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RESEARCH ARTICLE

Mangrove floral diversity and necessity for conservation of Interu mangrove swamp of River Krishna estuarine region Andhra Pradesh, India

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Abstract

Mangrove ecosystem is a unique coastal wetland habitat formed at the transition zone of marine and freshwater ecosystem and also having close interaction with adjacent ecosystems. They are of great ecological and socio economic significance. Moreover, mangroves act as bulkheads against natural calamities. Moreover, 90% of marine species spend part of their life cycle in the mangrove ecosystem meanwhile 80% of global fish catch are mangrove dependent. Worldwide in the long past this ecosystem are threatened due to anthropogenic intervention. In recent years Interu mangrove swamp of river Krishna estuarine region is subjected to severe degradation owing to human intervention such as rapid development in aquaculture activities, cutting of mangrove trees for timber/coal, lesser inflow of freshwater , hyper salinity, upland industrial pollutants and development of coastal corridor. In the present study records the 23 species of 14 families of mangrove plants of these 11 species are true mangroves and 12 species are mangrove associates. The causative aspects for decline of the mangrove swamp ecosystem and necessary steps for conservation are discussed.

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INTRODUCTION

Mangrove wetlands are self sustaining coastal ecosystems that have formed after long-term geomorphological processes having close interaction with adjacent ecosystems. Mangrove forests established at inter-tidal zones of estuaries, back waters, creeks, lagoons, marshes, swamps and mud flats of tropical and sub-tropical latitudes. The term 'mangrove' describes both the ecosystems and the plant families that have developed specialized adaptations to live in this tidal environment (Tomlison, 1986). In a dense mangrove forest light and shadows reflects on the water meanwhile fish, shrimp, crab and other larvae and adults hide among the submerged roots and trunks to protect their lives from prey and natural enemies. So that mangrove habitats are shelter to variety of species and performing as breeding and nursing grounds and also may support of coastal fish and fisheries (Manson *et al*., 2005).

Worldwide, about 80% of fish catch are mangrove dependent (Sandiliyan and Kathiresan, 2012) producing an annual catchments of almost 30 million tons in 2002 (FAO, 2004). Furthermore, 90% of marine organisms spend some portion of their life cycle within the mangrove ecosystem (Adeel and Robert, 2002; MadhusudhanaRao and Krishna, 2014). The extensive reviews on mangrove habit for terrestrial and mangrove fauna include: Hogarth (1999); Kathiresan (2003); Qusim and Kathiresan (2005); Nagelkerken *et al*., (2008); Sandiliyan and Kathiresan, (2012). Globally, the total mangrove area occupies only 0.1% of earth's continental surface particularly from 30°N to 30°S latitudes, of which India occupies only 3% of the mangrove flora (Giri et al., 2011; MadhusudhanaRao and Krishna, 2014).

Mangroves are woody halophytic plants that live in the environment of high salinity, extreme tides, strong winds, high temperature, and muddy anaerobic soils and have some physiological adoptions such as silt roots, pneumatophores (negative geographic roots) and vivipery. The salt tolerance of mangrove plants owing to its high osmatic potential and sclerophyllous (i.e. salt extraction glands) leaves (Macnae, 1968; Subodh kumar and Abhiroop, 2013). Globally mangroves are classified as 73 species of trees and shrubs (Sandilyan and Kathiresan, 2012). Moreover highest mangrove species diversity are found in Asia (39%) followed by Eastern Africa (21%); North and Central America (15%); South America (12.6) and Oceanica (12.4%).

According to Forest Survey of India, 4, 87,100 ha mangrove wetlands in India, nearly 2, 75,800 ha (56.7%) in the east coast and 1,14,700 ha (23.5%) along the west coast, the remaining 96,600 ha (19.8%) is located in the Andaman and Nicobar islands (FSI, 1999). The east coast mangroves are known to be highly diverse in composition with those of the west coast (Selvm *et al*., 2000). Andhra Pradesh has 58,250 ha under mangrove cover, representing 0.9% of the state total forest covered (Ravishankar *et al*., 2004).

