CHAPTER 3

ECOLOGY OF MANGROVES

Mangrove swamps are complex ecosystem and form ecotones between land and sea. The components of these are stratified both horizontally and vertically between the forest canopy and subsurface soil. Ecologically, mangroves are an assemblage of tropical trees and shrubs that inhabit the coastal intertidal zone. A mangrove is composed of variety of plant species whose special adaptations allow them to survive the variable flooding and salinity stress conditions imposed by the coastal environment. Therefore, mangroves are defined by their ecology rather than their taxonomy.

Mangroves have an ability to live in salt waters and are quite stable under varied physical and chemical conditions. The salt and nutrient concentrations in the mangroves are regulated by inflow of freshwater, inflow and out flow of salt water with each tidal cycle, precipitation and humidity. The salinity of interstitial water remains higher than the overlying water by an order of magnitude mainly because of high evaporation during low tide and retention of the salts due to the compactness of the substratum.

The mangrove ecosystem has a high detritus production and has a high rate of recycling within the ecosystem. In addition, the high productivity of the mangrove forest is supported by an increased supply of nutrients and by an availability of a large diversity in niches that are suited for the breeding, spawning, hatching and nursing of both sedentary and migratory marine and estuarine species. Removal of mangroves over the last few decades has dislocated the sedimentation of suspended matter supplied by rivers, which normally occurs within the mangroves. The sea grass beds and coral reefs, which are often closely associated with the mangroves, will be adversely affected by such sedimentation processes.

ENVIRONMENTAL PARAMETERS

The development of mangroves require a tropical climate, fine-grained alluvium soil, shores free of strong wave and tidal action, brackish water or saline conditions and a wide tidal range. These factors are responsible for occurrence and size, the species composition, distribution, zonation and other structural characteristics. The interrelationship of various parameters within the system as well as the functions of the various components makes it a unique self sustained and productive ecosystem.

Climate

Light, temperature, rainfall and wind all have a strong influence on the mangrove ecosystem. Apart from playing a significant role in the development of plants and animals, they also cause changes in physical factors such as soil and water. Light is vital for photosynthesis and growth processes of green plants. It also affects the respiration, transpiration, physiology and physical structure of plants. Mangrove plants are long-day plants and require high intensity and full sunlight. This makes tropical coastal zones an ideal habitat.

Frequent rain water and flushing wash out the surface salt and also leach down the salt particles and make the land suitable for the growth of mangrove. Rainfall can influence the air and water temperature, the salinity of the surface and ground, which in turn affect the survival of mangrove species. Mangroves prefer an annual rainfall ranging between 1500 - 3000 mm.

Tides and Wave action

Tidal fluctuations have the major role for mangrove habitats, as most mangroves grow well in between the Mean High Water Spring Tide (MHWST) and Mean Sea Level (MSL). Along the west coast, the tidal amplitude changes from south to north. At the southernmost tip of India (Kerala), tidal amplitude is minimal. However, at Goa this difference is about 1.5 to 2 meters. In the Gulf of Khambhat the highest tidal amplitude is about 8 to 9 m, while in the Gulf of Kuchchh it is around 5 meters. These are regular high tides which are also known as 'tidal bore' . Tides are also affected by freshwater discharge, particularly, floods during monsoon seasons.

Mangrove plants growing in the lower portion of the tidal range have their root systems covered by water at least twice a day. This usually means that the soil is permanently waterlogged. Land plants obtain oxygen for their root systems to carry out respiration by diffusion through the gas spaces in the soil. Waterlogging displaces air from the soil and effectively prevents this movement.

Salinity

Although, mangroves are facultative halophytes, they are adapted to highly saline environment.Mangroves, being quite large trees, require a plentiful supply of water. The water which evaporates from their leaves is pure but the water which is available to their roots contains a large amount of salt. The plant must either have a mechanism which enables it to exclude the salt while absorbing the water or it must be able to rid itself of any excess salt which it takes up. Several mangrove species deposit sodium and chloride in the bark of stems and roots. Other species deposit salt in senescent leaves, which later fall off the tree. Salt glands on the leaves also exclude salt. This can be seen as salt crystals.

