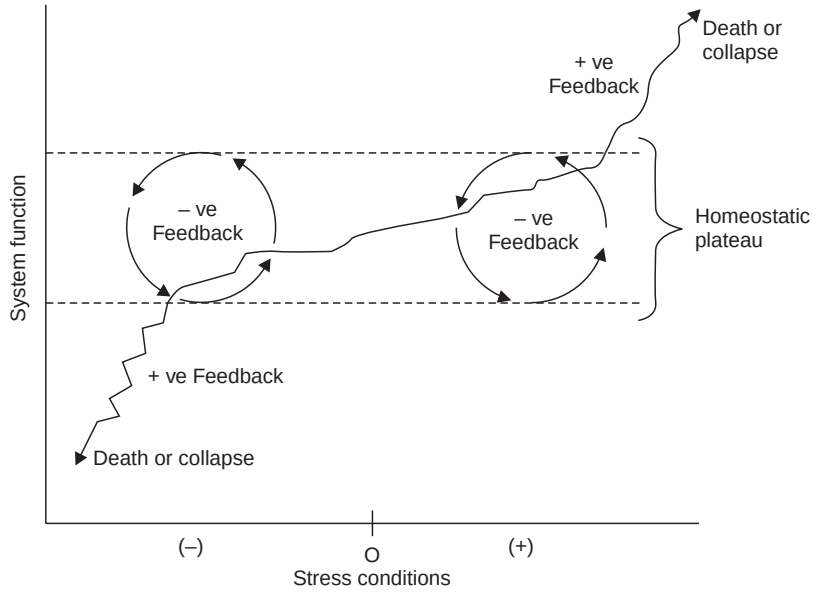


Fig. 3.14. Ecosystem regulation by homeostasis. On application of a stress, the negative feedback mechanisms start operating, trying to counter the stress to regulate the system. But beyond the homeostatic plateau, positive feedback starts which further accelerate the stress effects causing death or collapse of the organism/system.

■ ECOLOGICAL SUCCESSION

An ecosystem is not static in nature. It is dynamic and changes its structure as well as function with time and quite interestingly, these changes are very orderly and can be predicted. It is observed that one type of a community is totally replaced by another type of community over a period of time and simultaneously several changes also occur. This process is known as ecological succession.

Ecological succession is defined as an orderly process of changes in the community structure and function with time mediated through modifications in the physical environment and ultimately culminating in a stabilized ecosystem known as climax. The whole sequence of communities which are transitory are known as *Seral stages* or *seres* whereas the community establishing first of all in the area is called a *pioneer* community.

Ecological successions starting on different types of areas or substrata are named differently as follows:

(*i*) **Hydrarch or Hydrosere:** Starting in watery area like pond, swamp, bog

(*ii*) **Mesarch:** starting in an area of adequate moisture.

(*iii*) **Xerarch or Xerosere:** Starting in a dry area with little moisture. They can be of the following types:

Lithosere	:	starting on a bare rock
Psammosere	:	starting on sand
Halosere	:	starting on saline soil

Process of Succession

The process of succession takes place in a systematic order of sequential steps as follows:

(*i*) **Nudation:** It is the development of a bare area without any life form. The bare area may be caused due to landslides, volcanic eruption etc. (topographic factor), or due to drought, glaciers, frost etc. (Climatic factor), or due to overgrazing, disease outbreak, agricultural/ industrial activities (biotic factors).

(*ii*) **Invasion:** It is the successful establishment of one or more species on a bare area through **dispersal** or **migration**, followed by **ecesis** or **establishment.** Dispersal of the seeds, spores etc. is brought about by wind, water, insects or birds. Then the seeds germinate and grow on the land. As growth and reproduction start, these **pioneer species** increase in number and form groups or **aggregations.**

(*iii*) **Competition and coaction:** As the number of individuals grows there is competition, both inter-specific (between different species) and intra-specific (within the same species), for space, water and nutrition. They influence each other in a number of ways, known as **coaction.**

