

## INTERTIDAL AND SUBTIDAL ECOLOGY

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Marine ecology is a diverse subject of many facts, concepts and theories. The word ecology derived from the Greek word 'Oikos' means house. This word was introduced by Haeckel (1866) to describe an individual in relation to its environment. Later ecology was separated into the ecology of individuals (autecology) and that of population (synecology). There are four elements in the study of ecology, the individuals, the population, the group of population and lastly the community (or ecosystem). Ecology today is an extensive field almost as all-embracing as biology itself. The ecology of the sea has developed into the study of population and ecosystems.

### INTERTIDAL

#### Sandy beach

Sandy beaches dominate most temperate and tropical coast lines where they represent both recreational assets and buffer zones against the sea. The term sandy beach covers a range of environment from high energy open oceanic beaches to extremely sheltered estuarine sand flats. Sandy beaches can be divided into exposed and sheltered beaches, based on the exposure criteria. They can further be divided into tidal and atidal beaches. They occupy a dynamic interface position between sea and land. This ecosystem is comprised of (1) the sand body from the highest drift line of dune to beyond the break point of the wave and (2) the moving water out side. The configuration and topography of a sandy beach is determined by the interaction of waves, tides and the movement of sediment (Fig. 1). The continuous wave action and associated littoral sediment transport make an intertidal stretch unique environment for biogenic activities of marine organisms. The physico-chemical, geomorphological and biological features play important role in determining the distribution of fauna on these sandy beaches (Folk, 1974, Reise, 1985). The exposed oceanic beaches are unstable environment encompassing poor fauna compared to sheltered estuarine beaches. These beaches provide two habitat for faunal population. (1) The macrofaunal habitat (2) the interstitial habitat.

#### Ecological consideration

The sandy beach environment often provides stress conditions for the organisms which inhabit it (McLachlan, 1983). Basically two types of fauna inhabit it. They are (1) macrofauna (2) meiofauna. The macrofauna are several order of magnitude larger

than the meiofauna and therefore the two groups comprise two entirely separate faunal components with virtually no exchange of energy. The unstable and exposed intertidal areas of sandy beaches have generally impoverished macrofauna but abundant and diverse meiofauna (McIntyre, 1969, Ansari *et al.*, 1990). The main controlling factor of the fauna on sandy beaches is exposure to wave action, which largely determine slope, and both are related to particle size, which in turn porosity and permeability. The availability of food is an important biological factor which determines the distribution of meiofauna. Other important controlling factors are redox potential (Eh), interstitial water and oxygenation. Because of the moving sand and abrasive wave action, sandy beaches do not have macrophytes such as algae and rooted plants as compared to rocky shores and muddy areas. On the other hand there is an abundance of diatoms attached to sand grains and microflora on the sandy beaches. An important ecological feature of sandy intertidal environment is the clear zonation in the distribution of fauna and flora.

An important habitat is provided in between stices. The fauna inhabiting this intertidal system (meiofauna/interstitial fauna) is highly specialised and adapted for such a life. They include nematodes, copepods, turbellarians, foraminiferans and gastrotrichs. Their density can be up to one million individuals below each square meter of beach. They appear to feed on microorganisms and detritus. Although their exact role in the ecosystem is not clearly understood, they are believed to be useful in nutrient regeneration and energy transfer. Because of their short generation time and generally rapid metabolisms they may be useful organisms in providing an early warning of pollution dangers.

Of the large animals (macrofauna), a wide range of species make up the assemblage. On well sorted sandy beaches bivalves, polychaetes and crustaceans dominate. The distribution of these animals is far from uniform. There is an important zonation correlated with tidal height, different species being adapted to varying of emergence. Some species show maximum abundance near the low water mark while others congregate at mid and high water mark.

The special feature of sand beaches as ecosystems are related to the mobility and porosity of the substratum. The tides bring food (phytoplankton) and supply nutrients and oxygen to the animal community of the intertidal sandy beach. In sheltered beaches where water circulation is reduced due to poor porosity, resulting in anoxic condition and development of hydrogen sulphide. These conditions are detrimental and may alter the natural community.