River Krishna is one of the perennial rivers in the east coast of India that originating from the Deccan plateau flowing eastwards and opening in the Bay of Bengal near Machilipatnam in Andhra Pradesh. Krishna estuarine system occupies an area of 352 Km^2 (FSI, 2013) of which mangrove extends over an area of 25,000 ha which representing 5.13% of India and 42.9% of Andhra Pradesh state mangrove area (Krishna and MadhusudhanaRao, 2011). In the Krishna estuarine region, Interu mangrove swamp located in the North Eastern part and extends over an area of 1079 ha covering 560 ha mangrove vegetation (MadhusudhanaRao, 2011). It is a shallow water body with an average depth of 1-3 m and opens into Bay of Bengal with a channel of 200 m wide. Sea water enters into the swamp during high tide period through this channel and leaves during low tides. The swamp receives freshwater mainly from distributaries of River Krishna irrigation drains during monsoon and surface runoff of surrounding areas. Depending upon freshwater inflow into the swamp salinity varies.

The mangrove ecosystem is undergoing widespread degradation due to a combination of physical, biological, anthropogenic and social factors. A variety of human induced stress and factors such as change in water quality, soil salinity and sedimentation owing to diversion of freshwater in the upstream are causing degradation of mangroves. This is true in case of Krishna mangroves. The construction of dams across the river Krishna has particularly stopped flow of freshwater down the Prakasam barrage excluding the rainy season when the river Krishna is in flooding. Due to shrimp and fish farming activities in this region and possible impact of the decreasing inflow of the river water due to increased utilization of river water for agriculture and other anthropogenic activities may cause huge impact in this area. In the present study mangroves of Interu swamp and the change in the mangrove floral diversity, abundance and possible impact of pollutants and anthropogenic disturbances are discussed.

Materials and Methods

The present study has been carried out in the Interu mangrove swamp during December, 2009 to November, 2011. Interu mangrove swamp of river Krishna estuary extends between 18°14' E and 16° 16' N (Fig. 1). Periodic field visits to Interu mangrove swamp, mangrove forest areas have been made to record the present status of the mangrove plants in the ecosystem. According to Smith (1992) along with the study other criteria such as vegetation structure, inundation frequency and anthropogenic interference are taken into account. Line transect method was used to record the varying widths and quadrates from 4m×4m×10m×10m are laid from each transect. Plant materials collected during sampling are identified developed by the BSI (1998) and Kathiresan (2000). In certain selected pockets relative density of different species of mangrove plants has been recorded to estimate their abundance. The abundance and density represent the numerical strength of species in the community (Mishra, 1968).

Results and Discussion

In peninsular India, mangrove ecosystem of the river Godavari and Krishna are the largest wetland areas covering an extent of 58,520 ha of which Godavari mangrove systems represents 32,250 and that of Krishna 25,000 ha (Ahmad, 1972, Ramakrishna, 2000). In the Krishna estuarine region Interu mangrove swamp extends over an area of 1079 ha covering 560 ha mangrove vegetation (MadhusudhanaRao, 2011).

River Krishna joins Bay of Bengal chiefly through three distributaries. Hamsaladevi distributary branches off from the main river 60 km downstream from Prakasam barrage and opens in to Bay of Bengal north of Machilipatnam. After a distance of where the first distributary branches off from the main river, Gollamatta paya and Nadimeru distributaries branches out from the main river. The main river joins the bay at False Devi point (Varadarajulu *et al*., 1985). The river Krishna mangroves area has been declared as a wild life sanctuary in 1998 by the Govt. of India the total area of sanctuary is about 19.481 ha. The total area of drainage basin the river Krishna is about 2.6 $\times 10^5$ km^2 and mean value discharge is 6.0×10^{13} (Sarin *et al*., 1985). In view of the building of dams at Srisailam, Nagarjunasagar and Prakasam barrage, the inflow of the river water into the estuary has decreased, affecting the salinities levels in the estuarine region. Owing to the Prakasam barrage at Vijayawada freshwater discharge has reduced by 400 m^3/s from 1964-65 to 1994-95. This might have resulted in the formation of sand bars in the river mouth region that inhibits free intrusion of tidal water enter and release of mangroves and such problem is not noticed in river Godavari mouth (Kathiresan, 2005).

