J. Indian Soc. Coastal Agric. Res. 41(2): 134-139 (2023) https://doi.org/10.54894/JISCAR.41.2.2023.138963

Short Communication

Conservation and Restoration of Mangroves in Visakhapatnam Coastal Lands using the Encased Methodology

Received: 07.07.2023 Accepted: 19.10.2023

Coastal ecosystems provide limitless services such as provisioning (timber, seafood and fibre), cultural (aesthetic, recreational, and spiritual benefits) and regulatory (carbon sequestration and waste assimilation) for the society (Everard, 2021). Mangroves have a significant impact on sediment stabilization. Research conducted by Scoffin (1970) revealed that red mangroves (*Rhizophora mangle*) are among the most effective sediment binders compared to other plants and algae. The protective role of mangrove fringes in safeguarding shorelines has also been well-documented by Zamboni *et al.* (2022). The degradation of mangrove forests due to urban and agricultural development has raised global concerns, leading to a growing emphasis on the conservation and restoration of these vital natural resources (Zari *et al.,* 2019). Over a third of the ocean and roughly 60% of ecosystem services of coastal areas are heavily degraded by anthropogenic activities at the world level (Halpern *et al.,* 2008). Coastal development activities (cutting the mangrove forests), overfishing, dam construction, poor land use, habitat damage from fishing gear and direct disposal of wastewater without prior treatments have resulted in the depletion of the quantity and quality of the coastal ecosystem (Adam, 2002; Elisha and Felix, 2021; Srinivasan *et al.,* 2010). According to Mandal and Bar (2018), a study revealed that out of the 77 mangrove species, 65 of them are listed in the Red List of threatened species, categorized into 6 distinct groups.

A recent study was conducted by a team of the Indian Council of Forestry Research and Education - Coastal Ecosystem Centre (ICFRE-CEC) on formulating the strategies for conservation of mangroves in the Visakhapatnam district. The study revealed that *Avicennia marina* (Forssk.) Vierh. and *Excoecaria agallocha* L. are the dominant tree species in the creeks and estuarine regions, while *Acanthus ilicifolius* L. is sparsely distributed among the mangroves. Additionally, several mangrove associates, including *Aeluropus lagopoides*, *Cressa cretica* L., *Heliotropium curassavicum* L., *Sarcolobus carinatus* Wall., *Sesuvium portulacastrum*, *Suaeda maritima* and *Suaeda nudiflora*

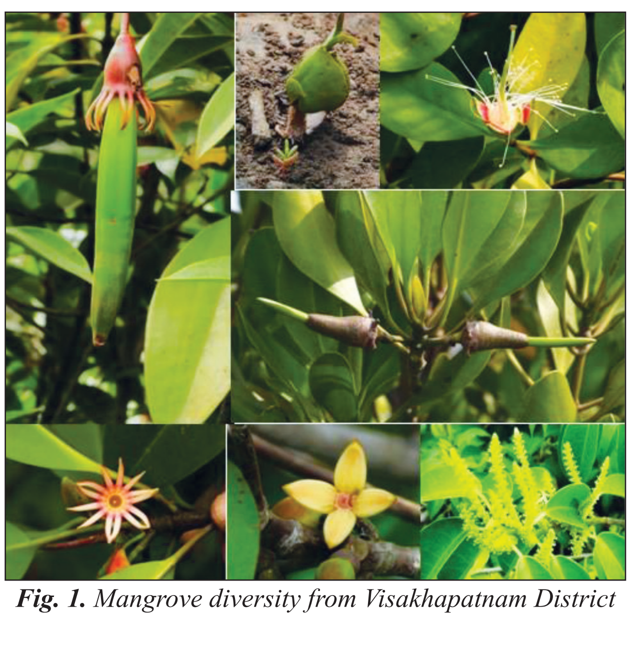

Fig. 1. *Mangrove diversity from Visakhapatnam District*

were recorded in the area. Nine true mangrove species with five mangrove associates were reported from the Visakhapatnam district (Fig.1). The ground truthing surveys revealed the presence of approximately 220 hectares of mangrove patches in the Visakhapatnam district. Surprisingly, these mangroves were not mentioned in the Forest Survey of India report, despite their regular mapping and monitoring of India's forest resources every two years. Furthermore, the growth of mangroves in many areas of the district has been negatively impacted by the high soil salinity.

