

**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, sea 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, wild life 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 Lakshadweep 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 Lakshadweep, 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 Lakshadweep 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.** Summery of CRZ categories.

<b>CRZ Category</b>	<b>Area Covered</b>	<b>Activities permitted</b>	<b>Activities prohibited</b>
CRZ - I	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.	Gas pipe line between LTL and HTL.	New constructions within 500m from HTL.
CRZ – II	Urban area with adequate facilities.	-	Seaward and along road constructions.
CRZ – III	Inadequately developed areas under municipal limits.	Minor constructions for water, drainage & sewerage facilities.	NDZ within 200m from HTL.
CRZ – IV	Groups of islands in the Indian seas.	Constructions beyond 200m from HTL.	Dredging & blasting around ESMH.

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, came 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<sup>2</sup> 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 hectars (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*, *Cariops 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<sup>2</sup> (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 led 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, eutrophication 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.



## ***SUMMARY AND CONCLUSION***

---

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 from 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 ambience 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.

## REFERENCES

---

- Agadi, V. V.; Bhosle, N. B. and Untawale, A. G. 1978. Metal Concentrations in Some Seaweeds of Goa (India); *Botanica Marina*; **21**(4): 247-250.
- Ahmad, E. 1972. Coastal Geomorphology of India; Orient Longman Ltd., Bombay; 222 pp.
- Ajana, A. M. 1980. Fishery of the Mangrove Oyster, *Crassostrea gasar* Adanson (1757), in the Lagos Area, Nigeria; *Aquaculture*; **21**: 129-137.
- Alagarsamy, R. 2006. Distribution and Seasonal Variation of Trace Metals in Surface Sediments of the Mandovi Estuary, West Coast of India; *Estuarine, Coastal and Shelf Science*; **67**: 333-339.
- Alagarswami, K. and Chellam, A. 1977. Change of Form and Functional Dimensional Relationship in the Pearl Oyster, *Pinctada fucata* from Gulf of Manner; *Indian Journal of Fisheries*; **24**: 1-14.
- Alvares, C. 2002. Fish, Curry and Rice, A Source book on Goa, its Ecology and Life-Style; The Goa Foundation, Goa; 377 pp.
- Ambasht, R. S. and Ambasht, N. K. 1998. Ecology of Indian Wetlands [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science; Easton; pp. 104-116.
- Anil, A. C. and Wagh, A. B. 1988. Accumulation of copper and Zinc by *Balanus amphitrite* in a Tropical Estuary; *Marine Pollution Bulletin*; **19**: 177-180.

- Anonymous. 1992. Coastal Environmental; Scientific Note; RSAM/SAC/COM/SN/11/92; Space Application Centre (ISRO); Ahmedabad; 114 pp.
- Anonymous. 1999. The Gazette of India, Notification, S.O. no. 114 (E); the Ministry of Environment and Forests, Feb 20, 1991.
- Anonymous. 2003. Community Zonation of Selected Mangrove Habitats of India Using Satellite Data; Scientific Note; SAC/RESIPA/MWRG/MSCED/SN/17/2003; Space Application Centre (ISRO), Ahmedabad; 92 pp.
- Anonymus. 2004. Mangroves of Goa; Research and Utilization Division, Forest Department, Goa; 26 pp.
- Anonymus. 2007. Status Report on Environmental Baseline Data Collection at Capao (Vaxim), an Island in Mandovi Estuary, Goa to Assess the Feasibility for Developing Recreational Facilities; National Institute of Oceanography, Goa; 29 pp.
- Ansari, Z. A. 1981. Seasonal Changes in Meat Weight and Biochemical Composition in the Black Clam *Villorita cyprinoids* (Grey); *Indian Journal of Marine Sciences*; **10**: 128-131.
- Ansari, Z. A. 1988. Ecology of Meiobenthos in Two Estuaries of Goa; a Ph. D. Thesis Submitted to the University of Bombay.
- Ansari, Z. A.; Nair, A.; Harkantra, S. N. and Parulekar, A. H. 1978. Studies on Dimensional Relationships in Green Mussel *Mytilus viridis* from two Environments; *Mahasagar Bulletin of the National Institute of Oceanography*; **11**(3&4): 201-205.



- Ansell, A. D. 1972. Distribution, Growth and Seasonal Changes in Biochemical Composition for the Bivalve *Donax vittatus* (de Costa) from Kames Bay, Millport; *Journal of Experimental Marine Biology and Ecology*; **10**: 137-150.
- Austin, H.; Haven, D. S. and Moustafa, M. S. 1993. The Relationship between Trends in a Condition Index of the American Oyster, *C. virginica*, and Environmental Parameters in Three Virginia Estuaries; *Estuaries*; **16**: 362-374.
- Awadallah, R. H.; Soltan, M. E. and Rashed, M. N. 1996. Relationship between Heavy Metals in Mud Sediments and Beach Soil of the River Nile; *Environmental International*; **22**(2): 253-258.
- Babukutty, Y. and Chacko, J. 1992. Trace Metals in an Estuarine Bivalve from the Southwest Coast of India; *Ambio*; **21**(4): 292-296.
- Baird, R. H. 1958. Measurement of Condition in Mussels and Oysters; *Journal Du Conseil International Pour L'exploration de la Mer*; **23**: 249-257.
- Balasubrahmanyam, K. and Natarajan, R. 1988. Seasonal Variations in the Biochemical Composition of *Meretrix casta* (Chemnitz) Occurring in Vellar Estuary; *CMFRI Bulletin*; **42**(1): 184-188.
- Barnabé, G. and Barnabé-Quet, R. 2000. Ecology and Management of Coastal Waters – The Aquatic Environment; Springer and Praxis Publishing, London; 396 pp.
- Bartlett, D. S. and Klemas, V. 1980. Evolution of Remote Sensing Techniques for Surveying Coastal Wetlands; University of Delaware, Delaware; 102 pp.

- Bayne, B. L. 1973. Physiological Changes in *Mytilus edulis* L. Induced by Temperature and Nutritive Stress; *Journal of the Marine Biological Association of the United Kingdom*; **53**: 39-58.
- Beer, T. 1997. Environmental Oceanography; 2nd Edition; CRC Press Inc, Florida; 367 pp.
- Beninger, P. G. and Lucas, A. 1984. Seasonal Variations in Condition, Reproductive Activity, and Gross Biochemical Composition of Two Species of Adult Clam Reared in a Common Habitat: *Tapes decussatus* L. (Feffreys) and *Tapes philippinarum* (Adams & Reeve); *Journal of Experimental Marine Biology and Ecology*; **79**: 19-37.
- Bergquist, D. C.; Hale, J. A.; Baker, P. and Baker, S. M. 2006. Development of Ecosystem Indicators for the Suwannee River Estuary: Oyster Reef Habitat Quality along a Salinity Gradient; *Estuaries and Coasts*; **29**(3): 353-360.
- Bhardwaj, R. K. 2007. Application of GIS Technology for Coastal Zone Management: A Hydrographer Perspective; [In: Management of Coastal Resources: An Introduction; (Ed.): Ranade, P. S.]; the Icafi University Press, Hyderabad; pp. 168-181.
- Bhargava, R. M. S.; Selvakumar, R. A. and Singbal, S. Y. S. 1973. Hydrobiology of Surface Waters along Panaji – Bombay Coast; *Indian Journal of Marine Sciences*; **2**: 103-107.
- Bhosale, L. J. 1979. Distribution of Trace Elements in the Leaves of Mangroves; *Indian Journal of Marine Sciences*; **8**: 58-59.
- Bhosle, N. B. and Matondkar, S. G. P. 1978. Variation in Trace Metals in Two Populations of Green Mussel *Mytilus viridis* L. from Goa; *Mahasagar Bulletin of the National Institute of Oceanography*; **11**: 191-194.

