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HUMAN'S IMPACTS ON THE PICHAVARAM MANGROVE ECOSYSTEM: A CASE STUDY FROM SOUTHERN INDIA

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INTRODUCTION

The Pichavaram mangrove ecosystem is situated along the Coromandel coast between the Vellar and Coleroon estuarine systems in south-east part of India (11° 29' N; 70° 49' E). This mangrove ecosystem is influenced by the mixing of neritic water (from Bay of Bengal), brackish water (from Vellar and Coleroon estuaries) and fresh waters (from irrigation channel of the Khan Sahib Canal). It covers an area of approximately 15 sq. km, about 40% of which is occupied by waterways, 50% by mangrove forests and the rest being mud-flats, sand-flats and salt-flats. This small ecosystem is playing an important role in sustaining coastal natural resources, by providing detritus, nutrient salts, vitamins, trace elements, etc. The structure and integrity of this dynamic but fragile ecosystem is influenced by various meteorological factors such as rainfall and wind, and is also subjected to anthropogenic pressure of diverse variety.

MATERIALS AND METHODS

Intensive collection of data and literature reviews were made to study the flora and fauna of this mangrove ecosystem. Physico-chemical and biological parameters were measured round the year. Fishery resources were assessed along with the natural habitat, growth stages and food habits of the species involved. The topography of the mangrove habitats and their interaction with adjacent ecosystems were noted. The management policies were also reviewed.

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RESULTS AND DISCUSSION

I. Illicit felling of mangrove plants. Some thousand families who live in the surrounding areas depend on this ecosystem for firewood. Most of these families get their firewood in illicit way, by cutting the vegetation. Limited licences were also issued for harvesting. As a result a vast stretch of luxuriant mangrove vegetation is subjected to unreparable destruction.

Avicennia marina Vierh. is the dominant species in Pichavaram mangroves. This species is commonly subjected to illicit felling for firewood. *Excoecaria agallocha* L. is common and large-sized trees are exploited for manufacturing canoe accessories. Huge trees of *Sonneratia apetala* Buch. Ham. once reported to be present in the area have totally vanished due to selective felling (Blasco, 1974; Blasco *et al.*, 1975). At present, only a few young trees of this species exist in this ecosystem. *Rhizophora apiculata* Bl. and *R. mucronata* Lamk. are the dominant mangrove species in the fringe communities which border the channels. These vegetations are also subjected to illicit felling, which result in the erosion of the banks in certain area. Moreover, certain valuable and rare species, e.g. *Xylocarpus mekongensis* Pierre, which grows immediately behind the *Rhizophora* fringe communities is uprooted due to erosion of the banks.

II. Grazing by cattles. Mangrove areas which are not within forest reserves boundary are subjected to intensive grazing by cattles. The licence system adopted by the Forest Department permits the harvest of mangrove leaves as cattle feed and also allows certain area to be used for cattle grazing. However, due to the lack of strict vigilance, the forest reserves were subjected to grazing also. Though the bigger trees are not affected, the shrubby formations which consist mainly of *Avicennia marina* are subjected to intensive destruction. These shrubby formations are not more than 0.6 m in height and occupying an area of approximately 3 sq. km located mainly in the northern side of the mangrove communities near Vellar estuary, along Killai backwaters. The cattles affect the principal mangrove seedlings dispersal and afforestation by grazing the intertidal grasses, which are the pioneers of mangrove colonization.

III. Bund construction for fishing. In Pichavaram mangroves, fishing is done by diverse manners. One of such methods is the so called 'fish fence trap' or locally known as 'Charu'. In this fishing technique, bunds are constructed to a height of upto the level of mid-tide which varies according to season and about 0.3 m wide. When the water level increases during the inflowing tide, the bunds will be completely submerged. Certain fishes, especially mullets such as *Liza parsia* (Hamilton - Buchanan) and *Ellochelon vaigiensis* (Quoy & Gaimard)

have the tendency to move towards the shore. During ebb tide, the water will reside through a mat made of bamboo cane, from the mid-water level upto the low water level. The fishes trapped inside the embankment and those trying to escape by leaping, are collected by a scoopnet or a bag made of cloth. The bunds constructed in this 'Charu' fishing method affect the pattern of the current leading to siltation which in turn gives rise to poor nutrient condition of the soil and causes the adjacent mangrove vegetation to perish. Furthermore since this fishing method is more intensively carried out in mangrove areas where the tidal amplitude is high (adjacent to sea), the bunds built will also act as barrier for the effective dispersal of viviparous mangrove seedlings thereby preventing further colonization of mangrove vegetation in the area. As a consequence of this, the area is subjected to severe sea erosion.

