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Diversity and Composition of Tree Species in Madhupur National Park, Tangail, Bangladesh

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Abstract

Madhupur National Park (MNP) is one of the last remaining patches of old-growth natural Sal forest left in Bangladesh where the forest is tropical moist deciduous type. A study was revealed to assess the tree species diversity and composition in this area. For determining tree species the study was conducted through extensive random quadrat survey methods with 20 m×20 m sized plots. Results of the study indicated that there were 139 tree species belonging to 100 genera and 40 families. The quadrat survey assessed the basal area, stem density, diversity indices and importance value index of the tree species having ≥5 cm D.B.H (Diameter at Brest Height). The basal area and stem density of the tree species were 20.689±1.08 m^2/ha and 1412.93±64.27 stem ha^{-1} while, diversity indices, i.e. Shannon-Wiener's diversity, Simpson's evenness, Margalef's species richness and Pielou's dominance indices indicated poor diversity in comparison to that of other PAs (Protected Areas) in South-Eastern region of Bangladesh. The structural composition based on height and D.B.H through reverse- J shaped curve indicated higher regeneration and recruitment but removal of trees of large growth classes. Sal (*Shorea robusta*) was the most dominant tree species that accounts 75% of the total tree individuals in the natural forest patches. However, some associates of Sal, i.e. Bhutum (*Hymenodictyon orixensis*), Gadila (*Careya arborea*), and Kusum (*Schleichera oleosa*) etc. were seemed to be rare in MNP.

Key Words: madhupur national park (MNP), structural composition, diversity indices, Bangladesh

Introduction

Forests play an important role in controlling the Earth's climate and biodiversity (Mandal et al. 2013) where floristic information is must for conservation of biodiversity (Rahman et al. 2017). However, the research of forest dynamics, floral and faunal interaction requires sound knowledge of forest structure (Reddy and Pattanaik 2009). Bangladesh has 3611 species of angiosperms belong to 198 families of which 2623 species under 158 families belong to dicotyledones and 988 species under 41 families belong to monocotyledons (Mashbub Uddin Ahmed 2008) where in recent, the total number of angiosperm species reach over 5,700 (Rahman 2015).

Tree species diversity and structure of Bangladesh has been heavily disturbed during the past several decades due to rapid population growth, energy deficit, resource shortage poor management strategy and lack of motivation on the needs of biodiversity conservation, which has resulted in the loss of wild biodiversity (Ashraful et al. 1997). Many plant and animal species widely distributed in the past have either become extinct or can only be found in some localized areas at very low population densities (Uddin and Misbahuzzaman 2007). Therefore, determination of forest

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composition, floral diversity including the structure of a forest is an essential feature in assessing the sustainability of protected forest areas of this country (Kanagaraj et al. 2016). Species area curve, species richness, various diversity index, stem density, species importance value index are used to assess population dynamics and their diversity (Gimaret-Carpentier et al. 1998). Besides, diameter distribution and related statistical model is important tool for evaluation of a forest. However, the prediction of the diameter distribution of a stand is of great need to forest managers, for maintaining the future silviculture treatments (Nanos and Montero 2002).

Sal (*Shorea robusta* Gaertn. f.) occurs gregariously on the southern valleys of the Himalayas and is distributed in Bangladesh, India and Nepal. Sal regenerates from seed origin or by coppicing; sprouting from root suckers is also very common where, both coppice and seed origin produce fertile seeds, and there is no difference in the vigor of the seedlings from coppice or seed origin (Gautam and Devoe 2006). The biodiversity of Sal forests is very wide and interesting both from ecological and conservation point of views (Alam 1995). Though, the 20th century's Sal forest covers a great extent of area with large biological resources in Bangladesh (Alam et al. 2008) but, in recent, devastating anthropogenic and natural impacts with overexploitation of forest resources have caused severe damage to Sal forest ecosystem (Hossain et al. 2013b).

Madhupur, once a vast haven of *S. robusta* and other local trees and rich biodiversity, is now dying woods (Roy et al. 2014). The tract of MNP consists of an area of 8,436 ha (Rahman et al. 2017). Out of that, 8,195.8 hectares are under Madhupur upazila of Tangail district and 240.2 hectares are under Muktagacha upazila of Mymensingh district. Biodiversity conservation was the main purpose for establishing this area as a National Park (Ahmed 2008). Different study was conducted for identifying the floral biodiversity of woody plants, which shows some biological diversity of tropical moist deciduous forests of Madhupur tract in Bangladesh (Rahman et al. 2010). Recently, biological conservation practices study conducted by Paul et al. (2013). Malaker et al. (2010a) reported the floristic composition of Madhupur Sal Forest upto genera. In addition, Malaker et al. (2008) revealed Jaus and Beribid bits tree species diversity of Madhupur Sal Forest. Besides, traditional use of plants and livelihood dependency of Garo community in Madhupur Sal Forest revealed by Malaker et al. (2010b). Earlier, Prain (1903) emphasized the exploration of the Madhupur forests which occupy the major Sal forests of the country. Alam (1995) studied the flora of whole sal forests of Bangladesh and a taxonomic study was done concentrating the flora of MNP by Rashid and Mia (2001). However, the previous studies are old and somehow provide only the list of available tree species where the density, availability, distribution, structure and diversity of the existing species is important for species specific and more practical conservation programs. Therefore, the study was undertaken to assess the current tree species composition, diversity and structure of MNP.

