

Subject: **Zoology**

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Paper No. : 12 Principles of Ecology
Module : 23 Marine Ecosystem



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Description of Module	
Subject Name	ZOOLOGY
Paper Name	Zool 12 Principles of Ecology
Module Name/Title	Ecosystem
Module Id	M23 Marine Ecosystem
Keywords	Ecosystem, aquatic ecosystem, marine ecosystem, estuary.

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1. Learning Outcomes

After studying this module, you shall be able to:

- ✓ Understand the types of ecosystem.
- ✓ Classify the aquatic organisms on the basis of their zone of occurrence.
- ✓ Know physico-chemical properties of marine ecosystem.
- ✓ Understand the different biota of ocean.
- ✓ Learn about estuary and its biotic components.

2. Introduction

The living organisms and the environment including all abiotic component such as water, air and temperature are interrelated and interact upon each other so that a flow of energy leads to a clearly defined trophic structure, biotic diversity and material cycles. The term Ecosystem was proposed by British ecologist, A.G. Tansley in 1935. The ecosystem represents the basic functional unit of ecology that can be explained as a system formed by the community and the environment.

The central theme of ecosystem is that the living organisms of a community not only interact among themselves but also have functional relationship with their non-living environment. Our earth can be considered as a giant ecosystem represented as biosphere in which biotic and abiotic factors continuously interact with each other. Though biosphere is a vast ecosystem yet it is difficult to study as a whole. Therefore, for our convenience of study, it can be divided into following major types:

- 1) Terrestrial ecosystem such as forest, grassland, mountain and desert.
- 2) Aquatic ecosystem such as fresh water or marine.

In this module we will discuss about marine ecosystem in details, whereas, terrestrial ecosystem and freshwater ecosystem will be discussed in other modules.

3. Aquatic Ecosystem

Waters covers about three quarters of the earth's surface either in the form of fresh water having salt concentration less than 0.5 % or as marine water having salt concentration more than 3.5 % or as brackish water with salt concentration intermediate between fresh water and saline water. It is on this basis, that aquatic ecosystems are categorized into

- 1) **Fresh water ecosystems:** It may be lotic (running water like river and stream) or lentic (standing water such as lake and pond).
- 2) Marine ecosystems - shallow seas and open ocean and
- 3) Brackish water ecosystems-estuaries and salt marshes.

4. Classification of Aquatic Organisms

Aquatic organisms found in the different types of aquatic ecosystems are classified on the basis of their zone of occurrence in water body and their ability to cross these zones. These organisms are unevenly distributed in the ecosystem and are classified on the basis of their life form or location into five groups:

- i) **Neuston:** These are unattached organisms which live at the air-water interface such as floating plants and several types of animals such as water striders, while other spend most of their time just beneath the air-water interface and obtain most of their food within the water such as beetles, back-swimmers etc.
- ii) **Periphyton:** These organisms which remain attached or adhere to stems and leaves of rooted plants emerging above the bottom mud. It includes sessile algae and their associated group of animals.
- iii) **Plankton:** It includes both microscopic plants and animals. The locomotory activity of the planktons is limited which restrict their distribution. Planktons are divided into Plants (phytoplankton) mainly algae and Animals (zooplanktons) mainly crustaceans and protozoans.

iv) **Nekton:** This group contains animals which are active swimmers, their relatively large size and powerful body can overcome the water currents. The animals range from swimming insects (about 2 mm size) to the largest animals, blue whale.

v) **Benthos:** The benthic organisms are living in or on the bottom region of the water. They show a variety of adaptations to the environment because bottom is more heterogeneous than open water or the surface.