- Bhosle, N. B.; Dhargalkar, V. K.; Matondkar, S. G. P. and Bukhari, S. 1976. Biochemical Composition of Mangrove Leaves from Goa; *Indian Journal of Marine Sciences*; **5**: 239-241.
- Blaber, S. J. M. 2000. Tropical Estuarine Fishes, Ecology, Exploitation and Conservation; Blackwell Science Ltd., USA; 372 pp.
- Blasco, F. 1977. Outline of Ecology, Botany and Forestry of the Mangals of the Indian Subcontinent; [In: Ecosystems of the World, 1: Wet Coastal Ecosystems; (Ed.): Chapman, V. J.]; Elsevier Scientific Publication Co., New York; pp. 241-260.
- Blasco, F. 1984. Climatic Factors and the Biology of Mangrove Plants [In: The Mangrove Ecosystem: Research methods; (Eds.): Snedakar, S. C. and Snedakar, J. G.]; UNESCO; Bungay, U.K.; pp. 18-35.
- Blasco, F. and Aizpuru, M. 2002. Mangroves along the Coastal Stretch of the Bay of Bengal: Present Status; *International Journal of Marine Sciences*; **31**(1): 9-20.
- Borchardt, T.; Burchert, S.; Hablizd, H.; Karbe, L. and Zeitner, R. 1988. Trace Metal Concentrations in Mussels: Comparison between Estuarine, Coastal and Offshore Regions in the Southeastern North Sea from 1983 – 1986; *Marine Ecology – Progress Series*; **42**: 17-31.
- Bourget, E. and Cossa, D. 1976. Mercury Content of Mussels from the St. Lawrence Estuary and Northwestern Gulf of St. Lawrence, Canada; *Marine Pollution Bulletin*; **7**: 237-239.
- Boyden, C. R. 1974. Trace Element Content and Body Size in Molluscs; *Nature*; **251**: 311-314.
- Boyden, C. R. and Romeril, M. G. 1974. A Trace Metal Problem in Pond Oyster Culture; *Marine Pollution Bulletin*; **5**(1): 74-78.

- Braganca, A. and Sanzgiri, S. 1980. Concentrations of Few Trace Metals in Coastal and Offshore Region of the Bay of Bengal; *Indian Journal of Marine Sciences*; **9**: 283-286.
- Bryan, G. W. 1973. The Occurrence and Seasonal Variation of Trace Metals in the Scallops *Pecten maximus* (L.) and *Chlamys Opercularis* (L.); *Journal of the Marine Biological Association of the United Kingdom*; **53**: 145-166.
- Burrough, P. A. 1986. Principles of Geographic Information Systems for Land Resources Assessment; Oxford University Press Inc., New York; 194 pp.
- \*Butler, P. A.; Andren, L.; Bonde, G. J.; Jernelov, A. and Reisch, D. J. 1971. Monitoring Organisms; [In: FAO Technical Conference on Marine Pollution and its Effects on Living Resources and Fishing, Rome, 1970. Supplement 1; Method of Detection, Measurement and Monitoring of Pollutants in the Marine Environment; (Ed.): Ruivo, M.]; Fishing News (Books) Ltd., London; pp. 101-112.
- Chai, P. K. 1980. Mangrove Forests of Sarawak; [In: Workshop on Mangrove and Estuarine Vegetation; (Ed.): Srivastava, B. P. L]; December, 1977; Faculty of Forestry, University of Pertanian, Serdang, Malaysia; pp. 1-5.
- Chakrabarti, P. 1995. Coastal Zone Management in Hooghly Estuary – An Operational Approach; *Indian Journal of Earth Sciences*; **22**(3): 125-134.
- Chandra, A. M. and Gosh, S. K. 2006. Remote Sensing and Geographical Information System; Narosa Publishing House Ltd., New Delhi; 298 pp.

- Chang, K. 2006. Introduction to Geographic Information Systems; 3<sup>rd</sup> Edition; Tata McGraw-Hill Publishing Company Ltd., New Delhi; 432 pp.
- Chatterji, A.; Ansari, Z. A.; Ingole, B. S. and Parulekar, A. H. 1985. Length-Weight Relationship of Giant Oyster, *Crassostrea gryphoides* (Schlotheim); *Mahasagar Bulletin of the National Institute of Oceanography*; **18**(4): 521-524.
- Chatterji, A.; Ansari, Z. A.; Ingole, B. S. and Parulekar, A. H. 1984. Growth of the Green Mussel, *Perna viridis* L., in a Sea Water Circulating System; *Aquaculture*; **40**: 47-55.
- Clark, J. R. 1996. Coastal Zone Management Handbook; Lewis Publication, CRC Press LLC, Florida; 694 pp.
- Clark, J. R. 1998. Coastal Seas – The Conservation Challenge; Blackwell Science Ltd., London; 134 pp.
- Congalton, R. G. and Gran, K. 1995. The ABCs of GIS: An Introduction of Geographic Information Systems; [In: Wetland and Environmental Applications of GIS; (Eds.): Lyon, J.G. and McCarthy, J.] CRC Press, Inc., Florida; pp. 9-24.
- Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R. V.; Paruelo, J.; Raskin, R. G.; Sutton, P. and Vanden Belt, M. 1997. The Value of the World's Ecosystem Services and Natural Capital; *Nature*; **387**: 253-260.
- Crosby, M. P. and Gale, L. D. 1990. A Review and Evaluation of Bivalve Condition Index Methodologies with a Suggested Standard Method; *Journal of Shellfish Research*; **9**: 233-237.

- Crowell, M.; Leatherman, S. P.; Buckley, M. K. 1991. Historical Shoreline Change: Error Analysis and Mapping Accuracy; *Journal of Coastal Research*; **7**(3): 839-852.
- D'Silva, C. and Kureishy, T. W. 1978. Experimental Studies on the Accumulation of Copper and Zinc in the Green Mussel; *Marine Pollution Bulletin*; **9**: 187-190.
- D'Silva, C. and Qasim, S. Z. 1979. Bioaccumulation and Elimination of Copper in the Rock Oyster *Crassostrea cucullata*; *Marine Biology*; **52**:343-346.
- Dalal, S. G. 1976. Interrelationship between Environmental Parameters and Foraminiferal Species in Mandovi and Zuari Estuaries; *Mahasagar Bulletin of National Institute of Oceanography*; **9**(1&2): 91-93.
- Dame, R. F. 1972. Comparison of Various Allometric Relationships in Intertidal and Subtidal American Oysters; *Fishery Bulletin*; **70**: 1121-1126.
- Danielsson, L. and Westerlund, S. 1984. Short-term Variations in Trace Metal Concentrations in the Baltic; *Marine Chemistry*; **15**: 273-277.
- Dare, P. J. and Edwards, D. B. 1975. Seasonal Changes in Flesh Weight and Biochemical Composition of Mussels (*Mytilus edulis* L.) in the Conwy Estuary, North Wales; *Journal of Experimental Marine Biology and Ecology*; **18**: 89-97.
- Das, P. K.; Murty, C. S. and Varadachari, V. V. R. 1972. Flow Characteristics of Combarjua Canal Connecting Mandovi and Zuari Estuaries; *Indian Journal of Marine Sciences*; **1**: 95-102.

- \*Day, J. H. 1981. The Nature, Origin, and Classification of Estuaries; [In: Estuarine Ecology with Particular Reference of Southern Africa; (Ed.): Day, J. H.]; Balkema A. A.; Cape Town, South Africa; pp. 1-6.
- De Medina, H. L. 2000. Chemical Parameters; [In: Handbook of Water Analysis; (Ed.): Nollet, L. M. L.]; Marcel Dekker, Inc.; New York; pp. 51-73.
- De Souza, R. J. S. 2006. Remote Sensing and GIS Tools for Integrated Coastal Zone Management – Goa State; a Ph. D. Thesis Submitted to Goa University.
- De Souza, T. R. 1979. Medieval Goa (A Socio-Economic History); Concept Publishing Company, New Delhi; 315 pp.
- De Sousa, S. N. 1983. Studies on the Behaviour of Nutrients in the Mandovi Estuary during Premonsoon; *Estuarine, Coastal and Shelf Science*; **16**: 299-308.
- De Sousa, S. N. and Sen Gupta, R. 1986. Variations of Dissolved Oxygen in Mandovi and Zuari Estuaries; *Indian Journal of Marine Sciences*; **15**: 67-71.
- De Sousa, S. N.; Sen Gupta, R.; Sanzgiri, S. and Rajagopal, M. D. 1981. Studies on Nutrients of Mandovi and Zuari River Systems; *Indian Journal of Marine Sciences*; **10**: 314-321.
- Dehadrai, P. V. and Bhargava, R. M. S. 1972. Seasonal Organic Production in Relation to Environmental Features in Mandovi and Zuari Estuaries, Goa; *Indian Journal of Marine Sciences*; **1**: 52-56.
- Demers, M. N. 2000. Fundamentals of Geographic Information System; 2<sup>nd</sup> Edition; John Wiley & Sons, Inc.; New York; 498 pp.