Materials and Methods

Study area

The park is situated in the northeastern part of Tangail Forest Division and a small portion is under the jurisdiction of Mymensingh Forest Division (Begum 2011). MNP is located at, 125 kilometers north of Dhaka (Capital of Bangladesh). It covers the land area between 24°30' to 24°50'N latitude and 90°00' to 90°10'E longitude, situated on the western side of Tangail-Mymensingh main road (Fig. 1). All physio-chemical characteristics (soil texture, colour, pH, organic matter, nitrogen, phosphorus, potassium and sulphur) of denuded and encroached areas soil are low here in comparison to the forests covered areas

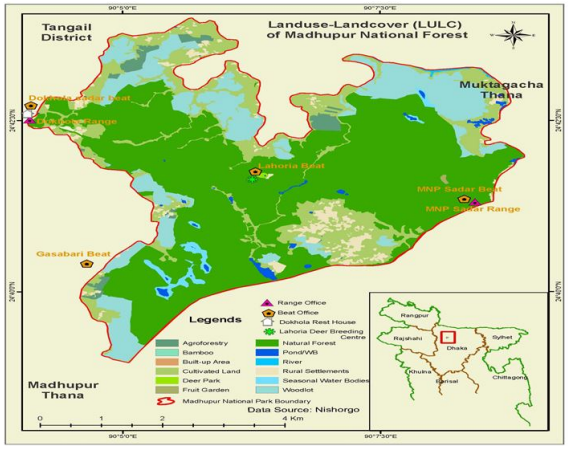

Fig. 1. Location of MNP in Tangail district.

(Mondol 2013). The mean annual temperature is 26°C and the average of monthly maximum and minimum temperatures are 27.5°C and 18.5°C respectively (Banglapedia 2008).

Data collection methods

For data collection, accessibility of the forest, vegetation density and stratification, human settlement within the forest, fragmentation of the forest patches, reconnaissance survey was conducted during December 2014 to July 2015 to cover whole area. Both the beat area and vegetation type were considered during the quadrat sampling of the area. Sample plot survey was fixed to 20 m×20 m by pre conducted Random sample method. A total of 58 sample plots were taken from all four beats (Sadar beat, Lahoria and Gasabari beats of MNP sadar range and Sadar beat of Dokhola range) to cover a sample intensity of 0.028% of total area (Fig. 2). Sample plots were determined based on the area of the respected forest (beat). Plots were taken both in natural and plantation forest patches having few, medium and dense tree cover. Position of each sample plot was then recorded using Ground positioning System (GPS) device. Plants having D.B.H≥ 5 cm were recorded from the quadrats. Total height and diameter at breast height (D.B.H) of all trees inside the demarcated plots were measured using Santo Clinometer and diameter tape respectively. For multi-stemmed trees the bole D.B.H was measured below the forking (if height is 1.3 m from the ground). Sampling with 20 m×20 m plot size was continued in each forest beat until the species accumulation curve reaches to level off and plots cover all densities of natural forest patches (Fig. 3). Species accumulation curve shows that at the initial stage of sampling survey 12 species were recorded from the 5 quadrats when survey area was 0.2 hectare. Number of tree species was increasing with the increasing number of plots surveyed. Rate of new tree species occurrence reduced greatly after 50 sample plots has been surveyed where the recorded number of species was 64. However, the common tree species were identified directly in the field, while the fertile samples of the unknown tree species were collected for the preparation of herbarium. Consultation was done with published journals and reference book like Encyclopedia of Flora and Fauna of Bangladesh (Ahmed et al. 2008).

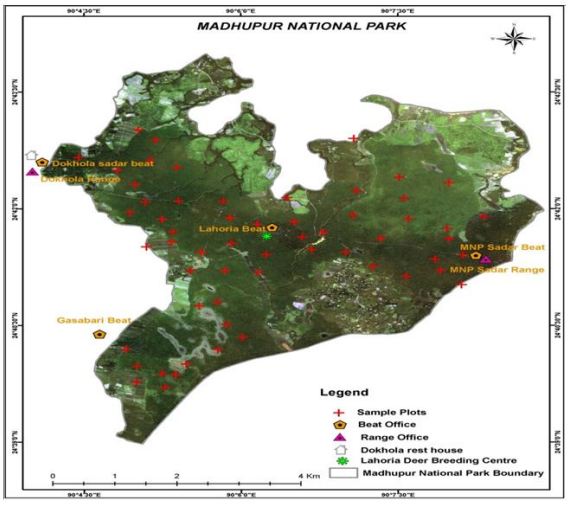

Fig. 2. Distribution of surveyed quadrats in the natural forests patches of MNP map.

