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Food-Web Management in the Pulicat Bird Sanctuary

P.J. Sanjeeva Raj*

ABSTRACT

Food web management is crucial for the management of any ecosystem and its biodiversity composition. Pulicat Bird Sanctuary has very low primary food resources so that the primary consumers, secondary consumers and to consumers are far below the carrying capacity of the sanctuary. Appropriate management strategies are suggested. Sullurpet Development Declaration drafted during the Flamingo Festival – 2007 is supplemented.

Key words : Pulicat Bird Sanctuary, Food webs, Primary, Secondary and Top consumers

Pulicat Bird Sanctuary is chiefly for feeding, for about 60 to 100 thousand water birds belonging to about 80 species that arrive during the post-monsoon season or winter (October to March), where as the Nelapattu Bird Sanctuary is for breeding, for about 20 species of these birds. Coastal birds such as Flamingos as well as gulls and several species of inland water birds arrive in search of food at this sanctuary, from far off regions of Northern India. The Bar Headed Goose, for example, comes from Ladakh and Tibet.

Ever since these two sanctuaries are declared Protected Areas from 1976, they are being ably managed by the Forest Department of Andhra Pradesh. However, the basic question that is increasingly facing this sanctuary is whether there is enough food for all these birds and for their nestlings too? Even at a modest rate of about five grams of food for each bird, per day, 50,000 birds need about 250 kilograms of food per day, and for a duration of five months, about 37.5 tons of food is required. If more birds arrive in any good monsoon, and stay longer and breed twice, much more food is needed. Fishermen and tribals also are competing for the same food. So, how can these birds and their breeding be sustained, if there is not adequate food for them to survive?

Food- Webs in the Pulicat Lake

In the food-webs of this lake, there are three links, namely: primary consumers, secondary consumers and top consumers.

Primary Food Sources (Detritus, Plankton and Algae)

Being a shallow lake, detritus (particles of decomposing plant and animal matter) is the major source of food, in this lake.

Since the lake opens into the sea near the Pulicat Town in the south, tidal influences bring in plankton (about 59 species of phytoplankton and 23 species of zooplankton), which is another source of food.

Lastly, about 10 species of filamentous algae and two species of Macrophytes, especially *Halophila ovalis* also are sources food as well as sources for detritus, when they die and decompose.

Unfortunately, these primary food sources in the Pulicat Lake are far below the requirements of a stable food pyramid in the lake, because the total biomass of these primary food sources is for below the total biomass of all higher level consumers that feed on these food resources, so that there is no eco-balance between food and its consumers.

Primary Consumers

Primary consumers of this food are worms (Polychaetes), amphipods (Crustaceans), snails (Gastropods), prawns and crabs. All these are benthic or bottom-living invertebrates, since they are all detritus feeders (detritivorous) and the detritus is at

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the bottom or floor of the lake. These primary consumers, in turn, are the food of fishes which are secondary consumers, in the lake.

Secondary Consumers

Secondary consumers in the Pulicat Lake are the fish. Out of the 168 species of fish recorded from this lake, only about 20-30 species are more common, and serve as the food of birds. Especially those fish that feed on phytoplankton like mullets, *Tilapia*, *Etroplus* and Half-beaks, those that feed on zooplankton like pony fishes and Perchlets, and some carnivorous cat-fishes that feed on prawns, are the common food of the birds of Pulicat Lake.

Top consumers

All the water birds in the Pulicat Lake are top consumers. Based on the food that they prefer, there can be five categories of birds:

(i) Flamingos that prefer to feed on floating algal filaments, and on worms, amphipods and small snails that lie buried in the bottom ooze.

(ii) Ducks and Teals prefer vegetable food or insects in paddy fields.

(iii) Openbills feed on snails and crabs in the lake as well as in paddy fields.

(iv) Egrets, Herons and Painted Storks feed on fish in the lake/or on crabs, frogs and insects in paddy fields; and

(v) Pelicans and Cormorants feed exclusively on fish in the lake, or in ponds nearby.

Management Strategies

In order to sustain the food resources of these birds in the Pulicat Bird Sanctuary, all the lower tropic (feeding) levels need to be promoted simultaneously, and not merely the fish.

1. Basically, without water, there cannot be any aquatic food for these birds, and hence the management of water in this sanctuary is the most primary concern. Pulicat Lake, as a whole, is but one ecosystem, despite its political division into the northern Andhra Pradesh and the southern Tamil Nadu. So, although it is an inter-state Lake, yet the single lake-mouth located in Tamil Nadu in the South, should be permanently kept open, for tidal flushing that brings in not only planktonic food but also fresh oxygen and seed (young ones) of fish, prawn and crab. Those fish like Tilapia and Cat-fishes that breed within the lake itself, should be promoted to breed (fish culture).

Additional lake-mouths can be opened in the Andhra Pradesh, or the waters from the Buckingham Canal or the Telugu Ganga could be directed into the Northern regions of the Pulicat Lake, at least during the breeding season of these birds.

2. Algae that are native to this lake, and the macrophyte like *Halophila ovalis* could be cultured on the bottom or floor of this lake, particularly in the northern sector.

The fresh water *Kudiri* Tank on the south of the SHAR Road and west of Athakanitippa, with water all round the year, reeds and vegetation to maintain bird life all round the year, even in summer, is a very good example to emulate for the development of a sustainable bird sanctuary.

3. Farmers, in and around the Pulicat Lake, need to be educated not to use excessive quantities of chemicals, fertilizers and toxic pesticides for their paddy fields, which are supplementary feeding grounds for these birds of the Pulicat Bird Sanctuary.

4. Local fishermen and tribals also should co-operate not to employ fine-meshed nets and bamboo traps (kodimelu), so as to conserve the fingerlings of fish which is the food of nestling birds.

5. Mud-flats within the lake and inter tidal zone along with western margin of the Pulicat Lake could be developed, for attracting more shore birds.

6. Trees of *Acacia nilotica* and *Barringtonia acutangula*, as in the Nelapattu Bird Sanctuary, may be developed on "Artificial Islands" within the sanctuary, to provide at-least roosting sites, if not nesting sites, for these birds of the Pulicat Bird Sanctuary.

Draft Sullurpet Declaration during Flamingo Festival 2007

1. Proposals should be sent to Government of India for declaration of Pulicat Lagoon as 'Ramsar site' in co-ordination with Government of Tamilnadu.

2. Conservation of Pulicat Lake and its Biodiversity by all protective measures.

3. Sustainable use of resources of Pulicat Lake for future generations.

4. Widening of existing sea-mouths by dredging and stabilizing by constructing suitable protective structures.

5. Opening of new sea-mouths near Chettipeta in the southern part of Sriharikota Island.

6. Catchment Area treatment to minimize sedimentation and siltation in Pulicat Lake.

7. Welfare of fisherman and other communities depending on Pulicat Lake.

8. Minimize developmental activities around Pulicat Lake in buffer zone of 10 km and curtailment of releasing pollutants into it.

9. Preparation of comprehensive Management Plan for Pulicat Lagoon.

Marine Ecosystems of India

K.Venkataraman*

ABSTRACT

Marine and coastal biological diversity (biodiversity) encompass an enormous variety of marine and coastal species, global oceans' cornucopia of living resources, myriad coastal and open sea habitats and a wealth of ecological processes that support all of these. Coastal ecosystems such as estuaries, wetlands and mangrove forests contain significant diversity and are highly valuable for communities living in coastal areas. Much of the world's biodiversity is found in highly diverse marine and coastal habitats. The Indian mainland coast is divided into two segments – the west coast and the east coast. Reefs are home to more species than any other ecosystem in the sea. In India, the reefs are distributed along the east and west coasts at restricted places. The mangrove habitats are dynamic, rich in species and are highly productive. Studies revealed that about 14 mangrove species are found along the India coast. Along the West Coast of India, there are nine important coastal lagoons. The fauna of the marine ecosystem is not evenly distributed throughout the oceans. About 1925 pelagic copepods have been described from marine waters of India. A majority of these species occurs in coastal waters supporting valuable fisheries. Among the coastal wetlands estuaries, mangroves and coastal lagoons are biodiversity-rich whereas brackish habitats have only a few specialized species. The marine fauna of India is rich and varied. Out of a total 22,000 species, about 4,000 species occur in the Indian Ocean, of which 1,800 species are from the Indian seas. Majority of the nektonic species is found in the coastal waters. About 26 species of sea snakes belonging to one family, hydrophiidae and five species of sea turtles were reported from seas around India. About 120 species are estimated to occur in all the seas and of these 30 are reported from seas around India. Sea cow occurs in near shore waters. Marine resources and biodiversity have traditionally been undervalued. Unregulated use of resources, increased demand for resources and rapidly expanding coastal development imperil the marine resources. There areseveral protected marine areas such as Gulf of Mannar, Gulf of Katch, Marine National Park of Andaman and Nicobar islands (Mahatma Gandhi Marine National Park) and Rani Jhansi Marine National Park. Marine and coastal ecosystems with their rich species diversity provide a wide range of important resources and services as well as maintain sustainably fisheries and other marine living resources. The two island ecosystems Lakshadweep and Andaman and Nicobar add to the ecosystem diversity in India. Gulf of Mannar, Gulf of Kachch and the two island ecosystems have rich coral reefs harboring valuable marine biodiversity. In this paper I have proposed a fundamental 18 changes in the approach by which biodiversity is measured and studied in the ocean by emphasizing integrated regional-scale research strategies within an environmentally relevant and socially responsible framework.

Key words : Marine ecosystems diversity, biological diversity, threats, conservation.

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Introduction

Marine and coastal biological diversity (biodiversity) encompass the enormous variety of marine and coastal species, the global oceans' cornucopia of living resources, the myriad coastal and open sea habitats and the wealth of ecological processes that support all of these. The oceans cover over 70% of the planet's surface area and account for 99% of the volume that is known to sustain life. Coastal ecosystems such as estuaries, wetlands and mangrove forests contain significant diversity and are highly valuable for communities living in coastal areas.

Much of the world's biodiversity wealth is found in highly diverse marine and coastal habitats. These habitats range from the shallow coral reefs to the ocean floor's soft sediments lying thousands of meters below the surface. While the total number of known marine species is smaller than those found on land, scientists are nonetheless continually discovering new concentrations of diversity. Coral reefs are already known to be among the richest habitats in species diversity on this planet. The dark deep sea bottom, subjected to tremendous pressure, is now thought to be a dwelling pace for thousands, or perhaps millions of small invertebrate animals that include crustaceans, molluscs and worms. In recent years, scientists, exploring the dim middle depths, have discovered numerous new species that compose, though less known, apparently productive ecosystems (De Fontaubert *et al.,* 1996).

Regardless of species counts, marine animals are more diverse than land animals at the higher, phyletic levels of evolutionary and taxonomic differentiation. All but one of the phyla (major branches on the tree of life) of animals is found in the sea whereas only about half of all phyla occur on land. Marine animals exhibit a correspondingly greater range of body forms and structures than are found among terrestrial species.

The biota of marine habitat also exhibits a diversity of survival strategies not found on land. The numerous planktonic life-forms of the ocean drift passively in the waters relying on ocean currents to transport them to new sources of nutrition and new habitats. Filter feeders sieve plankton and other floating material for food; they range from microscopic zooplankton to barnacles to sea anemones to baleen whales.

Until today, marine biodiversity is less well known than terrestrial biodiversity due to the difficulty in access and expense involved. We know surprisingly very little about marine life, even in the most familiar seascapes. For instance, scientists have hitherto identified twenty-two phyla of meiofauna, and two of them were identified only in the past two decades.

These animals, barely visible to the naked eye, live on the grains of coastal and ocean-bottom sands. Up to 10,000 such animals can be found in a handful of wet sands. Thousands of species may live in the soft bottom sands off the Atlantic coast of Canada. Yet only lately have scientists begun to suspect the important role they play in marine ecosystems. They are a major source of food for shrimp and bottom feeding fish and they consume detritus and pollutants in seawater that filters through the coastal and near shore sands.

Marine environment encompass an impressive diversity of ecosystem and habitats. Coral reefs, which are among the planet's largest and oldest structures created by living organisms, are home to dense concentrations of species and complex webs of inter-species interactions. Some coastal systems such as marshes, mangrove forests, and sea grass beds are characterized by high biological production. They are important both to other marine ecosystems and to human development because of the fisheries and other resources and services they provide (De Fontaubert *et. al.,* 1996).

Indian Ocean

The Indian Ocean is the smallest of the three 'great' oceans and geologically much of it is rather youthful. According to the International Hydrographic Bureau, its boundaries are as follows: Western limits: The meridian of Cape Agulhas to Antarctica; Eastern limits: South of Australia, Bass Strait, Cape Grim, Tasmania to Antarctica; North of Australia -Torres Strait; there is the Asian landmass. Marginal seas of the Indian Ocean include the Red Sea, the Gulf of Aden, the Persian Gulf, the Gulf of Oman, the Arabian Sea, the Laccadive Sea, the Bay of Bengal, the Andaman Sea, the Malacca Straits and the Singapore Straits. The two additional seas are the Mozambique Channel and the Great Australian Bight. The area covered by the Indian Ocean (excluding Arafura Sea) is 74,917,000 sq. km,

with a mean depth of 387 m. The maximum depth recorded is 7,437 m (24,444 feet).

