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FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

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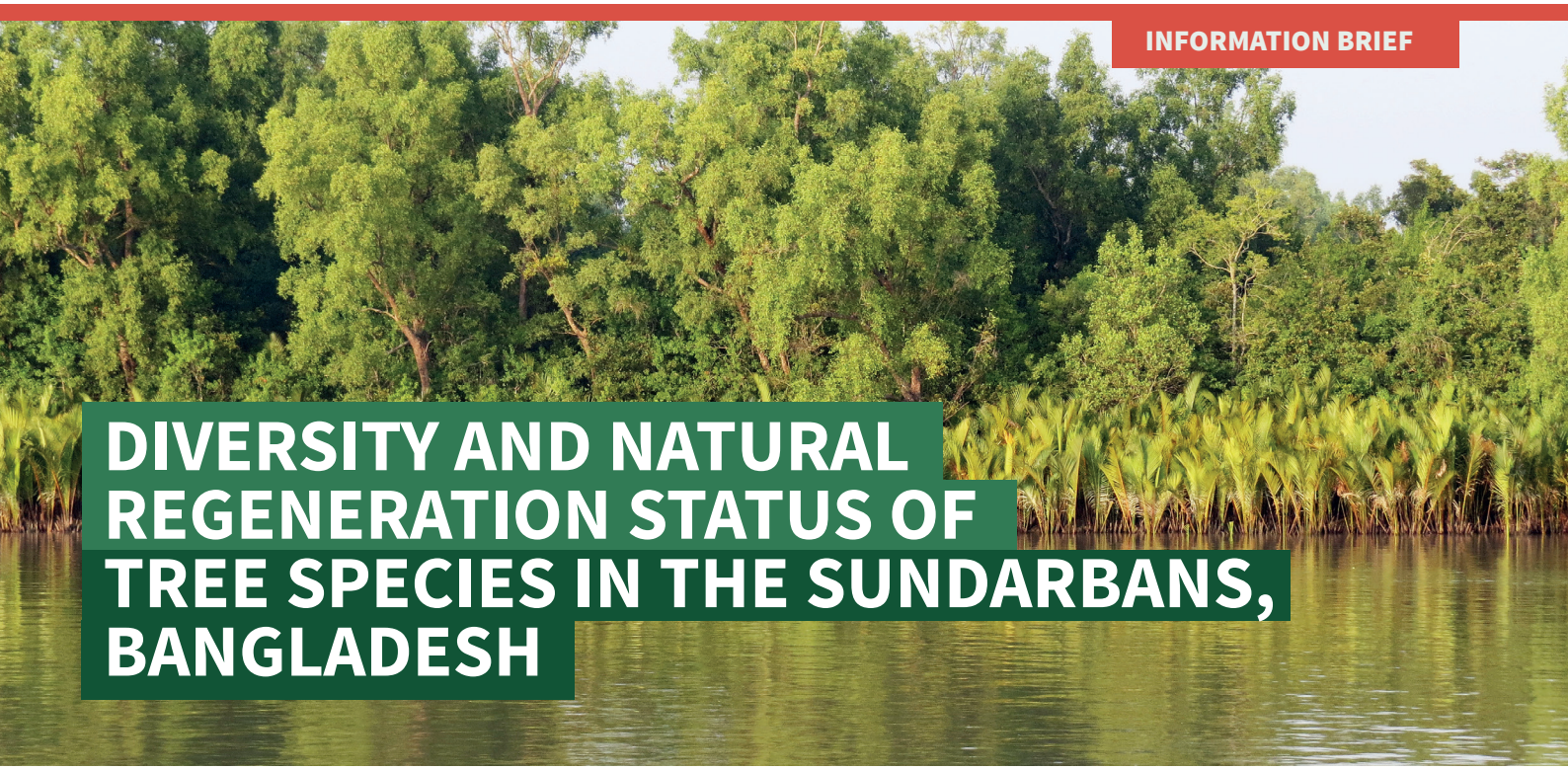
INFORMATION BRIEF



DIVERSITY AND NATURAL REGENERATION STATUS OF TREE SPECIES IN THE SUNDARBANS, BANGLADESH

KEY POINTS

- This study used data from 153 random sample plots of Sundarbans Reserved Forests collected during Bangladesh Forest Inventory between 2017 and 2019. Tree species composition, structure, distribution, diversity, regeneration and recruitment status were analyzed and compared in fresh water, moderate saline, and saline zones of Sundarbans.

- **Fresh water zone:** This zone harbours the most 23 tree species (out of 28 tree species), where 8 species are observed in this zone only. Among the available species, Bhaela is listed as Near Threatened in IUCN Red List category. Seedling and tree density is considerably higher in this zone than moderate and saline zones, while sapling density is substantially low. Sundri, Gewa and Amur are the three most dominant species and Sundri is the most densely populated species across all growth stages of this zone. Diversity is higher than the other two zones for saplings and trees. Five tree species showed no regeneration including Dagor, Dakur, Dhundul, Karanja and Sada Baen. In general, tree recruitment is fairly good in all zones, however, highest recruitment was observed in fresh water zone. Passur seems promising among 16 recruited tree species.