## ROCKY SHORE

Rocky shores occur where the coastal region is mountainous or at least rugged. Topographically they are more variable than sandy beaches (Fig. 2). Majority of rocky shores, on open coast, experience fully marine conditions but some experience the regular or intermitent low salinity and high turbidity of estuaries. Those in long narrow inlets may be subject to wide seasonal changes of temperature and salinity and to relatively little exchange of water with the open sea. Many rocky coasts are subjected to the conditions violence of oceanic swells and waves.

## BIOLOGICAL FEATURE

The biological feature of a rocky shore is the conspicuous exhibition of zonation. This spatial sequence of organisms up and down the shore is universal, involving much the same sort of organisms any where in the world. The shore is the transition between marine and terrestrial environment, but because of water movement associated with tides, waves and spray, the transition is gradual, creating a habitat neither fully marine nor fully terrestrial organisms can prosper. Organisms able to withstand different degree of stress replace each other on the marine terrestrial gradient. The inundation and exposure are important parameters which determine the distribution of organisms on rocky shores. The competition for resources and the restricted potential of any species to perform optimally under different environmental conditions are related with the settlement of organisms on rocky shore.

### Pattern of Zonation

As mentioned above the rocky shore exhibit striking zonation pattern (Boeden & Seed, 1985). Among the lower organisms the fucoid algae occupy well defined zones on a sheltered rocky shore. Among the animal community the typical species of open rocky shore surfaces are either attached (barnacles, mussels, oysters, tube worms) or if mobile are nevertheless capable of holding tightly to the surface of the rock or of retreating to protective clefts as occasion demands (limpets, snails). Much less conspicuous are small worms and crustaceans that live in the secondary habitat provided among closely packed mussel and barnacles or among the algae.

The upper level of intertidal rocky shore are characterised by large number of barnacles in conditions of exposure and by brown algae in shelter. The upper limit of both types of organisms often form conspicuous biological horizon. This exposure-shelter difference then persist in the mid and lower level. Thus barnacles may be joined with snails, limpet and short robust algae at high tide (Fig. 3).

Towards low tide level, where desiccation is less, not only the diversity increase but there often a marked change in the types of organisms. The fucoids are replaced by brown algae (kelp) (Fig. 4). The sponges, seanemone and the associated microspecies dominates. They together are referred as cryptofauna. At the mid tide level the dense bed of mussel and oyster can be seen. Below the low water there are several species of fishes, crabs and crustaceans, present below the submerged rocks. The lower shore characterised by the upper fringe of infralittoral population dominated by algae and by sudden elimination of the mid shore species.

In the functional structure of rocky intertidal areas, we may recognize several sources of primary production and input of organic matter. All these organic matter constitute the food of the other basic animals such as grazers, suspension and filter feeding forms.

### SHINGLE FORESHORE

Shingle is the term applied to those sediment which are larger in diameter than sand and have negligible capillary forces. It is an important constituent of marine coast in many parts of the world. Four environmental factors are responsible for the growth of a shingle beach. They are viability of material, wave, wind and tidal currents. Shingles are intermediate in habitat, between marsh and sand formation. There are three basic ecological consideration on shingle foreshore : substrate mobility, substrate composition and water availability.

The fauna and flora of shingle shore vary, depending on the fine fraction of the substrate. A number of vegetation form on shingle act as protective carpet and reduce erosion. Shingle foreshores contain other colonies of rare and declining species.

### SUBTIDAL MARINE ENVIRONMENT

The subtidal areas extend from the outer fringe of the infralittoral zone to the open sea. A generalised subdivision of this area is shown in Fig. 5. The subtidal area can be divided into benthic (sea bed) and pelagic (water column) both of which can be further subdivided according to depths. The pelagic zone consist of neritic and oceanic provinces, the former comprising the shallow (down to 100-200 m) coastal waters overlying the continental shelf. They are often highly productive and many of the world's important commercial fisheries are located in these inshore waters. The euphotic zone is that part of pelagic realm which is well illuminated. The average depth of euphotic zone is 30 m deep in coastal waters and some 150 m in the open ocean. The remainder of the depth gradient is aphotic which is permanently dark. The pelagic zone is further divided in to mesopelagic (1000 m) and bathypelagic (4000 m).