The early (of about 600 BC) navigators of the Indian Ocean were probably ancient Egyptians. Arabs and Chinese followed them later. Great oceanographic expeditions in the Indian Ocean included the British Challenger Expedition (1872-76); the German Expedition Valdivia (1898-99), the Dutch Expedition Siboga (1899-1900); the H.M.S. - Investigator; John Murrey Expedition (1930-34); Dana (1928-30); Galathea (1950-52); Albatross (1950-52) that brought us to the time of the International Indian Ocean Expedition (I.I.O.E., 1959-65), with the participation of numerous ships (Vema, Argo, Horizon, Pioneer, Chain, Vega, Anton Brunn, Discovery, Challenger II, Vityaz, Meteor, Diamantina etc.,) belonging to several countries. An important occurrence in the scientific study of the Indian Ocean was the establishment of PIOSA (the Pan-Indian Ocean Science Association) which meets every few years in various Indian Ocean countries to discuss matters relating to the scientific requirements of the Indian Ocean.

Oceanography

Along the Indian coast, the currents generally follow a clockwise circulation during the southwest monsoon and anti-clockwise circulation during the northeast monsoon. During the month of January, when the northeast monsoon is at its peak, the currents follow the coastline, having a southerly component off the east coast and a northerly component off the west coast of India. During the months of June and July, as the southwest monsoon reaches its peak, the flow is generally in the opposite direction. In the Andaman Sea, there is a general flow from east and west, or southeast to northwest during the northeast monsoon and in the opposite direction during the southwest monsoon period.

The surface layer of the Andaman Sea is generally well mixed to a depth of 100m, but a sharp decrease in temperature may occur in the eastern side of the Andaman and Nicobar Islands at depths of 25 to 50 m. There is a wide fluctuation in surface salinity in the Andaman and Nicobar Islands. Salinity is low during May to November; there is a recovery period in December and January; high salinity occurs from February to April. Upwelling occurs in both the Lakshadweep and Andaman Seas, included by wind stress and Coriolis force. Upwelling ceases in October in the Lakshadweep region. Tides in the Indian Ocean are mainly semi-diurnal, sometimes mixed. Spring rides range from 0.3 to 1.0 m in south India and the Lakshadweep and Maldive Islands and from 1.0 to 2.0 m in the Andaman Islands.

Temperature and Salinity

Temperature is probably the most important of all the major physical environmental factors, which mediate the life histories of marine organisms. Its effects are expressed in different distribution patterns, rates of growth, and in the timing of reproductive cycles. Sea surface temperature around the Indian coast varies considerably during the year and both the range and the pattern of isotherms differ between the west and the east. It may be seen that the temperature varies from a minimum of 10° C in the southern part to a maximum of 27° C or even higher (>28° C) towards the central and northern regions. Water temperature is relatively less (24-26° C) in the Arabian Sea and Bay of Bengal during the time of the northeast monsoon than other times. Similarly, beyond 30° S latitude, the temperature is very low (10-20° C) evidently due to the influence of the Antarctic Ocean. During the winter months, the surface temperature gradient for the whole region trends roughly north south. Along the West Bengal and Bangladesh coasts of the northeastern Bay of Bengal, the mean winter surface temperature is typically less than 25 degree centigrade. During the summer months, the temperature gradient runs approximately north-south on both the sides of the Indian coasts, with highest values of 32°C and upwards found along the south-east coast of the Bay of Bengal Sea, and a summer mean increase from 28 to 32°C upwards along eastern India.

Salinity is regarded as the second most important physical characteristic of the marine environment. Throughout the Indian coastal area, the total concentration of dissolved salts falls within a low range of about 35-40%0 (g/kg). However, over most parts of the Indian marine region, seasonal variation in both surface and bottom salinity is related to the penetration of oceanic water which has a salt concentration in excess of 35%. This salinity factor highly influences the fauna of this area.

Nutrients

The sampling of the Indian Ocean for nutrients (phosphates, nitrate, silicate) was conducted on a wide basis during the International Indian Ocean Expedition (IIOE) held during 1st September 1959 to 31st December 1965. Altogether, 9,536 stations were sampled and of which 2,982 stations had depths exceeding 1,950 m. In general, the concentration of inorganic phosphate in surface waters varied from a minimum of 0.2 $\mu g.at.l^{-1}$ (in most parts of the west, central and east Indian Ocean) to a maximum 1.0 $\mu g.at.l^{-1}$ (east Somalia, Arabian Coast, south Indian Ocean below 40° S latitude). However, exceptionally high values (4 $\mu g.at.l^{-1}$, 4000m South Indian Ocean; 12 $\mu g.at.l^{-1}$, Andaman-Myanmar Coast above Coral Banks) were also noticed. The concentration of nitrate varied from a minimum of 0.5 $\mu g.at.l^{-1}$ at most parts of the Ocean to a maximum of 10 $\mu g.at.l^{-1}$ below 40° S latitude and in another region close to Persian Gulf. The exception was in deep waters where the levels were about 40 $\mu g.at.l^{-1}$. Silicate ranged from a minimum of 3 $\mu g.at.l^{-1}$ to a maximum of 10 $\mu g.at.l^{-1}$. A very high level of silicate (130-140) was noticed in the Bay of Bengal close to the river mouths. In all these cases, nutrient levels were appreciably higher during southwest monsoon period (March-October) than at other times. The nutrient in the Indian Ocean is determined to a great extent by the control over the circulation exerted in the northern Indian Ocean by monsoon winds which directly transport surface waters away with a resulting replacement of deep nutrient rich waters. The high values of inorganic phosphate (0.6- 1.0 $\mu g.at.l^{-1}$) off Somalia and Arabia coasts during May-October (South West monsoon) are caused by near shore upwelling at these places. The relatively high (>5 $\mu g.at.l^{-1}$) silicate values at the Ganges head (Bay of Bengal) and off Malaysia are attributable to river runoff during the same period. In general, the concentration of inorganic phosphate, nitrate and silicate increased in the direction of Antarctic Sea, particularly around 40° S latitude, in the proximity of sub-tropical convergence. In comparison to Atlantic and Pacific oceans, the concentration of nutrients in the Indian Ocean is almost twice.

Dissolved Oxygen

Data collected during IIOE revealed appreciable variations in the dissolved oxygen concentration. Overall, the levels remained between 2 and 4 $ml.l^{-1}$. However, in the Arabian Sea (025 $ml.l^{-1}$; 200 m) and central equatorial region (0.3-1.25 $ml.l^{-1}$; 1200 m) the values observed were very low. In contrast, in the surface waters in Gulf of Aden and in the south (Mozambique channel and Antarctic bottom water, 4000 m) the dissolved oxygen values were maximum (>5 $ml.l^{-1}$). The presence of O_2 minimum layer in the Arabian Sea (100-1250 m) is yet another noteworthy feature of the Indian Ocean. In the upper part of this layer (down to 600 m) free hydrogen sulfide was discovered.

Marine Productivity

The Indian Ocean extending up to Antarctica has an area of about 75 million square km, which is roughly one fifth of the world's oceans. But the fish production from this ocean is very low at about 5 million tonnes, which is about one fourth of the world total annual catch. In terms of organic production and yield ratio, Indian Ocean presents a miserably low percentage as compared to those of Pacific and Atlantic Oceans. Thus, the yield ratio as percentage of carbon is roughly one third of the Pacific and one fourth of the Atlantic Oceans. This clearly reveals the wide gap in the potential harvestable stock especially in view of the fact that the average carbon fixation is almost similar for the Pacific, Atlantic and Indian Oceans with the western Indian Ocean indicating even slightly higher rate of fixation. The average annual gross production for all the seas is estimated to be about 55-70 $g/C/m^2$. Assuming a 40% loss due to respiration and an area of 361 million square kilometers for all the oceans, the total net production per year for all the seas works to about 1.2-1.5 X 10^{10} tonnes of carbon. Ryther (1963) has subsequently modified this value to 2 X 10^{10} tonnes. This value is practically the same as that estimated for the production on land. Of the 74,917 square km which is conventionally taken as the Indian Ocean region, 3.1 million square km is considered as coastal and near shore regions which sustain the major part of the fishery and have an annual net production of 560 X 10^6 tonnes. During the Galathea Expedition, it was found that the rate of organic production was practically high anywhere in the tropics in shallow waters, which was at variance with the observations of the earlier expeditions, which indicated a comparatively low productivity in the tropical seas. But with intensive

exploration during the International Ocean Expedition (1959-65) it was found that some of the world's highest values of primary production are in the upwelling regions of Somalia and South of Arabia. Based on the measurements made by several vessels during different seasons, Qasim (1977) estimated the production of the Indian Ocean at about 4 X 10^9 tonnes. But there is quite a large variation both in space and time in the Indian Ocean in general and coastal areas in particular. The reasons for these seasonal and spatial variations can be attributed to various factors.

Tides

It is interesting to know about the history of the record on the tidal effects of the Indian coast. The earliest tidal records were those taken by James Kyd at Khidirpur docks, Hugli Rover, 1806-1827, continued at Sagar Island, 1828-29. Then are those by Col. De Haviland at Chennai in 1821. Because of the investigations in England by Sir J. Lubbok and suggestions by Wheweli in 1833, the Asiatic Society was requested to take up the tidal observations along the Indian coasts. This resulted in the publication of the table of high water at places between Kolkata and Point Palmyras. The results of the Chennai observations were also published. The tidal observations noted by Lt. H. Siddons at Bangladesh and a review of tidal observations in the Indian Archipelago were published in 1839. In 1869, special tidal observations were carried out in the Hugli and Khidirpour dockyard and the Master Attendant at Kolkata produced annual tide tables.

On the West Coast, the first tide tables were those of Benjamin Norton at Mumbai in 1832. At Colaba, Captain Daniel Ross devised a contrivance for registering tides and this was put into operation by his successor Dr. Buist in July 1842. Captain Ross also recorded a set of tide tables for Mumbai from 1835-40. The above observations were followed by more numerous observations conducted by the survey, irrigation and marine departments at different locations along the coast.

Tides are a significant feature in the ecology of marine organisms, as well as an important factor for consideration by the marine biologists. All coastlines are subject to regular vertical changes in sea level although in some parts of the world these are so negligible and scarcely discernible. Around the Indian coast, tidal ranges are variable – at times quite complex - and some coastlines often experience spectacular tidal amplitudes. Tides in Indian coastal region are generally semi diurnal, with tidal ranges varying from place to place. While Sundarban, Gulf of Khambhat and Gulf of Kachch experience large tidal variations exceeding 5 m, the peninsular tip of India is subject to relatively low variation of around 0.5 m. The variation of tide level at some places along the Indian coast is shown below:

Place	**Spring Tidal Range** (m)	**Neap Tidal Range** (m)
Kandla	5.86	3.90
Mumbai	3.66	0.73
Goa	1.69	0.56
Mangalore	1.22	0.56
Cochin	0.63	0.23
Tuticorin	0.70	0.16
Chennai	1.01	0.41
Visakhapatnam	1.43	0.54
Paradeep	1.87	0.70
Calcutta	4.21	2.10

The current patterns near the river mouths are greatly influenced by tides. Wind and patterns of seasonal circulation mostly dominate the regions along the coast up to 2 kilometers from the coastline. Currents beyond a distance of 2 km from the coastline are once again significantly influenced by the tides. Surface currents tend to follow the monsoon winds. For several months at the end of each year current comes from the northeast, the Bay of Bengal and along the coast of India, rather than from the open ocean.

Animal Distribution

The marine faunas of the India are not the same everywhere. A survey of a moderately sheltered rocky shore on the eastern coast will reveal a suite of species slightly different from the west and the island ecosystem may be rich in species, but different groups of species will occur at each haul. Certain familiar species occur

commonly on all Indian coasts; certain others may have very limited distribution - being restricted, for example, to northeast or southwest coasts. Many species may simply be more common at one geographical extreme than the other, occurring with diminishing frequency along a north-south or east-west gradient. No marine species is ubiquitous, and even the most widely distributed species does not occur at constant frequency or density over the whole of their geographical range.

Marine Ecosystems Diversity in India

Coastal Ecosystem

Coastal zone represents 18% of the earth's total surface, providing space for 60% of the r human population, since about 70% of the world cities with population more than 1.6 million are located in the coastal zone. 90% of the world's fish catch is obtained from this zone. Interestingly, the hydrosphere of the coastal zone is only about 8% but represents about 18 to 33% of the total primary production. This zone is bio-geo-chemically more important as it buries and mineralizes 80-90% of organic matter and the approximate carbonate deposition is estimated to be 50%. This area also receives discharges of suspended matter, associated with elevated levels of pollutants, from major rivers and this accounts for 75 to 90 %. This zone has high biological potential as it serves as the feeding, nursery and spawning grounds with rich biodiversity with an intermediary biotope between marine and freshwater environments.

Coastal ecosystem plays a vital role in India's economy in view of its resources, productive habitats and rich biodiversity. India has a coastline of 7,516 km and of this the mainland accounts for 5,422 km. Lakshadweep coast extends up to 132 km and Andaman and Nicobar Islands have a coastline of 1,962 km. Nearly 250 million people dwell within a distance of 50km from the coast. The coastal area is assuming greater importance in recent years, due to the increasing human population, large-scale urbanization and accelerated developmental activities. The coastal regions have become a place of hectic human activity and the coastal ecosystems are now highly disturbed and very much threatened. The present approach to the management of coastal resources is not capable of sustainable development and therefore the coastal environments and resources are being rapidly degraded and eroded in India.