- **Moderate saline zone:** Seventeen (17) tree species were found in this zone. Garjan Jhanna is limited to this zone only. Sundri, Gewa and Goran are dominant species. Sundri is the most densely populated species at seedling and tree stage; while Gewa at sapling stage. Compared to other zones, number of seedlings, saplings and trees of different species showed less variation. Five tree species found in this zone have no regeneration including Keora and Baen. Among 10 successful recruited tree species, Baen showed the highest recruitment rate.

- **Saline zone:** Only 12 tree species were identified in this zone and among them Lota Sundri is confined to this zone. Sapling density is considerably higher compared to the other two zones; however, tree density is substantially lower. Goran is the most densely populated species at seedling and sapling stage; however, Gewa at the tree stage. Goran and Gewa are the most dominant (IVI) species at seedling and tree stages respectively, while, Goran and Gewa equally dominate the sapling stage. Two tree species including Keora and Lal Kakra have no regeneration. Successful tree recruitment rate of this zone is the lowest among three zones. Among six successful tree species recruited, Sundri was the highest .

- A globally endangered tree species (Sundri) and two near threatened (Hental and Goran) tree species were distributed across three zones.

INTRODUCTION

The Sundarbans, a designated Ramsar and World Heritage Site, is highly valued for its remarkable floristic and faunal composition, wildlife habitats, ecological, and socio-economic values. It covers an area of about 6017 km2 and is located in the southwest part of Bangladesh. Based on water salinity, the Sundarbans is divided into three distinct salinity zones: fresh water (salinity 2 dsm^{-1}), moderate saline (salinity 2–4 dsm^{-1}) and saline (salinity >4dsm^{-1}) (Siddiqi, 2001). Fresh water zone covers 28% area of the Sundarbans, while moderate saline 42% and saline zone 30% (Fig. 1) (Personal communication GIS unit of BFD, 2022)

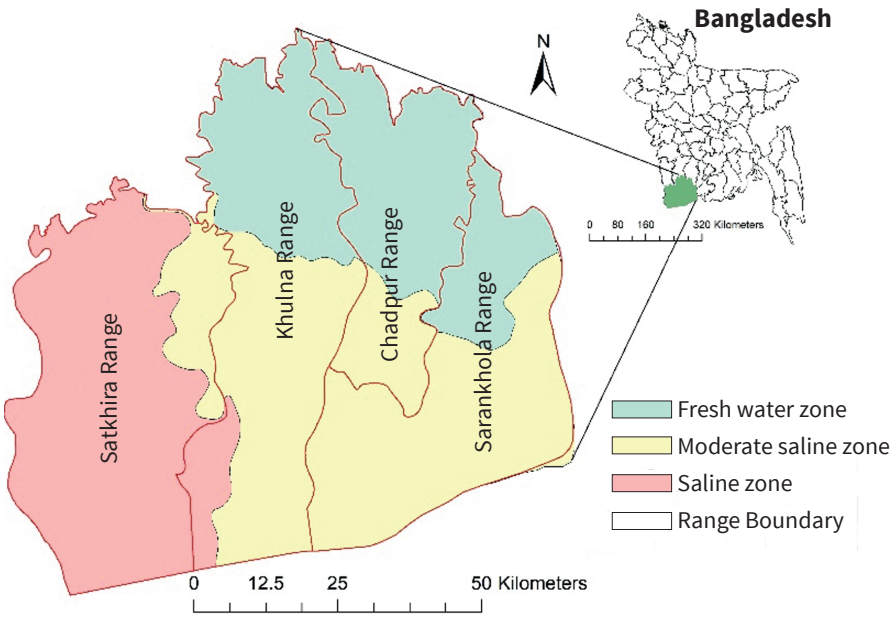


Figure 1: Location, salinity zones and administrative boundaries of the Sundarbans, Bangladesh

Differences in salinity might have an influence on tree species diversity and spatial distribution (Ahmed et al., 2011). On the other hand, the proportion of different growth stages (seedlings, saplings and trees) of various tree species helps in predicting any possible changes in forest composition. Information on the tree species composition and structure, and natural regeneration status at different tree growth stages of various gradient of saline zones is important to inform forestry practitioners, policy makers and researchers as to where their efforts will lead to desired management objectives. Hence the objectives of this report are to: (1) explore the tree species composition, structure and distribution pattern, (2) examine the tree diversity status and (3) determine natural regeneration and recruitment status by salinity zones and growth stages in the Sundarbans.

