CHAPTER 8

CONSERVATION AND MANAGEMENT OF MANGROVE HABITATS AND ASSOCIATED OYSTER BEDS

8.1. Introduction:

Mangrove ecosystem forms one of the ecological sensitive marine habitats (ESMH) at the niche between fresh water and marine environment. It requires more attention, from protection and conservation point of view, due to its ecological and economic importance as a coastal resource (Kathiresan & Qasim, 2005). The ecological importance of mangrove comes from protecting the coast from cyclones, strong wave action, floods, see level rise, solar UV-B radiation, green house effects and coastal erosion. The network system of mangrove roots traps the sediments, thus contributes to the stability of the shore and acts like a nutrient and metal sinks. The habitat provides the breeding and nursery grounds for many of the marine (crustaceans, molluscs, fin fishes, etc.) and terrestrial animals (birds, bees, and other wildlife). Being rich in organic matter, it forms an important source of food and plays vital role in the energy transfer in the near shore and estuarine water.

However, during recent decades, mangrove resources have been over exploited, particularly reclaimed, by diking, draining, or land filling, for residential, commercial, industrial, agricultural and real estate purposes.
The anthropogenic pressures are continued though these habitats have been protected vide CRZ (Coastal Regulation Zone) Act of 1990. The destruction has led degradation or loss of habitats, and dependant households are deprived of their livelihoods. Constantly increasing human interferences drew global attention to this sensitive environment for protecting it from over exploitation, and conservation and restoration.

India follows set of legal norms, based on the recommendations of NATCOM (National Mangrove Committee) through MoEF (Ministry of Environment and Forest) for effective management of mangroves. The present chapter discusses utilization and management practices of these natural habitats, in general.

8.2. Usage of the mangrove ecosystem in Goa:

Mangrove habitats along with a associated biota are of extreme importance, as a large coastal populations depends on these resources for their livelihood. These resources have been utilized traditionally in Goa, for different purposes such as:

8.2.1. Timber and Firewood:

Rural communities commonly utilize mangrove trees for timber, in minor constructions, such as fencing and as stakes for fishing nets and firewood. This continuous indiscriminate cutting of mangroves has led to the disappearance of large mangrove areas from certain localities.
8.2.2. Fodder:

Domestic cattle and goats feed on the leaves and seedlings of the mangrove trees. Buffalos graze on Perteresia beds, damaging associated mangrove seedlings, which delay the process of mangrove formations (Jagtap, 1985).

8.2.3. Salt Pans:

Mangrove from upper intertidal regions have been reclaimed and utilized for salt pans. The tidal brackish water is allowed to inter constructed ponds and trapped inside by using sluice gates. The water is dried by evaporation and salt is produced (Plate 8.1a).

8.2.4. Fisheries:

Mangrove water logged areas and waterways are being traditionally utilized for capture fisheries, shell fishes and crustaceans (Plate 8.1b,c,d). Fish farming in the mangrove region is also common in Goa. They are of two types, either permanent ponds or alternate ponds used as paddy fields and fish farms (pisciculture). State fisheries department has developed aquaculture ponds reclaiming major mangrove region from Chorao Island. Similarly, number of private aquaculture industries has initiated aquaculture activities in the close vicinity of mangrove regions in Goa.
Plate 8.1. Utilization of mangrove habitats from Goa for: (a) salt pans, (b) fishing activities, (c) exploitation of oysters, and (d) aquaculture farm.
8.2.5. Agriculture:
Several coastal marshes and mangrove areas have been reclaimed for agricultural purposes, particularly for growing paddy and vegetables. These low lying areas are locally called "Khazan lands" (Noronha and Nairy, 2003). The upstream regions of mangroves have been reclaimed and used for coconut plantations.

8.2.6. Manure:

The mud from the mangrove ecosystem is rich in minerals, humus and nutrients. It is utilized for baddy field and coconut plantations. Mangrove leaves and small branches are spread, dried and burnt, the ash then used as fertilizers.