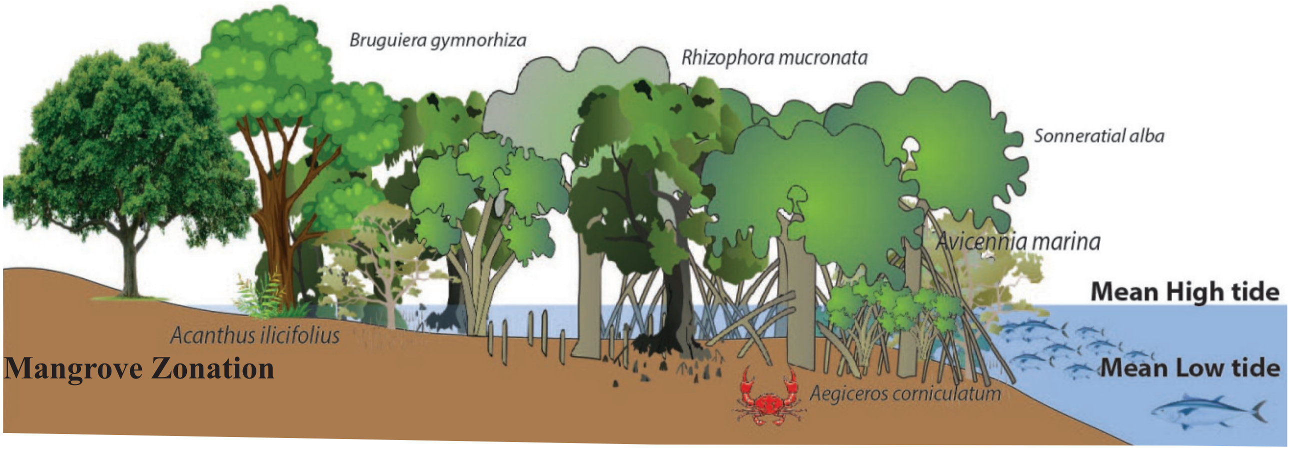
Nutrients

Another environmental parameter essential for mangrove growth is nutrient availability in the swamps. Nutrient availability affects photosynthetic performance and resource utilization of species and can alter species composition in forests. The high level of carbon allocation to roots in many forests in conjunction with mangrove litter fall and the low rates of decomposition imposed by anoxic soils results in mangrove ecosystems being rich in organic matter. Despite low rates of decomposition in anoxic soils, decomposition of mangrove organic material is also a major source of nutrients in the mangrove ecosystems via tidal flushing.

Soil

Mangroves develop under tidal regimes in salt and brackish water environments, such as estuaries, deltas and sediment-accreting open coasts. They may colonize sandy shores and corals, but the common soil substrates are clayey deposits. Mangrove soils are formed by the

Salt excretion



accumulation of sediment derived from coastal or river bank erosion or eroded soils from higher areas transported down along rivers and canals. Mangrove soil composes of – coarse sand – 3.9 to 4 %, fine sand – 38.2 to 38.6 %, silt – 29.5 to 33.1 % and clay – 3.9 to 4.3 %. In general substratum in mangrove is characterized by low oxygen, high salt content and fine grain sediments with high organic content.

MANGROVE CLASSIFICATION

Ecologically, mangroves are defined as an assemblage of tropical trees and shrubs that inhabit the coastal intertidal zone. A mangrove community is composed of plant species whose special adaptations allow them to survive the variable flooding and salinity stress conditions in the coastal environment. From a total of approximately 20 plant families containing mangrove species worldwide, only two families, *Pellicieraceae* and Avicenniaceae, are comprised exclusively of mangroves, while, in the family Rhizophoraceae, only four of its sixteen genera live in mangrove ecosystems.

ZONATION

On the basis of salinity, five zones of mangrove distribution are considered. These are the euhaline, polyhaline, mesohaline, oligohaline and limnatic zones. All mangroves grow along the shoreline; however, each species is limited to different areas within the tidal zone. The zonation is determined by tidal changes, elevation of the land and salinity of the soil and water. Tidal fluctuations play important roles in maintaining mangrove communities.

SUCCESSION

The succession of mangrove is dependent on the availability of seeds or propagules, their size or length and the tidal fluctuation. Seeds of grass, sedge, which are minute in size, will always establish themselves at the uppermost limit of the intertidal region. At the same time, seedlings of *Rhizophora, Kandelia, Ceriops* or, *Bruguiera* will be established according to their floating height. Avicennia and Sonneratia are the pioneer species in the muddy and sandy banks. These species are able to stand a high salinity, wave and wind. The extensive root system of these species traps and collects the sediment, including organic matter from decaying plant parts.