(*iv*) **Reaction:** The living organisms grow, use water and nutrients from the substratum, and in turn, they have a strong influence on the environment which is modified to a large extent and this is known as **reaction.** The modifications are very often such that they become unsuitable for the existing species and favour some new species, which replace them. Thus, reaction leads to several **seral communities.**

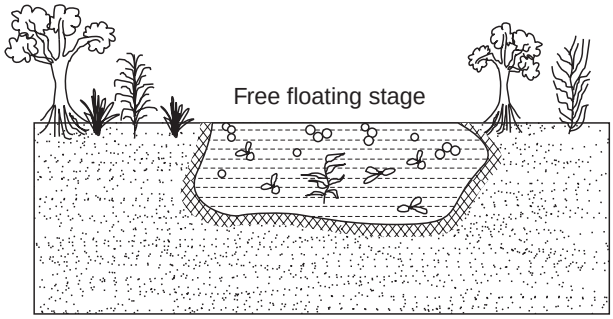
(*v*) **Stabilization:** The succession ultimately culminates in a more or less stable community called **climax** which is in equilibrium with the environment.

The climax community is characterized by maximum biomass and symbiotic (mutually beneficial) linkages between organisms and are maintained quite efficiently per unit of available energy.

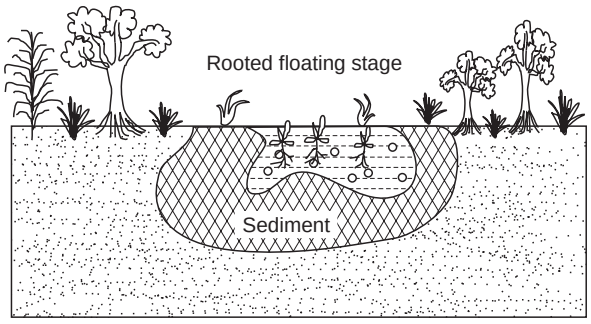
Let us consider very briefly two types of succession.

A. Hydrosere (Hydrarch): This type of succession starts in a water body like pond. A number of intermediate stages come and ultimately it culminates in a climax community which is a forest.

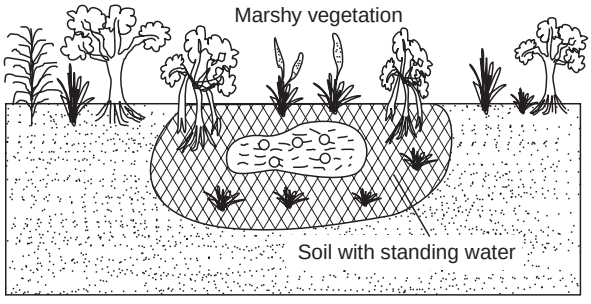
The pioneer community consists of phytoplanktons, which are free floating algae, diatoms etc. Gradually these are replaced by rooted-submerged plants followed by rooted-floating plants. Growth of these plants keep on adding organic matter to the substratum by death and



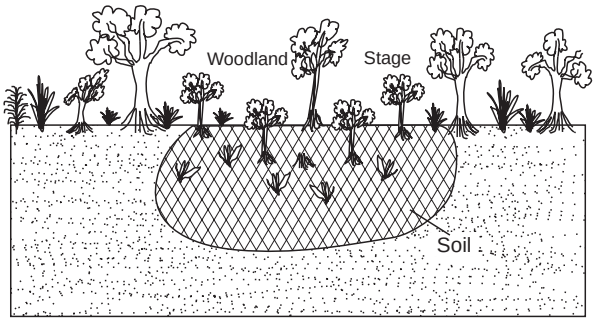
(*a*) Open water body (lake), sediment brought in by river.



(*b*) Sediment accumulation continues, organic debris from plants too add to soil formation and shrinking of water body occurs.



(*c*) A mat of vegetation covers the water which is mostly a marshy habitat now, with a small part as aquatic system.



(*d*) Eventually the former lake is covered by climax woodland community, representating a terrestrial ecosystem.

