covered with trees and undergrowth, and sometimes intermingled with pasture”. In the Dictionary of Flowering Plants (1951), Willis defined forest as a closed assemblage of trees allowing no break in the overhead canopy; homogeneous of one species or diversified.

The definition of forest adopted by the British, American and Indian foresters make interesting comparison, but they all fall short of ecological standard. The definition adopted by the Society of American foresters is: “a forest is a biological community dominated by trees and other woody vegetation”. In the British Commonwealth Forest Terminology, forest is “a plant community predominantly of trees and other woody vegetations usually with a closed canopy”. In Indian Forest Records, a forest is defined as “an area set aside for the production of timber and other forest produce or maintained under woody vegetation for certain indirect benefits it provides, i.e. climatic or protective”.

In 1960, FAO made a world forest inventory and defined forest as “all lands bearing vegetative associations dominated by trees of any size, exploited or not, capable of producing wood or of exerting an influence on the local climate or on the water regime or providing shelter for livestock and wildlife”.

From ecological standards, the Indian definition is perhaps the poorest. It does no describe forest even as a living community. The description of forest in other definitions ranges from “an assemblage of trees” to a biological community dominated by trees. But all the definitions fail to describe forest in exact ecological terms. Forest is a living system and not just a community. Therefore we would like to define forest as an ecological system dominated by tree populations.

Spurr and Barnes have given a little more elaborate definition of forest ecology. According to them, forest ecology is concerned with forest as a biological community with the interrelationships between the various trees and

other organisms constituting the community and with the interrelationships between these organisms and the physical environment in which they exist.

Though general principles of ecology apply to forest ecology also, there is a difference in forest ecology and ecology of other natural resources. Forests play a productive role also. Management practices alter natural conditions in forests. In most situations, forest ecology has to deal with semi-natural rather than natural conditions. Also the subject of forest ecology is not always the climax forest community. It is often a community, which has been stabilized under the continued influence of some biotic factors. The non-climax communities which forest ecology mostly deals with have been as much influenced by human intervention as by climate and soil.

Major role of forest ecology

There is much complexity in forest systems as compared to other ecosystems, chiefly for the following reasons:

* They posses a greater number of species in a unit are than do the other ecosystems
* They are much more subject to man-caused perturbations such as fire and grazing than are other ecosystems
* They are subject to successional changes
* They show great geographical variability
* They perform multiple roles, both natural and man-imposed and often there is a conflict between their natural and man-imposed functions
* They have a significant influence on some other vital systems such as river, lakes, pastures and agricultural lands

Because of the complexity and variability of forest ecosystems, it is difficult to establish a cause: effect relationship and predict with reasonable certainty the outcome of a human intervention in the system. Forest ecology is the tool, which enables the forester to cope with this difficulty. It makes him understand the components and functional processes of the forest system and help him identify the major determinants in the proper functioning of the system.

The major role that forest ecology is playing and would play is to introduce a systems approach in the thinking of the forester. He now takes into account the effect of his actions not only on a singletree population, but also on all the components of the ecosystems, as well as on other related ecosystems.

Another important role that forest ecology would play in India, as it would do in other developing countries, is in the rehabilitation of forests which have been degraded on account of mining, shifting cultivation, excessive grazing, fire or any other external causes. If the processes of rehabilitation conform to natural biological laws, the success would be ensured, both quantitatively and qualitatively. The Forest Research Institute at Dehradun has done some excellent work in perfecting technology for afforestation of mined areas on ecological principles.

Forest Ecology, Silvics and Silviculture

Forest ecology is closely related to silvics and silviculture. Forest ecology, as stated earlier, is the study of forest ecosystems. Silviculture implies methods of raising forest crops and their care up to the time of harvesting. Silvics is the scientific basis for the practice of silviculture. British Commonwealth Forestry Terminology defines silvics as the study of life history

and general characteristics of forest trees and crops with particular reference to environmental factors as the basis for the practice of silviculture. The society of American foresters defined silvics as that branch of ecology, which treats the life history and general characteristics of forest trees and stands with a particular reference to environmental factors. In Indian forestry there is no separate definition of silvics, and it is treated as a part of silviculture.

If we consider carefully the British and American definitions of silvics, it becomes obvious that silvics is more or less a synonym of ecology. The point that needs to be emphasized is that silviculture was never an empirical practice. It always took into account biological laws. But instead of considering forest as a biological system, silviculture treated it as a biological association or community. The concepts that basically governed Indian forestry were:

* 1. A forest was not only an aggregation of trees, but a definite biological entity composed of innumerable organisms and its environment, as that of any organism, is the product of all the external conditions, which influence it.
  2. A forest is not a fixed unit, but is in a constant state of change

The point intended to be brought home is that in adopting an ecosystem approach in forest management there would be no abrupt change either in theory or practice. The forester would only be graduating from the community to the ecosystem concept.

ECOLOGY AND ENVIRONMENT

What is Ecology?

The two components of nature, organisms and their environment are not only much complex and dynamic but also interdependent, mutually reactive and interrelated. Ecology, relatively a new science, deals with the various principles, which govern such relationships between organisms and their environment.

In 1859, the French Zoological, Isodore Geoffroy St. Hilaire had proposed the term ethology for “the study of the relations of the organisms within the family and society in the aggregate and in the community”. At about the same time the English Naturalism, St. George Jackson Mivart coined the term hexicology, which he defined in 1894 as “devoted to the study of the relations which exist between the organisms and their environment as regards the nature of the locality they frequent, the temperature and the amounts of light which suit them, and their relations to other organism as enemies, rivals, or accidental and involuntary benefactors”. The term ecology was coined by combining two Greek words, oikos (meaning house or dwelling place) and logos (meaning the study of) to denote such relationships between the organisms and their environment. Thus, literally, ecology is the study of organisms at home. There is some controversy about the author who coined the term ecology and first used it in the literature. For instance, Kormondy (1969) tried to give credit for the first use of the term ecology to Henry David Thoreau in 1858. There are, however, references in literature in favour of German biologist, H. Reiter also who is said to have used this term for the first time in 1868 (Reiter, 1885; Macmillan, 1897). Although, there is uncertainty about the original coining of

the term, there is consensus that the German biologist, Ernst Hacckel first gave substance to this term. Haeckel, although appears to have first used the term in 1886 and he regarded the ecology of an organism as” …. the knowledge of the sum of the relations of organisms to the surrounding outer world, to organic and inorganic conditions of existence……” Ecology as a distinct discipline grew out of natural history early in this century as natural historians began to collect their observations into a body of theory. In this process, vital was the work of Charles Darwin. Although his book on the origin of species was published in 1859, before the term ecology was coined it contained many seeds that could grow to dominate modern ecology, ecology has been defined in various ways by different authors. Warming (1895, 1905), who actually employed this science for the study of plants, defined in various ways by different authors? Warming (1895, 1905), who actually employed this science for the study of plants, defined oekologie as “the study of organisms in relation to their environment”. American ecologist Frederick Clements (1916) considered ecology to be the science of the community, whereas British Ecologist Charlest Elton (1927) defined ecology as “scientific natural history” concerned with the “sociology and economics of animals”. Woodbury (1954) treated ecology as “a science, which investigates organisms in relation to their environment, and a philosophy in which the world of life is interpreted in terms of natural processes”. Taylor (1936) defined ecology as “the science of all the relations of all organisms to all their environments”. Ancrewartha (1961), Petrides (1968) and Krebs (1972) defined it as “the scientific approach to the study of environmental interactions which control the welfare of living things; regulating their distribution, abundance, reproduction and evolution”.

However, the recent development in study of ecology has been the recognition of the fact that the biotic (living) and abiotic (non-living) components of nature are not only interrelated but both these components function in an orderly manner as a definite system, thus structure and function should be studied together for fuller understanding of this vast nature.

In Haeckel’s definition of ecology, he refers to the “surrounding outer world”, which we now call the environment of an organism. His “organic and inorganic conditions”, we call biotic and abiotic environmental factors, respectively. Biotic factors are the other organisms encountered, whether of the same or different species. Abiotic factors are the physical and chemical conditions such as temperature, moisture, respiratory gases and substrate. Odum (1963, 1969, 1971) with such an approach put forth a new definition of ecology, and in his own (1969) words “As you know ecology is often defined as the study of interrelationships between organism and environment. I feel that this conventional definition is not suitable; it is too vague and too broad. Personally, I prefer to define ecology as “the study of the structure and function of ecosystems” or we might say in a less technical way “the study of structure and function of nature”. With more or less similar concept, put about the triangle of nature, R. Misra (1967) defined ecology as “interactions of form, functions and factors”. These three interacting aspects i.e., form, function and factors integrate together to construct the triangle of nature. Krebs (1985) defined ecology in simple modern comprehensive way, as “ecology is the scientific study of the interactions that determine the distribution and abundance of organisms”.

