Critical marine habitat restoration programme - initiative on mangrove restoration in Kerala, India

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Introduction

Mangroves are unique habitats which function as nursery ground for several valuable species of finfishes and shellfishes and they play a vital role in supporting marine food chains, protecting coastal areas and in improving water quality. Mangroves in general have relatively high productivity and tend to create highly organic soil and also export organic matter to nearby marine environments. They are effective in stabilizing soils in intertidal areas. Some species of mangroves have been planted in the coastal areas as bio-protection shields to guard coastal households from wind and wave action. They provide shelter to several avian fauna which feed on its fruits and nest in the branches. Rare or endangered species of birds have also been documented in the mangroves.

During the last three to four decades, urbanization has increased the land value of coastal areas leading to felling of mangroves. This has directly affected the mangrove cover in most coastal regions. In an attempt to develop critical habitats in the coastal areas, an initiative was made to develop mangrove habitat in Kerala by the Central Marine Fisheries Research Institute, Kochi. This community based ecosystem restoration program was launched in June 2010.

The initiation

Three species of mangroves which are common mangrove vegetation of Kerala were selected for the restoration programme and for nursery development *viz., Rhizophora mucronata, Bruguiera gymnorrhiza* and *Bruguiera cylindrica.*

Rhizophora mucronata, locally known as *Valiya kandal* is globally popular as the Asiatic mangrove and this can grow up to 27-30 m height with 50-70 cm trunk diameter. This species usually has numerous lateral roots, developed from base of the trunk called stilt roots, hoop or pile-like, supporting the tree. Hanging air-roots are sometimes also produced from the lower branches. Fruits are edible and the fruit juice can be made into a light wine. The timber is heavy, difficult to saw and not durable unless it is dried for a long time. However, it can be used for construction, to make fish traps, house frames, pilings and poles. *Rhizophora* is used as firewood and to make charcoal. It is chipped and used for commercial paper and rayon production in Indonesia and East Malaysia. Tannins and dyes are extracted from the bark and a black to chestnut dye is obtained from the leaves. It is used in traditional medicines as an astringent and to treat angina, diarrhoea, diabetes, dysentery and hematuria. Old leaves and roots are used during childbirth while bark is used to treat blood in the urine. This species has been used for restoration programmes in India and several Asian countries.

Bruguiera gymnorrhiza is locally known as *Pena kandal*. This species can grow up to 30–35 m in height and typically develops knee roots. The propagule is edible and the wood is widely used for structural components of traditional homes and for other structures such as fishing stakes and spears. *Bruguiera* timber is harvested commercially for charcoal production in south-east Asia, although *Rhizophora* is preferred. This species has medicinal properties and has been used in traditional medicine. The bark is considered as an astringent and used to treat malaria, cure fish poisoning, treat diarrhoea and fever. In some areas, the fruit is used to treat eye problems and to stop bleeding. The leaves are used to control blood pressure. This species is common in the mangrove vegetation of Kerala.

Bruguiera cylindrica is locally known as *Cheriya kandal*. Young shoots and root tips are edible and considered as a vegetable and the bark is used as a cooking spice. The timber is heavy and tough and used in construction. It is also favoured as firewood and for conversion into charcoal. The bark produces a strange smell that scares fish away. In some countries essences are extracted by squeezing the pneumatophores and used to make perfumes. This species is common along both the coasts of India.

The propagule of these three species of mangroves were collected from southern part of Vypin Island located about 20 km from Moothakunnam which has a rich diversity of mangroves. During a function held in the village in connection with the World Environment Day (5th June, 2010), propagules were distributed to different groups of school children, women self help groups and other village youth who were interested to be partners in mangrove restoration (Fig.1). Of the nine groups who had initially volunteered to join the programme, only five continued the activity by developing mangrove nurseries at different locations in the village.