In the present study salinity ranges of Interu swamp in between 1.5‰ to 34‰ ppt and temperature ranges in between 26.5°C – 41.0°C. Salinity levels in the river Krishna estuarine region recorded to be relatively higher in comparison with those of river Godavary, due to lesser inflow of water from the catchment areas and the evaporation of river water which is relatively high (Selvam *et al*., 2003). Mangrove ecosystem of this region has been studied by Lakshminarayana (1992) and Benerjee (1997) reported 29 species and Mandal and Naskar (2008) recorded 36 species of mangrove plants in the estuarine region of river Godavari and Krishna. In the present study mangrove plants belongs to Interu swamp was 23 species of 14 families of these 11 species are true mangroves and 12 species are mangrove associates as per the criteria of adaption to the halophytic environmental conditions (Li and Lee, 1992) (Table 1). According to IUCN-2014 conservation status among all the reported mangrove species one species is near threatened, 12 species are least concerned and 10 species are not evaluated. According to Kathiresan (2010) globally, among all mangrove species in India are in the IUCN category of least concerned and only one species *Brownlowia tersa* is in the category of near threatened species which is not available in this region. In the present study *Ceriops decandra* is reported as near threatened species.

Among the entire true mangrove families recorded from the Interu mangrove swamp Rhizophoraceae exhibit rich diversity with four species. Abundance of plants was observed in a unit area to be higher in the North West part of the swamp. Of all the 23 recorded species *Avicennia marina, A. officinalis* was found to be dominant species in the North West part of the swamp while *A. marina* was noticed to be dominant in the South East part of the swamp followed by *B. cylindrical* and *Rhizophora* sps in order of relative abundance. Due to the high commercial value as timber/coal these species are exploited more intensively by the local populations. The present investigation found that *A. marina* is dominant species in Interu swamp region. Similar results were observed by Salvam (2003) in the river Krishna estuarine region.

Ravishankar et al. (2004) reported that the restoration of mangroves effected by the local communities such as expanding shrimp/fish culture actives, (Fig. 2) cutting of mangroves for timber/firewood, for construction of boats and other necessaries coupled with the re-habitation of the mangrove dependent fishermen communities. Decline of mangrove diversity in this region is due to different factors such as release of shrimp pond effluents into the wetland area containing un-utilized feeds and chemicals used in shrimp aquaculture and conversion of mangrove area into salt pens (Fig. 3). The impact of release of the shrimp pond effluent for nearly a decade has resulted changes in the mangrove diversity. UNEP (2011) clearly stated that during 1990-2010 the world mangrove cover reduction was 3% due to the land conversion for coastal development, agriculture and aquaculture.

There has been a noticeable decline in the mangrove plants *Avicenia officinolis* in this area. Studies carried out by Vaiphase *et al*., (2007) in Pak phanage, Thailand on the affect of the deposition of solid waste from shrimp ponds. Rangarao *et al*., (2003) indicate that pollutants and the effluents released from the aqua farms in to mangrove canals in the southern part of the bay of where mangroves are located affecting their diversity and abundance in Godavari mangrove forest area. Ravisankar *et al*., (2004) reported that the 14% of the aquaculture farming in Godavari estuarine region are developed in mangrove wetlands. Arisdason *et al*., (2008) concluded that the mangrove plant diversity has been affected in the river Krishna and Godavari estuarine region are due to biological pressures and other anthropogenic activities. The annual economic values of mangroves, the cost of products and services by provide, have been estimated to be US$ 200,000 to 900, 000 ha^{-1} (Wells *et al*., 2006).

Mangrove loss will also reduce coastal water quality, fertility, loss of biodiversity, eliminate fish and crustacean nursery habitat and eliminate major resources for human activities that rely on mangroves for numerous products and service (Ewel *et al*., 1998; Mumby *et al*., 2004, Nagelkerken *et al*., 2008; Walters *et al*., 2008). Mangrove destruction can also release large quantities of stored carbon and exacerbate global warming and climate change trends (Ramsar Secretariat, 2001; Kristeson *et al.,* 2008). Mangroves perform valued regional and site specific functions (Lewis, 1992; Ewel *et al*., 1998; Walters *et al.*, 2008). Mangrove sediment is rich in Organic Carbon (OC) and true mangrove species have higher carbon and higher sequestering potential capacity than mangrove associates (Subodh Kumar and Abhiroop, 2013) that is about 1023 Mg carbon per hectare (Donato et al., 2011). Reduced mangroves area and health, will increase the threat to human safety and shore line development from coastal hazards such as soil erosion, flooding, storm weave surges and tsunami (Danielsen *et al*., 2005; Dahdough-Guebas *et al*., 2005; Dahdough-Guebas *et al*., 2006). Mangroves acts as effective carbon sinks and sequester high amount of CO_2 that about 100 tons per hectare (Harty, 1997). Mangrove deforestation generates emission of 0.002-0.012Pg carbon/year that is virtually 10% of global emissions (Donato et al., 2011) which accounts about 0.7% of tropical forest area (Giri et al., 2011). Carbon emission is the principle cause for climate change and global warming. According to the UNEP (2011) the global CO_2 emission rise increased to 36% during 1992-2008 and it shows a gradual mean increase from 357 ppmv (parts per million by volume) in 1992 to 389 ppmv in 2011.

