

Ecology

Population and Community Ecology

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Significant Key words

*Population ecology: Population Characteristics, Dynamics and Regulation, Growth curves;
Community ecology: Community characteristics, methods of studying, frequency, density, cover, life forms,
biological spectrum; ecotypes; ecads.
Ecological succession*

Population Ecology

A population refers to a group of individuals of one kind with no barriers to exchange of genetic material in a given area at a given time. For example, population of human beings in a city, or population of squirrels or of lions in a forest, or pine trees in a given land (Photo 1). The study dealing with structure and dynamics of individuals in a population and their interactions with environment is known as Population Ecology. It has almost the same meaning as that of conventional term Autecology (the study of ecology of individual species or its population), which is less in use now. Population ecology is a significant branch of ecology that plays an important role in protecting and managing populations, especially those of rare species, through various means including PVA (Population Viability Analysis). PVA helps to determine whether a population would survive or face the risk of extinction (complete disappearance of a species from the biosphere) under a given set of environmental conditions. Further, each population has a minimum viable size - the size at which it can avoid the extinction due to various biotic and abiotic factors.



Photo 1. A population of Pine trees

There are two types of populations:

- a) Unitary Populations
- b) Modular Populations

In unitary populations, each individual is derived from zygote (the product of fertilization of male and female gamete) and the growth of such individuals is determinate and predictable. Examples include mammals (including humans), birds, amphibians and insects. Each cow has four legs, two eyes, and a tail., i.e., each individual shows a definite shape and size (Photo 2a).

In contrast, modular populations are those where an organism develops from a zygote and serves as a unit module and several other modules are produced from it, forming a branching pattern (Photo 2b). Examples of modular organisms are plants, sponges, hydroids, fungi, bacteria and corals. Some modular organisms such as trees may grow vertically while others like grasses spread horizontally on the substratum. The structure and pattern of modular organisms is not determinate and thus unpredictable.



Photo 2a. Unitary Population of Cow



Photo 2b. A Grass showing different Ramets

Biologists also use the term Genet to the organism, which arises from a zygote, whereas others arising asexually are known as Ramet. In a grass or weed species, a number of young plants may arise through runners or stolons, and upon separation from the parent plant form new plants; a group of such new plants is known as ramets (Photo 2b). Individuals of ramets are genetically alike and replica of parent plant. A group of ramets developing from a genet is known as clone since all organisms are genetically alike. The formation of ramets in the plant species is very common and can be easily seen in grasses.

The populations can be r-selected or K-selected. This type of classification of populations is based on their growth and survival strategies. r-Selected populations are characterized by high reproductive rates, rapid use of resources over a short span of time and high rates of intrinsic growth (r). These populations exhibit shorter life spans and are also known as opportunistic species. On the other hand, K-selected populations are slow growing and tend to be limited by the carrying capacity of the environment, i.e. K. Such populations have long life spans, high competitive ability and low rates of intrinsic growth (r).

The subject of population ecology can be divided into 3 sections for the sake of convenience:

- A) Population characteristics
- B) Population dynamics
- C) Population regulation

A. Population Characteristics

Populations are identified by a number of characteristics. These are: 1. Population size and density, 2. Patterns of dispersion, 3. Age structure, 4. Natalty, 5. Mortality, 6. Population growth and dispersal, 7. Biotic potential.

1. Population size and density

Population size is usually determined on the basis of density, i.e. number of individuals per unit area (if it is land) or per unit volume (if it is an aquatic system). For example, 200 trees found in one hectare of land tell us about the density of the tree population, or 15 fishes/m³ water indicates the density of fish population. Density of the population is often of two types - Crude density and Ecological density.

- Crude density is that density which takes in account all area of land or aquatic ecosystems under consideration, e.g. number of squirrels in a forest.
- Ecological density on the other hand, takes in account abundance of individuals in the actual area occupied by a population. If we consider the above example of squirrels, numbers of squirrels per unit area of the tree dominated patches (areas where squirrels are actually living) constitute ecological density.

The difference in the two types of densities becomes more apparent when the species are clumped together in a small area. However, crude density is studied frequently more than the ecological density because it is very difficult to determine the 'actual area' of inhabitation of a species. Further, the area of inhabitation may vary with developmental stages of species.

2. Patterns of dispersion

Pattern of dispersion means the manner in which individuals of a population are distributed in space and time. Dispersion may be spatial (varying with respect to space) or temporal (varying with time). In the latter, example of migratory birds is well- known. In case of spatial pattern, broadly three types of dispersion patterns are recognized.

- ❖ Regular or Uniform
- ❖ Random
- ❖ Clumped

Regular or Uniform dispersion: In this type, the individuals of a species occur uniformly which is observed in terms of almost equal distances between individuals (Figure 1). This type of dispersion is rare in natural ecosystems but common in manmade ecosystems like agro-ecosystems or tree plantations.

Random dispersion: In random dispersion, position of an individual in a population is unrelated to the positions of other individuals (Figure 1). In other words, individuals do not show any systematic pattern of dispersion. This type of dispersion is also rare in nature.

Clumped dispersion: In this type of pattern, the individuals of a species are clumped together in space in the form of patches (Figure 1). This type of patchy distribution is quite common in nature as individuals of a population occur together because of food availability or better survival rate as in animal populations. In plants, the clumped distribution is very common, and attributed to nutrient availability, specific habitat preference or better environmental conditions. Example of this kind can also be seen in the social aggregations that are formed in response to some environmental suitability.

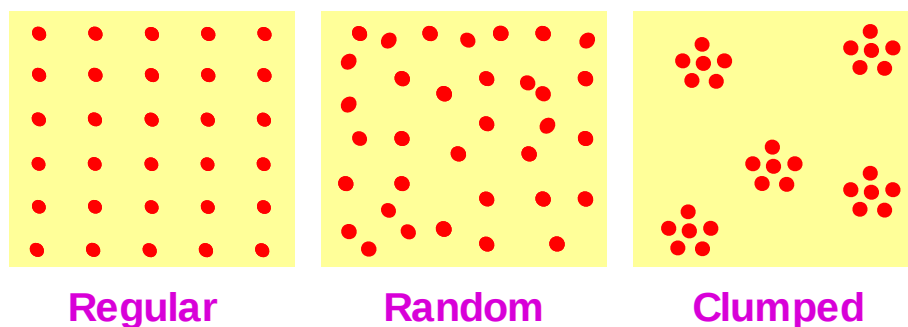


Figure 1. Different types of dispersion of organisms in a population

3. Age structure

A population is comprised of individuals of different age groups that constitute its age structure. Age structure of a population thus derives from the proportion of individuals in different age groups. For the sake of convenience, the age categories have been divided into three major stages, **Pre-reproductive**, **Reproductive** and **Post-reproductive**. The proportion of different stages in a population is presented graphically in the form of age pyramid. An age pyramid is thus a geometrical model showing the proportions of different age groups of a population. Populations with equal proportion of major three stages are said to be stationary populations (Figure 2a). A population with high number of young individuals as compared to the older organisms is increasing or progressive type and the pyramid of such a population would have a broader base (Figure 2b). On the other hand, if the number of older organisms is more than the younger ones, the population is said to be retrogressive or declining type. The base of the pyramid of such population would be narrow (Figure 2c).

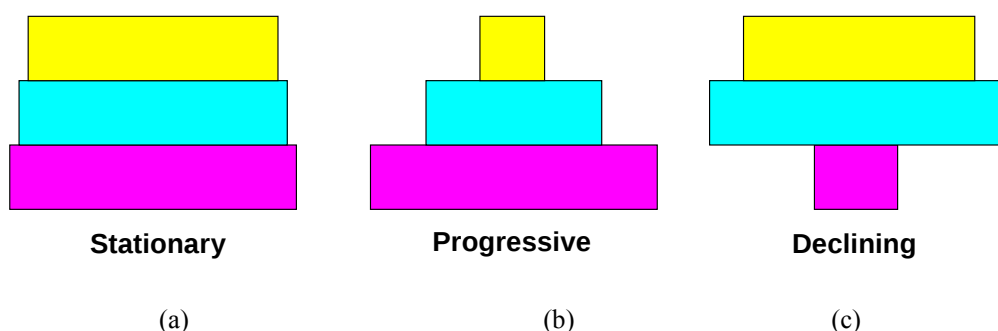


Figure 2. Different types of Age Pyramids

(■ Pre-reproductive; ■ Reproductive; ■ Post-reproductive).

