

ECOLOGY AND ENVIRONMENT MANAGEMENT

COMMUNITY CHARACTERISTICS

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COMMUNITY CHARACTERISTICS

The word community means unified group of organisms sharing something in common which may be a common religion (e.g. Christian community, Jain community), language (e.g. Bengali speaking community, Marathi speaking community), food (e.g. herbivore community & carnivore community among animals), taxonomic position (e.g. plant community, animal community) etc. Ecologically speaking, a biotic community or Biocoenose refers to a naturally occurring group of organisms-plants, animals and microorganisms-living in a physical habitat and are adapted to the prevailing physical environment, e.g. all organisms of desert community are adapted to live in extreme hot and dry conditions. Populations of organisms in a community not only share a common habitat but also interact with each other and are interdependent. Smith (1990) has defined a biotic community as 'a naturally occurring and interacting assemblage of plants and animals living in the same environment and fixing, utilizing and transferring energy in some manner'. In broad sense, it is the biotic component of ecosystem.

A different community occurs in each different habitat which may be large like an ocean or continent wide coniferous forest or small like a fallen acorn or a decaying log. Large sized communities which are more or less complete, self-sustaining units that need to receive only solar energy from outside are the **major communities**. Within these major communities are generally found small aggregations of organisms or **minor communities**, that are more or less dependent on the neighbouring communities for their energy source.

A community is **autotrophic** if it includes photosynthetic plants and gains its energy from the sun. When the energy input is in the form of fixed energy such as detritus coming into a cave or a stream, such communities are called **heterotrophic**. Autotrophic communities usually contain a number of heterotrophic microcommunities such as fallen logs and dead animals.

Community is an organized unit in which organisms are adapted to prevailing physical environment, linked to each other through feeding relationships and interact among themselves through competition, predation, parasitism and mutualism. These adaptations and interactions give a distinct structure to the community and also influence other characteristics like species diversity, dominance, growth and development.

STRUCTURE

Communities, whether terrestrial or aquatic have similar biological structures. They possess an autotrophic component, which fixes the solar energy and manufactures food from inorganic substances and a heterotrophic component which utilizes the food stored by the autotrophs, transfers energy and circulates nutrients by means of herbivory, carnivory and decomposition.

A community is most easily recognized and distinguished by its physical structure. Here the physical structure refers to pattern of spatial distribution of individuals and populations in a community. Not only the appearance of aquatic communities are quite distinct from that of terrestrial communities, there are pronounced differences among various terrestrial communities like forest, grassland, desert and also among various aquatic communities like pond, lake, river, stream, ocean.

Aquatic communities differ mainly with respect to salinity conditions (marine, brackish and freshwater) and by depth & flow of water (pond, lake, spring, stream).

The form and structure (Physiognomy) of terrestrial communities are determined by the growth form or life form of plants. The life forms and growth forms that prevail in a given area depend on the climate and the substrate or other special features of the habitat.

Growth forms and Life forms

Plants may be classified according to the growth forms. They may be tall or short, evergreen or deciduous, herbaceous or woody, trees, shrubs or herbs and these categories may further be subdivided into needle-leaf evergreen, broad leaf evergreen, evergreen sclerophylls, broad leaf deciduous, thorn trees and shrubs, dwarf shrubs, ferns, grasses, forbs, mosses, liverworts, lichens, algae. Another useful and widely accepted system of classifying plants is by life forms as proposed by Raunkiaer. His system of classification is based on the relation of ground surface to the plant's embryonic or regenerating (meristematic) tissue of seeds, bulbs, buds, tubers, roots etc. that remain inactive during unfavourable climatic regimes and resume activity when favourable conditions return. Raunkiaer (1934) recognized five principal life forms – Therophytes, Cryptophytes, Hemicryptophytes, Chamaephytes and Phanerophytes (Table 1.1 & Fig. 1.1). Since the life form is a morphological adaptation of a plant to survive in a given environment, some life forms would be more prevalent in some environments than in others. Thus, a community in warm, moist climate would have a high percentage of phanerophytes (Greek word phaneros=visible) with their regenerating tissue well above the ground; a community of desert area (high temperature and aridity) would be dominated by therophytes (Greek theros=summer); and a community consisting mostly of chamaephytes (Greek chame=on the ground, dwarf) and hemicryptophytes (Greek kryptos=hidden) would be characteristic of cold climates.

Table 1.1 - Raunkiaer's Life Forms

Name	Description
<i>Therophytes</i>	Annuals survive unfavorable periods as seeds. Complete life cycle from seed to seed in one season.
<i>Geophytes</i> <i>(Cryptophytes)</i>	Buds buried in the ground on a bulb or rhizome.
<i>Hemicryptophytes</i>	Perennial shoots or buds close to the surface of the ground; often covered with litter.
<i>Chamaephytes</i>	Perennial shoots or buds on the surface of the ground to about 25 cm above the surface.
<i>Phanerophytes</i>	Perennial buds carried well up in air, over 25cm. Trees, shrubs, and vines.

Unlike plants, there is no definite system to classify animals into life forms. Some of the life forms of animals recognized in terrestrial communities are fossorial (burrowing), cursorial (running), saltatorial (leaping), scansorial (climbing), arboreal (tree dwelling) and aerial (flying).

Organisms in aquatic habitats may be classified into following life forms:

- Plankton-These are free floating, microscopic organisms (both plants and animals) that are unable to move against water currents. Various spp. of algae, blue green algae, rotifers, protozoans are the planktonic forms.

- b. Nekton-These are actively swimming organisms which are able to navigate at will e.g. fishes, amphibians etc.
- c. Neuston-Organisms like water striders (insect) which are resting or swimming on the water surface are referred as Neuston.
- d. Periphyton or Aufwuchs-Organisms (both plants and animals) which are attached to or moving about on submerged surfaces like stems and leaves of rooted plants or submerged rocks and stones.
- e. Benthos-Organisms living in the bottom sediments like clam, snail, burrowing annelids are benthos.

