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Eco-Custodians: A Contemporary Analysis of Tree Species Composition and Regeneration Health in Ramsagar and Singra National Parks, Bangladesh

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ABSTRACT

This study systematically assessed tree species composition and regeneration status within two protected national parks in Bangladesh: Singra National Park and Ramsagar National Park. We employed a stratified random quadrat method across 100 sample plots (50 quadrats from each national park of 10 m x 10 m). Our findings revealed 45 tree species belonging to 25 families. Myrtaceae and Dipterocarpaceae were the most dominant family, having a maximum number of species. We identified 16 exotic species of 10 families and 29 native species of 19 families. Phytosociological parameters like density, frequency, abundance, and importance value index (IVI) were determined. *Shorea robusta* with an IVI of 47.38 dominated Singra National Park, while *Eucalyptus camaldulensis* with an IVI of 22.67 was most important in Ramsagar National Park. Regeneration status was good for 15.56% of species, fair for 24.44%, poor for 28.89%, and absent for 17.78%. This study implied the need for collaborative conservation strategies involving policymakers, conservationists, and local communities to ensure the parks' sustainable eco-custodianship.

1. Introduction

National parks of Bangladesh, mainly dominated by forest tree species, are crucial repositories of natural and bio-resources, playing a pivotal role in human well-being and environmental sustainability (Arora 2018; Hossain et al. 2020; Sarkar et al. 2017). Protected areas like national parks contribute significantly to biodiversity (Baraloto et al. 2013; Hossen and Hossain 2018) particularly the continuing viability of forest ecosystems depends on the intricate interplay of plant diversity and phytosociological characteristics, including plant composition, density, and other ecological features (Sarkar and Devi 2014). A better knowledge of the cycling of nutrients, animal-plant interactions, and the dynamics of forests also depends on collecting and updating such biodiversity data (Hossain et al. 2013; Kanagaraj et al. 2017; Rahman et al. 2019; Rimi et al. 2013; Sarkar 2016). Therefore, comprehensive phytosociological information is essential for planning effective conservation measures (Attua and Pabi 2013; Hossain et al. 2015; Rahman et al. 2019; Kacholi 2019) and formulating robust forest management programs (Sarkar 2016; Sarkar et al. 2017). Moreover, to ensure resilience and long-term sustainability in forest management decisions, data on floristic composition and community changes within ecosystems are needed to predict the effects of disturbances on composition and richness (Hossain et al. 2013; Kanagaraj et al. 2017; Rahman et al. 2019; Rimi et al. 2013; Sarkar 2016).

Information on phytosociological characteristics of tree species can help to understand the status of species regeneration (Tesfaye et al. 2010) because the nature and sustainability of forest communities are intrinsically tied to the regeneration status of species (Bargali et al. 2013; Rahman et al. 2011). Knowledge of the species composition of forests is also essential for regeneration capacity (Hossain et al. 2020; Hossen and Hossain 2018; Sarkar and Devi 2014), and it can help preserve biological variety (Sarkar et al. 2017). Moreover, the composition of tree species can demonstrate whether or not the species has a stable distribution that allows continuous regeneration. Natural regeneration is fundamental for biodiversity maintenance and conservation, aiding in predicting the future condition of forest ecosystems (Pradhan et al. 2019; Rahman et al. 2011; Tesfaye et al. 2010). Thus, understanding natural regeneration patterns is essential for addressing core forest management issues and achieving long-term sustainability and stability (Malik and Bhat 2016; Pradhan et al. 2019; Saikia and Khan 2013).

The forests of Bangladesh, once prosperous with around 5,000 angiosperm species and 1,609 fauna species, have witnessed significant biodiversity loss in recent decades (Chowdhury and Hossain 2020; Sobuj and Rahman 2011). Approximately 13% of the country's vascular plant species are now threatened in natural conditions, primarily due to population pressure, anthropogenic disturbances, excessive extraction of forest resources, and a lack of practical conservation efforts (Chowdhury and Hossain 2020; Dutta et al. 2015; Rimi et al. 2013). To lessen forest degradation and enhance biodiversity conservation, the classification of forest land as protected areas has been recognized as a crucial step toward achieving sustainability (Heino et al. 2015). Bangladesh has designated forest lands into various categories, including national parks, biodiversity conservation zones, eco-parks, and wildlife sanctuaries, aligning with global trends that highlight the pivotal role of protected areas in driving conservation efforts (Akber and Shrestha 2015; Humayun-Bin-Akram and Masum 2020; Masum et al. 2016; Masum et al. 2017; Xu et al. 2019; Yang et al. 2019). Despite these efforts, the vulnerability of global biodiversity remains a significant concern (Masum and Hasan 2020) due to the lack of accurate information on the structure and composition of tree species and their regeneration dynamics.

Ramsagar National Park and Singra National Park, nestled within the scenic landscapes of Bangladesh, stand as vital repositories of biodiversity, playing a crucial role in maintaining ecological equilibrium. However, the rapid pace of environmental change and anthropogenic influences pose significant challenges to the sustainability of these ecosystems (Hossain et al. 2020; Hossen and Hossain 2018). This research endeavors to identify critical challenges and potential opportunities for conservation initiatives. The insights from this study are anticipated to inform policymakers, conservationists, and local communities, fostering a collaborative approach towards sustainable eco-custodianship for the local ecosystems and global perspective. Therefore, recognizing the situation's urgency, this study aims to provide a nuanced understanding of the existing ecological conditions, focusing specifically on tree species composition and the regeneration dynamics in these protected areas.