8.3. The Coastal Regulation Zone (CRZ):

The MoEF, Central Government of India, is constantly instrumental for strengthening existing policies for protecting and improving the quality of the coastal environment. The legal system of coastal zone management in India came into force in 1991 (Anon, 1999). The Coastal Regulation Zone (CRZ) notification, under the environment Act, is one of the major norms limiting the activities in the coastal zone. It includes various laws for regulation of anthropogenic interferences by permitting environmental friendly developments.
Coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters, which are influenced by tidal action (in the landward side) up to 500 m from the high tide line (HTL) and the land between this HTL and LTL (low tide line) is declared as CRZ. The CRZ notification classifies the zones into four different categories for the purpose of regulation (Leelakrishnan, 1999), and includes following zones (Table 8.1):

8.3.1. CRZ-I:

It consists of ecologically sensitive and important areas, and includes mangrove wetlands, national parks, sanctuaries, wildlife habitats, places of outstanding natural beauty or historical heritage. Areas close to breeding and spawning grounds of fish, those likely to be inundated due to sea level rise (consequent upon global warming), and the area between LTL and HTL are covered under this category. New construction are not permitted within 500 meters of the HTL of CRZ-I. However, effluent or waste water discharge, for cooling process with sea water or construction activities for laying of oil or gas pipelines are allowed between LTL and HTL.

8.3.2. CRZ-II:

CRZ-II indicates sufficiently developed urban area with facilities of drainage, approach roads, water supply and sewerage mains. The new constructions are not permitted seaward side or along the existing roads or existing buildings. However, new constructions are permitted landwards, subject to regulations and existing norms of Floor Space Index/Floor Area Ratio by
the Town and Country Planning Department. Reconstruction of authorized buildings is also governed by these norms. The design and construction of the new buildings have to be maintained consistent with the surrounding landscape and local architectural style.

8.3.3. CRZ-III:

The relatively undisturbed areas are included under this category. It includes coastal zones in developed or undeveloped, and areas within municipal limits or in other legally designated urban areas, inadequately developed. Area within 200 meters from the HTL is declared as a No Development Zone (NDZ), where no constructions other than repairs of existing authorized structures are permitted. The designated coastal zone authority may allow limited construction for water supply, drainage, and sewerage facilities for local inhabitants. Agriculture, horticulture, gardens, pastures, parks, play fields, forestry and salt manufacture from seawaters are also permissible. Traditional rights and customary uses of existing fishing villages are recognized but permission to construct or reconstruct village units have to be strictly governed in accordance with certain set norms. Construction is allowed for permissible activities under the Notification.

8.3.4. CRZ-IV:

The zone consists of coastal stretches in Andaman and Nicobar Islands (Bay of Bengal) and Lakshadeep Islands (Arabian Sea). It also includes
small islands that do not form part of the other three categories. Norms of regulation are provided separately for Andaman and Nicobar and Lakshadeep, as well as other small islands. A few norms are common to all islands. Use of corals and sand are banned for construction purposes. Dredging and underwater blasting in and around coral formations are prohibited. In the case of Andaman and Nicobar Islands, no new construction shall be permitted within 200 meters of the HTL. In the case of Lakshadeep Islands and Small Islands, the size of the island is a factor in determining the distance from the HTL within which construction is permitted. The distance shall be laid down for each island in consultation with experts and with the approval of the MoEF, keeping in view the land use requirements for specific purposes vis-à-vis local conditions including hydrological aspects, erosion and ecological sensitivity.

In June 1996, The MoEF requested the National Institute of Oceanography (NIO), Goa, to delineate ecosensitive areas along the coastal stretches of Goa, including mangrove (Mascarenhas, 1999b). This law has been amended twice in January and July 1997.

8.4. Mangroves and the CRZ:

India is one of the leading countries in issuing laws meant for protection and conservation of mangrove forests. The history of conservation acts dates back to 1865, when the Indian Forest Act emerged. Later in 1927,
### Table 8.1. Summary of CRZ categories.