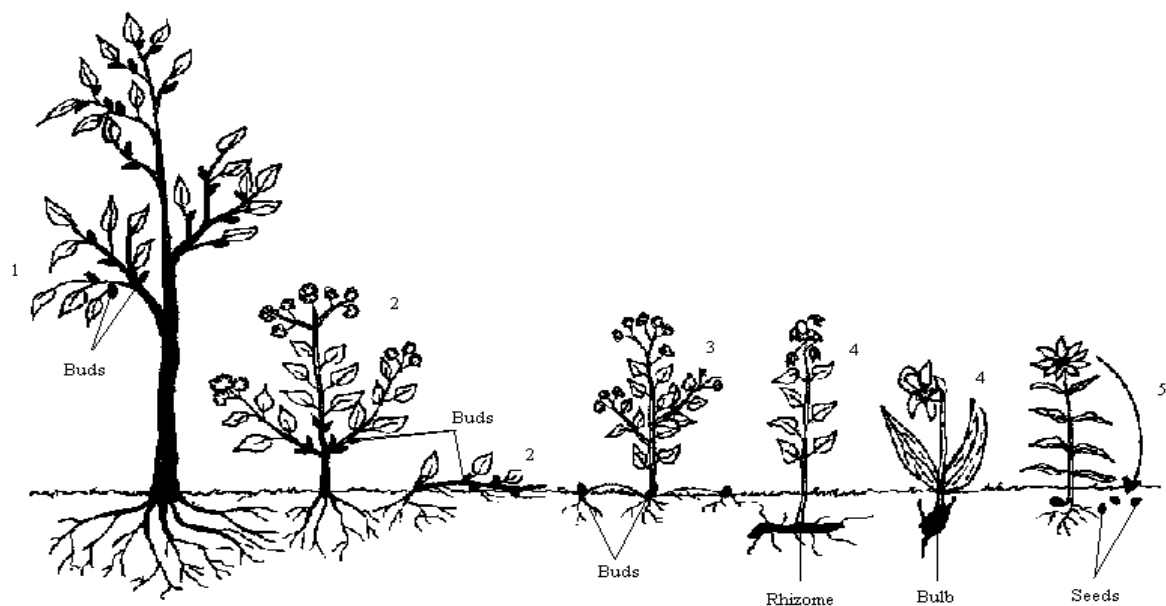


Figure 1.1 Raunkiaer's life forms. (1) Phanerophytes (2) Chaemaephytes (3) Hemicryptophytes (4) Cryphophytes and (5) Therophytes. Parts of the plant that survive/persist during unfavourable season are shaded dark.

Stratification

Stratification means vertical layering of organisms or environmental conditions in a community. In terrestrial community, stratification is determined largely by the growth and life form of plants which emphasize variation in height. Trees are generally taller than shrubs, which are usually taller than herbs and herbs are taller than lichens and mosses.

A well developed forest ecosystem has several layers or strata, each of which provide habitat for animal life. There is an aerial or epigeal stratification, which is above the soil and can easily be observed and a subterranean or hypogeal stratification which is in the soil (Fig. 1.2).

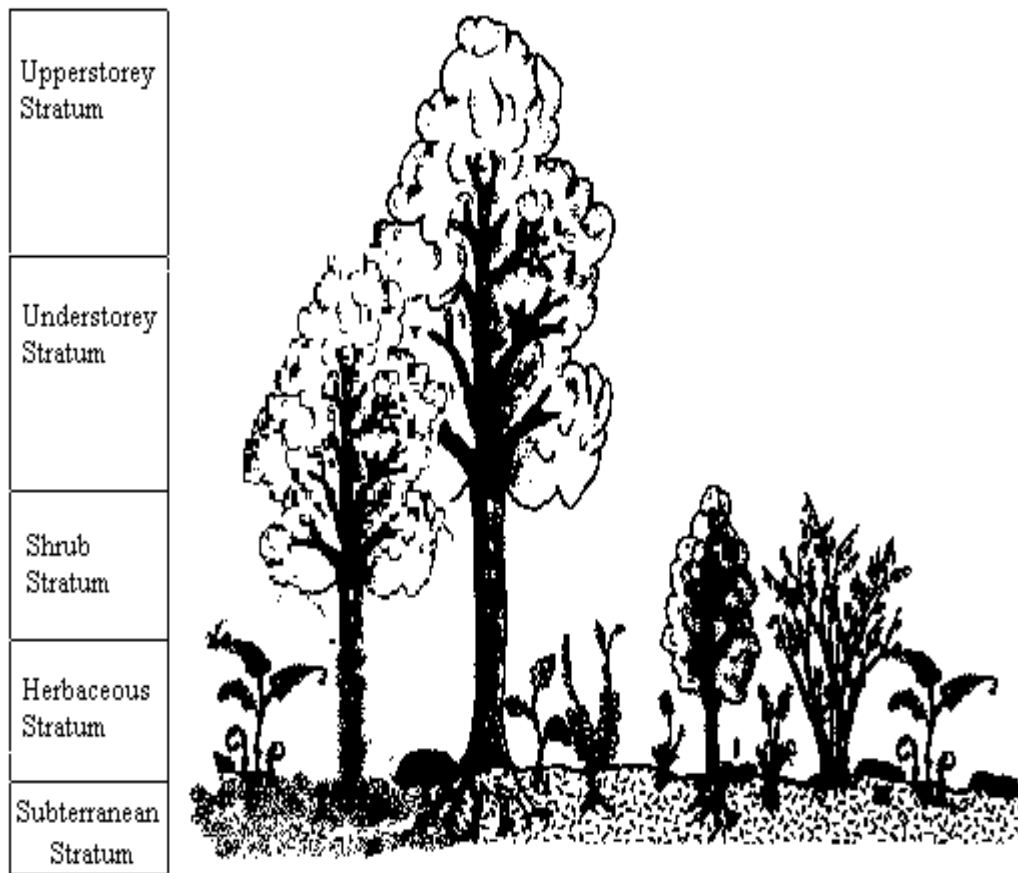


Figure 1.2 Stratification of plants in a forest ecosystem.

