Available online at: www.mbai.org.in doi:10.6024/jmbai.2020.62.1.2137-13

Comparison of seagrass restoration methods adopted in Palk Bay, India

V. Balaji*, V. Sekar and G. Murugesan
OMCAR Palk Bay Centre, Velivayal - 614 701, Thanjavur District, Tamil Nadu, India.

*Correspondence e-mail: director@omcar.org

Received: 15 Dec 2019 Accepted: 25 July 2020 Published: 30 July 2020

Original Article

Abstract

Seagrass habitats are under serious threat from diverse natural and human pressures, and calls for restoration measures to revive these invaluable habitats along the coast of India. This study compares three types of seagrass sprig restoration methods, namely PVC frames, bamboo frames and coir nets, to identify the best eco-friendly and cost-effective method suitable for community-based seagrass restoration projects. This study found that recovery of PVC frame for reuse partly damaged rhizomes. The cost for labour and materials for bamboo and coir method is lesser than the PVC frames. Coir ropes are flexible, light weight, easily available and the nets can be fabricated locally unlike PVC frames, the tubes for which have to be sourced from elsewhere. Coir nets can be tied with large number of seagrass sprigs fast, needs no technical manpower, and can be done involving local communities. This study observed more macrofaunal settlements in coir plots than bamboo and PVC frames. The material cost of bamboo frame was 46% lesser than the PVC frame, and same cost of coir frame was 102% lesser than the PVC frame. The labour cost of bamboo frame was 47% lesser than the PVC frame, and the same cost of coir frame was 33% lesser than the PVC frame. Thus, naturally degradable bamboo and coir nets are better, whereas coconut coir net method is the best as it is relatively of low cost, easily available and suitable for large scale, community-based seagrass restoration.

Keywords: *Seagrass restoration, Palk Bay, dugongs, community-based conservation, Cymodocea serrulata, Syringodium isoetifolium*

Introduction

Marine coastal habitats like seagrass beds are key ecosystems for humanity, providing valuable socio-economic and ecological services (Bayraktarov *et al.*, 2015). The ecosystem services of mangroves, coral reefs and seagrass beds have intricate linkages, especially by the presence of similar fauna as adults and juveniles (Bosire *et al.*, 2012). However, marine coastal habitats are degrading due to a variety of human activities (Lotze *et al.*, 2006). These eventually cause distress to the social and economic status of coastal communities, in local level and gross income at national level in developing countries that once had immensely benefitted from the marine coastal habitats. Hence, it is important to conserve and manage the coastal marine habitats like seagrass beds, and restore the degraded habitats to sustain benefits to the dependent communities. Further, since seagrass ecosystems are globally recognized as sinks for blue carbon helping in sequestering atmospheric carbon (Kennedy *et al.*, 2010), seagrass restoration will help in ameliorating the climate change. Fourteen species of seagrasses have been recorded in India and they are distributed in Andaman and Nicobar Islands, Lakshadweep Islands, east and west coast of mainland (Thangaradjou *et al.*, 2009). Seagrass beds in Palk Bay and Gulf of Mannar are degraded due to various manmade and natural threats (Thangaradjou *et al.*, 2009)

It is essential that degraded coastal ecosystems be brought back to previous stage by restoration and it is possible (Nobi *et al.*, 2013) by adopting appropriate techniques. Restoration projects in general aim bringing back the degraded ecosystem and associated flora and fauna close to its original condition, and provide the benefits to dependent communities (Wiens and Hobbs, 2015) in a sustainable manner. Looking at the fast rate of degradation and diverse anthropogenic pressures, there is dire need to focus on appropriate techniques and tools for restoring the degraded coastal ecosystems (Zhang *et al.*, 2018). Diverse seagrass restoration methods are followed in different parts of the world (Bologna and Sinnema, 2012; Marion and Orth, 2010; Bell *et al.*, 2008; Eriander *et al.*, 2016). In the case of seagrass restoration in developing countries, it is appropriate that the techniques are community based, low cost, eco-friendly and replicable. Thus, this study was carried out in 2017 in parallel with the seagrass rehabilitation project funded by Tamil Nadu Forest Department, Government of Tamilnadu, under their dugong conservation action plan in Palk Bay. Seagrass beds in Palk Bay, southeast coast of India, have undergone much degradation mainly due to activities associated with fishing and algal growth (Mathews *et al.*, 2010), a common issue in coastal states. The aim of the study is to identify the most efficient, low cost, eco-friendly seagrass transplantation frames (PVC vs. Bamboo vs. Coir net) using sprig method, replicable for community-based seagrass restoration projects around the world.