Analysis of field data

The field data were compiled and analyzed to determine density, relative density (RD %), frequency, relative frequency (RF %), abundance, relative abundance (RA %) and Importance Value Index (IVI) for study area. The equations (Eq. No. 1-9) used for calculating phytosociological characters are listed in Table 1 (Misra 1968; Dallmeier et al. 1992; Shukla and Chaudel 2000; Chowdhury et al. 2019). Besides, biodiversity indices such as Shannon's index, Simpson's diversity index (Simpson 1949), species evenness index, Margalef's index etc., for the MNP were excerpt from published articles and compared it with the findings of other government managed forests of the country. The equations (Eq. No. 1-4) used for calculating biodiversity indices are listed in Table 2.

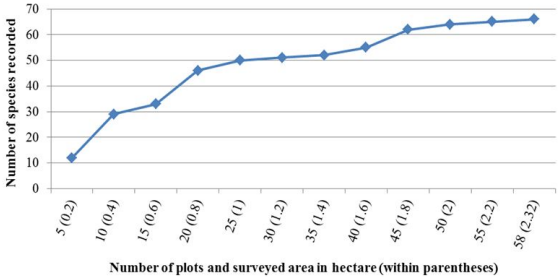

Fig. 3. Species accumulation for tree species sample survey.

Table 1. The list of equations used for calculating phytosociological characters of the vegetation

Phytosociological attributes	Formula	Equation no	References
Basal area/ha (BA)	$BA=\frac{\sum \Pi \times D2/4}{\sum \text{Area of all quadrate}}\times 10000$	1	Shukla and Chandel (2000), Chowdhury et al. (2019)
Density (D)	$D=\frac{a}{b}$	2	Shukla and Chandel (2000)
Relative density (RD)	$RD=\frac{n}{N}\times 100$	3	Misra (1968), Dallmeier et al. (1992)
Frequency (F)	$F=\frac{c}{b}$	4	Shukla and Chandel (2000)
Relative frequency (RF)	$RF=\frac{Fi}{\sum_{i=1}^{s}(Fi)}$	5	Misra (1968), Dallmeier et al. (1992)
Abundance (A)	$A=\frac{n}{c}$	6	Shukla and Chandel (2000)
Relative abundance (RA)	$RA=\frac{Ai}{\sum_{i=1}^{s}(Ai)}$	7	Shukla and Chandel (2000)
Relative dominance (D)	$RD=\frac{\text{Basal area of one specis}}{\text{Total basal area}}\times 100$	8	Hossain et al. (2013a), Chowdhury et al. (2019)
Importance value Index (IVI)	IVI=RD+RF+RA	9	Dallmeier et al. (1992), Shukla and Chandel (2000)

Here; D, D.B.H; a, total no. of individuals of a species in all the quadrats; b, total no. of quadrats studied; n, total no. of individuals of the species; N, total no. of individuals of all the species; c, total no. of quadrats in which the species occurs; Fi, frequency of one species; Ai, abundance of one species.

Table 2. The list of equations used for calculating biodiversity indices of the vegetation

Biodiversity indices	Formula	Equation No	References
Shannon-Wiener's diversity index (H)	$H=-\sum_{i=1}^{n}P_i\ln P_i$	1	Shannon and Weaver (1963)
Margalef's species richness index (R)	$R=\frac{(S-1)}{LN(N)}$	2	Margalef (1958)
Simpson's diversity index (D)	$D=\sum_{i=1}^{n}P_i^2$	3	Simpson (1949)
Species (Pielou's) evenness index (E)	$E=\frac{H}{Ln(S)}$	4	Pielou (1966)

Here; H, shannon-wiener's diversity index; N, total no. of individuals of all the species; Pi, number of individuals of ith species/total number of individuals; S, total number of species.

Results and Discussion

Tree species composition

A total of 139 tree species were recorded from the inner boundary of MNP. The species belongs to 100 genera and 40 families. Some common species of natural forest are: Sal (*Shorea robusta*), Sinduri (*Mallotus phillippensis*), Datoi (*Grewia nervosa*), Bohera (*Terminalia bellirica*), Neol (*Protium serratum*), Bheola (*Semicarpus anacardium*), and Joyna (*Schleichera oleosa*) (Table 3).