2. Materials and Methods

2.1. Study Area

The current investigation was conducted within the confines of Ramsagar National Park (RNP) and Singra National Park (SNP), integral biodiversity conservation areas in the Dinajpur forest range, a significant region in Northern Bangladesh. Positioned in Sadar Upazila, RNP is situated between latitudes 25º44' and 25º33' N and longitudes 88º30'−88º44' E (**Fig. 1**). Conversely, SNP is located in Birganj Upazila, with latitudes ranging from 25º90' to 26º30' N, and longitudes from 88º20' to 88º50' E, within the Dinajpur District. The soil in the study area is characterized as highland, displaying a silt loam texture with a pH value of 5.79, falling under the agro-ecological zone (AEZ-1), specifically the Old Himalayan piedmont (Ali et al. 2020). The region has a tropical monsoon climate, a scorching summer, a hot and humid wet season, and a cold and dry winter. The brief but crucial wet monsoon season spans from July–October, with standard monthly precipitation of 333 mm. The arid winter period, lasting from November–February, receives sporadic drizzles. The highest average temperature is recorded at 34.6°C, while the lowest reaches 9.7°C. The annual average rainfall is 181 mm (BBS 2020; Ray et al. 2023). The cold-dry season is marked by the lowest temperatures and relative humidity of the year, with variations noted yearly.

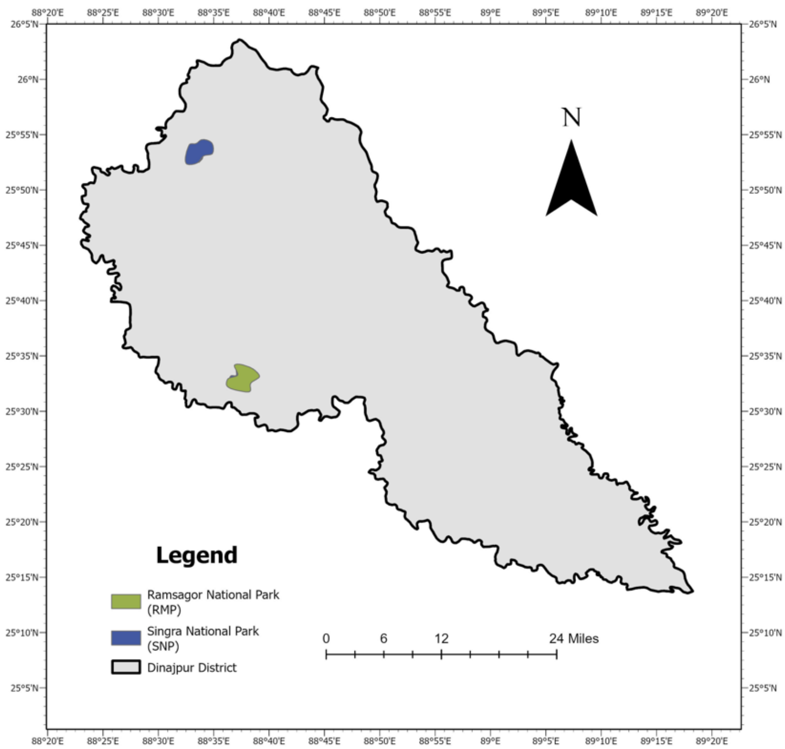

Fig 1. Study area map.

2.2. Data Collection

The research spanned from March–December 2022, encompassing the entire research process, including data collection, literature review, data analysis, and data interpretation. The quadrat method meticulously assessed tree species' phytosociological and regeneration status in the designated biodiversity conservation areas. Across each park, 25 sampling sites representing diverse natural forests and plantations were chosen for vegetation sampling. To quantify different tree species, two quadrats were strategically placed at each sampling site, selecting 100 quadrats from the two study areas (50 from RNP and 50 from SNP), each with a plot size of 10 m × 10 m. Furthermore, detailed records were maintained for all seedlings, saplings, and coppices, noting their origin as indigenous or exotic.

2.3. Data Analysis

All collected tree species were identified with the help of available references and literature. Phytosociological attributes, such as frequency, density, abundance, family relative density, family relative abundance, and importance value index, were calculated using specified formulas (**Table 1**). Various biological diversity indices, including Shannon-Wiener's diversity index (H), Simpson's dominance index (D), Dominance of Simpson index (D'), Margalef's species richness index (R), Simpson's species evenness index (E), Odum's Species diversity index (SDI), Shannon's maximum diversity (Hmax), and Shannon's equitability index (EH), were also computed to provide a comprehensive understanding of the diversity of tree species within the study areas. The regeneration status of the tree species was evaluated based on the population size of seedlings and saplings, following criteria established by Khumbongmayum et al. (2006) and Malik and Bhat (2016). Categories included "good" when seedlings > saplings > adults, "fair" when seedlings > or ≤ saplings ≤ adults, "poor" if a species survives only in the sapling stage, "none" when absent in both sapling and seedling stages but present only in adults, and "new" when a species lacks adults but has saplings and/or seedlings.