Scope of ecology

Ecology is the science that needs minimum time and labour for its introduction to a layman. Present day problems of varied nature in human life are directly or indirectly very much related to ecology, as their solution needs an ecological knowledge. These days ecology has been contributing very much to socio-economic, political and other similar policies of the world. It is so common to find references of ecology in socio-economic writings, magazines, weeklies and daily newspapers. There are interdependencies not only between ecology and other areas of plant sciences, but also between ecology and physical as well social sciences. Ecology indeed plays an important role in human welfare. This is primarily a field subject and modern ecology is concerned with the functional interdependencies between living things and their environment. Taylor (1936), in an attempt to define ecology, has very rightly pointed out the scope of ecology by stating that “ecology is the science of all the relations of all organisms to all their environments”. Ecology plays an important role in agriculture (crop rotation, weed control, etc.), management of grasslands (range management), forestry, biological surveys, pest control, fishery biology, and in the conservation of soil, wildlife, forest, water supplies, etc. The international problem of environmental pollution also needs ecological assistance.

Ecology – Science or Art: Its Relation to other Sciences

It is natural to think, and very often asked whether ecology is a science or an art. Before we think over the issue, we must attempt first to explain what we mean by science and art. Art is doing, science is understanding. For instance, a painter who paints beautiful picture is an artist. This is doing,

without understanding anything of the physics and chemistry of action of the pigments and oils being used in painting. On the other hand, the scientist aims to understand the glycerides in oils, their chemistry, the degree of unsaturation in the molecules etc. He does not paint the picture that the artist does. The information gathered through understanding of various principles that govern the function of nature (the science of ecology) are then applied quite surprising as how can we harmonize in one profession both, a science and an art, but it is true, and ecology, like some other science, has both, its science as well as its art. Indeed science and art go together, and are studied best together. Advancement in art depends on science, as more we shall learn and understand, newer the art would be. And it would be almost futile to investigate science unless it is applied in the development of art. Moreover, it would also be not incorrect to say that art inspires science to investigate more. For instance, if a scientist looks at any picture, he might think as how it can be made more attractive by advancement in the chemistry of pigments etc. The art of ecology developed first, which may be traced back to the period of prehistoric man. The science of ecology, like all phases of learning, developed gradually. But at present, we know much of the science of ecology, and it has helped us in the development of its art, as conservation of nature and natural resources, solution of pollution problems, etc.

As regards the relation of ecology to other life sciences, we should know first various divisions of biology. Biology, “the science of life” has its basic divisions such as morphology, ecology, genetics, evolution, molecular biology and developmental biology. These are basic divisions because they are concerned with fundamentals common to all forms of life. The various forms of

living organisms, are the taxonomic divisions of biology which deal with the morphology, physiology, ecology, etc. of specific kinds of organisms. The three large taxonomic divisions of biology are, botany (plants), zoology (animals) and microbiology (microorganisms). Other taxonomic divisions are smaller as they deal with limit group of organisms. These are mycology (fungi), phycology (algae), entomology (insects), protozoology, etc. Thus ecology is a basic division of biology and as such, is also an integral part of any and all the taxonomic divisions. Biology attempts to define and explain patterns within and among organisms at each of the following hierarchy of levels of organization:

|  |  |
| --- | --- |
| Level of organization | Basic divisions of biology |
| Organic molecules | Biochemistry |
| Subcellular organelles  Cells | Cell Biology |
| Tissues | Histology |
| Organs  Organ systems Organisms | Anatomy, Physiology |
| Populations  Communities  Ecosystems | Ecology |

Each level of organization has properties peculiar to it that are not identifiable at the levels below. But studies at higher levels must take account of the lower levels. For example, a random collection of tissues – say blood, muscle and connective tissue – do not make a heart. These tissues must interact in particular ways to form that organ. Similarly, a community may be a coherent unit (albeit much less tightly organized than a heart), which can be understood only by a consideration of the constituent populations and their interactions.

The three ecological levels of organization are somewhat distinct from one another because of the type of questions that are posed by ecologist, or rather what we actually emphasise at each level. Each ecological level and examples of the questions posed at each level and the approaches used to answer them are then described.

The three ecological levels of organization are somewhat distinct from one another because of the type of questions that are posed by ecologists, or rather what we actually emphasise at each level. Each ecological level and examples of the questions posed at each level and the approaches used to answer them are then described.

A population is a group of individual organisms of the same species in a given area. Population ecologists ask, “Why is this population of a particular density?” Answers lie in the inherent biology of the species (constraints imposed by the levels of organizations below), and the ways in which members of the population interact with their environment.

A community is a group of populations of different species in a given area. It may include all the populations in that area – all plants, all animals, and microorganisms – or may be defined more narrowly as a particular group such as the fern community, or the seed eating bird community of that area. A major concern of community ecologists is the questions, “Why is this community of a particular diversity?” Diversity is a combination of the number of species and the number of individuals of each species in a community. Another important questions is, “Why does a particular community occur at a given locations?” Answers are sought in the influences of the abiotic environment, how communities interact, and how communities change through

time. From evolutionary biology viewpoint communities are much looser assemblages than are populations and thus answers to problems at community level must be sought among the evolutionary histories of the constituent populations.

An ecosystem is the whole biotic community in a given area plus its abiotic environment. It therefore includes the physical and chemical nature of the sediments, water and gases as well as all the organisms. Ecosystem ecology emphasizes the movements of energy and nutrients (chemical elements) among the biotic and abiotic components of ecosystems. A major concern is, “How much and what rates are energy and nutrients being stored and transferred between components of a given ecosystem?” Because the ecosystem is the highest level of biological organization, all ecological concepts can be set within its framework. The biotic components of any ecosystem are linked as food chains. Food chains are interlinked to form complex food webs. Food webs are the basic units of ecosystem ecology. Thus ecology begins with populations and culminates in ecosystems.

Food webs are basic units since it is around them that energy and nutrient transfers take place. In addition to the organisms, there are also exchanges with the abiotic environment. The patterns of energy and nutrient movements differ significantly in their relationships with the abiotic environment and with the ecosystem boundary. Energy flows through ecosystems, being acquired from outside as light energy from the sun and being intimately lost from the ecosystem as heat dissipated by the respiration of all community members. Nutrients are cycled within ecosystems to a much greater extent.

Is there any relation of ecology with physical sciences, like physics, chemistry, mathematics, statistics, etc? It is evident that physical sciences are contributing very much to ecology, particularly in the study of populations; communities, ecosystems, etc. Physical sciences, these days, are contributing not only to ecology, but to other life sciences also, and it has become very common to find the statements like “life sciences are becoming oriented to physical sciences” and “physical sciences, now changing their field and becoming oriented to life sciences”. However, it would be proper to conclude that “all sciences, physical as well as biological, are pouring at a common pool – the ecology”. This interdisciplinary approach may prove to be very fruitful indeed for the solution of many problems ahead. In this way ecology is of all, and all are of ecology, and this provides an opportunity to persons of diverse fields to sit together around a common table and discuss mutual problems in order to secure fuller understanding of nature that would certainly help in the conservation of nature and natural resources and to boost agricultural production. Such mutual discussions should be of much help in the development of the modern art of ecology.

Historical Background

Although modern ecology developed mainly since 1990, allusions of the ecological ideas may be traced back to prehistoric man who utilized environmental information for food, shelter, medicines, etc., in order to survive the hardships of nature. In Indian writings as Vedic, Epic and Pauranic, etc., we may find references to ecological thoughts, and Chakra described the importance of Vayu (gases and air), Jala (water), Desha (topography) and Time in regulation of plants life. The Greek philosophers and scientists like

Hippocrates (father of medicine), Aristotle, Theophrastus, Reaumur described in their writings on natural history, the habits of animals and plants growing in different areas, Linnaeus (1707-1778) and Buffon, in his book “Natural History” in 1756 made notable contributions to ecology.

In 19th century, more areas were explored for flora and fauna mainly by

B.A. von Humboldt, Richard Spruce, Edward Forbes and J. Hooker who explored different continental areas.

In 1859, Geoffroy Saint Hilaire used the term ethology to refer to the study of relationships between organisms and environment. Reiter (1868) introduced the term oekologie in literature and E. Haekel (1869) put the first precise definition of ecology.

The community aspect in ecology was introduced by Le coq Sendtner and Kerner for plants. This view was later elaborated by Karl Mobius (1877) for animal communities. Notable contributions to plant and animal communities were made by S.A. Forbes (19887). Warming (1909), Cowles (1899), Clements (1916), etc. Schroeter and Kirchner (1896) introduced the term synecology in literature.