The Indian mainland coast is divided into two segments – the west coast and the east coast. The west coast is along the Arabian Sea and the east coast is along the Bay of Bengal. Other than these two mainland coasts, there are three island groups such as Lakshadweep in the south Arabian Sea, Andaman and Nicobar in the eastern Bay of Bengal. The east and west coasts are markedly different in their geo-morphology. The west coast is composed of heavy surf and rocky shores and headlands. The east coast is generally shelving with beaches, lagoons, deltas and marshes. It is also relatively low lying with extensive alluvial plains and deltas. The physical feature of the Indian coasts is characterized by different types of coastal and shore ecosystems like promontories (near Beypore in Kerala State), sand spits (at Karnataka and Andhra Pradesh), barrier beaches (along the Kerala coast), bayments (Mirya bay in Maharashtra), estuaries and offshore islands. Indian sub-continent has a long coastline of about 8000 km covering the 9 coastal states and the Union Territories of the Andaman and Nicobar and the Lakshadweep islands.

Further, the coastal zone of India is also endowed with a wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, sandy stretches and coral reefs which are characterised by unique biotic and abiotic properties and processes. More than half the Indian coastline is sandy. The west coast is predominantly rocky consisting of silt covered rocky flats or lime stone rocks, often with overhanging cliffs formed of green to black basalt. Sandy areas, rivers, creeks interrupt the rocky coast, and back waters. On the east coast, small stretches of rocky formations occur along Tamilnadu and Andhra Pradesh. The areas under major ecosystem/habitat categories of the coast are given below (Space Application Centre 1992):

Categories	Area in sq.km.	Categories	Area in sq.km.
Mudflat	2961	Lagoon/Backwaters	2132
Beach/Spit	1465	Flood prone area	3437
Shoal/Bar	93	Coastal dunes	2509
Coral reef	1270	Reclaimed area	1212
Mangroves	3979	Paleo Beach Ridges	434
Marsh vegetation	370	Paleo Mudflats	6821
Mudflat with vegetation	6125	Strand plain	1378
Beach vegetation	290	Salt affected area	697
		Salt pans	1617

The description of the coastline in India is as follows :

States	Sandy Coast (km)	Rocky Coast (km)	Muddy Coast (km)	Marsh Coast (km)	Approx. Total (km)
Gujarat	440	319	444	352	1555
Maharashtra	95	201	250	-	546
Goa	66	31	54	-	151
Karnataka	224	33	41	-	298
Kerala	459	23	88	-	570
Tamilnadu	574	31	394	-	999
Andhra Pradesh	354	32	512	74	974
Orissa	292	-	171	53	516
West Bengal	-	-	125	121	246
Total	**2504**	**670**	**2074**	**600**	**5853**

Realising the importance of the coastal ecosystems and its multiple uses, the ever exploding human population not only exploits the biological resources but also interferes with and modifies the basic coastal processes. Traditionally, coastal areas are densely populated because they are the places where trade, transport, communication and civilization take place. It is estimated that by 2000 AD, out of the 25 global mega cities, 15 would be the ones on the coast. In India, out of the three mega cities with population of more than 10 million (Delhi-13.2 million, Mumbai-16 million and Kalkota-16.5 million), Mumbai and Kolkata are coastal cities. The density of population in coastal areas far exceeds the national average. For example, in the state of Tamilnadu, the population density in coastal areas is 528 per sq. km against 372 per sq. km which is the state average. In parts of coastal cities like Mumbai, Kolkata and Chennai the population density ranged from 20,000 to 50,000 per sq. km. This increased population pressure has led not only to resource depletion but also environmental degradation caused by coastal

pollution, disposal of domestic and industrial wastes. As in most of the developing nations, the coastal environmental problems and issues in India are also concerned with the same three main factors: environmental degradation, resources depletion and user conflicts. The plan of the Integrated Coastal Zone Management (ICZM) has been recognized as a tool for addressing various options that ensure livelihood, security and environmental stability in coastal zones.

Coral reef ecosystem

Coral reefs form the most dynamic ecosystem providing shelter and nourishment to thousands of marine flora and fauna. They are the protectors of the coastlines of the maritime States. A few genera of corals are supposed to be older than prairies. This unique ecosystem is most productive because of its symbiotic association with algae called Zooxanthellae. Though they are the builders of the most massive structures ever created by living beings in the world, they are very fragile and vulnerable to natural disturbances, and human activities. Maritime States and population in the coastal areas mostly depend upon the coral reef ecosystem for their day-to-day living.

In India, all the three major reef types (atoll, fringing and barrier) are found, and the region includes some of the most diverse, extensive and least disturbed reef areas of the Indian Ocean and many of them are among the least scientifically known. The mainland coast of India has two widely separated areas containing reefs: the Gulf of Kutch in the northwest, which has some of the most northerly reefs in the world, and Palk Bay and Gulf of Mannar in the southeast. There are patches of reef growth on the west coast - for example, the coral reefs at Malvan. The Andaman and Nicobar have fringing reefs around many islands, and a long barrier reef (329 km) on the west coast. The reefs are poorly known scientifically but may prove to be the most diverse in India and possibly in the best condition. The Lakshadweep has extensive reefs but these are equally poorly known.

Reefs are home to more species than any other ecosystem in the sea. Although the total number of reef species in the world is still unknown, up to 3,000 species can be found together on a single reef in south east Asia and over 1,000 on a single Caribbean reef. Only tropical rainforests, estimated by some to be home to a staggering 30 million insects, have a greater number of species. Because of the vast number of fishes that inhabit them, reefs contain a larger number of vertebrates than rainforests. Reefs also contain many more major animal groups (Phyla) than any other ecosystem on land or in sea.

The richest reefs, with the greatest diversity of plants and animals, are in the region bounded by Indonesia, Malaysia, the Philippines and southern Japan. Of the approximate 700 reef coral species that are known to us, 600 are found in this region; over 400 are found in the Philippines and Japan, and about 350 in Indonesia, although there are probably many more to be discovered here. Up to 200 corals may occur on a single reef in south east Asia. This high diversity extends equally to other reef associates and is partly because of the greatest area of reefs found here and partly because of its geological history. When the sea level is lower, the region comprises of three separate basins, within each of which numerous species evolve. The variety of species on a reef decreases eastwards across the Pacific.

In India, the reefs are distributed along the east and west coasts at restricted places. Fringing reefs are found in Gulf of Mannar and Palk Bay. Platform reefs are seen along the Gulf of Kutch. Patchy reefs are present near Ratnagiri and Malvan coasts. Fringing and barrier reefs are found in Andaman and Nicobar islands and Atoll reefs are found in Lakshadweep. The absence of reef in Bay of Bengal (north east coast) is attributed to the immense quantity of freshwater and silt brought by the rivers such as Ganga, Krishna and Godavari. Satellite imagery (SAC, Ahmedabad) shows scattered patches of corals in the inter-tidal areas and occasionally at sub-tidal depths along the west coast of India notably at Ratnagiri, Malwan and Rede Port.

The mainland coast of India has the Gulf of Kutch in the northwest (Gujarat State) and Palk Bay and the Gulf of Mannar in the southeast (Tamilnadu State). Apart from these important off-shore island

groups of India, the Andaman and Nicobar islands in the Bay of Bengal and Lakshadweep in the Arabian Sea have extensive reef growth. The total area of coral reefs in India is estimated to be 2,374.9 sq. km.

A total of 199 species divided among 71 genera are recorded from India, including Lakshadweep, the Gulf of Kutch, Palk Bay and the Gulf of Mannar and Andaman and Nicobar Islands. Out of these 155 species belong to the hermatypes and 44 species to the ahermatypes. The Indian Ocean, as a whole, is known to harbor 88 genera of hermatypes (Scheer, 1984), which means 56.8 percent of the total known hennatypic genera of the Indian Ocean, is present in our waters. A comprehensive list of species from the Indian Ocean is not yet available. However, based on the present checklist, the following numerical list of genera and species is drawn up.

The hermatypes constitute 77.8% of the coral fauna and the ahermatypes the remaining 22.2%. Among the hermatypes, *Acropora* alone forms 20% and *Montipora* 13%, which are the two numerically rich genera. The members of the sub-order Astrocoeniina constitute 34.7%, Fungiina 25.7%, Faviina 22.6%, Caryophylliina 8% and Dendrophylliina 9% of the total coral fauna of India which includes both the hermatypes and ahermatypes types. No genus is endemic to India. The coral reefs of southeast India, Andaman and Nicobar Islands and Lakshadweep harbour *Acropora* community (Pillai, 1971, 1986). The coral growths in Gulf of Kutch are mostly found scattered and are in a juvenile stage.

Mangrove ecosystem

Mangroves are one of the most extraordinary ecological formations occurring almost exclusively in the tropics. Like the tropical rain forests, the mangroves have also played a very important role in the economics of our coastal population for thousands of years, providing them with a wide variety of goods and services including wood production, support for commercial and subsistence fisheries, aquaculture, salt production, shore-line and coastal erosion control.

Mangroves are salt-tolerant forest ecosystems of tropical and sub-tropical inter-tidal coastal regions near the river mouths. Between latitudes 30^0N and 30^0S, the shore-line marsh vegetation is replaced by *mangals* (a community of mangroves*)*. They form highly productive ecosystems since the inorganic nutrients, brought in by the incoming freshwater from land run-off, are trapped to form the source of energy for many organisms. A mangrove ecosystem constitutes a reservoir, refuge, feeding ground and ill nursery for many useful and unique plants and animals confined to this region. Though the export of decomposable organic matter into adjacent coastal waters, the mangroves provide an important nutrient input and primary energy source for many tropical estuaries. The mangrove ecosystem also protects coastal areas from sea erosion and the violent effects of cyclones and tropical storms. The warm, calm waterways of mangroves provide shelter and rich food for many juveniles and larvae of finfish and shellfish.

The Bay of Bengal is one of the two northern embayment of the Indian Ocean, flanked by the Indian peninsula and Sri Lanka in the west and the Andaman-Nicobar islands and Myanmar in the east. It is over 2 million square km in extent and acts as the recipient of two mighty rivers, the Ganges and the Brahmaputra, in addition to other rivers like Mahanadhi, Godavari, Krishna and Kaveri. Four states, West Bengal (157 km), Orissa (476 km), Andhra Pradesh (974 km),Tamilnadu and Pondicherry (938 km) share the eastern coastline. The total area of the exclusive economic zone (EEZ) of India, in the Bay of Bengal, is 515,500 square km. All the rivers discharge an estimated 71,650 km^3 of water into the Bay, causing dilution and covering the salinity between 30 and 34 ppt. The mangrove habitats are dynamic, rich in species and have high production. Hence, they have great ecological, social and economic significance. These areas are important for the marine fisheries, serving as they do as nurseries for many species of finfish and shellfish.

India has only 2.66% of the world's mangroves, 6.42% of mangroves exist in the South and Southeast Asia, 9.83% in America, 17.29% in West Africa,

25.69% in Australia and 46.65% of mangroves in east Africa and the Middle East. The total area of mangroves in India is estimated to be 4,827 square km. The east coast is endowed with the world's largest mangrove forest - the Gangetic Sunderbans in West Bengal. The Sunderbans mangroves are of the delta type. The 2109 square km area of Sunderbans has 30 of the 50 species of the true mangroves in the world. The mangrove area in Orissa is nearly 200 square km in extent and its degradation is placed at 20 square km over ten years, as per recent estimates. Andhra Pradesh has about 582 square km of mangrove area. The area under mangrove ecosystem in Tamilnadu is about 225 square km. One of the largest and most unspoiled mangrove forests in Tamilnadu is at Pitchavaram in Cuddalore district, spread over an area of 1100 ha. Out of India's total area under the mangroves, about 57% are found on the east coast, 23% on the west coast and the remaining 20% the Andaman and Nicobar islands. There are three types of mangroves in India namely deltaic, backwater-esturine and insular. The deltaic mangroves occur on the east coast (Bay of Bengal) where the mighty rivers make the delta. The backwater-esturine type of mangroves that exists in the west coast (Arabian) is characterized by typical funnel- shaped estuaries of major rivers (Indus, Narmada, Tapti) or backwaters, creeks, and neritic inlets. The insular mangroves are present in the Andaman and Nicobar islands, where many tidal estuaries, small rivers, neritic islets, and lagoons support a rich mangrove flora. The multiple uses of the coastal zone in general and the mangroves in particular, are recreation, tourism, forestry, agriculture, aquaculture, housing and commercial fishing. Well-known is the fact that this zone is very highly productive and also densely populated. A major concern is the ever-increasing use of this zone and its resources causes pollution due to domestic, industrial, municipal and agricultural wastes and lately also due to oil exploration.

Sea grasses occur in the infra-tidal and mid-tidal zones of shallow and sheltered localities of sea, gulf, bays, backwaters and lagoons. They are submerged monocotyledonous plants adapted to the marine environment for completion of their life cycle under water. They occur along the east and west coasts and Andaman and Nicobar islands. They form a dense meadow on the sandy and coral rubble bottoms and sometime in the crevices under water. In India, the earlier studies revealed that about 14 species are found along the India coast. The dominant species are *Cymodium rotundata, Enhalus acorodies, Halodule pinifolia pinifolia, H. uninervis, H. wightii, Halophila beccarii H. deeecipiens, H. ovalis, H. ovta, H. stipulacea, Syringodium isoetifolium, Thalassia hemprichii* and others. About 9 species of seagrass are extensively found in the Andaman and Nicobar islands. The unique ecological importance of the seagrass for the conservation of rare and endangered animals like marine turtles, dugongs, some common echinoderms, juvenile prawns and fishes is very well known.