METHODOLOGY

Nationwide Bangladesh Forest Inventory was conducted between 2017 and 2019 and forests were described in its basic structure, composition, diversity and regeneration by ecosystem types e.g. Sundarbans, Sal, Hill, coastal forests (http://bfis.bforest.gov.bd/bfi/bfi-data). This report used 153 random sample plots data of the Sundarbans while excluding the partial (incomplete) inventoried 20 plots and further reorganized (using shape files collected from GIS unit of BFD) by salinity zones (i.e., 56 plots for fresh water, 54 for moderate saline and 43 for saline zone) to facilitate analysis in order to fulfil the objectives of this information brief. Natural regeneration data was collected by laying out circular clustered plot of 2.5m radius for seedling (<2cm diameter) and sapling (2-10cm), 8m radius for small (10-30cm) and 19m for large trees (>30cm) (Henry et al., 2021). For clear and easy understanding we combined the small and large tree data as tree. And then we analysed the data using descriptive statistics (mean, percentage), tree species composition, vegetation structure (density and importance value index), biodiversity indices, distribution, conservation and regeneration status. Results are elaborated below.

RESULTS

Objective 1

TREE SPECIES COMPOSITION, DISTRIBUTION BY ZONE AND CONSERVATION STATUS

This study identified 28 tree species under 13 plant families (Table 1). Fresh water zone contains the most (23) tree species of 12 plant families followed by moderate saline zone 17 tree species of 10 plant families and the least in saline zone 12 tree species of nine plant families (Table 1). Rhizophoraceae is the dominant plant family with five tree species. Difference in floristic composition exists among salinity zones (Table 1). Some species are distributed in all salinity zones representing at least one growth stage (tree, sapling or seedling). Some others are restricted in fresh water zone, a few in moderate saline and only one in saline zone. Among 28 tree species, Sundri is recorded as endangered and Hental, Goran, and Bhaela as near threatened (IUCN red list, 2021) (Table 1).

Table 1: Tree species composition, conservation status and regeneration status in the Sundarbans.

Family	Local name	Scientific name	IUCN status	Regeneration status		
				Fresh water	Moderate saline	Saline
1. Apocynaceae	Karamcha	*Carissa carandas*	-	New	-	-
	Dagor	*Cerbera manghas*	LC	No	New	-
	Dakur	*Cerbera odollam*	LC	No	-	-
2 Arecaceae	Hental	*Phoenix paludosa*	NT	New	New	New
3 Euphorbiaceae	Gewa	*Excoecaria agallocha*	LC	Fair	Fair	Fair
	Batul	*Excoecaria indica*	DD	Fair	-	-
	Kechchua	*Glochidion lanceolarium*	-	New	-	-
	Bhaela	*Intsia bijuga*	NT	Poor	-	-
4. Fabaceae	Singra	*Cynometra ramiflora*	LC	Good	New	-
	Karanja	*Pongamia pinnata*	LC	No	-	-
5. Fagaceae	Hiddigach	*Castanopsis lanceifolia*	-	New	New	-
6. Malvaceae	Bhola	*Hibiscus tiliaceus*	LC	New	-	-
7. Meliaceae	Amur	*Aglaia cucullata*	DD	Good	Good	Good
	Dhundul	*Xylocarpus granatum*	LC	No	Fair	Fair
	Passur	*Xylocarpus mekongensis*	LC	Good	Fair	Fair
		Xylocarpus sp.	-	-	No	-
8. Myrsinaceae	Khalsi	*Aegiceras corniculatum*	LC	New	-	New
9. Rhizophoraceae	Lal Kakra	*Bruguiera gymnorrhiza*	LC	-	No	No
	Kakra	*Bruguiera sexangular*	LC	Good	Fair	-
		Carallia sp.	-	-	New	-
	Goran	*Ceriops decandra*	NT	New	New	New
	Garjan Jhanna	*Rhizophora apiculata*	LC	-	No	-
10. Sonneratiaceae	Keora	*Sonneratia apetala*	LC	Fair	No	No
	Choyla	*Sonneratia caseolaris*	LC	Fair	-	-
11. Sterculiaceae	Sundri	*Heritiera fomes*	EN	Good	New	Good
12. Tiliaceae	Lota Sundri	*Brownlowia tersa*	LC	-	-	New
13. Verbenaceae	Sada Baen	*Avicennia alba*	LC	No	-	-
	Baen	*Avicennia officinalis*	LC	Fair	No	Fair

IUCN Red List categories, LC = Least concern, DD = Data deficient, NT = Near threatened, VU = Vulnerable, EN = Endangered. Regeneration status: **good** if seedlings > saplings > adults; **fair** if seedlings > or ≤ saplings ≤ adults; **poor** if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults); **no** if a species is present only in adult form; **new** if the species has no adults but only seedlings or saplings.

TREE SPECIES COMPOSITION BY GROWTH STAGES AND ZONES

Species richness in terms of number of tree species varies in different salinity zones of Sundarbans as far as their growth stages are concerned (Fig. 2). In saline zone, given that number of species in seedling and sapling stage (9) is greater than that of tree stage, it signifies that in future the number of species at tree stage would become higher. However, the trend is different in moderate saline and fresh water zone. For example, in fresh water and moderate saline zone the number of species in sapling stage is less than the number of species in tree stage. This may lead to a reduction of the number of species in tree stage in future surveys.