During the first third of 20th century, there started to develop such specialized areas of ecology as paleo-ecology, zoogeography, oceanography, linology, etc. And then was introduced the population concept on which statistical studies and sampling techniques were employed for solving the community problems. This era is popularly called as era of population and community ecologists.

After the introduction of the term ecosystem in literature by Tansley in 1935, started the era of ecosystem approach to ecology. This could lead to the

development of the concepts of productivity, energy relations, etc. in ecology, which is sometimes referred to as the bioenergetic approach.

The present status occupied by ecology is quite evident by its role in solution of socio-economic and political problems. This includes the work on soil conservation, pollution, field managements. The Greek philosophy and science; the source of modern ecology which in sequential form include the work of Buffon and Linnaeus, the idea of natural processes, evolution and ecology, energy relations, environmental influences on organisms, distribution of organisms, communities of organisms and finally, the development of modern ecology in 20th century.

Ecology in India

The earliest contributions (1875 to 1929) to this discipline were mainly from some forest officers who presented purely descriptive accounts of forests. Indeed the first comprehensive ecological contribution was made by Winfield Dudgeon (1921) who published an ecological account of the Upper Gangetic plains employing the concept of seasonal succession therein. This was, however, elaborated later by Saxton (1922), Misra (1946, 1958, 1959), however, contradicted this view of succession, and concluded that the processes mentioned therein might be better referred to as seasonality of communities rather than true ecological succession.

Phytosociological approach to the study of plant communities was for the first time made by Agharkar (1924) mainly for the grasslands. Bharucha in colloboration with his associates (1930, 1936, 1957) at Bombay contributed mainly to the phytosociology of grasslands. Simultaneously Champion (1929, 1935, 1937), Troup (1925), Bor (1947, 1948), etc. engaged themselves in the

study of ecology of forest vegetations. Autoecological studies on a number of forest trees were made by Champion and Pant (1931), Jagat Singh (1925), Phadnis (1925) and Champion and Griffith (1947).

Comprehensive autecological studies in India were indeed initiated by Misra, R., who after his return from Leeds (U.K.) contributed to autecology of herbaceous plants of different habitat conditions such as aquatics (1944), ravines and eroded river banks (1944) and lowlying areas (1948). Misra and S.Rao (1948) studied the autecology of *Lindenbergia polyantha*, revealing a number of important facts about the distribution of this species. The extensive investigations into the phytosociology of grasslands and mangroves by Bharucha (1941), deserts by Sarup and co-worker and forests by Puri, G.S. (1950, 1951, 1960) made turning point in the history of development of ecology in the country.

The first two value centers of ecology were established by R. Misra at the Department of Botany, Banaras Hindu University and by Bharucha at the Institute of Science, Bombay in 1930s. Misra did extensive work from 1937 onwards at Banaras on grasslands, wastelands, playgrounds, lakes and ponds, lowlying lands, riparian eroded slopes and ecotypic differentiation. He moved to Saugor in 1946 and by 1950, Misra established a strong school of ecology at Saugor (M.P.). Then he moved to Varanasi in 1956, and developed here another internationally recognized center of ecological investigations. After this gap of about ten years (1946-1955), the Banaras Centre was reactivated to work in diverse areas (1955–1962) in eco-physiology (Kaul), root-soil interrelationships of grasslands (Ramam) and riparian lands (Ambasht), ecotypic differentiation

(Ramakrishnan) and reproductive capacity of herbage species (Sant and Nelvigi).

In the next phase (1963-1971) the Banaras center concentrated on autecology of medicinal plants and weeds (Tripathi), grasslands productivity (Singh) and forest litter decomposition and productivity (Singh).

Keeping in view the role of biological productivity in human welfare, launching of IBP (International Biological Programme) by ICSU (International Council of Scientific Unions) made an important landmark in the development of ecology in India. Under this programme extensive study of the productivity of different kinds of ecosystems of the world was undertaken. Misra and a team of his associates and students had contributed much to the programme, UNESCO in 1968 could arrange a Biosphere Conference, when UNO was entrusted to formulate a long term programme. In 1972, UNO arranged an International Conference at Stockholm (Sweden). In 1971, under UNESCO, there was launched an intergovernmental programme, IBP (International Biological Programme) in which the Indian side was led by Misra. The objective of this programme was to study in detail the effects of different kinds of ecosystem of biosphere upon man. MAB/UNESCO workshop on tropical deciduous forest and derived ecosystems was organized at Varanasi in 1975. This was followed by work on natural and man-altered ecosystems of tropical deciduous forest and savannas type. Nutrient dynamics, primary productivity and energetics (Ambash), abiotic variables (Misra) and pollution effects (Rao) were studied.

In recent years work on bioproductivity, soil plant relationship and pollution ecology were directed at different ecosystems. Besides Banaras, active centers of ecological research are at Ujjain, Rajkot, Shillong, Jaipur, Srinagar

(Kashmir), Kurushetra, Nainital, Delhi, Gorakpur, Gwalior and Pilani. Ecological studies on different groups of animals have been made by Roonwal, Mani, Prakash, Das, Hora, Panikker, Krishnamoorthy and Ananthakrishnan.

With the establishment of a strong School of Ecology by 1960’s at Banaras, there developed simultaneously an active research center of fungal ecology under the leadership of Roy, who in collaboration with his students made synecological studies on the rhizosphere mycoflora of different kinds of plants. One of his students, Dwivedi, with a team of researchers, besides rhizosphere mycoflora, has also been contributing to ecology of fungi active in the decay of herbaceous plants, forest litters, etc. Khanna, Sharma and Rai contributed to the succession of air borne fungi on decaying grasses. Some other active centers of fungal ecology are at Madras, established by Sadasivan and later continued by Subramanian, and at Saugar and Lucknow established by Saksena and Rai respectively. A brief account of history of plant ecology in India is presented by Misra and Singh (1971) and Misra and Gopal (1973). Mani (1974) has given historical account of animal ecology in India.

Terminology of Ecology

Each science has its own terms and concepts. Anticipating that the reader has already some background of general biological terms, some other terms that are of frequent usage in the subject of ecology, are being explained below for the convenience in understanding the subject matter.

Species, vegetation, flora – A species, according to Merrell (1962), is a natural biological unit tied together by the sharing of a common gene pool. However, in ecology, where we very much think of its distribution and growth in nature, the species is generally defined as “a uniform interbreeding population

spread over time and space”. And for maintenance of its uniformity in structure, function reproduction, growth and development, it preserves its own genetic stock. The collective and continuous growth of plants in space is called vegetation. Thus, vegetation is actually the totality of plant growth including large or small populations of each species intermixed in a region; or in other words, we may say that vegetation is the sum total of plant population covering a region. Communities are discrete units of vegetation. Flora is the species content of the region irrespective of the numerical strength of each species. Thus, vegetation (whose units are communities) is described whereas flora is listed.

Population, community – A population is a group of individual organisms of the same species in a given area. A community is a group of populations of different species in a given area. It thus includes all the population in that area – all plants, all animals, and microorganisms. A community may also be defined in a narrow sense as a fern community, algal community, seed-eating bird community in that area.

Factor, environment, habitat – Any external force, substance, or condition that affects organisms in any way, is known as a factor. The sum of all such factors constitutes the environment. It thus becomes indeed a complex of so many factors, better referred to as the environmental complex. The place, where an organism lives, or the place where one would go to find the particular organism is known as the habitat of that organism. The habitat of an organism actually represents a particular set of environmental conditions suitable for its successful growth.

Adaptation, ecasds, ecotypes – Any species puts each efforts to make full use of the available nutrient pool and other environmental conditions prevailing in the area of its growth. It ensures its own protection against adverse conditions of its habitat. This all is accomplished by the development of some characteristics. Any feature of the organism or its parts, which is of definite significance in allowing that organism to exist under the conditions of its habitat, is thus called adaptation. Some of the species have more than one kind of populations, spread over wide range of habitat conditions. As ecad of a plant species is a population of individuals, which although belong to the same genetic stock, but differ markedly in vegetative characters such as size, shape, number of leaves, stems, etc. These variations are simply environmentally induced, and thus are temporary or reversible, i.e. one type of ecad may change into another with the change in its habitat. An ecotype on the other hand, is a population of individuals of a species, which are genetically different. Since different ecotypes are interfertile, these are kept under the same taxonomic species. Their variations are permanent and irreversible as these are genetically fixed.

Biological clocks – Plant species possess physiological mechanisms that indicate particular seasons of the year, and thus plant species are known as biological clocks.