5. Factors Limiting the Productivity of Aquatic Habitat

The most important factors that affect the productivity of an ecosystem are sunlight and oxygen. It distinguishes aquatic ecosystem from the terrestrial ecosystems where moisture and temperature are the main limiting factors. The main factors which control the productivity of aquatic ecosystems are:

i) **Sunlight:** It is a major limiting factor for water bodies as light gradually diminishes when it passes down the column of water. The upper layers of the aquatic ecosystems up to which light can penetrate and photosynthetic activity occurs, forms the photic zone. The depth of photic zone can be determined by the transparency of water.

ii) **Temperature:** The temperature of water body declines very slowly than the temperature of air because water has relatively higher specific heat than air. Since water temperatures are less subject to change, the aquatic organisms living in the water are stenothermal (having narrow temperature tolerance). As a result, even small changes in water temperatures can lead to higher mortality in the aquatic organisms as comparable to changes of temperature in air where terrestrial organisms are present.

iii) **Transparency:** Clearness of water influences the extent of light penetration in aquatic ecosystem. It is indirectly related to turbidity. Suspended particulate matters such as clay, silt and phytoplankton make the water turbid. As a result, the extent of light penetration can significantly affects the photosynthetic activity of aquatic plants.

iv) **Dissolved oxygen:** Oxygen in the terrestrial ecosystems occurs in the atmosphere along with other gases in a fixed concentration. However, in aquatic ecosystems, oxygen is present in water as dissolved state where its concentration varies depending on various factors that

influence the input and output of oxygen in water. In fresh water the average concentration of dissolved oxygen is 0.0010 % (10 ppm) by weight, which is 150 times lower than the concentration of oxygen present in an equivalent volume of air.

The concentration of dissolved oxygen in the aquatic ecosystem depends entirely on the photosynthetic activity of aquatic plants or air water interface through which oxygen enters the aquatic ecosystem. Moreover, water turbulence and wave activity in open water increases the rate of oxygen transfer from air to water. The transfer of oxygen is also affected by the surface area of the water. A wide shallow section of a river has a larger surface area for oxygen transfer than a narrow deep segment.

6. Marine ecosystem

Marine ecosystem is one of the largest reservoirs of water. The total biomass in the marine ecosystems far exceeds that of all fresh water ecosystems put together. Marine ecosystem consists of seas and oceans that cover 70.8% of the earth's surface and hold around 97% of the Earth's water. The total volume of marine ecosystem is approximately $1370 \times 10^6 \text{ km}^3$ and has an average depth of 3750 m (the greatest known depth being 10,750 meters in the Marianas Trench). As being the largest reservoir of water, oceans strongly influence climate by regulating the hydrological cycle on the earth.

The **Pacific ocean** is the largest marine ecosystem with $179.7 \times 10^6 \text{ km}^2$ area (figure 1). It is the coldest (average 3.36°C) and least saline (34.6 ppt) ocean. The **Atlantic ocean** is warmer (average 3.73°C) and more saline (average 34.9 ppt). The **Arctic ocean** is smallest and shallower, **whereas**, The **Antarctic ocean** bears wide variations in temperature range from -1.8°C to 10°C . The **Indian ocean** covers $77 \times 10^6 \text{ km}^2$ area with an average depth of 3872 m.



Figure.1: Pacific Ocean from space.

6.1: Physico-chemical properties of marine ecosystem:

Marine ecosystems are of great ecological significance and have certain salient features (figure 2):

1) Salinity: The Sea is salty and its salinity is quite constant, averaging about 3.5 %. Sodium chloride is the main salt being 27 % while the rest are chloride, sulphates, bicarbonates, carbonates, calcium, potassium and magnesium salts. The salinity of marine water vary from one place to another.

