Mangroves as Bio-shield in Coastal Conservation: A Case Study from Godavari Delta, India

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Abstract

Godavari mangroves (322.22 Km^2), being the ecological bio-shields along the coastal Andhra Pradesh, India, forms the second largest formations of mangrove ecosystem. In recognition of its National and Global Biodiversity significance, a part of this landscape/seascape is notified as Coringa Wildlife Sanctuary comprise of Mangrove forests of about 235.70 Km^2. It is one of the Estuarine Protected Areas in India, located 20 km from Kakinada city in Andhra Pradesh acts as a protective buffer against ravages from the cyclonic/tsunami impacts to Kakinada city. Coringa Mangroves as the nature's mechanism that protects the soil, supports sustainable fisheries, provides hospitable habitats for wide range of biodiversity with varied sources of genes. Currently these ecosystems suffer from various anthropogenic threats especially from the main production sectors operating in the landscape/seascape. These are the sectors of fisheries, aquaculture, manufacturing industries, oil and gas exploration, etc. These activities are impacting the overall ecological integrity of the mangrove ecosystems, with associated impacts on the livelihoods of local people. Hence an urgent action is required for conservation and restoration of Mangroves as an insurance against the perceived threats.

KEYWORDS: Godavari Mangroves, Mangrove Ecosystem services, Coringa Wildlife sanctuary

1. INTRODUCTION

Mangroves are the estuarine forest ecosystems of tropical and semi-tropical regions of the World. About 90% of the global mangroves are growing in developing countries and they are under the condition of critically endangered and nearing extinction in twenty six (26) countries. Mangroves act as the most important "ecological bio-shields" for the coasts. It has been widely recognized that they protect our shoreline, harbour a unique biodiversity, help fisheries and protect coastal population against storms, cyclones, tsunamis etc. Mangroves are estimated to absorb up to 80 percent of the wave energy during storms and typhoons, in addition to other benefits such as coastal protection and water filtration. Besides these, Mangroves have tremendous social ecological and economic value. . The annual economic value of mangroves, by the cost of products and services they provide, has been estimated to be anything \$200,000 - \$900,000 per hectare. Other economic benefits are Flood control, Industrial wastewater treatment, Agriculture production, Support for downstream fisheries, Firewood, Fishing, Recreation, Domestic sewage treatment, Freshwater supply for local people, Carbon sequestration etc. Of late Ecological services of mangroves have been realized as mechanism of Flood control, Groundwater refill, Shoreline stabilization & protection against storms, water purification by absorbing impurities and harmful heavy metals and help us to breathe a clean air by absorbing pollutants in the air.

India is prone to frequent tropical storms, more so in the Bay of Bengal. In India, about 308 storms had recorded from the year 1891 to 2014, of which 113 were severe. It is believed and predicted that the frequencies of such storms will be more and intensity would be much worst in near future because of the Climate Change. In addition to strong winds and rain, tropical cyclones are capable of generating high waves, damaging storm surge. Heavy rains, however, can cause significant flooding inland, and storm surges can produce extensive coastal flooding up to 40 kilometers from the coastline. Andhra Pradesh is extremely vulnerable to cyclones, storm surges and floods. The state risks being battered by cyclones of moderate to severe intensity every two to three years. Since 1975, the state had faced more than 60 cyclones. Some of them are moderate and a few of them are very severe. In the past 40 years, there may not be a single year in which the state did not experience a storm, a cyclone or heavy rains and floods. The deadliest cyclone in the past 40 years was the one that struck Andhra's coast in November 1977, killing about 10,000 people. About 250,000 cattle heads perished, one million houses were damaged and crops on 1.35 million hectares were destroyed that year.