- Deshmukh, B.; Bahuguna, A.; Nayak, S.; Dhargalkar, V. K.; Jagtap, T. G. 2005. Eco-Geomorphological Zonation of the Bangaram Reef, Lakshadweep; *Journal of the Indian Society of Remote Sensing*; **33**(1): 99-106.
- Dobson, M. and Frid, C. 1998. Ecology of Aquatic Systems; Addison Wesley Longman Limited; U.K.; 222 pp.
- Dridi, S.; Romdhane, M. S. and Elcafsi, M. 2007. Seasonal Variation in Weight and Biochemical Composition of the Pacific Oyster, *Crassostrea gigas* in Relation to the Gametogenic Cycle and Environmental Conditions of the Bizert Lagoon, Tunisia; *Aquaculture*; **263**: 238-248.
- Dubois, M.; Gilles, K. A.; Hamilton, J. K.; Robers, R. A. and Smith, F. 1956. Colorimetric Method for Determination of Sugars and Related Substances; *Analytical Chemistry*; **28**: 350-356.
- \*Dugan, P. J. 1990. Wetland Conservation: A Review of current Issues and Required Action. IUCN, the World Conservation Union, Switzerland. 96 pp.
- \*Duke, N. C. 1992. Mangrove Floristics and Biogeography; [In: Coastal and Estuarine Studies: Tropical Mangrove Ecosystems; (Eds.): Robertson, A. I. and Alongi, D. M.]; American Geophysical Union, Washington D. C.; pp. 63-100.
- Durve, V. S. 1964. On the Percentage Edibility and the Index of Condition of the Oyster *Crassostrea gryphoides* (Schlotheim); *Journal of the Marine Biological Association of India*; **6**(1): 128-135.
- Durve, V. S. 1973. Malacological Difference between the Oysters *Crassostrea gryphoides* (Schlotheim) and *Crassostrea madrasensis* (Preston); *Indian Journal of Fisheries*; **20**(2): 624-625.



- \*Durve, V. S. and Bal, D. V. 1961. Studies on the Chemical Composition of the Oyster, *Crassostrea gryphoides* (Schlotheim); *Journal of the Zoological Society of India*; **13**: 70-77.
- Dwivedi, T.; Kandrika, S. and Ramana, K. V. 2004. Comparison of Classification of Remote Sensing Data for Land-Use / Land-Cover Mapping; *Current Science*; **86**(2): 328-335.
- Elbaz-Poulichet, P.; Martin, J. M.; Huang, W. W. and Xhu, J. X. 1987. Dissolved Cd Behavior in Some Selected French and Chinese Estuaries, Consequences of Cd Supply to the Ocean; *Marine Chemistry*; **22**: 125-136.
- Engel, B. A.; Srinivasan, R. and Rewerts, C. 1993. A Spatial Decision Support for Modeling and Monitoring Agriculture Non-Point-Source Pollution [In: Environmental Modeling with GIS (Eds.): Goodchild, M. F.; Parks, B. O. and Steyaert, L. T.]; Oxford University Press; New York; pp. 231-237.
- English, S.; Wilkinson, C. and Baker, V. 1997. Survey Manual for Tropical Marine Resources; 2<sup>nd</sup> Edition; Australian Institute of Marine Science, Townsville; 390 pp.
- Esteves, S. 1966. Goa and its Future; P.C. Manaktala and Sons Private LTD., Bombay; 146 pp.
- Fang, J.; and Wang, K. X. 2006. Spatial Distribution and Partitioning of Heavy Metals in Surface Sediments from Yangtze Estuary and Hangzhou Bay, People's Republic of China; *Bulletin of Environmental Contamination and Toxicology*; **76**: 831-839.
- Fedra, K. 1993. GIS and Environmental Modeling [In: Environmental Modeling with GIS; (Eds.): Goodchild, M. F.; Parks, B. O. and Steyaert, L. T.]; Oxford University Press; New York; pp. 35-50.

- Filho, P. M. W.; Martins, E. S. F. and da Costa, F. R. 2006. Using Mangroves as a Geological Indicator of Coastal Changes in the Bragança Macrotidal Flat, Brazilian Amazon: A Remote Sensing Data Approach; *Ocean & Coastal Management*; **49**: 462-475.
- Folch, J.; Lees, M. and Sloane, G. H. 1957. A Simple Method for the Isolation and Purifications of Total Lipids from Animal Tissues; *Journal of Biological Chemistry*; **226**: 497-509.
- Fondekar, S. P. and Reddy, C. V. G. 1974. Arsenic Content in the Coastal and Estuarine Waters around Goa; *Mahasagar Bulletin of the National Institute of Oceanography*; **7**: 27-32.
- Fondekar, S. P. and Reddy, C. V. G. 1976. Arsenate and Arsenite Levels in the Coastal and Estuarine Waters of Goa; *Mahasagar Bulletin of the National Institute of Oceanography*; **8**: 157-163.
- Fonseca, J. N. D. 2001. Historical and Archaeological Sketch of the City of Goa; Asian Educational Services, New Delhi; 348 pp.
- Fowler, S. W. and Heyraud, M. 1980. Biologically-Transformed Zinc and its Availability for Bioaccumulation by Marine Organisms; [In: Management of Environment; (Ed.): Patel, B.]; Wiley Eastern Limited, New Delhi; pp. 389-398.
- Fowler, S. W. and Oregioni, B. 1976. Trace Metals in Mussels from the N. W. Mediterranean; *Marine Pollution Bulletin*; **7**: 26-29.
- Frías, J. A. and Rodriguez, R. 1990. Oyster Culture in Cuba: Current State, Techniques and Industry Organization; [In: Oyster Culture in the Caribbean; (Eds.): Newkirk, G. F. and Field, B. A.]; Mollusc Culture Network, Dalhousie University, Nova Scotia; pp. 51-74.

- Gabbott, P. A. 1983. Development and Seasonal metabolic Activities in Marine Molluscs; [In: The Mollusca, Vol. 2: Environmental Biochemistry and Physiology; (Ed.): Hochachka, P. W.]; Academic Press, New York; pp. 165-217.
- Gabbott, P. A. and Bayne, B. L. 1973. Biochemical Effects of Temperature and Nutritive Stress on *Mytilus edulis* L.; *Journal of the Marine Biological Association of the United Kingdom*; **53**: 269-286.
- Gabbott, P. A. and Stephenson, R. R. 1974. A Note on the Relationship between the Dry Weight Condition Index and the Glycogen Content of Adult Oysters (*Ostrea edulis* L.) Kept in the Laboratory; *Journal Du Conseil International Pour L'exploration de la Mer*; **35**: 359-361.
- \*Galstoff, P. S. 1931. The Length-Weight Relationship of the Shells of the Hawii Pearl Oyster, *Pinctada* sp.; *American Naturalist*; **65**: 423-433.
- \*Galstoff, P. S. 1964. The American Oysters *Crassostrea virginica* Gmelin; *U.S. Fish and Wildlife Service Fishery Bulletin*; **64**: 1-480.
- George, M. D. 1989. Some Aspects of Chemical Speciation of Cadmium, Lead and Copper in some Indian Estuaries and Coastal Waters; a Ph. D. Thesis Submitted to the University of Poona.
- George, M. D. and Sawkar, K. 1981. Originically Associated Copper in Mandovi and Zuari Estuaries; *Mahasagar Bulletin of the National Institute of Oceanography*; **14**(1): 71-73.
- George, M. D.; Sawkar, K. and Reddy, C. V. G. 1984. Determination of Cd, Pb and Cu in Mandovi Estuary by Different Pulse Anodic Stripping Voltammetry; *Indian Journal of Marine Sciences*; **13**: 64-68.
- Gomes, O. J. F. 1996. Village Goa (A Study of Goan Social Structure and Change); S. Chand and Company Ltd., New Delhi; 440 pp.

- Gopal, B. 1998. Wetland Types [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science, Easton; pp. 27-34.
- Gordon, M.; Knauer, G. A. and Martin, J. H. 1980. *Mytilus californianus* as a Bioindicator of Trace Metal Pollution: Variability and Statistical Considerations; *Marine Pollution Bulletin*; **11**: 195-198.
- Goswami, S. C. and Singbal, S. Y. S. 1974. Ecology of Mandovi and Zuari Estuaries: Plankton Community in Relation to Hydrographic Conditions during Monsoon Months, 1972; *Indian Journal of Marine Sciences*; **3**: 51-57.
- Gulati, K. L.; Nagpaul, K. K. and Bukhari, S. S. 1979. Uranium, Boron, Nitrogen, Phosphorus and Potassium in Leaves of Mangroves; *Mahasagar Bulletin of the National Institute of Oceanography*; **12**: 183-186.
- \*Haug, A.; Melsom, S. and Omang, S. 1974. Estimation of Heavy Metal Pollution in Two Norwegian Fjord Areas, Analysis of the Brown Algae *Ascophyllum nodosum*; *Environmental Pollution*; **7**: 173-193.
- Hickman, R. W. 1979. Allometry and Growth of the Green-Lipped Mussel *Perna canaliculus* in New Zealand; *Marine Biology*; **51**: 311-327.
- Holland, D. L. and Spencer, B. E. 1973. Biochemical Changes in Fed and Starved Oysters, *Ostrea edulis* L. During Larval Development, Metamorphosis and Early Spat Growth; *Journal of the Marine Biological Association of the United Kingdom*; **53**: 287-298.
- Hoq, M. E. 2007. An Analysis of Fisheries Exploitation and Management Practices in Sundarban Mangrove Ecosystem, Bangladesh; *Ocean & Coastal Management*; **50**: 411-427.