IV. Weir construction for aquaculture purposes. The Mangrove channels close to neritic influence support natural formation of algal weeds and sea grasses. Among the algal weeds found in this area are *Gracilaria verrucosa* (Hudson) Papenfuss, *G. lichenoides* (L.) Harvey, *Enteromorpha intestinalis* L. , *E. compressa* (L.) Grev., *Chaetomorpha antennina* Kuetzing, *Hypnea musciformis* (Wulfin) Lamouroux, and *Cladophora* sp. Of these, species of the first three mentioned genera are dominant. The sea grass communities consist of *Halophila ovalis, Halophila* sp. and *Syringodium isoetifolium*. In addition epiphytic diatoms such as *Achnanthes, Navicula, Pleurosigma, Diploneis, Amphiprora* and *Amphora* are also found adhering to the algal weeds mentioned above. The gross production of this seaweed formation is around 6 g C/m^2/day and the net production being 5 g C/m^2/day (Kannan & Krishnamurthy 1978). This high rate of production and the resulting luxuriant growth of sea weed formations is caused by the optimum nutrient level, ideal turbidity condition and less meritic water mixing prevailing in these parts of mangrove ecosystem. Marine and estuarine species of fish such as *Siganus canaliculatus* (Schneider), *S. javus* Linnaeus, *Etroplus suratensis* (Bloch), *Scatophagus argus* (Linnaeus) and *Therapon puta* Cuvier and shell fish such as *Penaeus semisulcatus, P. monodon* and *Scylla serrata* utilize these algal and sea-grass communities as nursery ground. The construction of weirs for aquaculture practices results in the total disappearance of these sea-weed formations and thereby causing the decline in herbivorous fishery resource of the area.

V. Sluice construction for agricultural purposes. The annual rainfall of this area is about 150 cm, and c. 70% is contributed by northeast monsoon (October to December). However, in certain years, the monsoon rain may fall slightly earlier or fails to arrive causing the annual rainfall to drop to below 100 cm. The area receives only mild showers during southwest monsoon which takes place in June - July. Though this area receives excessive rainfall during northeast monsoon, the paddy cultivation starts only from June/July onwards. As such the success of this agriculture activity depends on the amount of rain received during the

southwest monsoon in the catchment area. To ensure sufficient water supply, the Mathur dam has been constructed in the Cauvery catchment area. This dam provides water to the cultivated lands via Coleroon river, a distributory of the Cauvery river. The Pichavaran mangroves receive brackish water from the Coleroon estuary. During the monsoonal floods, freshwaters flow into the mangroves from Coleroon river. However during non-monsoonal floods the mangrove ecosystem receives only freshwater from Uppanar, a so called river situated in the upstream, which receives freshwater from the Khan Shabib Canal. A sluice is constructed in the upstream of Uppanar to prevent saline water from penetrating into the paddy cultivation area, as well to regulate the freshwater inflow into the mangrove ecosystem. As a consequence the freshwater inflow into the mangrove ecosystem is very limited during non-monsoon months (January - September), affecting the growth of mangrove vegetation. The construction of dams and sluices thus alters the natural supply of freshwater, leading to the ecological inbalance of the mangrove ecosystem.

Hilsa ilisha (Hamilton-Buchanan) and *Nematolosa nasus* (Bloch) are some anadromous fishes affected by the sluice construction. *Hilsa ilisha* is very rare in this mangrove. Juveniles of *Nematolosa nasus* are common but the adults are sporadic in occurrence. The weir construction makes these fishes avoid the mangroves. Eels are represented by members of five families, viz. the Anguillidae, Muraenidae, Muraenesocidae, Ophichthyidae and Congridrae. Of these, species of the Anguillidae are catadromous. Juveniles of *Anguilla bicolor* and *A. bengalensis* are common during monsoon season. The sluices act as barrier during non-monsoon months by blocking the pathways of these eels.

During cyclonic and intensive monsoon periods (October-December), sudden outburst of water leads to food web alteration in mangroves. Under such condition, marine species will become totally absent, and the habitat is occupied mainly by certain estuarine and fresh water species. Heavy siltation in certain area has resulted in the shallowness of the mangrove channels. Since Pichavaram mangroves are situated in between two estuarine systems, the tidal phenomenon of the estuaries allows more silt to enter into backwaters of the mangroves. For a short period after flood, the column of water is separated from the detritus rich soil by alluvial and silt layer. This condition to some extent alters the community structure and food source available in the mangrove ecosystem. The heavy release of water also drags freshwater weeds such as *Eichhornia* sp. growing extensively in certain upstream areas, which cause eutrophication and surplus production of hydrogen sulphide after their death and decay.