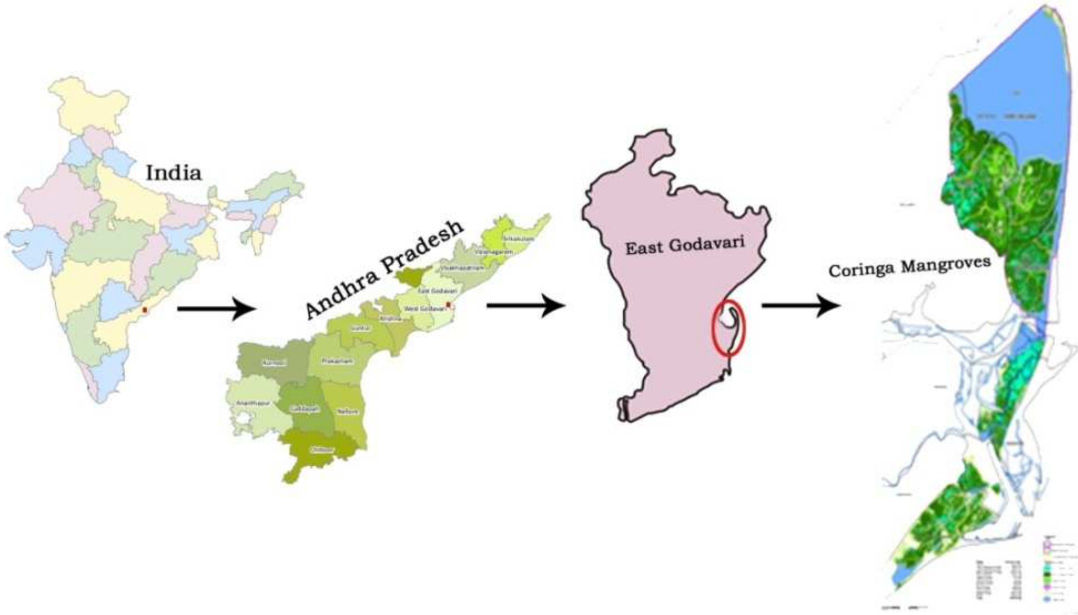
It is fortunate to have about nine coastal states of India that support 7% of the World mangroves with species richness and diversity. In India, Mangroves occur in Sunderbans (West Bengal), Andaman & Nicobar Islands, Bhithara Kanika (Orissa), Godavari and Krishna mangroves (Andhra Pradesh) and Pitchavaram mangroves of (Tamilnadu) in the Eastern part and Gujarat, Maharastra, Goa along the west coast of India.

In Andhra Pradesh the mangroves occur at Godavari and Krishna river mouths which are rich in biological diversity next to Sunderbans in the East coast of India. The river Godavari and its main channels namely Coringa and Gaderu contributed through siltation, dense Mangroves formation known as “Godavari Mangroves” spreading over an area of 322.22 Sq.km. These mangrove trees and shrubs not only characterize the ecosystem but also formed a traditional biological resource base to the local inhabitants to define subsistence economy besides protecting the region from ‘**cyclones and tsunamis’.**

2. ABOUT THE STUDY AREA:

Godavari Mangroves in Andhra Pradesh forms the second largest formations of mangrove ecosystem along India’s East coast. In recognition of its National and Global Biodiversity significance, a part of this landscape/seascape is also notified as” Coringa Wildlife Sanctuary” comprise of Mangrove forests of about 235.70 Km^2. It is one of the Estuarine Protected Areas in India, located 20 km from Kakinada city in Andhra Pradesh acts as a protective buffer against ravages from the cyclonic/tsunami impacts to Kakinada city. The location of the area is given in Map-1.

Map-1 Location sketch of Coringa Mangroves



Coringa Mangroves as the nature's mechanism that protects the soil, supports sustainable fisheries, provides hospitable habitats for wide range of biodiversity with varied sources of genes. The backwaters of the river, offer an ideal and dynamic patches of mangroves ecosystem as natural habitat for representative floral and faunal diversity. Here in Coringa, totally 34 main floral species are recorded, of which 16 species are true mangroves while 18 are associated mangrove species. Coringa sanctuary along with Krishna sanctuary in Andhra Pradesh has distinction in being the only area where all the three species of *Avicennia* i.e. *Avicennia alba, Avicennia officinalis* and *Avicennia marina* are found. All the three species of *Avicennia* occur in mixed patches. However pure crops of *Avicennia officinalis, Avicennia marina* and *Avicennia alba* are also noticed. *Avicennia officinalis, Excoecaria agallocha, Acanthus illicifolius* and *Ceriops decandra* are found from shore to a distance of 45 mt. both on right and left sides of creeks and later their density decreases.