The seaweed communities prefer somewhat flat and rocky coastal wetlands that gradually slope towards the sea with marked tidal effect of complete submergence during high tide and successive exposure during low tide. Its distribution extends from open shore formation to inter-dial lagoons, bays, rockpools, and puddles or in creeks and inlets along the infralittoral region of the coast. Different species are abundantly found along the west coast, Andaman and Nicobar islands, Lakshadweep and Minicoy. Its occurrence along the east coast is very scanty except in places like Chilka, Pamban and Cape Comorin.

About 120 species of seaweeds have so far been recorded in the coastal wetlands in India. Some of the important seaweeds are *Enteromorpha compressa, Ulva lactuca, Acetabularia crenulata, Dictyosphaeria cavernosa, Chaetomorpha media, Caulerpa corynephora,* C. *paltata, odium iyengarii,* C. *tomentosum, Halimeda macroloba, Dictyota atomarica, Ectocarpus breviarticvulatus, P.olysiphonia vaariegata, Grateloupia indica* and *Sargassum duplicatum*. These plant communities serve as sustainable life support for food, shelter, fertilizer, production of iodine, potash, glue, agar, algin, vitamin, antibiotic and others. The detailed studies on Indian seaweed, their survey, quantitative assessment and different problems for extracting valuable products for commercial export are to be given greater emphasis in the future.

Estuaries and lagoon ecosystem

Estuaries are an integral part of coastal environment. They are the outfall regions of the river, forming the transitional zone between the fluvial and marine environs. Historically the term estuary has been applied to the lower tidal reaches of a river. Most of the great cities of the world have developed around the estuaries. Of the ten largest metropolitan areas in the world, New York, Tokyo, London, India, the coastal population density has been quite high since many centuries and the metropolitan cities like Mumbai, Kolkata and Chennai have developed around estuaries. Even at the time of Harappan civilization, exploitation of estuarine and riverine resources was intense - for instance, the Indus delta (Mohan-jo-daro), the Ganga-Bramaputra delta and the harbours in Bengal and South India where Greek-Roman sea trade flourished.

Estuaries are semi-enclosed and sheltered coastal bodies of water. They have been the focal point of maritime studies and activities. As they are semi-enclosed, they serve as natural harbor for trade and commerce. They are also effective nutrient traps and provide a vital source of natural resources to man and used for commercial, industrial and recreational purposes. Biodiversity in this ecosystem is very impressive. They are the best settling places for clams and oysters. They also act as nursery ground for a variety of shrimps and some fin-fishes.

Ecosystem diversity is reflected in the formation of estuaries at the mouth of 14 major rivers, which together account for 83% of the total catchment area and 85% of the annual runoff into seas around India (Qasim and Sengupta, 1984). These estuaries harbour lush mangrove vegetation, which add to the organic production. In some locations along the coast, backwaters stretch over vast areas and have a few specialized faunal groups. The total estimated area under the estuaries is approximately 2 million hectares and the backwater is 1.9 million hectares. As far as biodiversity is concerned, the two lagoons - Chilka and Pulicat on the east coast, are the important wetlands.

In India, we have a combined river length of 45,000 km comprising of 113 major and minor rivers. The health status and the biological diversity of the Indian estuarine ecosystem are steadily deteriorating due to human activities. The dumping of enormous quantities of sewage into the estuary has drastically reduced the population of the mature fishes. It has also caused considerable ecological imbalance and resulted in large-scale disappearance of flora and fauna. Further, infusion of untreated municipal waste-water and industrial effluents into these water bodies has led to serious water pollution including heavy metal pollution, which gets biomagnified and reaches man through food-chain implications. The following are the major east coast estuaries: Hoogly, Rushikulya, Godavari and Krishna, Edaiyur, Ennore, Cooum, Adyar, Uppanar, Vellar, Kollidam, Kavery, Agniyar and Kallar. The west coast estuaries are: Asthamudi, Korapuzha, Beypore, Periyaar, Kaninamkulam, Vembanad, Netravathi and Gurupur, Gangolli, Pavenje, Kali, Arnba, Mahirn, Puma, Mahi and Madovi and Zurai.

Coastal lagoon is a shallow coastal water body separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets parallel to shore. The ocean entrance(s) can at times be blocked by sediment deposition as a result of wave action and littoral drift. Coastal lagoons are usually found on low-lying coasts and normally aligned with their largest diameter parallel to the seashore. A number of lagoons are present on the east and west coasts of India. There are 17 noteworthy lagoons (8 on the east and 9 on the west) along the Indian coasts. The east coast of India, extending from the international border of India and Bangladesh in the northeast to Kanyakumari in the south is 2,545 km long. It covers the states of West Bengal, Orissa, Andhra Pradesh, and Tamilnadu. It is over 2 million square km in extent and acts as the recipient of mighty rivers of the subcontinent namely the Ganga and Brahmaputra. The other major Indian rivers that drain into the Bay of Bengal are the Mahanadi in the northern region, the Godavari and Krishna in the central region and the Kaveri in the southern region. There are also a number of minor rivers draining into the Bay. The coast is endowed with extensive areas of estuaries, brackish water lagoons, mangroves, coral reefs and seaweed beds. These

coastal habitats are ecologically dynamic, rich in species and have high organic production. Hence, they carry great ecological, social and economic significance. These areas are important for the marine fisheries, serving as they do as nurseries for many species of shellfish and fin fish. There are eight important lagoons on the East Coast of India. They are Chilka, Pulicat, Pennar, Bendi, Nizampatnam, Muttukadu, Muthupet and Gulf of Mannar. Along the West Coast of India, there are nine important coastal lagoons. With their connecting canals they stretch from Calicut on the north to Trivandrurn on the south. Typical examples, among others, are the Ashtamudi lagoon near Quilon and the Vembanad lagoon near Alleppey. The lagoonal ecosystem along the west coast of India are: Vembanad, Ashtamudi, Paravur, Ettikulam, Veli, Murukumpuzha, Talapady , Lagoons of Bombay coast and Lakshadweep lagoons (Kavaaratti and Minicoy lagoons).

Pelagic and benthic ecosystems

The fauna of the marine ecosystem is not evenly distributed throughout the oceans. It is estimated that 90 percent of marine species live in about 50 million sq. km of the total 352 million sq. km. The patterns of biodiversity are determined by the availability of light in the sea. The pelagic ecosystem is dominated by plankton, which is classified on the basis of size as picoplankton (02.-2 mm), nanoplankton (2-20 mm) microplankton (20-200 mm) and mesoplankton (>200mm). Mesoplankton includes copepods, rotifers etc. Larvae of many benthic invertebrates represent mesoplankton.

Sponges, coelentrates, molluscs and echinoderms have planktonic larvae. Copepods, cladocerans, mysiids, rotifers, chaetognaths, hemichordates and protochordates have planktonic adults. Copepods are important primary grazers. About 1925 pelagic copepods have been described from marine waters of India. It is estimated that there are 3500 to 4500 species of marine phytoplankton in the world but we do not have any such data for Indian seas. Plankton occurs everywhere in the sea and they differ only in the species composition and relative abundance. The rich nutrient present in the coastal waters forms the basis for the presence of many species of diatoms whereas the nutrient deficient oceanic waters contain dinoflagellates. There is generally a gradual decline in phytoplankton abundance from coastal to oceanic water. Plankton plays important role in the primary productivity and produces half of the world's oxygen and fixes 27 giga tons of carbon each year. Pelagic life also includes nekton represented by shrimpfish, squid, cuttle fish, reptiles, whales and sea cows. Pelagic life thus has a tremendous diversity in form and function. Dominant taxa in the nekton are fishes represented by about 4000 species in the Indian Ocean - of which about 50% occur in the Indian seas. A majority of these species occurs in coastal waters supporting valuable fisheries. Among reptiles, sea snakes and turtles are important and represented by 50 and seven species in the world respectively. These are generally oceanic forms but majorities of these often swim near to the shore and visit the shore at some part of their lives. About 26 species of snakes belonging to the family Hydrophiidae and five species of sea turtles are reported from seas around India. The seashore offers a veritable feeding and breeding ground for a number of birds. From the available data, it has been inferred that there are 12 families, 38 genera and 145 species of seabirds that occur, in the coastal ecosystem.

Till recently the deep sea, which constitutes a major part of the ocean, was perceived as species poor environment. But now surprisingly the estimate of the numbers of species in the deep seas ranges from 5-10 million. This staggering range reflects our attempt to fill the gap that hitherto existed in our knowledge of marine biodiversity. It is now well established that the oceans are rich in supraspecific categories, especially at the phyletic level. Out of the 33 animal phyla recorded so far from the world, 15 are endemic to the sea and 5 have predominantly marine occurrence. The taxonomic status of the groups representing the evolutionary branches off Protista is still in a fluid state. The kingdom is divided into about 70 phyla. As many as 1000 new species are discovered every year. The assumption that terrestrial ecosystem has more species than the marine ecosystems can no longer be considered a certainty. From the recent studies it is found that

the number of benthic invertebrates includes millions of species instead of 60,000.

Coastal and marine fisheries in India

Marine fisheries constitute a highly productive sector in India, a source of valuable food and employment, and a net contributor to the balance of payment. For India with strong interests in fisheries, the largest fish production comes from the coastal capture fisheries, which contribute on an average, 62% of the total fish production (including freshwater fishes). The marine jurisdictional area called the Exclusive Economic Zone (EEZ) is extensive, spanning 2.02 million square km, which works to 38% of the total (5.30 m. square km) marine, freshwater and land areas of the country. In the 3651 fishing villages situated along the 8129 km coastline, about 1 million people are employed full time in marine capture fisheries. The fishing sector, which is dominated by small scale and semi- industrial operators, supports several ancillary industries such as boat building yards, processing plants etc. Of the marine products export of 385,818 t valued at Rs. 1.1 billion US $ during 1997-1998, about 310,000 t (80%) was from the capture fisheries - but this formed only 11.5% of the marine fisheries. Marine fisheries production, which was only 0.5 million tones in 1950, increased over the years and peaked to 2.7 m t in 1997. In 1997, the production (2.2 m t from inshore waters (<50 m depth) has reached the maximum harvest potential (2.2 m t) and hence scope for further increase in production from inshore waters is limited.

Marine biodiversity in India

Among the coastal wetland estuaries, mangroves and coastal lagoons are biodiversity-rich areas, whereas the other brackish habitats have only a few specialized species. It is generally believed that there is a reduction in the species number in estuaries compared to adjacent seas and in-flowing river system. However, as far as Indian estuaries are concerned the statement is partly true. The upper riverine ecosystem does not harbor as many species as its estuary. It has been observed that as the distance increases from the sea the number of species decrease. Salinity becomes an influencing regulatory factor.

The marine fauna of India is rich and varied. The coastline encompasses almost all types of inter-tidal habitat, from hyper-saline and brackish lagoons, estuaries, and coastal marsh and mudflats, to sandy and rocky shores with every degree of exposure and widely varying profile. Sub-tidal habitats are equally diverse. Each local habitat reflects the prevailing environmental factors and is further characterized by its biota. Thus, the marine fauna itself demonstrates gradients of change throughout the Indian coasts.

Much remains to be known about the number and types of the species of flora and fauna, which live in India. The algae, fungi, ferns, bryophytes and lichens are less known than the flowering plants. For the flowering plants, the location and population size are known even for the most threatened species. Invertebrates are generally less well known than the vertebrates. For birds, and now increasingly for reptiles, amphibians and mammals, most species have estimates.

Out of the total 32 animal phyla, 15 are represented by the taxa in the marine ecosystem. They may constitute either migratory or resident species. The former includes pelagic crustaceans, coelenterates (medusae), Cephalopod molluscs, fishes, reptiles, birds and mammals. Amphibians are generally absent in estuaries. The benthic macro fauna comprises resident species of polychaetes, molluscs, sipunculas and mud- burrowing fishes. Among invertebrate, sponges, phoronids and echinoderms generally do not prefer estuarine ecosystem. In India estuarine species diversity seems to be maximum in Molluscs. About 245 species belonging to 76 genera under 54 families were cataloged. Another important taxa, polychaeta are represented by about 167 species belonging to 97 genera under 38 families. Maximum diversity has been observed in the much-studied Hoogly-Matlah estuary (West Bengal). Macro organisms and meofauna of Indian estuaries are not properly investigated. Estuarine mud may contain rich variety of bacteria, flagellates, ciliates nematodes, ostracodes, harpacticoid copepods, rotifers, gastrotriches, arachnids and tardigrades.

Free swimmers or nekton are important components of marine biodiversity and constitute important fisheries of the world. The dominant taxa in the nekton are fish, others being crustaceans, molluscs, reptiles and mammals. Out of a total 22,000 species, it has estimated that about 4,000 species occur in the Indian Ocean of which 1,800 species are from the Indian seas. Majority of the nektonic species is found in the coastal waters. It is estimated that 40 species of sharks and 250 bony species represented the oceanic fishes.