Fig. 1. Distribution of mangrove propagules to self help groups

The nursery reared seedlings were collected back from the respective groups by CMFRI after three months for further planting and restoration based experiments. The details of the growth and survival of the three species of seedlings during the nursery phase and other related aspects are presented here.

Mangrove nursery development

The propagules were planted in small garden nursery polybags, three fourth filled with clay dominated mud collected from the nearby estuary (Fig. 2). Necessary instructions as listed below for proper care of the seedlings for better survival and growth of the propagules were given to the village groups.

Fig. 2. Mangrove propagules planted by SHG in mud filled polybags

Protocol for development of mangrove nursery:

- Select propogules which are ripe.
- Do not expose the propogules to direct sunlight.
- If the propagules become dry before planting, sprinkle water on the propagules to moisten them.
- Prepare the planting container by punching small holes on the cover.
- Fill the bags three fourths with clayey mud.
- Do not use sand or sand dominated sediment.
- Insert 1/3 part of the propagule into the sediment and place in shade .
- Water the growing propagule daily or on alternate days preferably with estuarine water to avoid wilting and desiccation.
- If the leaves are attacked by worms, these should be removed and then herbal insecticides like neem oil or neem based pesticides such as Azadirectin or tobacco decoction should be sprayed on the leaves.

Peoples' participation

The propagules were reared by five different groups of villagers comprising youth (Group A) and school children (Groups B to E). The biological details regarding the growth observed in the five nurseries and for the three species are given below.

Group A, Village youth

Three village youth who were interested in rearing the seedlings, developed a mangrove nursery beside the estuary (Fig. 3). They planted the propagules in the small packets as instructed and placed them in a shaded area such that the growing propagules were not exposed to direct sunlight. They watered the plants using a small pump every alternate day in the evening after coming back from their respective work places. They were committed and took care of the growing seedlings.

Fig. 3. Mangrove seedlings in community nursery, ready for transplanting

Group B, C, D and E

These groups were school children and were supported by their teachers (Fig. 4). The children developed a mangrove nursery in a shaded area in the school premises. They watered the plants daily but had to discontinue during holidays which affected the survival of the seedlings. The details regarding the number of propagules distributed to each group and the survival of the seedlings after three months of rearing are given in Table 1.

Fig. 4. Growth observations of mangrove seedlings at the end of nursery stage

An analysis was made on the reasons for varied survival rates and these are listed in Table 2. The major cause for non-survival of seedlings was root decay due to inappropriate punching of holes in polybags containing mud which served as nursery raising medium. This was observed in all the nurseries. Improper planting of propagule in the polybags and lack of regular watering were also reasons for wilting and decay of propagule/sapling. Moreover, pest attack especially by the leaf eating caterpillar and desiccation of propagules owing to delayed planting were also reasons for poor growth performance in the nurseries. Wherever pest attack was observed, the leaves were sprayed with Azadirectin (neem based bio-pesticide) and the worms were manually removed and destroyed.

Survival and growth of different species of mangroves

R. mucronata was the main species selected for the restoration programme. An average of 78.8% survival (N=2013) was observed and the survival percentages ranged between 78.1 to 100% in the nurseries maintained by different groups.

Table 1. Details regarding the survival of mangrove seedlings reared by the different groups in the village

Group	Group members	Total no. of propagules reared	Percentage survival of propagules
A	Village youth, Moothakunnam	2948	80.9
B	Teachers Training Centre, Moothakunnam	58	67.2
C	Govt. Boys Lower Primary School, Moothakunnam	55	81.8
D	Govt. Girls Lower Primary School, Moothakunnam	125	65.6
E	SNMHS, Moothakunnam	173	72.8
	Total	3359	Average 79.7

Table 2. Reasons for varied survival percentages of the mangrove seedling reared by different village groups