Fig. 3.15. Ecological succession: A hydrach—from lake to woodland community.

decay and thus a layer of soil builds up and shallowing of water takes place. Then Reed swamp (marshy) stage follows in which the plants are partly in water and partly on land. This is followed by a sedge-meadow stage of grasses then by a woodland consisting of shrubs and trees and finally by a forest acting as climax. (Fig. 3.15)

B. Xerosere (Xerarch): This type of succession originates on a bare rock, which lacks water and organic matter. Interestingly, here also the climax community is a forest, although the intermediate stages are very different.

The pioneer community here consists of crustose and foliose lichens. These lichens produce some weak acids and help in disintegrating the rock, a process known as *weathering*. Their growth helps in building up gradually some organic matter, humus and soil. Then comes the community of mosses, followed by herbs, shrubs and finally the forest trees. Throughout this gradual process there is a slow build up of organic matter and water in the substratum.

Thus, succession tends to move towards mesic conditions (moderate condition), irrespective of the fact, whether it started from a dry (Xeric) condition or a moist (hydric) condition and it culminates in a stable climax community, which is usually a forest.

MAJOR ECOSYSTEM TYPES

Let us consider types, characteristic features, structure and functions of some major ecosystems.

■ FOREST ECOSYSTEM

These are the ecosystems having a predominance of trees that are interspersed with a large number of species of herbs, shrubs, climbers, lichens, algae and a wide variety of wild animals and birds. As discussed above forests are found in undisturbed areas receiving moderate to high rainfall and usually occur as stable climax communities.

Depending upon the prevailing climatic conditions forests can be of various types:

(*a*) **Tropical Rain Forests:** They are evergreen broadleaf forests found near the equator. They are characterized by high temperature, high humidity and high rainfall, all of which favour the growth of trees. All through the year the climate remains more or less uniform. They are the richest in biodiversity. Different forms of life occupy specialized areas (niches) within different layers and spaces of the ecosystem depending upon their needs for food, sunlight, water, nutrient etc.

We come across different types and layers of plants and animals in the tropical rain forests. e.g. the **emergent layer** is the topmost layer of the tallest broad-leaf evergreen trees, below which lies the **canopy** where top branches of shorter trees form an umbrella like cover. Below this is present the **understory** of still smaller trees. On the tree trunks some woody climbers are found to grow which are known as **Lianas**. There are some other plants like **Orchids** which are **epiphytes** i.e. they are attached to the trunks or branches of big trees and they take up water and nutrients falling from above. The orchids have special type of leaves to capture and hold the water. *Some large epiphytes can hold as much as 4 litres of water, equivalent to a small bucket*! Thus, these epiphytes almost act like mini-ponds suspended up in the air, in the forest crown. That is the reason why a large variety of birds, insects and animals like monkeys have made their natural homes (habitats) in these forests (Plate II).

The understorey trees usually receive very dim sunlight. They usually develop dark green leaves with high chlorophyll content so that they can use the diffused sunlight for photosynthesis. The **shrub layer** receives even less sunlight and the **ground layer** commonly known as **forest floor** receives almost no sunlight and is a dark layer. Most of the animals like bats, birds, insects etc. occupy the bright canopy layer while monkeys, toads, snakes, chameleons etc. keep on moving up and down in sunny and darker layers. Termites, fungi, mushrooms etc. grow on the ground layer. Warm temperature and high availability of moisture facilitate rapid breakdown (decomposition) of the dropped leaves, twigs etc. releasing the nutrients rapidly. These nutrients are immediately taken up by the **mycorrhizal** roots of the trees.

Plate II. Tropical rain forest.

Interestingly, the flowers of forest trees are very large, colourful, fragrant and attractive which helps in pollination by insects, birds, bats etc. *Rafflesia arnoldi*, the biggest flower (7 kg weight) is known to smell like rotten meat and attracts flies and beetles which help in its pollination (Plate III).