The study revealed that a total of 66 tree species were growing within the natural forest patch. Though 139 tree species were recorded from the whole MNP, but all of them were not available in the sample plots because many of them were planted in the road sides, homesteads, participatory forestry plots, and yards of forest office and rest house. However, comparatively lower number (19) of tree species were recorded belongs to 19 genera of 17 families from Jaus beats of Madhupur Sal forest by Malaker et al. (2008) and maximum number found by Malaker et al. (2010a) where they revealed a total 131 tree species from Madhupur Sal forest.

Table 3. List of tree species recorded from MNP

No.	Scientific name	Local name	Family	Use
1	*Abroma augustum* (L.) L. f.	Ulotkombol	Sterculiaceae	M
2	*Acacia auriculiformis* A. Cunn. *ex* Benth. & Hook	Akashmoni	Mimosaceae	F, N, T
3	*Acacia mangium* Willd.	Mangium	Mimosaceae	F, Fd, T
4	*Aegle marmelos* (L.) Corr.	Bel	Rutaceae	Fd, M, T
5	*Albizia chinensis* (Osb.) Merr.	Chesra koroi	Mimosaceae	Fd, N, T
6	*Albizia lebbeck* (L.) Benth. & Hook	Kala Koroi	Mimosaceae	Fd, M, N, T
7	*Albizia procera* (Roxb.) Benth.	Shil koroi, Sada koroi	Mimosaceae	F, M, T
8	*Albizia richardiana* (Voigt.) King & Prain	Raj koroi	Mimosaceae	N, T
9	*Alstonia scholaris* (L.) R. Br.	Chatian	Apocynaceae	M, N
10	*Annona squamosa* L.	Ata	Annonaceae	Fd, M
11	*Antidesma acuminatum* Wall. in Wight.	Chokoi	Euphorbiaceae	Fd
12	*Antidesma ghaesembilla* Gaertn.	Chokoi, Elena	Euphorbiaceae	Fd
13	*Antidesma* spp	Moisa chokoi	Euphorbiaceae	Nk
14	*Aphanamixis polystachya* (Wall.) R.N. Parker.	Ptiraj	Mimosaceae	Fd, M, T
15	*Aporosa* sp.	Kharjon	Euphorbiaceae	F, Fd
16	*Aquilaria agallocha* Roxb.	Agar	Thymeliaceae	N
17	*Araucaria cunninghamii* Sw.	Christmas tree	Araucariaceae	N
18	*Ardisia colorata* Roxb.	Vet	Myrsinaceae	M
19	*Areca catechu* L.	Supari	Arecaceae	Fd, M, T
20	*Artocarpus chama* Hamilton	Chapalish, Chambal	Moraceae	Fd, T
21	*Artocarpus heterophyllus* Lamk.	Kanthal	Moraceae	Fd, N, T
22	*Artocarpus lacucha* Buch.-Ham.	Borta	Moraceae	Fd, M, T
23	*Averrhoa carambola* L.	Kamranga	Oxalidaceae	Fd, M, N
24	*Azadirachta indica* A. Juss.	Neem	Meliaceae	M, N
25	*Barringtonia acutangula* (L.) Gaertn.	Hijal	Lecythidaceae	F, M, N
26	*Bauhinia malabarica* Roxb.	Chokakola	Caesalpiniaceae	F, N
27	*Bischofia javanica* Blume	Kanjal bhadi	Euphorbiaceae	M, T
28	*Bixa orellana* L.	Ranggula	Bixaceae	M, N
29	*Bombax ceiba* L.	Shimul	Bombacaceae	M, T
30	*Borassus flabellifer* L.	Tal	Arecaceae	Fd, M, N, T
31	*Bridelia tomentosa* Bl.	Sitki	Euphorbiaceae	M
32	*Butea monosperma* (Lamk.) Taub.	Polash	Fabaceae	N
33	*Callicarpa arborea* Roxb.	Bormala	Verbenaceae	F, Fd, M
34	*Careya arborea* Roxb.	Gadila, Kumbi	Lecythidaceae	N, T
35	*Cassia fistula* L.	Sonalu, Banor noli	Caesalpiniaceae	Fd, M, N, T
36	*Chukrasia tabularis* A. Juss.	Chickrassi	Meliaceae	M, N, T
37	*Cinnamomum tamala* Nees & Eberm.	Tejpata	Lauraceae	M, N
38	*Citrus maxima* (Burm.) Merr.	Jambura	Rutaceae	M, N
39	*Citrus reticulata* Blanco	Komla	Rutaceae	Fd, M
40	*Cleistocalyx nervosum* (DC.) Kosterm.	Ludijam, Dephajam,	Myrtaceae	M
41	*Cocos nucifera* L.	Narikel	Arecaceae	Fd, M, N, T
42	*Cordia dichotoma* Forst. f.	Bolla gota, Bohal	Boraginaceae	Fd, M, N
43	*Croton tiglium* L.	Bish khagor, Jamai gota, Jamal gota	Euphorbiaceae	M, N
44	*Cryptocarya amygdalina* Nees.	Ojha	Lauraceae	Fd, T
45	*Delonix regia* Rafin.	Krisnachura	Caesalpiniaceae	N
46	*Derris robusta* (Roxb. *ex* DC.) Benth.	Katenga	Fabaceae	F, T
47	*Dillenia indica* L.	Chalta	Dilleniaceae	Fd, M, T