	Reasons for wilting / lack of growth of seedling	A	B	C	D	E	Overall ranking
Root decay	Drainage holes not properly punched	4	3	2	3	3	3
Planting of propagule	The shoot end was inserted into the clay instead of the root end	4	0	1	4	3	2.4
Watering the propagules	Not done routinely as instructed	1	4	2	2	3	2.4
Attack by pests	Worm attack was seen on the leaves during the third month of rearing	2	0	0	0	2	1.2
Desiccation (wilting) of propagule before planting	The propagules could not be planted in time after removal from the parent plant	1	1	1	1	1	1

B. gymnorrhiza was the second dominant species (N=866) and the average survival was 77.1 %. The survival in the nurseries ranged between 27.8 and 82.3%. *B. cylindrica* (N=480) had comparatively high survival rate (average= 87.7%). Survival percentage (80.9%) was highest in the nursery of village youth who took care of a total of 2948 seedlings followed by Group E which recorded a survival of 72.8%.

Growth of the propagule

Rhizophora mucronata

The shoot length of *R. mucronata* (Rm) reared by the different groups varied and ranged between a minimum of 26 cm and a maximum of 57.5 cm. The average root collar diameter was 15.1 mm with a minimum of 10.3 mm and maximum of 21.52 mm. The shoot diameter ranged between 3.4 mm and 6.8 mm, with a mean of 4.7 mm. The number of nodes ranged between 2 and 3 and the inter nodal length ranged between 2 and 14 cm. The number of leaves reared by the groups showed wide variation ranging between a minimum of 2 leaves and a maximum of 7 numbers. The average leaf area was 29.1 cm^2 with a minimum of 16.7 and maximum of 49.31 cm^2. The leaf area per seedling was estimated as an overall mean of 116.7 cm^2 with a minimum of 43 cm^2 to a maximum of 229.68 m^2.

Bruguiera gymnorrhiza

The growth of this species was comparatively lower than *R. mucronata* but faster than *B. cylindrica*. The average shoot length was 22.3 cm with a minimum of 14 cm and a maximum of 37.5 cm. The seedlings had an average root collar diameter of 15.5 mm with a minimum of 11.6 and a maximum of 20.3 mm. The mean shoot diameter was 5.2 mm with a minimum of 2.8 mm and a maximum of 9.1 mm. The number of nodes was lowest (1 no.) in the nursery of Group C and highest of 6 nos. in Group A nursery. The inter-nodal length also showed wide variation ranging between a minimum of 3 cm and a maximum of 8 cm. The foliage of the seedlings varied with individual seedling. In some, there were only three leaves while in other seedlings there were nearly 10 leaves in three months. The average unit area of leaves was 18.7 cm^2. Individual variation in unit leaf area ranged between a minimum of 4.93 cm^2 and a maximum of 33.27 cm^2. The leaf cover area per seedling was estimated as an overall mean of 99.2 cm^2, with a minimum 18.42 and maximum of 266.16 cm^2.

Bruguiera cylindrica

The growth of *B. cylindrica* was slow compared to that of *R. mucronata* and *B. gymnorrhiza*. This species had grown to an average height (shoot length) of 15.1 cm which is much lower than other two species. The corresponding root collar diameter was also small (6.4 mm). The shoot diameter showed a mean of 3.2 mm. The number of nodes varied between 2 and 4, seedlings had about 4 to 7 leaves. The inter-nodal length ranged between 2.5 and 6.4 cm and the average leaf area was 7.1 cm^2 $leaf^{-1}$. The leaf cover area per seedling showed a mean of 34.8 cm^2 (Table 3).