3. Results and Discussion

3.1. Phytosociological Status of Ramsagar National Park and Singra National Park

A total of 1,261 and 1,275 tree species have been identified in RNP and SNP, respectively, as detailed in **Table 2** and **Table 3**. The data in **Table 2** and **Table 3** underscore the remarkable richness in tree diversity within both conservation areas. In RNP, *Eucalyptus camaldulensis* exhibited the highest density and relative density at 2.84 and 11.26%, respectively, followed by *Mangifera indica* and *Bauhinia purpurea*. In SNP, *Shorea robusta* dominated with the highest density and relative density, followed by *E. camaldulensis* and *Acacia auriculiformis*. At the same time, *Syzgium cumini* recorded the lowest density and relative density. Furthermore, RNP exhibited the highest frequencyand relative frequency for *M. indica*, *Azadirachta indica*, and *E. camaldulensis*. In SNP, *S. robusta* led with the highest frequency and relative frequency, followed by *A. indica* and *A. auriculiformis*. In terms of abundance and relative abundance, *Polyalthia longifolia*, *E. camaldulensis*, and *B. purpurea* dominated in RNP, whereas in SNP, *S. robusta*, *E. camaldulensis*, and *Tectona grandis* took precedence. Among the biodiversity conservation areas, *E. camaldulensis* recorded the highest importance value index (IVI) in RNP and *S. robusta* boasted the highest IVI (47.38) in SNP. Notably, *Syzgium cumini* displayed the lowest IVI values. The IVI indicates that a species reflects its position of dominance in a heterogeneous population; it could potentially be used to construct a species' dominant relationship and provide a full grasp of species' structures within an ecosystem (Sarkar and Devi 2014). This study shows that the dominant species in RNP are *E. camaldulensis*, *M. indica*, and *P. longifolia*, while *S. robusta*, *E. camaldulensis*, and *A. auriculiformis* are the dominant species in SNP. These plants are significant from the perspectives of both commercial and biodiversity conservation.

Table 1. List of equations used for calculating phytosociological parameters and biodiversity indices for tree species in Ramsagar National Park and Singra National Park, Bangladesh

Biodiversity attributes	Equation	Explanation	References
Density (D)	$D = \frac{n}{m}$	D is the diversity species, n is the number of species' individuals, and m is the total number of plots sampled.	Murniasih (2022); Shukla and Chandel (2000)
Relative density (RD)	$RD = \frac{D}{\sum D_i} \times 100$	RD is Relative density, and $\sum D_i$ is the density of all species.	Misra (1968); Dallmeier et al. (1992)
Frequency (F)	$F = \frac{f}{m} \times 100$	F is the species' frequency, and f is the number of plots in which the species is present.	Shukla and Chandel (2000); Elzinga et al. (1998)
Relative frequency (RF)	$RF = \frac{F}{\sum F_i} \times 100$	RF is the relative frequency, and $\sum F_i$ is the frequency of all species.	Misra (1968); Dallmeier et al. (1992)
Abundance (A)	$A = \frac{n}{f}$	A is abundance.	Shukla and Chandel (2000)
Relative abundance (RA)	$RA = \frac{A}{\sum A_i} \times 100$	RA is relative abundance, and $\sum A_i$ is abundance of all species.	Shukla and Chandel (2000)
Importance value index (IVI)	IVI=RD+RF+RA	IVI is an important value index.	Dallmeier et al. (1992); Harefa et al. (2024)
Family relative density (FRD)	$FRD\ (\%) = \frac{N_f}{T_i} \times 100$	FRD is the family relative density, N_f is the number of individuals in a family, and T_i is the total number of individuals.	Mori et al. (1983)
Family relative diversity (FRDI)	$FRDI\ (\%) = \frac{N_s}{T_s} \times 100$	FRDI is the family relative diversity, N_s is the number of species in a family, and T_s is the total number of species.	Mori et al. (1983)
Species diversity index (S_{DI})	$S_{DI} = \frac{S}{N}$	S_{DI} is the species diversity index, S is the total number of species, and N is the total number of individuals of all the species.	Odum (1971); Kohli et al. (1996)
Margalef 's species richness index (R)	$R = \frac{(S-1)}{Ln\ (N)}$	R is the species richness index, and n is the number of individuals of each species.	Margalef (1958)
Shannon-Weiner's diversity index (H)	$H = -\sum P_i Ln\ P_i$	H is the Shannon-Weiner diversity index, and Pi is the number of individuals of one species/total number of individuals in the samples.	Shannon and Weaver (1963); Zaki et al. (2022)
Shannon's maximum diversity index (H_{max})	$H_{max} = Ln\ (S)$	H_{max} is Shannon's maximum diversity index.	Kent and Coker (1992)
Shannon's equitability index (E_H)	$E_H = \frac{H}{H_{max}}$	E_H is Shannon's equitability index, and H is the Shannon-Weiner diversity index.	Kent and Coker (1992)
Species evenness index (E)	$E = \frac{H}{Log\ (S)}$	E is the species evenness index, and S is the total number of species.	Pielou (1966)
Simpson's diversity index (D)	$D = \sum P_i^2$	D is the Simpson index, and P_i is the number of individuals of one species/total number of individuals in the samples.	Misra (1968); Dallmeier et al. (1992)
Dominance of Simpson index (D')	$D' = 1 - D$	D' is the dominance of the Simpson index.	Magurran (1988); Simpson (1949)