The natural regeneration potential of mangrove species varies depending on the substratum type and water availability in the area. Additionally, the lack of space has intensified competition between species, further hindering natural regeneration efforts. In order to safeguard the genetic material, a nursery was established where mangrove propagules were collected from their natural habitat. Through experimental trials, it was observed that the survival of mangroves was influenced not only by water and sediment quality factors but also by the presence of high wave action. The growth of mangroves was primarily influenced by three key factors: sandy substratum, elevated water salinity, and the impact of strong waves. The encased methodology was developed to tackle the limitations associated with traditional planting techniques and promote the effective establishment of mangroves in areas such as high-energy shorelines, bulkheads, and revetments. These specific locations face challenges of limited natural recruitment and the ineffectiveness of traditional planting techniques.

The key principles of the encased methodology involve isolating individual seedlings within tubular encasements and facilitating their adaptation to the external environment of the restoration site. The success of encased methodology results from specifications for encasement preparation, propagules or seedling selection, and positioning of both encasements and seedlings according to elevation and tidal regimes. Not obvious from casual observation, the early stage of development produces an efficacious root system anchoring the plant inside the encasement. This anchoring phenomenon is so strong that after the first three months, the physical body of the seedling will actually break if an attempt is made to pull it from the encasement.

Field data collection was conducted between April, 2021 and August, 2022 to gather information on the natural regeneration of mangroves. Randomly selected areas within the mangrove-covered regions of Pudimadaka and the Port area were chosen for data collection. At each designated spot, a minimum of 5 plots measuring 10 x 10 m^2 were laid out randomly, with a distance of 100 m between each plot. The intention was to lay the plots in a straight line (transect), but when entering the mangroves was not feasible, the plots were placed 100 m apart. Within each plot, 5 quadrates measuring 1 x 1 m^2 were positioned, with 4 at each of the 4 corners and 1 in the middle. The counting of natural regeneration involved considering seedlings (ranging in length from 1 to 50 cm) and saplings (ranging in length from 51 to 150 cm) (Tomlinson, 2004). A total of 200 mangrove seedlings were planted in 4 block plantations at two locations (142 at Appikonda and 58 at Bheemili) (Fig. 2). The species composition was selected based on the abiotic parameters. The survivability ratio is very low at Appikonda (22.53%) compared with Bheemili (60.34%) (Tables 1 and 2). This must be due to high wave action and sandy sediment conditions prevailing in the Appikonda.

As per the results of these preliminary experimental plantations and abiotic parameters, it was decided to plant mangrove seedlings in a strategic manner by using Riley Encased Methodology (REM) (Riley, 1995). The study was conducted in the Gosthani estuary, situated at latitude 17°53′ - 17°56′ N and longitude 83°26′ - 83°28′ E. This estuary is one of the east-flowing rivers originating in the Ananthagiri Hills of the Eastern Ghats. It stretches for 120 km before joining the Bay of Bengal near Bheemunipatnam, Visakhapatnam. The river relies on rainfall and receives an average of 110 cm, mainly from the southwest monsoon.

The encased method used in this study is relatively straightforward, and the materials utilized are cost-effective. Standard PVC pipes were tested as an encasement option, proving to be adequately rigid to support the seedling during the development of aerial roots (Riley, 1995). For the encasement, we selected PVC pipes with a diameter of 10 cm (4 inches) to ensure sufficient soil capacity for providing adequate nutrition to the seedlings. The length of the pipe depends on the

(a) (b) (c)

Fig. 2. *Various mangrove seedlings (a) Acanthus ilicifolius (b) Volkameria inermis and (c) Avicennia marina growth in traditional block plantation at Appikonda and Bheemili*

Table 1. *Survivability of traditionally planted mangrove species at Appikonda*

Sl. No.	Mangrove species	Number of saplings planted	Number of saplings surviving
1.	*Acanthus ilicifolius*	4	2
2.	*Avicennia marina*	100	15
3.	*Bruguiera cylindrica*	8	5
4.	*Bruguiera gymnorhiza*	4	0
5.	*Excoecaria agallocha*	2	1
6.	*Rhizophora apiculata*	8	2
7.	*Ceriops tagal*	8	3
8.	*Volkameria inermis*	8	4
Total		142	32 (survival percentage = 22.53%)

Table 2. *Survivability of traditionally planted mangrove species at Bheemili*

Sl. No.	Mangrove species	Number of saplings planted	Number of saplings surviving
1.	*Avicennia marina*	32	22
2.	*Bruguiera cylindrica*	5	5
3.	*Bruguiera gymnorhiza*	3	2
4.	*Excoecaria agallocha*	5	0
5.	*Rhizophora apiculata*	8	3
6.	*Ceriops tagal*	5	3
Total		58	35 (survival percentage = 60.34%)

soil substratum, with a 3 m long pipe (1.5 m inside the soil and 1.5 m above the soil) used for the sandy substratum, and a 1 m pipe (0.5 m inside the soil and 0.5 m above the soil) used for muddy substratum (Fig. 3).