4. Natality

Natality means production of new individuals (offspring) of an organism in a population. The new individuals can be formed through birth (as in human beings), hatching (for example, in chicken eggs), germination (in plants), or cell division (lower organisms). The number of offspring produced per female per unit time is known as *rate of natality*. Natality can be of two types:

- ❖ Maximum or Absolute natality
- ❖ Ecological natality

Maximum or Absolute natality also known as *Fecundity rate* means maximum offspring produced under most suitable environmental conditions. This value is theoretical (since the environmental conditions are never static and keep on changing) and constant for a given population.

Ecological natality also known as *Fertility rate*, on the other hand, refers to number of offspring produced under prevailing environmental conditions.

5. Mortality

Mortality refers to death of individuals in a population. Rate of death of individuals referred to as Mortality rate is of two types:

- ❖ Minimum mortality rate
- ❖ Ecological mortality rate

Minimum mortality rate, or also known as *Physiological longevity*, refers to the theoretical minimum death rate which occurs under ideal conditions of environment with minimum limiting factors. This value is a theoretical value and constant for a given population. Under actual environmental conditions, the death rate may be more and this actual death rate is referred to as *Ecological mortality*.

The other way of expressing mortality is vital index, which is ratio of birth to death rate and expressed as percentage.

$$\text{Vital Index} = \frac{\text{Number of births} \times 100}{\text{Number of deaths}}$$

The most popular way to express mortality in a population is to prepare a survivorship curve. A *survivorship curve* for a given population is a graph drawn between numbers of survivors (on a log scale) on Y-axis against age on the X-axis. In general, there are three patterns of survivorship curves (Figure 3).

Type 1 - It is also known as *highly convex curve*. It reflects higher rate of survival or low rate of mortality of younger individuals as compared to the older ones. This type of curve is found in human beings.

Type 2 - This curve shows a steady death of individuals per unit time throughout the life, and is found in some reptiles, corals, honeybees and rodents. This shows a *straight-line relationship* between age and number of survivors.

Type 3 - This is also known as *highly concave curve*. It shows higher mortality of individuals at young stage as compared to old stage. It is found in plants, sea urchins and fish species.

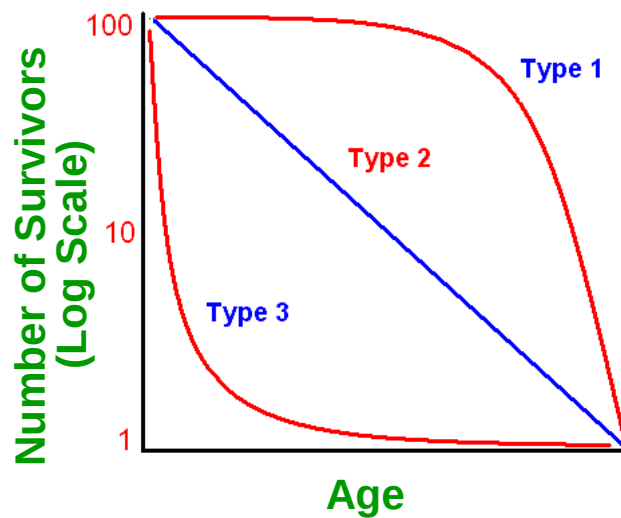


Figure 3. Different types of survivorship curves found in different populations.

Environment may have significant impact on survivorship curves of a given population. For example, plant population may show one type of survivorship curve under drought and another type of curve under humid conditions.

6. Population growth and dispersal

Individuals of a population keep migrating out (Emigration) or into populations (Immigration). Thus, population size and density keep changing with time. In addition, birth (b) and death (d) of individuals also change population size. Immigration and birth increase population size whereas emigration and death decrease its size. Thus, in a given population if $\text{birth} + \text{immigration} > \text{emigration} + \text{death}$, the size of population would increase. On the other hand, if the $\text{birth} + \text{immigration} < \text{emigration} + \text{death}$, then the size of the population would decrease.

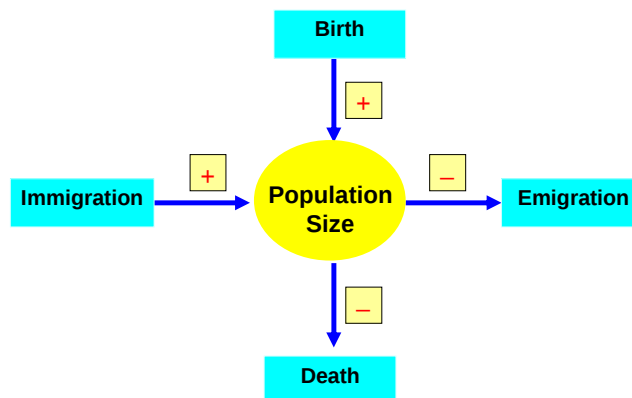


Figure 4. Influence of immigration, emigration, death rate and birth rate on population size.

7. Biotic potential

It is the inherent power of a population to grow and reproduce when environmental conditions are favorable and resources are unlimited. Biotic potential is represented by r .

B. Population Dynamics

Populations are never static and keep changing in time and space. These changes in population size over time show varied trends. When environment is unlimited (adequate space and food supply) the specific growth rate (population growth rate per individual) of populations becomes maximum and constant under a set of environmental conditions. On the other hand, if the food supply or other resources are limited, the growth rate is typically sigmoid, i.e. increases slowly in the beginning followed by rapid increase and then becomes constant as it approaches the upper limit. To address these growth patterns, there are two types of growth models. These are:

- a. J-shaped or Exponential Growth Model
- b. S-shaped or Sigmoid or Logistic Growth Model

a. *J-shaped or exponential growth model*

In exponential growth type population increases geometrically or exponentially until there is resource limitation or population growth is limited by other factors. Growth then declines rapidly until favorable period is restored. Mathematically this growth model can be expressed as rate of population increase with time t , i.e.

$$dN/dt = rN$$

Where N = population size, t = time, and r = intrinsic rate of natural increase.

The value of r is the maximum when resources are not limiting. Since the curve drawn between population size (Y-axis) and time (X-axis) is *J-shaped*, it is also known as *J curve* or *J-shaped growth model* (Figure 5a).

b. *Sigmoid or S-shaped growth*

When population growth occurs at a place where resources are limited, it attains a sigmoid or S-shaped curve showing minimum death during early stages. The population increases in size until it reaches an upper limit. This upper limit is known as the *Carrying capacity*, which is denoted by ' K '. *Carrying capacity thus may be defined as capacity of an ecosystem to support maximum number of individuals of a species*. As the population size increases, population growth rate declines as it approaches carrying capacity. Sigmoid growth is thus density dependent and can be expressed by the following equation:

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

Where N = population size, t = time, r = intrinsic rate of natural increase, and K = carrying capacity.

When N equals K , the growth rate becomes zero and the population reaches equilibrium.