Among reptiles, sea snakes and turtles are important and represented worldwide by 50 and seven species respectively. These are generally oceanic forms but majority of these often swim near to the shore and visit the shore at some part of their life. About 26 species of sea snakes belonging to one family, hydrophiidae and five species of sea turtles were reported from seas around India. Oceanic islands seem to harbor more reptiles in their marine environment. All the sea snakes and four species of turtles in their marine environment are known from islands of Andaman and Nicobar. Nesting sites of an amphibious snake were reported from the shores of north Andaman Islands (Whitaker, 1985). Turtles visit the shore during the breeding season to lay their eggs. The shore visit of these turtles especially the olive ridley is a spectacular sight on the sandy beaches at Gaginnatha near Bitharkanika in Orissa. The Andaman and Nicobar islands have best nesting beaches for the leatherback, the hawksbill and the green turtle and also the olive ridley (Baskar, 1993).

The seashore offers a variable feeding and breeding ground for a number of birds. It is difficult to define precisely the avian component of marine biodiversity. There are some special species, which are exclusively dependent on marine ecosystem, while a few others are generalists without much dependence on it. From the available data, it has been inferred that there are 12 families, 38 genera and 145 species, which occur in the coastal ecosystem.

Marine mammals belong to three different orders - Sirenia, Cetacea and Carnivora. About 120 species are estimated to occur in all the seas and of these 30 are reported from seas around India. But majority of these is oceanic forms and occasionally a few individuals may get stranded on the shore. Sea cow occurs in near shore waters.

Marine biodiversity of India

Name of the group	No. of species
Algae	425
Protista	
1. Sarcornastigophora 2. Ciliophora	750
Animalia	
1. Porifera	500
2. Cnidaria	842
3. Ctenophora	100
4. Platyhelminthes	350
5. Gastrotricha	98
6. Kinorhyncha	10
7. Annelida	440
8. Mollusca	3370
9. Bryozoa	170
10. Entoprocta	8
11. Phoronida	3
12. Brachiopods	3
13. Arthropoda	
a) Crustacea	2430
b) Pycnogonida	16
c) Merostomata	2
14. Sipuncula	35
15. Echiura	43
16. Tardigrada	5
17. Chaetognatha	30
18. Echinodermata	765
19. Hemichordata	12
20. Chordata	
a) Proto chordata	116
b) Pisces	1800
c) Amphibia	3 *
d) Reptiles	31
f) Aves	145
g) Mammalia	30
TOTAL	**12,462**

Human impacts on marine biodiversity

Though human impacts on marine and coastal biodiversity are less understood and publicized than those on the terrestrial biodiversity, their potential effects are no less threatening. The major direct threats to marine and coastal biodiversity can be divided into five interrelated categories: pollution (from land and other sources), over exploitation of marine living resources, introduction of alien species, habitat degradation caused by coastal development, global climate change and ozone depletion.

Some of the harmful human impacts on marine biodiversity stem from lack of understanding of the importance of marine biodiversity. Marine resources and biodiversity have traditionally been undervalued. This puts marine resources on a lower priority level when compared to land biodiversity. Unregulated use of resources, increased demand for resources and rapidly expanding coastal development imperil the marine resources.

The belated realization of the need for action after the damage becomes apparent and this perpetuates the destructive cycle. Communities that depend on marine resources face the long-term challenge of sustainability. But they are also often confronted with immediate economic hardship. For a developing country like India, action is hardly ever preventive and is usually undertaken only after irreversible damage has taken place.

In the face of this increasing uncertainty, the adoption of a precautionary approach is a *sine qua non* to the conservation of marine and coastal biodiversity. The precautionary principle, which is now widely recognized as an emerging part of customary international environmental law, requires that no harmful action be undertaken until all the effects on marine and coastal biodiversity have been clearly identified and weighed against the expected benefits. Moreover, this precautionary approach should cover all the activities of the past, present and future - bearing in mind the cumulative impact that these activities will have on marine biodiversity.

Keeping the above facts and figures in mind, several international instruments are available to achieve the convention's objectives with respect to marine biodiversity. The following are the important instruments with greatest potential for synergy with the Convention on Biological Diversity (CBD).

- *United Nations Convention on the Law of the Sea, Montego Bay, (UNICLOS).*
- *Agenda* 21, *Rio de Janeiro,* 1992.
- *UN Agreement on Straddling and Highly Migratory Fish Stocks', New York,* 1995, *and FAO Code of Conduct for Responsible Fishers, Rome 1995.*
- *The UN General Assembly Drift-Net Resolution* 46/15, 1991.
- *UNEP Conference on Protection of the Marine Environment from Land Based activities, Washington,* 1995.
- *Protocol on Substances that Deplete the Ozone Layer,* 1987 *(Montreal Protocol).*
- *The Framework Convention on Climate Change, Rio de Janeiro, (FCCC).*
- *United Nations Conference on the Sustainable Development of Small Island Developing States, Bridgetown,* 1994.
- *Convention on International Trade in Endangered species, Washington*, 1973 *(CITES)*
- *International Convention for the Prevention of pollution from Ships (MARPOL),* 1973-1978.
- *The Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, London*, 1972 *(London Convention).*
- *Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar,* 1971 *(Ramsar Convention).*
- *International Convention for the Regulation of Whaling, ~ Washington,* 1946 *(ICRW).*

Conservation, status, threats and problems

India has signed and ratified several international conventions relating to oceans and ocean-related activities. The important ones are the following: MARPOL 1973/1978; London Dumping Convention 1972; Convention on Civil Liability for Oil Pollution Damages (CLC 1969) and its Protocol 1976; Fund 1971 and its Protocol 1979 and Convention on Biodiversity (1992).

Many acts and rules relating to coastal and marine activities exist in the country. The following are the important ones.

Indian Fisheries Act 1897 and its Amendments 1920 and 1980; Indian Ports Act 1902; Merchant Shipping Act 1974; Wildlife Protection Act 1972; Water (prevention and Control of Pollution) Act 1974; Indian Coast Guard Act 1974; and Marine Zones of India (Regulation of Fishing by Foreign Vessels) Act 1981 and Environment Protection Act 1986. As per the Coastal Regulation Zone notification, the coastal states must prepare a coastal zone management plan identifying and classifying the CRZ areas within 1 year from the date of CRZ notification (Ministry of Environment and Forests Notification, August, 1994).

The CRZ notification also states that during the interim period till the coastal zone management plans are prepared and approved, all developmental and other activities within CRZ should not violate the provisions of this notification. As per the Environmental Protection Act, 1986 and Coastal Regulation Zone Notification 1991, the following activities are banned in the land part of the country. 1. Setting up and expansion of new industries, fish processing units except those, which require waterfront. 2. Manufacture or handling or storage of disposal of hazardous substances and discharge of untreated waste and effluents from industries, cities or towns and other human settlements. 3. Dumping of fly ash from thermal power stations and other solid waste dumping. 4. Land reclamation, bunding or disturbing the natural course of seawater. 5. Mining of sand, rocks and other substrate materials other than raw minerals. 6. Withdrawal of ground water within 200 m of high tide level. 7. Any construction activity between the low and high tide lines and 8. Alteration of the sand dunes, landscape and other natural features.

In the ecologically sensitive areas, construction of civil and other structures like breakwaters for harbour, floating industries, laying of pipelines, reclamation of sea and its bed, sea bed mining and ship breaking activities are prohibited. However, they may be permitted at a no-impact distance from the outer limit of environmentally sensitive areas. Discharge of untreated and treated domestic, industrial, aquaculture wastes, nuclear and thermal power plants, dredged materials and operational discharges are prohibited in environmentally sensitive areas. Although marine ecosystems have a larger coverage than the other ecosystems, these are poorly represented among world's protected areas. Only 100 of the 1162 national parks of United Nation list include or adjoin reef ecosystem. In India 4 out of the 504 protected areas (national parks 86, sanctuaries 448 and biosphere reserves 7) are with reference to marine ecosystems. There are Gulf of Mannar, Gulf of Kachch, Marine National Park of Andaman and Nicobar islands (Mahatma Gandhi Marine National Park) and Rani Jhansi Marine National Park. The protected areas (of about 102) of the Andaman and Nicobar islands cover substantial areas of marine waters also. In 1980 the Gujarat State Government constituted the first marine sanctuary in India in the Gulf of Kachch to cover an area of 456 sq. km. from Okha to Jodiya having a core area of 162.9 sq. km. On May 24, 1989, the second Mahatma Gandhi Marine National Park was notified in the Andaman island and it covered an area of 281.5 sq. km.

Consequently, effective research and extension programmes, which are critical to the conservation and management of marine ecosystem, have been given priority. The following institutions under the Government of India are engaged in the research and extension as well as conservation and management of the Marine and Coastal Ecosystems of India: Ministry of Agriculture, Department of Agriculture and Cooperation; Fishery Survey of India, Central Institute of Fisheries, Nautical and Training, Integrated Fisheries project, Central

Institute of Coastal Engineering for Fishery, Development of coastal marine fisheries, Development of fisheries harbours, Assistance for strengthening fish marketing infrastructure, Fish Farmers Development Agency, Brakishwater Fish Farmers Development Agency, Deep-sea Fishing, Fisherman welfare schemes, Department of Agriculture Research and Education, Central Marie Fisheries Research Institute, Central Inland capture Fisheries Research Institute, Central Institute of Freshwater Aquaculture, Central Institute of Brackish water Aquaculture, Central Institute of Fisheries .Technology, Central Institute of Fisheries Education, National Bureau of Fish Genetic Resources, National Research Centre on Coldwater Fisheries, Ministry Commerce, Ministry of Food Processing Industries, Ministry of Environment and Forests, Zoological Survey of India, Annamalai University, Centre of Advanced studies on Marine Biology, Madurai Kamaraj University, Andhra University etc.

Despite the above mentioned acts and regulations, the resources of marine ecosystems in India, are being over-exploited. Apart from over-exploitation, pollution from land-based sources is another major threat to marine resources. The population influx and increased tourism in some coastal places are responsible for indiscriminate destruction of marine resources. Recent spurt in aquaculture activities increased the demographic pressure and the related environmental manipulation. All the above mentioned reasons have led to biodiversity conservation problems in India. The situation may be improved by taking examples from other regions of the world where the marine ecosystem is conserved more effectively.

Importance of marine and coastal ecosystem

Marine and coastal ecosystems, and the diversity of species that compose their structure, provide a wide range of important resources and services. Food from the sea, particularly fish, crustaceans and molluscs, is a major source of human consumption. Marine fish provided about 84 million tons of human food and livestock supplements in 1993 (FAO, 1995). The fisheries producing this catch are a major source of employment for many of the world's coastal States. Small-scale fisheries harvest a large proportion of the world's catch. Fish accounts for about 16 per cent of the average individual's intake of animal protein worldwide (FAO, 1993), and the percentage is even higher in many developing countries (WRI, 1996).

Marine and coastal ecosystems also provide many critically important services for humanity such as a) storing and cycling nutrients, b) regulating water balances, c) buffering land and protecting it against erosion from storms and waves, d) filtering pollutants, e) regulating planetary balances in hydrology and climate f) removing the primary greenhouse gas through the ocean's photosynthetic pump, carbon dioxide from the atmosphere and producing one third to one half of the global oxygen supply.

Coral reefs, estuaries, lagoons and shallow coastal waters are particularly valuable for human population because of the goods and services they provide. They are among the most biologically productive systems on the earth. Some reefs and mangroves provide sea defenses and buffer the impacts of tropical storms thereby mitigating the erosive effects of waves and storm surges. All of these systems provide nurseries and feeding grounds for many coastal and pelagic species of fish including the most important sources of fish for human consumption.

Marine species provide many other products as well, including edible seaweed, ingredients for food and cosmetics, industrial chemicals and dyes and a host of other products. Medical researches have already identified a number of marine organisms that produce previously unknown bioactive compounds, including anti-viral and anti-tumor agents, which may soon have medicinal applications. One compound derived from a sea sponge to treat herpes is worth US $50 to $100 million annually (Norse, 1993).

This diversity of species and ecosystem in the marine and coastal environment is the basis for the production of goods and services valuable to human communities. While we tend to measure the ocean's

value in terms of harvests of particular species used for food and other purposes, marine and coastal ecosystems provide important ecological services that are rarely perceived until they are lost. Species do not live in isolation, but they are part of and dependent upon vast ecological communities and systems. The conservation of biodiversity is therefore an important part of managing economically valuable living resources.

Actions and relevant international agreements for conservation and management of marine and coastal ecosystems

The need to devise methods to manage and protect marine ecosystems came to be recognized internationally during the course of the 1950s and early 1960s. Thus, the world conference on national parks (1962) considered the need for protection of coastal and marine areas. But the development of practical responses to this need required a legal framework – particularly, for addressing the sovereignty and jurisdictional rights of nationals to the seabed beyond the customary three-mile territorial sea. During 1958, three conventions collectively known as the Geneva Conventions on the Law of the Sea were adopted. The three conventions were convention on the continental shelf, the convention on the high seas, and the convention on conservation of living resources of the high seas.

Increasing technical capability to exploit mineral resources on or beneath the seabed and to exploit fishery resources in deep waters led to the marathon Third United Nations Conference of the Law of the Sea which was held between 1973 and 1982. During the 1970s there was increasing recognition and mounting concern regarding the regional nature of the environmental problems of the marine resources of the world. In 1971, the Convention of Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) was held, defining wetlands to conclude many coastal marine habitats. In 1972, the Convention for the Protection of the World Cultural and Natural Heritage (known as the World Heritage Convention) was held to give international recognition to areas 'of outstanding universal value' and these could include marine areas.