The benthic area of neritic water covers the continental shelf which rapidly descends down to continental slope and continental rise. The oceanic floor is usually termed as the abyssal plain (4000-6000 m). There are mid oceanic ridges rising 2000 m above the abyssal plain. The hadal region covers the sea floor below 6000 m. This includes the oceanic trenches.

## ECOLOGICAL FEATURES

The subtidal marine environment provides a phylogenetic diversity of life. Representative of all kingdoms occur in the sea. The marine organisms regardless of their phylogenetic position can be placed into two large categories depending on whether they live on the water mass (pelagic) or on or in the sediment (benthic).

The pelagic category is very large and includes all those organisms of the water column which are distributed at the mercy of currents (plankton), and those usually large species which can swim more powerfully (nekton).

The plankton suspended in seawater range in size and phylogenetic position from bacteria to large jelly fish. Based on their size they can be divided into ultraplankton (< 2  $\mu$ m), nanoplankton (2-20  $\mu$ m), microplankton (20-200  $\mu$ m) macroplankton (200-2000  $\mu$ m) and megaplankton (> 2000  $\mu$ m). The nano and microplankton are collectively called phytoplankton while macro and megaplankton are called zooplankton.

The plankton display a number of interesting features. The phytoplankton are the sole source of the food energy which feed the entire oceanic food web. They are microscopic and vary in shape. The shape and size of phytoplankton play important role in keeping them at the pelagic realm. They produce complex organic molecule directly from carbon dioxide and inorganic nutrients in the presence of sunlight and chlorophyll.

Members of zooplankton possess locomotary systems to counteract gravity, but nevertheless they also possess adaptations like body oil globules for lowering their specific gravity. This allows them to remain in the upper water column of the pelagic realm. The zooplankton include representative of virtually every phylum either as adult (holoplankton) or as egg and larvae (meroplankton). They are the primary consumers of phytoplankton and provide the vital link between the primary producers and secondary consumers (carnivores).

## BIOLOGICAL PROPERTIES

Grazing - The zooplankton generally appear in abundance after the major peaks in the phytoplankton, suggesting that herbivorous grazing contributes to decline of the phytoplankton biomass. The phytoplankton growth is stimulated by nutrients and animal

excretion. The copepods are the most important grazer. The effectiveness of grazing depends on the size of the phytoplankton and varies seasonally and spatially.

Patchiness - The distribution of plankton in the euphotic zone is often very patchy. Patches range from a few metres to over 100 metres in width. Patchiness is more pronounced in coastal waters where conditions (salinity, temperature, nutrients) are generally more variable. Open ocean plankton tends to be rather more uniformly distributed. Various processes such as turbulence, current circulation, grazing and reproduction promote patchiness.

Vertical migration - Many zooplankton species undertake extensive (> 100 m) diurnal vertical migration (Fig. ). Although this complex behaviour pattern varies extensively both within and between species there is, nevertheless a remarkable consistency in the general pattern. The "Deep Scattering Layer" are nothing but the migration of zooplankton. During day light the zooplankton occur deep in the water column. At dark the organisms ascend to the surface to feed on the phytoplankton. During total darkness they disperse, but at dawn they reaggregate at the surface before descending to their day time depth. Large species can swim at speed of 200 m per hour. The movement may be regulated by an internal biological clock. Diurnal variation in light intensity appear to provide the proximate stimulus for migration but the significance of this remarkable phenomenon is still far from clear.

## NEKTON

Free swimming animals of pelagic realm are called nekton. Nektonic organisms are differentiated from the planktonic forms only on the basis of swimming ability and size. The large cephalopods, crustaceans (prawns) and vertebrate (fish, turtle, seal) comprising this group of pelagic organisms are the secondary consumers of the sea.