MANGROVE ECOTYPES

Mangroves colonize protected areas along the coast such as deltas, estuaries, lagoons, and islands. Based on topographic and hydrological characteristics within each of these settings a number of different mangrove ecotypes have been defined. A fringe mangrove forest borders protected shorelines, canals, and lagoons, and is inundated by daily tides. An estuarine mangrove forest flanks the estuarine reaches of a channel and is periodically flooded by nutrient-rich fresh and brackish water.

Behind the fringe, interior areas of mangroves harbor basin mangrove forests, characterized by stagnant or slow-flowing water. Scrub or dwarf mangrove forests grow in areas where hydrology is restricted, resulting in conditions of high evaporation, high salinity, low temperature or low nutrient status. In such stressful environmental conditions mangroves show stunted growth.

ADAPTATIONS IN MANGROVES

To survive in the environment of high salinity, water logging, anaerobic conditions, high wave action and muddy soil mangrove plants have undergone various physical, anatomical, morphological, reproductive and physiological adaptations.

Modified leaves

Mangrove leaves have developed various xeromorphic features such as size, thick cuticle, sunken or chambered stomata, water storage tissue, palisade like mesophyll, bundles terminating in tracheid and mucus cells. Mangrove leaves can also restrict the opening of their stomata to conserve its fresh water. Some mangrove species orient their leaves and branches in such a way that they are shielded from the sun. These features help plants to reduce water loss and water conservation while growing in such environment.

Roots for aeration and mechanical support

Mangroves have evolved special morphological adaptations to cope with lack of oxygen. Mangroves have shallow root systems to avoid the lack of oxygen in deeper soils. As a result, most of the root biomass is found above 70-cm soil depth. The mangrove substrate has thick mud with litter, debris and bacteria which are decomposed by utilizing the oxygen available in the soil.

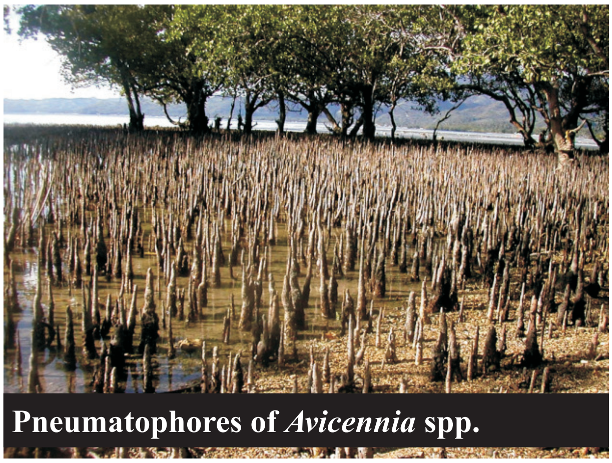
To overcome this, the mangrove plants have developed long secondary roots known as pneumatophores which come up out of the water into the air. These specialized roots contain spongy tissue connected to the exterior of the root via small pores called lenticels. Lenticels and spongy tissue in mangrove roots and modified branches facilitates gaseous exchange. Prop roots in the Rhizophora possess many lenticels. The tissue of the prop roots consists of aerenchyma and is connected with the lenticels. Through this aerenchyma, air can be provided to the submerged parts of the tree.

Stilt and prop roots

Different species of mangroves have developed different types of roots, with different functions such as, mechanical support, breathing roots and for nutrient up take. Mangrove root system is not deep but is extensively branched forming network. In Rhizophora mangrove roots called stilt roots are given off from the trunks in the form of arch and further divide into more arches after coming in contact with the soil (Fig.). The soft, slender and flexible roots called prop roots are also given off from the lower branches towards the soil that can re-branch and gives additional support to the plants. These aerial roots allow for the transport of atmospheric gases to the underground roots.

Lenticles

Prop roots



Pneumatophores of *Avicennia* spp.