2) Light: It acts as a limiting factor in the ocean as it significantly contributes to the biomass production and distribution of marine flora and fauna. On the basis of penetration of light in water, ocean can be divided into two horizontal zones:

a) The photic or euphotic zone: The photic zone of sea reaches from water surface to a depth of 200 meters. In this zone light penetrate and support the process of photosynthesis in aquatic plants. This zone is also known as epipelagic zone which is characterized by gradients of light decreasing from top to the lower level, temperature and salinity.

b) Aphotic zone: It is present below photic zone and distinguishable into three further sub-zones:

i) Mesopelagic zone: This zone extends from 200 meters to 1000 meters. It is semi-dark zone where negligible amount of light penetrates in it. The temperature gradient is almost even show gradual decline with depth and without much seasonal variation. Further this zone contains a minimum oxygen concentration and a maximum of nitrate and phosphate salts.

ii) Bathypelagic zone: This zone extends from 1,000 meters to 2,000 meters and there is almost complete darkness as the light is not able to penetrate this zone.

iii) Abyssopelagic or benthopelagic zone: this zone is completely dark and temperature is low and uniform at 3°C, also the pressure hydrostatic pressure is enormous.

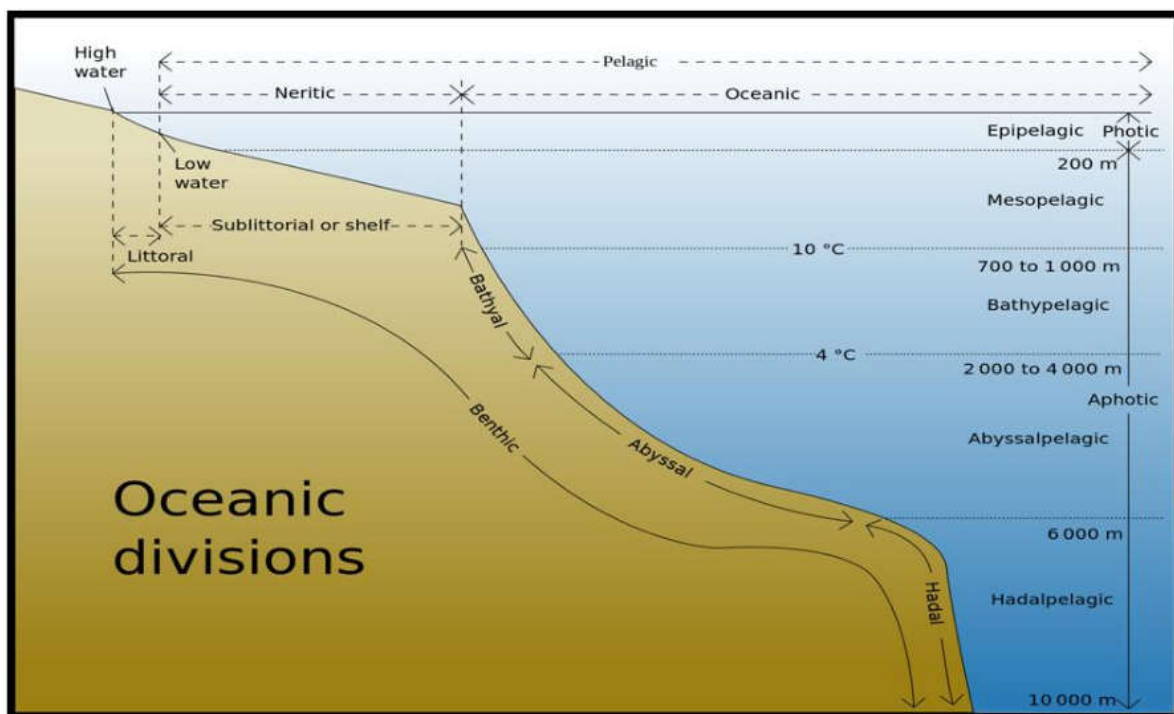


Figure.2: Different divisions of an ocean.

3) Temperature: The range of temperature in the oceans and seas are less than land temperature. Also, the temperature remains almost constant in the oceans in contrast to the land or terrestrial ecosystems. The temperature ranges from 2°C in the polar seas to around 32°C or higher in the tropical seas. The annual difference of temperature usually does not exceeds more than 6°C in any part of the sea.