Material and methods

The transplantation site is located at Manora (Lat 10°14'52.34" N, Long 79°18'34.14"E), a coastal village in northern Palk Bay (Fig. 1). It is located about 1.3 km from the shoreline and 1.5 km from a natural seagrass bed that served as the donor site in the present study. The site is selected based on the seagrass acoustic survey conducted earlier (Balaji, 2018) and after detailed interactions with the local fishers. Here, macroalgal beds were also seen spread often up to 1 km from the shoreline.

Of the several methods tested, sprig method using square shaped PVC frames has been considered as the most feasible seagrass transplantation in Gulf of Mannar (Edward *et al.*, 2019). In the present study, the seagrass sprigs, collected from natural seagrass meadows by scuba diving, were transported to a boat, and tied on to PVC and bamboo frames and coconut coir net with participation of local fishers. Each transplantation frame was laid in an area of 100 m^2 at a depth of ~4 meters. Two common seagrass species namely *Cymodocea serrulata* and *Syringodium isoetifolium* were collected from the donor site, which is about 1 km from the transplantation site. In the transplantation site, PVC frames, Bamboo frames and coir nets (made of coconut fibre) were installed at 4m depth. The details of the three methods were compared as follows.

PVC frame method

This method was followed as per the Seagrass Rehabilitation Project Guidelines developed under Dugong Conservation Action Plan of Tamil Nadu Forest Department. Four PVC pipes (2 cm diameter and 1 meter long) joined using "L" bend to make 1m^2 frames were filled with sand to add weight to settle on the sea floor. After sealing the tubes using water-resistant adhesives, jute ropes were tied inside these frames to form square webs. The seagrass sprigs collected from donor sites were attached to these jute ropes (120 sprigs per frame), and the frame along with sprigs were submerged and fixed on the seabed using "U" shaped iron clamps. In total 100 such PVC frames (100 m^2) were installed on the seabed.

Bamboo frame method

Frames (1 m^2 size) were made using 2 cm wide and 1 m long bamboo slivers (Fig. 2). Jute ropes were tied in the bamboo

Fig. 1. Map of Palk Bay showing study area in northern Palk Bay

frame and 120 seagrass sprigs were tied on to it in the same pattern as the PVC frames. Then the frames were fixed on the seafloor using "U" shaped iron clamps. In total 100 such bamboo frames (100 m^2) were installed.

Coir frame method

Coir ropes were tied to make nets of 3-meter width and 6-meter length (18 m^2) with mesh size similar to the PVC and bamboo frames. In total 2160 seagrass sprigs were tied (Fig. 3) at a rate of 120 seagrass sprigs/m^2, similar to PVC and Bamboo frames. The whole unit was fixed on the sea floor using "U" shaped iron clamps. The total number of five and half coir frames were used to cover 100 m^2 area.

Cost/m^2 is an important factor for determining long-term implementation and replication of any seagrass rehabilitation methods in community-based projects. In this study the cost, from sourcing materials and fabrication up to installation of the frames in the seabed was estimated for each method on a 100 m^2 area basis. The cost estimates did not include expenses related to transport, scuba diving and monitoring. Of the total 300 m^2 nets and frames thus installed at the seabed, 5 randomly selected frames (5 m^2 area) each of PVC, bamboo and coir nets were monitored in 3rd, 5th and 7th months by scuba diving, recorded percentage cover (%), shoot density and invertebrate macro fauna in each frame. Environmental parameters (Atmospheric temperature, water temperature, salinity and pH) were recorded every month. As the experimental sites are located close to each other, water samples for nutrients such as phosphate, nitrate and nitrite were collected from the mid-point of the three plots and analysed following Strickland and Parsons (1972) every month. Pearson correlations were computed among environmental parameters, seagrass growth and macro fauna density for the three samplings in 3rd, 5th and 7th month of the experiment. The seagrass growth between the three sites was compared using Chi- square test in SPSS software.