- Hunt, G. R. 1980. Electromagnetic Radiation: The Communication Link in Remote Sensing [In: Remote Sensing in Geology; (Eds.): Siegal, B. S. and Gillespie, A. R.] John Wiley & sons, New York; 702 pp.
- \*Hutchings, P. and Saenger, P. 1987. Ecology of mangroves; University of Queensland Press, St. Lucia, Australia; 432 pp.
- Jagtap, T. G. 1983. Metal Distribution in *Halophila beccarii* (Aschers) and Surrounding Environment along the Central West Coast of India; *Mahasagar Bulletin of the National Institute of Oceanography*; **16**(4): 429-434.
- Jagtap, T. G. 1985. Ecological Studies in Relation to the Mangrove Environment along the Goa Coast, India; a Ph. D. Thesis Submitted to Shivaji University, Kolhapur.
- Jagtap, T. G. 1987. Seasonal Distribution of Organic Matter in Mangrove Environment of Goa; *Indian Journal of Marine Sciences*; **16**: 103-106.
- Jagtap, T. G. and Untawale, A. G. 1980. Effect of Petroleum Products on Mangrove Seedlings; *Mahasagar Bulletin of the National Institute of Oceanography*; **13**(2): 165-172.
- Jagtap, T. G., Untawale, A. G. and Inamdar, S. N. 1994. Study of Mangrove Environment of Maharashtra Coast using Remote Sensing Data; *Indian Journal of Marine Sciences*; **23**: 90-93.
- Jagtap, T. G.; Chavan, V. S. and Untawale, A. G. 1993. Mangrove Ecosystems of India: A Need for Protection; *Ambio*; **22**(4): 252-254.
- Jagtap, T. G.; Desai, K. and Rodrigues, R. 2003. Coastal Vegetation: Patterns in a Tourism Region; [In: Coastal Tourism, Environment and Sustainable Local Development; (Eds.) Noronha, L. *et al.*]; TERI, New Delhi; pp. 121-150.

- Jagtap, T. G.; Murthy, P. S. and Komarpant, D. S. 2002. Mangrove Ecosystem of India: Conservation and Management; [In: Wetlands Conservations and Management; (Ed.): Hosetti, B. B.]; Pointer Publishers, Jaipur; pp. 34-64.
- Jagtap, T. G. and Nagle, V. L. 2007. Response and Adaptability of Mangrove Habitats from the Indian Subcontinent to Changing Climate; *Ambio*; **36**(4): 328-334.
- Jagtap, T. G.; Naik, S. and Nagle, V. L. 2001. Assessment of Coastal Wetland Resources of Central West Coast, India, Using LANDSAT Data; *Journal of the Indian Society of Remote Sensing*; **29**(3): 143-150.
- Jayasurya, P. K.; Kaladharan, P.; Rajagopalan, M. S.; Roy, D. S. and Sadhu, A. K. 2005. Mangrove Vegetation; [In: Mangrove Ecosystems, a Manual for the Assessment of Biodiversity; (Ed.): Parayannilam, G. S.]; Central Marine Fisheries Research Institute, Cochin, India; pp. 1-16.
- Jingchun, L.; Chongling, Y; Macnair, M. R.; Jun, H. and Yuhong, L. 2006. Distribution and Speciation of some Metals in Mangrove Sediments from Jiulong River Estuary, People's Republic of China; *Bulletin of Environmental Contamination and Toxicology*; **76**: 815-822.
- Jones, A. M.; Jones, J. M. and Baxter, J. M. 1979. Seasonal and Annual Variations in the Allometric Relationships of Shell and Soft Body Characters of *Patella vulgata* L.; [In: Cyclic Phenomena in Marine Plants and Animals; (Eds.): Naylor, E. and Hartnoll, R. G.]; Pergamon Press; 199-206.
- Jorgensen, C. B. 1976. Growth Efficiencies and Factors Controlling Size in Some Mytilid Bivalves, Especially, *Mytilus edulis* L., Review and Interpretation; *Ophelia*; **15**: 175-192.

- Joseph, M. M. and Madhyastha, M. N. 1984. Annual Reproductive Cycle and Sexuality of the Oyster *Crassostrea madrasensis* (Preston); *Aquaculture*; **40**: 223-231.
- Kathiresan, K. and Qasim, S. Z. 2005. Biodiversity of Mangrove Ecosystem; Hindustan Publishing Corporation (India), New Delhi; 251 pp.
- Klemow, K. M. 1998. Wetland Mapping [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science; Easton; pp. 1-26.
- Knox, G. A. 2001. The Ecology of Seashores; CRC Press LLC, New York; 557 pp.
- Korringa, P. 1976. Farming the Cupped Oysters of the Genus *Crassostrea*, Development in Aquaculture and Fisheries Science, Volume 2; Elsevier Scientific Publishing Company, Amsterdam; 224 pp.
- Kremling, K. and Petersen, H. 1984. Synoptic Survey on Dissolved Trace Metal Levels in Baltic Surface Waters; *Marine Pollution Bulletin*; **15**: 329-334.
- Krishna, N. D. R.; Westinga, E. and Huizing, H. 1999. Monitoring Land Cover Changes Using Geoinformatics in Some Communal Lands of Zimbabwe; Proceedings of Geoinformatics: "Beyond 2000"; International Conference on Geoinformatics for Natural Resource Assessment, Monitoring and Management; 9-11 March 1999, Dehradun, India; pp. 92-101.
- Krishnamurthy, K.; Chaudhary, A. and Untawale, A. G. 1987. Mangroves in India: Status Report; Government of India, Ministry of Environment and Forests, New Delhi; 150 pp.

- Kumar, R. B. 1995. Coastal Tourism and Environment; APH Publishing Corporation, New Delhi; 254 pp.
- Kumari, L. K.; Kaisary, S. and Rodrigues, V. 2006. Bio-accumulation of Some Trace Metals in the Short-neck Clam *Paphia malabarica* from Mandovi Estuary, Goa; *Environment International*; **32**: 229-234.
- Kumari, L. K. and Nair, V. R. 1988. Seasonal Variations in the Biochemical Composition of the Clam *Tellina angulata* from Bombay; *Journal of the Indian Fisheries Association*; **18**: 449-458.
- Kumari, L. K.; Rajagopal, M. D. and Vijayaraghavan, S. 1977. Some Aspects of Biology and Biochemistry of the Backwater Clam, *Meretrix casta* (Chemnitz); *Mahasagar Bulletin of the National Institute of Oceanography*; **10**(3&4): 157-163.
- Kumari, L. K.; Vijayaraghavan, S.; Wafar, M. V. M.; Royan, J. R. and Rajendran, A. 1978. Studies on Detritus in a Tropical Estuary; *Indian Journal of Marine Sciences*; **7**: 263-266.
- Kunte, P. D. and Wagle, B. G. 1994. Analysis of Space-Borne Data for Coastal Zone Information Extraction of Goa Coast, India; *Ocean and Coastal Management*; **22**: 187-200.
- Kunte, P. D. and Wagle, B.G. 1997. Remote Sensing Application for Delineating Coastal Vegetation - A case study; *Current Science*; **72**(12): 239-241.
- Kureishy, T. W.; Sanzgiry, S. and Braganza, A. 1981. Some Heavy Metals in Fishes from the Andaman Sea; *Indian Journal of Marine Sciences*; **10**: 303-307.
- Kureishy, T. W.; Sanzgiry, S.; George, M. D. and Braganza, A. 1983. Mercury, Cadmium and Lead in Different Tissues of Fishes and in



Zooplankton from the Andaman Sea; *Indian Journal of Marine Sciences*; **12**: 60-63.

- Lakshmanan, P. T. and Nambisan, P. N. K. 1980. Biochemical Composition of the Bivalve Mollusca *Villorita cyprinoides* var *cochinensis* (Hanley) and *Meretrix casta* (Chemnitz); *Indian Journal of Marine Sciences*; **9**: 65-67.
- Lannig, G.; Flores, J. F. and Sokolova, I. M. 2006. Temperature-Dependent Stress Response in Oysters, *Crassostrea virginica*: Pollution Reduces Temperature Tolerance in Oysters; *Aquatic Toxicology*; **79**: 278-287.
- Lawrence, D. R. and Scott, G. I. 1982. The Determination and Use of Condition Index of Oysters; *Estuaries*; **5**: 23-27.
- Leatherland, T. M. and Burton, J. D. 1974. The Occurrence of Some Trace Metals in Coastal Organisms with Particular Reference to the Solent Region; *Journal of the Marine Biological Association of the United Kingdom*; **54**: 457-468.
- Leelakrishnan, P. 1999. Environmental Law in India; Butterworth, New Delhi; 194 pp.
- Lillesand, T. M.; Kiefer, R. W. and Chipman, J. W. 2004. Remote Sensing and Image Interpretation; 5<sup>th</sup> edition; John Wiley & sons (Asia) Private Ltd., Singapore; 763 pp.
- Lowery, O. H.; Rosenbrough, N. J.; Farr, A. L. and Randell, R. J. 1951. Protein Measurements with the Folin-Phenol Reagent; *Journal of Biological Chemistry*; **193**: 265-275.
- Lubet, P. 1976. Ecophysiologie de la Reproduction Chez Les Mollusques Lamellibranches; *Haliotis, Paris*; **7**: 49-55.