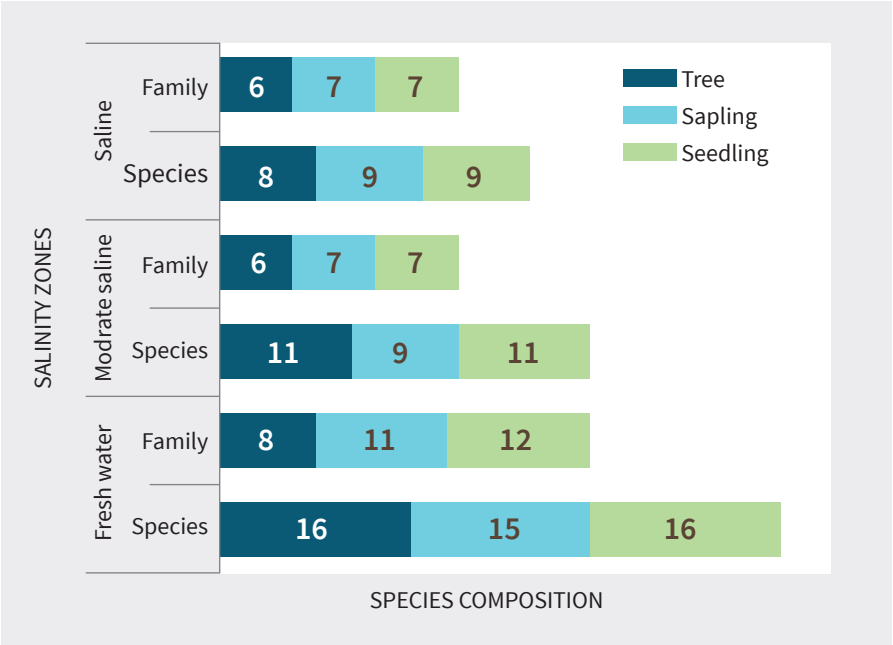


Figure 2: Tree species composition by salinity zones and growth stage

Objective 2

TREE SPECIES DIVERSITY

The Shannon-Wiener diversity index value indicates a fairly good tree species diversity across the Sundarbans (from 0.92 to 1.52) (Fig. 3). This diversity is more or less similar to other mangroves of the world, for example, Navsari, India (0-1.179), Delta Tumpat, Kelantan, Malaysia (0.38-1.54), Tegal Port, Central Java, Indonesia (0.7-1.44) and mainland Tanzania, (1.38-1.54). In general, tree species diversity is higher in fresh water zone and gradually decreases to the saline zone. However, as the diversity of seedling in fresh water and moderate saline zone is less than sapling, means that in the future there is a risk of gradual decrease in sapling and tree diversity.

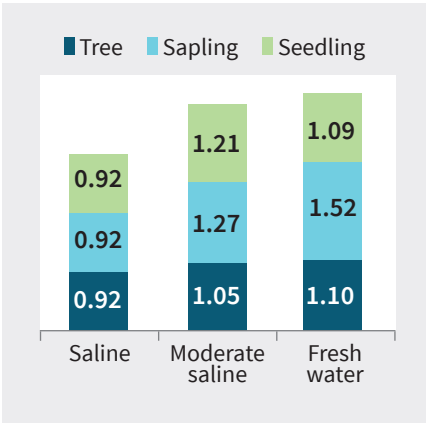


Figure 3: Shanon-Weiner Diversity Index

Fresh water zone is the highest species-rich (Margalef Richness Index) area in all three growth stages compared to the other two salinity zones (Fig. 4). Sapling exhibited the highest species richness followed by seedling and tree. Species richness in seedling stage of fresh water and saline zone is less than sapling, so there is a possibility of gradual decrease in species richness of these two zones.

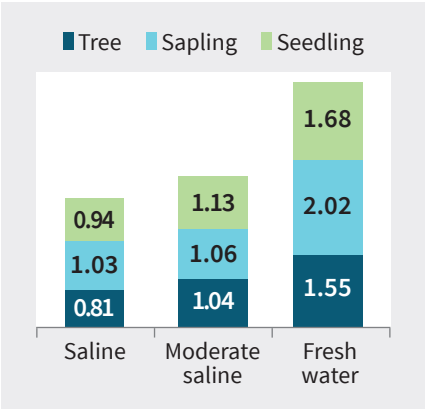


Figure 4: Margalef's Richness Index

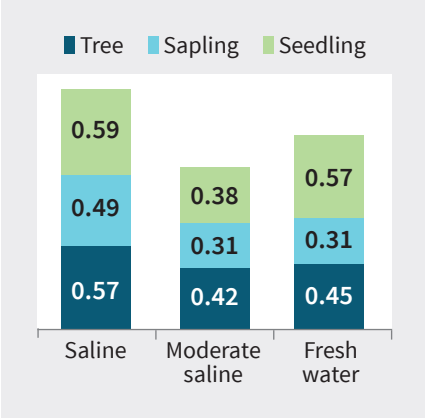


Figure 5: Simpson's Dominance Index

Simson's Dominance Index (SDI) ranges between 0 (no dominant species) and 1 (extremely dominated). Saline zone is dominated by a few species in all three regeneration stages of tree compared to the other two zones; where, moderate saline zone showed the lowest dominancy in all of those categories (Fig. 5). Seedling exhibited the highest