From top to bottom, the aerial strata include upperstorey tree stratum or canopy, understorey tree stratum, shrubby stratum, herbaceous or ground stratum and moss lichen stratum or forest floor. Below forest floor is the subterranean stratum which is occupied by the roots of plants belonging to other strata. The roots may be spread nearer the ground or may be deep penetrating thereby permitting the plants to draw water and nutrients from different layers of soil. Even though this zone is not visible to the eye, it plays a major role in the community by root absorption and the rhizosphere effect it exerts on the roots. The canopy is the major site of primary production and has a marked influence on the structure of the rest of the forest. Dense foliage of canopy vegetation curtail the light penetration, acts as wind breaker, modify the relative humidity and create a microclimate favourable to the establishment of other species under its cover. In tropical rain forests where canopy is almost closed, the lower layers are poorly developed. But in the forests of dry climate where canopy is fairly open, considerable light reaches the lower layers and understorey tree stratum, shrub and herb layers are well developed. The nature of both shrub and herb layers depends not only on the density of overstorey but also on soil moisture conditions and slope position which can vary from place to place throughout the forest. Height of these strata vary but in general, the trees of height above 20m constitute the canopy and those of height 10-20m comprise the understorey tree layer. The shrubby stratum is characterized by plants of height 1 to 10m, most of which are the young trees of upper strata but also some species that never grow very tall, such as hazel, dogwood

and wild pear. The herbaceous stratum constitute herbs that can grow at the most to 1m and also the young growths of upper strata. The mosses and liverworts form still another vegetational layer on the forest floor. The lichens and epiphytes which need a support to fix themselves grow at different strata on the tree trunk and branches. The subterranean stratum alongwith the forest floor are the major sites of decomposition of forest litter & where nutrients are released to nutrient cycle. These are characterized by detritovores (spp. of protozoa, diplopods, nematodes, molluscs, annelids, crustaceans, collembolans, acarids) and their predators (spiders, myriapod chilopods, predatory acarids, pseudoscorpions). Animal species are adapted to live in the physical structure provided by vegetational stratification. Although considerable interchange takes place among several strata, many highly mobile animals confine themselves to only a few layers. Different groups of bird species, for example, may be found feeding and nesting near the ground, in the shrub and understorey tree foliage and high up in the canopy. Squirrels nest high above the ground, mice at, or near the ground surface, and moles beneath the surface.

Other communities like grasslands also exhibit a distinct stratification, although only three strata, namely the herbaceous layer, the ground or mulch layer and the root layer are recognized. The root layer is most developed in the grassland than in any other ecosystem, and the mulch layer has a pronounced influence on plant development and animal life. The height of herbaceous stratum varies in different grasslands and also changes through the seasons.

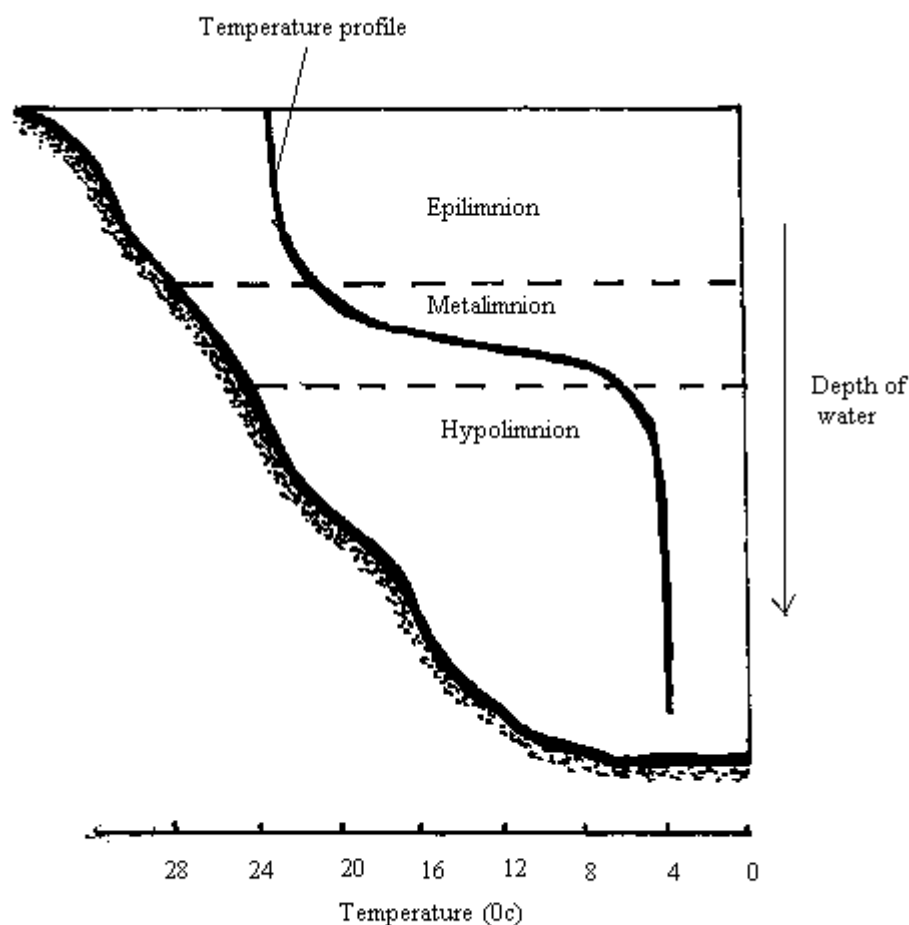


Figure 1.3 Stratification of a temperate lake in summer.

Although we are more readily conscious of stratification in terrestrial environment, it also occurs in aquatic systems. However, it is to be noted that in terrestrial ecosystems, stratification of plants within a community lead to stratification of environment (e.g. light penetration, humidity) and animal life (e.g. ground dwellers, arboreal) whereas in aquatic

ecosystems, stratification of the environment (light penetration, temperature profile, oxygen profile) lead to stratification of both plant and animal aggregations. A well stratified lake of temperate region in summer contain three layers-a layer of warm, oxygen rich, free circulating surface water, the epilimnion; a middle layer of steep temperature gradient, the metalimnion; and a deep layer of non-circulating cold water about 4⁰ C and often low in oxygen, the hypolimnion (Fig. 1.3).

All deep aquatic bodies, on the basis of light penetration exhibit two zones-an upper layer of effective light penetration (euphotic zone) which is the site of photosynthesis and dominated by phytoplankton, and a lower layer where light is insufficient (aphotic zone) for photosynthesis and dominated by consumers. Also present below the water layers is the bottom mud where decomposition is predominated. Plankton generally occurs in the upper euphotic zone, whereas free swimming fish occurs in lower segments of water, followed by sedentary (e.g. coral) and bottom dwelling forms (e.g. crabs, clams) and the latter in turn is followed by those that burrow the bottom surface.

In general, the finer the vertical stratification of a community, the more diverse is its animal and plant life. Thus a forest ecosystem with a highly stratified structure supports more numbers of species than a grassland with few strata. Similarly, the greater variation in the vertical gradient of light, temperature and oxygen in aquatic system supports the greater diversity of life.