longifolia, *E. camaldulensis*, and *B. purpurea* dominated in RNP, whereas in SNP, *S. robusta*, *E. camaldulensis*, and *Tectona grandis* took precedence. Among the biodiversity conservation areas, *E. camaldulensis* recorded the highest importance value index (IVI) in RNP and *S. robusta* boasted the highest IVI (47.38) in SNP. Notably, *Syzgium cumini* displayed the lowest IVI values. The IVI indicates that a species reflects its position of dominance in a heterogeneous population; it could potentially be used to construct a species' dominant relationship and provide a full grasp of species' structures within an ecosystem (Sarkar and Devi 2014). This study shows that the dominant species in RNP are *E. camaldulensis*, *M. indica*, and *P. longifolia*, while *S. robusta*, *E. camaldulensis*, and *A. auriculiformis* are the dominant species in SNP. These plants are significant from the perspectives of both commercial and biodiversity conservation.

Table 2. Different phytosociological values of tree species of Ramsagar National Park

Family name	Scientific name	Quantity	RD (%)	RF (%)	RA (%)	IVI
Anacardiaceae	*Mangifera indica (*L.)	127	10.07	4.63	5.77	20.48
	Spondias pinnata (L.f.)	18	1.43	2.78	1.36	5.57
	Semecarpus anacardium (L.)	44	3.49	2.78	3.33	9.6
Annonaceae	*Polyalthia longifolia* (S.)	89	7.06	1.67	11.24	19.97
Bombacaceae	*Bombax ceiba* (L.)	12	0.95	2.04	1.24	4.23
Caesalpinieae	*Tamarindus indica* (L.)	25	1.98	2.22	2.37	6.57
	Bauhinia purpurea (L.)	91	7.22	2.78	6.9	16.89
Combretaceae	*Terminalia bellirica* (Roxb.)	18	1.43	2.22	1.71	5.35
	Terminalia arjuna (Roxb.)	17	1.35	3.33	1.07	5.76
Dilleniaceae	*Dillenia indica* (L.)	11	0.87	1.85	1.25	3.97
Dipterocarpaceae	*Shorea robusta* (Roxb.)	53	4.2	2.41	4.63	11.25
	Hopea odorata (Roxb.)	13	1.03	1.85	1.48	4.36
Elaeocarpaceae	*Elaeocarpus floribundus* (L.)	22	1.74	2.22	2.08	6.05
Euphorbiaceae	*Phyllanthus emblica* (Retz.)	23	1.82	2.04	2.38	6.24
Fabaceae	*Dalbergia sissoo* (Roxb.)	14	1.11	2.78	1.06	4.95
Leguminosae	*Xylia dolabriformis* (Roxb.)	11	0.87	2.22	1.04	4.14
Lythraceae	*Lagerstroemia speciosa* (L.)	18	1.43	3.15	1.2	5.78
Meliaceae	*Swietenia mahagoni* (L.)	19	1.51	3.7	1.08	6.29
	Azadirachta indica (A. Juss.)	70	5.55	4.26	3.46	13.27
	Melia sempervirens (L.)	16	1.27	2.59	1.3	5.16
Mimosaceae	*Acacia auriculiformis* (C.)	15	1.19	2.59	1.22	5.00
	Albizia saman (J.)	13	1.03	2.22	1.23	4.48
	Albizia procera (B.)	12	0.95	2.41	1.05	4.41
	Albizia lebbeck (L.)	21	1.67	2.04	2.17	5.87
	Acacia mangium (Willd.)	19	1.51	1.67	2.4	5.57
	Albizia richardiana (Voigt.)	10	0.79	2.04	1.03	3.86
Moraceae	*Ficus benghalensis* (L.)	17	1.35	1.48	2.42	5.25
	Ficus roxburghii (L.)	18	1.43	2.78	1.36	5.57
	Ficus comosa (Roxb.)	15	1.19	1.11	2.84	5.14
	Artocarpus heterophyllus	33	2.62	2.96	2.34	7.92
Myrtaceae	*Eucalyptus camaldulensis* (D.)	142	11.26	4.07	7.34	22.67
	Syzgium cumini (L.)	74	5.87	2.78	5.61	14.25
Oxalidaceae	*Averrhoa carambola* (L.)	27	2.14	2.41	2.36	6.91
Rhamnaceae	*Zizyphus mauritiana* (Lamk.)	15	1.19	2.41	1.31	4.91
Rubiaceae	*Anthocephalus chinensis*	16	1.27	3.15	1.07	5.49
Rutaceae	*Aegle marmelos* (L.)	23	1.82	2.22	2.18	6.23
Sapindaceae	*Litchi chinensis* (Sonn.)	30	2.38	2.96	2.13	7.47
Verbenaceae	*Tectona grandis* (L. f.)	15	1.19	2.41	1.31	4.91
	Gmelina arborea (Roxb.)	35	2.78	2.78	2.65	8.21

Notes: RD = Relative density, RF = Relative Frequency, RA = Relative Abundance, and IVI = Importance value index.