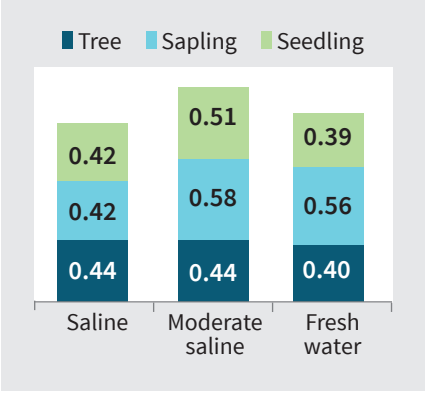


Figure 6: Pielou's Evenness Index

dominance of fewer species followed by tree and sapling in saline zone. This means that the number of species as well as density of some species (for example Sundri) will be reduced when they grow to sapling stage.

Pielou's Evenness Index (PEI) indicates the degree of structuring of community and constrained between 0 (high variation of species) and 1 (low variation). Moderate saline zone has the highest evenness in the number of each species in all three stages of forest growth (Fig. 6). In contrast, fresh water zone exhibited the highest variations in the number of individuals of each species in seedling and tree stage whereas saline water zone in sapling stage. **In general, species were more evenly distributed in moderate saline zone.**

Objective 3

REGENERATION STATUS BY SALINITY ZONES AND SPECIES

Densities of seedling, sapling and tree varies from salinity zone to zone and from species to species (Fig. 7). However, it showed a general declining trend from seedling towards sapling and tree irrespective of salinity zones (as expected). A marked gradual decline is evident for sapling from saline to fresh water zone. On the other hand, a notable decrease is found for tree in fresh and moderate compared to saline zone (Fig. 7).

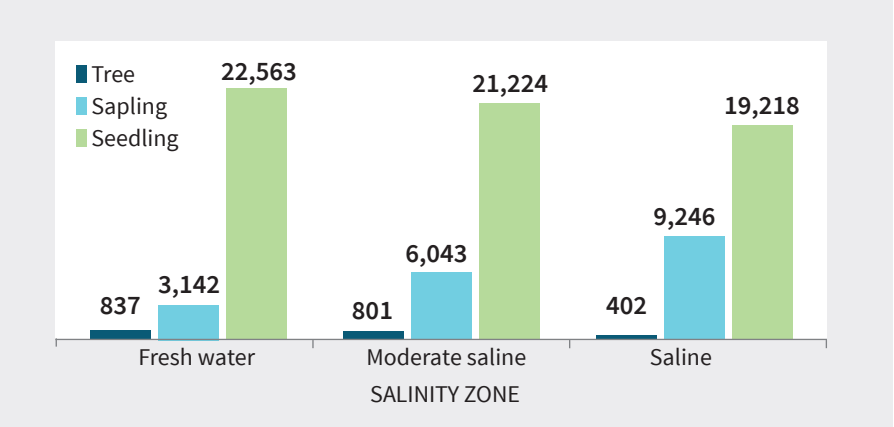


Figure 7: Tree species density by zones and growth stage

Tree species zonation dynamics of the Sundarbans along salinity gradient revealed Sundri is the most densely populated species in all growth stages of fresh water zone and seedling and tree stage of moderate saline zone. On the other hand, the density of Gewa is the highest in sapling of moderate saline zone and tree stage of saline zone; whereas, Goran is in the seedling and sapling stage of saline zone (Fig. 8).