Breathing roots

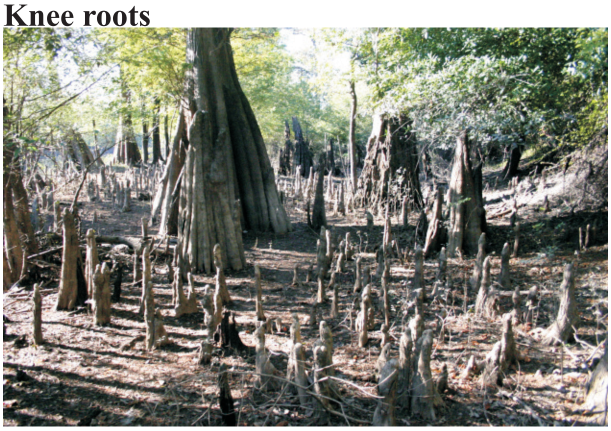
Mangroves are adapted to survive in anaerobic sediments through specialized root structures. Plants require oxygen for respiration in all living tissues including the underground roots. The soil that is not water logged, air diffusion between sediment grains can supply this requirement, however, in water logged soil these spaces are filled with water containing lower oxygen level than air. In Avicenniia and Sonneratia underground roots give off aerial vertical roots that project from the soil called pneumatophores .

In Avicennia they are finger like and grow up to 30 cm tall where as in Sonneratia they grow slowly to become woody and may grow up to 50 cm and sometimes can even reach 3 m in height. These roots are called breathing roots and facilitate exchange of gases between atmosphere and underground roots. During low tides, air is taken up through the openings in pneumatophores and transported to living root tissues.

Knee roots

In mangrove species like Bruguiera and Ceriops, the horizontal root growing just below the soil surface periodically and grow vertically upwards and loops

Knee roots



Buttress roots

downwards to resemble a bent knee. By repetition, a single horizontal root develops series of knees at regular intervals.

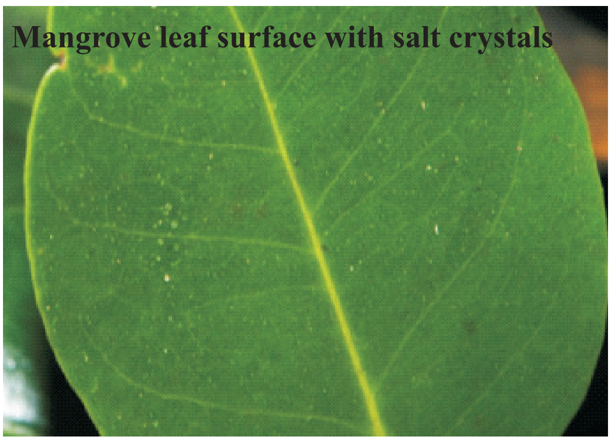
Buttress roots

In Xylocarpus sp., the horizontal roots grow vertically upwards on the upper side for the entire length. The roots also curve in a snake like fashion so wavy, plank-like structures radiate outwards from the trunk base. These roots get intertwined with other roots and create intricate mesh. The exposed vertical portion of the root helps in aeration. The buttress root act in tension and compression and make a much larger contribution to anchorage than the thin lateral of non-buttress trees.

Salt Tolerance

Mangroves do not need salt to survive, but rather they have evolved the means of surviving where other plants cannot, thus carving out a unique niche for themselves with little competition for space and nutrients from other plants. To get rid of salt, mangroves exclude salts through filtration at the surface of the root. Root membranes prevent salt from entering while allowing the water to pass through. This is effective at removing the majority of salt from seawater. Some mangrove plants can

Mangrove leaf surface with salt crystals




Rhizophora propagules

exclude about 90% of the salt in the salt water they absorb with a special filter in the roots.

Salt is partially excluded by the roots, however, some salt still enters in which is excreted through the salt glands present in their leaves. In fact, the leaves of many mangrove plants have the most efficient salt excreting systems. Excreted salt can be seen or tasted on the surface of the leaves covered with whitish crystals.

Some mangrove species like Brugueira, Lumnitzera, Sonneratia etc. do not secrete salt. They can selectively absorb only certain ions from the solution by the process called ultrafiltration. However, even with this, salt excretion is not complete. Some salt is lost by transpiration through the leaf surface or accumulates in some cells in the old leaves which are shed.