Reduced fresh water drainage and even absence of fresh water supply into the mangrove ecosystem for most part of the non-monsoon (summer, premonsoon and post monsoon) periods, restricts the width of the estuary systems. This in turn leads to minimum tidal amplitude of only

1.5 m in average, causing poor growth of the mangrove vegetation. The normal size of certain mangrove plants such as *Rhizophora apiculata, R. mucronata, Sonneratia apetala, Avicennia marina, Ceriops decandra* and *Excoecaria agallocha* is very small in Pichavaram mangroves, when compared with the size of the same species growing in other geographical areas (Table 1). Poor tidal amplitude, continuous illicit felling, grazing by cattles, and mineral deficiency due to heavy siltation may be the causes of this low size range. Furthermore cyclonic storms in this monsoonal area could expose the tall trees to be easily uprooted, and thus the reduction in the overall size of the trees could be regarded as advantagous adaptation.

During normal summer season (May/June) the wind speed is between 8-15 kmph. However, during cyclonic seasons, the wind speed increases to at least 5 to 6 folds greater than in summer. The shallow waterways of the mangrove ecosystem (average 1 m) become very turbid during the wind stress, caused by the mixing of bottom sediments with turbulent waters. This results in the shifting of light extinction coefficient value to 8, and that of dissolved oxygen content to as high as 6.0 ml/l. During this period, the seston content is as high as 0.3 g/l. As a consequence of the high turbidity the habitat is not fit for most of the marine biota, which are principally low-turbidity tolerant species.

VI. Illicit fishing. In Pichavaram mangroves some 185 species of fish and 20 species of shell-fish are harvested, of which only 5-10 species of fish and 5 species of shell-fish are available in harvestable size and quantity. However, illicit fishing of most juvenile marine fishes and prawns using drag-nets, stake-nets and small mesh sized cast nets from these mangroves, will affect the future of large scale fishery in the area. The drag-nets uproot the benthic sea weeds, thereby spoiling the nursery potential of the mangrove habitat. The stake-nets when set-up in the water column act as barrier for the movements of fishes. This leads to avoidance by most of the marine species to enter into the mangrove ecosystem. Smaller mesh sized (<1 cm) cast-nets locally known as "Paranda Valai" and "Nadukatti Valai" are effective in harvesting juvenile fishes and prawns. Prohibition for the usage of drag-nets and stake-nets will minimise juvenile fishery harvest and thereby improving the yield of marine fishery. Mesh size regulation will help to prevent the illicit fishing of juvenile fishes.

VII. The importance of mangroves to coastal biotic communities. It is generally acknowledged that brackish water system brings organic and inorganic nutrients of terrestrial origin into the sea, making the sea water becomes more fertile and favourable for high phytoplankton production and the development of pelagic communities. The plankters, after their death, will undergo decomposition and become detritus, which are utilized by benthic marine communities. A brackish water system when associated with mangroves (also known as estuarine lagoonal and

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Table 1. The geographical range in normal sizes of some mangrove species.

Species	Max. Height (metre)	Max. diam. (cm)	Locality	Present Study Area	
				Max. Height (metre)	Max. diam. (cm)
1. *Rhizophora apiculata*	40	40	North East Sumatra	6	30
2. *Rhizophora mucronata*	35	40	Peninsular Thailand	8	30
3. *Sonneratia apetala*	30	90	Godavari & Bengal	10	30
4. *Avicennia marina*	10	**	Mozambique	4	30
5. *Ceriops decandra*	20	**	South East Asia	2	15
6. *Excoecaria agallocha*	24	**	Papua New Guinea	5	30

** Data not available.

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deltaic mangroves) contribute detrital material through defoliation and degradation by microbes, ciliates and certain crustaceans.

The average microbial population of Pichavaram mangrove sediments is seven folds greater than that of marine sediments, being 70 x 10^6/g and 10 x 10^6/g respectively. The ratio between bacterial and fungal population in the mangrove sediments is 1:7000. The mangrove sediment is composed of clay, silt and sand with the mean values being 40%, 25% and 35% respectively; it is also rich in organic and inorganic nutrients, with the organic matter being 7% and the inorganic phosphate and sulphate being 0.5 mg/g and 3.5 mg/g respectively. The mean total phosphorus content in marine and mangrove sediments does not show much variation in this area, the value being around 0.45 mg/g. The benthic production is also very high as indicated by the values of pigment concentration in the mangrove sediment, which are 5, 16 and 20 unit g^{-1} (dw) for chlorophyll a, bacteriochlorophyll a and phaeopigment respectively.