4) Concentration of Nutrients: The marine environment is low in concentrations of dissolved nutrients and are measured in parts per billion (ppb). Whereas, the salts concentration present in higher amounts, eg., sodium chloride is measured in parts per thousand (ppt). As the nutrients are present in low amount they acts as limiting factors in the productivity of marine ecosystems and determining the size of marine population.

5) Alkalinity: The Sea is alkaline in nature because the electrical dissociation forces of cation molecules are larger in concentration than that of anions. The average pH of the sea remains around 8.2 and also acts as buffer which resists changes in pH.

6) Pressure: Pressure of water increases as the depth increase which varies in the ocean from 1 atmospheric pressure at the surface to 1000 atmosphere at the greatest depth. Pressure changes in the sea are several times higher than on land and so have a prominent effect on the distribution of life in the sea.

7) Continuity: The Sea is a continuous body of water. All the oceans such as Pacific, Indian, Arctic and Antarctic are connected together. However, several abiotic factors like salinity, temperature, and depth of sea restrict the distribution and free movement of marine organisms.

8) Depth: The depth of sea differs in different region and can also form the deepest part of earth. The aquatic life is present in all depth but maximum diversity is confined to continental shelf and islands.

9) Currents: The Sea water is never static and is in continuous circulation by means of water currents. It may be driven by winds, cosmic forces and varying water densities. Most world-wide water currents occur at the surface and at great depths of sea water. These currents determine the interchange between the surface and deep water masses as well as horizontal movements.

10) Waves and tides: The Sea is dominated by several kinds of waves and tides, which are produced by the pull of moon, sun and gravitational forces.

11) Circulation of nutrients in the coastal zone: Circulation of nutrients from the sea bottom to the upper surface occurs in the coastal regions by the following two processes:

i) Upwellings: It occurs where the winds cause the surface waters to be blown offshore, which are then replaced by the cold nutrients rich waters from the deep

ii) Outwellings: It occurs where the sea is enriched by nutrient rich estuarine waters entering into it.

6.2: Organization of the Marine Ecosystem:

The marine habitat is distinguishable into two zones (figure 2):

i) Benthic Zone:

It forms the basin or floor of the ocean, regardless of depth. Horizontally, it is divided into two sub zones. The upper most portion is called supra littoral zone, comprising the beach down to the edge of the ocean. Beyond this is the littoral zone which represents the area between the upper and lower tide levels and also called inter-tidal zone. Littoral zone is situated on the shore of the ocean. Next to this is the sub-littoral or continental shelf which extends from the littoral zone to the commencement of the continental slope. The continental shelf is the extension of underwater continent and its depth extends from 125 meters to 200 meters. Next to continental shelf, there is a rapid decline and this is called the continental slope. After some distance the continental slope forms the continental rise which may be geologically active. This region has canyons and trenches which are responsible for underwater eruptions and avalanches. The continental slope and rise together constitute the bathyal zone. The bathyal zone is 200 meters deep which descends rapidly to a depth of 3,000 or 4,000 meters. From this point, the bottom drops for further several thousand meters around 6,000 m to form the broad flat abyssal plains where temperature is never above 4°C.

ii) Pelagic Zone:

It represents the free water zone, filling the basin. The water contained in the sea basin, constitute the pelagic zone which is further divided into the following zones:

- a) The neritic zone situated above the sub littoral zone or the continental shelf. It starts from the edge of littoral zone and extends up to the edge of continental shelf with a depth of 200 meters.
- b) Deep open sea of the oceanic zone which is divided on the basis of light penetration as discussed in the physico-chemical property of light of the oceans.

6.3: Biota of Oceans:

Life in the sea is not particularly abundant, though the diversity of organisms is very high. Almost every major group of animals and every major group of algae and plants can be found

in the oceans except vascular plants and insects which have few marine representatives, however they are abundant in estuaries. The marine organisms can be categorized on basis of depth into littoral, neritic, pelagic and benthic zones:

i) Biota of Littoral Zone: It is the shore region which is continuously disturbed by waves, tides, temperature, salinity and light. Thus, the environment is highly disturbed, unstable and difficult. The organisms are alternately exposed and submerged during low and high tide. Thus, this zone is also called intertidal zone. The animals are largely dependent on planktons and detritus or dead particles. The non diatoms and other algae are also found in this zone. Crustaceans and worms burrow in the sand and other microscopic organisms such as copepods, protozoan and rotifers live in the water (figure 3). Various species of fishes and shrimps are also found in this zone which undergo vertical migration according to the movement of water.