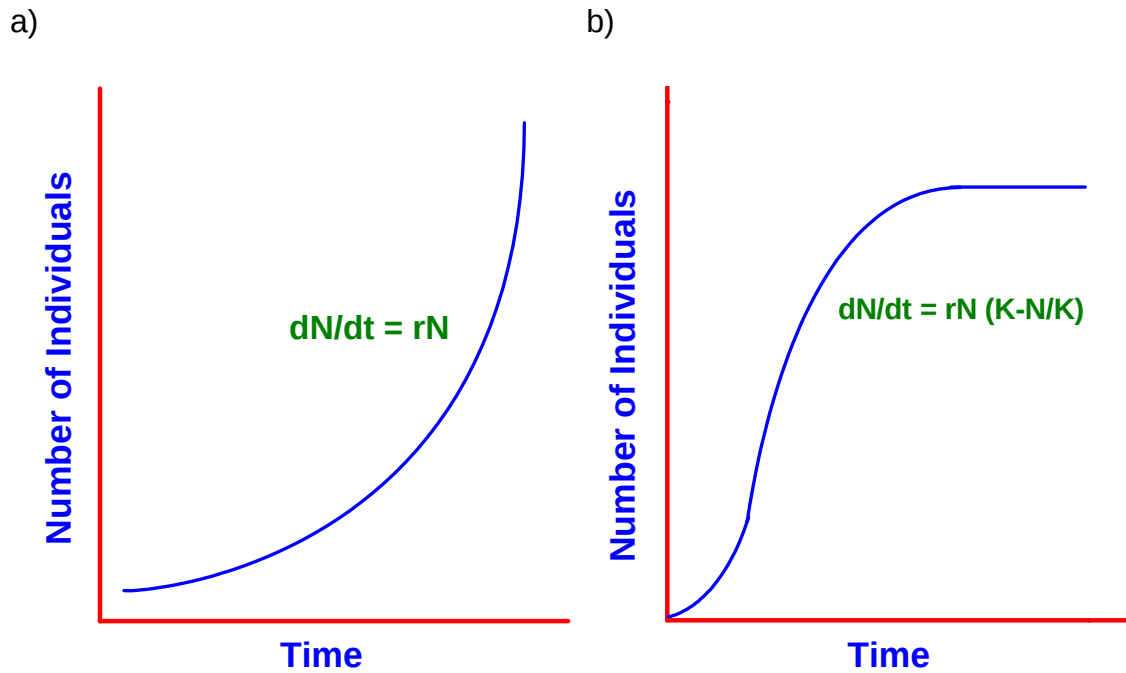


Figure 5. Population Growth Models; a: J-shaped or Exponential; b: Sigmoidal or S-shaped.

Figure 5

Allee's Principle

W.C. Allee, an ecologist known for his extensive research on social behaviour of animals, gave a concept known as Allee's principle. *Allee's principle is a relationship between population density and survival of animals.* According to Allee, both under-crowding (low population density) and over-crowding (high population density) limit growth and survival of a population. There are a number of examples (in both plants and animals) where Allee's principle holds good. A number of plant species occur in groups, which may be in response to habitat preference or suitable climatic or environmental conditions or due to reproductive strategies. Within a group, the survival rates of species increase in response to the adverse environmental conditions. For example, species of *Polygonum pleibium* prefers to grow in clayey soil and often form groups or patches. Likewise, populations of *Stellaria media* or *Anagallis arvensis* form patches owing to their preference for better moisture conditions. Some species form groups or patches due to vegetative reproduction or due to lack of effective seed dispersal mechanism. Survival chances and fitness of such species is best at moderate populations. As the population density increases beyond limit, there is competition for resources, and it is detrimental to growth and survival of such species. The Allee's Principle is also valid in animal populations. There are a number of social insects, termites, ants, which survive and grow best at moderate densities and are able to overcome harsh conditions. Bees and colonial bird are the best examples of group survival. Allee's principle is also very relevant to human beings who form social aggregations particularly in the urban environment.

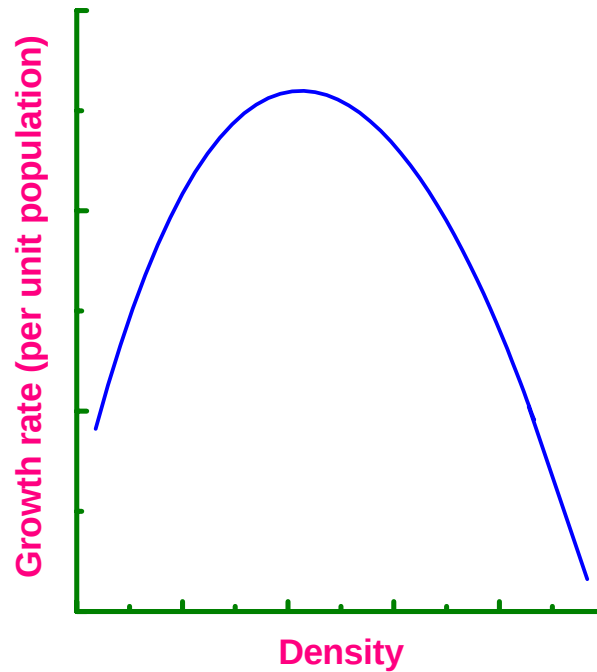


Figure 6. A curve showing Allee's Principle

C. Population Regulation

A number of factors like availability of food, space, water, and pests may regulate population size. In general, the factors responsible for population regulation can be **density dependent** (competition, predation, parasitism, disease outbreak, or herbivory) or **density independent** (environmental factors). In density dependent factors, competition (particularly intra-specific i.e. between individuals of same species) plays a major role in limiting population size. Among the density independent factors, floods, fire and other natural calamities remove large proportion of the populations and thus decrease their density.

Sometimes individuals of a population release toxic substances in the soil or water, which tend to limit the growth of their own type of plants (*consepecifics*) and thus control over-crowding of a species at a particular place. This is known as **autoallelopathy or autotoxicity** - a type of interaction where one species releases toxic substances into environment that are detrimental to individualists own growth. Autotoxicity is well demonstrated in a number of food plants like alfalfa (*Medicago sativa*), figs (*Ficus* species), grape (*Vitis vinifera*) and peach (*Prunus persica*) orchards; in aquatic and wetland plants like *Typha*, *Phragmites*, *Juncus* and algae; and in forest tree or shrub species like *Casuarina*, Walnut (*Juglans* species), Coffee (*Coffea arabica*) and tea (*Camellia sinensis*),

Another interesting observation wherein organisms regulate their population prevalent in plants and even in some sessile animals is self thinning. *Self- thinning* results from a specific relationship between density and biomass of individuals. When a plot is drawn between density (log scale, X-axis) and biomass (log scale, Y-axis), it results in a slope of $3/2$ or 1.5 and is known as *Self-thinning* or $3/2$ law or *Yoda's $3/2$ law* (Fig. 7). It means as the density increases, the biomass of species decreases leading to self-thinning of population. It is universal in plants and seen in all groups from mosses to trees.

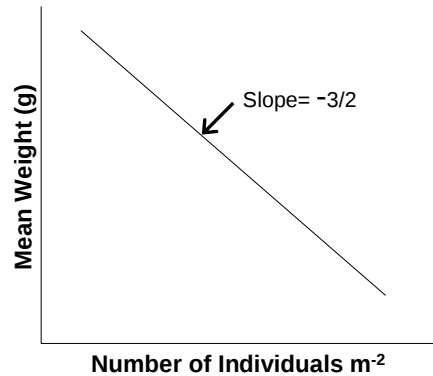


Figure 7. Relationship between plant density and biomass indicating Yoda's $-3/2$ law.

Community Ecology

Community ecology has almost similar meaning as that of *Synecology*.

The concept of community is very old and traced back to the times of Theophrastus (370-250 BC). A **community**, also known as **biotic community** or **ecological community** or **biocoenosis**, refers to a group of co-existing and interacting populations in a given space and time (Photo 3). For example, a forest community is reflection of co-existence and interactions of a variety of populations – the trees, shrubs, herbs, grasses, animals, and microorganisms. In other words, it is the biological part of the ecosystem distinct from the abiotic part. Earlier, a community was interpreted as a **superorganism** because it was thought to behave as a single entity. In contrast to this, another view perceived community as a collection of species where each individual species has its own identity.