Table 3. Phytosociological values of tree species of Singra National Park

Family name	Scientific name	Quantity	RD (%)	RF (%)	RA (%)	IVI
Anacardiaceae	*Mangifera indica* (L.)	13	1.02	2.21	2.01	5.25
	Spondias pinnata (L.f.)	18	1.41	3.51	1.76	6.68
Bombacaceae	*Bombax ceiba* (L.)	43	3.37	3.87	3.81	11.06
Caesalpiniaceae	*Senna siamea* (Lamk.)	28	2.20	4.80	2.00	9.00
	Cassia fistula (L.)	34	2.67	2.95	3.95	9.57
Caesalpinieae	*Tamarindus indica* (L.)	21	1.65	4.43	1.63	7.70
Combretaceae	*Terminalia bellirica* (Roxb.)	33	2.59	2.95	3.84	9.38
	Terminalia chebula (Retz.)	41	3.22	3.87	3.63	10.72
	Terminalia arjuna (Roxb.)	47	3.69	2.95	5.46	12.10
Dipterocarpaceae	*Shorea robusta* (Roxb)	311	24.39	6.46	16.53	47.38
Euphorbiaceae	*Phyllanthus emblica* (Retz.)	31	2.43	2.77	3.84	9.04
Lythraceae	*Lagerstroemia speciosa* (L.)	25	1.96	4.80	1.79	8.55
Meliaceae	*Swietenia mahagoni* (L.)	23	1.80	4.61	1.71	8.13
	Azadirachta indica (A. Juss.)	69	5.41	6.46	3.67	15.54
	Melia sempervirens (L.)	15	1.18	2.40	2.15	5.72
Mimosaceae	*Acacia auriculiformis* (C.)	93	7.29	5.90	5.40	18.60
Moraceae	*Artocarpus heterophyllus*	14	1.10	2.40	2.00	5.50
Myrtaceae	*Syzgium cumini* (L.)	12	0.94	2.03	2.03	5.00
	Eucalyptus camaldulensis (D.)	139	10.90	5.17	9.23	25.3
	Syzygium fruticosum (Dc.)	19	1.49	2.58	2.52	6.60
Palmae	*Borassus flabellifer* (L.)	16	1.25	2.58	2.13	5.96
Rhamnaceae	*Zizyphus mauritiana* (Lamk.)	17	1.33	3.32	1.76	6.41
Rutaceae	*Aegle marmelos* (L.)	27	2.12	3.69	2.51	8.32
Sapotaceae	*Madhuca longifolia* (J. Konig)	26	2.04	4.61	1.93	8.59
Verbenaceae	*Tectona grandis* (L.f.)	89	6.98	4.24	7.20	18.42
	Gmelina arborea (Roxb.)	71	5.57	4.43	5.50	15.50

Notes: RD = Relative density, RF = Relative Frequency, RA = Relative Abundance, and IVI = Importance value index.

3.2. Different Biodiversity Indices of the Tree Species in Ramsagar National Park and Singra National Park

Table 4 presents diversity indices for two selected areas, RNP and SNP. The Shannon-Winner diversity index in RNP is 3.32, with a maximum potential of 3.66. The equitability is low at 0.02, and the species diversity index is 0.03, suggesting moderate diversity. The species richness index is relatively high at 5.32, indicating the dominance of a few species. The species evenness index is 0.06, and the dominance of Simpson index is 0.95, suggesting a less pronounced dominance of a single species.

Table 4. Different biological diversity indices of tree species of Ramsagar National Park and Singra National Park, Bangladesh

Selected areas	Diversity index							
	H	H_{max}	EH	S_{DI}	R	E	D	D'
RNP	3.32	3.66	0.02	0.03	5.32	0.06	0.05	0.95
SNP	2.80	3.26	0.86	0.02	3.50	1.98	0.10	0.90

Notes: H = Shannon-Winner diversity index, H_{max} = Shannon's maximum diversity index, EH = Shannon's equitability index, S_{DI} = species diversity index, R = species richness index, E = species evenness index, D = Simpson index, and D' = dominance of Simpson index.

In SNP, the Shannon-Winner diversity index is lower at 2.80 with a maximum potential of 3.26 and an equitability of 0.86, indicating a more even distribution of individuals among species.

The species diversity index is 0.02, reflecting moderate diversity. The species richness index is 3.50, and the species evenness index is higher at 1.98, indicating lower diversity than RNP. The dominance of Simpson index is 0.90, suggesting a relatively higher dominance of a single species than RNP. These indices collectively offer insights into the ecological diversity and dominance patterns, highlighting distinctions between the selected areas.