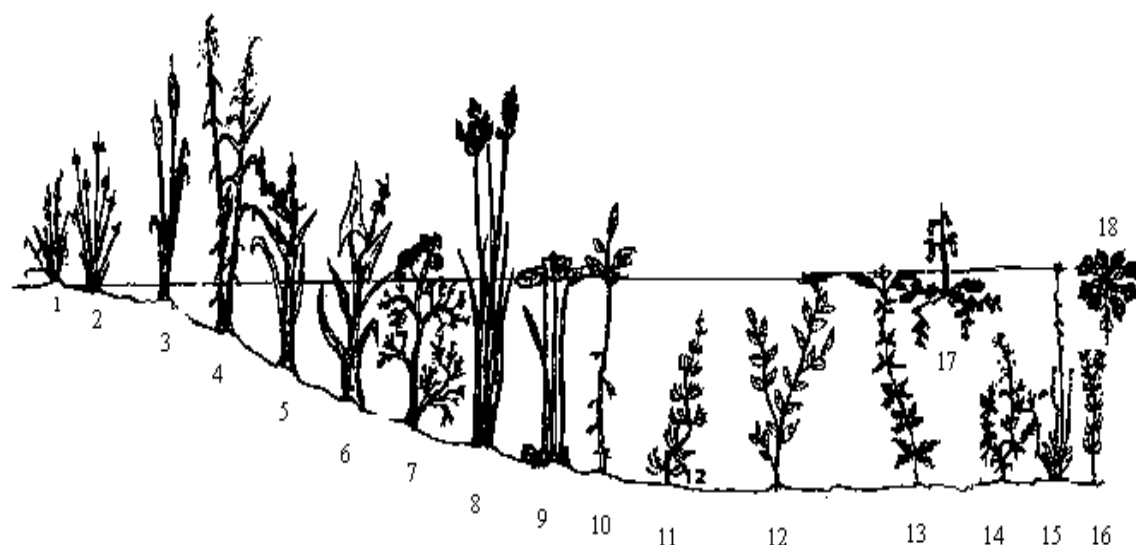
Horizontal heterogeneity

Examination of a countryside or an old field shows that there is no homogeneous distribution of vegetation. There are patches of herbaceous plants, small groves of trees, thickets of shrubs, mats of grasses and even bare areas that form a mosaic pattern across the landscape. Such spatially separated patches of vegetation produce a horizontal heterogeneity, which in turn influences the distribution of animal life (Wiens, 1976).

Horizontal heterogeneity results from an array of environmental and biotic influences. The growth and distribution of plants are influenced by soil conditions (texture, fertility, moisture), variation in topography, patterns of light and shade (e.g. herbaceous plants are clustered where pools of light reach the forest floor through canopy), microclimatic differences and also disturbances caused by fire and wind. Another major factor that influences the distribution of plants is the reproductive pattern and dispersal of seeds. Plants with wind dispersed and animal dispersed seeds are distributed widely, while plants with heavy seeds or with vegetative reproduction are generally clustered in one area. Biotic interactions such as competition for space, light, water and nutrients and allelopathic interference lead to the spacing of individuals.

Horizontal changes in the physical environment are sometimes reflected in zonal changes in plant and animal components of communities. A good example of horizontal distribution of plants, in an aquatic environment is the zonation of pond population. As one moves from the edge of pond towards deep waters, concentric zones of vegetation are observed (Fig. 1.4). The first zone is that of halophytes-the rooted plants that live in moist environment in which only the underground parts are submerged e.g. Ranunculus, Monochoria, Cyperus and Rumex. Also present in this zone are cattails (Typha), bulrushes (e.g. Scirpus) and arrowheads (Saggitaria). This zone is a spawning ground for fishes and nesting site for aquatic birds like warblers, waterhens and ducks. The next zone is of hydrohalophytes (semi-aquatic species)-the rooted plants with leaves and flowers developing above the water level e.g. water lilies and pond

weeds. This is followed by the zone of hydrophytes (aquatic species). These include submerged rooted plants like *Elodea*, *Vallisneria*, *Myriophyllum*, *Hydrilla*, *Chara* and also floating plants like *Wolffia*, *Lemna*, *Azolla*, *Salvinia*, *Pistia* and *Utricularia*. Finally, the deep water zone is characterized by phytoplankton.



- | | | | | |
|------------|-------------------------|--------------------------|------------------------|------------------------|
| 1- Carex | 5- Bur-reed | 9- Water lily | 13- Myriophylla | 17- <i>Utricularia</i> |
| 2- Rush | 6- <i>Sagittaria</i> | 10- Amphib.knotgrass | 14- <i>Elodea</i> | 18- Water chestnut |
| 3- Bulrush | 7- Aquat.
ranunculus | 11- <i>Ceratophyllum</i> | 15- <i>Vallisneria</i> | |
| 4- Reed | 8- Lake Scirpus | 12- Pond weeds | 16- <i>Chara</i> | |

Fig.- 1.4 Horizontal zonation of vegetation in a pond.

Ecotone and Edge effect

An important aspect of community structure is the boundary between one habitat and its neighbours. Boundary of a habitat may be relatively sharp and distinct called the **edge** or there may not be a distinct border but one community may intergrade very gradually into another and this transition zone is referred as **ecotone** (Fig.1.5). Some well known examples of ecotone are those between forest and grassland, cold and warm waters in marine environment, intertidal zone on the sea beach and the estuaries.

Edges may result from abrupt changes in soil type, topographic differences and microclimatic differences. Such edges are **inherent** and are usually stable and permanent. The edges may also result from natural disturbances like livestock grazing, timber harvesting, land clearing and agriculture and are termed as **induced**. They are not permanent and can be maintained only by periodic disturbances, otherwise they will change or disappear with time. Both types of edges may be abrupt or transitional resulting in an ecotone.