Faunal diversity: Dynamic mangroves ecosystem of the Coringa Wildlife Sanctuary supports rich biodiversity Over 269 species of birds are found within and outside the wildlife sanctuary besides 137 species of Phytoplanktons, 73 species of Fungi, 9 Microorganisms, 81 species of Zooplankton, 126 species of Micro benthos, 28 groups of meio-benthos, 114 species of macro-benthos, 52 species of Foraminiferids, 14 species of Amphibians, 109 species of insects, 430 species of Fin-fish, 27 species of Reptiles, and 18 species of Mammals were recorded. To quote few of them are the Fishing Cat, Otter, Jackal, Estuarine Crocodile (locally extinct), Sea Turtle, Sea Gull, Pelican, Open-billed Stork, Grey Heron, Snipes, Flamingos on transit etc.

2.1 Frequency and status of cyclones in the study Area:

Major cyclones that hit the study area: Coringa region was completely destroyed and 20,000 of its habitants were drowned by three tidal waves spawned by a cyclone that hit the city at the end of 1789 (December). Although the detailed information is sparse, it was apparently the first of the three waves that did the major damage, sinking most of the ships moored in the harbour, flooding every alley and small street, crushing businesses, government buildings, and thatched roof dwellings that housed much of the city's population. The second wave, less intense than the once before and after it, hit the area a glancing blow, saving most of its fury for the countryside surrounding the city. The third wave was followed the path of the first, adding measurably to the depth of the water in the city and surrounding countryside. It went on to hit Yanaon (Yanam), a city nearby. Enormous quantities of mud and silt choked the entrance to the mouth of the river, hampering the search for bodies and cloaking the ruins of a once bustling city now reduced to one building and the shattered remains of its smashed docks.

In November 1839, three lakh people lost their lives in a cyclone and tidal wave that assaulted Coringa. The city was never entirely rebuilt. It took the rebuilders of Coringa many years to reconstruct their ancient city after the triple waves of the cyclone of 1789. And then, 40 years later, a gigantic 40-foot (12.19-m) tidal wave, spawned by enormous cyclone, once again wiped out the city, destroying 20,000 vessels in its harbor and killing 3,00,000 people. It was one of the worst cataclysms ever to hit this cyclone-ravaged area, and the ancient city of Coringa was never wholly rebuilt after it. Besides, this time, Coringa was unable to recover economically and remains a very small village today. This storm caused the third largest loss of life from any tropical cyclone worldwide that had happened since 1500 AD and account for seven of the 10 deadliest hurricanes, typhoons and cyclones in recorded history. This second disaster of such magnitude to occur is less than a half-century, the coringa cyclone prompted the British to shift a larger fraction of their fleet operations to Calcutta, a port city that eventually proved no less storm-swept than Coringa.

Some of the factors responsible for vulnerability of the region and the state to cyclone are:

1. Almost half of the storms in the Bay of Bengal become severe cyclones often accompanied by storm surges.
2. Low lying areas along the coast are vulnerable to extensive flooding and deep inland sea water incursion.
3. High concentration of population, infrastructure and economic activities along the coast.
4. Lack of proper maintenance of the flood protection and irrigation systems, drains, embankments etc.,
5. Lack of comprehensive coastal zone and delta management