Also in 1972, the Governing Council of the United Nations Environmental Program (UNEP) was set up and entrusted the task of ensuring that emerging environmental problems received adequate consideration by the governments. In 1975, IUCN conducted a conference on Marine Protected Areas in Tokyo. The report of that conference noted increasing pressures upon marine environments and called for the establishment of a proper monitoring system. In 1981, a workshop was organized as part of the UNESCO Division of Marine Science COMAR (Coastal and Marine) Program to consider research and training priorities for coral reef management. An outcome of this workshop, which was held in conjunction with the IV International Coral Reef Symposium, was the publication of the UNESCO Coral Reef Management Handbook. In 1982, the IUCN Commission on National Parks and Protected Areas (CNPPA) organized a series of workshops on the creation and management of marine and coastal protected areas as part of the Third World Congress on National Parks at Bali, Indonesia.

UNESCO organized the First World Biosphere Reserve Congress in Minsk, USSR in 1983. It was recognized that the Biosphere Reserve concept is potentially applicable to the marine environment and that an integrated, multiple use Marine Protected Area can conform to all the scientific, administrative and social principles that define a Biosphere Reserve under the UNESCO Man and Biosphere (MAB) Program.

During 1987, the World Commission on Environment and Development (WCED) published its report "Our Common Future", which highlighted the importance of marine conservation. During November of the same year, the General Assembly of the United Nations welcomed the WCED report. At the same time, it also adopted the "Environmental Perspective to the year 2000 and beyond", which was developed by UNEP in tandem with the WCED report. During 1988 UNEP AND IUCN published the three volume "Coral Reefs of the world", a global directory of coral reefs prepared by then IUCN Conservation Monitoring Center. These and other publications have highlighted the serious threats that confront marine areas around the world.

All these above-mentioned activities helped to formulate the marine conservation at a global level and on a larger scale.

Convention on biological diversity

The Convention on Biological Diversity is a legally binding agreement that was opened for signature at the Earth Summit in Rio de Janeiro in 1992 with over 145 countries subscribing to it. The Convention's objectives are the conservation of biological diversity, the sustainable use of biodiversity's components, and the equitable sharing of benefits derived from genetic resources. The Convention defines biodiversity as "the variability among living organisms from all sources including, terrestrial, marine and other aquatic

ecosystems and the ecological complexes of which they are part. This includes diversity within species and between species and of ecosystem".

Under the Convention, each subscriber is required to protect components of coastal and marine biodiversity within its national jurisdiction. As defined by the law of the sea, embodied in the United Nations Convention on the Law of the Sea (UNCLOS), coastal States can exercise jurisdictional rights over vast areas of the marine realm, including inland waters, the terrestrial sea, the contiguous zone, the exclusive economic zone (EEZ), and parts of the continental shelf.

Action in the following eight general categories will be critically important in the application of the Biodiversity Convention to the marine and coastal realm. The first five areas are those identified in the Jakarta Mandate (see below). The last three actions aim to support implementation of the Mandate. While these eight areas of action are priorities in most marine and coastal ecosystems, each subscriber will select or develop its own means of implementation and priorities within these eight areas. The points for action are: 1. Institute integrated coastal area management (ICAM), including community-based coastal resource management, and prevention and reduction of pollution from land-based sources, 2. Establish and maintain marine protected areas for conservation and sustainable use, 3. Maintain sustainably fisheries and other marine living resources, 4. Ensure mari-culture operations are sustainable, 5. Prevent introduction of and eradicate harmful alien species, 6. Identify priority components of biodiversity and monitor their status and offer protection, 7. Build capacity to study and share the benefits from marine genetic resources, 8. take responsibility for trans-boundary and global threats to marine biodiversity.

Action points 1 to 5 correspond to the priorities identified in the Jakarta Mandate adopted by the second Conference of Parties (COP) in 1995. Action points 6 to 8 are recommended, as action needed to support the first five action points.

This ambitious action plan reflects the Biodiversity Convention's comprehensive approach that seeks conservation and development in every sector that affects biodiversity. Implementing this action plan require major changes in policies and programs by all parties to the convention, both developed and developing. Many countries have very limited resources to devote to reshaping policies and institutions for sustainable use and conservation; this is especially true of developing countries.

Marine biodiversity conservation in India

India has a long coastline of about 8000 km, stretching along ten states and two archipelagos. The coast is indented by a number of rivers, which form estuaries at their confluence with the sea. The complex coastal ecosystems comprise of estuaries, lagoons, mangroves, backwaters, salt marshes, mud flats, rocky shores and sandy stretches. Besides, there are three gulfs, one on the east coast, Gulf of Mannar and two on the west coast, Gulf of Kachch and Gulf of Kambath. The two island ecosystems Lakshadweep and Andaman and Nicobar add to the ecosystem diversity in India. Gulf of Mannar, Gulf of Kachch and the two island ecosystems have rich coral reefs harboring valuable marine biodiversity.

The continental shelf area is the seabed and submarine area extending from coast up to 200 m depth. The shelf has an average width of 32 km along the Andhra coast, but is wider, being 175 km, off the Maharashtra coast. The total shelf area which is divisible into inshore (up to 50 m depth) and offshore regions (between 50 m and 200 m depth) occupies an area of about 4,14,686 sq. km. The total shelf area of India represents about 0.55% of the surface area of the Indian Ocean. Exclusive Economic Zone (EEZ) is an area beyond and adjacent to territorial waters with a limit of 200 nautical miles from the base line. The Indian EEZ has 1.8 million sq. km area and represents about 2.7% of the Indian Ocean. In India the EEZ on the west coast (including Lakshadweep) constitutes maximum (42.5%) followed by Andaman and Nicobar islands (29.7%) and east coast (27.8%).

Conclusion and strategies for conservation and management of marine ecosystem

"The future historians of science may well find that a crisis that was upon us at the end of the 20th century was the extinction of the systematist, the extinction of the naturalist, the extinction of the biogeographer-those who would tell the tales of the potential demise of global marine diversity".

Carlton (1993, p.507)

Study for understanding the changes in marine biodiversity resulting from human activities, calls for ecological and oceanographic research covering a broad range of spatial scales and over long time scales for capturing the dynamics of the system. This paper proposes a fundamental 18 changes in the approach by which biodiversity is measured and studied in the ocean by emphasizing integrated regional-scale research strategies within an environmentally relevant

and socially responsible framework. This is now possible because of recent technological and conceptual advances within the ecological, molecular, and oceanographic sciences. A major goal of this paper is to improve the diversity of life in the sea, in order to improve conservation and management plans.

A well-defined set of biodiversity lessons learnt in other regions of the world is proposed for implementation in several different types of regional-scale marine ecosystems. These ideas will offer meaningful comparisons across different habitats of the causes and consequences of changes in biodiversity due to human activities. This lesson requires significant improvement in taxonomic expertise for identifying marine organisms and documenting their distribution, knowledge of local and regional natural patterns of biodiversity, and an understanding of the processes that create and maintain these patterns of space and time.

Biodiversity Conservation in India can be best managed by the following guidelines:

- Clear understanding of what is valuable
- Application of anthropogenic objectives of maintaining biodiversity so that it is of actual or possible value to humankind
- Recognition of priority of local people
- Biodiversity conservation practiced with a precisely and with well-defined targets
- Need for rapid expansion in taxonomy in order to interpret, manage, conserve and sustainably use biodiversity and the need to pull together existing data from all sources by forming an information network of all agencies in the country
- Knowledge about the extent and state of biodiversity is necessary to understand the measures of biodiversity.
- Priorities for biodiversity conservation identified to understand what values are important, which genes/species/habitat and how much biodiversity should be conserved and how should biodiversity be conserved.
- To achieve best biodiversity conservation objectives, improved methodologies practiced for different projects, more effective policy and targeted projects with highest priority.

The pressure on natural habitats associated with increasing population and economic growth will continue to lead to the loss of biological diversity. Recognition of the scale of the problem, the nature of the underlying causes, and the limited resources available to counteract powerful destructive trends will definitely lead to an optimum way of conserving the Biological Diversity of the Marine Ecosystems of India.

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Useful Macrophytes in the Vembanad Kole Ramsar Site, Kerala

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ABSTRACT

The Kole wetland of Thrissur is a part of the Vembanad Kole Ramsar site and it is one of the largest and highly productive and also the most threatened wetlands in the State. Etymology of "Kole" refers to the peculiar type of paddy cultivation carried out from December to May and this Malayalam word, local language of this state indicates bumper yield of high returns, in case floods do not damage the crops. The paper deals with the economically important macrophytes used by local people in and around the Kole wetlands for their daily life and enumerates eighty plant taxa of economic importantance occurring in the Kole wetlands. Brief notes the utilization of the resources, mode of preparation and administration of the drugs also are presented. The use classes includes as food, fodder, medicine, mats and baskets, thatching and house hold materials, green manure, feed for fishes and ducks.

Introduction

Macrophytes are the integral components of wetlands, which are amongst the most productive ecosystems on the earth (Nandan and Singh, 2004). They are emerging as one of the most potential resources due to their high productivity and easy availability for utilization as food, fodder, medicine, fiber, ornament, paper, pulp, basketry materials, thatching materials, fuel wood, fencing materials etc. A perusal of literature (Inasu, 1991; Khader, 1993; Anon. 1992 and 1993; Johnkutty and Venugopal, 1993; Sivaperuman, 2004; Sivaperuman and Jayson, 2005) shows that there is no information regarding the uses of these valuable resources of the area. Therefore, an investigation has been made to explore their utility and economy in the life of people inhabiting the adjoining villages of the Kole wetlands of Thrissur.

Study Area

Topography

The Kole wetlands of Thrissur lie between 10º 20' and 10º 40' N latitudes and 75º 58' and 76º 11' E

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longitudes. The Kole wetlands with an extent of 13,632 ha are spread over Thrissur and Malappuram Districts in Kerala State. They extends from the northern banks of Chalakudy River in the South to the southern banks of Bharathapuzha River in the North. Eastern side of Kole wetlands is the Thrissur town and western side extends up to Arabian Sea. The Kole wetlands are low lying tracts located 0.5 to 1 m below the MSL and they remains submerged for about six months in a year. The River Keecheri and Karuvannur bring the floodwater into the wetlands, which finally empty into the Arabian Sea.

Climate

The climate around the Kole wetland is monsoonic. It is characterised by hot-dry summer (March to May), moist-rainy (mid- June to October) and sub humid winter (November to February). The average annual rainfall is 3,200 mm and the temperature varies from 28º C to 31.5º C.

Importance

Etymology of "Kole" refers to the peculiar type of paddy cultivation carried out from December to May and this Malayalam word indicates bumper yield of high returns if floods do not damage the crops (Johnkutty and Venugopal, 1993). The Kole wetland is regarded as the rice bowl of the central Kerala of substantial socio-economic, and cultural value. The people living in and around the Kole wetlands are fewer and belong to four occupational categories such as Agriculture, Fisheries, Poultry and Animal, Husbandry. Agriculture is the major occupation of the people of the Kole wetlands and ninety per cent of the people are practicing agriculture, mostly paddy. Kole wetlands are generally rich in their floral and faunal diversity. The Kole wetland is a part of the Vembanad-Kole wetlands; it has been identified as one of the nineteen Ramsar sites in India, declared in the year 2002.

Materials and Methods

The present study was conducted from November 1998 to August 2007. The floristic composition was noted by making visual observations and specimen samples were collected at different reproductive stages during different seasons to prepare herbarium specimens to their correct identity. The specimens were critically examined and identified with the help of available field keys, taxonomic revisions, monographs and floras viz. Flora of Madras Presidency, Gamble (1915-36); Indian Flora, Hooker (1872-97); Flora of Tamil Nadu and Carnatic, Mathew (1981-1984 and 1991). The local people were interviewed to gather information about the utilization or economic aspects of these plants/ parts/products for their daily lives. Neighbouring villages also were visited to assess the prospects of these plants from time to time.

Results and Discussion

The study brings to light that at least eighty macrophytes growing profusely in the Thrissur Kole wetlands are utilized by the native folk residing in and around the Kole wetlands. These macrophytes collected are categorised into diverse uses (Table 1). The utilization includes as food (Young shoots of *Ipomea aquatica*, flower, rhizome and fruiting torus of *Nymphae stelleta, N. lotus, N. pubescens);* fodder *(Commelina benghalensis, Scirpus grossus);* medicine *(Ammania baccifera, Ludwigia repens)* mats and baskets *(Pandanus furcatus, Cyperus papyrus);* thatching and housing materials *(Arundo donax, Eleocharis geniculata);* green manure *(Ludwigia parviflora, Trapa bispinosa)* feed for fishes and ducks *(Utricularia flexuosa, Hydrilla verticillata)*. Among the collected plants, 34 plants are used in medicine, 11 plants as fodder, 10 as food, 6 as food and medicine, 2 as fodder and medicine, 5 for feed for ducks and fishes, 5 for baskets and mats, 2 for thatching and housing materials, *Spilanthus calva* used as fish poison and *Nymphoides indicum* used to gather a yellow dye for ornamentation. These uses are mostly confined to household purposes.

The commercial exploitation of macrophytes for medicine *(Eclipta prostrata, Cardiospermum halicacabum, Glinus lotoides)* fish food *(Utricularia flexuosa, Hydrilla verticillata)* and multipurpose materials like *(Arundo donax, Pandanus furcatus,*

Saccharum spontaneum) solves their financial burden to a great extent. The efficient utilization of available resources to an optimum level makes the life of native people prosperous in general. But abundant growth of these plants in cultivated area cause great economic lose to the farmers and they spend more time for weeding operations and for applying herbicides to control the plants. The discriminate use of agricultural chemicals like insecticides, herbicides, inorganic manures etc. lead to ecological problems due to persistence of these chemicals in the system.