Ecotone, life form, biological spectrum – Although plant species grow in association with each other in groups as communities in nature, there is hardly distinguishable a point or sharp line of distinction between the two different communities. There is generally a zone of transition, presenting a situation of special ecological interest between two different types of

communities, which is known as an ecotone. A life form is the sum of the adaptation of the plant to climate. This viewpoint is considered in the physiognomic methods of study of plant communities. The percentage distribution of species among the various life forms of a flora is called the biological spectrum of that place.

Ecological succession (primary, secondary, autogenic, allogenic) – Vegetation is hardly stable, and thus dynamic, changing over time and space. Although comparatively less evident than vegetation, animal populations, particularly lower forms, also show dynamic character to some extent. Succession is a natural process by which different groups or communities colonize the same area over a period of time in a definite sequence. The succession, which starts from a primitive substratum without previous living matter, is known as the primary succession, whereas that starting from previously built up substratum where living matter already exists, is known as the secondary succession. If the existing community, as a result of its reaction with the environment, causes its own replacement, such a succession is known as autogenic succession but if the replacement of the existing community takes place due to the influence of any external force, condition, etc., such course is known as the allogenic succession.

Climax, monoclimax, polyclimax, biome – In the natural process of succession, one community continues to follow another, until a stage comes when a type of community cannot be displaced under the prevailing environmental conditions. This final, terminal community that can maintain itself more or less indefinitely in equilibrium with the prevailing environment, is known as the climax community and the stage is said to be the climax.

According to one theory, at a time, there is only one climax community which is chiefly controlled by the climate, and this view is popular as monoclimax theory. Some others believe that under natural conditions, it is very common to find at a time more than one type of climax communities differing widely from each other in the same climatic conditions, and this theory is known as polyclimax theory. Such a complex of several types of communities, some in climax stage, and others in different stages of succession, maintained under more or less similar climatic conditions is known as a biome.

Ecosystem, biosphere (ecosphere), standing stage (standing quality), standing crop, biomass, ecological pyramids – In a given area, the biotic assemblage of all the organisms, plants as well as animals (i.e. communities) interacts with its physical environment in such a manner that there is a flow of energy leading to clearly defined trophic structure, biotic diversity, and material cycles within a system, known as an ecological system or ecosystem. An ecosystem is the whole biotic community in a given area plus its abiotic environment. The earth’s living organisms interacting with their physical environment may be considered as a giant, vast ecosystem, which is the largest and most nearly self sufficient biological system we know, and this is designated as the biosphere or ecosphere. Thus the planet earth along with the atmosphere (air, land, water) that sustains life is known as biosphere.

The amount of inorganic substances, such as P, S, C, N, H, etc., present at any given time in the environment of an ecosystem, is known as the standing state or standing quality. The amount of living material, present in a component population at any time, is known as the standing crop, which may be expressed in terms of numbers or weight per unit area. Biomass is the

sanding crop expressed in terms of weight (i.e. organism mass) of the living matter present. Ecological pyramids are the graphic representations of the trophic structure and function at successive trophic levels of an ecosystem, which may be shown in terms of their number, biomass or energy content.

Food chain, food-web, productivity (primary, secondary, gross primary, net primary, net) – In any ecosystem, various living organisms (plants, animals) are arranged in a define sequence according to their food habits. Plants are producers, which are eaten by herbivores, which in turn are eaten by carnivores. This transfer of food energy from the source in plants through a series of organisms (arranged in a linear manner) with repeated eating and being eaten is known as a food chain in an ecosystem. However, under natural conditions in the same ecosystem, depending upon the variety of organisms as based on their food habits, there generally operate a number of linear food chains at a time. These chains are interlinked with each other at several points. This interlocking pattern of a number of food chains forms a web-like arrangement known as a food-web.

The rate of production i.e. amount of organic matter accumulated in the living component of an ecosystem in unit time is referred to as the productivity of the ecosystem. Primary productivity is defined as the rate at which radiant energy of sun is stored by photosynthetic and chemosynthetic activity of producers (chiefly green plants) in the form of organic substances, used as food materials. The rates of energy storage at consumer levels are referred to as secondary productivity. Gross primary productivity is the total rate of photosynthesis, including the organic matter used up in respiration during the period of measurement. This is also called total photosynthesis or total

assimilation. Net primary productivity is the rate of storage of organic matter in plant tissues in excess of that utilized in respiration by plants during the period of measurement. This is also called apparent photosynthesis or net assimilation. Net productivity of a community is the rate of storage of organic matter not used by heterotrophis i.e. net primary production minus heterotrophic consumption, during the period under consideration.

Biogeochemical cycles – More or less circular pathways, through which the chemical elements, including all the essential elements of the protoplasm, circulate in the biosphere from environment to organisms and back to the environment, are known as the biogeochemical cycles.

Ecological niche, ecological equivalents – Ecological niche of an organism includes the physical space occupied by it, its functional role in the community, i.e. trophic position, and its position in environment gradients of temperature, moisture, pH, soil, etc. and the conditions of existence (cf. habitat, which includes only the physical space where an organism lives). Organisms that occupy the same or similar ecological niches in different geographical regions are known as ecological equivalents.

Conservation, pollution – Conservation means to ensure the preservation of a quality environment for the organisms in terms of their nutrition, recreation, etc., and to ensure at the same time through planned manipulations, a continuous yield of useful plants, animals and materials by maintaining a balanced cycle. Pollution is an undesirable change in the physical, chemical or biological characteristics of our air, land and water, that may or will harmfully affect human life directly or indirectly.

Basic concepts of ecology

Like other sciences ecology too has its own principles and basic concepts, which are as follows:

1. All living organisms and their environment are mutually reactive, affecting each other in various ways. Animal population, flora, and vegetation are interdependent through the environment and are mutually reactive.
2. Environment, which is actually a complex of several inter-related factors and is much dynamic (i.e. varying with time and space), works as a sieve selecting organisms for growth from so many forms, as its one or the other factor becomes critical at critical stages of the life cycle of the species.
3. The species puts each effort to maintain its uniformity in structure, function, reproduction, growth and development by preservation of its genetic pool. However, species is also plastic and reacts to the varying environment to get itself adjusted structurally and physiologically in the changing environment. This is achieved by the degree of plasticity set by the genetic constitution of the species. The various forms of a species, in order to meet the challenge of changed environment, may arise by virtue of somatic plasticity, the ecads, or by the reorganization of their genes during sexual reproduction, the ecotypes. Thus species may increase their capacity of tolerance towards changing environment by developing ecads and ecotypes.
4. It is not only the environment which influences the life of organisms, but organisms too modify their environment as a result of their growth,

dispersal, reproduction, death, decay, etc. Thus, the environment is caused to change due to organisms activities. The dynamic environment and organisms make ways for the development of different kinds of organisms through a process known as succession. The process continues till the development of a community which is now more or less stable and is now able to keep itself adjusted in equilibrium with the environment. This final stage of community is called a climax.

1. Clements and Shelford (1939), however, put forth a concept of biome wherein all plants and animals are related to each other by their coaction and reaction on the environment. According to their view, under similar climatic conditions, there may simultaneously develop more than one communities, some reaching to climax stage, others under different stages of succession. This complex of several communities in any area, represented by an assemblage of different kinds of plants, animals, etc., sharing a common climate, is called a biome.

In the above account, basic concepts of ecology have been explained mainly upon structural basis. However, with the introduction of ecosystem concept in ecology, functional aspects along with the structural ones are also to be strongly emphasized. Tansley (1935) thus emphasized the role of environment, with its various factors interacting with each other in his comprehensive term ecosystem which involves all the non-living and living factors working in a complex. With this new concept in modern ecology, following are the basic concepts.

1. When both, biotic and abiotic components are considered, the basic structural and functional units of nature are ecosystems. Discrete

biological units consist of populations and communities, including biomes. Each population occupies a specific niche, a unique functional position with respect to other organisms with which it interacts.

1. There exist varying degrees of +, – or even neutral interactions among organisms, at both, inter and intraspecific levels, which determine along with abiotic parameters, the degree of success a particular population has within a given habitat. Population ecologists study interactions at population as well as community levels. They study competition, usually between populations from the same trophic level (such as herbivores competing for the same grass i.e. population ecology involving individuals of same species), and prey-predator interactions between members of adjacent trophic levels (i.e. population ecology involving interactions between individuals of different species, at community level).
2. Also, there are involved energetics of ecosystem, as energy is the driving force of this system. The radiant energy is trapped by the autotrophic organisms (producers) and is transferred as organic molecules to the heterotrophic organisms (consumers). This energy flow is uni-directional or non-cyclic.
3. The chemical components of the ecosystem move in defined cycles – biogeochemical cycles. Within the ecosphere, biological systems frequently regulate the rate of movement of cycling of the chemicals. Role of water as the universal solvent for biological systems is much relevant here.
4. Successful growth of the organisms is governed by limiting factors. For success in growth and reproduction with a particular habitat, an

organism requires various essential factors from its environment. The success of an organism is limited not only by deficiencies in substances or conditions but also by excesses. The minimal and maximal levels of tolerance for all ecological factors of a species vary seasonally, geographically and according to the age of the population.