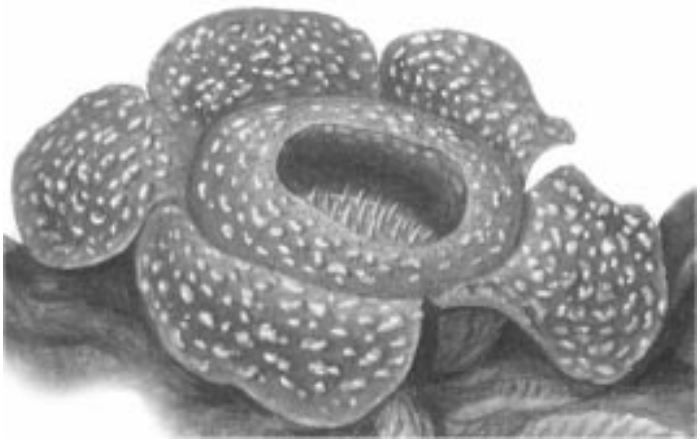


Plate III. Rafflesia—the biggest flower.

The Silent Valley in Kerala is the only tropical rain forest lying in India which is the natural habitat for a wide variety of species.

Being the store-house of biodiversity, the forests provide us with an array of commercial goods like timber, fuel wood, drugs, resins, gums etc. Unfortunately there is cutting down of these forests at an alarming rate. Within the next 30-40 years we are likely to be left with only scattered fragments of such forests, thereby losing the rich biodiversity and the ecological uses of forests, discussed earlier in unit II.

(*b*) **Tropical deciduous forests:** They are found a little away from the equator and are characterized by a warm climate the year round. Rain occurs only during monsoon. A large part of the year remains dry and therefore different types of deciduous trees are found here, which lose their leaves during dry season.

(*c*) **Tropical scrub forests:** They are found in areas where the dry season is even longer. Here there are small deciduous trees and shrubs.

(*d*) **Temperate rain forests:** They are found in temperate areas with adequate rainfall. These are dominated by coniferous trees like pines, firs, redwoods etc. They also consist of some evergreen broad-leaf trees.

(*e*) **Temperate deciduous forests:** They are found in areas with moderate temperatures. There is a marked seasonality with long summers, cold but not too severe winter and abundant rainfall throughout the year. The major trees include broad leaf deciduous trees like oak, hickory, poplar etc.

(*f*) **Evergreen coniferous forests (Boreal Forests):** They are found just south of arctic tundra. Here winters are long, cold and dry. Sunlight is available for a few hours only. In summer the temperature is mild, sun-shines for long hours but the season is quite short. The major trees include pines, spruce, fir, cedar etc. which have tiny, needle-shaped leaves having a waxy coating so that they can withstand severe cold and drought. The soil is found to get frozen during winter when few species can survive. The leaves, also know as needles, fall on the forest floor and cover the nutrient poor soil. These soils are acidic and prevent other plants from growing. Species diversity is rather low in these forests.

■ GRASSLAND ECOSYSTEMS

Grasslands are dominated by grass species but sometimes also allow the growth of a few trees and shrubs. Rainfall is average but erratic. Limited grazing helps to improve the net primary production of the grasslands but overgrazing leads to degradation of these grasslands resulting in desertification. Three types of grasslands are found to occur in different climatic regions:

(*a*) **Tropical grasslands:** They occur near the borders of tropical rain forests in regions of high average temperature and low to moderate rainfall. In Africa, these are typically known as **Savannas**, which have tall grasses with scattered shrubs and stunted trees. The Savannas have a wide diversity of animals including zebras, giraffes, gazelle, antelopes etc. During dry season, fires are quite common. Termite mounds are very common here. The termites gather the detritus (dead organic matter) containing a lot of cellulose and build up a mound. On the top of the mound fungi are found to grow which feed upon this dead matter including cellulose and in turn release methane, a greenhouse gas.

Tropical savannas have a highly efficient system of photosynthesis. Most of the carbon assimilated by them in the form of carbohydrates is in the perennating bulbs, rhizomes, runners etc. which are present underground. Deliberate burning of these grasslands can relase huge quantities of carbon dioxide, another green house gas, responsible for global warming.