The present study also indicates that the floral diversity of the wetlands need be conserved, since extreme changes in climatic factors and natural disasters like spate coupled with anthropogenic disturbances tend to affect the biodiversity in an area. On account of that, this valuable water body requires immediate conservation and management so as to meet the material needs of the local people now and for all times to come.

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Sl. No.	Species Name	Family	Category	Uses
1	*Nymphaea lotus* Hk. f. & T.	Nymphaceae	Floating herb	Flower and Rhizome Cooked as vegetable
2	*Nymphaea pubescens* Willd.		Floating herb	Fruting torus and Rhizome Cooked as vegetable
3	*Nymphaea stellata* Willd.		Floating herb	Rhizome raw with slight sweet taste
4	*Cleome viscosa* L.	Capparidaceae	Herb	Leaf paste applied on wounds and ulcers and a poultice of pasted seeds is used to relieve chronic joint pains
5	*Drymaria cordata* (L.) Willd. *Ex* Roern & Schult	Caryophyllaceae	Herb	Leaves used as fodder
6	*Cardiospermum halicacabum* L.	Sapindaceae	An annual climber	The herb is used for hair-oil preparations for curing dandruff, alopecia, and for darkening hair; the aqueous tract is used as a cooling hairwash. The leaves are emetic and stimulant and in powdered form are used externally for healing wounds
7	*Cassia occidentalis* L.	Fabaceae	Woody herb	Leaves are used both externally and internally to treat scabies, itches and ring worm.
8	*Crotalaria juncea* L.		Under shrub	Seeds are used as purgative
9	*Mimosa rubicaulis* Lam		Straggling shrub	The crushed leaves are applied to relieve bums
10	*Mimosa pudica* L.		A diffuse prickly	Leaves used as fodder and leaf paste applied on forehead to herb relieve head ache

Sl. No.	Species Name	Family	Category	Uses
11	*Ammania baccifera* L.	Lythraceae	A glabarous erect herb	A decoction of the leaves used as external remedy for skin diseases
12	*Ammania multiflora* L.		A glabarous erect herb	The ashes of the plant are mixed with coconut oil and applied to cure herpetic eruptions
13	*Ludwig.ia repem*' Roxb.	perennial herb	A semi shrubby erect	A decoction of plant is used as purgative and vermifuge
14	*Ludwigia parviflora* Roxb.	Onagraceae	A semi shrubby erect perennial herb	Entire plant used as green manure
15	*Trapa bispinosa* Roxb.		Floating herb	Entire plant used as green manure
16	*Trianthema portulacastrum* L.	Aizoaceae	Herb	An infusion of the roots are given internally to constipation, strangury, dropsy and antidote to alcohol poisoning
17	*Glinus lotoides* Linn.	Molluginaceae	A prostrate herb	The dried plant is used as purgative and the juice from the crushed plant is used to treat itches and other minor skin irritations
18	*Mollugo pentaphylla* L.		An erect slender annual herb	The bitter leaves are considered antiperiodic and they are warmed after smearing with oil and applied to the ear to relieve ear ache

Sl. No.	Species Name	Family	Category	Uses
19	*Borreria articularis* (L.F.) F.N. Williams	Rubiaceae	Procumbent herb	A decoction of the herb is used to treat head ache and roots is used as an mouth wash and seeds are used in the treatment of dysentery, fever and coryza
20	*Oldenlandia corymbosa* L.		Sub erect annual herb	The powdered plant is eaten with curd to treat venereal diseases and the juice is applied to palms and soles to relieve burning sensations associated with fever
21	*Acanthospermum hispidum* DC.	Asteraceae	A branched herb	The crushed herb is used in the form of a paste to treat skin ailments; an essential oil extracted from the leaves possesses antibacterial and antifungal properties
22	*Ageratum conyzoides* L.		A polymorphic, aromatic annual herb	The leaves are considered as stypic and the pounded roots is taken daily for a week after menstruation to treat dysmenorrhoea
23	*Eclipta prostrata* L.		An erect much hairy herb	The plant juice is administrated with aromatics to treat branched jaundice and fevers. The leaves are used a vegetable
24	*Emilia sonchifolia* DC.		A erect herb	The crushed leaves are used externally to promote healing of breast abscesses and the leaves are rubbed on the fore head to relieve head aches
25	*Sphaeranthus indicus* L		An aromatic herb	The leaf juice boiled with milk and sugar, is prescribed for cough
26	*Spilanthus calva* DC.		An annual herb	Crushed plant is used as a fish poison
27	*Synedrella nodiflora* (L.) Gaertn.		An erect herb	The juice of the leaves are used to treat ear ache

Sl. No.	Species Name	Family	Category	Uses
28	*Tridax procumbens* L.	Asteraceae	A hispid procumbent herb	The leaves are cooked and eaten as vegetable
29	*Vernonia cinerea* Less.		An erect herb	Made in to a paste with limejuice, the seeds are used for destroying lice. The leaf juice is given for treatment of amoebiasis
30	*Nymphoides cristatum* Gmel.	Menyanthaceae	Floating herb	Flowers used as vegetable
31	*Nymphoides indicum* Thw.		Floating herb	Flowers mixed with lime yield a yellow dye
32	*Convolvulus arvensis* L.	Convolvulaceae	Twining herb	The roots are used as purgative
33	*Ipomea aquatica* Forsk.		Rooted floating	Leaves are used as vegetable
34	*Utricularia aurea* Lour.	Lentibulariaceae	Rooted floating	Ash of entire plant mixed with gingelly oil applied on wounds
35	*Utricularia flexuosa* Vahl.		Rooted floating	Entire plant used as feed for fishes
36	*Utricularia stellaris* L.		Rooted floating	Entire plant used as feed for fishes
37	*Hygrophila auriculata*	Acanthaceae (K. Schum.) Heine	A stout herb	The decoction of the plant used to treat rheumatism
38	*Leucas cephalotes* Spr.	Lamiaceae	Annual herb	Leaf juice with honey is a remedy for cough and cold
39	*Alternanthera sessilis* R.Br.		Annual herb	Young shoots used as cooked vegetable
40	*Digera muricata* (L.) Mart.		Annual herb	Paste of seeds and flowers given internally to treat urinary discharges

Sl. No.	Species Name	Family	Category	Uses
41	*Hydrilla verticillata* Royle	Hydrocharitaceae	Anchored submerged	Entire plant used as feed for fishes and ducks
42	*Limnocharisflava* Linn.		An aquatic herb	Whole plant feed for ducks
43	*Vallisneria spiralis* Linn.		Anchored submerged	Entire plant used as feed for fishes and ducks
44	*Eichhornea crassipes* Solms.	Pontederiaceae	Free floating herb	The whole plant juice used as the remedy for emaciation
45	*Lindernia hyspoides* Thw.		Free floating herb	Whole plant Used as green manure in coconut mixed plantations
46	*Monochoria vaginalis* Kunth.		An aquatic herb	The entire plant, excluding the roots, is eaten as vegetable The root is chewed to relieve tooth ache
47	*Commelina benghalensis* L.	Commelinaceae	Emergent	Shoot used as fodder
48	*Cyanotis axillaris* R.& S.		Emergent	Shoot used as fodder
49	*Pandanusfurcatus* Roxb.	Pandanaceae	Densely branched shrub	Leaf fibre used for making mats
50	*Typha an~stata* B. & Ch.	Typhaceae	Herb	The young shoots, rhizomes and inflorescence are edible
51	*Typha bispinosa* Hk.f.		Herb	The young shoots, rhizomes and inflorescence are edible
52	*Pistia stratiotes* L.	Araceae	Floating herb	The whole plant juice used as the remedy for emaciation and blood purification

Sl. No.	Species Name	Family	Category	Uses
53	*Lemna f!;ibba* Linn.	Lemnaceae	Floating herb	Entire plant used as cattle feed
54	*Lemna polyrrhiza* Linn.		Floating herb	Entire plant used as cattle feed
55	*Potamogeton indicus* Roxb.		Herb	Leaves edible
56	*Zanichella palustris* Linn.		Annual herb	Seed powder is used given women after delivery to increase breast milk.
57	*Najas indica* (Willd.) Cham.	Najadaceae	An annual/ perennial herb	A paste of the roots is used externally to promote healing wounds
58	*Blyxa talboti* Hook. f.	Cyperaceae	An annual / perennial herb	Stem used for making small baskets and carpets
59	*Bulbostylis barbata* (Rottb.) Kunth ex Clarke		Herb	Shoot used as fodder. Rhizome paste as stomachic
60	*Cyperus bifax* Clarke, Bull.		Annual herb	Stem split used for weaving baskets
61	*Cyperus haspan* Linn.		Annual herb	Dried stem used for making mats
62	*Cyperus iria* Linn.		A glabrous annual herb	A plant is considered as stomachic
63	*Cyperus papyrus* Rottb.		An annual / perennial herb	Stem is used for making carpets and knots
64	*Cyperus rotundus* Linn.		An annual/ perennial herb	A paste of the roots is used externally to promote healing wounds

Sl. No.	Species Name	Family	Category	Uses
65	*Eleocharis geniculata* (L.) R.& S.	Cyperaceae	An annual/ perennial herb	Entire plant used for thatching roofs
66	*Kyllinga brevifolia* Rottb.		An annual/ perennial herb	Root tuber paste is a remedy for stomach disorders
67	*Rhynchospora corymbosa* Vahl.		An annual/ perennial herb	Shoot used as fodder
68	*Scirpus grossus* Linn.		An annual herb	Shoot used as green forage
69	*Arundo donax* L.	Poaceae	A tall grass	Inflorescence is used for making broomstick. Dried stem used as fuel wood and also used as material for fencing
70	*Coix lachryma-Jobi* L.		A stout grass	The plant and its juice are given to treat ulcers. Root juice used to treat menstrual disorder.
71	*Cynodon dactylon* Pers.		A creeping perenial	Infusion of the plant used as a remedy for fresh cuts and grass wounds
72	*Dactyloctenium aegypticum* (L.) *Beauv*		An annual herb	The whole plant is used to treat worm infestation and wounds
73	*Dimeria pubescens* Hack.		Emergent	Forage
74	*Echinochloa colona* Link.		Emergent	Shoot used as forage
75	*Echinochloa crusgali* Beauv.		Emergent	Shoot used as green forage

Sl. No.	Species Name	Family	Category	Uses
76	*Echinochloa sta,f!;nina* Beauv.	Poaceae	Emergent	Shoot used as green forage
77	*Saccharum spontaneum* L.		A tall erect perennial grass	A paste prepared from the root is mixed with black pepper is applied to relieve
78	*Azolla pinnata* R. Br.	Azollaceae	An aquatic herb	Used as cattle feed
79	*Marsilea minuta* Linn.	Marsileaceae	An aquatic herb	The whole plant is eaten as vegetable. The plant juice used as eye drop for the treatment of eye diseases.
80	*Ceraptopteris thalictroides*	Parkeriaceae (L.) Brongn.	A stout herb	The fronds are used as a poultice in skin complaints. The expanded fronds are boiled and eaten as vegetable, while the un expanded fronds are eaten raw as a salad vegetable

Environmental Geography Education for Sustainable National Development

G.C. Bhattacharya*

ABSTRACT

Environmental Geography Education is the call of the day through which we can ensure sustainable national development in raising the level of awareness and creating increased sensitivity towards our environment. In this paper, the objectives of environment-based geography education are outlined. The paper also indicates the procedure to be followed and offers some useful suggestions.

Key Words: Environmental Geography Education, Sustainable, National Development.

The term national development indicates growth and progress of a nation in multi-dimensional and multifarious ways experienced through qualitative and quantitative enhancement resulting in improved status and situation. It is being considered in terms of economic prosperity, social uplift and social change. But often, such progress may not be accepted as a real one though it may result in some positive development. For example, industrial development may bring economic prosperity due to enhancement in production. But if it is causing severe environmental pollution, then the developmental aspect may be nullified with reference to sustainability of development. Most of the Indian rivers like Kali at Meerut, Jamuna at Delhi, Ganga at Kanpur, Gomti near Lucknow, Dajora at Bareilly, Damodar between Bokaro and Panchet, Hoogly near Kolkata, Sone at Dalmiyanagar, Cauvery in Tamilnadu and Bhadra in Karnataka are all severely polluted due to the establishment and functioning of many mills, industries and power stations. Enrichment of aldehydes, ammonia, carbon monoxide, chlorine, nitrogen oxides, sulphur dioxide and suspended particles of ash, soot, smoke and dust in the air causes pollution and harmful side effects. Mills and industries creating environmental pollution are now being considered as responsible for creating negative impact on the sustainability of development. The modern means of transportation is also causing, to some extent, the same impact and are being labelled as the agents of pollution. On account of this, the gaseous fuel is now being preferred especially in the metropolitan areas. Doval(1992) has noted that the air of New Delhi contained 350-500 micrograms/m3 of suspended particles,15-20 micrograms/m3 of sulphur dioxide and 10-15 micrograms/m3 of oxides of nitrogen during the summer months and the extent of noise pollution was much beyond the prescribed tolerance limits. Similar is the case of cement, leather and other industries. Even construction of dams and power stations are also not found beyond such disputes causing harm to the natural and consequently to socio-cultural environment of human beings. Construction of the Tehri hydroelectric power project in India has raised the possibilities of natural hazards like earthquakes and ecological imbalances. Construction of Narora atomic power plant in the zone of alluvial soil and located in the earthquake belt of the country, is raising a number of issues like possible radiation during natural hazards.