An ecotone has its own unique features and species composition. For example, an ecotone between forest and grassland has steep gradients of wind flow, moisture, temperature and solar radiation between the extremes of open land and forest interior. Only those species which are competitively superior and highly adaptable to such conditions colonize such areas. Plants of the edge tend to be opportunistic and shade intolerant. They grow well in a relatively xeric conditions (high evapotranspiration and low soil moisture) and fluctuating temperatures. Animal species of the edge are usually those that require, as part of their habitat or life history, two or more adjacent communities that differ greatly in structure. For example, whitetail deer browse in open field but hide in forest cover, the American robin (*Turdus migratorius*) requires

trees for nesting and grassy areas for feeding. Such species which actively occupy an ecotone taking advantage of the resources of both habitats are termed as edge species. Many game species like deer, rabbits, grouse, pheasants can be classified as edge species because they

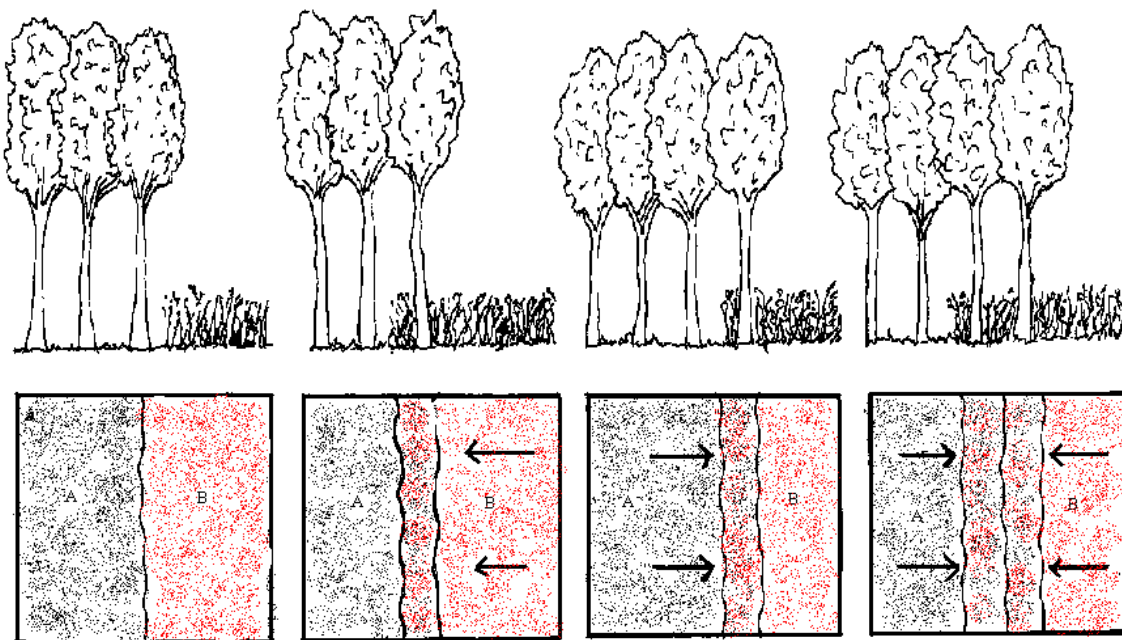


Figure 1.5 Edge and types of ecotones. (a) An abrupt, narrow edge with no development of ecotone. (b) Community B advances in to community A to produce ecotone. (c) Community A advances in to community B to produce ecotone. (d) Plants of both communities invade each other to create a wide ecotone.

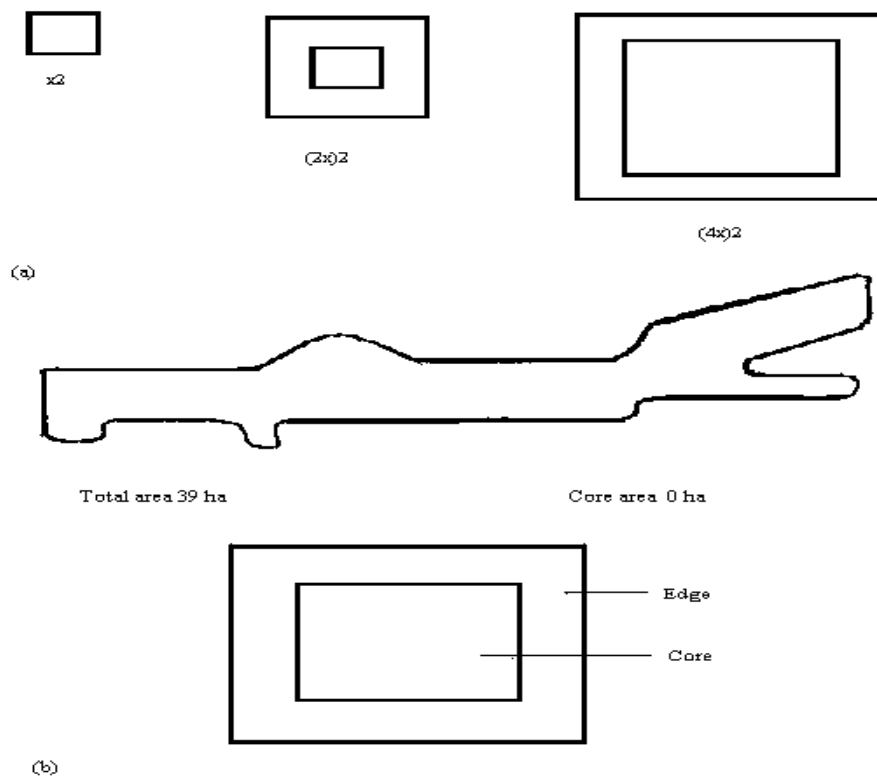


Figure 1.6 (a) Edge area increases as the size of habitat increases.

(b) Shape can be as important as size in determining the edge. Although two areas in the figure are of similar size, no place in top figure is far enough from the edge to have characteristics of core habitat, while the bottom habitat has a significant core.

are most plentiful in the boundary zones between different types of habitat. Because well developed ecotonal communities may contain organisms characteristics of each of the overlapping communities plus the species living only in the ecotone region, the variety and density of life are greater in ecotone. This phenomenon has been called the **edge effect** (Leopold 1933).

The edge effect is dependent on the amount of edge available-its length and width. A sharp edge, such as that between a clear-cut and uncut forest, may be a poor habitat, and although increasing the amount of edge increases diversity, excessive edge (many small blocks of habitat created by fragmenting the landscape) reduces the biodiversity. The adjoining communities must have sufficiently large core habitat areas to have a true ecotone. Depending on how far edge effects extend from the boundary differently shaped habitat patches may have very dissimilar amounts of interior area (Fig. 1.6). The edge effect is also influenced by the degree of contrast between adjoining vegetational communities (Patton, 1975). The greater the contrast between adjacent vegetational communities, the greater should be the species richness. An ecotone between a forest and grassland should support more species than an edge between a young and mature forest.

SPECIES DOMINANCE

A community consists of a number of species, each occupying a different niche and playing a different role, but all are not equally important in determining the nature and function of the community. It is only a single species or a group of species that generally exert the major controlling influence. Species exerting this important control are called **dominants**. In many communities, dominant species are those which are numerically most abundant e.g. grasses are dominant in a grassland. But numerical abundance alone is not sufficient. In a forest, the herbs or small trees may be most numerous but it is the few large trees that overshadow them and which are dominant. Here, dominance is measured in terms of biomass or basal area. Dominants are generally the most prominent organisms which make the largest contribution to energy flow and mineral cycling and modify the environment for all other organisms within the community by tempering with light, moisture, temperature and other conditions.