Salinity is one of the most important factors in mangrove establishment and early development (Ball, 2002). Most of the mangroves are facultative halophytes (i.e. they grow better in some salt but do not necessarily require it for growth). However, salinity causes the distribution and zonation patterns in the mangrove ecosystem (Twilley and Chen, 1998). Naidoo (1990) observed that salinity causes the reduction of biomass in *B. gymnorhiza* where as Lin and Sternberg (1993) witnessed that higher salinity negatively effect on photosynthesis and reduces the growth rate of mangroves. However, salinity tolerance limit varies from species to species in a same genera i.e. *R. maucronata* seedling perform well in 30‰ where as *R. apiculata* are better at 15‰ (Kathiresan and Thangam, 1990). Earlier and studies have demonstrated the optimal growth rates occur in 5-75% seawater concentrations (Burchett *et al*., 1984, 1989; Naidoo, 1987; Ball, 1988; Smith and Snedakar, 1995), depending on species and seeding growth stage. Temperature is a major factor that varies greatly within the forests, geographically across the distributional range of mangrove vegetation and direct impact on seedlings establishment. Low temperature is widely regarded as the primary control on latitudinal limits of mangroves globally (Lugo and Zucca, 1977; Tomlinson, 1986; Duke *et al*., 1998). During the present study temperature varies from 26.5°C to 41.0°C. Rajani Kumari and Mrutyunjaya Rao (2009) opined that the seasonal variations of temperature are owing to the climatic changes and relatively low in Krishna estuary (~4) when compare (~8) to other tropical estuaries.

Like all other floral species mangroves has no exemption against the pollution and acting as pollution sinks with ruthless human interference and industrial pollutants (Bayens, 2012). Moreover, organism habitat in marine and estuaries can bio accumulate trace metals which is express as BSAF (Biota-Sediment Accumulation Factor) to denote a ratio of concentration of pollution in the tissue and the same pollutant in the sediment (Subhod Kumar and Chowdhury, 2013). Earlier literature reviews emphasized that trace metals (22 metals); Polycyclic Aromatic Hydrocarbons (PAHs); Endocrine Disrupters compounds (EDCs); Pharmaceuticals and Personal Care Products (PPCPs) and Persistent Organic Pollutants (POPs) have been identified potential pollutants in the mangrove environment and these pollutants affects the biodiversity of the ecosystem of these heavy metals have been adversely effecting the mangrove flora (Bayen, 2012). Usually metal accumulation is more in mangrove roots than areal parts thus, mangrove tissue are not generally consider as effective indicator of pollution. Generally, metal accumulation potential capacities are different degree in different species (Lewis et al., 2011). Scientific studies on effect of pollution mangrove plant biological response observed that trace pollutants are identified for reduction photosynthesis (Mac Fralane et al., 2003).