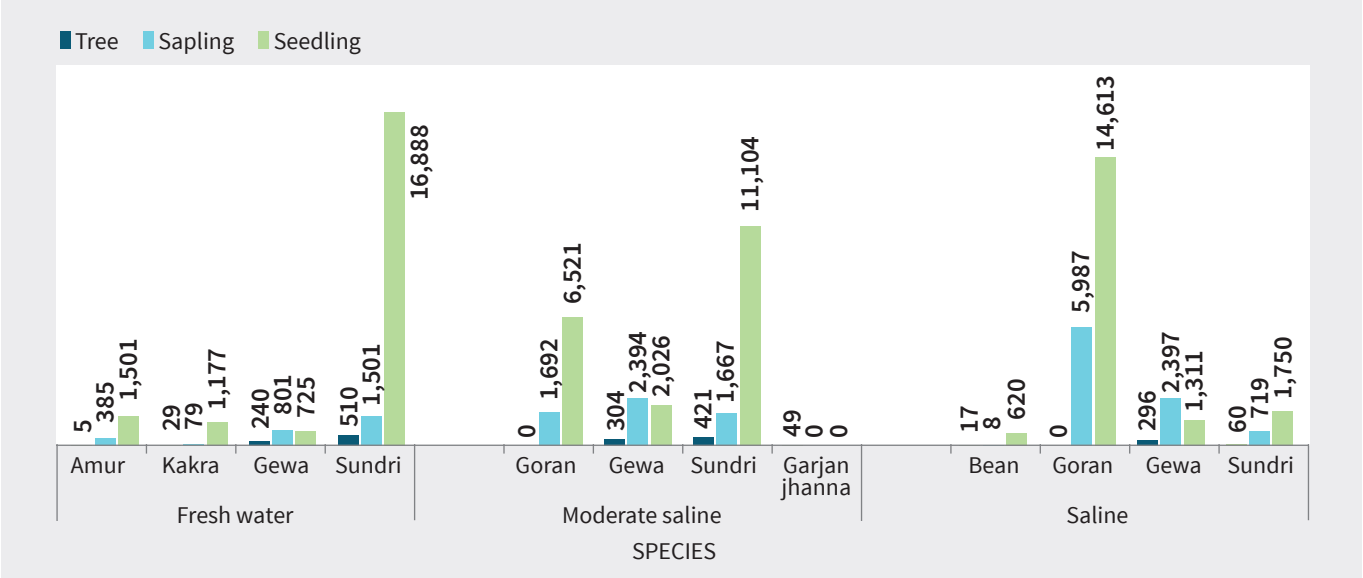


Figure 8: Density distribution of important species by zones

For the species dominance (Importance Value Index) of fresh water zone, Sundri is the dominant species in the all three growth stages and Gewa was the co-dominant species in sapling and tree, and Amur and Hental were the equally co-dominant species in seedling (Fig. 9). On the other hand, in moderate saline zone, Sundri is the dominant species in seedling and tree stage and Gewa at the sapling stage. Co-dominant species at the seedling stage is Goran and Gewa, sapling stage Sundri and tree stage Goran (Fig. 9). Furthermore, in saline water zone, Goran highly dominates in the seedling stage and Gewa in the tree, however sapling is equally dominated by Goran and Gewa. Seedling is equally co-dominated by Sundri and Gewa, sapling by Sundri and tree layer by Sundri and Passur (Fig. 9).