Vivipary and Crypto-vivipary

Vivipary as a life history strategy helps mangroves


Avicennia seed

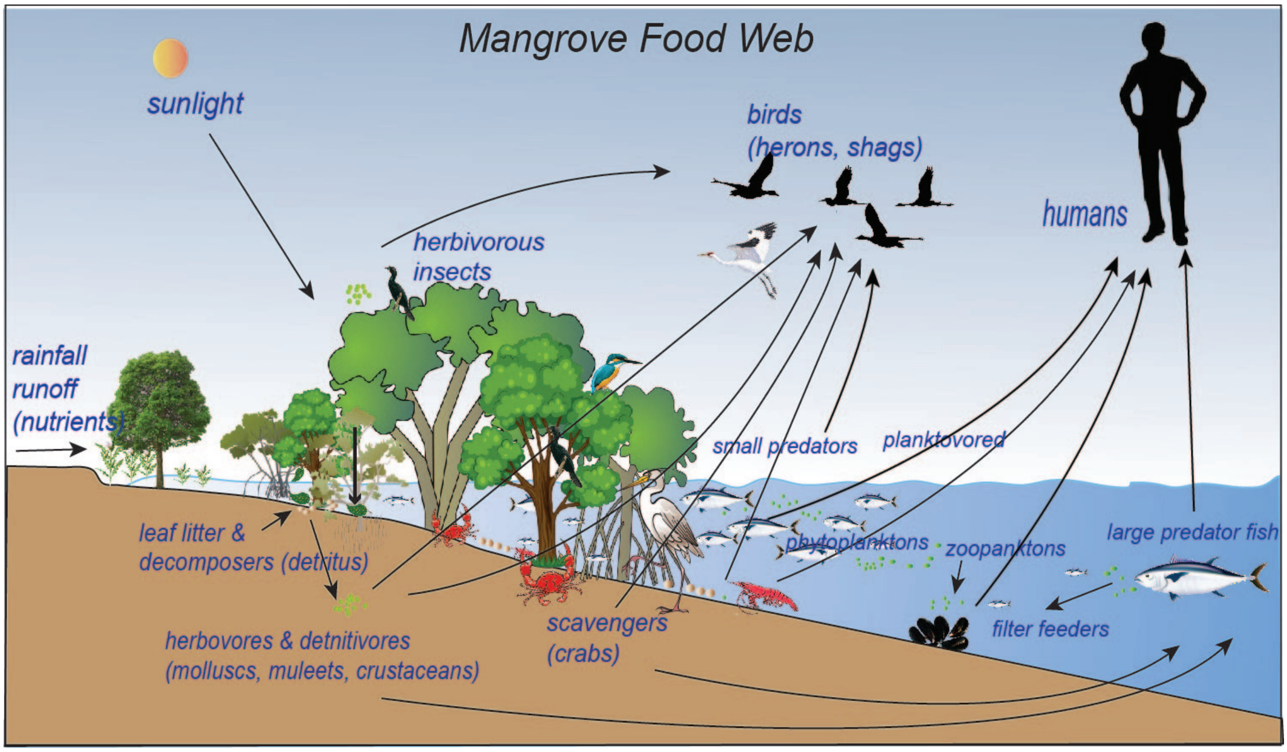
cope with the varying salinities and frequent flooding of their intertidal environments and increases the likelihood that seedlings will survive. Since most non-viviparous plants disperse their offspring in the dormant seed stage, vivipary presents a potential problem for dispersal. Most species of mangroves solve this problem by producing propagules containing substantial quantity of nutrient reserves that can float for an extended period. In this way, the propagule can survive for a relatively long time before establishing itself in a suitable location.

Buoyancy, currents, and tides disperse mangrove propagules and deposit them in the intertidal zone. Once established, the numerous seedlings face not only the stresses of salinity and variable flooding but also competition for light. Apart from these, seedlings and saplings have very low survival rates. Tree growth, survival, and the ensuing forest structure are determined by the mangrove forests' ecotype.

Most mangroves are hermaphroditic (both sexes are present in an individual organism). Mangroves are pollinated almost exclusively by animals like bees, small insects, moths, bats, birds etc., except for Rhizophora, which is primarily self-pollinated. Mangroves have one of the most unique reproductive strategies in the plant world. As mangrove plants can only thrive in a narrow range of conditions, many species have developed fascinating techniques of reproduction. All mangrove plants share two reproductive adaptations – Vivipary and propagule dispersal.

Vivipary and dispersal are reproductive adaptations that give mangroves an increased chance for survival. Similar to terrestrial plants, mangroves reproduce by flowering with pollination occurring via wind and insects/ animals. Once pollination occurs, the seed remains attached to the parent plant.Mangrove species like Rhizophora, Ceriops, Bruguiera, Kandelia etc. produce seedlings which stay attached to the parent plant until it germinates into a propagule or embryo.