Mac Farlane et al., (2003) observed that *Avicenna* is of cosmopolitan in distribution and is thought to have more metal accumulation than other mangroves and Cu, Pb, are identified to be accumulate in high concentrations in root than soil concentration where as in leaf tissue, Cu, Zn, are found more than 10% of that in root. Of these three metals Pb is the least mobile element. Moreover, *A. marina* can act as a bio-indicator of metal pollutants particularly to Cu, Zn, and Pb. Sarangi et al., (2002) stated that Fe, Cu, Mn, Zn can accumulate higher concentration in *A. officinalis* than that of *Xylocarpus granatun, B. cylindrical, R. mucronata* and *C. decandra*. However, *Avicinnea* sp. is one of the most tolerant species in respect to heavy metals amongst mangroves. Owing to the higher accumulation capacity of pollutants *A. officinalis* abundance has been decreasing in the study area. Alongside, Nornha et al., (2003) developed a frame work considering five parameters as indicators of coastal vulnerability assessment in coastal districts of India (i.e. Urbanization, industrialization, Aquaculture/Agriculture, Port activity, tourism and stressed ecosystem) and place the Krishna district as a severely affected region. Furthermore, NDMA (National Disaster Management Authority) reported that the Indian subcontinent is one of the most horrible effected regions in the world and is exposed to nearly 10% of world's tropical cyclones. UNDP (2004) stated that India is the second most vulnerable countries from storm surge next to Bangladesh. ICZMP (2010) evaluated that an average nine cyclones (cyclones and super cyclones) per year is subjected to the Indian coast. In addition to cyclones the Indian coast is vulnerable with the emerging factors like SLR (Sea Level-Rise), tides and currents effect, shoreline erosion, tsunami and the newly joined saltwater intrusion (Sudha Rani et al., 2015).

Conclusion:

Along with frequent affect of natural calamities the mangrove ecosystem of Ineru swamp of river Krishna estuarine region facing severe threat owing to the anthropogenic activities like industrialization, urbanization, construction of port city coupled with aquaculture/agriculture, utilization mangrove for their society needs. Particularly, in the Interu mangrove swamp salinity affect mangrove ecosystem biodiversity due to the lesser inflow of the freshwater into the swamp which might have resulted formation of sand bars in swamp mouth region. For the past two decades the aquaculture activities have been increasing rapidly in this area. This activity might have been affecting the swamp ecosystem. The study will provide updated information on the Krishna estuarine region for the sustainability of the mangrove ecosystem otherwise Krishna mangrove ecosystem would meet the upcoming predictions propose that 30-40% of coastal wet lands (IPCC, 2007) and 100% of mangrove forests (Duke et al., 2007) could be lost in the coming 100 years if the present rate of loss continues.

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Table 1. Taxonomic composition and conservation status (IUCN-2014) of mangrove flora from Interu swamp of River Krishna estuarine region, Andhra Pradesh, India

S. No	Family	Scientific Name	Local Name	Growth Habit	TM / AM	IUCN status
1.	Cyperaceae	*Fimbristylis ferruginea*(L.)Vahl	---	Gr.	AM	LC
2.	Poaceae	*Aeluropus lagopodioides* Trin.ex Thwaites	---	Gr.	AM	NE
3.	Boraginaceae	*Heliotropium curassavicum* L.	---	Herb	AM	NE
4.	Aizoaceae	*Sesuvium portulacastrum* (L.)L.	Vangaredukura	Herb	AM	NE
5.	Amaranthaceae	*Salicornia brachiata* Roxb.	Saakati Pusalu; Barillakoyalu	Herb	AM	NE
6.	Amaranthaceae	*Suaeda maritima* (L.) Dumort.	Uppaaku; Ilakura	Herb	AM	NE
7.	Amaranthaceae	*Suaeda monoica* Forssk. ex J.F. Gmel.	---	Herb	AM	NE
8.	Amaranthaceae	*Suaeda nudiflora* (Muhl.ex Willd.)Moq.	Revu cada	Herb	AM	NE
9.	Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco	Guggilliam	Tree	TM	LC
10.	Fabaceae	*Dalbergia spinosa* Roxb.	Chillanki; Chillingi	Shrub*	AM	NE
11.	Fabaceae	*Derris trifoliata* Lour.	Angarvalli; Nalla tiga	Shrub*	AM	NE
12.	Acanthaceae	*Acanthus ilicifolius* L.	Alchi; Alisi; Alasyakampa	Shrub	AM	LC
13.	Avicenniaceae	*Avicennia alba* Blume	Gunda mada; Vilavada mada	Tree	TM	LC
14.	Avicenniaceae	*Avicennia marina* (Forsk.) Vierh.	Tella mada	Tree	TM	LC
15	Avicenniaceae	*Avicennia officinalis* L.	Nalla mada	Tree	TM	LC
16	Lamiaceae	*Volkameria inermis* L.	Pisingi; Pisung; Eruppichha	Shrub	AM	NE
17	Euphorbiaceae	*Excoecaria agallocha* L.	Chilla; Tilla; Tella	Tree	TM	LC
18	Rhizophoraceae	*Bruguiera cylindrica* (L.) Blume	Varavada; Vurada	Tree	TM	LC
19	Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam	Duddu ponna; Thudda ponna	Tree	TM	LC
20	Rhizophoraceae	*Ceriops decandra* (Griff.)Ding Hou	Gatharu	Tree	TM	NT
21	Rhizophoraceae	*Rhizophora apiculata* Blume.	Uppu ponna; Kaaki ponna	Tree	TM	LC
22	Combretaceae	*Lumnitzera racemosa* Willd.	Kadivi; Thanduga; Kadavi	Tree	TM	LC
23	Lythraceae	*Sonneratia apetala* Buch.-Ham.	Kalingi	Tree	TM	LC