<table>
<thead>
<tr>
<th>CRZ Category</th>
<th>Area Covered</th>
<th>Activities permitted</th>
<th>Activities prohibited</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRZ - I</td>
<td>ESMH, national parks, sanctuaries, historical heritage, breeding and spawning grounds of fish, areas likely to be inundated due to sea level rise and area between LTL and HTL.</td>
<td>Gas pipe line between LTL and HTL.</td>
<td>New constructions within 500m from HTL.</td>
</tr>
<tr>
<td>CRZ – II</td>
<td>Urban area with adequate facilities.</td>
<td>-</td>
<td>Seaward and along road constructions.</td>
</tr>
<tr>
<td>CRZ – III</td>
<td>Inadequately developed areas under municipal limits.</td>
<td>Minor constructions for water, drainage &amp; sewerage facilities.</td>
<td>NDZ within 200m from HTL.</td>
</tr>
<tr>
<td>CRZ – IV</td>
<td>Groups of islands in the Indian seas.</td>
<td>Constructions beyond 200m from HTL.</td>
<td>Dredging &amp; blasting around ESMH.</td>
</tr>
</tbody>
</table>
comprehensive act was adapted for the management of mangrove forests from Sundarbans. The National Forest Policy was introduced in 1980, known as the Forest Conservation Act. It prevented the conversion of mangrove regions into non-forestry purposes. The Environment (Protection) Act, come into force during 1986, in which tidal forests were declared as the most ecologically sensitive habitats. Discharge of industrial waste and dumping of any kind of solid or liquid wastes in such areas were banned by this act.

According to the CRZ notification, mangrove regions in the country have been categorized under CRZ-I (Ecological Sensitive Zone). As per the CRZ-I, no developments are allowed in the mangroves or in the vicinity, prior to assessment of environmental impact (EIA), and clearance from the MoEF (Jagtap et al., 2002). The CRZ rules prohibit any development activities in mangrove having an area of 100 m$^2$ or more, with a buffer zone of at least 50 m along the coast, from the highest HTL.

However, the ever increasing human pressures continue to degrade and constant threat for mangrove habitats. Violation of the CRZ notification could be observed in several sensitive areas, including dumping of wastes, roads and illegal construction are crawling in the mangrove and vicinity zones (Plate 3.3). Therefore, strict enforcement of CRZ act needs to be implemented for effective conservation and protection of these ecologically sensitive ecosystems.
8.5. Conservation and Restoration of Mangrove Habitats:

Singh & Odaki (2004) defined conservation as preservation of natural resources from destructive influences, natural decay, or waste. Mangrove habitats continue to decrease around the world at an alarming rate mainly as a result of the increased population and their activities in the coastal zones. Conservation of these habitats meant for the maintaining of their rich biodiversity, sustainability of fishery, forestry and other products, and protection of coastal areas from fiery effects of natural calamity (Kathiresan & Qasim, 2005).

Constant measures are required to be taken to prevent deforestation of mangrove forests. Regular monitoring of these areas to control illegal felling of the trees should be implemented. Solely, individual states have been encouraged by MoEF to have their own Action Plan for mangrove management. Mangrove habitats from Chorao Island in the Mandovi Estuary of Goa, was declared as a bird sanctuary (Dr. Salim Ali Bird Sanctuary) in 1987 (Plate 8.2) incorporating more than 200 hectares (Jagtap et al., 2003).

Restoration of an ecosystem can be defined as the act of bringing it back or nearly to its original or pristine condition (Kathiresan & Qasim, 2005). Reforestation and afforestation activities are already planned by the Government of Goa. The State Social Forestry Division has proposed to
Plate 8.2. Conservation of mangrove habitats: (a) Dr. Salim Ali Bird Sanctuary, Chorao, (b) Nursery for growing mangrove seedlings in the sanctuary.
develop approximately 50 hectares of mangrove plantations per year, as follow-up of the State National Mangrove Plan for the sustainable management of mangrove resources (Jagtap et al., 2003).