Table 3. Continued 1

No.	Scientific name	Local name	Family	Use
48	*Dillenia scabrella* Roxb. *ex* Wall.	Ajuli, Ajugi	Dilleniaceae	Fd, T
49	*Diospyros blancoi* A. DC.	Bilati gab	Ebenaceae	Fd, T
50	*Dipterocarpus alatus* Roxb. *ex* G. Don	Baitta garjan	Dipterocarpaceae	M, T
51	*Dipterocarpus costatus* Gaertn.	Sada garjan	Dipterocarpaceae	F, N, T
52	*Dipterocarpus turbinatus* Gaertn.	Telia garjan	Dipterocarpaceae	N, T
53	*Elaeis guineensis* Jacq.	Oil pulm	Arecaceae	Fd, N
54	*Elaeocarpus floribundus* Blume	Jalpai	Elaeocarpaceae	Fd, N, T
55	*Erythrina fusca* Lour.	Kanta mander	Fabaceae	F, N
56	*Erythrina variegata* L.	Mander	Fabaceae	F, M, N
57	*Eucalyptus camaldulensis* Dehnh.	Eucalyptus	Myrtaceae	F, N, T
58	*Eucalyptus citriodora* Hook.	Eucalyptus	Myrtaceae	F, T
59	*Ficus benghalensis* L.	Bot	Moraceae	Fd, M, N
60	*Ficus hispida* L. f.	Dumor, Kodora	Moraceae	Fd, T
61	*Ficus racemosa* L.	Jagya dumur	Moraceae	Fd, M, N
62	*Ficus religiosa* L.	Bot	Moraceae	Fd, M
63	*Ficus rumphii* Bl.	Bot	Moraceae	Fd, M
64	*Ficus virens* Ait.	Pakur, Pakar, Paikur	Moraceae	Fd
65	*Flacourtia jangomas* (Lour.) Raeusch.	Pheyala gola, Painna gola	Flacourtiaceae	Fd, M, T
66	*Garcinia cowa* Roxb. *ex* DC.	Cao	Clusiaceae	Fd, M
67	*Garuga pinnata* Roxb.	Sada Jiga	Burseraceae	Fd, M, T
68	*Gliricidia sepium* (Jacq.) Kunth *ex* Walp.	Gliricidia	Fabaceae	M, N
69	*Gmelina arborea* Roxb.	Gamar, Jogi	Verbenaceae	M, T
70	*Grevillea robusta* A. Cunn. *ex* R. Br.	Fern tree	Proteaceae	T
71	*Grewia asiatica* L.	Kapaia	Tiliaceae	Fd, N
72	*Grewia nervosa* (Lour.) Panigr.	Datoi	Tiliaceae	F, Fd
73	*Grewia serrulata* DC.	Khulla damor	Tiliaceae	Fd, N
74	*Haldina cordifolia* (Roxb.) Ridsdale	Kaika, haldu	Rubiaceae	T
75	*Hevea brasiliensis* (Willd. *ex* A. Juss.) Muell.-Arg.	Rubber	Euphorbiaceae	Fd, M, N, T
76	*Holarrhena antidysenterica* (L.) Wallich. *ex* Decne.	Kuruch	Apocynaceae	M
77	*Hopea odorata* Roxb.	Telsur	Dipterocarpaceae	M, N, T
78	*Hymenodictyon orixensis* (Roxb.) Mabberlly	Bhutum	Rubiaceae	N, M
79	*Lagerstroemia parviflora* Roxb.	Sidha	Lythraceae	N, T
80	*Lagerstroemia speciosa* (L.) Pers.	Jarul	Lythraceae	N, T
81	*Lannea coromandelica* (Houtt.) Merr.	Jiga	Burseraceae	Fd, M, N, T
82	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Harinagola	Sapindaceae	Fd
83	*Limonia acidissima* L.	Kodbel, Koethbel	Rutaceae	Fd, M, T
84	*Litchi chinensis* Sonn.	Litchi	Sapindaceae	Fd, M, T
85	*Litsea glutinosa* (Lour.) Robinson	Kharajora, Menda	Lauraceae	M
86	*Litsea monopetala* (Roxb.) Pers.	Kharajora	Lauraceae	M
87	*Madhuca longifolia* (Koenig) MacBride	Mahua	Sapotaceae	M, T
88	*Mallotus philippensis* (Lamk.) Muell.-Arg.	Sinduri	Euphorbiaceae	T
89	*Mangifera indica* L.	Aam	Anacardiaceae	F, Fd, T
90	*Manilkara zapota* (L.) P. van Royen	Sofeda	Sapotaceae	Fd, M
91	*Melia azedarach* L.	Ghoranim, Bokhain	Meliaceae	M, T
92	*Miliusa velutina* (Dunal) Hook. f. & Thom.	Gandhi gajari	Annonaceae	Fd
93	*Mimusops elengi* L.	Bakul	Sapotaceae	M, N, T
94	*Mitragyna parvifolia* (Roxb.) Korth.	Futikadam	Rubiaceae	Nk
95	*Moringa oleifera* Lamk.	Sajna	Moringaceae	Fd, M