Fig. 2. Preparation of bamboo frames with jute ropes by fishermen

Fig. 3. Seagrass sprigs are being tied by fishermen in coir net frames

Results and discussion

The study observed maximum atmospheric temperature (35.2°C) in May and minimum temperature in September (28°C) in the sites selected (Fig. 4). The maximum water temperature was recorded as 34.1 °C in May and minimum as 26°C in September. Similar patterns were observed in salinity, and pH level showed minor variations. All the three nutrients such as nitrate, nitrite and phosphate were observed to be the maximum in May and minimum in September (Fig. 5). Mean percentage cover (Fig. 6), shoot density (Fig. 7) and macro fauna density (Table 1) gradually increased with time in all the three types of frames and no significant difference was observed between the three, showing that seagrass growth pattern is similar among the selected methods. The macrofauna such as gastropods (1.6±0.04), bivalves (2.2±0.05), echinoderms (2±0.05), coelenterates (2.6±0.05) and crustaceans (1.9±0.05) were observed in higher numbers in coir plots, where more sponges were observed in bamboo plots. No shoots and leaves were observed after one month of transplantation, but the live rhizomes with new roots were found extending into the sediment. The new shoots came up after ~40 days of transplantation in both *Cymodocea serrulata* and *Syringodium isoetifolium*. Similar trend was observed in seagrass growth in all the three plots possibly due to two reasons; a) Similarity between the plots in terms of water quality, depth and distance from the shoreline, and b) The experiment was started in the beginning of summer and completed at the end of summer, when there

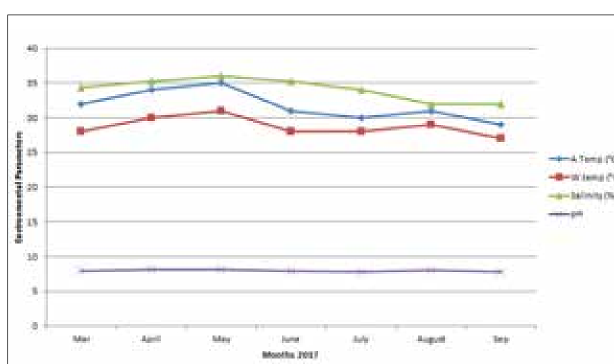

Fig. 4. Environmental parameters of seagrass restoration site

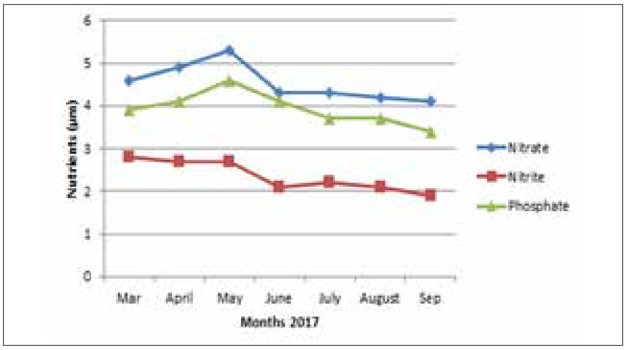

Fig. 5. Nutrient parameters of seagrass restoration site

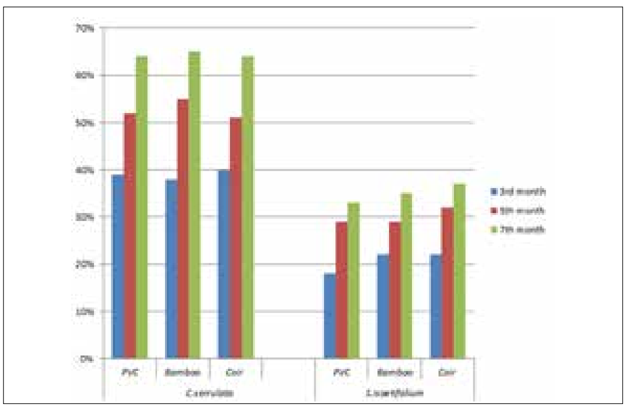

Fig. 6. Seagrass percentage cover/m2 within PVC, Bamboo and Coir frames.