Regeneration of mangrove forest could be divided to natural and artificial (Kathiresan & Qasim, 2005). Natural regeneration involves natural process of establishment of seeds of mangrove. This activity is cost effective and causes no disturbance to the habitat and develops the forest pattern, in the similar way to the original forest (Plate 8.3a). Artificial regeneration could be carried out by nursery development and transplanting seedlings or mangroves in degraded or new areas (Plate 8.3b). Some of the khazan lands, which were used for pisciculture and presently abandoned, may be utilized for the afforestation of mangrove (Jagtap, 1985). The technical know-how developed for nursery development and afforestation on mangroves, by various organizations including National Institute of Oceanography (NIO), have been provided to various State Forest Departments and private sectors, being implemented for the restoration of mangroves by afforestation. The fallow land, which is being influenced by tides, and is not utilized for any purpose, could also be utilized for afforestation of mangroves.

Continuous monitoring of newly established seedlings, either by natural or artificial means, is required as they are subjected to major threats by domestic cattle and fishing activities. They are also threatened by insects
Plate 8.3. Regeneration of mangrove plants. (a) Natural growth of seedlings, (b) Artificial planting of seedlings in the field.
and fungal infestation, therefore, limited use of insecticides and fungicides may be applied (Jagtap, 1985). The nursery development and transplantation operations are economically quite feasible. Natural seedlings of *Rhizophora spp.*, *Avicennia spp.*, *Sonneratia spp.*, *Kandelia spp.*, *Ceriops spp.* and *Bruguiera spp.* have been practiced for plantation by State Forest Department in Goa, and other parts of central west coast.

Vegetative propagation forms a useful technique to overcome the inadequate supply of seedlings of some of species, as their propagates do not occur throughout the year. Species like *Bruguiera gymnorhiza*, *Ceriops tagal*, *Kandelia candal* and *Aegiceras coruicnlatum* have been reported to be disappearing very rapidly along the central west coast of India (Jagtap, 1985). Conservation and afforestation of these particular species may help preserving rich mangrove diversity in the country.

The spacing between seedlings remains important factor during the plantation process. Zonation also forms another important factor in afforestation operations, naturally a particular species prefer right kind of ecological and geomorphological set ups. The Rhizophoraceae may be planted in front line along the waterways. *S. alba* could also be considered planting towards water fronts in polyhaline and mesohaline zones, while *S. caseolaris* in oligohaline zones. Other species should be planted behind them (Jagtap, 1985). Spacing can be maintained at 1x1 – 2x2 m (Chai, 1980). Suitable plots may be made depending on area of availability.
Distance of about 10 m should be maintained between each two plots each measuring 100 m$^2$ (Jagtap, 1985).

8.6. Avoiding Major Changes in the ecosystem:

Mangroves are fragile ecosystem as extremely sensitive to some of the factors responsible in altering the prevailing biological, physico-chemical and physical properties of the ambiance. However, conservation of each ecologically significant habitat and its associated environment can be met by preventing major changes in factors responsible for imbalance or damage to it. Clark (1996) pointed out some guidelines for resource sustainability, which are: (i) Maintaining the topography and character of the forest substrate and water channels, and avoiding all the processes that lead to excessive sedimentation, erosion, or alterations to the chemical characteristics. (ii) Coastal structures should be designed to ensure the natural patterns and cycles of tidal activities and freshwater runoff. (iii) Maintain the normal salinity of the ecosystem. (iv) Avoiding constructions that might potentially alter the natural equilibrium between accretion, erosion and sedimentation. (v) Development of contingency or disaster plans to protect the mangrove ecosystem from the damaging effects of oil and other hazardous materials, particularly in areas which are close to sources of pollution. (vi) Avoid all activities that would result in the impoundment of mangroves.
8.7. Public Awareness and People Participation:

Lack of awareness about the value of the mangrove ecosystem has lead to their rapid destruction. Educational programs are very important to increase the public awareness of local people about the ecological and economic values and functions of mangrove forests, and also the negative impacts of their misuse. Social awareness would enable participation of public in conservation and management of mangroves.