Figure.3: A collection of marine zooplankton composed of copepods, Daphnia and other tiny animals.

The organisms that are found in the intertidal zone are adapted to either resist the desiccation during low tide or can form the burrow to water level. For instance, intertidal polychaets live tubicolous mode of life to prevent themselves from desiccation during low tide by retaining sufficient moisture. Barnacles suspend their metabolic activity during dry periods to protect themselves from desiccation. Many plants have jellylike substances like agar which prevent

them from drying by absorbing and retaining large quantities of water. Moreover, in drought condition, most of shore animals use oxygen stored in the blood plasma such as nereid *Arenicola*. As this zone is continuously disturbed by waves, so many organisms on a sandy or rocky beach have adapted various methods to withstand the effect of waves.

Many types of seaweed have tough flexible body which can bend with the wave action, whereas, animals either develop hard calcareous shells (some mollusks, Bryozoa, barnacles and crabs) or have strong leathery skin (starfish, sea anemone, octopus etc). Moreover, several sedentary shore animals like sponges (figure 5) and tunicates have developed adhesive mechanism by which they can firmly attach to the substratum.

ii) Biota of the Neritic zone: This zone occurs below littoral zone and constitutes about 75% of total area of ocean. The structure of community changes with change in depth. This zone show high productivity as the light can penetrate deeper and also exhibit higher species diversity due to presence of abundant nutrients.

The communities in neritic zone are richer and more diverse than the communities present in either open sea or even in the tropical rain forests. The most common producers are phytoplanktons such as diatoms and dinoflagellates. In addition, availability of light causes the development of different algal species, ranging from giant kelp forest to smaller communities of red, green and brown algae which are attached to the bottom, also significantly influence the productivity of neritic zone. The zooplanktons present in this zone are similar to pelagic zone. However, populations of temporary zooplanktons or meroplankton are more numerous as compare to the open sea. Various larval forms grow into large organisms that will later become part of either nekton or benthos. Organisms which remain for their entire life cycle in the plankton are called holoplankton or permanent plankton.



Figure.4: Different forms of zooplanktons.

The mature forms of protozoan (green flagellates, rhizopod, forminifera, actinopod and radiolarians), cnidaria (*Pleurobranchia* and many siphonophores), certain flatworms, arthropods (copepods and *Calanus*) and tunicates (*Oikopleura*) are most important components of zooplanktons (figure 4).

Nekton organisms include the rich fauna of fishes, crustaceans, whales, sea snakes, seals, sea-otters, large squids (figure 5) and others that live and feed there. Fish species include several species of sharks, flying fish, herring-like species including sardine and herring and their relatives (haddock and pollack), flat fish like sole, halibut, salmon, sea trout and mackerals including bonito and tuna. Several species of mammals like seals, porpoises, dolphins and whales, certain arthropods such as crustaceans and marine birds (penguins and pelicans) are also included in this zone.



Figure.5: Giant Squid.