### Characteristic

1. Ability to swim freely in search of food, to maintain their body position and to move against the current.
2. Highly developed muscular system.
3. Species with great energy requirement to counteract gravity.
4. Development of buoyancy devices to achieve neutral density.
5. Reduction in body tissue to a gelatinous consistency to reduce metabolic requirement.
6. Development of bioluminescent organ.
7. Large jaws and distended stomach.
8. Shoaling behaviour

## Distribution

Concentration of nekton are the characteristic of zones of high zooplankton biomass. Most of them are carnivore although some are herbivorous and a few take detritus. Their distribution is patchy and concentrated in the region situated near the marginal parts of the shelf and immediately beyond them as the concentration of plankton is high in this zone. This is the main reason for all the major fishery to be found in this region. Although they are present from surface to bottom, they are highly abundant in the areas of upwelling. This means they exist by exploiting the highly productive areas of the shelf.

## Ecological factors

The distribution of nekton is governed by a number of abiotic and biotic factors. As seen above, availability of food is one factor which determine the abundance. Increasing water depth, composition of the population, morphological, physiological and reproductive singularities of the species also play leading role in the aggregation of nektonic organisms.

## TROPHIC RELATION

The pelagic food web is a complex system of different food chain. A simplified version of the food chain is shown in Fig. 6. Most autotroph fix carbon through photosynthesis. These then provide food directly or indirectly for a variety of consumers which occupy many trophic levels. Primary consumers (zooplankton, herbivorous fish) feed directly on producers, secondary consumers are carnivores feeding on the primary consumers, tertiary consumers feed on the secondary consumers and so on. Decomposers break down organic detritus releasing simple molecules which are reused by the autotroph. However species change their feeding habits during their life cycle and are rarely confined to a single trophic level. Below eutrophic level the food is manufactured by the chemosynthetic bacteria.

## SUBTIDAL BENTHOS

By far the greater part of the sea floor is below the euphotic zone where light intensity is too attenuated to support photosynthesis. The organisms that live there are therefore forced to rely on a supply of food from above the water column. The animals that live near or at the bottom sediment are collectively called benthos. Benthic environment is essentially a two dimensionally habitat as compared to three dimensional pelagic environment.

## Ecological feature

Benthic environment is characterized by reduced oxygen, stable environmental conditions, and reduced food supply. The subsurface sediment of the subtidal areas are inhospitable by virtue of being rich in hydrogen sulphide, methane, ferrous ions etc. which are formed as a result of biological activity. The water-sediment interface always has oxygen and food and therefore most of the faunal communities are restricted to this layer only. Between the areas of aerobic and anaerobic decomposition lies a zone of rapid transition in which the redox potential (Eh) changes rapidly. Most organisms can only dwell below this zone if they can oxygenate their surrounding. A number of polychaetes are known to bioturbate the sediment for oxygenation. It could be said that hydrodynamic and structural properties of the sediment are the important physico-chemical parameters for benthos.

The quality of food reaching the bottom varies greatly from place to place. At the very edge of the sea the bottom may be within the euphotic zone, a variety of plants grow and supply organic matter to consumers. In deeper waters there may be an input of plant detritus from the rich coastal areas and a good proportion of the primary production from the euphotic zone reaches the sea bed. However, in the deeper water the plant material has to make long slow journey to sea floor, and most of it is consumed by organisms living in the water column.

### Types of bottom animals

The fauna of seafloor is very diverse, almost all major groups of invertebrates are represented, as well as the fish. There are several ways of grouping these animals: by size, by mode of life, or by feeding habits. A ready division often used by benthic ecologists is (1) infauna, organisms that live within the bottom deposits and (2) epifauna, those that live on or above the seafloor. Polychaete worms, burrowing crustaceans, burrowing bivalve, other marine worms are the example of infauna, while scallops, starfish, holothurians, sea urchin, sea anemone, bryozoans and mussel are the example of epifauna. The infauna are again divided on a size basis into macrobenthos, meiobenthos and microbenthos, with the dividing lines set at about 1 mm and 0.1 mm respectively. Benthic animals have evolved three main methods of feeding: they filter material from the water (filter feeder), feed on the bottom deposit (deposit feeder) or prey on other animals (predators).