(*b*) **Temperate grasslands:** They are usually found on flat, gentle sloped hills, winters are very cold but summers are hot and dry. Intense grazing and summer fires do not allow shrubs or trees to grow.

In United States and Canada these grasslands are known as **prairies,** in South America as **Pampas**, in Africa as **Velds** and in central Europe and Asia they are known as **Steppes.**

Winds keep blowing and evaporation rate is very high. It also favours rapid fires in summer. The soils are quite fertile and therefore, very often these grasslands are cleared for agriculture.

(*c*) **Polar grasslands (Arctic Tundra):** They are found in arctic polar region where severe cold and strong, frigid winds along with ice and snow create too harsh a climate for trees to grow. In summers the sun-shines almost round the clock and hence several small annual plants grow in the summer. The animals include arctic wolf, weasel, arctic fox, reindeer etc. A thick layer of ice remains frozen under the soil surface throughout the year and is known as **permafrost**. In summer, the tundra shows the appearance of shallow lakes, bogs etc. where mosquitoes, different type of insects and migratory birds appear.

■ DESERT ECOSYSTEMS

These ecosystems occur in regions where evaporation exceeds precipitation (rainfall, snow etc.). The precipitation is less than 25 cm per year. About 1/3rd of our world's land area is covered by deserts. Deserts have little species diversity and consist of drought resistant or drought avoiding plants. The atmosphere is very dry and hence it is a poor insulator. That is why in deserts the soil gets cooled up quickly, making the nights cool. Deserts are of three major types, based on climatic conditions:

(*a*) **Tropical deserts** like Sahara and Namib in Africa and Thar desert, Rajasthan, India are the driest of all with only a few species. Wind blown sand dunes are very common.

(*b*) **Temperate deserts** like Mojave in Southern California where day time temperatures are very hot in summer but cool in winters.

(*c*) **Cold deserts** like the Gobi desert in China has cold winters and warm summers.

Desert plants and animals are having most typical adaptations for conservation of water. Many desert plants are found to have reduced, scaly leaves so as to cut down loss of water due to transpiration or have succulent leaves to store water. Many a times their stems get flattened and develop chlorophyll so that they can take up the function of photosynthesis. Some plants show very deep roots to tap the groundwater. Many plants have a waxy, thick cuticle over the leaf to reduce loss of water through transpiration. Desert animals like insects and reptiles have thick outer coverings to minimize loss of water. They usually live inside burrows where humidity is better and heat is less. Desert soil is rich in nutrients but deficient in water.

Due to low species diversity, shortage of water and slow growth rate, the desert plant communities, if faced with a severe stress take a long time to recover.

■ AQUATIC ECOSYSTEMS

Aquatic ecosystems dealing with water bodies and the biotic communities present in them are either freshwater or marine. Freshwater ecosystems are further of standing type (**lentic**) like ponds and lakes or free-flowing type (**lotic**), like rivers. Let us consider some important aquatic ecosystems.

(*a*) **Pond ecosystem:** It is a small freshwater aquatic ecosystem where water is stagnant. Ponds may be seasonal in nature i.e. receiving

enough water during rainy season. Ponds are usually shallow water bodies which play a very important role in the villages where most of the activities center around ponds. They contain several types of algae, aquatic plants, insects, fishes and birds. The ponds are, however, very often exposed to tremendous anthropogenic (human-generated) pressures. They are used for washing clothes, bathing, swimming, cattle bathing and drinking etc. and therefore get polluted.

(*b*) **Lake ecosystems:** Lakes are usually big freshwater bodies with standing water. They have a shallow water zone called **Littoral zone,** an open-water zone where effective penetration of solar light takes place, called **Limnetic zone** and a deep bottom area where light penetration is negligible, known as **profundal zone** (Fig. 3.16).