The benthic communities of neritic zone (Sub littoral zone) consist of creeping, crawling, and sessile organisms. Large varieties of animals including bryozoa, sea cucumber, clams, lobster, shrimps, snails, crabs, brittle star, starfish, anemones, foraminifera, sponges and annelids. The diversity of organisms are more in this zone than in the deeper zone. The bottom of this zone is rocky, muddy or sandy with variable temperature compared to the deeper part of the sea.

iii) Biota of Pelagic Zone:

This region constitutes 90 per cent of the total ocean surface and is less rich in species and numbers of organisms. The most abundant pelagic phytoplanktons are still the dinoflagellates and diatoms (figure 6)

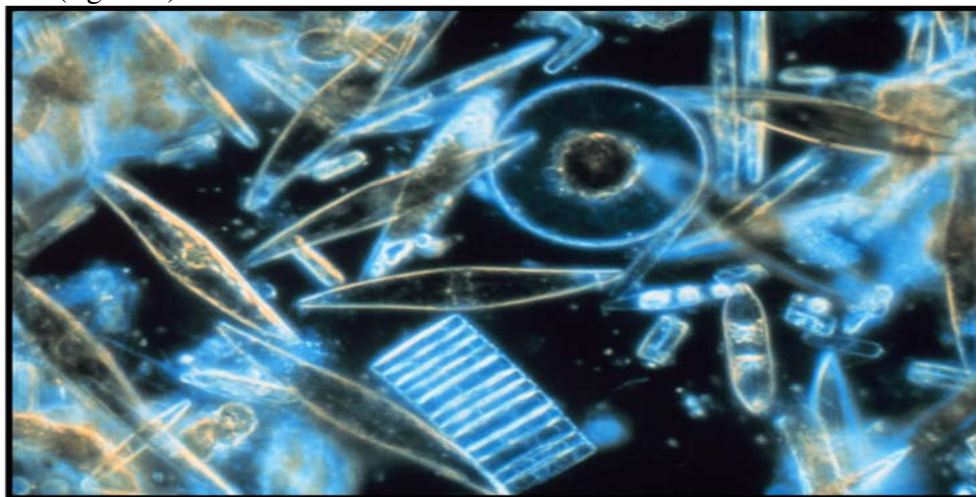


Figure.6: Various forms of Diatoms.

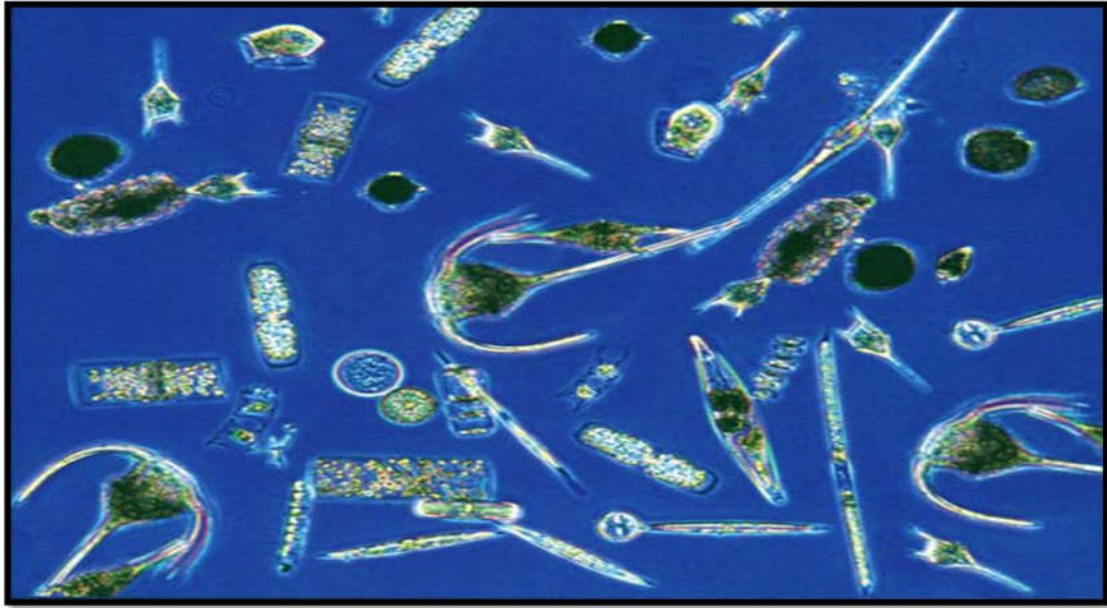


Figure.7: Different species of phytoplanktons.