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

According to Evans (1956), the ecosystem involves the circulation, transformation and accumulation of energy and matter through the medium of living things and their activities. Thus, the dynamic abiotic components of the environment and the assemblage of plants and animals there, as a result of interactions between themselves keep modifying and changing each other, and this leads to the development of ecosystem

1. Then come the probabilities of disruption and exploitation of ecosphere.

As a result of natural condition or activities of man, species diversity of an ecosystem is reduced. It leads to a set back to the state of development and reduction in the stability of the ecosystem. Man’s exploitation of ecosystems is directed toward channeling productivity to his needs. Applied ecology or human ecology is the use of ecological concepts to describe human activities and the determination of ways in

which people can best obtain their needs from ecosystems. Ecosystems, which are substantially altered by human activities, are called managed, whereas those free from such disturbances are referred to as natural.

Approaches to Ecology – Its Main Subdivisions and Developmental Facets The definition of ecology makes it quite evident that fuller understanding

of nature involves the study of plants, animals and their environment. A perusal of the developmental history of ecology reveals that ecological studies made from time to time are based upon three principal aspects – taxonomic affinities, habitat and levels of organization. Accordingly, these approaches could lead to the development of the following main subdivision of ecology.

* 1. Based on taxonomic affinities

In early days of ecology, botanists and zoologists engaged themselves separately in the study of ecology of plants and animals respectively. This led to the development of such sub-divisions as (i) plant ecology and (ii) animal ecology. In each, there may be taken specialized fields like ecology of pines, insect ecology, avian ecology, bacterial ecology and ecology of mosquitoes, turtles, etc. However, modern ecologists feel that the principles in the study of plants and animals are not only much similar, but these two great groups of organisms are very much inseparably interrelated with each other. Thus, modern ecology prefers not to make much distinction between ecology of plants and animals. The term ecology indeed includes the interrelationships and interdependencies of all kinds of organisms with their environment.

* 1. Based on habitat

Some ecological though of the study of habitats and their effects upon the organisms. There are selected a number of different types of habitats such as freshwater, marine, estuarine, grasslands, forests, arid lands, etc. These are then studied in detail for their possible relationship with the kinds of organisms present there. Such a habitat approach led to the development of third subdivisions of ecology, known as (iii) habitat ecology.

* 1. Based on the levels of organisation

With such an approach to the ecology of area, units of study are either individual organisms or groups of organisms. Accordingly the other two, fourth and fifth subdivisions of ecology are (iv) autecology and (v) synecology.

Autecology

This is also known as ecology of individuals, where we study the relation of individual species to its environment. Thus at a given time, emphasis is given on the requirements and reaction of an individual species together with the influence of environment upon it. With an autecological approach, individual species are the units of study. These are studied for details of their geographic distribution, morphology, taxonomic position and life-cycle, etc., alongwith the various ecological factors which might influence different stages of their life cycles.

Synecology

Under natural conditions, however, organisms – plants, animals, microbes, etc., live together as a natural group affecting each other’s life in several ways. Thus, more complex situations exist where the units of study,

instead of single organisms are groups of organisms known as a community. Such an approach where units of study are groups of organisms is called synecological approach.

Depending upon the conditions, as these exist, synecology may deal with.

* + 1. Population ecology – A recently developed field, where the units of study are pure stands of individuals of a single species – population. As a result of aggregation of these individuals, it becomes desirable to study the interdependencies between them, and the populations are studied in terms of their size, growth rates, etc., which are chiefly governed by the interactions of the members of population. Thus, population ecology is the study of such and other similar relationships of group of organisms. The main job of population ecologist is, “Why is this population of a particular density?” To answer this and other questions he studies competition, usually between population from the same trophic level (herbivores competing for same grass). Population ecology is also concerned with communities. A population ecologist also studied interactions between populations of different species in a community. For instance, study of prey-predator interactions between members of adjacenet trophic levels of a community.
    2. Community ecology – In contrast with population ecology, here the units of study are groups of individuals belonging to different species-plants as well as animals. The living (biotic) components of the community are studied mainly for the nature of interdependencies between individuals of different species. Major concerns of community ecologist are, “Why is this community of a particular diversity? Why does a particular community occur at a given location? How communities interact and how these change through time?”
    3. Biome ecology – In nature, we generally find that there may exist a complex of more than one communities, some in their climax stages and others in different stages of succession, and these all communities grow under more or less similar climatic conditions in an area. Thus in biomes, as units of study there are studied interaction between different communities of area.
    4. Ecosystem ecology – This has been the most recent development in ecology. It is established that not only living (biotic) but also non-living (abiotic) components of the nature interact with each other. These interacting biotic and abiotic components, then interact with each other to form an integrated system

– ecosystem or ecological complex or ecological system. Thus it becomes the most complicated synecological approach to the ecology of an area, where the units are the whole system living as well as non-living components. Here we mainly emphasize the similarities and differences in food relationships among living organisms and various forms of energy supporting their life. This has also been referred to as bioenergetic approach in modern ecology.

Ecosystem ecology thus emphasize the movements of energy and nutrients among the biotic and abiotic components of ecosystems. A major concern is, “How much and what rates are energy and nutrients being stored and transferred between components of an ecosystem?”

BIOTIC FACTOR

Under natural situation, organisms live together influencing each others life directly or indirectly. Such vital processes as growth, nutrition and reproduction depend very much upon the interactions between the individuals of same species (intraspecific interaction), or between those of different species (interspecific interaction). Pollination, seeds and fruits dispersal, grazing, parasitism, interactions between indeed very much complex. The effect of man upon vegetation has been much pronounced. Under natural conditions, we find interdependencies between animals themselves, between plants themselves, as well as between plants and animals. Such interactions are found in various gradations, being for whole life or are casual and temporary. Moreover, interdependency may exist between species which are taxonomically widely different, such as between trees and bacteria, or between elephants and ants. The relationship between species may be beneficial to both, harmful to both, or beneficial or harmful to one and neutral for the other.

For different types of relationships among organisms, various authors have used different terminology. There is no general agreement on various terms. We shall now consider the various kinds of relationships among organisms and the different terms used for them.

Relationships among Organisms

Most of the ecologists are in favour of the use of the term symbiosis, which literally means ‘living together’, in its broader sense. Thus, most of the ecologists include all types of interactions including parasitism under ‘symbiosis’. The use of the term in its broader sense, divided all types of

symbiotic relationships between organisms into two groups viz., (i) positive and

(ii) negative interactions. But others, like Clarke (1954), restrict the use of the term symbiosis only for such types of interactions which are mutually beneficial and where one or both the species are benefited and neither is harmed. The relations where at least one of the species is harmed have been grouped under antagonism.

The various symbiotic phenomena between organisms have been grouped and interpreted in various ways by different authors. For instance, Haskell (1949) proposed the idea of a ‘stronger’ and a ‘weaker’ partner in the two species involved during their association. On the basis of the evident effects of such an association, there were proposed a number of such terms, as predation, allotrophy, symbiosis, amensalism, neutrality, commensalism, synnecrosis, allolimy and parasitism. McDougal (1918) grouped all, i.e., beneficial as well as harmful effects of association under the single term ‘symbiosis’ and classified them into two major groups (i) disjunctive symbiosis – where associated organisms are not in constant contact, and (ii) conjunctive symbiosis – where dissimilar organisms live in contact with each other. Each of the tow has been further subdivided into – social (no direct relationship) and nutritive (with food relationship). The latter may be antagonistic or reciprocal. Lianas and epiphytes have been classified under ‘social conjunctive’, parasites under ‘antagonistic nutritive conjunctive symbiosis’, and the lichens, mycorrhiza and nitrogen-fixing organisms under ‘reciprocal nutritive conjunctive symbiosis’.

Haskell’s elaborate classification of ‘coactions’ between species is adopted by Burkholder (1952), who on the basis of several combinations of 0 (no

significant interaction), + (growth, survival, or other population attribute benefited), and – (population growth or other attribute inhibited) between two species, the various types of interactions have been grouped into nine types of interactions. The possible combinations are 00, --, ++, +0, -0, +-, three of which (++, --, and +-) have in turn been commonly subdivided, and the whole scheme resulted into nine types of possible interactions.