Participation of local user communities plays an important role in conservation and management of the mangrove resources. It allows people to take responsibility and make decisions in the present and future state of mangrove ecosystem. Government, the community of local resource users, non governmental organizations (NGOs), academic research institutions and other stakeholders (fish traders, money lender, tourism promoters) should share their responsibility and authority in decision making of the sustainable utilization and management of natural resources. Such kind of system is called as “Joint natural resources Management” or “Co-Management” (Pomeroy & Katon, 2000). These management options enable people and other organizations understanding the resource crisis and management problems. It gets people involved in law enforcement efforts to preserve the natural resources. With the support of local leadership, the efforts from the central government will be relieved by sharing responsibilities between the national government and the local units on sustainable resource management.
Establishment of mangrove information centers could be established at local and national levels would be of a great value in educating and creating awareness at different levels (Jagtap et al., 2002). These centers would be responsible for creating data base on various types of information on mangrove habitats such as their area, composition, endangered species, fisheries, land-use pattern, reclamation, etc.

8.8. Ecotourism and Recreation:

The state of Goa is one of the most popular tourism destinations of international repute. Encouraging ecotourism activities for recreation will definitely promote tourism industries in Goa and helps in rural development programs, without harming the mangrove environment. It will also increase the public awareness and improve the human – mangrove interrelationship. Some ecotourism activities such as canoeing, fishing, hiking, swimming and snorkeling, bird and wildlife watching and photography could be possible in mangrove areas of Goa. In fact, such activities have been initiated in the state during recent years to a little extent.

However, massive tourism is extremely difficult to control within the existing resources and manpower, and hence, it may adversely affects the fragile ecosystem. Therefore, the impact of tourism should be assessed in a well-planned manner and it must be managed properly to avoid damage to mangrove habitats. Mangrove forests should be managed as an
investment, where the earned interest remains analogous to the sustained productivity of the system (Clark, 1996).

Declaration of wildlife sanctuaries prevented local people from utilizing natural resources, which are affecting their livelihood. Hence, local people need to be provided with alternative livelihood supports. Kathiresan & Qasim (2005) opined that tourism development in the marine protected areas form potential avenues for additional employment. The Government should also take responsibility to improve people's skills for these new opportunities.

8.9. Traditional Aquaculture:

Mangrove swamps along the brackish and estuarine waters are generally used for fish farming. These habitats form an important nursery and breeding grounds and source of food for valuable fishes, crustaceans and shell fishes. Low-lying khazan lands adjacent to mangrove areas are used for paddy cultivation during monsoon, when the fields are filled with the rainfall freshwater. This followed by prawn culture in brackish water brought in through inlets of some low-lying areas. In addition to fish farming within mangrove areas, the estuarine waterways within mangrove habitats could be utilized for oyster and mussel culture by establishing cement blocks, Raft culture or floating cages in the intertidal zone.

The mangrove related brackish water culture seems to be a viable industry, which will provide additional protein sources and employment in rural areas
(Jagtap, 1985). However, excessive conversion of mangrove areas to aquaculture ponds will adversely affect the ecosystem (Clark, 1996), as has been seen in the past. It is therefore, very important that such activities in mangrove and vicinity regions be developed with expert advise.

8.10. Management of oyster beds in the mangrove ecosystems:

Mangrove ecosystems are considered to be a suitable site for culturing oysters. The ecosystem provides protection against excessive wind and wave actions; sufficient tidal and current flow to change the water of the oyster farm; supply adequate amounts of nutrients for the production of phytoplankton for the growth and fattening of oysters; suitable temperature and salinity; and adult oyster stock are available in large numbers in the vicinity of culture site for ensuring continuous supply of oyster seeds. All the above mentioned factors are essential for establishing oyster farm to make culture profitable (Santhanam et al., 1990).