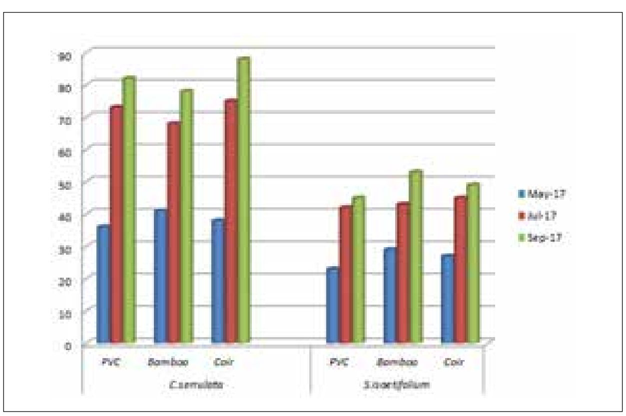

Fig. 7. Mean Shoot Density of sea grasses/m2 within PVC, Bamboo and Coir frames

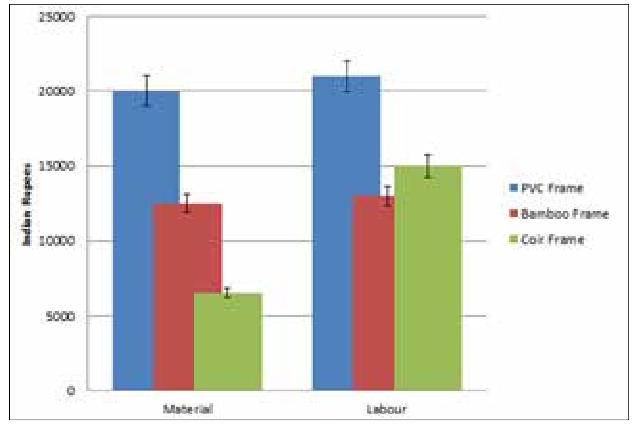

Fig. 8. Expenditure for the three seagrass restoration methods per 100 m^2

was optimum conditions for seagrass growth and no huge variation in environmental parameters.

The key difference between the three methods was the usage of different materials (frames) to keep the seagrass rhizomes close to the seafloor. The focus of this study being mainly finding the low cost, eco-friendly frame materials as alternative to PVC frames, it is important to consider the cost of each method for deciding upon large scale implementation of seagrass transplantation in future. The difference in expenditure between the three seagrass frame methods is significant due to variation in labour and material cost per 100 m^2 area (Fig. 8). In the case of bamboo frame, the material cost was 46% lesser than that of the PVC frame. The material cost for coir frame was 63% lesser than the bamboo frame and 102% lesser than that of the PVC frame. The labour cost for bamboo frame was 47% lesser than the PVC frame. In the case of coir frame, it was 14% higher than the bamboo frame, but 33% lower than the PVC frame. Additional cost was incurred for retrieving PVC frames, a non-biodegradable material that may possibly release during its slow breakdown some chemicals harmful for the restored sea grass system, while the bamboo and coir frames being biodegradable were left permanently on the seafloor.

No significant difference could be found in seagrass growth (percentage cover and shoot density) among the 3 different

Table 1. Macro faunal density recorded in PVC, bamboo and coir sites in 3rd, 5th and 7th months of the experiment.

Macro fauna	PVC Site			Bamboo Site			Coir Site		
	3rd	5th	7th	3rd	5th	7th	3rd	5th	7th
Gastropods	0.9±0.05	0.9±0.04	1.2±0.03	1±0.04	0.5±0.02	1.5±0.04	0.2±0.03	1.6±0.04	0.9±0.02
Bivalves	0.6±0.02	1.2±0.05	1.8±0.08	0.8±0.02	1.3±0.03	1.2±0.04	0.1±0.02	1.8±0.06	2.2±0.05
Sponges	0.5±0.02	1.4±0.04	2.1±0.02	0.6±0.02	1.2±0.04	2.1±0.05	0	1.2±0.05	1.8±0.05
Echinoderms	0.3±0.01	0.5±0.02	1.2±0.06	1.2±0.06	0.2±0.02	0.8±0.03	0	0.9±0.02	2±0.05
Coelenterates	0.8±0.02	1.3±0.04	1.3±0.05	0.5±0.03	0	1.6±0.02	0.1±0.02	0	2.6±0.05
Crustaceans	1.2±0.04	1.2±0.04	1.8±0.03	0.1±0.02	0	1.4±0.05	0.3±0.02	1.8±0.06	1.9±0.05