Table. Possible combinations of 0, + and – to give different kinds of interactions (Burkholder, 1952)

|  |  |  |
| --- | --- | --- |
| Combinations | Detailed effect(s) | Interaction type |
| 0 0 | Neither population affects the other | Neutralism |
| - - | Direct inhibition of each species by the other | Competition (direct interference type) |
| - - | Indirect inhibition where common resource is in short supply | Competition (resource use type) |
| - 0 | Population 1 inhibited, 2 not affected | Amensalism |
| + - | Population 1, the parasite, generally smaller than 2, the host | Parasitism |
| + - | Population 1, the predator, generally larger than 2, the prey | Predation |
| + 0 | Population 1, the commensal, benefits  while 2, the host, is not affected | Commensalism |
| + + | Interaction favourable to both but not  obligatory | Protocooperation |
| + + | Interaction favourable to both and  obligatory | Mutualism |

1. Positive interactions. Where populations help one another, the interaction being one-way or reciprocal. These include (i) commensalisms

(ii) protocooperation and (iii) mutualism.

1. Negative interactions. Where members of one population may eat members of the other population, compete for foods, excrete harmful wastes, or otherwise interfere with the other population. These have been sub-divided into (i) competition, (ii) predation, (iii) parasitism, and (iv) antibiosis.

In the present discussion by the author, the terms ‘symbiosis’ has been used in its broader sense, and all types of interrelationships, following Odum (1971), have been grouped into two groups. However, the detailed scheme is somewhat different. Before we proceed to discuss individual type of interaction, it would be desirable to present first an artificial key that would help understanding various types of such interactions.

Artificial key to the various types of interactions included under symbiosis

Either one or both the species benefited Both the species derive benefit Association more or less obligatory, Essential for survival of both

Positive interactions Mutualism, e.g. pollination, Fruit and seed dissemination,

Lichens, symbiotic nitrogen fixers Mycorrhizae, Zoochlo rellae, etc.

Association non-obligatory, not essential for survival of either population

Protocooperation or non-obligatory mutualism, e.g. Sea anem one attached to hermit crab shells

Only one species benefited, neither is harmed

Commensalism, e.g. Lianas, Epiphytes, Bamacles attached to whales, Hydroids on fish, Crab in the mantle cavity of oyster, Rhizosphere and Phyllosphere microorganisms

Either one or both the species harmed Negative interactions

One species harms the other making its direct or indirect use

Exploitation

Use for shelter or support Some ants and birds inhabiting others dwelling sites

Use for food

Food derived from the host without causing its death

Food derived by killing the host

Parasitism

Predation, e.g. browsing, grazing, seedling destruction, plants as food, carnivorous plants

One species produces a poisonous

substance or a change in environmental conditions inimical to another species, none derives benefit

Antibiosis

Both the species may be harmed in reciprocally unfavourable relationship, where some features exist in short supply

Competition

Various interactions among the organisms i.e. ‘symbiosis’ may be of two broad types:

Positive Interactions

Here populations help one another, and either one or both the species are benefited. This benefit may be in respect of food, shelter, substratum or transport, and the association may be continuous or transitory, obligate or facultative and the two partners may be in close contact (their tissues intermixed with each other) or one of them may live within a specific area of the other or attached to its surface. These beneficial interactions are divided into:

1. Mutualism

Mutually beneficial interspecific interactions are more common in the tropics than elsewhere. Here both the species derive benefit. In such association, there occurs a close and often permanent and obligatory contact more or less essential for survival of each. The two populations enter into some sort of physiological exchange. The following are some common examples of mutualism:

1. Pollination by animals. Bees, moths, butterflies etc., derive food from the nectar, or other plant product, and in return bring about pollination.
2. Dispersal of fruits and seeds. Seeds and fruits are commonly transported by animals. The fruits are eaten by birds, mammals etc., and seeds contained in them are dropped in the excrement at various places.
3. Lichens. These are examples of mutualism where contact is close and permanent as well as obligatory. Their body is made up of a matrix formed by a fungus, within the cells of which an alga is embedded. The fungus makes moisture as well as minerals available, whereas alga manufactures food. Neither of the two can grow alone independently in nature. Lichens grow abundantly on bare rock surfaces.
4. Symbiotic nitrogen fixers. This is a well known example of mutualism, where the bacterium *Rhizobium* forms nodules in the roots of leguminous plants, and lives symbiotically with the host. Bacteria obtain food from the higher plant and in turn fix gaseous nitrogen, making it available to plant. Similarly, root nodules of *Alnus, Alopecurus, Casuarina, Cycadacease, Myrica, Podocarpus* etc., and leaves of about 400 species non-legumes are examples of such associations.
5. Mycorrhizae. This is also an example of similar nutrition in fungi that form mycorrhizal structures either inside the roots, or on outside surfaces of plants. Ectotrophic mycorrhizae are very common in nature on pines, oaks, hickories, and beech, and endotrophic ones occur in red maple and are common in roots and other tissues of many orchids and members of Ericaceae. In ectotrophic mycorrhizae, the fungal hyphae are the natural substitutes of root hairs absorbing water and nutrients from the soil. In some cases, the plants are restricted in their distribution to

acidic soils, which suit to the fungus partner. In endotrophic mycorrhizae, fungi occur internal to the root tissue.

1. Zoochlorellae and zooxanthellae. Some unicellular plants, especially algae, known as Zoochlorellae, live symbiotically in the outer tissues of certain sponges, coelenterates, mollusks and worms. Some brown or yellow cells, probably flagellates (Zooxanthellae) are also present. Algae are photosynthetic and produce nitrogenous compounds beneficial to hosts and in exchange, they obtain materials released by metabolism of hosts animals. The unicellular green algae, *Chlorella vulgaris* lives within the gastrodermal cells of *Hydra*. Alga, through photosynthesis provides food and oxygen to Hydra, which in turn provides shelter, nitrogen wastes and CO2 to *Chlorella.* Similar relationship exists between the alga, Zoochlorella and a planarian, *Convoluta roscoffensis*.
2. There are associations between animals themselves. For example, termites which feed on wood and the protozoans (specis of *Trichonympha*) present their guts. Termites cannot digest cellulose of wood. The protozoans digest cellulose for termites and in return obtain food and shelter from the termite.

Mathematical models of mutualism received much less attention than those of competition and predation. The simplest Lotka-Volterra model produces unrealistic predictions, with both populations increasing indefinitely.

1. Commensalism

In this association between members of different species only one is benefited and neither is harmed. Here two or more populations live together

without entering into any kind of physiological exchange. One is benefited without any effect on the other. Some common examples are:

* 1. Lianas. These are vascular plants rooted in the ground and maintain erectness of their stems by making us of other objects for support. Thus, with much economy of mechanical tissues they are able to get better light. Lianas are common in dense forest of moist tropical climates. They maintain no direct nutritional relationship with the trees upon which they grow. On the basis of the type of device used for climbing their supports, lianas may be leaners, thorn lianas, twiners or tendril lianas. Common lianas are species *Bauhinia, Ficus* and *Tinospora.*
  2. Epiphytes and epizoans. Epiphytes are plants growing perched on other plants. They use other plants only as support and not for water or food supply. They differ from lianas in that they are not rooted into the soil. Epiphytes may grow on trees, shrubs, or larger submerged plants. They grow either on the trunks or leaves. Epiphytes are most common in tropical rain forests. Many orchids, bromeliads, hanging ‘mosses’, *Usnea* and *Alectoria* are well known epiphytes. Some of them show intermediate gradations between epiphytes and parasites, as well as between epiphytes and lianas. For example, a fern *Nephrolepis,* in the beginning remains rooted in the soil, late on spreading its rhizome over tree trunk, sooner or later becoming completely separated form the soil, thus becoming an epiphyte. In *Tsuga heterophylla,* seeds germinate on tree surfaces, where their seedlings in ht beginning live as epiphytes till they develop their own roots, by which ultimately maintain relation with soil and thus become independent. In epiphytes, there is a special

layer – velamen over the root surface. The cells of the velamen are whitish, which can take up abundant water rapidly from the atmosphere.

Some plants grow on the surfaces of animals. For example, green algae grow on the long, grooved hairs of the sloth. Similarly, *Basicladia* (Cladophoraceae) grows on the backs of freshwater turtles.