The dominant organism may be scarce, yet by its activity, control the nature of the community. In the intertidal community, for example, the predatory star fish Piaster feed on a number of prey species that are similar in habits and thereby reduce competitive interactions between them, so all these different prey species coexist (Paine 1966). If the star fish is removed, a number of species disappear and one of them becomes dominant. Here, the predator is controlling the structure of community and, therefore, regarded as dominant or keystone species. Removal of the dominant would result in important changes not only in the composition of community but also in the physical environment (micro climate), whereas removal of non-dominant would produce much less change.

The dominance of a species is dependent on the prevailing physical and chemical conditions also. A species becomes dominant because it can exploit a range of environmental conditions more efficiently than the other species. A nutrient-deficient lake is characterized by a predominance of diverse assemblage of diatoms. Excess of sewage discharge in this lake results in the shifting of dominance from diatoms to a few blue green algae that are better adapted to exploit this nutrient-rich system (Edmundson 1970).

Dominance in a community is determined by measuring the relative importance of each species. The importance value of a species can be quantified either by measuring its relative abundance (ratio of number of individuals of one species to the total number of organisms of all species) or relative dominance (ratio of basal area occupied by one species to total basal area) or relative

frequency (ratio of frequency of occurrence of one species to the total frequency of occurrence of all species) or a combination of all such measurements.

Simpson (1949) had given a simple equation to determine the index of dominance

$$c = \sum (n_i / N)^2$$

where c = dominance index

n_i = importance value for each species

(number of individuals, biomass, basal area, production and so forth)

N = total of importance values of all species

This equation gives an idea of concentration of dominance in a community. Suppose a community is composed of 5 species, each having an importance value of 2 (based on the density of $2/m^2$) which means all species are equally important. In another community of 5 species, one species has importance value of 6 and others have 1 each. If we calculate c from above equation, we get a value of 0.2 for the first community and 0.4 for the second in which dominance was more concentrated (in one species in this example).

Dominance is generally more concentrated in communities where physical factors are extreme, say in deserts, tundra and other extreme environments, whereas dominance is shared by large number of species in biologically controlled ecosystems like tropical forests.

Species abundance and diversity

Communities in different environments vary not only in the number of species they contain but also in the relative number of individuals in each species. Of all the total number of species in a community, only a few are abundant, and a majority of them are rare. Abundance is related to density (number or biomass per unit area) but a species with same density in two communities may differ in abundance. Large number of individuals occurring at one place in the community will not be referred to as abundant while the same number of individuals spread throughout the community may appear to be abundant. Thus species abundance represents the manner in which species divide up the niche space.

Species diversity has two components – (i) the richness or variety component and (2) the evenness or apportionment component. A number of indexes have been proposed to compute species diversity for purpose of comparison among communities. One of the simplest way of ascertaining species diversity is to determine the number of species per unit area, but in making comparisons, one must make certain that the sample sizes are comparable. Another simple index is the Margalef equation –

$$D = S - 1/I_n N$$

Where D = diversity index

S = number of species

N = total number of organisms

Both these indices measure only one component of diversity i.e. richness. The two communities may have the same richness but differ in the equitability in the apportionment of individuals among species. For example, two communities each containing 10 species and 100 individuals have the same Margalef index, but could have widely different evenness indices depending upon the apportionment of 100 individuals among 10 species. The community having 91 individuals of one species and 1 individual each of rest of the nine species would

have minimum evenness and the community having 10 individuals per species would have the maximum evenness index.

One of the most widely used index that includes both richness and equitability is the Shannon-Weaver index (1949) that measure the diversity by the formula_

— S

$$H = - \sum_{i=1}^S p_i \ln p_i$$

where H = diversity index

S = number of species

i = species number

p_i = proportion of individuals of total sample belonging to i^{th} species i.e. $p_i = (n_i / N)$

n_i = number of individuals of i^{th} species

N = total number of individuals.

This index is a measure of uncertainty. The higher the value of H, the greater is the probability (or uncertainty) that the next individual chosen at random from a collection of species containing N individuals will not belong to the same species as the previous one. The lower the value, the greater the probability that the next individual encountered will be the same species as the previous one. The higher value of H signifies the greater species diversity of the community; either there is a greater number of species or there is more even distribution of individuals among species or both. If the number of individuals per species is not known, biomass or even productivity, which is ecologically more appropriate parameter, can be used to determine the diversity index.

In comparing two or more communities with different diversity indices, the number of species present and the number of individuals in each species are usually apparent, but the degree of evenness in the distribution of individuals among species is not known. This evenness may be evaluated by an equitability index.

$$e = H / \ln S \text{ (Pielou, 1966)}$$

Diversity indexes may be used to compare species diversity within a community (α , alpha diversity), between communities or habitats (β , beta diversity), and among communities over a geographical area (γ , gamma diversity) (Whittaker 1972).

Species diversity changes along the latitudinal and altitudinal gradients on the earth. Species of nesting birds (Fisher 1960), mammals (Simpson 1964), fishes (Lowe-Mc Connell 1969), lizards (Pianka 1967) and trees (Monk 1967) decrease from the tropics to the arctic. Mountain areas generally support more species than flatlands because of topographic diversity. However, in the oceans, species diversity is less in the continental shelf region where food is abundant but environment is changeable, but high in deep waters where food is less abundant, but the environment is more stable (Smith 1990).

Many hypotheses have been proposed to explain the differences in species diversity in different regions of the world. Fisher (1960) and Simpson (1964) proposed that evolutionary older communities hold a greater species diversity than the younger communities. Tropical communities being older have a greater species abundance than the temperate or arctic

communities. The high species diversity of tropics is also related to the climatic stability of this region (Fischer 1960; Connell & Orias 1964). Through evolutionary time, the environment of tropics, of all the regions of earth, has probably remained the most constant and under such conditions, selection favours specialist organisms with narrow niches. Because each species uses a small fraction of total resources, more species are able to exist in regions of constant climate. At regions where climate is severe and unpredictable, as in arctic, selection favours organisms with broad limits of tolerance for variation in physical factors and with more generalized food habits.