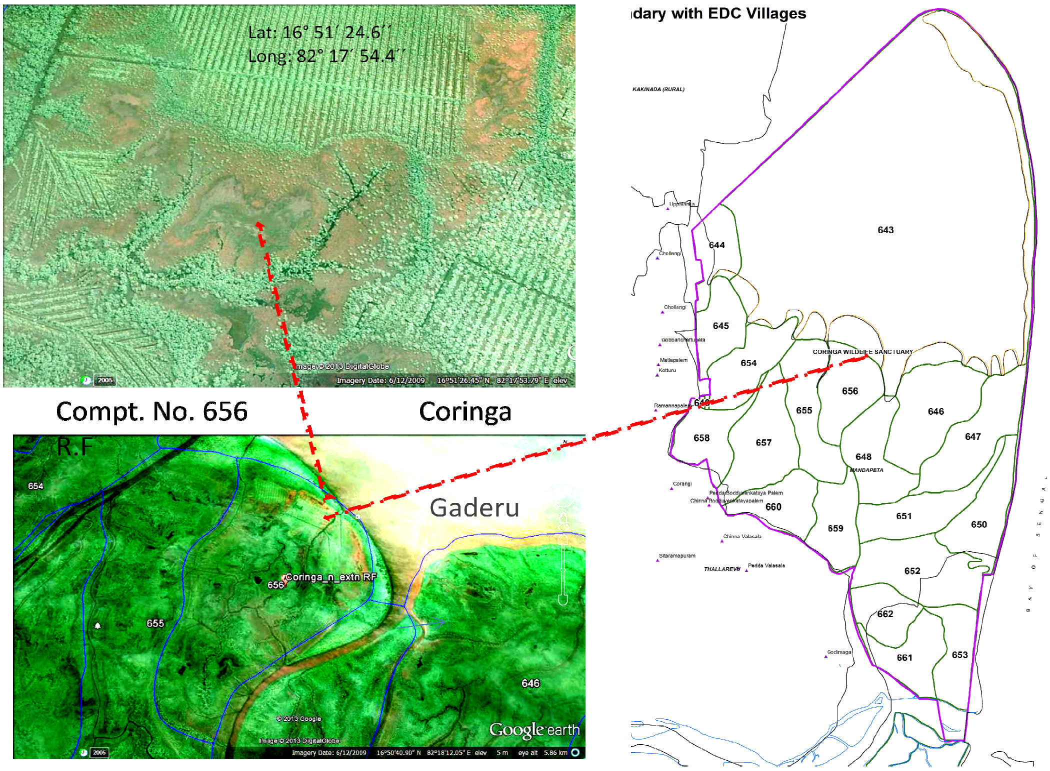
Hence an urgent action is required for Conservation and Restoration of Mangroves as an insurance against natural calamities like cyclones and tsunamis as the city of Kakinada and neighbouring villages are within the destructive zone of influence being almost equal or little more altitudinal geographical plane. There are many areas which are lower than the mean sea level and vulnerable to the destructive cyclones like "Hud Hud", Neelam, Phalin, Laila etc., All these areas need to be restored with the mangroves which act as Bioshield. Initially it is proposed to take up this work in the Protected Area i.e Coringa Wildlife Sanctuary (CWLS) and subsequently extend to the adjacent areas.

At present, these Mangrove ecosystems suffer from various anthropogenic threats especially from the main production sectors operating in the landscape/seascape. These are the sectors of fisheries, aquaculture, manufacturing industries, oil and gas exploration, etc. These activities are impacting the overall ecological integrity of the mangrove ecosystems, with associated impacts on the livelihoods of local people. It has been identified the vulnerable and areas to be restored in EGREE region, as shown in the following table-1 and through the maps-2-4.

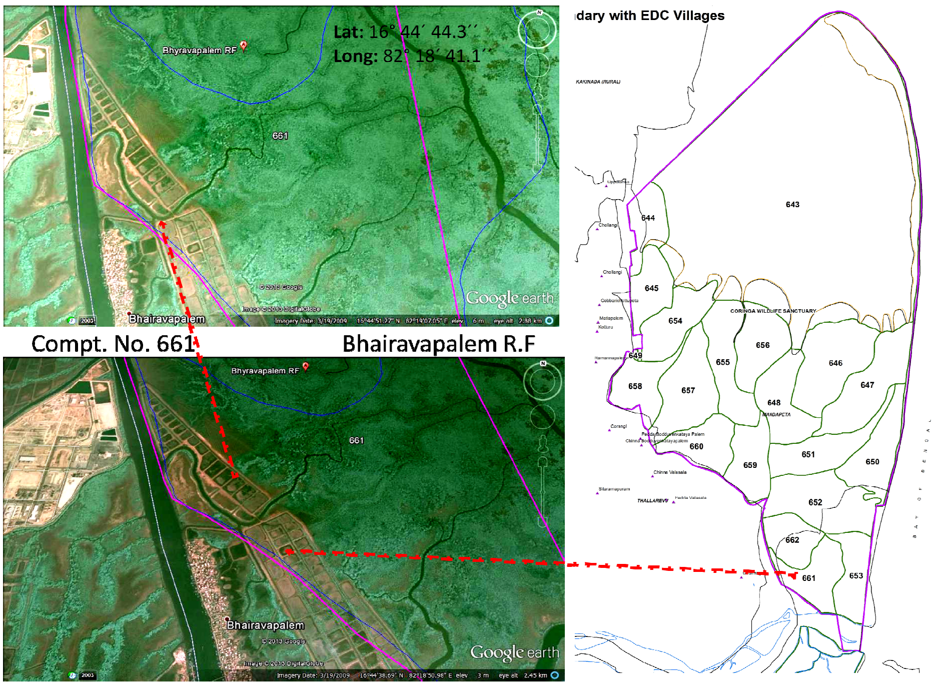
Table-1: Areas recommended for plantation in study area