Each community has spatial limits or boundaries. The boundaries between communities may be very sharp such as boundary between a forest and a lake or less sharp, e.g. boundary between two types of forests or a forest and a grassland community. Often there is some transitional area between two communities that is known as *Ecotone* where species of both adjacent communities are found. The ecotonal communities are rich in species diversity because of the edge effect (contrasting environmental conditions at the boundaries or the edges supporting a high species richness). For instance, a patch of land between two forest communities will have animals and plants common to both the forest communities.

Characteristics of Communities

There are various characteristics of communities such as species diversity, structure and composition, dominance, succession (or developmental history) and trophic structure. Each one of these is discussed as under:

Species diversity: Each community is composed of taxonomically different species. *Species diversity* refers to number of different species in the community including both abundant and rare species. Species diversity is very high in natural communities like tropical rain forests or coral reefs in oceans, whereas it is very low in physically or human controlled communities. Species diversity has two components: species richness and species evenness. In simple words, species richness refers to different types of species and their numerical strength. Technically, it refers to ratio between different species (S) and total number of species (N). Species evenness refers to a measure which qualifies as to how even species are in terms of their number. In a community, it refers to the apportionment of each species. For example, a community is quite even if there are 10 species with 10 or 9 individuals of each species; whereas a community is uneven if there are 10 species of which one species has 90 individuals and the rest 9 species have only 10 individuals.

Species diversity can be measured by using various diversity indices – the mathematical expressions based on species abundance data. Species diversity can be measured separately either as species richness or evenness or diversity as a whole. *Species richness* is measured by Index of richness (denoted by R in the formulae given in Box 1) given by Margalef (1958). *Species evenness* can be measured with evenness index (denoted by E) given by Hill (1973). *Diversity of the species* can also be calculated directly with a variety of indices, of which two

commonly used are Shannon-Weiner Index or simply the Index of diversity or Shannon's index (denoted by H' ; as given by Shannon and Weaver, 1963) and Index of dominance (or λ) or Simpson's index given by Simpson (1949) (See Box 1). Shannon's index has a direct relationship with the species diversity, whereas index of dominance has an inverse relationship. The formulae for calculating various species diversity indices are given in the Box 1.

Box 1. Formulae for calculating various species diversity indices.

Richness Index	$R = \frac{S - 1}{\text{Log } N}$	as per Margalef (1958)
Index of dominance	$\lambda = \sum_{i=1}^S (n_i / N)^2$	as per Simpson (1949)
Index of diversity	$H' = - \sum_{i=1}^S n_i / N \ln n_i / N$	as per Shannon-Weaver (1963)
Evenness Index	$E = \frac{1/\lambda - 1}{e^{H'} - 1}$	as per Hill (1973)

Where, S = total number of species, N = total number of individuals of all the species in a given area, n_i = number of individuals of the i th species of the area.

For a community to be stable, it requires two components - **Resilience** and **Resistance**. *Resilience* is the ability of a community to recover after facing a disturbance or displacement. *Resistance*, on the other hand, is the ability of a community to avoid disturbance (any event that alters structure of a community) or displacement (shifting of the community to some other place). One of the reasons for the species rich complex communities acquiring stability is that any change in one or a few species would be compensated by the other species. Some other studies, however, have indicated that greater complexity in a community leads to instability. Thus, it remains controversial whether complexity of a community leads to stability or unstable conditions. However, ecologists have successfully found a relationship between competition and diversity or stability. If the competition is severe, there is low diversity because only those species survive what are able to withstand harsh conditions by suitably adapting themselves. On the other hand, if the competition is weak and the requirements of species do not overlap, the species will not fight for resources and thus more and more species can coexist. The competition becomes intense if the resources for the life support system – food, air, water, space, sunlight (in case of plants, especially) are scarce and the requirements of the species overlap.

Community Structure and Composition:

Each community has its own structure and composition. For instance, the community of rain forests in silent valley will be different from that of rain forests in Arunachal Pradesh. Community structure is often expressed in terms of its major growth form such as trees in forests or grasses in grasslands. The arrangement of different growth forms determines the structural pattern of the community. In a community, spatial arrangement of the components is also very important. For example, in a forest, some plants may be shade loving and confined to understorey while others are adapted to intense sunlight like emergent trees.

Still other plants need better soil-moisture and some may grow in dry stony areas. Likewise, in a pond ecosystem the plants that need soil will remain confined to the edges of pond, while the free-floating will cover the water surface. This horizontal distribution of a community is known as *zonation*.

In aquatic bodies, particularly lakes and ponds, three different types of zones differentiated on the basis of light availability and depth of water are very common such as Littoral zone, Limnetic zone and Profundal zone (Figure 7). Each of these zones supports distinct community.

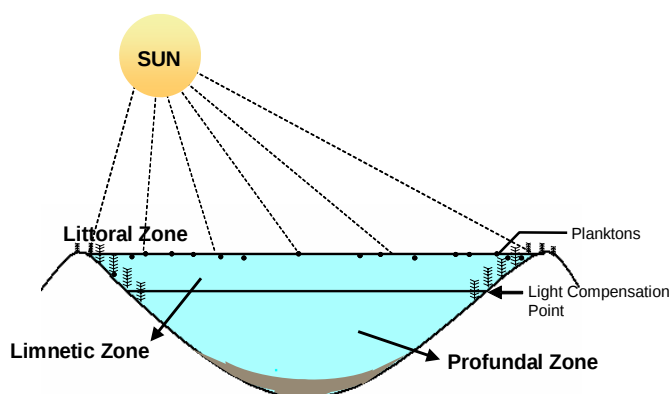


Figure 8. Different layers (communities) in a pond formed in response to light.

Figure 8

Littoral zone is the zone on the sides of the water body where water is shallow and thus light can penetrate upto the bottom. Most of the rooted plants are found in this zone. Some of these plants are *Trapa*, *Typha*, *Sagittaria*, *Scirpus*, *Marsilea* and *Hydrilla*.

Limnetic zone is the open free surface of ponds and lakes up to which light penetrates. Since this zone of water is fully illuminated, photosynthetic (autotrophic) organisms like green algae, blue green algae and even free-floating or submerged higher plants occupy it. These organisms are typically adapted for floating or swimming. These can be planktons (organisms that are able to float), nektons (organisms that are able to swim and navigate) and also neustons (organisms that rest or swim on the surface). The level of water upto which light penetrates is known as *Light Compensation Point*.

Profundal zone, on the other hand, is the deep-water zone of the ponds and lakes beyond light compensation level where heterotrophic (non-photosynthetic) organisms live. The organisms of this zone are dependent on Limnetic zone for food and in return replenish nutrients.

In some ponds and lakes there is little distinction between littoral and Limnetic zone and in such cases the upper surface of water up to light penetration point is known as Euphotic zone.

The pond water can also be divided into *Epilimnion* and *Hypolimnion* based on temperature differences. In between the two layers there is an intermediate zone known as **Thermocline** (Figure 8). This type of distinction is very common in temperate lakes, wherein during the summer season the top water layers become warmer

compared to the lower layers. As a result, the water circulates only in the top warmer layers and does not mix with the lower colder water layers. This creates a sharp temperature gradient separating upper circulating warmer layers known as Epilimnion from lower non-circulating colder layers known as Hypolimnion. In between Epilimnion and Hypolimnion is Thermocline - a zone differentiating the two layers of water based on temperature difference.

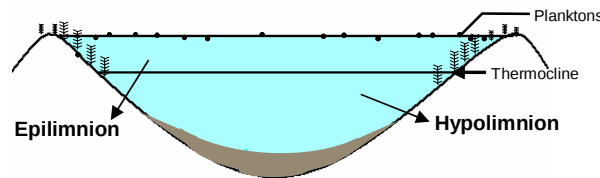


Figure 9. Different layers (communities) in a pond formed in response to temperature.

The forest communities are highly stratified (forming distinct vertical storeys). In a typical forest, there are five different vertical storey *viz.* subterranean part (deep in soil), forest floor, herbaceous vegetation, shrubs, and trees. In contrast, grasslands show poor vertical stratification. It has only two layers - a subterranean part with roots and rhizomes and herbaceous part consisting of grasses, herbs and weeds.