Table 3. Continued 2

No.	Scientific name	Local name	Family	Use
96	*Murraya paniculata* (L.) Jack	Kamini	Rutaceae	M, T
97	*Neolamarckia cadamba* (Roxb.) Bosser	Kadom	Rubiaceae	M, N, T
98	*Nyctanthes arbor-tristis* L.	Sheuli	Verbenaceae	M, N
99	*Oroxylum indicum* (L.) Kurz	Thona	Bignoniaceae	M
100	*Peltophorum pterocarpum* (DC.) K. Heyne	Halud krisnachura	Caesalpiniaceae	Fd, N, T
101	Phoenix acaulis Buch. −Ham. *ex* Roxb.	Khudi khejur	Arecaceae	Fd
102	*Phoenix sylvestris* Roxb.	Khejur	Arecaceae	Fd, M, N
103	*Phyllanthus emblica* L.	Amloki	Euphorbiaceae	Fd, M, N
104	*Plumeria rubra* L.	Kat-golap	Apocynaceae	M, N
105	*Polyalthia longifolia* (Sonn.) Thw.	Debdaru	Annonaceae	N
106	*Protium serratum* (Wallich *ex* Colebr.) Engl.	Neul, Neur	Burseraceae	Fd, T
107	*Psidium guajava* L.	Payara	Myrtaceae	F, Fd, M, N
108	*Pterospermum acerifolium* (L.) Willd.	Moos	Sterculiaceae	M
109	*Ricinus communis* L.	Varenda	Euphorbiaceae	M
110	*Samanea saman* (Jacq.) Merr.	Raintree	Mimosaceae	F, Fd, N, T
111	*Schleichera oleosa* (Lour.) Oken.	Joyna, Kusum	Sapindaceae	Fd, M, N, T
112	*Semecarpus anacardium* L.f.	Bheula, Bhela	Anacardiaceae	Fd, N, T
113	*Senna siamea* (Lamk.) Irwin & Barneby	Minjiri	Caesalpiniaceae	Fd, M, T
114	*Shorea robusta* Roxb. *ex* Gaertn. f.	Sal	Dipterocarpaceae	T
115	*Spondias pinnata* (L.f.) Kurz	Amla, Bon amra	Anacardiaceae	Fd, M, N
116	*Sterculia villosa* Roxb. *ex* Smith	Udal	Sterculiaceae	M, N
117	*Stereospermum colais* (Buch.-Ham. *ex* Dillw.) Mabberley	Dharmara	Bignoniaceae	M, T
118	*Streblus asper* Lour.	Sheora	Moraceae	F, Fd, M
119	*Suregada multiflora* (A. Juss.) Baill.	Suregada	Euphorbiaceae	T
120	*Swietenia mahagoni* Jacq.	Mahagoni	Meliaceae	T
121	*Syzygium cumini* (L.) Skeels	Kalojam	Myrtaceae	Fd, T
122	*Syzygium firmum* Thw.	Dhakijam	Myrtaceae	Fd, N
123	*Syzygium fruticosum* DC.	Putijam, Titijam	Myrtaceae	Fd, T
124	*Tamarindus indica* L.	Tentul	Caesalpiniaceae	Fd, T
125	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Pirilagota, Piralo	Rubiaceae	M
126	*Tectona grandis* L. f.	Shegun	Verbenaceae	M, T
127	*Terminalia arjuna* (Roxb. *ex* DC.) Wight & Arn.	Arjun	Combretaceae	M, T
128	*Terminalia bellirica* (Gaertn.) Roxb.	Bohera	Combretaceae	Fd, M, T
129	*Terminalia chebula* Retz.	Haritaki	Combretaceae	Fd, M, N, T
130	*Toona ciliata* M. Roem.	Toon, Rongi	Meliaceae	T
131	*Trema orientalis* (L.) Blume	Jigni	Ulmaceae	F, Fd, N
132	*Vitex glabrata* R. Br.	Hakuni gach, Baskura	Verbenaceae	Fd, M, T
133	*Vitex peduncularis* Wallich. *ex* Schauer	Hakuni gach, Goda Arsol, Bankura	Verbenaceae	Fd, M, T
134	*Wendlandia tinctoria* (Roxb.) DC.		Rubiaceae	Nk
135	*Wrightia arborea* (Dennst.) Mabb.	Dudh kuruch	Apocynaceae	M
136	*Xylia xylocarpa* (Roxb.) Taub. var. *kerrii* (Craib & Hutch.) Neilsen	Lohakath	Mimosaceae	M, N, T
137	*Zanthoxylum rhetsa* (Roxb.) DC.	Bajna	Rutaceae	M, N, T
138	*Ziziphus mauritiana* Lamk.	Boroi	Rhamnaceae	Fd
139	*Ziziphus rugosa* Lamk.	Anoi, Anai gota	Rhamnaceae	Fd, M