The tides and wind cause waves and turbulance which facilitate the mixing of sediment with overlying water column. The mixing results in high seston content (180 mg/l), high light extinction coefficient (8.0), and high oxygen content (6 ml/l). The turbidity and seston content of Pichavaram mangrove water are about 55 times and 20 times more than that of the nearby sea, respectively. The nutrient concentration in mangrove waters also increases due to drainage, wind, tide and shallowness of the water system. For instance, the silicate concentration is about 10 times more than that of sea water (mean value 105 and 11 µg at./l respectively). The concentration of nitrates, inorganic phosphates and dissolved organic copper of mangrove water is, respectively, 4 x (12 and 3 µg at./l), 20 x and 2 x (0.14 and 0.07 µg at./l) more than that of seawater. The mean values of total phosphorous and nitrite of mangrove water have been reported to be 1.5 µg at./l and 0.23 µg at./l respectively. The nutrient-enriched mangrove water mixes with comparatively nutrient-poor neritic water by means of tidal ebb and flow, and as a result the productivity of coastal ecosystem is boosted.

Though the primary production and chlorophyll values of mangrove water are comparatively higher than that of the sea water, the nannoplankton and phytoplankton biomass is lower in the mangrove than in marine ecosystem. The mean values of chlorophyll a, b, c, bacteriochlorophyll a, c and d are 0.02, 0.004, 0.01, 0.025, 0.012, 0.011 mg/l from mangrove waters and 0.03, 0.001, 0.003, 0.003, 0.01 and 0.006 from neritic waters respectively. Carotenoid concentration of mangrove water is 5 times more than that of sea water (0.01 MSPu/l and 0.002 MSPu/l, respectively); phaeopigment concentration of mangrove water is 0.006 mg/l. The gross production per unit volume (m^3) of water sample in mangrove waterways is 320 times more than that of coastal waters,

whereas the increase in production is only 6 folds according to unit area (m^2) of the waterbody. The mean value of gross production in the mangrove water is 320 $mgC/m^3/hr$, of which 35% of the produced energy is spent for respiration.

The mangrove vegetation, being autotrophic is able to carry out photosynthesis and thus increasing the biomass production of the ecosystem. The defoliation of senescent leaves, alluvial and freshwater input by flood and the role played by bacteria, fungi, ciliates, nematodes, etc., result in nutrient enrichment of the habitat. The planktons, bacterioplanktons, epiphytes and seaweeds in the waterways utilize the nutrient-enriched condition and produce more organic matter. All these productions result in the formation of energy-rich food known as detritus, which is transported into the coastal ecosystem by tides. Thus the mangroves provide detritus to benthic marine communities.

The prawn production of Pichavaram mangroves is estimated at 110 kg/ha/year, whereas that of adjacent Vellar estuary's (which is devoid of mangrove) is only 20 kg/ha/year. Fish production of the mangroves is 150 kg/ha/year, whereas that of Vellar estuary is only 100 kg/ha/year. About 400 tonnes of penaeid prawns are harvested from adjacent coastal waters. Of these, about 74% of the catch is contributed by those prawns which are using mangroves as nursery ground. About 5,000 tonnes of fishes are harvested from the adjacent sea, of which 12% of the catch is contributed by those fish species using mangroves as nursery ground. Many juveniles of coral fish utilize the Pichavaram mangroves as nursery ground. The principally detritus-feeding prawn juveniles are becoming food for those juvenile coral fishes. These coral fishes are not effectively harvested from the sea, due to lack of appropriate fishing technology.

Depending on the species, the exploitation of about 2.5 tonnes of undersized prawns from c.15 sq. km. of mangrove area leads to a loss of 10 to 50 folds of harvest from the adjacent coastal waters. This is in addition to those losses through predation, natural mortality and energy transfer from one trophic level to another. The maximum loss is implicted on *Penaeus monodon* and the minimum on *Metapenaeus dobsoni*.

Of the 185 species of fish occurring in Pichavaram mangroves, about 100 are marine juveniles, most of them using this ecosystem as nursery ground and for shelter. The harvesting of juvenile fin-fish is also the most intensive in mangrove ecosystem, leading to a minimum loss of about 5,000 tonnes to the adjacent marine fish-harvest. Of this loss, about 40% is contributed by juvenile pelagic fish and the rest by juvenile demersal fish.

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