A total of 60 seedlings from five species (*Avicennia marina, Bruguiera cylindrica, B. gymnorhiza, Ceriops tagal,* and *Rhizophora apiculata*) were selected for the plantation. A block plantation method was employed, with a 2 m gap between each species. To plant the seedlings, the PVC pipe was longitudinally cut along its entire length. This cut allowed for unrestricted growth in the cross-sectional area of the tree. As the plant's girth expands beyond the diameter of the pipe, it automatically opens up, accommodating the enlargement of the trunk and root system. Another advantage of the longitudinal cut is that it facilitates the removal of the pipe. To enable water and aeration, holes were drilled along the length of the pipe.

The results of our study indicated that seedlings planted within PVC encasements had the highest survival percentage because of their protection from waves and currents. Out of the total 60 saplings planted across all species, 55 survived, resulting in an overall survival percentage of 91.66% (Table 3). In contrast, the survival ratio significantly declined at Appikonda (22.53%) and Bheemili (60.34%) when traditional planting techniques were utilized, whereas a survival rate of 91.66% was achieved using the encased methodology. This suggests a reasonably successful implementation of the plantation efforts, with a majority of the saplings successfully surviving and growing. Kent (1999) conducted a study to assess the effectiveness of encasement and traditional planting techniques for red mangroves (*Rhizophora mangle*) in environments with moderate to high wave energy. Their findings aresimilar to ours, indicating that seedlings planted within full-length PVC encasements exhibited the highest survivorship and growth due to their protection from waves and currents.

The encased methodology defies the constraints of conventional mangrove plantation methods by

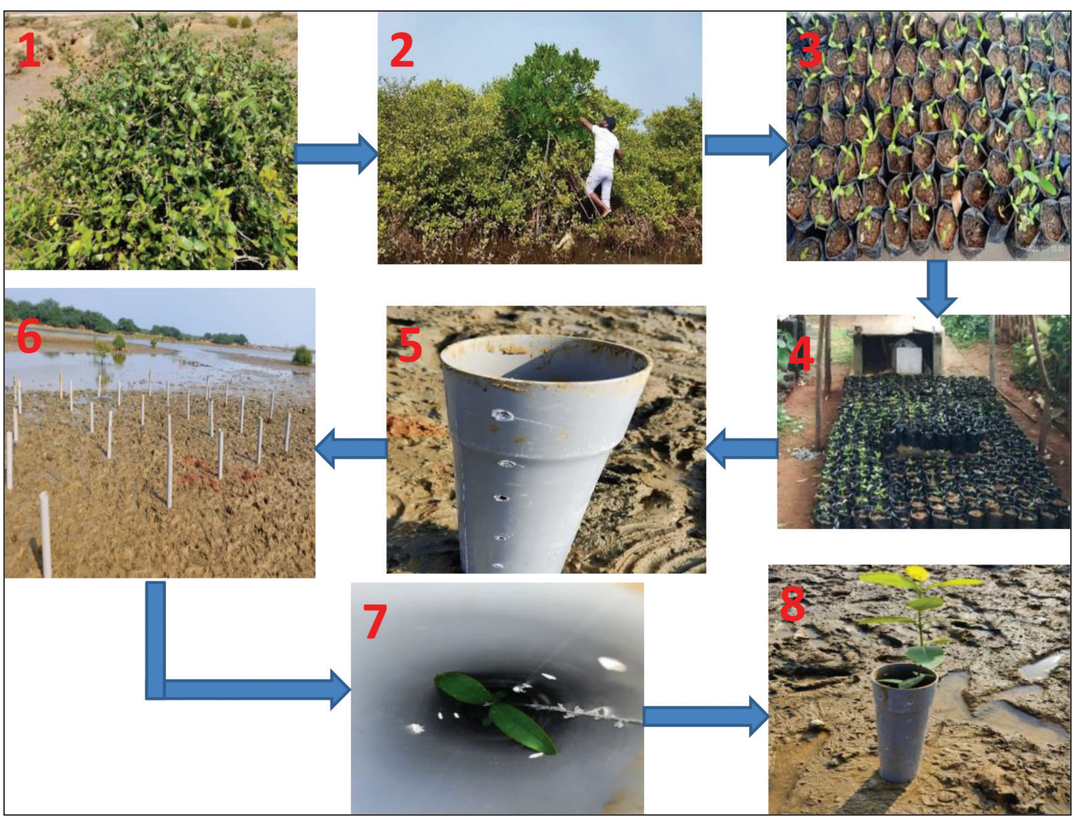

Fig. 3. *Steps involved in the encased methodology*

Table 3. *Percentage survivability of experimentally planted (Encased Methodology) mangrove species at Gosthani river, Bheemunipatnam, Visakhapatnam.*