F, fuelwood; Fd, food and fodder; M, medicinal; N, miscellaneous non-timber uses (other than fuel, food, fodder and medicinal); T, timber; Nk, not known.

Present study revealed less tree species composition compared with other forests in the Chittagong Forest Division. Hossain and Hossain (2014) reported the availability of 169 tree species in the sample plots of Chunati Wildlife Sanctuary. On the contrary, the number of species present in the present forest is more than the tropical forests. Hossain et al. (2015) found 107 tree species belonging to 72 genera and 37 families from the Kamalachari Natural Forest of Chittagong South Forest Division. Hossain et al. (2012) reported 77 species from the Dudhpukuria natural forest. A total of 93 tree species was found in Chunati Wildlife Sanctuary till now (Nath et al. 2016) where Das et al. (2018) recorded 32 trees species with D.B.H ≥ 11 cm belonging to 24 genera and 19 families, Motaleb and Hossain (2011) found 62 tree species from the Tankawati Natural Forest, Rahman et al. (2016) recorded 52 tree species in Kaptai National Park and 135 species and 105 genera of 45 families were found in North central Eastern Ghats of India (Naidu et al. 2018).

Density and diversity indices of tree species in MNP

Tree species composition in the natural forest patches of the four beats (National Park Sadar beat, Lahoria beat, Gasabari beats of MNP Sadar Range and Dokhola sadar beat is almost the same but basal area per hectare varied in the studied beats. Lahoria beat was represented by maximum basal area (24.41±4.54 m^2) per hectare, whereas the remaining three beats have almost comparable basal area per hectare (Table 4). Tree species stem density was maximum (1657.89±146. 08 stem per ha) in MNP sadar beat followed by Gasabari beat (1407.69±86.89 stem per ha). The tree species diversity indices, i.e. Shannon-Weaver index (Shannon and Weaver 1963) was maximum (1.142±0.16) in Lahoria beat followed by Gasabari (0.872±0.11), Dokhola sadar (0.863±0.17), and MNP Sadar (0.701±0.14).

On the other hand, Simpson's dominance indexes for all the four beats were comparable. MNP sadar beat was represented by highest (0.688±0.06) Simpson's dominance index value. The study revealed that Lahoria beat has maximum (1.884±0.24) species richness index followed by Gasabari (1.533±0.16) beat. Pielou's proposed species evenness index which indicates the evenness of species within the plant community where evenness index of Lahoria beat found maximum (0.534±0.05) (Pielou 1966).

The field data from all the beats were combined together considering the MNP as single ecological niche for existing plant community. The study revealed that, basal area and stem density of the tree species were 20.689±1.08 m^2ha^{-1} and 1412.93±64.27 stem ha^{-1} respectively. The basal area is more than Kaptai Deer Breeding Centre (14.36 m^2/ha) of Rangamati South Forest Division (Mohajan et al. 2016) whereas density was higher than that is of 555 stem ha^{-1} of Chunati Wildlife Sanctuary (Hossain and Hossain 2014), 855 stems ha^{-1} of Durgapur hill forest (Rahman et al. 2019) and 709 stems ha^{-1} in Tropical Forest of Eastern Ghats, India (Reddy et al. 2011). Hossain et al. (2013b) reported tree species (≥10 cm D.B.H) density of 468 stem ha^{-1} in Dudhpukuria-Dhopachari Wildlife Sanctuary. However, the index value indicates that tree species diversity is poor in

Table 5. Quantitative status of tree population and different diversity indices of tree species for whole MNP

Category	Value
Basal area (m^2) per hectare	20.689±1.08
Number of stems per hectare	1,412.93±64.27
Shannon-Weaver diversity index	0.870±0.07
Simpson dominance index	0.634±0.03
Margalef's richness index	1.482±0.12
Pielou's species evenness index	0.437±0.02