Dominance: A community is a heterogeneous assemblage of species. Not all species present in it are equally important and thus only a few of them have a major controlling influence based on their number, size or productivity. Such groups of species are not taxonomically related and influence the energy flow and affect the environment of other species. These are known as **Ecological Dominants**. In land communities, some plants have a major influence over the others by virtue of their greater number (Numerical dominance). These protect and provide shelter to the organisms and are capable of influencing physical environment.

Trophic Structure: In addition to above, each community has its own trophic structure or organisms grouped based on feeding habits. Trophic structure of a pond consists of a variety of organisms as producers (which can prepare their own food through photosynthesis), consumers (heterotrophs which can not prepare their own food but are dependent on producers for nutrition directly or indirectly) and decomposers (which decompose the dead and decaying matter and in this way release nutrients). Rooted or free-floating green plants (macrophytes), free-floating minute organisms (phytoplanktons – green algae and diatoms) constitute producers or autotrophs of a pond community. The consumers may be primary (herbivores that directly feed on green plants or algae), secondary (carnivores that feed on herbivores) or tertiary (feeding on other carnivores). Zooplankton or floating minute animals like rotifers, crustaceans and protozoans, which feed on phytoplanktons, constitute herbivores in the pond community. In addition, there are several animal species associated with the green plants and feed on them. Some herbivores are also present at the bottom of the pond and feed on dead decaying plant parts. These may be beetles, mollusks or even crustaceans. Some birds and domesticated animals such as cow, goat and buffaloes also feed on green plants found in the pond especially on the margins in the littoral zone. Fishes constitute the secondary consumer of the pond feeding largely on herbivores. Some insects are also included in this category. In the pond, some larger fish or the game fish that feed on smaller fish constitute tertiary consumers. Besides there are varieties of decomposers (microconsumers – since they take a fraction of food) in the pond and these decompose complex, dead and decaying matter into simpler forms like nutrients, which are absorbed by the plants for their growth and development.

Trophic structure of a forest community also has a same pattern but with different species composition. In a forest, the autotrophs or the producers are the trees, which are also the dominant species. Additionally, the forests also have shrubs, herbs and grasses that are autotrophic and form a distinct understory, but their role is lesser than that of trees. The type of the trees in the forests varies from place to place depending upon environmental conditions.

For example, a typical tropical moist deciduous forest is composed of tree species like teak (*Tectona grandis*), sal (*Shorea robusta*) or Queen's myrtle (*Lagerstoemia parviflora*); whereas a temperate deciduous forest has trees like oak (*Quercus*), maple (*Acer* sp.), birch (*Betula* sp.) and spruce (*Picea* sp.). The primary consumers in the forests include ants, beetles, leafhoppers, spider and bugs that feed on tree leaves. Besides, there are larger animals like elephants, nilgai, squirrels, rabbits, flying foxes and birds, which feed on shoots or fruits of the trees. Birds, snakes, lizards and foxes constitute secondary consumers whereas lions and tigers constitute tertiary consumers. The decomposers include several types of fungi, bacteria and actinomycetes.

Succession: Succession is the orderly process of community development and refers to the continuous, unidirectional and sequential change in the species composition of a given community over time. It involves various stages during which a specific set of species occupy the area and replaced by the next group of species. All these stages of succession are known as seral stages. The first stage of succession when the bare area is colonized for the first time is known as Pioneer stage and such species are referred to as Pioneer species. The final, mature, stable and long lasting community is known as Climax community.

Methods of Studying Communities

Plant communities can be studied by different methods such as floristic (by simply studying various genera and species) and physiognomic (based on Raunkiaer's life forms) and phyto-social methods. Of these, phyto-social methods are preferred. In these, the data on the vegetation is collected in terms of types of species present and individual number of each type in an area. As the areas are very large, it is not possible to count every plant, thus the area is divided into smaller units known as **sampling units**. Three types of sampling units are generally considered for studying various plant communities. These are: a) Area, b) Line, and c) Point. Area and line both are based on definite size of the sampling unit while point is used in those situations where it is difficult to determine area e.g. thick forest. Sampling unit where definite area is selected is known as **Quadrat**. Quadrat is thus a sampling unit of definite area that is usually a square but it can also be a rectangle or circle. Size and number of quadrats are determined based on the objective and features of area under consideration. Depending upon the purpose of study, the quadrat may be list quadrat (where species present in the area are listed), list-count quadrat (where species are listed as well as their numbers counted), chart quadrat (where all details like distribution of species, their number are recorded on a graph paper periodically using an instrument pantograph) and permanent quadrat (used in the experimental studies where vegetation is recorded for a long time to find out changes). **Transect** is the term used in cases where sampling unit is a strip of definite area. Transect may be a line or belt depending upon the study area. In a line transect, sampling is usually done across a line. In belt transect, an area (belt) of suitable size is selected where the sampling is done. Belt transects are particularly used in forests and can be further divided into segments for convenience.

For determining quadrat size, species-area curve method is used. Sampling unit size is increased gradually (starting from a minimum) and the number of types of species counted in each sampling unit. It is continued until number of species become constant for three consecutive times. Then, a graph is drawn between area (X-axis) and number of species (Y-axis) and from the curve so obtained, optimum size of quadrat (where the number of species becomes constant) is determined.

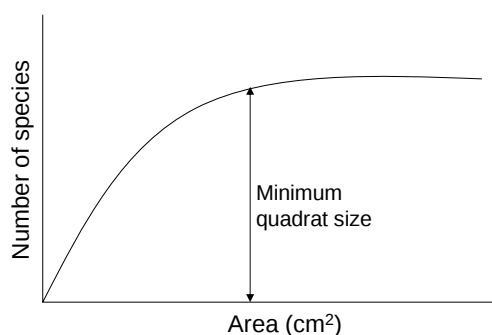


Figure 10. A typical species-area curve for calculating the minimum quadrat size.

Point is used as a sampling unit in areas where determination of suitable area is not possible with quadrats e.g. in thick forests and large grasslands. For this, a number of movable pins (usually 10) are inserted in a wooden frame at 45° angle is known as Point frame. Point frame is laid randomly in an area, plants hit by the pins are recorded, and their frequency determined.

Community Features

Communities may be identified and recognized by several features that may be quantitative, qualitative or synthetic.

Quantitative characters: Quantitative characters are those that can be measured, e.g. density, abundance, frequency, cover area and basal area of species present in a given area. These values can be expressed as absolute or as relative values.

Density and Abundance: Density of a species reflects the numerical strength of species in a given community.

$\text{Density} = \frac{\text{Total number of plants of a species present in all Quadrats}}{\text{Total number of Quadrats studied}}$

For more clarity see example in Table 1 where density of five species has been shown as calculated by the above formula. Another important aspect about density is that if the size of the quadrat is either lesser or more than 1m², the final value of density is presented equivalent to 1m². This is true only in grasslands or communities of a smaller area, but not in forests or aquatic systems.

Table1: vegetation analysis of a small area showing values of density, abundance and frequency.

Sp.	Q1	Q2	Q3	Q4	Q5	Total	Density	Abundance	Frequency
1	20	40	43	21	26	150	150/5 = 30	150/5 = 30	5/5×100= 100
2	22	-	-	21	7	50	50/5 = 10	50/3 = 16.7	3/5×100= 60
3	100	-	-	25	25	150	150/5 = 30	150/3 = 50	3/5×10 = 60
4	-	-	-	25	10	35	35/5 = 7	35/2 = 17.5	2/5×100= 40
5	50	25	25	100	100	300	300/5 = 60	300/5 = 60	5/5×100= 100
Total	192	65	68	192	168	685	137	174.2	360

Q means quadrat; 5 quadrats of 1m² were laid.

$$\text{Relative density of a species} = \frac{\text{Individual density of a species}}{\text{Total density of all species encountered}}$$

Density can also be presented as relative density. Relative density is calculated based on following formula:

Note: Since the relative value of density is less than 1.0. It can thus be converted into percent by multiplying with 100.