- Lucas, A. and Beninger, P. G. 1985. The Use of Physiological Condition Indices in Marine Bivalve Aquaculture; *Aquaculture*; **44**: 187-200.
- Lyon , J. G. and McCarthy, J. 1995. Introduction to Wetland Applications [In: Wetland and Environmental Applications of GIS; (Eds.): Lyon, J.G. and McCarthy, J.] CRC Press, Florida; pp. 27-30.
- Mahadevan, S. and Nayar, K. N. 1987. Ecology of Oyster Beds; [In: Oyster Culture – Status and Prospects; (eds.): Nayar, K. N. and Mahadevan, S.]; *Bulletin of Central Marine Fisheries Research Institute*; **38**: 7-13.
- Manjappa, H.; Gowda, G.; Rajesh, K. M. and Mridula, R. M. 2003. Sediment Characteristics of Mangrove Areas of Brackish Water Impoundments; *Indian Journal of Fisheries*; **50**(3): 349-354.
- Mann, R. 1979. Some Biochemical and Physiological Aspects of Growth and Gametogenesis in *Crassostrea gigas* and *Ostrea edulis* Grown at Sustained Elevated Temperatures; *Journal of the Marine Biological Association of the United Kingdom*; **59**: 95-110.
- Manson, F. J.; Loneragan, N. R.; Harch, B. D.; Skilleter, G. A. and Williams, L. 2005. A Broad-Scale Analysis of Levels between Coastal Fisheries Production and Management Extent: A Case Study for Northeastern Australia; *Fisheries Research*; **74**: 69-85.
- Mascarenhas, A. 1999a. Some Observations on the State of the Coastal Environment of Goa, West Coast of India; Proceedings, Workshop on Integrated Coastal and Marine Area Management Plan for Goa; pp. 204-224.
- Mascarenhas, A. 1999b. The Coastal Regulation Zone of Goa: Oceanographic, Environmental and Societal Perspective; *Current Science*; **77**(12): 1598-1605.

- Mascarenhas, A. 2000. Human Interference along the Coast of Goa; [In: Environmental Problems of Coastal Areas in India; (Ed.): Sharma, V. K.]; Bookwell, New Delhi; pp. 145-167.
- Mohan, D. and Kalyani, M. 1989. Seasonal Variations in Biochemical Composition of Green Mussel *Perna viridis* (Linnaeus); *Mahasagar Bulletin of the National Institute of Oceanography*; **22**(3): 113-120.
- Mohan, M. V. 1980. Allometric Relationships in the Green Mussel, *Perna viridis* L.; *Indian Journal of Marine Sciences*; **9**: 224-226.
- Morris, A. W. 1974. Seasonal Variation of Dissolved Metals in Inshore Waters of the Menai Straits; *Marine Pollution Bulletin*; **5**: 54-58.
- Mukerji, K. G. and Mandeep, 1998. Mycorrhizal Relationships of Wetlands and Rivers Associated Plants; [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science, Easton; pp. 240-257.
- Murali, R. M.; Vethamony, P.; Saran, A. K. and Jayakumar, S. 2006. Change Detection Studies in Coastal Zone Features of Goa, India by Remote Sensing; *Current Science*; **91**(6): 816-820.
- Nagabhushanam, R. and Bidarkar, D. S. 1978. Studies on Seasonal Changes in the Biochemical Constituents of the Oyster *Crassostrea culcullata*; *Indian Journal of Fisheries*; **25**(1&2): 156-164.
- Nagabhushanam, R. and Deshmukh, R. S. 1974. Seasonal Changes in Body Components Indices and Chemical Composition in the Estuarine Clam *Meretrix meretrix*; *Indian Journal of Fisheries*; **21**: 531-542.
- Nagamani, K. and Ramachandran, S. 2003. Land Use / Land Cover in Pondicherry Using Remote Sensing and GIS; [In: Proceedings of the Third International Conference of Environment and Health, Chennai,

India; (Eds.): Bunch, M. J.; Suresh, V. M. and Vasantha, K.]; 15-17 December 2003, Chennai; pp. 300-305.

- Nair, A.; Ansari, Z. A.; Harkantra, S. N. and Parulekar, A. H. 1977. Uptake of Copper by the Mussel *Mytilus viridis* L.; *Indian Journal of Marine Sciences*; **6**: 90-91.
- Nair, A.; Dalal, S. G. and Ansari, Z. A. 1978. Growth of the Bean Clam *Donax incarnatus* Gmelin from a Sandy Beach at Benaulim, Goa; *Indian Journal of Marine Sciences*; **7**(3): 197-199.
- Nairy, K. S.; Kazi, S.; Abraham, M. and Jorge, R. 2003. The Baga-Nerul Watersheds: Tourism, Local Stakes, and Transformations; [In: Coastal Tourism, Environmental, and Sustainable Local Development; (Eds.): Noronha, L. *et al*]; TERI; New Delhi; pp. 61-93.
- Nascimento, I. A. 1990. Biological Characteristics of Mangrove Oysters in Brazil as a Basic for their Cultivation: A Review of Reproductive Cycles and Growth; [In: Oyster Culture in the Caribbean; (Eds.): Newkirk, G. F. and Field, B. A.]; Mollusc Culture Network, Dalhousie University, Nova Scotia; pp. 17-33.
- Naskar, K. and Mandal, R. 1999. Ecology and Biodiversity of Indian Mangroves; Part I: Global Status; Daya Publishing House; Delhi; 361 pp.
- Nayak, G. N. 2002. Impact of Mining on Environment of Goa; India International Publisher, New Delhi; 112 pp.
- Nayak, S. 1993. Role of Remote Sensing Applications in the Management of Wetland Ecosystems with Special Emphasis on Mangroves; *Proceedings of UNISCO Curriculum Workshop on Management of Mangrove Ecosystem and Coastal Ecosystem, Dec. 8,*

1993, Department of Marine Living Resources, Andra University, Visakhapatnam, India; 1-21.

- Nayak, S. and Bahuguna, A. 2001. Application of Remote Sensing Data to Monitor Mangroves and Other Coastal Vegetation of India; *Indian Journal of Marine Sciences*; **30**(4): 195-213.
- Nayak, S. R.; Gupta, M. C. and Chauhan, H. B. 1985. Monitoring of Wetland and Shoreline on the Part of Gujarat Coast using Landsat Data; *Proceedings of 6<sup>th</sup> Asian Conference on Remote Sensing (ACRS)*; Asian Association of Remote Sensing, Hyderabad; pp. 348-353.
- Nayak, S.; Chauhan, P.; Bahuguna, A. and Nath, N. 1996. IRC-1C Applications for Coastal Zone Management; *Current Science*; **70**(7): 614-618.
- Noronha, L. 2003. Introduction and Overview; [In: Coastal Tourism, Environmental, and Sustainable Local Development; (Eds.): Noronha, L. *et al*]; TERI; New Delhi; pp. 1-28.
- Noronha, L. and Nairy, K. S. 2003. Changing Uses, Ecosystem Valuation, and Perceptions: The Case of Khazans in Goa; [In: Coastal Tourism, Environmental, and Sustainable Local Development; (Eds.): Noronha, L. *et al*]; TERI; New Delhi; pp. 253-268.
- Novotny, V. 2003. Water Quality, Diffuse Pollution and Watershed Management; 2<sup>nd</sup> Edition; John Wiley & Sons, Inc., New York; 864 pp.
- Oswin, S. D. and Kathiresan, K. 1994. Pigments in Mangrove species of Pichavaram; *Indian Journal of Marine Sciences*; **23**: 64-66.
- Páez-Osuna, F.; Zazueta-Padilla, M. and Osuna-López, J. I. 1993. Biochemical Composition of the Oysters *Crassostrea iridescens* Hanley and *Crassostrea corteziensis* Hertlein in the Northwest Coast of Mexico:

Seasonal Changes; *Journal of Experimental Marine Biology and Ecology*; **170**: 1-9.