Mangrove propagules are actually seedlings, not seeds. After the seed has developed its root and stem, it falls into the water. For some time, the whole seedling floats horizontally on the tides and currents and when the seedling reaches brackish coastal water, the less buoyant root sinks, flipping the whole seedling to a vertical position where the root can hopefully touch bottom and take hold. This type of germination is called “viviparous germination”.



Some mangroves like Avicennia, Sonneratia, Aegiceras etc. produce large quantity of seeds and fruits which have a buoyant outer coating to float until reach favorable water salinity. When the salinity is right, the coating peels off, and the seed sinks to the bottom and takes hold and grows. This type of germination is called "crypto-vivipary germination". Some mangroves produce large seeds or fruits that float and tide acts as the method of dispersal to avoid crowding of young plants. The seedlings can survive a long time until they find a suitable place to germinate and grow.

DETRITUS FORMATION

For many organisms, mangrove forests serve as the starting place for their food web. Its detritus serves as a nutrient source for planktonic and epiphytic algal food webs. The decomposition in mangrove consists of three processes, fragmentation, leaching and saprophytic activity. Mangroves are an important part of estuarine food webs, producing large amounts of leaf litter. Leaves from the mangrove trees when drop in to water, they are quickly decomposed by fungi, bacteria and other microorganisms. This decomposed matter is referred to as detritus which is flushed into the estuary by the incoming and outgoing tides. This becomes important food source for marine and estuarine life including economically important shrimps, crabs, and fishes.

Mangrove plants produce detritus on average 1 kg m2 y-1. Some of this detritus is directly consumed by small animals, like crabs, shrimps, gastropods and fishes, but most of it has to be broken down further before the nutrients are available to other animals or plants.

NUTRIENT REGENERATION AND MINERALIZATION

The important processes of mangrove ecosystem are distribution of nutrients and mineral elements to the estuarine and near shore organisms. The process of nutrient regeneration, cycling and trace metal distribution as well as absorption in food chain and balancing Carbon-Nitrogen ratio in mangrove ecosystem is most significant. The tides transport food out to sea from the mangroves every time they retreat, making the mangrove an important food and nutrient source for animals and plants of other nearby ecosystems such as coral reefs, seaweeds, sea grasses and to the open ocean.

TROPHIC RELATIONSHIP AND FOOD CHAIN

A trophic level is composed of organisms that make a living in the same way. That is they are all primary producers (plants), primary consumers (herbivores) or secondary consumers (carnivores). Dead tissue and waste products are produced at all levels. Scavengers, detritivores, and decomposers collectively account for the use of all such waste. The consumers of carcasses and fallen leaves may be other animals, such as crows and beetles, but ultimately it is the microbes that finish the job of decomposition.

Mangrove is considered as keystone mutualistic species; if it is removed or harmed whole ecosystem collapses. Mangrove interacts with various components of the ecosystem at different level and in different ways to maintain this highly productive ecosystem. There is a need to study these interrelationships to understand the functioning of mangrove ecosystem for better management.

ECOLOGICAL SERVICES

Shoreline Stabilization

Mangroves play a very important role in soil formation, shoreline protection and stabilization. Mangroves extensive aboveground root structures (prop roots, stilt roots, and pneumatophores) act as a sieve, reducing current velocities and shear and enhancing sedimentation and sediment retention. The intricate matrix of fine roots within the soil also binds sediments together. Not only do mangroves trap sediments, they also produce sediment through accumulated, mangrove derived organic matter. Mangrove leaves and roots help maintain soil elevation, which is especially important in areas of low sediment delivery. By enhancing sedimentation, sediment retention and soil formation, mangroves stabilize soils, which reduce the risk of erosion, especially under high energy conditions such as tropical storms, cyclones and high wave actions, floods, tsunamis, earthquakes, etc.

Coastal protection

Apart from being very productive, mangroves form natural barriers which provide shore protection both under normal sea conditions and during storms. At least 70-90% of the energy of wind-generated waves is absorbed by mangroves depending on their health and maturity. It serves as a buffer zone between the ocean and the shore. Their roots hold the shoreline together, limiting erosion and attenuating the waves. By reinstating the buffering capacities of the coastal mangroves and the legally mandated 'green-belt' along the inlets, the mangroves will reduce the vulnerability of the coastal communities to environmental shocks and stresses caused by storms and typhoons. The tsunami that struck in 2004 has provided an opportunity to illustrate that healthy mangroves serve as a natural barrier against massive waves protecting infrastructure developments and saving lives as “Shelter belt”.