The species' composition, distribution, and status in both biodiversity-protected areas are extremely limited or nearly extant in this study. According to Adekunle et al. (2013), diversity indices measure the diversity of various species; the higher the value, the greater the diversity and abundance of these species. The two areas designated for biodiversity conservation have a rich diversity of trees. Still, according to **Table 2**, **Table 3**, and **Table 4**, the tree species in the RNP and SNP were much lower than those in some other biological conservation forests. In comparison to Bangladesh's existing conservation areas, the majority of diversity indices showed a high representation of floral variation regarding Chunati Wildlife Sanctuary (3.762) (Hossain and Hossain 2014), Tankawati Natural Forest of Chittagong (3.25) (Motaleb and Hossain 2011), and Dudhpukuria-Dhupachori Wildlife Sanctuary (4.45) (Hossain et al. 2013). The Shannon-Wienner diversity index was relatively similar to that of Chunati Wildlife Sanctuary (3.762). In comparison to Medha Kachhapia National Park (0.45) (Chowdhury and Hossain 2020), Chunati Wildlife Sanctuary (0.056) (Hossain and Hossain 2014), and Madhupur National Park (0.634) (Rahman et al. 2019), the Simpson's index (RNP 0.05; SNP 0.1) was found to be lower in the study areas. The lower phytosociological features in the studied area may cause the lower Simpson's index. However, compared to other forests, the species richness index revealed low tree species diversity at RNP and SNP, with values of 5.32 and 3.50, respectively (**Table 4**).

Researchers discovered higher richness index than RNP and SNP in several biodiversity conservation areas; these included the Chunati Wildlife Sanctuary (Hossain and Hossain 2014), the Tankawati natural forest of Chittagong (Motaleb and Hossain 2011), and the Dudhpukuria-Dhupachori Wildlife Sanctuary (Hossain et al. 2013). Compared to Madhupur National Park (1.48), richness index of RNP and SNP was greater (Rahman et al. 2019). In comparison to Chunati Wildlife Sanctuary (0.7834) (Hossain and Hossain 2014) and Dudhpukuria-Dhupachori Wildlife Sanctuary (0.853) (Hossain et al. 2013), species evenness (0.2106) was also found to be lower in RNP (0.06) and more significant in SNP (1.98).

3.3. Regeneration Status of the Tree Species in Ramsagar National Park and Singra National Park

About 2,536 individuals were found in the two biodiversity conservation areas (**Table 2** and **Table 3**), consisting of 45 species under 25 families with 36 genera. RNP recorded the highest number of tree species (39 species) between the two biodiversity conservation areas. The floristic composition of RNP (39 species) and SNP (26 species) was not good enough compared to other biodiversity conservation areas of Bangladesh. For example, Rimi et al. (2013) recorded a total of 272 plant species at RNP of 237 genera and 132 families where timber was 28, fruit 19, medicinal 75, fodder 17, palm 06, spices 05, ornamental 06, aquatic plants 41, cultivated crops 18 and weed species 57. There were 32 plant species identified in all, comprising 5 herbs, 4 shrubs, 4 climbers, and 19 tree species SNP (Ali et al. 2020). In addition, the study's estimated tree species composition was found to be lower than that of other forest ecosystems, including Madhupur National Park (139 tree species, 100 genera, and 40 families) (Rahman et al. 2019), Himchari National Park (117 tree species, 37 families), and the Kamalachari natural forest of Chittagong

(107 tree species, 72 genera, and 37 families) (Hossain et al. 2015). However, the results were in close agreement with the observations made by Rahman et al. (2011) at Khadimnagar National Park (43 species), the Talagaor Eco Park of Bangladesh (31 species), and Dulhazara Safari Park (31 tree species) (Uddin and Misbahuzzaman, 2007). Due to overexploitation, the diversity of tree species at RNP has reduced significantly over the past eight years.

Results indicated that 15.56% of tree species exhibited "good" regeneration status, 24.44% showed "fair" regeneration condition, and 28.89% showed "poor" regeneration status. A total of 17.78% of tree species were "not regenerating" at all, and 13.33% of tree species, which were available only in the sapling or seedling stage, were considered "new" in the two conservation areas (**Table 5**). Generally speaking, various manufactured and natural variables can affect species regeneration (Sarkar and Devi 2014). At the community level, the tree species regeneration quality was deemed satisfactory, with a "good" renewal status. However, 17.78% of the tree species were found to be "not regenerating", which might impact future population numbers in RNP and SNP. The study site may have experienced disturbances such as firewood collection, grazing, and insufficient biotic capacity of tree species, which can affect fruit and seed germination or the successful transformation of seedlings into saplings, resulting in the occurrence of species under "not regenerating" conditions.

Furthermore, juvenile individuals of any species are more vulnerable to anthropogenic disturbances and environmental stressors. The capacity of tree species to create more plantings and their ability to survive and produce seedlings and saplings determines how effective tree species regeneration is (Sarkar and Devi 2014). A forest with a robust canopy cover may have decreased the survival of seedlings beneath a good canopy by limiting the penetration of sole light into the forest (Sarkar and Devi 2014). A large number of essential and valuable tree species fall under the "new", "poor", and "none" categories of regeneration. Six tree species, or roughly 13.33% of the total, were "new", meaning they had recently arrived or colonized the site with saplings or seedlings. It is possible that seeds were spread by animals or birds dropping them, and a favorable microsite may have colonized the research location. Another likely explanation is that the folks are incredibly impoverished and have been shut off from the community, yet they have saved the seed until a good time to germinate. On the other hand, factors including light, canopy density, soil moisture, nutrients, and human pressures all impact a species' ability to regenerate (Sarkar and Devi 2014). Thus, the small canopy openings improve light access on the forest floor, which helps certain species in their seedling development (Wagner et al. 2011).