Thus we can say that the technological development may provide us with enormous power and ensure economic prosperity but at the same time, it may result in unimaginable environmental destruction such as global warming, ozone layer depletion, acid rain, soil degradation, deforestation and disappearance of many plants and animal species from the biodiversity. So, it is understood that due to development of raw-resource based economy in most of the developing countries, there is a severe increase in pressure on their limited natural and other resources. The present crisis is not due to lack of resources and its basic scarcity but on account of unjust exploitation and unequal distribution of such resources (Chiappo, 1978). It is mainly the result

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of avaricious profit seeking. The cause of the ecological problems is not essentially hunger but over-consumption, wastage and short-sighted commercial greed of the civilised world.

Development

The development of any kind in itself bears no negative value but the policy behind is of supreme importance. It is the policy of profit maximisation that has actually led to the environmental crisis. Schuyler (1983), accepted that the growth rate of population, steady depletion of natural and other non-renewable resources and the stress on the environmental assets constitute the basic problems. But Saxena (1996) boldly believed that the kind of development that we have had, can neither take us very far nor can it ensure the survival of human race for a longer duration of time on earth. Meadows, *et.al*.(1972) concluded by asserting that if the present growth trend in world population, industrialisation pollution, food production and resource depletion continued without any change, then the limits to growth will be reached sometimes within the next one hundred years and may even cause sudden decline in both population and industrial production. Thus, they want to establish the conditions conducive for economic stability consistent with sustainable ecological balance for future development. The state of global equilibrium would be designed so that the basic material needs of each and every person on earth may be fulfilled and offered an equal opportunity to realise his/her individual human potential.

Sustainable development

Any development which is favourable to the ecological and economic balance as well as consistent with nature may be defined as sustainable. United Nations Environment Programme (1987) it was specified that sustainable development should meet the needs of the present without compromising with the ability of future generation to meet their needs …on the basis of prudent management of available global resources and environmental capacities as well as the rehabilitation of the environment previously subjected to degradation and misuse. Thus, Technical Committee on Cognitive Networks (TCCN), UNEP and Water Watch Penang (WWP) (1991) attempted to define sustainable development as improvement of the quality of human life while living within the carrying capacity of supporting eco-system. The development which may destroy the environment or culture and social traditions in any way, may not be taken as sustainable. That alone is sustainable which may, in real sense, conserve and preserve to produce sustainable benefits. In the World Commission Report on Environment and Development (1987), it was specified that the sustainable development contains two key concepts – the essential needs of the poor of the world and the limitations of technology and social organisations imposed on the ability of the environment to meet the present and future needs. Saxena (1996) mentioned that the development is to be planned in such a manner that it meet the needs of all sections of the society and provide opportunity to all to satisfy their aspiration for better life. Disinger (1990) characterised such development as sustainable which is essentially based on participation, organisation, education and empowerment of people than that of being merely production centred. According to him, it is required to be appropriate to environment, resource and culture, history and social system as well as to technology, equitably fair and just in terms of distribution as well as a balance establisher between freedom and order, groups and individuals, work and leisure and settlements and nature.

Thus, it is obvious that we are not only in need of development which is merely profit and gain oriented but sustainable in terms of ecological balance and existence of human culture and traditions too. For this purpose, education may certainly be considered as a powerful instrument in general and environmental geography education, in particular which indeed is an integrated form of environmental aspects in geography education related with global ecological system.

Environmental Geography Education

To establish an integration between the traditional geography education and the environmental aspects of it in formal and/or in other settings, it was considered as essential to design curriculum framework in such a way that it may enhance the possibilities of being more harmonious living with environment. Such of a programme, is required to compromise between the two, highlighting over the formal and non-curricular approaches. Nagchowdhary and Bhatt (1987) emphasised upon the balance establishment between technosphere and biosphere that could be achieved through by turning away from the technological goals of defence preparedness to the peace oriented, resource conserving developmental targets. Knamiller (1983) suggested that environmental education curriculum for sustainable development including skills, concepts and facts especially in the context of local specific environment instead of highlighting over the knowledge based contents more.

To impart such education, cultivation of knowledge and use of the process of scientific observation by the learners may be considered as essential in place of using the good old pattern of cramming of the content matters for mere memorisation of the fact and figures. It is the geography education which plays a significant role in fostering the power of observation, ability to gather relevant information and to examine critically over the possible alternatives to find out solutions of various problems and issues concerned with the communities and societies. It is also required to make decisions consciously as well as to follow up those decisions taken through action based plans. Thus, the environmental issue linked geography education may be in a position to replace the existing pattern of knowledge based schooling with the help of activity and action oriented programmes. It is said that without such efforts, the environmental geography education may also be converted into a mere school or university level discipline like others including mathematics and social sciences. In such of a situation, central focus may be given upon learning of concepts, skill components and some related fact and figures basically through curriculum dependent activities to be performed in classrooms. The very nature of curriculum dependent education has widened the gap between educational institutions and people and their societies which reinsure inculcation of inability to fulfil the environmental prerequisites while encouraging consumer orientedness. In terms of establishing better ecological balance and promoting interdependent existence through environmental geography education, rigid curriculum and achievement of high academic outcomes through it, may be no longer of any use and thus will certainly required to be discarded in the new century.

Ecological Existence

The philosophy behind the concept of environmental geography education is concerned with the existence of human beings in terms of sustainable ecological balance in nature. This may be specified as ecological existence of humankind. Ecology, as Tansley (1935) defined is the discipline or study of the interrelationship among organisms and between organisms and their environment. Thus, establishment of a balanced interrelationship among various ecological units may be considered as the ecological balance, in a layman's terminology. The nature has developed it among the ecosystems, irrespective of its terrestrial or aquatic nature for maintenance of its dynamic harmony within the interacting abiotic components like climatic, edaphic and physiographic factors as well as biotic components such as producers, consumers and decomposers linked through the systems of energy and nutrients or materials flow. For example, plants are basically the producers; monkeys, deers and elephants are the primary consumers; dogs, cats, leopards are the secondary consumers and lions are the tertiary consumer, in a specific food chain. In this chain of food or food webs of more complicated network; energy flow occurs from producers to the tertiary consumers with diminishing return of the magnitude of energy, as the remaining energy during consumption goes back to the environment again. Any imbalance in the chain of energy flow and elements flow like in the cycles of water, nitrogen, carbon dioxide etc. may cause a disastrous effect upon the existence probability and survival of organisms on the globe of the earth. While saying this, we are inevitably becoming concerned with the physical or bodily existence for which each and every organism used to do some efforts, consciously or sub-consciously. Basically the western philosophers used to consider such existence as of prime importance through the struggle for existence that promotes the theory of survival of the fittest and advocates becoming the fittest and strongest to face the hard competition and life struggles. Certainly, it is important, especially in the world of sub-human creatures that are without any ability to think, discuss and acquire knowledge and wisdom. On the other hand, when we consider and believe in the idea of social animal, it is admitted that the human beings are also a sort of animal who used to learn to suppress their animal instincts and behave in a rational and socially approved way. Though this ideology also is not in a position to uplift the human beings from the stage of animal to superior living beings but the concept of social existence is generated through it, as people are expected to consider the expectations and norms of the society to maintain their social existence and certainly to sacrifice their freedom also, up to some extent as and when needed. Here, it is considered that the existence of an organism is dependent upon the members of the group or community. Thus, one should live and let others to live with the same dignity and freedom as desired for ones own self which is perhaps, the motto of such sort of existence. Some animals also used to live in groups to form their own community. A number of people, religious groups and nations especially of the South East Asia do believe in this type of philosophy, based on non-violence and peace which is considered as require for the development of group feelings, social outlook and positive attitude towards life. At this stage of co-existence, man used to act as a civilized animal who not only lives for him/herself but also for others for the sake of enhancement of probability of

continuation of life on the globe of the earth by more than fifty percent. But in this proposition, hymans are yet required to cross the level and limits of animals living aside all the passions of selfishness, materialistic gain and achievements, craze for physical and sensual pleasures etc.

This may not thus be the last and ultimate goal of life for humankind. The third and highest order of existence is more close to the nature and in Indian ideology, termed as Natural or Spiritual Existence when one not only aspires to get benefit from all others but also to sacrifice even at the cost of ones own existence. To let others live and prosper at the cost of own life and living is the fundamental idea behind such proposition where consumption is not only the target but natural harmony setting and causing of ecological balance may be the ultimate goal. In such of a situation, not only the strongest and fittest but the weakest and most unable and unfit one may also be able to sustain own existence and enjoy equal rights due to sacrifice of others and of one who is the strongest. The basic idea is related with the believe that each and every living being possess a spiritual realm of existence too besides the external or physical one which is non perishable and of permanent nature. In the society, where the physical and social existence used to be considered as the highest in order, often the eternal values ,traditions and humanity based considerations are usually being disrupted and degenerated to cause ultimate ecological imbalance and eventually top impose existential challenges before the humankind. It is only possible thorough sacrifice and love that man can cross the stage and limitations of animal instincts, to realise the spiritual eternity of soul and consequently eternal self.

The environmental geography education is based upon this highest order of spiritual existence and may ensure its acquisition or realisation through training, with the motto of service above self. Recognition of one's own entity and superior existence through scientific approaches and procedures is the basic purpose of implementing this philosophy and thus of environment based geography education, the objectives of which may be specified as:

- ❖ to enable one to be critically aware towards the issues concerned with community, society and human rights,
- ❖ to inculcate the ability to make decisions consciously and to take stand accordingly in the process of development,
- ❖ to explore the alternatives for setting the social requirements based issues, actions, norms and activities imposing challenges on ecological needs and realities,
- ❖ to enable one to acquire problem solving ability through the positive attitude formation to serve others including subhuman creatures with equal sense of honour and sympathy,
- ❖ to enable one to be eco-friendly and agent of environmental purification for nature and
- ❖ to develop environmental ethics among the persons concerned.

Procedure

On the basis of the above objectives, the steps to act may be defined as identification of the problem/issue, analysis of its various aspects, enquiring into those aspects and situations, gathering of fact and figures concerned with ecology and environment, recording and analysing information and data collected for the purpose of having a concluding solution as well as for the purpose of decision making, investigation based learning through participation in community activities and actions to set the ecological balance and environmental order, values, ethics etc. To follow the procedure, it is obvious that revitalisation of the existing schooling pattern is inevitable on one hand and of geography education curriculum on the other, through amalgamation of environmental approach and geography education for the service of community and society of human as well as of subhuman level.

Educational Implications

Many educational implications are expected and among them one is related with inculcation of environmental ethics among future generation following its three dimensional model. In this model, it is specified that ethics may possess three main aspects of sensitisation, reverence and affection. To be environmentally ethical, one has to develop a strong sensitivity among him/her towards environment. Now, people are much aware of environmental issues but rarely sensitive to those issues. One is knowledge bound and the other is action oriented in nature, basically concerned with feelings. Secondly, one must develop a sense of reverence to the nature and environment so that may apply the mental ability of judgement and decision making while taking any adverse decision against it. Affection is related with sense of affection to the nature or environment as one may used to feel with own children. If all three dimensional aspects are being developed well, one may become ethical towards environment.

Measures Suggested

Through a small group opinion survey, including twenty five geography teachers and teacher educators selected on

random sampling basis, to know about the way to implement environmental geography education, the following measures were accounted analytically:

(i) 31 percent of the respondents was of the view of setting free and flexible academic and administrative as well as organisational climate to implement environmental geography education in educational institutions while arranging teaching sessions preferably in biosphere rather than in closed classroom setting,

(ii) 25 percent of them suggested for replacing the existing knowledge based curriculum of geography education through provision of learning experience and activity oriented practicum sessions,

(iii) more than 80 percent of the respondents were found in favour of nonformal and supportive audio-visual media based packages to illustrate and explain the philosophy of spiritual existence and the related human values to the learners along with ecological requirements and biodiversity,

(iv) 35 percent of the experts was in opinion that some provisions may be there related with training in ecological balance and awareness development activities through environmental geography education while ensuring some measures to control and minimise biocides,

(v) more that 50 percent of the opinion giving experts considered the use of observation, field exploration and heuristic techniques essential for the study of nature and organisation of intensive programmes through environmental geography education to stress over the significance of preservation and protection of natural vegetation cover on the surface of the earth which is diminishing at a fast rate to serve the greed of human beings much beyond the limit of their needs,

(vi) Lastly, remodelling of existing teacher education programme was also recommended by the group of experts to enable the prospective geography teachers to serve the needs of future generation through environmental geography education and to motivate them to inculcate environmental ethics among the learners so that observation of environmental rights may be possible.

Conclusions

It may be concluded on the basis of the suggestions and recommendations obtained that the existing geography education is expected and required to be overhauled in tune of the ecological considerations and needs of the society and community of a democratic country while ensuring sustainable development on the way of achievement of quality in educational endeavours .For making such attempts fruitful, implementation of environmental geography education is very much needed so that at the same time, problems of natural consequences and disasters of extreme order may be solved which may impose challenge on the very existence of not only mankind but of all organisms on the globe of the earth in near future. Along with the existence of physical and social nature, one that of spiritual may also be brought into the notice of all members of the society to enable them to be involved in development of proper environmental ethics and establishment of the motto of service above self.

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