Abbreviations: Gr. = Graminoid; Shrub*= Shrub climbing; --- = Not Evaluated; TM = True Mangrove; AM = Associated Mangrove; NE= Not Evaluated; LC= Least Concern; NT= Near Threatened

Fig 1. Aerial view of the Interu mangrove swamp of River Krishna estuarine region, Andhra Pradesh, India

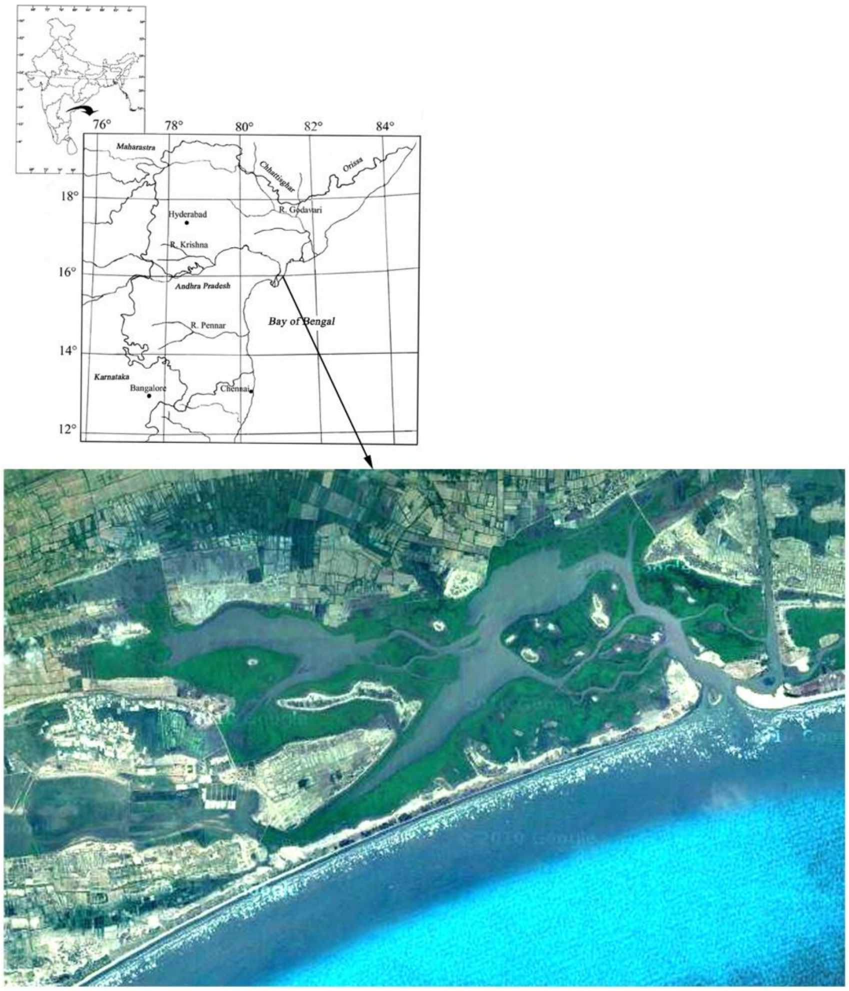

Fig 2. Preparation of shrimp culture ponds in the mangrove vegetated area in the Interu mangrove swamp, Krishna estuarine region of Andhra Pradesh, India.

Fig 3. Salt Pens prepared in the mangrove area of Interu mangrove swamp, Krishna estuarine region of Andhra Pradesh, India.

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