Animal Habitat and breeding and feeding grounds

Mangroves provide both habitat and a source of food for diverse animal communities that inhabit both the forest interior and the adjacent coastal waters. Some animals depend on the mangrove environment during their entire lives while others utilize mangroves only during certain time of their life stages, usually during reproductive and juvenile stages.

Mangroves dense aerial root system, which is most highly developed within the intertidal zone, provides a substrate for colonization by algae, wood borers, and fouling organisms such as barnacles, oysters, mollusks, and sponges. From the diverse group of invertebrates found in mangroves, arthropods, crustaceans, and mollusks are among the most abundant and have a significant interactive role in mangrove ecosystem. As mentioned earlier, some species of crabs, recognized as predators, can influence mangrove forest.

Shrimp, an important fisheries resource, find food and shelter in mangrove forests. Likewise, commercially important bivalves such as oysters, mussels, and clams are commonly found in and around mangrove roots. Many animals found within mangroves are semi-aquatic or derived from terrestrial environments. Numerous insect species are found in mangrove forests; some play critical roles as mangrove pollinators, herbivores, predators, and as a food source for other animals.

Amphibians and reptiles such as frogs, snakes, lizards, turtles and crocodiles also inhabit mangrove forests. Birds use mangroves for refuge, nesting, roosting and feeding. Around 200 species of birds have been reported in and around mangrove communities. Most of these birds do not depend completely on mangroves, and use these habitats only during part of their seasonal cycles or during particular stages of the tide for roosting and feeding.

Mammals living in mangrove forests include raccoons, wild pigs, rodents, jackals, civets, otters, monkeys, bats etc. Apart from these other terrestrial animals living nearby do visit mangroves for food and shelter. Many endangered species can be found living in mangrove forests. Royal Bengal Tiger is the best example in Gangetic Sunderbans.

Pollution Control and Coastal Water Quality improvement

Mangroves are the Earth's natural filtering system, capable of absorbing pollutants such as heavy metals and other toxic substances, as well as nutrients and suspended matter (e.g. sewage). In addition to the sediment pollution, mangroves also help to control other forms of pollution, including excess amounts of nitrogen and phosphorous, petroleum products, and halogenated compounds. Mangroves prevent these contaminants from polluting the ocean waters through a process called rhizo-filtration. Microorganisms use enzymes to break down such pollutants and make stable the potentially dangerous substances, thus treating the effluent that runs through the mangrove system.

Awareness campaign on mangroves

Service to local community

In addition to benefiting the natural ecosystems, traditionally, mangroves have been sustainably used by coastal inhabitants for food production, medicines, fuel wood, and fodder as well as construction materials. There are number of traditional medicines used by the local inhabitants to cure diseases that flourish during epidemic. Many indigenous coastal inhabitants rely on mangroves to sustain their traditional cultures. In this way, the ability of mangroves to act as habitat to many possible food sources, as well as its ability to remain stable while growing tall and strong, are very important to human communities as well. All of these natural ecosystem services will improve access to food resources and increase income for the coastal communities through sustainable livelihood initiatives

Mangrove Fisheries

The conservation of mangroves is needed as it plays most important role in sustaining the fisheries. Mangroves and salt marshes provide carbon and nutrients to nearby coastal environment which nourish shrimp fisheries. The contribution of mangroves to adjacent fisheries is although difficult to evaluate, a number of studies having shown good statistical correlations between area of mangroves and prawn fishery.

The important ecological role of the mangroves is the detritus, which help in feeding and provides breeding and nursery grounds for many commercially important juvenile fishes, mussels, crabs, shrimps, oysters etc. The mangrove forest is essential to the long term well-being of many other people whose livelihoods depend on the fisheries. There are different types of faunal communities in mangrove which are dependent on the water component in one way or the other.

A wide range of commercial and non-commercial fish and shellfish also depend on these coastal forests. The role of mangroves in the marine food chain is crucial. When mangrove forests are destroyed, declines in local fish catches often result. Assessments of the links between mangrove forests and the fishery sector suggested that for every hectare of forest cleared; nearby coastal fisheries lose some 480 kg of fish per year.