seagrass experimental methods, as seen from the Chi-Square test, done between the seagrass growth in PVC, Bamboo and Coir frames on one to one basis. There was no significant difference between the percentage cover of sea grasses between PVC site and Bamboo site (x^2 (4) = 6; p <0.199). Similar non-significant differences were seen between Coir and PVC plots in shoot density and percentage cover as well. This indicates that material of the frames does not have any impact on the establishment of seagrass in the sea bed. The correlation coefficients obtained between nutrients, macro fauna and environmental parameters were non-significant.

Pollution from plastic and its additives are considered as a threat to human health (Meeker *et al*., 2009) and environment (Ruddle, 1982). However, PVC frames for seagrass transplantation was already carried out in Gulf of Mannar (Patterson and Dsouza, 2015). In the present study, effort was made to remove the PVC frames after 7th month and 89% of PVC frames were recovered, the rest could not be recovered due to the dense growth of restored seagrass. Recovery of PVC frame for reuse was an additional effort which lead to partial damaging of the rhizomes. No efforts to examine the pollution impacts of such plastics left in the restoration sites were reported from any other seagrass restoration projects. Bamboo frames and tubes were tested in Thailand for eco-friendly transplantation. In the present study, bamboo frames were found significantly of low-cost than PVC frames and moreover, if left on the seafloor they would slowly decompose and be covered by restored sea grasses. The present study has used coconut coir nets for the first time in the world for seagrass transplantation. The key advantage of using coconut coir nets is that they are locally available in coastal areas around the world (Mitra, 2018). The coir ropes are flexible, light weight and local communities can easily prepare them for seagrass restoration much easily than PVC frames. This study observed more macrofauna settlements in coir plots than bamboo and PVC frames. Coir nets can be tied with large number of seagrass sprigs quickly within a short time by local communities and needs lesser scuba diving for recovery and associated works. Thus, it cuts the cost of materials and technical manpower. Most importantly, the material cost of coir net is the lowest of all the three methods. However, coconut coir nets have also some limitations. Due to their positive buoyancy during the initial days of seagrass transplantation, they tend to float; but that can be avoided by keeping them submerged in water for 3 days before installing in the field. The cost of bamboo frames is higher than coir nets. Thus, naturally degradable bamboo and coir nets are better suited for eco-friendly seagrass restoration, in which coconut coir method is the best as it is relatively low cost, easily available and suitable for large scale, community-based seagrass restoration. There is a need to continue this research in testing bamboo, coir and other degradable frames at various depths and seasons. However, as of now looking at the finding of the study it is recommended to preferably use coconut coir frames and then bamboo frames for large scale, low cost, eco-friendly seagrass transplantation.

Acknowledgements

Authors thank Thanjavur and Pudukkottai District Forest Offices of Tamil Nadu Forest Department for providing financial support for seagrass transplantation under Tamil Nadu Biodiversity and Greening Project. Authors also thank Dr. P. A. Azeez, Former Director of SACON for the comments on the manuscript.

References

Balaji, V. 2018. Acoustic survey of seagrass beds in northern Palk Bay, India, *Indian. J. Geo-Mar Sci.,* 47(8): 1607-1615.

Bayraktarov, E., E. Saunders, S. Abdullah, M. Mills, J. Beher, H. Possingham, P. Mumby and C. E. lovelock. 2015. The cost and feasibility of marine coastal restoration, *Ecol. App.,* 26(4): 1055-1074.

Bell, S. S., A. Tewfk, M. O. Hall and M. S. Fonseca. 2008. Evaluation of seagrass planting and monitoring techniques: Implications for assessing restoration success and habitat equivalency. *Restor. Ecol.,* 16: 407-416.