S. No	RF/Range	Beat	Compt. No	Area of Compt. (ha)	Area Available for plantation (ha)	Nature of the Area	Latitudes and Longitudes (around)	Reference
1	Coringa Kakinada WLM	Coringa	656	700.85	50	Degraded	16° 51´ 24.6´´ 82° 17´ 54.4´´ Elevation 5m	Map - 2
2	Bhairavapalem Kakinada WLM	Bhaira-vapalem	661	603.29	50	Encroached, Abandoned aquaculture farm land area inside the Sanctuary Boundary	16° 44´ 44.3´´ 82° 18´ 41.1´´ Elevation 3m	Map - 3
3	**Buffer** Rathikalava; Kakinada (T) (Adjacent Bhairavalanka Village)	Rathikalava	670	615.37	100	Degraded land and Encroached, Abandoned aquaculture farm land area within and outside the RF.	16° 41´ 41.8´´ 82° 17´ 56.9´´ Elevation 4m	Map - 4
Total Area to be planted					**200**			

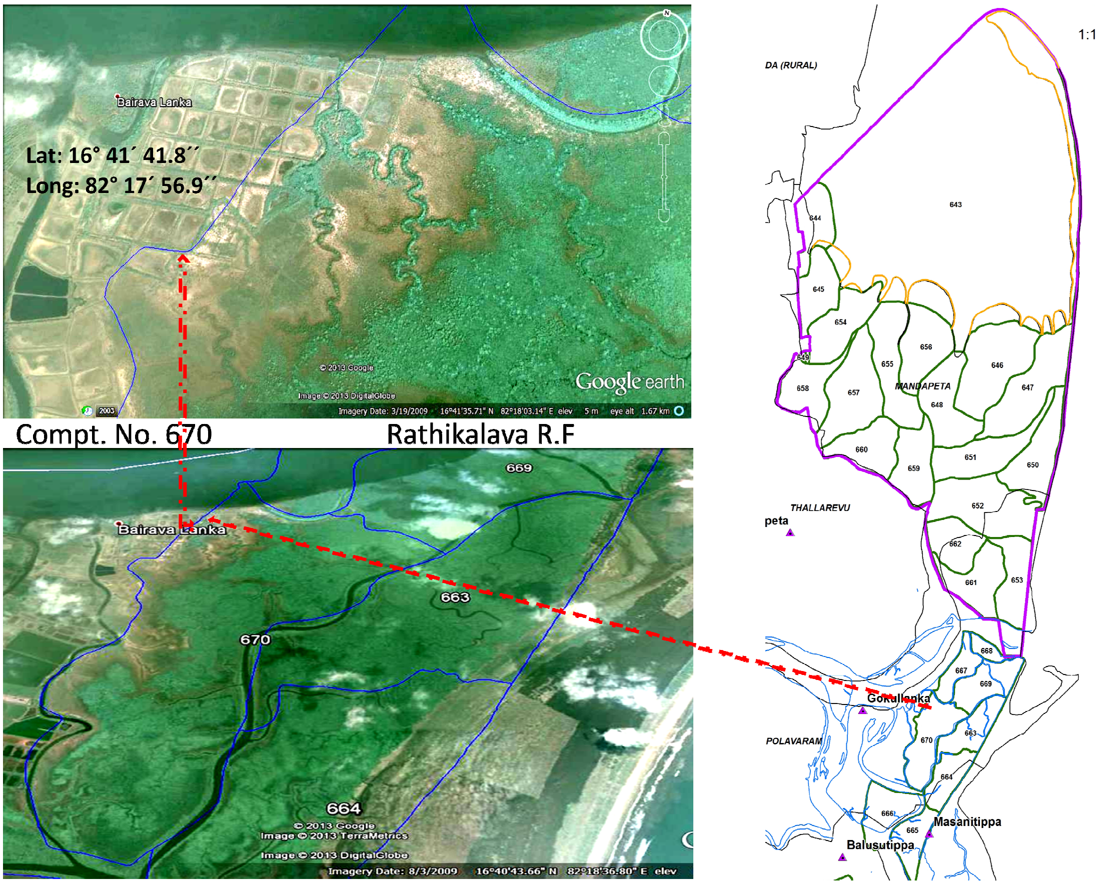
MAP-2: *Location Sketch for Proposed Plantation area at Coringa*