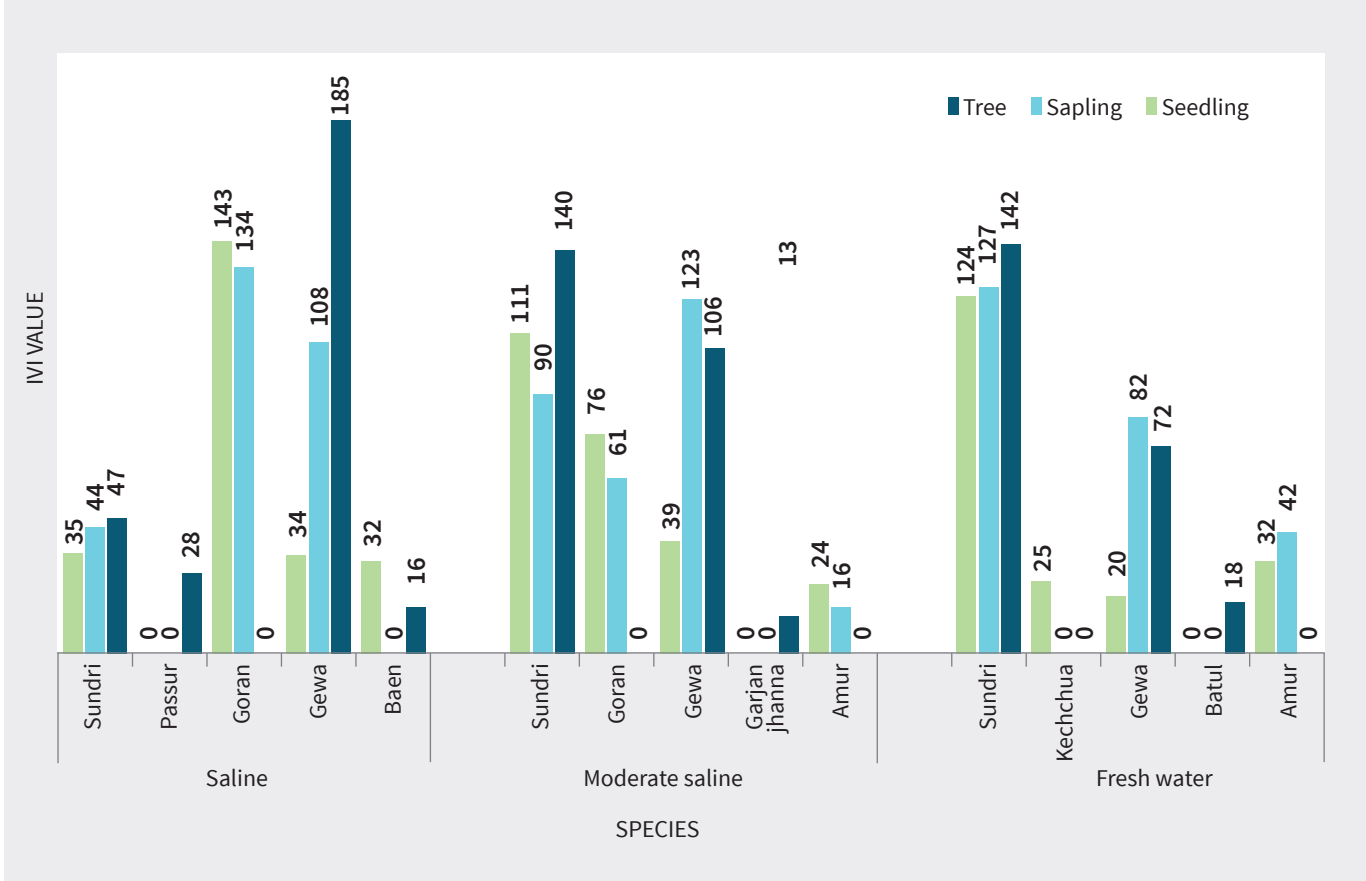


Figure 9: Importance value index (IVI) of top five species by zones and growth stage

REGENERATION STATUS BY SALINITY ZONES

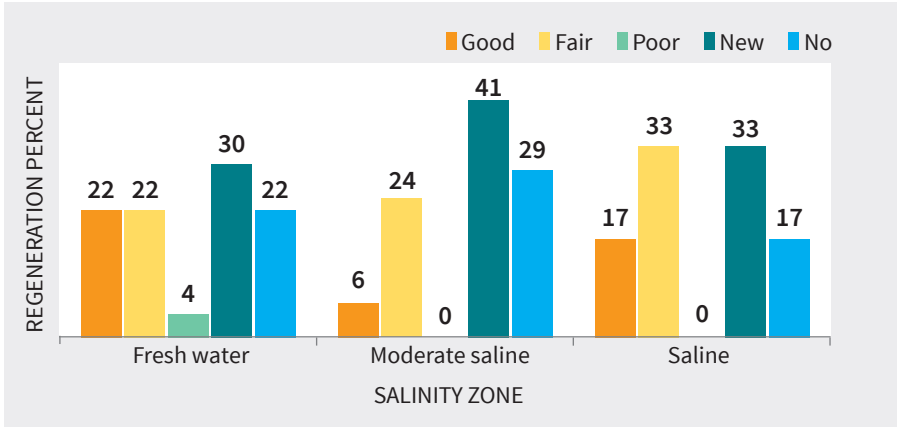


Figure 10: Regeneration status by zones

On the basis of seedling, sapling and tree density, different types of regeneration status of individual tree species were observed in different salinity zones (Table 1). A good number of species (9 of 28) across zones showed new regeneration. However, it is alarming that a significant number of species (6 of 28) showed no regeneration which in future may have an impact on the composition of the forest (Fig. 10). Further study is needed to identify the appropriate causes and proper conservation efforts.

Across zones, (see Table 1) Amur showed good, Gewa fair, and Goran and Hental new regeneration. Sundri showed good regeneration in fresh water and saline zone; however, new in moderate saline zone. Bhaela which

is available only in the fresh water zone, showed poor regeneration. Quality honey producing species Khalsi showed new regeneration in the fresh water and saline zone. Singra (honey producing species) performed good in fresh water zone and new in moderate saline zone. Passur showed good in fresh water and fair in both moderate saline and saline zone. Keora showed fair in fresh water zone. A number of important species such as Keora and Lal Kakra had no regeneration in moderate saline and saline zone, Dhundul in fresh water and Baen in moderate saline zone. On the other hand, Dakur, Karanja and Sada Baen which are available in fresh water zone and Garjan Jhanna in moderate saline zone had no regeneration.

RECRUITMENT STATUS BY SALINITY ZONES AND SPECIES

Given the seedling density per ha is very high (Fig. 7), the recruitment percentage from seedling to sapling or from sapling to tree or successful tree recruitment is low, indicating a severe competition for survival and establishment (Fig. 11). In freshwater zone, sapling to tree ratio is better than other two saline zones, i.e., more saplings are established as trees due favourable conditions. Interestingly in saline zone, about one third of the seedlings survived to sapling which may suggest a higher adaptive capacity of seedlings in saline water zone.

SPECIES-WISE SUCCESSFUL TREE RECRUITMENT OF IMPORTANT SPECIES

In fresh water zone, 16 species had successful tree recruitment. Among the four important species Passur showed a good recruitment (25%) which is the highest in this zone while Gewa, Baen and Sundri had low recruitment (<15%). In Moderate saline zone, 10 species had successful recruitment, among the important species Bean showed very high recruitment and Passur, Gewa and Sundri showed very low recruitment