Carbon Sequestration

Mangrove swamps have the potential to act as highly efficient sinks of carbon as they sequester atmospheric carbon and store in their aboveground and belowground biomass and in sediments. Mangroves sequester the atmospheric carbon dioxide into organic compounds in their biomass through the process of primary production. This biomass can be later consumed by local fauna, exported to adjacent ecosystems, re-mineralized back into the atmosphere or stored in the sediments. Mangrove soils are rich in organic matter and contain moderate to high carbon concentration.

An ecosystem based approach to manage carbon sinks first requires the quantification of the carbon sequestered and stored by mangrove forests through reliable scientific measures. There is a need to educate the general public as well as scientists that carbon can be priced and inform them about the current status of carbon prices as seen in market based approaches, as derived from integrated assessment models or through constructed economic experiments. The knowledge of the value of this carbon can encourage countries to lower the rates of deforestation of mangroves and improve the status of their natural carbon sinks.

Ecotourism

Many mangrove areas are potentially suitable for ecotourism. The indigenous biodiversity offers great attraction to tourists and poses as great assets in ecotourism economy. In recent years, many mangrove forests have become accessible through board walkways. Informative signage, arboretum, nature education centers, information centers on the biodiversity of flora and fauna will help tourist to know about mangrove in its natural environment. It is possible for tourists to spend an entire day in the mangroves looking and appreciating interesting and unique plants, animals and processes..

The mangrove swamp is an ideal place for bird watchers as it serves as a bird sanctuary for indigenous attractive kingfishers, shrikes, dark green and yellow and migratory birds etc. Canoeing or peddled boats in the mangrove swamps and appreciating wild life will attract many nature tourists.

To sustain the ecotourism industry, there need to be recognition of the importance of the services mangroves offer to costal inhabitants and unique flora and fauna it possesses. The Government on its part needs to channel revenue generated from eco-tourism activities into conservation of the mangrove swamps. This can be done by promoting the mangroves ecotourism products and collaborate with big and small successful tourism players to introduce and bring their clients to the site as extended visit.

ENVIRONMENTAL CONCERNS

· The mangrove ecosystem is a sustainable resource that provides huge numbers of people with food, tannins, fuel wood, construction materials and even medicines. When a mangrove forest is protected, it will support an entire population of coastal residents.

· Mangroves offer protection of property and life from floods and storms, as well as reduction in erosion and siltation.

· Plants in mangrove forests can absorb nitrates and phosphates, cleaning up and restoring water near the shore in a natural and completely cost-free manner. Unfortunately, as with many of our natural resources, mangrove forests are quickly being lost to pollution and reclamation for development.

· Another contributing factor to the devastation of mangrove forests is the governmental and industrial classification of these areas as useless swamp land.

· Mumbai and many coastal places along the Indian coast, vast mangrove areas are being reclaimed and converted for developmental activities.

· Overall, up to 50% of the world's mangrove destruction can be attributed to the shrimp farm activity.

· Increased conservation efforts for mangrove protection are needed to address clearing of these areas for shrimp farming and land development.

MANGROVE MORTALITY

Mangrove mortality from biological sources includes competition, disease, pollution, herbivory, predation and natural tree senescence. All developmental stages are affected, including propagules, seedlings, saplings and trees. However, mangroves in early stages of development experience higher mortality rates and mortality is generally density dependent. At the tree stage, smaller trees are at higher risk due to competition with larger trees for light and/or nutrients.

Mangrove diseases include impacts from fungi that defoliate and kill black and red mangroves. Insects such as scales and caterpillars cause defoliation of Avicennia species. Extensive mangrove areas of Khorjuvem, Aldona, Pomburpa, Chorao, Divar etc. along the Goa coast have been attacked by Pablia species of insect found mostly in teak plantation. This insect when enters caterpillar stage of its life cycle graze voraciously on the mangrove foliage before entering in to cocoon stage.

After completing these stages of life cycle full fledge insect leaves the plants and lost foliage reappears within 20 to 25 days. This phenomenon has been observed along the west and east coasts of India every year during September to December. This is a natural phenomenon occurring throughout the Indian coast. Beetles and other boring insects are also known to kill mangroves. Rhizophora seedlings are especially vulnerable to mortality caused by the boring beetle, gastropods as well as overgrazing algae.

Crabs are important predators of propagules and are a major source of mortality at the young stage. Differences in predation rates on seedlings of different mangrove species may eventually alter species dominance in the adult trees. Overall, these various biotic disturbances have a relatively minor impact on the mangrove forest when compared to deforestation and reclamation for developmental purpose with larger-scale environmental impacts.