Management of natural oyster beds is important to insure the long-term sustainable yield. Annual survey provides critical information on the abundance of oysters in each bed. It also helps in providing continuous monitoring of these beds to investigate the temporal changes of the population. Increasing public awareness of local people is essential in controlling oyster overexploitation. Guiding fishermen about the time they should halt collecting oysters allows small specimens to grow to the recommended marketable sizes for better benefits. It is also necessary to
teach them the suitable techniques for culturing oysters in their respective areas. Several techniques have been established centuries ago (Santhanam et al., 1990). The pole (stick) method, stake method, and rack and tray/string cultural methods, are advisable techniques for mangrove’s shallow and muddy areas. Factors that adversely influence the health of oysters should be monitored. Abnormal temperature and salinity, food, predators (carnivorous flatworms and oyster drills), parasites, diseases, entrophication and pollution may be dangerous for the oysters, and lead to their mass mortality (Santhanam et al., 1990).

Planting of clean shells revitalizes the natural oyster beds, expands and improves habitat for dependant marine life and provides critical habitat for juvenile oyster (spat) recruitment, ultimately increasing oyster abundance. Shell planting and regulated harvesting practices, based on sound biological data, will enable the mangrove’s oyster resources to continue contributing to the well being of the people that depend on this resource for part of their livelihood.

8.11. Roles of Remote Sensing and GIS in mangrove Management:

Rapid developments in the coastal regions, and ever increasing demands for land and natural resources, have been constant threat for the existing sensitive coastal marine habitats. An effective management of mangrove environment requires instant information on its structure and composition, area extent and ambient characteristics. Importance of remote sensing data
and Geographic Information System (GIS) for the management and development planning of the optimum sustainable utilization of natural resources has been recently will established (Anon, 2003). Mapping of various types of wetlands, including mangroves, could be used as a baseline data for classifying, preservation, conservation and utilization of the coastal zone, which forms the first step towards a rational mangrove ecosystem management (Nayak, 1993). The baseline data and RS and GIS tools are of a great value in constant monitoring of natural resources.

Remote sensing provides a repetitive coverage of the same area, which help in evaluating the changes occurring in the area of mangroves and its surroundings. Continues monitoring of the changes helps in predicting the likely impacts and threats imposing on these habitats and society. It forms a handy tool for the decision makers to initiate the proper measures to mitigate the impacts of threats and protect the natural habitat. The GIS has an ability to handle much larger database of specific criteria (e.g. mangrove ecosystem), and make use of shared database. It also helps to eliminate duplicated records, creating a potential for significant economic savings and improving operational efficiency (Bhardwaj, 2007).

Determining the accurate area and dimensions of the coastal mangrove habitat are very essential for the marine natural resources. It helps for mangrove classification, mapping mangrove resources, habitat assessment, monitoring spatial and temporal degradation and land cover changes of the mangrove, and for the planning and mitigating the impacts
of man-made disasters to the nature (Krishna et al., 1999). The increasing use of remote sensing data and GIS by various organizations and decision makers forms a valuable tool to help solve the planning and management issues in the mangrove habitat and the ambient coastal zone.

8.12. Conclusion and Recommendations:

Mangrove and dependant resources, including oyster beds from the state of Goa are very limited. The low lying regions in the state are also limited due to steep topography, resulting into narrow belt of low lying land. As a result, the agricultural activities in the state remain on very small scale. Being tourist destination of international repute, the ever increasing related demands continue to pressurizing marine habitats, particularly mangrove environments.

Though mangroves in the country have been protected vide CRZ regulations, in general, strict implementation of the act needs to be followed. Coastal zone development authorities do encounter difficulties in the implementation of CRZ act due to certain ambiguities. For example, private land prior to 1991, either fallow or agriculture, infested by mangroves due to the poor maintenance or breakage of embankments, are not allowed by owner to develop.