Larger swimming animals are also present in open ocean water. These may be separated into surface pelagic and deeper water pelagic communities. In the surface pelagic zone, phytoplanktons include diatoms and dinoflagellates (figure 7), zooplanktons are mostly copepods which feed on phytoplanktons, other animals are euphausiids (krill) (figure 8), arrow worms, comb jellies and tunicates.



Figure.8: Antarctic krill (*Euphausia superba*).

Marine deep pelagic communities consist of detritus feeders such as sea lilies which rise above the sea floor while clams and tubeworms stay burrowed in mud. The deep pelagic communities are heterotrophs which feed on the plankton and dead particulate organic matter and excreta of fishes which swim between surface and deeper water. The communities also consist of carnivore copepods and several crustaceans along with colonial bacteria. In the deeper part, animals may be blind or may have bioluminescent organs.

iv) Biota of Benthic zone:

It extends from boundary of continental shelf to the deepest oceans. Since there is no light, plants are absent and only heterotrophic communities are present which live on in the mud surface and bacteria. The deep benthic zone is rich in diversity though strange, occupying cold and dark space surviving under intense pressure and scarcity of food.

7. Estuary

Estuary is a zone where fresh water rivers meet the salty water of the ocean resulting in brackish water, intermediate in salt content and water density (figure 9). They form the transitional zones called ecotone between the sea and rivers and possess unique biological make up. These are complex ecosystems of high productivity, often combining salt marshes and mud flats with deeper water and linking fresh water communities with those of oceans. Estuaries function both on planktonic based and detrital based food web. About 80% of commercial marine fishes depend in many ways on estuaries (eg., food, spawning ground etc.). In India, estuaries can be seen in plenty along the coast of Kerala.



Figure.9: The estuary of the Veleka in the Black Sea.

7.1: Features of Estuaries:

The physico-chemical properties of the estuaries have large variation and form a stressful environment for organisms living there. This is the one reason which causes few larger organisms to occur in this area as compare to smaller organisms. The most peculiar feature of the estuary is the fluctuation in salinity which forms a gradient that varies seasonally with the topography, tides and amount of fresh water.

There is deposition of sand particles which is controlled by water currents and size of sand particles. If water current is strong, it causes deposition of coarse (sand) particles, however, in calm or low water current, only fine silt will settle down. These particles have many organic origins derived from terrestrial as well as marine systems which increase the concentration of accumulated substrate.

Another important factor is temperature which fluctuates rapidly and continuously under prevailing atmospheric conditions and fresh water input. Temperature variation is also present vertically. The temperature of surface water of estuary is higher than deeper waters.

All these variations i.e. the salinity, texture of substrate, temperature, organic matter and available oxygen is controlled by wave action and currents. The intensity of wave action is

small in the estuaries causing settling of fine sediments, which allow growth of rooted plants. Water currents in estuaries are caused primarily by tidal action and river flow. Currents are generally confined to channels but velocities sometimes can reach up to several knots. The higher velocity is observed in the middle and lowest is found at the bottom.

The water current is also responsible for two important natural processes in the estuary called erosion and deposition. However, the process of deposition of different organic and inorganic contents in estuaries dominates erosion process, resulting in net deposition of silt. During the parts of the year when water movement is very slow it leads to reduced content of oxygen, algal blooms and occurrence of fish deaths.

Due to the deposition of sand or silt particles, the turbidity of estuaries increases. Turbidity remains lower at the origin of estuary and increases with distance inland. The higher turbidity decreases the light penetration which restricts the growth and photosynthetic activity of phytoplankton and benthic plant, thereby reducing the productivity of these producers. Another important parameter is dissolved oxygen content in water that is inversely related to temperature and salinity i.e. increases in temperature and salinity decreases dissolved oxygen concentration in water. The higher content of organic matter increases the biological oxygen demand for bacterial population to degrade these matters which causes oxygen depletion in water. Therefore, the sediments below few centimeters are anoxic unless they have large particle size or large population of burrowing animals (like ghost shrimp, *Balanoglossus* etc.) which oxygenate lower sediment layers by their burrowing activities.