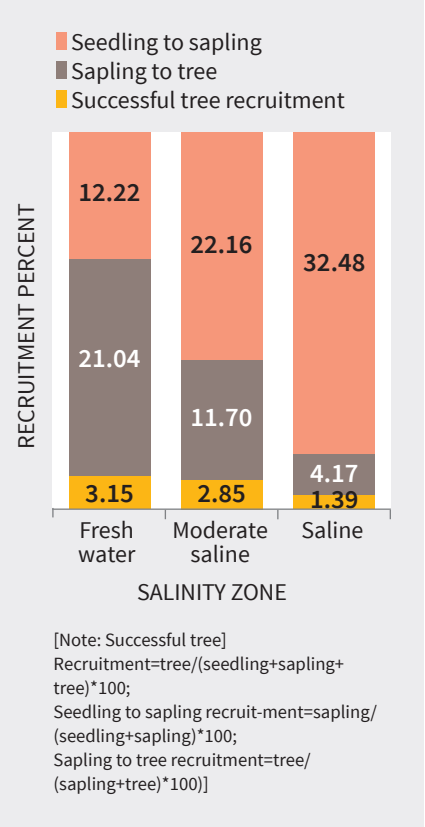


Figure 11: Recruitment percent by zone

(<7%). In Saline zone, 8 species had the successful tree recruitment, among four important species Passur showed a good recruitment (about 30 %) while, Sundri, Baen and Gewa showed a low recruitment (2-8%) (Fig. 12). **In conclusion, successful tree recruitment of Baen was very good in moderate saline zone, on the other hand, Passur was good in fresh water and saline zone.**

In fresh water zone, 8 species had sapling to tree recruitment of which Baen showed very good recruitment while, Passur, Sundri and Gewa exhibited a good recruitment rate (23-40%). In moderate saline zone, among 6 recruited species Baen and Passur showed very high recruitment (72-100%), whereas Gewa and Sundri showed a low level of recruitment (11-20%). In saline zone, Passur and Baen had very good recruitment (68-79%); however, Gewa and Sundri showed low to very low recruitment (11-7%). **In general, Passur and Baen were consistent in their high sapling to tree recruitment irrespective of salinity zones.**

In fresh water zone, 16 species had seedling to sapling recruitment, where recruitment percent of Gewa and Passur were very good (>50%); in converse, Baen and Sundri showed very poor recruitment (4-8%). In Moderate saline zone, among 6 species, Gewa had a high seeding to tree recruitment in where Sundri had low (13%) and Passur had a very poor recruitment (3%). In saline zone, 6 species had the seedling to tree recruitment, Gewa had a very high seedling to sapling recruitment and Sundri reasonable (29%) and Passur and Baen very low (Fig. 12). Overall, **Gewa maintained a high seeding to sapling recruitment rate (>50%) in all saline zones.**

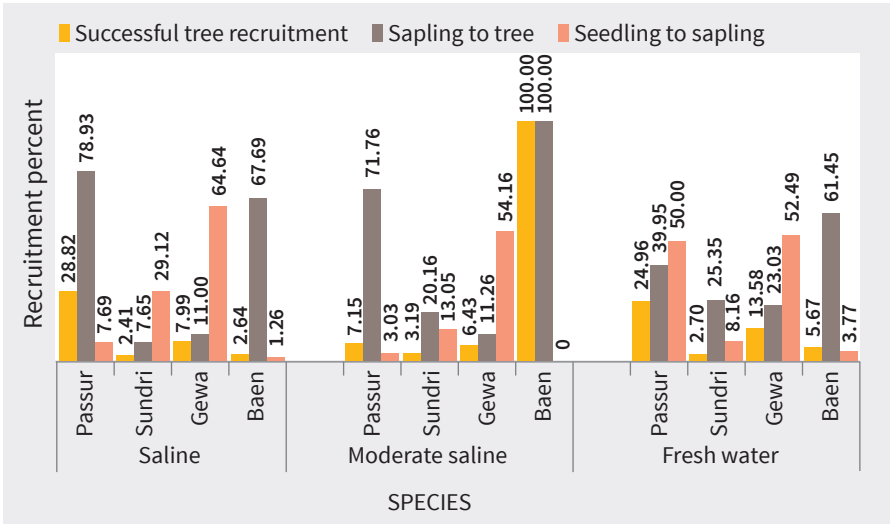


Figure 12: Recruitment status of four important species by zone

CONCLUSIONS

Salinity was found to play a key role in shaping mangrove composition and structure. A good number of mangrove tree species (28) occurred in the Sundarbans with the dominance of Sundri in fresh water, Sundri and Gewa in moderate saline, and Goran and Gewa in saline zone. This implies that Sundri is highly adaptive to fresh water and moderate saline zone; whereas, Goran only occurs in saline zone. Relatively good species composition and diversity was observed in the fresh water zone. This highlights the significance of increasing fresh water flow through the Sundarbans. Findings indicate that some important native species of Sundarbans including Bhola, Choyla and Sada Baen were found to be absent in moderate and saline water zone which suggests that if the area of saline zones increases then some of these species may disappear. No regeneration of five tree species in fresh water and moderate saline zone is alarming for the future tree composition. Several edaphic (salinity, fresh water flow, soil etc.) and climatic factors (sea level rise, temperature, precipitation, cyclones etc.) might be responsible; however, further research is suggested to identify the underlying causes. A relatively good percentage of successful tree recruitment in fresh water zone suggests that fresh water is more favourable for species to survive until tree stage. The information evolved during this study will be a baseline for forest managers, researchers, policy makers and advantageous for monitoring, management and policy making purposes considering that mangrove rejuvenation efforts with a preference given to species' association and location.

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