From the above example (Table 1), the relative density for species 1 is calculated by taking its individual density i.e. 30 and dividing it by 137, i.e. total densities of all species. To convert it into percent relative density, multiply it with 100. It comes out to be 21.80%. Likewise, the relative density of other species can be calculated.

Abundance is also calculated like density but in this case, only those quadrats are considered for calculation where a species actually occurs. For example, if a species has occurred in only 3 quadrats out of total 5 studied, then the total number of individuals of the species is divided by 3 (instead of 5, as in case of density). The difference between density and abundance thus becomes clear from the example given in Table 1. The formula for calculation of species abundance is:

$$\text{Abundance of a species} = \frac{\text{Total number of plants in all the Quadrats}}{\text{Number of Quadrats of occurrence of plant species}}$$

Abundance is also presented on the basis of unit area, i.e. 1m² especially in smaller areas or grasslands. However, it is not much used as compared to density in ecological studies. It can also be multiplied by 100 to get percent abundance.

$$\text{Relative abundance of a species} = \frac{\text{Individual abundance of the species}}{\text{Total abundance of all species encountered}}$$

Frequency: Frequency is another important parameter of vegetation analysis, which reflects the spread, distribution or dispersion of a species in a given area, and given in percent. For example, a species is distributed uniformly in an area there is greater probability of its occurrence in all quadrats and it would have maximum frequency. In another case, a species may be clustered or present only in a part of the area. In this case, it will occur only in few quadrats and hence it would have lesser frequency. The frequency of a species in a given area is studied by either quadrat method or transects and is calculated by the following formula:

$$\text{Frequency} = \frac{\text{Number of Quadrats in which a species occurs}}{\text{Total number of Quadrats studied}} \times 100$$

Thus, if a species occurs in 5 out of total 10 quadrats studied, its frequency would be 50%. If a species occurs in all the quadrats studied, its frequency would be 100%. The frequency determination also becomes clear from Table 1.

Frequency is a very important quantitative parameter. Raunkiaer (1934) made an elaborative study on the frequency of species in about 8000 quadrats and based on his data, he divided species into 5 classes viz. A, B, C, D, E. The distribution of frequency in 5 classes is given hereunder in Table 2.

Table 2. Raunkiaer's frequency classes.

Frequency Class	Frequency Range
A	1-20%
B	21-40%
C	41-60%
D	61-80%
E	81-100%

Further, Raunkiaer suggested *Law of frequency* and *Normal Frequency Diagram* based on the data from his studies in all the natural ecosystems. According to law of frequency, species poorly distributed or dispersed in an area are likely to be presented more compared to those that have better or more dispersion in an area. In other words, $A > B > C > D > E$, i.e. A is greater than B, which is greater than C, and C may be greater or equal or lesser than D, which in turn is lesser than E. Raunkiaer's normal frequency diagram was a histogram made on the basis of the average frequency data in which value of class A was 53%, that of B 14%, C 9%, D 8% and E 16%. Raunkiaer also prepared a normal frequency diagram, a J-shaped curve, which represents homo- or hetero-geneity of a community. It is a J-shaped curve. After the preposition of Law of frequency, a number of studies were undertaken in various parts of the world and similar observations were obtained especially in the natural and undisturbed ecosystems. In disturbed ecosystems, however, the frequency distribution varies from that of normal as proposed by Raunkiaer.

Like density, frequency can be expressed in relative terms. For this, sum of frequencies of all species is calculated and following formula is applied:

$$\text{Relative frequency of a species} = \frac{\text{Individual frequency of the species}}{\text{Total frequency of all species encountered}}$$

This can also be converted into percent relative frequency by multiplying with 100. The relative value is important in further determining importance value index of species, which gives the total ecological status of species.

Basal Area and Dominance: Cover area, also known as herbage area, is usually confined to above-ground parts and is defined as percent area occupied by the above ground parts of species per unit area. It tells us about the dominance of a species in terms of area occupied by its aerial parts in given vegetation. Basal area is calculated from the point of ground where the stem of the plants pierces out of the ground. At this junction, i.e. near the ground, the diameter of the stem is measured with scales, calipers, or screw gauge. Based on formula for any area measurement i.e. πr^2 , the basal area of each species is calculated. Normally for a species, basal area of a large number of its individuals is determined and then the average value is calculated. This average value is then multiplied by density value of that species which gives the value of basal area per square meter, also known as *dominance*.

For dominance also, relative value is calculated as per the following formula:

$$\text{Relative dominance of a species} = \frac{\text{Individual dominance of a species}}{\text{Total dominance of all species encountered}}$$

This can also be converted into percent relative dominance by multiplying with 100. In case of trees, circumference of trees is measured at breast height (1.5m from base). From circumference, the radius is calculated and in turn from radius, area is calculated. In trees, the crown area is calculated based on area of its crown that is measured by taking radius along crown perimeter on the ground surface starting from the stem of the tree. If the crown of the tree is not circular which is normally so, then several values of radii are measured across different lines and then average radius is calculated. Area is then calculated by simple formula, i.e. πr^2 .

Qualitative characters of communities: These characters are not measurable but calculated on the basis of various qualitative features such as phenology, physiognomy, life forms and biological spectrum.

Phenology: It refers to the periodic occurrence of different events in the life cycle of a species. It means when does a species germinates, grows vegetatively, flowers and produces seeds, and how and when disperses the seeds. All this information about a species is determined periodically and presented in the form of a **phenogram**. A phenogram is simple hexagonal structure presenting different events in the life of a species, e.g. the six arms of phenogram show period of germination, vegetative growth, flowering time, fruit formation, seed maturation and death of the species. In a community, each species has its own phenology and this reflects a great diversity.

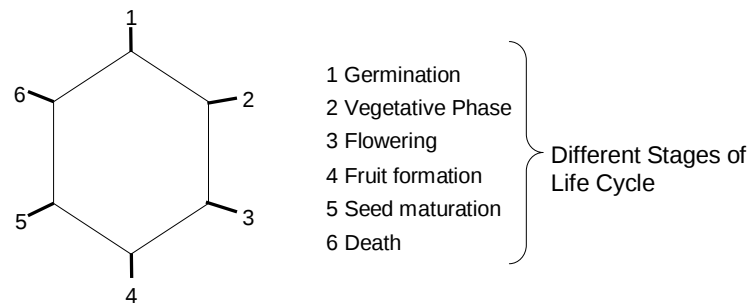


Figure 11. A typical phenogram showing different stages in life cycle of plants.

Physiognomy: Physiognomy refers the outer appearance of a community and is an important parameter that tells us about the structure of community. It is based on the growth form of its dominant species. For example, a grassland community is dominated by grasses, forests by trees and chaparral community by shrubs.

Life Forms: Life forms better known as *Raunkiaer's life forms* or *Botanical Life Forms* were proposed in 1934 by a Danish botanist Christen C. Raunkiaer. According to Raunkiaer, in a community it is very important to know how a plant survives during unfavourable conditions. He took the criterion of protection of perennating buds during adverse conditions as an adaptation of plant to climate. Accordingly he proposed a system known as Raunkiaer's system in which plants were categorized into various life forms based on the position of their buds during seasons of unfavourable conditions (too much cold or too much hot). Raunkiaer considered five major types of life forms *viz.* Phanerophytes, Chamaephytes, Hemicryptophytes, Cryptophytes, and Therophytes.