### Distribution

The distribution of benthic animal do not follow binomial distribution. Generally they are distributed uniformly in the coastal belt where food is plenty. However their distribution on the seafloor is dependent on several ecological factors. The abundance of benthic fauna varies from region to region. The



density and biomass varies by an order of magnitude from shallow subtidal areas to the deepest part of the ocean. The density and biomass reduced to a minimum in the deeper zone. There is a significant influence of water depth on the abundance of benthic fauna. The abundance and standing stock biomass also decreases when one moves from shore towards the open sea. There is a

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Depth (M)	Biomass g m
0 - 200	200
200 - 3000	20
>3000	0.2
whole ocean	18.5

consistency in the decreasing trend. However, the diversity increase as we go in the deeper waters. Deep benthic environment is a stable environment and therefore a number of species inhabit this.

#### Benthic Community

The aggregation of different species of benthic organisms in a given area regularly is called the community. There may be different communities occurring in different sediment types and in different depth zone. Different communities have been named after the dominant species.

#### Factors affecting benthos

Among physico-chemical parameters temperature, salinity, dissolved oxygen, substratum, turbulence, waves, currents and water depth are important for the benthic animals. Biological parameters such as food availability, predation and competition play major role in the formation of benthic communities (Wildish, 1977).

#### Importance of benthos

Study on benthic animals started during the last century and is pursued more vigorously in the present century. Benthic animals are essentially an integral part of the system and therefore must be studied. Most of the benthic animals form the main food of demersal fishes and bottom dwellers and therefore they are important in the marine food chain. A number of benthic animals are exploited for economic or commercial purpose. Benthic animals possess sedentary and sessile life and therefore ideally suited for the study of pollution of the coastal marine environment.

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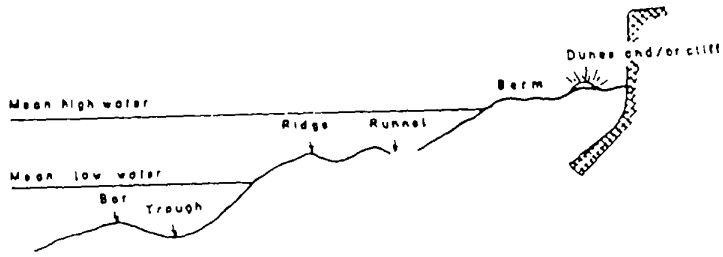


Fig 1. Generalized profile of a sand-beach

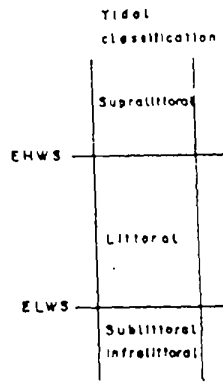


Fig 2

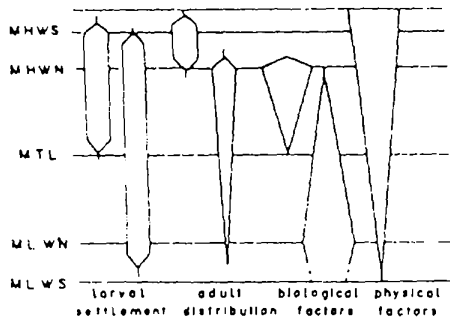


Fig 3 Distribution of adult and recently settled barnacles

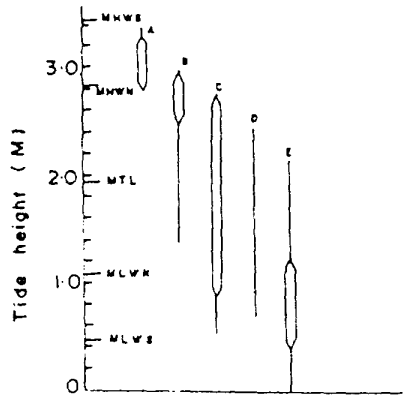


Fig. 4 Zonation of algae

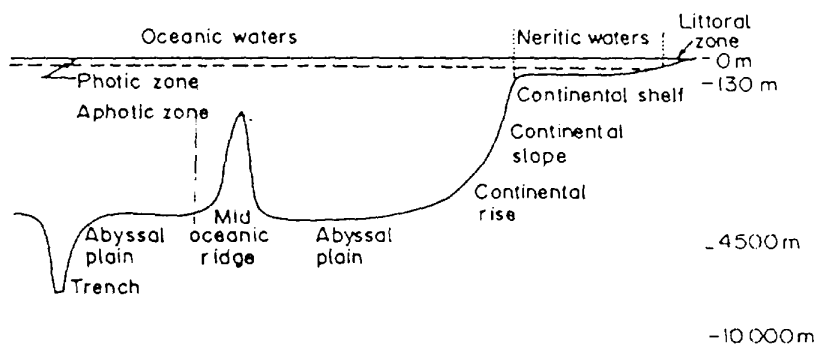


Fig. 5 SECTION OF THE OCEAN SHOWING THE MAJOR HABITAT SUBDIVISIONS.