MAP – 3 *Location Sketch for Proposed Plantation area Bhairavapalem*



Map: 4 ***Location Sketch for Proposed Plantation area at Rathikalava RF***



3. METHODOLOGY AND TECHNIQUES:

Restoration of mangrove system is based on natural conditions such soil substrata, inundation levels of brackish water, topography of the region etc. It is believed that exploration of all possible steps in restoring of the disappeared natural breeding ponds of fish and other invertebrates is important. While restoring the mangrove ecosystem the care was taken that all natural aquatic ponds are protected and water inflows into these ponds were maintained. Geomorphic (physiography) and hydrological characteristics of the area play an important role in mangrove restoration, particularly in fixation of dimensions of canals that are developed for free flow of water. The salinity in the Saveru creek and Rathikalava Reserve Forest varies from 6 psu during the south-west monsoon to 31 psu during fair weather season. In the Coringa Wildlife Sanctuary area, salinity varies from 5 psu during the south-west monsoon to 30 psu during fair weather season.

3.1 Selection of species: Mangroves often occur in zonations. Zonation occurs because different species of mangrove need particular conditions to grow. Some species require more water than others. Some species are able to tolerate more saline soils than others. The species occurring in a zone depends on: depth, duration and frequency of tidal inundation; soil salinity; amount of fresh water availability. Planting staff should understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species. The following are the details of mangrove species to be planted suiting to the conditions of different tidal zones (Table - 2).

Table 2: Showing the details of the species to be planted in the different tidal zones

Class	**Flooded By**	**Dominant Species**	**Height of the Tide in feet *(meters)***	**Flooding Frequency *(times/month)***
1	All high tides	*Rhizophora mucronata* and *R. apiculata* *R.mucronata* prefers areas under greater freshwater influence	0-8 (2.44)	56-62
2	Medium high tides	*Avicennia alba, A. marina, Sonneratia alba* and *R. mucronata*	8-11 (3.35)	45-59
3	Normal high tides	*Rhizophora spp. (often dominates), Ceriops tagal, Xylocarpus granatum, Lumnitzera littorea* and *Exoecaria agallocha.*	11-13 (3.96)	20-45
4	Spring high tides	*Bruguiera spp., Xylocarpus spp., Lumnitzera littorea* and *Exoecaria agallocha.*	13-15 (4.57)	2-20
5	Abnormal (equinoctial tides)	*Brugeira gymnorrhiza (dominates), Instia bijuga, Nypa fruticans, Herritera littoralis, Exoecaria agallocha,* and *Aegiceras spp.*	15	2