1. Phanerophytes (*Phanero* – visible; *phytes* – plants; plants where buds are visible): These are those plants whose buds are situated high up on the plant on the top of the shoots. These are either naked or covered with scales. Phanerophytes are very common in tropical areas and their number decreases towards temperate and polar areas. Based on the height of trees, phanerophytes are further divided into 4 categories:

- a) Mega-phanerophytes – trees taller than 30 m
- b) Meso-phanerophytes – trees between 8 – 30 m
- c) Micro-phanerophytes – trees between 2 – 8 m height
- d) Nano-phanerophytes – shrubs shorter than 2 m but more than 25 cm

2. Chamaephytes: These are those plants whose buds are close to ground or maximum up to 25 cm. These plants are found in colder regions at high altitudes or latitudes, e.g. Temperate America. During the growing season, sometimes the aerial parts of chamaephytes die and cover the buds. Fresh growth occurs during the onset of favourable season.

3. Hemicryptophytes: These are also found in the cold regions where buds remain covered under surface soil (but not deep-seated), and are protected. These include annual (plants which complete their life cycle in one year or one season) or biennial (which complete their life cycle in 2 years or 2 seasons) herbs.

4. Cryptophytes: These are also known as Geophytes. In these plants, the buds remain buried under soil such as bulbs and rhizomes. Such plants are mostly found in the arid regions of the world.

5. Therophytes: These are the ephemerals or seasonal plants that complete their life cycle quickly under favourable conditions and during the rest of the unfavourable conditions remain in the form of seeds.

Besides these five major categories, Raunkiaer also identified epiphytes (plant growing on or attached to other plants) as a separate category of life forms. Additionally, he also divided cryprophytes into three subtypes: geophytes (plants buried in soil with subterranean or perennating buds), hydrophytes (plants submerged or floating in aquatic systems with perennating buds inside water), and halophytes (plants in marshy swampy areas with high salt concentrations).

Biological Spectrum: It refers to the relative percentage of species of different life forms in a given community is and is also known as **Phyto-climatic Spectrum**. Thus for preparing a biological spectrum percentage of each of the 5 life forms is calculated. Raunkiaer (1934) also prepared a normal biological spectrum of flora of the world based on his elaborative and extensive ecological studies. For the normal biological spectrum, the percent values of different life form are given (Table 3).

Table 3. Percent of different life forms in a community forming a normal biological spectrum.

Life Form	Relative % of species
Phanerophytes	46
Chamaephytes	9
Hemicryptophytes	26
Cryptophytes	6
Therophytes	13

The biological spectrum obtained for any area is compared with normal biological spectrum that reflects the variations or deviations from the normal. It is generally thought that biological spectrum of a region reflects its environmental or the climatic conditions. For example, higher ratio of phanerophytes in an area indicates tropical conditions and those of chamaephytes reflect extreme cold conditions. Thus, it has been suggested as an indicator of climatic condition of an area. However, its utility is limited since biological spectrum is disturbed when the environmental conditions fluctuate. Further, biotic stress also affects the biological spectrum of an area that too limits its use.

In addition to various qualitative and quantitative features, communities are identified by various synthetic features such as *Importance value index (IVI)* and various ecological indices like index of diversity, index of dominance, index of evenness, and index of richness (see Box 1). IVI is calculated by adding relative density, relative dominance and relative frequency (the method of their calculation is already stated). IVI is an important parameter, which indicates the overall ecological importance or status of species such as its numerical strength, its degree of dispersion and area of ground covered by it. Various indices such as index of diversity, index of dominance, index of evenness, index of richness can be determined by standard formulae as indicated in Box 1. For this, computer based software are also available, of which the most widely used is the one given by Ludwig and Reynolds (1988) pertains to statistical ecology.

Ecotypes and Ecads:

Environmental conditions exhibit great fluctuations. Plant species have to tolerate these variations in the environmental conditions, which may be reflected in terms of different climatic conditions, habitats, edaphic conditions or even different geographic areas. The survival of species in such conditions is dependent upon its ecological amplitude – the extent to which a species may tolerate environmental variations. Species with a wider ecological amplitude have better adaptability and *vice versa*. The response of a species to a particular environmental condition may be reflected through several morphological variations (changes in the external appearance, i.e. in terms of height, number and size of leaves, number of branches, number of flowers produced, size of flowers and seed output).

Thus, even within a species several morphological races or forms may be encountered. Swedish gene ecologist G. Turesson first gave this concept (occurrence of morphological races of a species) in 1922 and 1930. He stated that variations within species go hand in hand with environmental variations. For example, individuals of a species growing at higher altitude may be dwarf or short in height in comparison to those growing in plain areas. A number of differences in morphology of a species can be seen in response to different habitat or climatic conditions. Often these variations may become genotypic or inheritable i.e. transferred from one generation to the other. In other words, these variations become genetically fixed. Such morphological races where variations in their external appearance are transferred from one generation to the other are known as **Ecotypes**. Ecotypes thus are those individuals of a species that vary in external appearance and their variations are genetically fixed and irreversible. Other names for ecotypes are **ecological** or **physiological races**. If such ecotypes are brought under similar environmental conditions, differences between them persist since these are genetically fixed. However, these are merely ecological races and cannot be given the rank of new species since these are inter-fertile (these individuals can breed together or reproduce). For example, *Euphorbia hirta*, known as Lal dudhi in Hindi, has two ecotypes: **Ecotype 1** is erect type growing in moist areas. **Ecotype 2** is a prostrate type that grows in dry conditions. Likewise, ecotypes have been reported in a number of plants in response to climatic, edaphic and even biotic conditions.

In some cases, the individuals of a species growing under different environmental conditions differ in external appearance but these changes are only temporary, not permanent, and hence reversible. When such morphologically different races are brought under similar environmental conditions, the variations within them disappear and their next generations are alike. Such morphological races of a species that exhibit temporary variations in response to different environmental conditions are known as **Ecads**. Other names for ecads are **Ecophenes**, **Habitat Forms** or **environmentally induced variations**. Ecads are found in a number of species e.g. in *Euphorbia hirta* where two ecotypes have been reported, the ecotype 2 found in dry conditions possesses two ecads. Ecad 1 is totally prostrate and grows on the dry and hard soil. Ecad 2 grows on the footpaths. In grasses, it has been seen that temporary variations arise in response to grazing. There may be differences with respect to number of culms, number of spikes, number of spikelets per spike and number of seeds produced.

Ecological Succession

Plant communities keep changing with time and space. These changes in the communities may either be due to changing environmental conditions or communities themselves such as their mutual interactions. Thus, in an area, one community may replace the other, and in turn, may be got replaced by another community. This change in community structure and composition over a period until there is a formation of a stable community is known as **Ecological succession**. Ecological succession has also been termed as **Ecosystem development** by some ecologists. It is predictable and orderly process. The final stable community formed at the end of succession exists for a longer period and is in harmony with the existing environmental conditions. This final stable community is known as **Climax community**, whereas the communities that appear for a shorter time, and are replaced in succession are termed as **Seral communities** or **Seral stages**. The plant community that colonizes an area for the first time is termed as **Pioneer community** and such plants as **Pioneers** or **Primary colonizers**.

Types of Succession

Primary and Secondary Succession: If the succession starts from the primary substratum free of any living or organic matter (unoccupied habitat), it is termed as primary succession. It may occur in terrestrial (land) or aquatic (in water) ecosystems and is slow in nature. Secondary succession, on the other hand starts from already build-up substratum. In such areas, plant community earlier occupying the area get altered due to disturbances like sudden changes in climate, fire, floods or some biotic interference. The succession starting from such a substratum is termed as secondary succession and it is comparatively rapid.

Autogenic and Allogenic Succession: During the process of succession, the mutual interactions among the living organisms of the community change the environment. These changes make the environment unfavourable for the existing community and thus cause its replacement. However, such changes may be congenial for some other community. This type of succession where the community replacement occurs due to reasons created by community itself is known as Autogenic succession. If during the succession, the replacement of one community by the other may be caused by environmental factors and not by living organisms, then the succession is termed as Allogenic succession.

Autotrophic and Heterotrophic Succession: A succession in which green plants or the autotrophs dominate, so that there is a continuous energy flow during the whole process, is known as Autotrophic succession. In contrast, succession wherein heterotrophs such as bacteria, fungi, actinomycetes or even animals dominate and there is a continuous decline in the energy flow is known as Heterotrophic succession.