S. No	Mangrove species	Number of saplings planted	Number of saplings surviving	Survival percentage (%)
1	*Avicennia marina*	40	38	95
2	*Bruguiera cylindrica*	4	4	100
3	*Bruguiera gymnorhiza*	5	4	80
4	*Rhizophora apiculata*	6	6	100
5	*Ceriops tagal*	5	3	60
Total		60	55	91.66%

achieving notable advancements in both the survival percentage and growth of mangroves along high-energy shorelines. This innovative approach challenges preconceived notions and expands the possibilities for successful mangrove establishment. By utilizing protective encasements and emphasizing adaptation, the methodology creates an optimal environment for mangroves to thrive in challenging coastal conditions. The encased methodology marks a significant breakthrough in mangrove plantation, presenting a transformative solution to enhance the resilience and conservation of these vital ecosystems.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this short communication.

R. PATEL[1]* and T. SRINIVAS[2]

[1]ICFRE-Institute of Forest Biodiversity,
Dulapally - 500 100, Hyderabad, Telangana, India
[2]ICFRE-Coastal Ecosystem System,
Visakhapatnam- 530 003, Andhra Pradesh, India

**Corresponding author*: E-mail: patelr@icfre.org/rubypatelssac@gmail.com

REFERENCES

Adam, P. (2002). Saltmarshes in a time of change. *Environmental Conservation* **29**(1): 39-61. https://doi.org/10.1017/S0376892902000048.

Elisha, O.D. and Felix, M.J. (2021). Destruction of coastal ecosystems and the vicious cycle of poverty in Niger Delta Region. *Journal of Global Agriculture and Ecology* **11**(2): 7-24.

Everard, M. (2021). *Ecosystem Services: Key Issue*, Routledge, Oxford, UK.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madlin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. (2008). A global map of human impact on marine ecosystems. *Science* **319**: 948-952. https://doi.org/10.1126/science.1149.

Kent, C.P.S. (1999). A comparison of Riley encased methodology and traditional techniques for planting red mangroves (*Rhizophora mangle*). *Mangroves and Salt Marshes* **3**: 215-225.

Mandal, R.N. and Bar, R. (2018). *Mangroves for Building Resilience to Climate Change*. Apple Academic Press. New York, USA. 362 p. https://doi.org/10.1201/9780429487781.

Riley, Jr.R.W. (1995). Encased replanting - A red mangrove replenishment methodology, Proceedings of the Twenty Second Annual Conference on *Ecosystems Restoration and Creation,* F.J. Webb, Jr. and P.J. Cannizzaro (eds.), Hillsborough Community College, May 1995, Tampa, Florida, USA. pp 165-179.

Scoffin, T.P. (1970). The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini Lagoon, Bahamas. *Journal of Sedimentary Petrology* **40**(1): 249-273.

Srinivasan, U.T., Cheung, W.W., Watson, R. and Sumaila, U.R. (2010). Food security implications of global marine catch losses due to overfishing. *Journal of Bioeconomics* **12**: 183-200.

Tomlinson, P.B. (2004). *The Botany of Mangroves*, Cambridge Tropical Biology Series, Cambridge University Press, Cambridge, UK. 419 p.

Zari, M.P., Kiddle, G.L., Blaschke, P., Gawler, S. and Loubser, D. (2019). Utilising nature-based solutions to increase resilience in Pacific Ocean cities. *Ecosystem Services* **38**: 100968. https://doi.org/10.1016/j.ecoser.2019.100968.

Zamboni, N.S., da Cunha Prudêncio, M., Amaro, V.E., de Matos, M.D.F.A., Verutes, G.M. and Carvalho, A.R. (2022). The protective role of mangroves in safeguarding coastal populations through hazard risk reduction: A case study in northeast Brazil. *Ocean and Coastal Management* **229**: 106353. https://doi.org/10.1016/j.ocecoaman.2022.106353.