Globally, mangrove restoration programmes have been initiated by several nations. Though mangrove seedlings grow fast, their survival rates

Table 3. Details of growth of *Rhizophora mucronata* (Rm), *Bruguiera gymnorrhiza* (Bg) and *Bruguiera cylindrica* (Bc) after rearing the propagule for a period of 3 months from June to September 2010 at Moothakunnam village nurseries

Species		No. of leaves	No. of nodes	Inter-nodal length (cm)	Shoot length (cm)	Shoot dia. (mm)	Root collar dia. (mm)	Leaf area (cm^2 $leaf^{-1}$)	Leaf cover area (cm^2)
Rm	Range of group average (overall mean)	3.2 - 4.8 (4)	2 - 2.4 (2.2)	3.8 – 8.79 (6.4)	33.9 – 46.13 (40.7)	4.0 – 5.66 (4.7)	12.11-18.46 (15.1)	23.02 – 36.21 (29.1)	92.1-145.86 (116.7)
	Overall minimum - maximum	2 - 7	2 - 3	2 – 12.7	30 - 57.5	3.4 – 6.8	10.3 - 21.52	16.7-49.31	50.1-229.68
Bg	Range of group average (overall mean)	4 - 6.4 (4.8)	2 – 5 (3.3)	4.5 - 6.77 (5.7)	18.3-28.62 (22.3)	3.01 – 8.58 (5.2)	12.74-18.17 (15.5)	9.414 – 27.73 (18.7)	60.25-177.5 (99.2)
	Overall minimum - maximum	3 - 10	1 - 5	3 - 8	14-37.5	3 – 9.1	11.6-18.96	6.14 – 33.27	18.42-266.16
Bc	Range of group average (overall mean)	4 – 6.4 (4.8)	2 – 3.4 (2.8)	3 – 5.36 (4.07)	13.5 – 17.1 (15.01)	2.27 – 4.62 (3.2)	4.3-7.7 (6.4)	5.37 - 8.2 (7.1)	21.48-51.09 (34.8)
`	Overall minimum - maximum	4-6	2-4	2.5 -6.4	11 - 19	1.86 - 8	4.3 – 7.87	5.35 – 9.98	21.48-78.82

have been generally low in restoration sites mainly because of unscientific method of project implementation and also due to lack of support from villagers residing near the restoration area. The present study indicates that with proper care, propagules of *R.mucronata*, *B. gymnorrhiza* and *B. cylindrica* can be grown as seedlings for planting at selected sites. Such seedlings can be used for developing selected areas for eco-tourism which will support growth of ecosystem services. This will also help bio-construction of ecosystem and the villagers can be partners in this programme. Such restoration would increase the suitability of these habitats as nursery grounds for commercially important resources which will increase the productivity of the coastal ecosystem. The increased mangrove foliage will also help in carbon sequestration and support mitigation measures for climate change.

The seedlings were planted in selected areas at Moothakunam with the involvement of villagers. The ground area of *R.mucronata* planted was estimated as 670 m^2, with a spacing of 0.75 x 0.75 m in triangular pattern of planting. Similar ground area for *B. gymnorhiza* and *B. cylindrica* were estimated as 167 m^2 and 105 m^2 respectively.

Mean leaf area cover per unit ground area (m^2 leaf area per m^2 ground area) was calculated as 0.045 for *R. mucronata*, 0.0397 for *B. gymnorhiza* and 0.014 for *B. cylindrica*. Net canopy photosynthesis for the planted mangroves was estimated as 0.029 g C h^{-1} for *R. mucronata* 0.026 g C h^{-1} for *B. gymnorhiza* and 0.0091g C h^{-1} for *B. cylindrica*.

This study indicates the potential to develop community based mangrove nurseries for restoration programmes. With proper planting of the saplings, the mangrove cover in Kerala State can be improved. This can also support development of nursery areas for seed of finfishes and shellfishes. The carbon sequestration by the mangrove leaves especially near urban areas which are close to the sea is of critical importance due to the present concern on global warming. The mangrove canopy serve as lungs purifying the urban atmosphere loaded with high carbon dioxide accumulation owing to fuel discharge and dense population. Studies on mangrove restoration have shown that mangroves from the 10^{th} year of planting can sequester carbon @ 46.9 t ha^{-1} $year^{-1}$.