Further, based on the nature of environment (primarily moisture conditions) at the start of the succession, the succession can be of following types:

Hydrarch or Hydrosere: If the succession begins from a water body, it is termed as Hydrosere or Hydrarch. The water body could be lake, pond, stream, bog or even the swampy area.

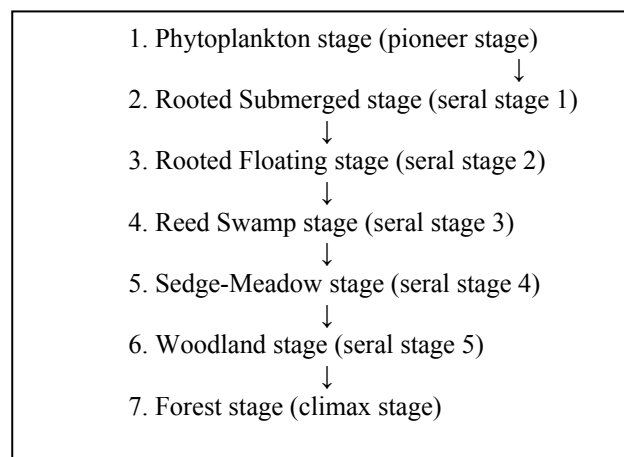
Xerosere or Xerarch: In this case, the succession begins from the dry conditions with very little moisture content, for example, a desert area, sandy areas, rocks etc. If specifically the succession starts from the rocky areas, it is known as **Lithosere**, whereas if it starts from a sand dune it is known as **Psammosere**.

Mesosere or Mesarch: If the succession starts in an area with adequate moisture conditions and temperature, it is known as mesosere or mesarch.

Halosere: Halosere is a type of succession occurring in a saline area i.e. where concentration of salt in the substratum is very high.

Process of Hydrosere

A hydrosere, also known as hydrarch, starts from a water body like pond, lake or pool that is gradually converted into a forest through an orderly process. The various plant communities come in sequence during this succession are grouped into seven main stages as follows:



Phytoplankton stage: The first organisms that colonize the pond are free-floating blue green algae or the green algae, diatoms and bacteria. These constitute the pioneers of the hydrosere. At this time, the substratum is free of any organic matter or soil and the pH of the water is also very low. However, when such organisms grow for some time and complete their life cycle some organic matter is added into the substratum and gradually the environment of pond becomes favourable for other community and unfavourable for exiting community. Besides organic matter, some silt or the sediments are brought from the adjoining areas by wind or the wave action of the pond water.

Rooted submerged stage: Rooted submerged hydrophytes (aquatic plants with roots but remain under water) like *Hydrilla*, *Utricularia*, *Elodea*, *Vallisneria* and *Potamogeton* invade when the pond is a bit shallower and contains organic matter. These plants grow for some time and after their death and decay, further build up the substratum and gradually the water level of the pond decreases and it becomes shallower. With this change in environment, the conditions become favourable for some other community.

Rooted Floating Stage: Several root bearing plants and having large floating leaves invade the pond, when it is about 2-5 feet deep. These are *Nelumbo*, *Nymphaea*, *Trapa* and *Monochoria*. These become associated with other free-floating plants like *Lemna*, *Salvinia*, *Azolla* and *Wolffia*. With the dense growth of these plants, the water level of the pond further decreases and becomes rich in salts and organic matter. Lot of sediments also accumulates in the pond at this time and the environment of pond becomes suitable for some other types of plants.

Reed-Swamp Stage: This stage is dominated by plants *Typha*, *Sagittaria* and *Scirpus*. The roots of these plants remain buried in the muddy soil while their above ground parts are exposed to air. This stage is also known as *amphibious stage* since plants are found in the semi-aquatic conditions. Due to dense growth of these plants, more and more biomass and soil is added and the conditions of pond become inhospitable for the present community and thus new community starts colonizing.

Sedge-Meadow stage: At this time, the pond becomes very shallow with reduced water and accumulated soil rich in salts and organic matter. The species that colonize such areas are the grasses and sedges. They also form a dense growth and due to higher rates of transpiration, the water level of the pond decreases a lot and the conditions become almost mesic which are ready to support different plants.

Woodland stage: With the pond becoming constantly drier, many terrestrial plants invade the area and establish there. These are mostly the shrubs and the tree species. Due to the growth of these plants, the area becomes rich in humus, minerals and a variety of microbes. The conditions may favour the establishment of tree species.

Forest stage: When the pond is completely turned into land, many tree species invade the area depending upon the climatic conditions. In tropical areas, the tropical woody species becomes established, whereas in the temperate areas suitable temperate species colonize. With the establishment of tree species, several other herbaceous plants get established in the floor of the forest. The forest becomes self sustainable and is in harmony with the climatic conditions.

The community matures into a forest and lasts for a longer time. This mature community is known as **Climax community**.

Process of Lithosere, a type of Xerosere

This type of succession starts from a rock, which is in un-weathered state and lacks any organic matter or moisture content. At this stage, only the simple plants like lichens can colonize. The lichens are then followed by various other plants that contribute towards building up of the soil substratum congenial for supporting a mature forest community. Various plant communities that colonize in succession one after the other are summarized as under:

1. Crustose lichen stage (pioneer stage)
↓
2. Foliose lichen stage (seral stage 1)
↓
3. Moss stage (seral stage 2)
↓
4. Herb stage (seral stage 3)
↓
5. Shrub stage (seral stage 4)
↓
6. Forest stage (Climax stage)

Crustose-lichen stage: The first organisms colonizing the rock are lichens, which stick to the surface of rocks and form a crust. These constitute the pioneers of the lithosere. At this stage, the substratum of rock is hard without any organic matter and poor moisture content. In such a harsh environment, only the hardy species of lichens like *Rhizocarpon* or *Lecanora* can survive. These lichens release some acidic substances in the substratum that brings about weathering of rock and besides after the completion of life cycle of these lichens some organic content is added to the rock substratum that enriches it. Gradually, the rock substratum changes and a thin layer of soil is added to it that contains some organic matter also. This becomes unsuitable for the crustose lichens and soon the other organisms like foliose type of lichens colonize the rock.

Foliose-lichen stage: The foliose lichens include species of *Parmelia* or *Dermatocarpon*. These are characterized by their large-sized leaf like thalli and these are also able to absorb more water in their body. With the excessive growth of these thalli the rock substratum becomes enriched with humus that forms a layer along with the soil. In the mean time, the environment of the rock becomes different and unsuitable for foliose type of lichens.

Moss stage: With the appearance of a thin soil layer enriched with humus, the rock surface become suitable for some moss species particularly the xerophytic ones that can survive in the dry environment. Such moss species are *Polytrichum*, *Tortula* or *Grimmia*. After the completion of life cycle of these moss species, more biomass and moisture adds to the substratum and thus the soil layer becomes quite thick and able to support herbaceous species.

Herb stage: With the change in the habitat of rock (a thick layer of soil with organic matter, moisture or minerals), many herbs start invading. These include many grasses that grow there for some time. With their growth, the rock surface is further broken down into smaller pieces and soil layer becomes thick retaining more moisture, minerals or organic matter. After completion of their growth, soil becomes more enriched and the conditions of the substratum no longer remain xeric. Soon the shrubby vegetation with perennial habit appears there.

Shrub stage: The shrubs appear at this stage when the soil substratum is quite built up after weathering of the rock. With their excessive growth, these overshadow the grasses and herbaceous vegetation and further add organic matter into the soil after their completion of life cycle. At this stage, many tree species invade the substratum that gradually converts the area into forest.

Forest stage: When the rock completely converts into land, many tree species invade the area depending upon the climatic conditions. These establish themselves and form association with several other herbaceous and shrubby plants. The forest so developed becomes self sustainable and maintains a balance with other biotic and abiotic components. This forest community stays for a longer time and is known as **Climax community**.

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