A v ariety of microorganisms, saprophytic bacteria and fungi, and protozoans live within tissues or cavities of higher plants and animals. Some microbes are found in lower intestines of animals. *Escherchia coli* found in human colon. Some invertebrates grow as fixed commensals attached to plant or other animals. *Ostrea frons* grows on the roots of the red mangrove and certain barnacles found on the backs of whales. Several species of mollusks, barnacles and tube worms are found attached to the shells of horseshoe crab, *Limulus polyphemus.*

* 1. There are several commensals that make temporary contact with other organisms. For example, squirrels, monkeys, tree frogs, snakes, birds, insects etc., use trees and other plants for substratum, shelter or breeding sites. Certain beetles are found in nests of meadow mice. A small tropical fish, *Fierasfer* finds shelter within the cloacal cavity of a sea cucumber. Sponges generally harbour a rich fauna within their spongocoel.
  2. Some commensals as oyster crab, *Pinnothers ostreum* is found in the mantle cavity of the oyster. In addition to shelter, it also gets food from the host mollusk, oyster, without causing any harm. In oceans there are many commensals. For examples, in the burrow of the echiuroid worm, *Urechis caupo*, three commensals, namely small goby, scale worm and pea crab are found, which get shelter in the burrow. Hydroids and vorticellians use fish for

transport. Some as *Treponema macrodentium* living in mouth of man and

*Entamoeba coli* in the intestine of man are harmless commensals.

* 1. Some hitherto not mentioned associations. Besides above cited various associations, there exist in nature some similar situations where we find such associations between a variety of microorganisms and higher plants. For instance, the zone of soil around the roots of higher plants characterized by intense microbial activity, known as rhizosphere, the surface proper of the roots growing in soil – the rhizoplane, the boundary layer of air over the green leaves with active microbes – phyllosphere, and the leaf surface – phylloplane, constitute important ecological niches, where we find rich populations of microorganisms mainly fungi, actinomycetes and bacteria, that remain all the time active there. It is now well established that, from the living roots as well as leaves of higher plants, there is a continuous diffusion of their metabolic products, mainly sugars and amino acids therein. Thus, these are nice examples of commensalisms. Moreover, it is also known that these microorganisms in turn provide protection to roots and leaves against the attack by pathogens directly by inhibiting the growth of the pathogens. It has also been shown very recently that some microorganisms present in soil as well as in air produce some metabolic products, which have been identified as the auxins. If it happens so indeed, then these microbes may perhaps play an important role in regulating the growth and development of the higher plants, and under such situations the associations approach towards mutualism. Thus, the situation mentioned here may belong to commensalisms, mutualism or even gradation between two, depending upon ht conditions present at that particular type of association.

1. Protocooperation

However, in some cases the association is ahead of commensalisms, where both the populations are benefited. But the association, although benefited to both, is not obligatory i.e. not essential for the survival of either population (cf mutualism, where survival depends mostly on each other). Such associations are referred to as protocoopertaion or non-obligatory mutualism. One good example is of a coelenterate, sea anemone – *Adamisia palliata* attached to the shells of hermit crab – *Eupagurus prideauxi*. The sea anemone is carried by the crab to fresh feeding sites and crab in turn is said to be protected from its enemies by sea anemone. Some ecologists prefer to include this association under commensalisms.

Negative Interactions

These include the relations, in which one or both the species are harmed in any way during their life period. Some (Clarke, 1954) prefer to call such types of associations as antagonism. Such negative interactions are generally classified into three broad categories, as exploitation, antibiosis and competition which are discussed in details as follows:

1. Exploitation

Here one species harms the other by making its direct or indirect use for support, shelter, or food. Thus exploitation may be in respect of shelter or food.

* 1. Shelter – Among animals there are cases where one species of ants use another species as slave labour. For example, *Polyergus* workers raid nests of *Fomica* and the latter feeds and builds nests for master *Polyergus*. Similarly, the so-called ‘parasitic birds, as cuckoo and cowbird never build their own

nests and female lays eggs in the nest established by birds of another usually smaller species.

* 1. Food – The various relationships in respect of food may belong to:

1. Parasitism – A parasite is the organism living one or in the body of another organism and deriving its food more or less permanently from its tissues. Those organisms, which derive their nourishment only partly and remain in contact with their hosts only for a short period of their life cycles, however, are not true parasites. The typical parasite lives in its host without killing it, whereas the predator kills its prey upon which it feeds. Yet there are parasites, which kill their hosts and are predators, which eat only a part of their prey. Some persons include the parasitic vascular plants under partial parasites. A wide variety of plants and animals are parasites in their mode of existence. There are some parasitic vascular plants. Species of *Cuscuta* (total stem parasites) grow on other plants on which they depend for nourishment. Young stem twines around the host stem from which adventitious roots develop that finally penetrate the stem of the host, establishing relationship with its conducting elements. The specialized roots are called haustoria. Other examples of such association are total root parasites as *Orabanche, Conopholis* and *Epifagus* (Orobanchaceae) which are found on roots of higher plants. *Rafflesia* is found on roots of Vitis. Members of the family Loranthaceae (*Viscum album*, *Loranthus* spp.) are partial stem parasites. They grow rooted in branches of host trees. Others like *Santalum album* and *Thesium* are partial root parasites. Their roots are attached to host plants. Majority of parasites are microorganisms, of which fungi, bacteria, mycoplasmas, rickettsias and viruses parasitise plants as well as animals. Animals parasitic on animals

belong to protozoa, various invertebrates, and a few vertebrates, whereas animals parasitising plants are some gall wasps and gnats, the eggs of which are laid on stem and leaves of plants. Parasitism may occur even within the species. For example, in deep-sea angler fish, *Photocorynus spiniceps*, the male lives as permanent parasite upon the head or side of the female, obtaining nourishment for blood supply. This type of relationship is common in higher plants where the growing pollen tube may be conceived off as a male plant parasitic on the tissues of the stigma and style of the flower. The detailed account of parasitism is beyond the scope of present text. To this relationship may also be added the hyperparasites, which are chiefly fungi growing parasitically on other parasites. For example, a pycnidal fungus, *Cicinnobolus cesatii* is found as hyperparasite on a number of powdery mildew fungi.

1. Predation – In contrast with a parasite, which derives nourishment from its host without killing, a predator is free living, which catches and kills another species for food. Most of the predatory organisms are animals, but there are some plants (carnivores) also, especially fungi, which feed upon other animals. In some animals only the adults are predatory whereas the young are parasitic. In other animals, such as insects, most of the eating is done by larvae. Predators feed upon the adults, or larvae or even eggs of their prey. A number of fungi, such as species of *Dactylella, Dactylaria, Arthrobotrys, Zoophagus* capture insects, nematodes and other worm-like animals. Such fungi use specialized structures, the traps or snares, formed on their mycelia to capture the nematodes. The following are some of the common examples of predation:
2. Browsing and grazing – Herbivores kill the plants and use unharvested herbs, shrubs or even trees as their food and sometimes pose much problems of management of natural and artificial vegetations. Different plants receive varying degrees of harmness as a result of browsing and grazing. Many insects and ruminants browse highly over the vegetation. Cattle, camels, goats, etc. frequently browse the tender shoots of shrubs and trees and sheep graze the grasses. Generally annuals suffer more due to grazing than the perennials, shrubs are damaged less than herbs. Grazing and browsing may bring about marked changes in vegetation. Grazing in shrubby vegetation generally increases the number and sizes of the shrubs by removing the competitive grasses.
3. Seeds and seedling destruction – Animals such as insects, squirrels, mice, rodents, etc. consume much quantities of seeds as food. Moreover, they browse seedlings of shrubs and trees, and damage most of them by trampling.
4. Plants as food – Aquatic plants are frequently eaten by animals like ducks, fish, muskats, etc. and they really create problems of management of these water bodies. Aquatic filter feeders destroy the diatoms, flagellates and other algae.
5. Carnivorous plants – A number of plants as *Nepenthes, Darlingtonia, Sarracenia, Drosera, Utricularia, Dionaea* consume insects and other small animals for their food. They are also known as insectivorous plants. They are adapted in remarkable ways to attract, catch and digest their victims. Their leaves or foliar appendages produce proteolytic enzymes for digestion of the insects. The carnivorous habit in plants is said to be an incidental feature of

their nutrition, since none of them is dependent upon its animals prey for nitrogenous compounds.

To a population ecological predation is an important interspecific interaction, which may determine the population growth. Laboratory studies have been made to derive Lotka Volterra equations, though less informative. Behavioural aspects of predation as functional response have been studied. Such response is affected by rate of encounter and handling time.