- Pai, R. and Reddy, M. P. M. 1981. Distribution of Nutrients off Malpe, South Kanara Coast, *Indian Journal of Marine Sciences*; **10**: 322-326.
- Parsons, T. R.; Maita, Y. and Lalli, C. M. 1984. A Manual of Chemical and Biological Methods for Seawater Analysis; Pergamon Press; Oxford, U.K.; 173 pp.
- Parulekar, A. H.; Dalal, S. G.; Ansari, Z. A. and Harkantra, S. N. 1982. Environmental Physiology of Raft-Grown Mussels in Goa, India; *Aquaculture*; **29**: 83-93.
- Parulekar, A. H.; Dhargalkar, V. K. and Singbal, S. Y. S. 1980. Benthic Studies in Goa Estuaries: Part III – Annual Cycle of Macrofaunal Distribution, Production and Trophic Relations; *Indian Journal of Marine Sciences*; **9**: 189-200.
- Parulekar, A. H.; Dwivedi, S. N. and Dhargalkar, V. K. 1973. Ecology of Clam Beds in Mandovi, Cumbarjua Cana and Zuari Estuarine System of Goa; *Indian Journal of Marine Sciences*; **2**: 122-126.
- Parulekar, A. H.; Nair, S. A.; Ansari, Z. A.; Harkantra, S. N.; Chatterji, A.; Ingole, B. S. and Roy, J. M. 1984. Ecology and Culturing of Edible Bivalves in Goa; *Indian Journal of Marine Sciences*; **13**(4): 190-192.
- Patel, B.; Pawar, S.; Balani, M. C. and Patel, S. 1980. Macroalgae as 'Sentinal' of Trace and Heavy Metals in the Management of Coastal Environment; [In: Management of Environment; (Ed.): Patel, B.]; Wiley Eastern Limited, New Delhi; pp. 371-388.

- Patnaik, P. 1997. Handbook of Environmental Analysis; Chemical Pollutants in Air, Water, Soil and Solid Wastes; CRC Press, Inc.; Florida; 584 pp.
- Patrick, S.; Faury, N. and Gouletquer, P. 2006. Seasonal Changes in Carbohydrate Metabolism and its Relationship with Summer Mortality of Pacific Oyster *Crassostrea gigas* (Thunbrg) in Marennes-Oléron Bay (France); *Aquaculture*; **252**: 328-338.
- Peerzada, N. and Dickinson, C. 1988. Heavy Metal Concentration in Oysters from Darwin Harbour; *Marine Pollution Bulletin*; **19**: 182-184.
- Phillips, A. M. 1969. Nutrition, Digestion and Energy Utilization; [In: Fish Physiology, Volume 1: Excretion, Ionic Regulation, and Metabolism; (Eds.): Hoar, W. S. and Randall, D. J.]; Academic Press, New York; pp. 391-432.
- Phillips, D. J. H. 1976a. The Common Mussel *Mytilus edulis* as an Indicator of Pollution by Zinc, Cadmium, Lead and Copper, I. Effects of Environmental Variables on Uptake of Metals; *Marine Biology*; **38**: 59-69.
- Phillips, D. J. H. 1976b. The Common Mussel *Mytilus edulis* as an Indicator of Pollution by Zinc, Cadmium, Lead and Copper. II. Relationship of Metals in the Mussel to Those Discharged by Industry; *Marine Biology*; **38**: 71-80.
- Phillips, D. J. H. 1977a. The Use of Biological Indicator Organisms to Monitor Trace Metal Pollution in Marine and Estuarine Environments – A Review; *Environmental Pollution*; **13**: 281-317.
- Phillips, D. J. H. 1977b. Effects of Salinity on the Net Uptake of Zinc by the Common Mussel *Mytilus edulis*; *Marine Biology*; **41**: 79-88.

- Phillips, D. J. H. 1978. The Common Mussel *Mytilus edulis* as an Indicator of Trace Metals in Scandinavian Waters. II. Lead, Iron and Manganese; *Marine Biology*; **46**: 147-156.
- Phillips, D. J. H. 1979. The Rock Oyster *Saccostrea glomerata* as an Indicator of Trace Metals in Hong Kong; *Marine Biology*; **53**: 353-360.
- \*Pomeroy, R. S. and Katon, B. M. 2000. Mangrove Rehabilitation and Coastal Resource Management Project (MRCRMP) of Mabini-Candijay, Bohol, Philippines: Cogtong Bay; *Proceedings of Asia-Pacific Cooperation on Research for Conservation of Mangroves, Okinawa, Japan*; 265-278.
- Ponniah, A. G. 1988. A Study on Biochemical Genetics on *Crassostrea madrasensis* of Cochin; *CMFRI Bulletin*; **42**(1): 189-192.
- Popham, J. D.; Johnson, D. C. and D'Auria, J. M. 1980. Mussels (*Mytilus edulis*) as 'Point Source' Indicators of Trace Metal Pollution; *Marine Pollution Bulletin*; **11**: 261-263.
- Qasim, S. Z. 2004. Handbook of Tropical Estuarine Biology; Narendra Publishing House, Delhi; 131 pp.
- Qasim, S. Z. and Sen Gupta, R. 1980. Present Status of Marine Pollution in India; [In: Management of Environment; (Ed.): Patel, B.]; Wiley Eastern Limited, New Delhi; pp. 310-329.
- Qasim, S. Z. and Sen Gupta, R. 1981. Environmental Characteristics of the Mandovi – Zuari Estuarine System in Goa; *Estuarine, Coastal and Shelf Science*; **13**: 557-578.
- Qasim, S. Z.; Parulekar, A. H.; Harkantra, S. N.; Ansari, Z. A. and Nair, A. 1977. Aquaculture of Green Mussel *Mytilus viridis* L.: Cultivation on Ropes from Floating Rafts; *Indian Journal of Marine Sciences*; **6**: 15-25.



- Qasim, S. Z. and Wafar, M. V. M. 1990. Marine Resources in the Tropics; *Resources Management and Optimization*; **7**(1-4): 141-169.
- Quayle, D. B. and Newkirk, G. F. 1989. Farming Bivalve Molluscs: Methods for Study and Development, Advanced in World Aquaculture, Volume 1; International Development Research Centre; Canada; 294 pp.
- \*Quayle, D. B. 1988. Pacific Oyster Culture in British Columbia; *Fisheries Research Board of Canada Bulletin*; **218**: 241 pp.
- Raghavan, B. R.; Vinod, B. T.; Dimple, K. A.; Prabhu, H. V.; Udayashankar, H. N. and Murthy, T. R. S. 2001. Evaluation of the Nethravathi Spit Complex, West Coast of India: Integrated Change Detection Study Using Topographic and Remotely Sensed Data; *Indian Journal of Marine Sciences*; **30**(4): 268-270.
- Rajendran, N. and Sanjeevi, S. B. 2004. Flowering Plants and Fern in Mangrove Ecosystems of India, an Identification Manual; ENVIS Publication Series, New Delhi; 110 pp.
- Rajendran, N.; Kurian, C. V. and George, V. 1987. Mercury Concentrations in *Crassostrea madrasensis* (Preston) from Cochin Backwaters; *Journal of Marine Biological Association of India*; **29**: 237-243.
- Ramachandran, S.; Anitha, S.; Balamurugan, V.; Dharanirajan, K.; Vendhan, K. E.; Divien, M. I. P.; Vel, A. S.; Hussain, I. S. and Udayaraj, A. 2005. Ecological Impact of Tsunami on Nicobar Islands (Camorta, Katchal, Nancowry and Trinkat); *Current Science*; **89**(1): 195-200.
- Ramachandran, S.; Sundaramoorthy, S.; Krishnamoorthy, R.; Devasenapathy, J. and Thanikachalam, M. 1998. Application of Remote Sensing and GIS to Coastal Wetland Ecology of Tamil Nadu and

Andaman and Nicobar Group of Islands with Special Reference to Mangroves; *Current Science*; **75**(3): 236-244.