Related to climatic stability is the productivity hypothesis of Connell and Orias (1964). This hypothesis proposes that the diversity of a community is determined by the amount of energy flowing through the system which in turn is influenced by the limitations of ecosystem and by the degree of stability of the environment. This means more the food produced, greater is the diversity. Although this is true in general sense, there are exceptions to it. In some aquatic systems, for example, increased input of sewage or other nutrients results in decrease in diversity. In marine environment, deep water zones of low productivity have a higher abundance of species than the continental shelf region of higher productivity (Sanders 1968).

The spatial heterogeneity hypothesis relates the complexity of flora and fauna to the complexity and heterogeneity of the physical environment. The greater the variation in topography and the more complex the vertical structure of the vegetation, the more types of habitats the community contains and the more types of species it will hold. This is supported by the fact that the forest with highly stratified vertical structure holds more species of birds (Mac Arthur 1972; Pearson 1971).

Sanders (1968) has combined the environment stability hypothesis and time hypothesis in the stability time hypothesis. He suggested that two contrasting types of communities exist – the physically controlled and biologically controlled. In physically controlled communities, the fluctuating physical conditions lowers the probability of reproductive success and survival of organisms because of the severe physiological stress. Although organisms in time evolve adaptive mechanisms to meet these conditions, the diversity remains low. In the biologically controlled communities, physical conditions are relatively uniform over long periods of time and are not critical in controlling the species. Inter-specific competition exerts the major controlling influence and species evolve to adapt to the presence of other species by partitioning the resources. The importance of competition in the evolution of species and specialization of niches was also emphasized in the competition theory (Dobzhansky 1951; Williams 1964).

The predation theory (Paine 1966) proposes that a high species diversity exist in those communities in which predators reduce the numbers of prey to a level where inter-specific competition among them is greatly reduced, allowing the co-existence of number of prey species.

It is difficult to explain the species diversity at local, regional and global level by any one hypothesis. There are a number of variables that can control the species diversity in natural communities. These variables can be the structure of habitat, diversity of microhabitats, nature of physical environment, competition, predation, availability of food and nutrients, time, disturbance and geographical barriers.

CLASSIFICATION AND NAMING OF COMMUNITIES

Community, like any other biological unit, need to be classified in order to be studied, described and compared with the similar communities in other regions or habitats. There are several approaches to community classification, each arbitrary and each suited to a particular need or view point.

Since the gross structure or physiognomy is the easily recognizable feature of communities, they can be most conveniently classified and named according to dominant species or life forms such as coniferous or deciduous forest, short or tall grass prairie, coral reef or oyster-bed community. This classification works well where there are but one or two dominant species or species groups, as for example, in the sage brush and shad scale desert communities which remain conspicuous at all times. Sage brush grow well in those areas of desert where precipitation is relatively high and soil is deep, more permeable and relatively saline free whereas shad scale grow well in drier areas where soil is rich in mineral salts. In many cases, dominance is not so conveniently concentrated and species composition may change continually with the seasons as in many plankton type communities.

Communities are often regarded as distinct natural units or associations. This is true for such communities which have sharply defined habitat boundaries. Such communities may be classified by physical features of the habitat such as ponds, streams, tidal mud flats, sand dunes. But more often than not, community boundaries are hard to define; one community type blends into another. Associations among species of a community are generally not rigid and unique. Species are not, in general, bound together into groups of associates which must occur together. Those organisms which are adapted to a specific set of environmental conditions are often found together and confined to certain habitats but others which can tolerate a wide range of environmental conditions are found over wide area as part of many associations. Species shift in abundance and dominance because of change in altitude, moisture, temperature and other physical conditions. This results in a sequence of communities showing a gradual change in composition and complexity from one extreme of environmental gradient to the other. This sequence of communities along the environmental gradients is referred to as **continuum**. Since there are no sharp boundaries between individual communities of different types along the continuum, the ecologists choose same statistical criteria like frequency distribution, similarity coefficient etc. to order these communities along the environmental gradients. This statistical orientation of communities in a continuum along a gradient is called **ordination**. Ecologists have used various ordination techniques to classify plant communities.

Another approach to classify communities is based on species composition with emphasis on dominance, constancy, fidelity and diagnostic species. Communities are grouped into classes, orders, alliances and associations (Whittaker 1962; Mueller-Dombois and Ellenberg 1974). Such a classification involves **fidelity**, the faithfulness of a species to a community type. Species with low fidelity occur in a number of different communities and those with high fidelity in only a few. The greater the ratio of constant species to the total number of species, the more homogeneous is the community and the more sharply it can be delineated. Species can be grouped as **exclusive**, those completely or nearly confined to one type of community; **characteristic**, those most closely identified with a certain community; and **ubiquitous**, those with no particular affinity to any community. The species grouped as characteristic, high in constancy and dominance are the ones that define the community type.

GROWTH AND DEVELOPMENT

Communities are dynamic entities, changing more or less regularly over time. Each community with its particular environment has its own developmental history. The growth and development of community can be studied in a barren area. Arrival of some organisms and their propagules to this area mark the beginning of community development. Only a few of these propagules are capable of successful growth and establish themselves in this area, thereby constituting the pioneer community (the first stage in community development). New species keep on invading this area resulting in intense competition. Also the environment keeps on

changing due to change in climatic condition and physiography and also due to activities of species themselves. Only those organisms best able to cope-up with changing conditions would survive. This process continues till a relatively stable community which is more or less in complete harmony with environment is established. This entire process of community development is highly directional and ordered change. This directional change-the **succession** will be discussed in detail in the next chapter.

POPULATION INTERACTIONS AND HOMEOSTASIS

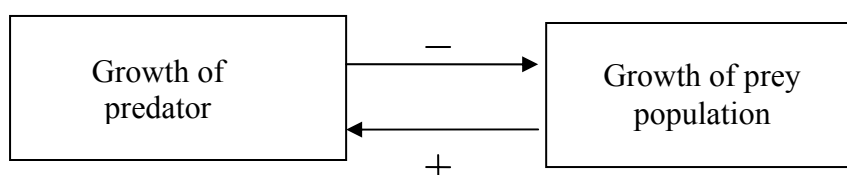
Homeostasis is the term generally applied to the tendency for a biological system to resist change and to remain in a state of equilibrium. Homeostasis at the organism level is a well known concept in physiology. In organisms, the major control mechanisms are neural and hormonal which function through the feedback systems. At the community or ecosystem level, control mechanisms mainly operate in the pathways of mineral cycling and energy flow, thereby involving the microbial subsystems that regulate the storage and release of nutrients and population interactions that control the population density.