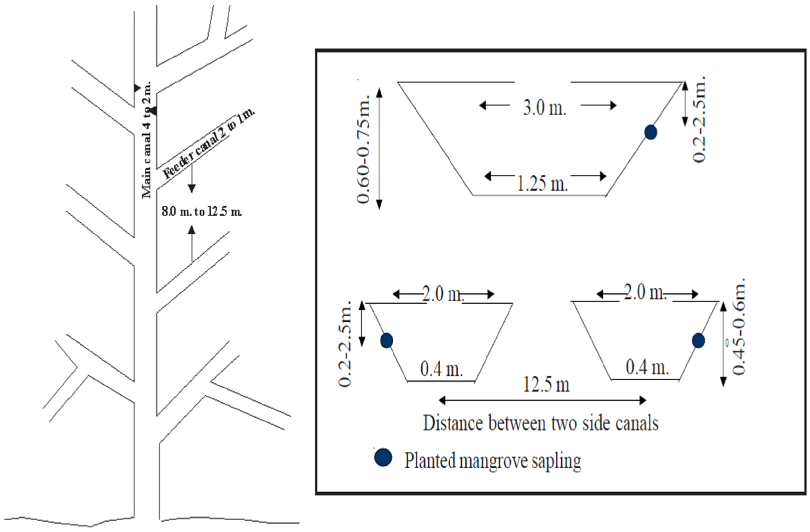
3.2 Fishbone Method Technology: The standard method of Fishbone channeling is recommended to adopt for regeneration. It has been observed in all the planted areas earlier, many of the natural fish nursery ponds have disappeared as they have not been given due importance at the time of designing itself.

Simulation or restoration of mangrove ecology shall be based on nature’s design. It is also recommended to explore possibilities of restoring all disappeared natural breeding ponds of the fish and other invertebrates. Implementing authority shall take care while regenerating the areas such that all natural aquatic ponds are protected and the courses of water inflows into them shall be maintained.

Restoration of mangroves shall be done only when the salinity of the degraded area is brought down. In order to reduce the salinity, fishbone type canals are to be dug and tidal flushing and draining of stagnant water is facilitated. This results in brining the salinity levels to 60 ppm in summer to fresh water level during monsoon seasons. After a buffer period of three months, the nursery shall be raised, mangrove saplings are planted along the trapezoid shaped canals in the degraded areas.

Canals are designed like fishbone in order to facilitate easy inflow and outflow of tidal water. The main canals shall be dug at an angle of 45° to the natural creek, while the side canals can be dug at an angle of 30° to the main canal. This needs a preplanning, by marking canals using pegs and chalk powder. The canals are to be dug in a trapezoidal shape in order to plant the saplings at the mid level of the canal. Geomorphology and hydrology in mangrove restoration based on the contour survey and hydrology study, canal depths and dimensions shall be fixed, corresponding to the topography and tidal amplitude of the selected restoration site. As a result, tidal water entering during the highest of high tides stagnates in the saucer shaped area due to the elevation of edges, temperature and salinity of the stagnant water increases and shoots up to 114 ppm during summer.

FISH BONE METHOD



The levees salinity variation in the Saveru creek and Rathikalava RF, varies from 6 ppm during the south-west monsoon to 31 ppm during fair weather season. In the Coringa Wildlife Sanctuary area, at Matlapalem canal, salinity showed a variation from 4.6 ppm during the south-west monsoon to 30 ppm during fair weather season. Based on the hydrological studies, the depth of canals for restoration was decided to be 0.65 m with reference to mean sea level so as to have adequate tidal flushing.

The depth of the main canal varied from 0.45 to 1.0m and the side canals from 0.6 to 0.45 m as per the contour. The top width of the main canal can be between 2 m and 3.5 m and the respective bottom width could be between 1.0 m and 0.4 m The dimensions of the side canals shall be 2 m top width, m bottom width and 0.45 m depth. In case, the canals are dug closely to the dimension of the side canals shall be reduced accordingly to 1.25 m top-width, 0.2 m bottom width and 0.4 m deep.

Based on the salinity levels of soil, mangrove species shall be selected for planting in the degraded areas. Species like *Avicennia marina, Avicennia officinalis and Excoecaria agallocha* could tolerate wide range of salinity. Mangroves namely *Aegiceras cornicularum, Bruguiera gymnorrhiza, Rhizophora apiculata, Rhizophora mucronata* and *Xylocarpus moluccensis* shall also planted to ensure genetic diversity. Eight month old mangrove saplings raised in the nursery may be used for planting. The mangrove saplings shall be planted along the slopes (20-25cm from the top) of the canals with a spacement of 2 m.