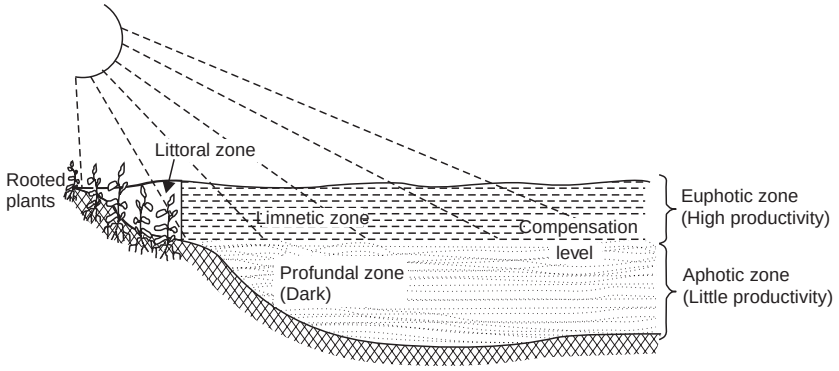


Fig. 3.16. Zonation in a lake ecosystem.

The Dal Lake in Srinagar (J & K), Naini Lake in Nainital (Uttaranchal) and Loktak lake in Manipur are some of the famous lakes of our country.

Organisms : The lakes have several types of organisms:

(*a*) **Planktons** that float on the surface of waters e.g. *phytoplanktons* like algae and *zooplanktons* like rotifers.

(*b*) **Nektons** that swim e.g. fishes.

(*c*) **Neustons** that rest or swim on the surface.

(*d*) **Benthos** that are attached to bottom sediments e.g. snails.

(*e*) **Periphytons** that are attached or clinging to other plants or any other surface e.g. crustaceans.

Stratification : The lakes show stratification or zonation based on temperature differences. During summer, the top waters become warmer than the bottom waters. Therefore, only the warm top layer

circulates without mixing with the colder layer, thus forming a distinct zonation:

Epilimnion : Warm, lighter, circulating surface layer

Hypolimnion : Cold, viscous, non-circulating bottom layer.

In between the two layers is **thermocline**, the region of sharp drop in temperature.

Types of Lakes : Some important types of lakes are:

(*a*) **Oligotrophic lakes** which have low nutrient concentrations.

(*b*) **Eutrophic lakes** which are overnourished by nutrients like nitrogen and phosphorus, usually as a result of agricultural run-off or municipal sewage discharge. They are covered with "algal blooms" e.g. Dal Lake.

(*c*) **Dystrophic lakes** that have low pH, high humic acid content and brown waters e.g. bog lakes.

(*d*) **Endemic lakes** that are very ancient, deep and have endemic fauna which are restricted only to that lake e.g. the Lake Baikal in Russia; the deepest lake, which is now suffering a threat due to industrial pollution.

(*e*) **Desert salt lakes** that occur in arid regions and have developed high salt concentrations as a result of high evaporation. e.g. great salt lake, Utah; Sambhar lake in Rajasthan.

(*f*) **Volcanic lakes** that receive water from magma after volcanic eruptions e.g. many lakes in Japan. They have highly restricted biota.

(*g*) **Meromictic lakes** that are rich in salts and are permanently stratified e.g. lake Nevada.

(*h*) **Artificial lakes or impoundments** that are created due to construction of dams e.g. Govindsagar lake at Bhakra-Nangal.

Streams

These are freshwater aquatic ecosystems where water current is a major controlling factor, oxygen and nutrient in the water is more uniform and land-water exchange is more extensive. Although stream organisms have to face more extremes of temperature and action of currents as compared to pond or lake organisms, but they do not have to face oxygen deficiency under natural conditions. This is because the streams are shallow, have a large surface exposed to air and constant motion which churns the water and provides abundant oxygen. Their dissolved oxygen level is higher than that of ponds even though the green plants

are much less in number. The stream animals usually have a narrow range of tolerance to oxygen. That is the reason why they are very susceptible to any organic pollution which depletes dissolved oxygen in the water. Thus, streams are the worst victims of industrial development.

River Ecosystem: Rivers are large streams that flow downward from mountain highlands and flowing through the plains fall into the sea. So the river ecosystems show a series of different conditions.