Bologna, P. A. X. and M. S. Sinnema. 2012. Restoration of Seagrass Habitat in New Jersey, United States, *J. Coas. Res.,* 278: 99-104.

Bosire, J. O., G. Okemwa and J. Ochiewo. 2012. Mangrove linkages to coral reef and seagrass ecosystem services in Mombasa and Takaungu, Kenya. KMFRI, 1-41p.

Edward, J. K. P., K. D. Raj, G. Mathews, P. D. Kumar, A. Arasamuthu, N. Dsouza and D. S. Bilgi. 2019. Seagrass restoration in Gulf of Mannar, Tamil Nadu, Southeast India: a viable management tool. *Environ. Monit. Assess.,* 191(430): 1-14.

Eriander, L., E. Infantes, M. Olofsson, J. L. Olsen and P. Moksnes. 2016. Assessing methods for restoration of eelgrass (Zostera marina L.) in a cold temperate region, *J. Exp. Mar. Biol. Ecol.,* 479:76-88.

Kennedy, H., J. Beggins, C. M. Duarte, J. W. Fourqurean, M. Holmer, N. Marba and J. J. Middelburg. 2010. Seagrass sediments as a global carbon sink: Isotopic constraints. *G. Bio. Cyc.,* 24(4):1-8.

Lutze, H. K., H. S. Lenihan, B. J. Bourque, R. H. Bradbury, R.G Cooke, M.C Kay, S.M. Kidwell, M. X. Kirby, C. H. Peterson and J. B. C. Jackson. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312 (5781): 1806-1809.

Marion, S. R. and R. J. Orth. 2010. Innovative techniques for large-scale seagrass restoration using Zostera marina (eelgrass) Seeds, *Restor. Ecol.,* 18(4): 514-526.

Mathews, G., K. Diraviyaraj, T. Thinesh, Jamila Patterson, J. K. Patterson Edward and Dan Wilhelmsson. 2010. Status of seagrass diversity, distribution and abundance in Gulf of Mannar Marine National Park and Palk Bay (Pamban to Thondi), Southeastern India, *South Indian Coastal and Marine Bulletin,* 2(2):1-21.

Meeker, J. D., S. Sathyanarayana and S. H. Swan. 2009. Phthalates and other additives in plastics: human exposure and associated health outcomes. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.,* 364: 2097-2113.

Mitra, A. 2018. Can coconut tree be a potential sink of carbon?, Techno. Intl. J. Health, Engineering, *Management & Science.* 2 (4): 134 - 137.

Nobi, E. P., E. Dilipan, T. Thangaradjou and P. K. Dinesh Kumar. 2013. Restoration scaling of seagrass habitats in the Oceanic Islands of Lakshadweep, India using geospatial technology. *Appl. Geomat.,* 5(2): 167-175.

Patterson, J. K. and N. Dsouza. 2015. Rehabilitation of degraded seagrass area in Tuticorin coast of Gulf of Mannar, Tamil Nadu, to support long term conservation of seagrass habitats - SGF Project Final Report. SDMRI. 1:1-12.

Ruddle, K. 1982. Environmental pollution and fishery resources in Southeast Asian Coastal Waters. Man, Land and Sea. The agricultural development Council, Bangkok. 15-35 p.

Strickland, J. D. H. and T. R. Parsons. 1972. A Practical Hand Book of Seawater Analysis. Fisheries Research Board of Canada Bulletin, 157 Strickland, J. D. H. and T. R. Parsons. 1972. A Practical Hand Book of Seawater Analysis. Fisheries Research Board of Canada Bulletin, 2nd Edition. 157: 310 p.

Thangaradjou, T., E. P. Nobi, E. Dilipan, K. Sivakumar and L. Kannan. 2009. Threats to the Seagrasses of India. *Seagrass Watch,* 39: 20-21

Wiens, J. A. and R. J. Hobbs. 2015. Integrating conservation and restoration in a changing world, Bioscience, 65(3): 302-312.

Zhang, Y. S., W. R. Cioffi, R. Cope, P. Daleo, E. Heywood, C. Hoyt, C. S. Smith and B. R. Silliman. 2018. A Global Synthesis Reveals Gaps in Coastal Habitat Restoration Research. Sustainability, 10: 1-15.