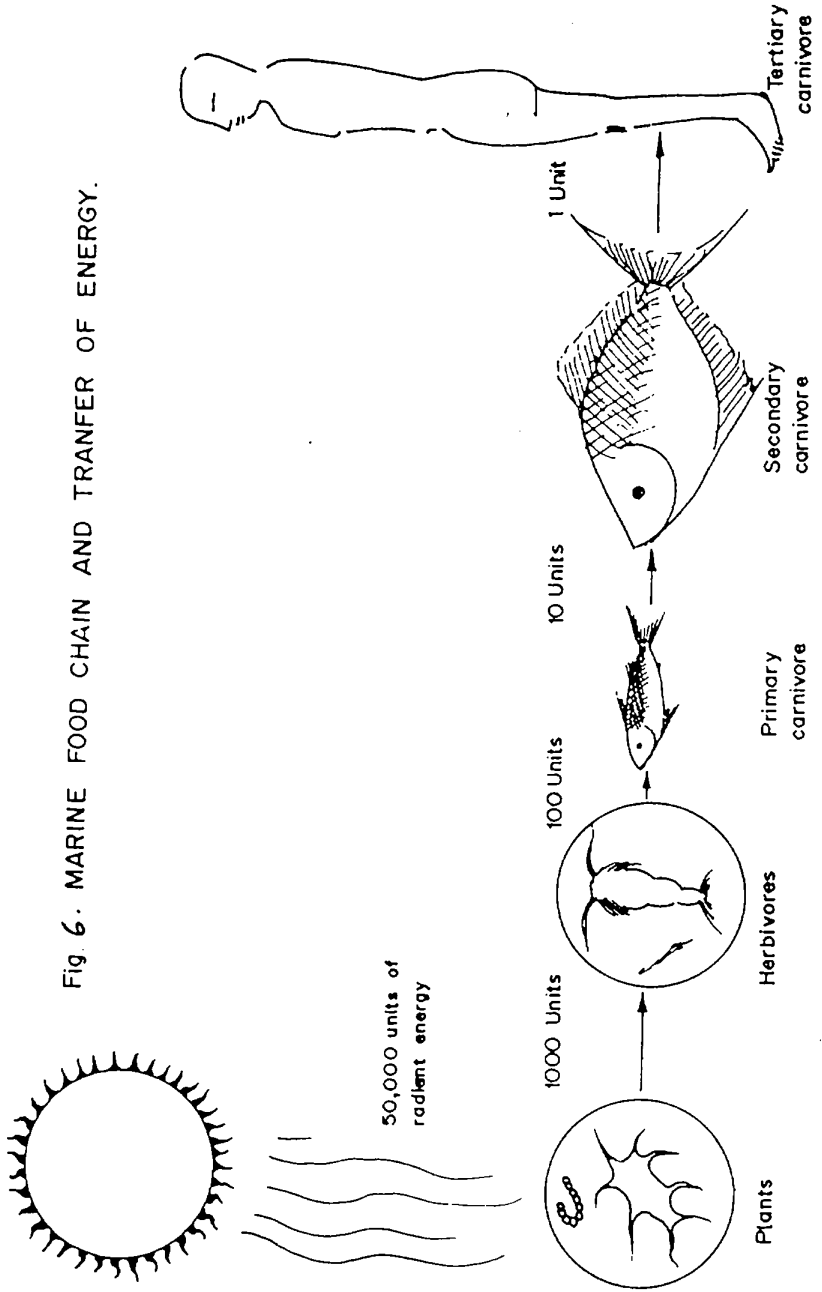


Fig. 6. MARINE FOOD CHAIN AND TRANSFER OF ENERGY.