The mountain highland part has cold, clear waters rushing down as water falls with large amounts of dissolved oxygen. The plants are attached to rocks (periphytons) and fishes are cold-water, high oxygen requiring fish like trouts.

In the second phase on the gentle slopes, the waters are warmer and support a luxuriant growth of plants and less oxygen requiring fishes.

In the third phase, the river waters are very rich in biotic diversity. Moving down the hills, rivers shape the land. They bring with them lots of silt rich in nutrients which is deposited in the plains and in the delta before reaching the ocean.

Oceans

These are gigantic reservoirs of water covering more than 70% of our earth's surface and play a key role in the survival of about 2,50,000 marine species, serving as food for humans and other organisms, give a huge variety of sea-products and drugs. Oceans provide us iron, phosphorus, magnesium, oil, natural gas, sand and gravel.

Oceans are the major sinks of carbon dioxide and play an important role in regulating many biogeochemical cycles and hydrological cycle, thereby regulating the earth's climate.

The oceans have two major life zones: (Fig. 3.17)

Coastal zone with relatively warm, nutrient rich shallow water. Due to high nutrients and ample sunlight this is the zone of high primary productivity.

Open sea: It is the deeper part of the ocean, away from the continental shelf (The submerged part of the continent). It is vertically divided into three regions:

(*i*) **Euphotic zone** which receives abundant light and shows high photosynthetic activity.

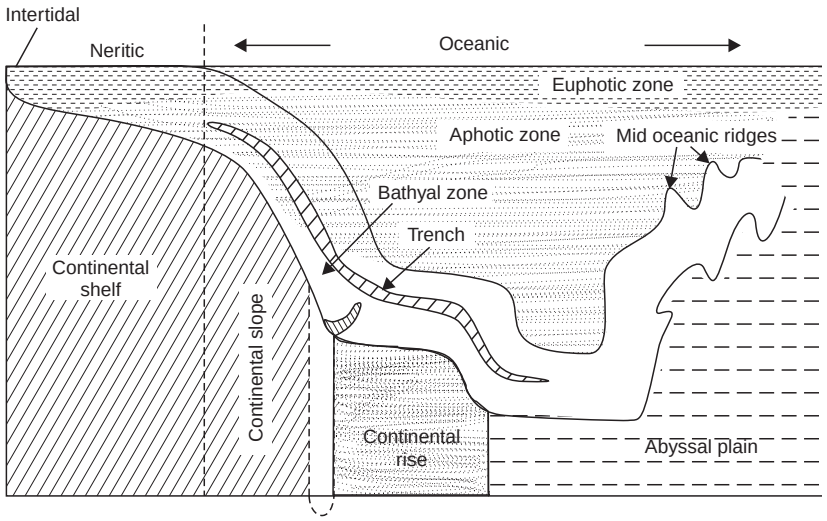


Fig. 3.17. Vertical and horizontal zonation of a marine ecosystem.

(*ii*) **Bathyal zone** receives dim light and is usually geologically active.

(*iii*) **Abyssal zone** is the dark zone, 2000 to 5000 metres deep. The abyssal zone has no primary source of energy i.e. solar energy. It is the world's largest ecological unit but it is an incomplete ecosystem.

Estuary

An estuary is a partially enclosed coastal area at the mouth of a river where fresh water and salty seawater meet. These are the transition zones which are strongly affected by tidal action. Constant mixing of water stirs up the silt which makes the nutrients available for the primary producers. There are wide variations in the stream flow and tidal currents at any given location diurnally, monthly and seasonally. Therefore, the organisms present in estuaries show a wide range of tolerance to temperature and salinity. Such organisms are known as **eurythermal** and **euryhaline**. Coastal bays, and tidal marshes are examples of estuaries.

Estuaries have a rich biodiversity and many of the species are endemic. There are many migratory species of fishes like eels and salmons in which half of the life is spent in fresh water and half in salty water. For them estuaries are ideal places for resting during migration, where they also get abundant food. Estuaries are highly productive ecosystems. The river flow and tidal action provide energy subsidies for the estuary thereby enhancing its productivity. Estuaries are of much use