This individual state has its own yardsticks to define and demarcate the CRZ area. Development in the private property in the CRZ regions has been discouraged or faces great hurdles. However, mangrove and similar
habitats under revenue Department observed to develop for the responsible authorities in the interest of public. In view of the above points, following recommendations could be made for sustainable utilization of mangrove and associated natural resources:

- Re-evaluation and amendment of the CRZ acts if necessary.
- Preparation of RS and GIS based wetland maps on greater scale.
- Regular monitoring of alterations in and close to the mangrove areas.
- Restoration and after care of plantations.
- Evaluation of fisheries potential dependant of mangroves.
- Detailed investigations on growth pattern of oyster in and around mangrove habitats.
- Developing appropriate technology for oyster farming.
- Involvement of local communities in the management of habitats
- Increasing awareness at various levels regarding importance of mangrove ecosystems.
- Safeguarding interest of land owners in CRZ area.
- Uniform policies for permitting development in coastal zones.
- Developing contingency plan for the state mangroves.
About 40% of the world’s population residing within 100 km of the coastline. The major portions of coastal regions, particularly from the tropic, are characterized by ecological sensitive fragile ecosystems such as seagrass, corals, seaweeds, mangroves, obligate halophytic and sand dunes, essentially because they represent the interface between the land and the sea. Goa with about 105 km long coastline has limited resources of ecological sensitive marine habitats.

Mangroves form one of these major habitats, sustaining various types of fauna and flora of socioeconomic values. The physical structure of fishes and invertebrates is greatly influenced by mangroves. These habitats support small scale fisheries and produce nearly one million tones of fin fishes, mollusks, crabs and shrimps. Oysters form edible and economically feasible source of commercial importance. Mangrove forests along with its ambient environment are conducive for oyster and their larval settlement.

This study would be of a great help in detecting the changes in mangrove ecosystems of Goa in the last decade, as well as its present situation and distribution. This would also aid in monitoring and management of mangrove resources. The investigations would greatly help in understanding the environmental characteristics and productivity of the oyster beds associated with the mangrove ecosystems, and to
evaluate their potential bioindication ability for trace metals pollution in these habitats.

In view of the above points, the change in land use pattern in mangrove regions from the state, during last three decades, have been evaluated, using remote sensing and GIS techniques. The oyster beds associated with the mangrove environment form selected localities, have been investigated for a period of twelve months from August 2005 to July 2006. Data generated during present studies revealed an increase of approximately 22\% in mangrove area in the state from 1997 to 2006, suggesting better status of the habitat compared to the other regions along the west coast of India. Although ground truth data confirmed new formations and rehabilitation of mangroves, loss of habitats has also been observed in a number of localities. Recently, mangrove habitats have been subjected to tremendous pressures from increased anthropogenic activities, particularly land conversion, grazing and habitat fragmentation. The state of Goa, being a tourist destination, is intensively pressurized from economical activities, leading to deterioration of coastal habitats, particularly mangrove and sand dunes.

Hydrological parameters influencing mangroves showed marked spatial and temporal variations. Monsoon season plays a vital role in influencing mangrove environment. Cloud cover, precipitation as well as strong wind during monsoon decrease the summer high temperature and increasing relative humidity in the range of 83\% - 86\%. Fresh water runoff reduces
temperature and salinity, and enriches the habitat with nutrients, POC and DO during rainy period (June – September).

The study of oyster beds in the mangrove habitats from Goa revealed that these beds are subjected to sever exploitation. Unmanaged removal of oyster ultimately leads in declining the natural population. Approximately 64 – 84% of the oyster beds, studied presently, have been damaged. *Crassostrea madrasensis* and *C. gryphoides*, though form the communities constituents, the former dominate the beds. *Crassostrea madrasensis* species was not reported earlier from Goa, and hence present investigation report the same for the first time.