However, about 20 tree species were the same in both RNP and SNP, while the rest were found to be different. About 60% of families were represented by only one species, while two and three species represented 32% of families, and 8% of families comprised more than three species in the two study areas. Moreover, 16 exotic species were recorded in the study areas, whereas 29 indigenous species were recorded. Family relative density (FRD), family relative diversity (FRDI), and family importance value (FIV) index of recorded species are also calculated for the two study areas (**Table 5**). The highest FRD for both RNP and SNP was recorded from Myrtaceae (15.22%), followed by Dipterocarpaceae (14.87%) and Anacardiaceae (8.68). However, individually in RNP, the highest family relative density (FRD) found in Myrtaceae (17.13%), followed by Anacardiaceae (14.99%) and Caesalpinieae (9.20%), and in SNP it was from Dipterocarpaceae (24.39%), followed by Myrtaceae (13.33%) and Verbenaceae (12.55%). The highest FRDI for both RNP and SNP was recorded from Mimosaceae (13.33%), followed by Moraceae (8.89%) and Comdretaceae (6.67%), which was the same with Meliaceae, Myrtaceae, and Anacardiaceae.

Table 5. Family relative density, family relative diversity, family importance value index, species classification, and regeneration status of recorded species in Ramsagar National Park and Singra National Park

Family	FRD (%)			FRDI (%)			FIV			Species	Origin	Regeneration	
	RNP	SNP	Both	RNP	SNP	Both	RNP	SNP	Both			Mode*	Status
Anacardiaceae	14.99	2.43	8.68	7.69	7.69	6.67	22.68	10.12	15.34	*Mangifera indica*	Indigenous	Sd, Sp	Good
										Spondias pinnata	Indigenous	Sd, Sp	Fair
										Semecarpus anacardium	Indigenous	Sd, Sp	Poor
Annonaceae	7.06	-	3.51	2.56	-	2.22	9.62	-	5.73	*Polyalthia longifolia*	Exotic	Sd, Sp	Poor
Bombacaceae	0.95	3.37	2.17	2.56	3.85	2.22	3.52	7.22	4.39	*Bombax ceiba*	Indigenous	Sd, Sp	Poor
Caesalpiniaceae	-	4.86	2.44	-	7.69	4.44	-	12.56	6.89	*Senna siamea*	Exotic	Sd, Sp	Fair
										Cassia fistula	Exotic	Sd, Sp	Fair
Caesalpinieae	9.20	1.65	5.40	5.13	3.85	4.44	14.33	5.49	9.85	*Bauhinia purpurea*	Indigenous	Sd, Sp	Poor
										Tamarindus indica	Exotic	Sd, Sp	Poor
Combretaceae	4.60	9.49	7.06	7.69	11.54	6.67	12.29	21.03	13.73	*Terminalia arjuna*	Indigenous	Sd, Sp	Poor
										Terminalia bellirica	Indigenous	Sd, Sp	Poor
										Terminalia chebula	Indigenous	Sd, Sp	Poor
Dilleniaceae	0.87	-	0.43	2.56	-	2.22	3.44	-	2.66	*Dillenia indica*	Indigenous	Sd, Sp	None
Dipterocarpaceae	5.23	24.39	14.87	5.13	3.85	4.44	10.36	28.24	19.31	*Shorea robusta*	Indigenous	Copp	Good
										Hopea odorata	Indigenous	Copp	None
Elaeocarpaceae	1.74	-	0.87	2.56	-	2.22	4.31	-	3.09	*Elaeocarpus floribundus*	Indigenous	Sd, Sp	Fair
Euphorbiaceae	-	2.43	1.22	-	3.85	2.22	-	6.28	3.44	*Phyllanthus emblica*	Indigenous	Sd, Sp	Fair
Fabaceae	1.11	-	0.55	2.56	-	2.22	3.67	-	2.77	*Dalbergia sissoo*	Exotic	Natural	None
Leguminosae	0.87	-	0.43	2.56	-	2.22	3.44	-	2.66	*Xylia dolabriformis*	Exotic	Sd, Sp	None
Lythraceae	1.43	1.96	1.70	2.56	3.85	2.22	3.99	5.81	3.92	*Lagerstroemia speciosa*	Exotic	Sd, Sp	Poor
Meliaceae	8.33	8.39	8.36	7.69	11.54	6.67	16.02	19.93	15.03	*Melia sempervirens*	Indigenous	Sd, Sp	Fair
										Swietenia mahagoni	Exotic	Sd, Sp	Poor
										Azadirachta indica	Indigenous	Sd, Sp	Good