1. Antibiosis

The term antibiosis generally refers to the complete or partial inhibition or death of one organism by another through the production of some substance or environmental conditions as a result of metabolic pathways. Here none of them derives any benefit. These substances and/or conditions are harmful (antagonistic) to other organism. The phenomenon of antibiosis is much common among microbial world. Production of chemicals that are antagonistic to microbes – the antibiotics is well known. Bacteria, actinomycetes and fungi produce a number of antimicrobial substances which are widespread in nature. Burkholder (1952) reported that about 50 per cent of the species of actinomycetes, and 50 per cent of the lichens as well large number of higher plants produce substances that inhibit molds and bacteria. Antagonistic substances are also reported in some algae, as for example in cultures of *Chlorella vulgaris*, some substance accumulates which inhibits the growth of the diatom, *Nitzschia frustrulum*. Substances produced by senescent cultures of *Chlorella* and of the diatoms, *Navicula* and *Scendesmus*, inhibit the filter feeding of *Daphnia* in laboratory. Pond blooms of blue green algae especially *Microcystis* are known to produce toxins such as hydroxylamine which causes

death of fish and cattle. In marine waters, populations of some microbes, popularly known as red tide, cause catastrophic destruction of fish and other animals. There has been accumulating day by day much information on the subject, detailed account of which is beyond the scope of present discussion, for which the reader is referred to books on microbiology and medicine.

The term antibiosis would also include such phenomena as hypersensitive reactions that involve the interaction between microorganisms, particularly pathogenic ones and are harmful to one or both.

1. Competition

Competition occurs when individuals attempt to obtain a resource that is inadequate to support all the individuals seeking it, or even if the resource is adequate individuals harm one another in trying to obtain it. The resources competed for can be divided into two types: (i) Raw material such as light, inorganic nutrients, and water in autotrophs and organic food and water in heterotrophs, (ii) space to grow, nest, hide from predators, etc. In higher plants this is manifested in spatial patterns; in animals by spatial patterns or movements. It is an important area of population ecology, in both situations, involving populations of same species as well as interacting populations of different species. Thus competition may be (i) intraspecific, occurring between members of the same population as well (ii) interspecific, occurring between populations of different species. Competition thus is usually between members of the same trophic level.

* 1. Intraspecific competition – This is often called scramble competition and is an important density – dependent factor regulating populations. The

wildebeest population is though to be regulated by intraspecific scramble competition for a limited supply of grass of adequate quality in dry season.

This competition is responsible for leveling off or fluctuations around a certain density of a population. Exact mechanism may vary in different species. It is worked out in azuki bean weevil (*Callosobruchus chinensis*), the bettle feeding on stored legume seeds. At high density, female fecundity is reduced because overcrowding leads to fewer successful matings due to mechanical interferences between individuals. These collisions are the main factors causing the decrease in population density. Subsidiary effects are increased egg mortality and increased larval competition for food at high density. The egg mortality is due to adults knocking eggs from the sites at which they were laid.

* 1. Interspecific competition – This is also called a contest (interference competition). The classical mathematical model of competition between two species is called the Lotka competition equations in honour of the two cofounders. Based on the logistic model, these equations predict the following three types of outcome:

1. One species only survives, it being the one with the greater negative effect on its competitor. Growth of the surviving population to its carrying capacity is slower than if the second population had been absent.
2. Both species coexist indefinitely. This occurs when interspecific competition is less intense than intraspecific one in both species. Neither population reaches the carrying capacity it would have in the absence of other species.
3. The species beginning at higher density persists, and the other is eliminated. This is a special case when the populations have equally negative effects on the growth of each other, but interspecific competition is stronger than intraspecific one.

In laboratory experiments, made on *Paramecium* spp. (*P. caudatum* and

*P. aurella*), one species was eliminated. However, with insects the model fit less closely. But in this case also with two species of beetles (*Tribolium castaneum* and *T. confusum*) that feed on stored flour, one species could survive and the other died out.

The Lotka-Volterra model also predicts the possibility of coexistence. But this may not occur in species with near-identical resource use and population growth.

Gause’s Principle

In experiments with a heterogenous environment or with interspecific differences coexistence may be found. In finely ground wheat flour, *Tribolium* always displaces another flour beetle *Oryzaephilus*, largely due to predation on the pupae of the second species of *Tribolium*. When cracked whole wheat grains are used, the species coexist indefinitely because *Oryzaephilus* larvae pupate within the grains, thereby escaping from *Triboliu*. That the effect is largely one of physical protection for the pupae was demonstrated further by using ground flour to which capillary tubes were added. The *Oryzaephilus* pupated inside the tuber and both popultions persisted. Such results led to the formulation of what is often called Gause’s principle, though never stated clearly by Gause. Slobodkin (1961) stated the hypothesis as follows:

“Given a region of physical space in which two species do persist indefinitely—there exists one or more properties of the environment or species, or of both, that ensures, ecological distinction between the two species—“. In the above said example of four beetles, ecological distinction is the ability of one beetle larvae to pupate in confined spaces safe from predation. Gause’s hypothesis was restated by Hardin (1960) as the competitive exclusion principle which in its simplest form, states that “complete competitors can not coexist.” This concept is a cornerstone of ecology, particularly in the form of its corollary of ecological segregation, the populations will evolve to use environment in slightly different ways, thereby reducing competition and permitting coexistence.

In field, most populations are regulated by competition, primarily for food. Competitive displacement has occasionally been observed in the field. Introduction of wasp parasite, *Opius oophilus* to control a fruit fly pest in Hawaii, apparently displaced the other two wasp species from the field. The tramp ant, *Wasmannia auropunctata* hasdisplaced all the native ants in some areas of santa Cruz island in the Galapagos group. Competition in the field has also been demonstrated for some lizards. There are many examples of coexistence also through ecological segregation in many insects as ants in field conditions.

Competition theory and ecological segregation have also been demonstrated for plants. Here ecological segregation often takes the form of specialization in growth form or degree of tolerance of environmental stresses rather than food. Furthermore in plants, distinction between scramble and contest competition is often obscure.

Interspecific competition between plants may manifest itself by chemical aggression or allelopathy. Here one species produces chemicals the inhibit or kill competing plants. Such interactions have been demonstrated in laboratory, but their common occurrence and significance in the field is unclear. Allelopathy may also occur even in intraspecific competition as in forest tree, *Grevillea* in Australia. The roots appear to produce water-soluble substance that inhibits the establishment of adjacent seedlings of the same species.

Competition is also involved in ecological niche. Any population can only survive and reproduce within certain environment limits. For example, it will only tolerate a certain range of temperature, humidity etc. These two abiotic actors are niche dimensions. If a third is added, say size of food item eaten, this can be represented three-dimensionally. The resulting rectangular box is the niche space in which the population can survive and reproduce with respect to these three important factors. Further dimensions, as type of substrate or size of nesting site available, could be added to produce a conceptual n-dimensional hyper volume or niche.

The Hutchinsonian (1965) niche just described is “obtained by considering a hyperspace every coordinate of which corresponds to a relevant variable in the life of a species of organism. A hyper volume can therefore be constructed, every point of which corresponds to a set of values of he variables permitting the organism to exist.” The fundamental niche of a species is the hyper volume that a population can fill in the absence of competitors. Closely related species of competitors will have similar requirements along the niche dimensions so that their niches will overlap one another. If the niche of one species completely overlaps that of another, then one of the species will be

eliminated according to the competitive exclusion principle. If the niches overlap partially, coexistence is possible in two ways. Either one species fully occupies its own fundamental niche, excluding the second species from part of its fundamental niche and leaving it to occupy a smaller realized niche or both species have restricted realized niches, each utilizing a smaller range of particular niche dimensions than they would in the absence of other species. Niche theory leads to ecological segregation and can be regarded as an extension of Gause’s hypothesis. It has been shown for some subterranean legless lizard, *Typhlosaurus lineatus* eating the termites. This lizard adjusts to a realized niche with respect to food size, thereby reducing interspecific competition with another species, *T. gariepensis*.

Microclimate

Temporal and spatial variations in each ecological factor are well known. Very frequently, however the values of some ecological factors in the immediate surroundings of the organism differ markedly from their regional values. That, is the immediate climate (real climate) of the organism is often sharply different from the average climate of the region, as reported by standard meteorological records. Such local variations are of considerable importance in limiting the distribution of organisms. Realisation of such a fact led to the development of the concept of ‘microclimate’ among ecologists. Microclimate thus refers to local combinations of factor, which differ from the regional climate. For instance, wind, rate of evaporation, humidity, temperature etc., prevailing in areas of limited size make up the microclimate. Some prefer to use the term ‘microenvironment’. The areas involved in a microclimate are generally never so extensive and may be of variable extent. For example, microclimate may

include a large volume, like layer of a forest, or it may be as small as the conditions on/within a single leaf. Thus local variations in climatic factors may involve distances of variable size. For example it is several meters in the surroundings, whereas for forms in soil, a leaf surface, in rock crevices, under bark of trees, the distance measures only a fraction of a centimeter.