3.2.1 Subsequent Operations:

Desilting: The bunds formed by the deposition of the excavated soil during canal digging will silt the canals during the monsoon seasons. The silted canals have to be de-silted before the onset of summer, because during summer the tidal amplitude is generally low. Tidal flushing is very important during summer because the soil salinity will shoot up due to high temperature and cause damage to the roots of the seedlings. Such seedlings will be replanted in the following monsoon season. The survival percentage is measured in the initial period for better monitoring. Initially the growth rate was slow and after 2 to 3 years the seedling growth rate was faster. The natural regeneration of the seedlings also occurs simultaneously. After four years, the planted saplings start bearing fruits, which will regenerate, and the density of the area will increase.

Technical failures: Over the years, as seen in the field, there are many failed restoration plantations, invariably wasting both time and money as the seedlings were planted without considering its ecological requirements (substrate height, water flow, and appropriate species selection) and resulted in failure within a year after planting. There are many such areas available for re-planting, especially in the buffer zone. In order to minimize the failures and to make the field staff to understand the reasons for the failure, the life cycle of various mangrove species referred for plantation, is given in the following table-3:

Table-3: Showing the life cycle of species preferred for plantation

Species	Type of Seed	Months	Indicator of Maturity	Size at Maturity
Avicennia marina	Propagule	December, January, February	Yellow fruit skin	Weight of seed > 30 g
Brugeira gymnorrhiza	Propagule	May, June, July, August, September, October, November, December	Reddish brown body	length > 20 cm
Ceriops tagal	Propagule	August, September	Yellow collar, brown/	length > 20 cm

			green body	
Rhizophora apiculata	Propagule	December, January, March, April	Reddish collar	length > 20 cm, diameter > 14 mm
Rhizophora mucronata	Propagule	September, October, November, December	Yellow collar, green Body	length > 50 cm
Sonneratia alba	Fruit	April, May, June, September, October	Float in water	fruit > 4 cm
Xylocarpus granatum	Fruit	September, October, November	Yellow/brown fruit Floats in Water	Weight of seeds inside fruit 30 g each.

4. RESTORATION OF WETLANDS: Due consideration shall be given to recover the lost wetland area in the region in order to resume back the lost ecosystem services. While in implementation the following assumptions can be considered:

- Restoration can reverse some degradation but many damages are not reversible;
- Wetland restoration approaches and techniques shall be near natural; and
- Restoration policies can improve with time and experience.

5. CONCLUSIONS:

1. The coastal mangrove forests act as bio-shields to protect the lives and valuable assets against the coastal hazards including tsunamis, cyclones, wind and salt spray and coastal erosion. Options for protection of mangroves include soft and/or hard solutions and sometimes hybrid of the two as suggested in the present study. It may be necessary to divide coastal land in to different zones so as to prevent (further) the settlements and establishment of infrastructure along the vulnerable zones.
2. The degree of protection offered by coastal bio-shields depends on a number of variables, including: (i) the characteristics of the hazard itself (e.g. type, force, frequency); (ii) the features of the site (e.g. bathymetry, coastal geomorphology); and (iii) the characteristics of the bio-shield (e.g. type of forest/tree, width, height and density of the forest).
3. Importance of incorporating coastal protection as an integral part of coastal area planning and management is recognized.
4. Options for protection include: soft and hard solutions and a hybrid of the two. If none of these is appropriate and viable, it may be necessary to zone coastal land use to prevent (further) settlement and construction of valuable assets in the vulnerable zone.
5. While planting mangroves in the degraded areas, it is important to match the species with the site in order to avoid high mortality and low performance of the planted

trees. Some forest types and tree species cannot survive or thrive in areas exposed to specific coastal hazards; therefore, they are not candidates for protective measures.
6. Development of bio-shields is not possible in all situations owing to, *inter alia*, biological limitations, space constraints, incompatibility with priority land uses and prohibitive costs.
7. The level of knowledge and understanding of the functions of forests and trees in coastal protection is still insufficient and there is a lack of multidisciplinary research and cooperation in this field.
8. Our study reveals that many years are required to establish mangroves as viable bio-shields that could offer protection against coastal hazards.

Mangroves, admittedly, are not only important but crucial for the coastal areas. Since estuarine areas are highly populated areas, the slightest ecological imbalance will take a heavy toll. They play a vital role in stabilizing these areas. No engineering and technological solutions can be sought for stabilizing these areas. Even if we negate all benefits of mangroves as forests, their value **as "protector of shore-line"** is enough to convince us for conserving them**.**

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