Family	FRD (%)			FRDI (%)			FIV			Species	Origin	Regeneration	
	RNP	SNP	Both	RNP	SNP	Both	RNP	SNP	Both			Mode*	Status
Mimosaceae	7.14	7.29	7.22	15.38	3.85	13.33	22.52	11.14	20.55	*Acacia auriculiformis*	Exotic	Sd, Sp	Good
										Albizia lebbeck	Exotic	Sd, Sp	Fair
										Acacia mangium	Exotic	Sd, Sp	New
										Albizia saman	Exotic	Sd, Sp	None
										Albizia richardiana	Exotic	Sd, Sp	None
										Albizia procera	Exotic	Sd, Sp	None
Moraceae	6.58	1.10	3.82	10.26	3.85	8.89	16.84	4.94	12.71	*Ficus benghalensis*	Indigenous	Sd, Sp	New
										Ficus roxburghii	Indigenous	Sd, Sp	New
										Artocarpus heterophyllus	Indigenous	Sd, Sp	Poor
										Ficus comosa	Indigenous	Sd, Sp	None
Myrtaceae	17.13	13.33	15.22	5.13	11.54	6.67	22.26	24.87	21.89	*Eucalyptus camaldulensis*	Exotic	Copp	Good
										Syzygium fruticosum	Indigenous	Sd, Sp	New
										Syzgium cumini	Indigenous	Sd, Sp	Poor
Oxalidaceae	2.14	-	1.06	2.56	-	2.22	4.71	-	3.29	*Averrhoa carambola*	Indigenous	Sd, Sp	Fair
Palmae	-	1.25	0.63	-	3.85	2.22	-	5.10	2.85	*Borassus flabellifer*	Indigenous	Sd, Sp	New
Rhamnaceae	1.19	1.33	1.26	2.56	3.85	2.22	3.75	5.18	3.48	*Zizyphus mauritiana*	Indigenous	Sd, Sp	Fair
Rubiaceae	1.27	-	0.63	2.56	-	2.22	3.83	-	2.85	*Anthocephalus chinensis*	Indigenous	Sd, Sp	New
Rutaceae	1.82	2.12	1.97	2.56	3.85	2.22	4.39	5.96	4.19	*Aegle marmelos*	Indigenous	Sd, Sp	Poor
Sapindaceae	2.38	-	1.18	2.56	-	2.22	4.94	-	3.41	*Litchi chinensis*	Indigenous	Sd, Sp	Fair
Sapotaceae	-	2.04	1.03	-	3.85	2.22	-	5.89	3.25	*Madhuca longifolia*	Indigenous	Sd, Sp	Fair
Verbenaceae	3.97	12.55	8.28	5.13	7.69	4.44	9.09	20.24	12.73	*Gmelina arborea*	Indigenous	Sd, Sp	Good
										Tectona grandis	Exotic	Copp	Good

Notes: RNP = Ramsagar National Park, SNP = Singra National Park, FRD = family relative density, FRDI = family relative diversity, FIV = family importance value index.

Whereas individually in RNP, the highest FRDI was found in Mimosaceae (15.38%), followed by Moraceae (10.26), and in SNP, it was from Combretaceae, Meliaceae, and Myrtaceae (11.54%), followed by Anacardiaceae, Verbenaceae, and Caesalpinieae (7.69%). In the case of FIV, the highest value for both RNP and SNP was found from Myrtaceae (21.89), followed by Mimosaceae (20.55) and Dipterocarpaceae (19.31), but individually in RNP, it was recorded from Anacardiaceae (22.52), followed by Mimosaceae (22.52) while in SNP the highest family importance value (FIV) was from Depterocapaceae (28.24), followed by Myrtaceae (24.87) and Combretaceae (21.03). The study also showed that no tree species were found in the RNP of 4 families (Caesalpiniaceae, Euphorbiaceae, Palmae, and Sapotaceae). On the other hand, no species of 8 families did not exist in SNP among the 25 families recorded from the two study areas. Regarding families, the two most prevalent families in RNP and SNP were Myrtaceae and Dipterocarpaceae. These two families' dominance is most likely due to the tremendous dispersal of their seeds, pollen grains, and other materials by the wind, water, birds, animals, bats, and humans.

4. Conclusions

Singra National Park (SNP) and Ramsagar National Park (RNP), the two protected areas in the northern part of Bangladesh recognized as vital biodiversity repositories, have faced challenges from environmental changes and anthropogenic influences. The study provided nuanced insights into the current conditions, focusing specifically on tree species composition and regeneration dynamics. Ramsagar National Park and Singra National Park harbor prevailed considerable tree diversity, with Myrtaceae and Dipterocarpaceae being the most dominant families. *Eucalyptus camaldulensis* was the most important species in RNP, while *Shorea robusta* dominated SNP. Despite moderate diversity indices, the regeneration status of several tree species is a significant concern. Although 15.56% of species exhibited good regeneration, 17.78% were not regenerating. This highlights the urgent need for targeted conservation interventions to address the factors hindering regeneration success. Effective biodiversity management strategies are crucial for these protected areas. These should incorporate collaborative initiatives involving policymakers, conservationists, and local communities to safeguard vulnerable species, promote sustainable resource use, and ensure the parks' long-term ecological health. These findings also recommended initiating a holistic approach toward preserving other critical biodiversity hotspots in Bangladesh and the broader discourse on global biodiversity conservation.

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