- Ranade, P. S. 2007. Conservation and Management of Mangroves; [In: Management of Coastal Resources: An Introduction; (Ed.): Ranade, P. S.]; the Icafi University Press, Hyderabad; pp. 129-148.
- Rao K. V. and Nayar, K. N. 1956. Rate of Growth in Spat and Yearlings of the Indian Backwater Oyster *Ostrea madrasensis* (Preston); *Indian Journal of Fisheries*; **3**: 231-260.
- Rao, D. S. and Madhavan, N. 1964. On Some pH Measurements in the Arabian Sea along the West Coast of India; *Journal of the Marine Biological Association of India*; **6**(2): 217-221.
- Rao, K. K. 1974. Ecology of Mandovi and Zuari Estuaries, Goa: Distribution of Foraminiferal Assemblage; *Indian Journal of Marine Sciences*; **3**: 61-66.
- Rao, K. V.; Kumar, L. K. and Dwive, S. N. 1975. Biology of the Green Mussels, *Mytilus viridis*; *Indian Journal of Marine Sciences*; **4**: 189-197.
- Rao, P. P.; Raju, A. V. and Nair, M. M. 1985. Geomorphology of Goa [In: Earth Resources for Goa's Development – A Collection of Seminar Papers]; Geological Survey of India, Hyderabad; pp. 583-586.
- Rao, T. A. and Suresh, P. V. 2001. Coastal Ecosystems of the Karnataka State, India: I. Mangroves; Karnataka Association for the Advancement of Science, Central College, Bangalore; p. 4.
- Rattan, P. 1994. Ecobiology of Pearl Spot (*Etroplus suratensis* Bloch) in Goa Waters; a Ph. D. Thesis Submitted to Goa University.
- Rivonkar, C. U. 1991. Ecology of Raft Grown Green Mussels *Perna viridis* L.; a Ph. D. Thesis Submitted to Goa University.

- Rivonkar, C. U. and Parulekar, A. H. 1995. Proximate Biochemical Composition and Caloric Potential in the Raft-Grown Green Mussel *Perna viridis*; *Journal of Marine Biological Association of India*; **37**: 231-236.
- Rivonkar, C. U. and Parulekar, A. H. 1998. Seasonal Variation of Major Elements (Ca, Mg) and Trace Metals (Fe, Cu, Zn, Mn) in Cultured Mussel *Perna Viridis* L. and Seawater in the Dona Paula Bay, Goa; *Indian Journal of Marine Sciences*; **27**: 411-415.
- Robert, R.; Trut, G.; Borel, M. and Maurer, D. 1993. Growth, Fatness and Gross Biochemical Composition of the Japanese Oyster, *Crassostrea gigas*, in Stanway Cylinders in the Bay of Arcachon, France; *Aquaculture*; **110**: 249-261.
- Roustaian, P. 1994. Ecology of the Rock Oyster, *Saccostrea cucullata* (Bivalvia: Ostreidae) at Band Moalem Coast along Northeastern Persian Gulf; *Indian Journal of Marine Sciences*; **23**: 242-243.
- \*Roy, P. S.; Kaul, R. N.; Sharma Roy; M. R. and Garbyal, S. G. 1985. Forest Type Stratification and Delineation of Shifting Cultivation Areas in the Eastern Part of Arunachal Pradesh Using Landsat MSS Data; *International Journal of Remote Sensing*; **6**: 411-418.
- Roy, P. S.; Ranganath, B. K.; Diwakar, P. G.; Vohra, T. P. S.; Bhan, S. K.; Singh, I. J. and Pandian, V. C. 1991. Tropical Forest Type Mapping and Monitoring Using Remote Sensing; *International Journal of Remote Sensing*; **12**(11): 2205-2225.
- Ruiz, c.; Martinez, D.; Mosquera, G.; Abad, M. and Sánchez, J. L. 1992. Seasonal Variations in Condition, Reproductive Activity and Biochemical Composition of the Flat Oyster, *Ostrea edulis*, from San Cibrán (Galicia, Spain); *Marine Biology*; **112**: 67-74.

- Sajeev, R. and Subramanian, V. 2003. Land Use / Land Cover Changes in Ashtamudi Wetland Region of Kerala – A Study Using Remote Sensing and GIS; *Journal Geological Society of India*; **61**: 573-580.
- Sankaranarayanan, V. N. and Qasim, S. Z. 1969. Nutrients of the Cochin Backwaters in Relation to Environmental Characteristics; *Marine Biology*; **2**: 239-247.
- Sankaranarayanan, V. N. and Reddy, C. V. G. 1973. Copper Content in the Inshore and Estuarine Waters along the Central West Coast of India; *Current Science*; **42**: 223-224.
- Sankaranarayanan, V. N.; Purushan, K. S. and Rao, T. S. S. 1978. Concentration of some of the Heavy Metals in the Oyster, *Crassostrea madrasensis* (Preston), from the Cochin Region; *Indian Journal of Marine Sciences*; **7**: 130-131.
- Santhanam, R.; Rmanathan, N. and Jegatheesan, G. 1990. Coastal Aquaculture in India; CBS Publishers and Distributors, Delhi; 180 pp.
- Saraswathy, M. and Nair, N. B. 1969. Biochemical Changes in Relation to the Breeding Cycles of *Nausitora hedleyi* Schepman (Bivalvia: Teredinidae); *Current Science*; **38**(7): 158-160.
- Sardessai, S. and Sundar, D. 2007. Variability of Nitrate and Phosphate; [In: The Mandovi and Zuari Estuaries; (Eds.): Shetye, S. R.; Kumar, M. D. and Shankar, D.]; National Institute of Oceanography, Goa; pp. 59-66.
- Sarkar, A. 1998. Environmental Aspects of the Wetlands; [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science, Easton; pp. 198-214.

- Sarma, V. V. S. S.; Kumar, M. D. and Manerikar, M. 2001. Emission of Carbon Dioxide from a Tropical Estuarine System, Goa, India; *Geophysical Research Letters*; **28**(7): 1239-1242.
- Sathe, P. V. and Sawkar, K. 2003. Landform Changes from Remote Sensing Data; [In: Coastal Tourism, Environment and Sustainable Local Development; (Eds.) Noronha, L. *et al.*]; TERI, New Delhi; pp. 151-165.
- Schaefer, R.; Trustschler, K. and Rumohr, H. 1985. Biometric Studies on the Bivalves *Astarte elliptica*, *A. borealis* and *A. montagui* in Kiel Bay (Western Baltic Sea); *Helgolönder Meeresunters*; **39**: 245-243.
- Schumacker, E. J.; Dumbauld, B. R. and Kauffman, B. E. 1998. Investigations using Oyster Condition Index to Monitor the Aquatic Environment of Willapa Bay Washington; *Journal of Shellfish Research*; **17**: 338-339.
- Seed, R. 1968. Factors Influencing Shell Shape in the Mussel *Mytilus edulis*; *Journal of the Marine Biological Association of the United Kingdom*; **48**: 561-584.
- \*Seed, R. 1973. Absolute and Allometric Growth in the Mussel *Mytilus edulis* (Mollusca, Bivalvia); *Proceedings of Malacological Society of London*; **40**: 343-357.
- Segar, D. A.; Collins, J. D. and Riley, J. P. 1971. The Distribution of the Major and Some Minor Elements in Marine Animals, Part II. Molluscs; *Journal of the Marine Biological Association of the United Kingdom*; **51**: 131-136.
- Selvam, V.; Ravichandran, K. K.; Gnanappazham, L. and Navamuniyammal, M. 2003. Assessment of Community-Based Restoration of Pichavaram Mangrove Wetland Using Remote Sensing Data; *Current Science*; **85**(6): 794-798.

- Sen Gupta, R. and Qasim, S. Z. 2001. Health of the Indian Ocean; [In: The Indian Ocean – A Prospective; (Eds.): Sen Gupta, R. and Desa, E.]; Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi; pp. 327-371.
- Sen Gupta, R. Singbal, S. Y. S. and Sanzgiri, S. 1978. Atomic – Absorption Analysis of a Few Trace Metals in Arabian Waters; *Indian Journal of Marine Sciences*; **7**: 295-299.
- Shafee, M. S. 1978. Variations in Biochemical Composition of the Green Mussel *Perna viridis* Linnaeus of Ennur Estuary, Madras; *Mahasagar Bulletin of the National Institute of Oceanography*; **11**(1&2): 101-104.
- Shetye, S. R.; Suresh, I. and Sundar, D. 2007. Tides and Sea-Level Variability; [In: The Mandovi and Zuari Estuaries; (Eds.): Shetye, S. R.; Kumar, M. D. and Shankar, D.]; National Institute of Oceanography, Goa; 29-38 pp.
- Shimizu, M. and Tsuji, S. 1980. Heavy Metal Content of the Common Mussel *Mytilus edulis*, and its Variation; [In: Management of Environment; (Ed.): Patel, B.]; Wiley Eastern Limited, New Delhi; pp. 409-416.
- Siddique, G. and Ahmed, M. 2002. Oyster Species of the Sub-tropical Coast of Pakistan (Northern Arabian Sea); *Indian Journal of Marine Sciences*; **31**(2): 108-118.
- \*Sidhu, S. S. 1974. Studies on Mangrove of India: 1. East Godavari Region; *Indian Forester*; **89**: 337-351.
- \*Silker, W. B. 1964. Variations in Elemental concentrations in the Columbia River; *Limnology & Oceanography*; **9**: 540-545.