Organisms in a community are all interdependent either directly or indirectly for food, shelter, reproduction and protection. Herbivores depend on the plants for food and many plants are dependent on the animals for pollination and seed dispersal. Such beneficial interactions take the form of commensalisms, mutualism and protocoperation. There are other types of interactions like competition, predation and parasitism in which at least one of the interacting group is adversely affected (for details refer the chapter on Population interactions). Interactions whether beneficial or detrimental tend to bring about a relatively stable state of equilibrium between these different but interdependent groups of organisms. Competition, Predation, parasitism and mutualism are some of the important interactions that can have controlling influence on the population density of interacting groups.

Competition: It is quite obvious that the species which are living together will have competition for resources. Plants compete for light, nutrients, moisture, space and animals compete for food and space. They co-exist by partitioning their resources and by avoiding each other in the regions of niche overlap (Gause's principle). This limits the resource availability and thus restricts their abundance and distribution and over a period of time, a state of equilibrium is reached among the competing species. This state of equilibrium is disturbed when exotic species are introduced in the community. Exotic species of birds when introduced into the Hawaiian islands excluded the native species with similar ecological requirements (Moulton & Pinn 1986). Similarly, when two plankton feeding fishes, the alewife and rainbow smelt were introduced in lake Michigan, the populations of seven native fishes with similar food habits declined drastically (Cnowder et.al.1981).

However, the role of competition as a controlling influence on community structure is obscure because the outcome of competition can have alternative explanations. Other factors like weather, climate, predation etc. can influence and modify the competitive relationships in a community.

Predation: A predator prey system exhibits an interaction of positive and negative feedback which in the initial stages of interaction result in oscillations of both populations (see chapter on Population interactions) but after a period of evolutionary adjustments a homeostatic control sets in:



A predator not only has a negative feedback control on the growth of prey population but it also influences competitive relationships among species. The role of herbivores in influencing plant community structure has been well demonstrated. A classic example is the influence of rabbits on the diversity of species in English pastures. A sharp reduction in the rabbit population from myxomatosis, in southern England, resulted in an aggressive growth of meadow grass in fields inhabited by the large blue butterfly, *Maculinea arion*. Heavy grass resulted in the extinction of open-ground ant colonies, the nests of which were utilized by large blue caterpillars. As a result, the large blue is nearly extinct. The loss of one keystone grazing herbivore, the rabbit, resulted in the local extinctions of two other species as well.

The influence of predation on community structure also occurs at the level of carnivore. An example is the rocky intertidal community on the Pacific coast of Washington state which consists of four species of algae, a sponge, filterfeeding barnacles and mussels, browsing limpets and chitons, a predatory whelk, and the predatory starfish *Piaster ochraceus*. Both barnacle and mussels, when given the opportunity, aggressively compete for the space and exclude other sessile organisms. Paine (1966) removed the top carnivore, the starfish, that feeds on sessile barnacles and mussels as well as on limpets and chitons, and excluded it for two years from an 8m long and 2m deep area. On the control areas, nothing changed. On the area where the starfish was removed, barnacles settled successfully but were soon crowded out by the mussels. All but one species of alga disappeared for the lack of space, browsers moved away for the lack of space and food, and the number of species dropped from 15 to 8. Apparently, the predaceous starfish by feeding on barnacles and mussels made space available for competitively subdominant species, helping to maintain species diversity and a more complex intertidal community structure.

Parasites and diseases: Parasites and pathogens are an integral part of natural communities. Their overall effect on community structure becomes most apparent when an outbreak of disease decimates or reduces an affected population. This happens when parasites or pathogens are introduced into a population with no evolved defences. For example, American chestnut tree (*Castanea dentate*) was an important member of the Appalachian region of eastern North America constituting upto 40% of total forest biomass. It had its share of parasites and diseases. Likewise, the oriental chestnut tree (*Castanea mollissima*) of China has its own share of parasites including the fungus *Endothia parasitica* which attacks the bark of the stems. In 1904, the fungus was accidentally introduced into the United States. The American chestnut tree proved to be non-resistant to this new parasite. By 1952, all the large chestnut trees had been killed, their place being taken up by oaks and birches and thereby changing the composition of North American forest. Rinderpest, a viral disease whose natural host is cattle was introduced in Africa through cattle imports. The disease spread swiftly through populations of African buffalo and wildebeest and decimated their populations, affecting the entire ecology of East African Savanna ecosystem. Similarly, the outbreak of mange disease in foxes periodically regulate their population in New York. The disease is highly density-dependent and transmitted from fox to fox through the mange mite (*Sarcoptes scabiei*).

Mutualism: Mutualistic associations are exceedingly widespread and are as important as competition, predation and parasitism in determining the structure and function of communities. Algal-fungal symbiosis in the lichens, association of plants roots with mycorrhizae and association between cellulose-digesting microorganisms and animals for example, ungulate-rumen bacteria and termite-intestinal flagellate partnerships are a few common examples of mutualism in which neither can survive without being physically associated with the other. Mutualistic relationships are not always symbiotic; some mutualists live independent lives, yet

they cannot survive without each other. One example is the relationship of yucca plant and the yucca moth. The yucca depends upon the yucca moth for pollination, and the larvae of yucca moth feed on yucca seeds. Another example is of ant and acacia. The ants live in the special cavities of the branches of acacia from which they derive shelter and almost complete diet at all stages of development. In turn, the ants protect the plants from herbivores. At the least disturbance, the ants swarm out of their shelters, emitting repulsive odours and attacking the intruder until it is driven away. When the ants are removed experimentally, the tree is quickly attacked and often killed by defoliating insects. Neither the ants nor the acacia can survive in the absence of each other.

The indirect effects of species on one another may be as important as their direct interactions, and may contribute to network mutualism. When food chains function in food web networks, the organisms at each end of trophic series – for example, plankton and bass in a pond – do not interact directly. Bass benefit by eating planktivorous fishes, which are supported by the plankton, whereas plankton benefit when bass reduce the population of plankton predator.

The ultimate reality is that all positive and negative interactions operate together in food webs at the community and ecosystem levels. Food web is not merely a collection of species interactions but is a functional system, having its own control mechanism. A food web has a **top-down** control which refers to the upstream components – for example, herbivore control over plants and predator control over herbivores and a **bottom-up** control which refers to role of nutrients and other physical factors in determining primary production. Both types of control operate in all natural situations, although their relative importance may vary from one situation to the other.

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