7.2: Biota of Estuaries:

The estuarine community is the mixture marine, fresh water and brackish water components but the diversity remains lower than marine community and fresh water community. This is due to the variation in the estuary's physical environment. Thus, the great productivity of estuaries is built on a narrow base.

The plants of the estuary are of four basic types:

- i) Phytoplankton,
- ii) marginal marsh vegetation
- iii) mud-flat algae and
- iv) Epiphytic plants growing on the marginal marsh vegetation.

Because of the turbidity in water, phytoplanktons are normally uncommon. However, great blooms of certain algae are well known which include *Spartina* and *Salicornin*. Most of the estuarine algae are of marine origin and commonly occurring genera include *Ulvn*, *Entrromorpha*, *Chaetomorpha* and *Cladophora*. These are often seasonally abundant, disappearing during certain seasons.

The commonly found plants are marginal and marsh vegetation that include marsh grasses, mangroves and marsh submerged filamentous colonial green algae. Only few herbivores are present to feed on them and large proportion enters into detritus food chain. The mud-flats are exposed during low tide which provides the site for photosynthesis by diatoms and filamentous blue-green algae.

The animals of estuaries are related to wetlands such as marshes and swamps. The commonly found estuarine animals are oysters, crabs, clams and lobsters. Various animals enter the estuary from fresh water which includes mollusks, various insect larvae and annelid worms and some marine zooplankton are also showing their presence along several types of larger animals.

8. Summary

In ecosystem, the living organisms of a community not only interact among themselves but also have functional relationship with their non-living environment. The Ecosystem can be classified into Terrestrial and Aquatic ecosystem. Aquatic ecosystems are categorized into Fresh water ecosystems, Marine ecosystems and brackish water ecosystems. Organisms living in the aquatic ecosystems are classified on the basis of their zone of occurrence in water body and their ability to cross these zones. It includes Neuston which live at the air-water interface, Periphyton remain attached or adhere to stems and leaves of rooted plants, Plankton are both microscopic plants and animals, Nekton are active swimmers and Benthic organisms are living in or on the bottom region of water.

The most important factors that affect the productivity of an ecosystem are sunlight, transparency, temperature, and oxygen. Marine ecosystem is one of the largest reservoirs of water and has great ecological significance. Marine ecosystem has several physico-chemical

properties including salinity, light, temperature, nutrients, alkalinity, pressure, continuity, water depth, water current, waves and tides and circulation of nutrients. The marine habitat is distinguishable into two zones, benthic zone which form the basin or floor of the ocean and other is pelagic zone that represents the free water zone.

The marine organisms can be categorized on basis of depth into littoral, neritic, pelagic and benthic zones. Littoral Zone is highly disturbed, unstable and difficult. The organisms include some mollusks, Bryozoans, barnacles and crabs. Neritic zone is highly productive and includes phytoplankton such as diatoms and dinoflagellates. Nekton includes the rich fauna of fishes, crustaceans, whales, sea snakes etc. Pelagic Zone constitutes 90 per cent of the total ocean surface having phytoplanktons like dinoflagellates and diatoms. Zooplanktons are mostly copepods and other animals are arrow worms, comb jellies and tunicates. Benthic zone is rich in diversity though strange, occupying cold and dark space and surviving under intense pressure and scarcity of food.

Estuary is a zone where fresh water rivers meet the salty water of the ocean resulting in brackish water, intermediate in salt content and water density. The physico-chemical properties of the estuaries have large variation and it forms a stressful environment for organisms living there.

The plants of the estuary are of four basic types that include phytoplankton, marginal marsh vegetation, mud-flat algae and Epiphytic plants growing on the marginal marsh vegetation. The commonly found estuarine animals are oysters, crabs, clams and lobsters.