- Singbal, S. Y. S. 1976. Diurnal Variation of Some Physico-Chemical Factors in the Mandovi Estuary of Goa; *Mahasagar Bulletin of the National Institute of Oceanography*; **9**: 27-34.
- Singbal, S. Y. S.; Sanzgiri, S. and Sen Gupta, R. 1978. Total Mercury concentrations in the Arabian Sea Waters off the Indian Coast; *Indian Journal of Marine Sciences*; **7**: 124-126.
- Singh, V. P. and Odaki, K. 2004. Mangrove Ecosystem: Structure and Function; Scientific Publishers (India), Jodhpur; 297 pp.
- Stephen, D. 1980a. The Reproduction Biology of the Indian Oyster *Crassostrea madrasensis* (Preston), I. Gametogenic Pattern and Salinity; *Aquaculture*; **21**: 139-146.
- Stephen, D. 1980b. The Reproduction Biology of the Indian Oyster *Crassostrea madrasensis* (Preston), II. Gametogenic Cycle and Biochemical Levels; *Aquaculture*; **21**: 147-153.
- Stevens, T. H. 1998. Economic Value of Wetlands; [In: Ecology of Wetlands and Associated Systems; (Eds.): Majumdar, S. K.; Miller, E. W. and Brenner, F. J.]; the Pennsylvania Academy of Science; Easton; pp. 486-496.
- Strickland, J. D. H. and Parsons, T. R. 1977. A Practical Handbook of Sea Water Analysis; Ministry of Supply and Service; Canada; 310 pp.
- Talbot, V. 1985. Relationship between Cadmium Concentrations in Seawater and Those in Mussel *Mytilus edulis*; *Marine Biology*; **85**: 51-54.
- Talbot, V. 1987. Relationship between Lead Concentrations in Seawater and in the Mussel *Mytilus edulis*: A Water-Quality Criterion; *Marine Biology*; **94**: 557-560.

- Talbot, V.; Magee, R. J. and Hussain, M. 1976. Lead in Port Phillip Bay Mussels; *Marine Pollution Bulletin*; **7**: 234-237.
- Tomlinson, P. B. 1986. *The Botany of Mangroves*; Cambridge University Press, New York; 419 pp.
- Townend, J. 2002. *Practical Statistics for Environmental and Biological Scientists*; John Wiley & Sons Ltd., U. K.; 276 pp.
- Turner, R. E. 2006. Will Lowering Estuarine Salinity Increase Gulf of Mexico Oyster Landings?; *Estuaries and Coasts*; **29**(3): 345-352.
- Udaybaskar, S.; Anil, A. C. and Wagh, A. B. 1983. Iron Accumulation in the Sessile Barnacle, *Balanus amaryllis* (Darwin); *Marine Pollution Bulletin*; **14**: 236-237.
- Untawale, A. G. and Jagtap, T. G. 1999. Socioeconomic Significance of Mangroves for Coastal People of India: A Changing Scenario; [In: *Mangrove Ecosystems Proceedings*]; Proceedings of Symposium on Significance of Mangrove Ecosystems for Coastal People; Thailand 19-21 Aug. 1996; pp. 91-101.
- Untawale, A. G. 2006. Change of Coastal Land Use, its Impact, and Management Options; [In: *Multiple Dimensions of Global Environmental Change*; (Ed.): Sonak, S.]; TERI, New Delhi; pp. 23-43.
- Untawale, A. G. and Parulekar, A. H. 1976. Some Observations on the Ecology of an Estuarine Mangrove of Goa; *Mahasagar Bulletin of the National Institute of Oceanography*; **9**(1&2): 57-62.
- Untawale, A. G.; Dwivedi, S. N. and Singbal, S. Y. S. 1973. Ecology of Mangroves in Mandovi and Zuari Estuaries and Interconnecting Cumbarjua Canal of Goa; *Indian Journal of Marine Sciences*; **2**: 47-53.



- Untawale, A. G.; Wafar, S. and Bhosole, N. B. 1980. Seasonal Variation in Heavy Metal Concentration in Mangrove Foliage; *Mahasagar Bulletin of the National Institute of Oceanography*; **13**(3): 215-223.
- Untawale, A. G.; Wafar, S. and Jagtap, T. G. 1982. Application of Remote Sensing Techniques to Study the Distribution of Mangroves along the Estuaries of Goa; [In: *Wetlands: Ecology and Management (Proceedings of the First International Wetlands Conference)* New Delhi, India, 10-17 Sep. 1980; (Eds.): Goapal, B.; Turner, R. E.; Wetzel, R. G. and Whigham, D. F.]; National Institute of Ecology and International Scientific Publications, Jaipur; pp. 51-67.
- Upadhyay, V. P.; Ranjan, R. and Singh, J. S. 2002. Human Mangrove Conflicts: The Way Out; *Current Science*; **83**(11): 1328-1336.
- Valenta, P.; Nurnberg, H. W.; Klahre, P.; Rutzel, H.; Merks, A. G. A. and Reddy, S. J. 1983. A Comparative Study of toxic Trace Metals in the Estuaries of the Ooster and Westerscheldt and of the Sierra Leone River; *Mahasagar Bulletin of the National Institute of Oceanography*; **16**: 109-126.
- Venkataraman, R. and Chari, S. T. 1951. Studies on Oysters and Clams: Biochemical Variation; *Indian Journal of Medical Research*; **39**(4): 533-541.
- Wafar, M. V. M.; Vijayaraghavan, S. and kumari, L. K. 1976. Seasonal Changes in the Nutritive Value of the Green Mussel, *Mytilus viridis* Linné; *Indian Journal of Marine Sciences*; **5**: 252-254.
- Wafar, S. 1987. Ecology of Mangroves along the Estuaries of Goa; a Ph. D. Thesis Submitted to Karnataka University, Dharwad, India.

- Wafar, S.; Untawale, A. G. and Wafar, M. V. M. 1997. Litter Fall and Energy Flux in a Mangrove Ecosystem; *Estuarine, Coastal and Shelf Science*; **44**: 111-124.
- Wagle, B. G. 1982. Geomorphology of the Goa Coast; *Proceedings, Indian Academy of Sciences*; **91**(2): 105-115.
- Wagle, B. G. 1987. Geomorphology and Evolution of the Coastal and Offshore Areas of Maharashtra and Goa, India; a Ph. D. Thesis submitted to the University of Bombay, India.
- Wagle, B. G. and Vora, K. H. 1980. Rocks for Coastal Protection; [In: Manual on Protection and Control of Coastal Erosion in India; (Eds.): Bruun, P. and Nayak, B. U.] National Institute of Oceanography, Goa; pp. 63-64.
- Walne, P. R. 1972. The Influence of Current Speed, Body Size and Water Temperature on the Filtration Rate of Five Species of Bivalves; *Journal of the Marine Biological Association of the United Kingdom*; **52**: 345-374.
- Walter, H. 1977. Climate; [In: Ecosystem of the World 1: Wet Coastal Ecosystems; (Ed.): Chapman, V. J.]; Elsevier Scientific Publication Co., New York; pp. 61-67.
- Walting, H. R. and Walting R. J. 1976. Trace Metals in *Choromytilus meridionalis*; *Marine Pollution Bulletin*; **7**: 91-94.
- Widdows, J. and Bayne, B. L. 1971. Temperature Acclimation of *Mytilus edulis* with Reference to its Energy Budget; *Journal of the Marine Biological Association of the United Kingdom*; **51**: 827-843.

- Williams, C. S. 1969. The Effects of *Mytilicola intestinalis* on the Biochemical Composition of Mussels; *Journal of the Marine Biological Association of the United Kingdom*; **49**: 161-173.
- Williams, D. C. and Lyon, J. G. 1995. Use of a Geographic Information System Database to Measure and Evaluate Wetland Changes in the St. Mary's River, Michigan; [In: Wetland and Environmental Applications of GIS; (Eds.): Lyon, J.G. and McCarthy, J.] CRC Press, Florida; pp. 125-139.
- Zandee, D. I.; Kluytmans, J. H. and Zurburg, W. 1980. Seasonal Variation in Biochemical Composition of *Mytilus edulis* with Reference to Energy Metabolism and Gametogenesis; *Netherlands Journal of Sea Research*; **14**(1): 1-29.
- Zar, J. H. 2006. Biostatistical Analysis; Fourth Edition; Pearson Education, Inc.; 663 pp.
- Zingde, M. D.; Singbal, S. Y. S.; Moraes, C. F. and Reddy, C. V. G. 1976. Arsenic, Copper, Zinc and Manganese in the Marine Flora and Fauna of Coastal and Estuarine Waters around Goa; *Indian Journal of Marine Sciences*; **5**: 212-217.
- Zingde, M. D.; Singbal, S. Y. S. and Reddy, C. V. G. 1979. Some Observations on Pollutants of Velsao Bay (Goa); *Mahasagar Bulletin of the National Institute of Oceanography*; **12**(2): 69-74.

(\*) = Not referred in original.