The results revealed lower values of percentage edibility (PE) during the post-monsoon season, whereas higher values were observed in both species during pre-monsoon season. *Crassostrea madrasensis* produced better edible biomass compared to the same by *C. gryphoides*. However, both species showed comparatively higher condition index (CI) values in the pre-monsoon season, and lower values during post-monsoon season. The correlation between values of PE and CI in *C. madrasensis* was found to be highly significant at the 1% level. The allometric results revealed that the increase in total weight and meat (wet) weight are mostly dependent on the increase of the shell length. However, the increase in the total weight coincided with the increase in the flesh wet weight, indicating that contribution of soft tissue to the total weight was highly significant ($r = 0.7615$).
Molluscs including bivalves and oysters form a low-cost subsistence food of the coastal people, especially for the fishing communities. The nutritive value in molluscs is influenced by the various ecological and environmental parameters in ambience. Annual variations in water contents of oyster could be attributed to the salinity concentrations in the water column. The water contents of *C. madrasensis* was negatively correlated with the water salinity (r= -0.3675 & -0.13074). Higher values of proteins and lipids in the oyster’s tissue have been found during monsoon season when salinity in ambience remains to very low. Therefore, the rich contents of proteins and lipids in oyster tissue could be attributed to the higher concentrations of food availability in ambience during monsoon. Both parameters found to be positively correlated with POC concentration in the water column. Negative correlation was found between water contents and lipids. Carbohydrates in the tissue of *C. madrasensis* ranged from 1.52% to 4.19%, with lower values during post-monsoon season, which increased during pre-monsoon and monsoon seasons.

*Crassostrea madrasensis* were reported to have higher caloric values during monsoon season. These values were positively correlated to major biochemical constituents. It was noticed that carbohydrates, proteins and lipids in *C. madrasensis* were significantly influenced by the conditions of ambient environment such as quantity of food availability, temperature and salinity. The optimum time for harvesting oyster population found to be during pre-monsoon season between February and May, when CI, PE and the caloric values, remain higher. Regulation
on oyster exploitation was felt for the sustainable development of oyster fisheries, which is presently lacking in the state.

Certain bivalve species have been reported to be of a great ecological importance, and serve as an indicator or a flag species, for monitoring the environmental quality by analyzing trace metals in their tissue. The hinterland and the coastal waters from Goa estuaries are intensively used for mining of manganese and iron ores and their transportation, respectively, for the last four decades. The major mangrove formations from the state exist along this Mandovi-Zuari and Cumbarjua canal estuarine complex. The estuaries also receive discharge of waste water arising from anthropogenic and industrial activities. The attempts have been made to evaluate the concentrations of selected trace metals from water, major mangrove flora and its associated oyster _C. madrasensis_, and to find its bioindicating ability for trace metal pollution.

Insignificant correlations were found between metal concentrations in _C. madrasensis_ in the ambient waters and the mangrove species. The insignificant relations between metal values in oyster tissue and ambience could be attributed to the metal bioaccumulation kinetics in oysters, which may be slow relative to short-term fluctuations in metal concentrations in the surroundings. Therefore, metal concentrations in oyster at any particular times may not exactly reflect the quantum of metal in ambiance at the same time. Since oyster possesses ability to accumulate high concentrations of metals, it might be harmful to the animal as well as to its consumers including human being. Therefore, it
is essential that concentration of metal pollutants should be kept under continuous observations to ensure the acceptable limits. The present findings revealed that the *C. madrasensis* may not serve as an efficient indicator of metal pollution. Therefore, it is suggested that the indication ability of this species for different trace metals need to be evaluated further to draw the firm conclusion on its suitability as bioindicator.

Mangrove habitats subjected to various anthropogenic threats by over exploitation, particularly reclamation of these areas for residential, commercial, industrial and agricultural purposes. Conservation of these habitats meant for the maintaining of their rich biodiversity, germplasm, sustainability of utilization of fishery, forestry and other products and protection of coastal areas from fiery effects of tidal waves and cyclones. Management of natural oyster beds is important to insure the long-term sustainable yield. Shell planting and regulated harvesting practices, based on sound biological data, will enable the mangrove’s oyster resources to continue contributing to the well being of the people that depend on this resource for part of their livelihood.
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