Table 4. Quantitative status of tree density and diversity indices in different beats of MNP

Forest beats	Basal area (m^2) per hectare	Number of stem per hectare	Shannon-Weaver diversity index	Simpson's dominance index	Margalef's richness index	Pielou's species evenness index
MNP Sadar	19.43±1.17	1,657.89±146. 08	0.701±0.14	0.688±0.06	1.199±0.23	0.362±0.05
Lahoria	24.41±4.54	1,256.25±104.31	1.142±0.16	0.518±0.06	1.884±0.24	0.534±0.05
Gasabari	20.34±1.26	1,407.69±86.89	0.872±0.11	0.629±0.04	1.533±0.16	0.438±0.04
Dokhola Sadar	19.52±1.19	1,219.64±99.07	0.863±0.17	0.664±0.07	1.470±0.31	0.450±0.06

Table 6. Density, relative density (RD), relative frequency (RF), relative abundance (RA) and relative dominance (RD) and importance value index (IVI) of the tree species (≥ 5 cm D.B.H) recorded from MNP

SL. no.	Scientific name	Stem/ha	RD (%)	RF (%)	RA (%)	RD (%)	IVI
1	*Acacia auriculiformis*	4.74	0.33	0.26	5.02	0.01	0.60
2	*Acacia mangium*	0.43	0.03	0.26	0.46	0.00	0.29
3	*Albizia chinensis*	0.86	0.06	0.51	0.46	0.01	0.58
4	*Albizia lebbeck*	1.29	0.09	0.77	0.46	0.01	0.87
5	*Albizia procera*	0.86	0.06	0.26	0.91	0.02	0.33
6	*Antidesma acuminatum.*	0.43	0.03	0.26	0.46	0.00	0.29
7	*Antidesma ghaesembilla*	2.59	0.18	1.03	0.68	0.01	1.22
8	*Aporosa* sp.	23.28	1.63	2.83	2.24	0.11	4.57
9	*Artocarpus lacucha*	1.29	0.09	0.26	1.37	0.00	0.35
10	*Bauhinia malabarica*	9.48	0.67	3.34	0.77	0.05	4.06
11	*Bombax ceiba*	0.43	0.03	0.26	0.46	0.00	0.29
12	*Bridelia tomentosa*	4.31	0.30	2.06	0.57	0.03	2.39
13	*Cassia fistula*	1.72	0.12	0.51	0.91	0.02	0.66
14	*Cleistocalyx nervosum*	2.16	0.15	0.77	0.76	0.01	0.93
15	*Cordia dichotoma*	0.43	0.03	0.26	0.46	0.00	0.29
16	*Croton tiglium*	0.86	0.06	0.51	0.46	0.05	0.62
17	*Cryptocarya amygdalina*	21.98	1.54	5.91	1.01	0.11	7.57
18	*Derris robusta*	1.72	0.12	0.77	0.61	0.05	0.94
19	*Dillenia scabrella*	9.05	0.63	3.60	0.68	0.16	4.39
20	*Elaeocarpus floribundus*	1.29	0.09	0.26	1.37	0.02	0.36
21	*Eucalyptus camaldulensis*	1.29	0.09	0.26	1.37	0.01	0.36
22	*Ficus benghalensis*	1.72	0.12	1.03	0.46	0.90	2.05
23	*Ficus hispida*	0.86	0.06	0.26	0.91	0.01	0.33
24	*Ficus racemosa*	0.86	0.06	0.51	0.46	0.00	0.58
25	*Ficus religiosa*	0.43	0.03	0.26	0.46	0.10	0.39
26	*Garcinia cowa*	2.16	0.15	0.26	2.28	0.01	0.42
27	*Garuga pinnata*	3.88	0.27	1.03	1.03	0.12	1.42
28	*Glochidion multiloculare*	0.86	0.06	0.51	0.46	0.00	0.58
29	*Gmelina arborea*	14.22	1.00	0.26	15.05	0.14	1.39
30	*Grewia asiatica*	6.03	0.42	3.08	0.53	0.05	3.56
31	*Grewia nervosa*	22.41	1.57	2.57	2.37	0.12	4.27
32	*Grewia serrulata*	7.33	0.51	2.83	0.70	0.05	3.39
33	*Haldina cordifolia*	5.60	0.39	2.06	0.74	0.02	2.47
34	*Holarrhena antidysenterica*	0.86	0.06	0.51	0.46	0.01	0.58
35	*Hymenodictyon orixensis*	1.72	0.12	0.77	0.61	0.01	0.90
36	*Lagerstroemia purviflora*	4.74	0.33	2.31	0.56	0.02	2.67
37	*Lagerstroemia speciosa*	3.02	0.21	0.51	1.60	0.02	0.74
38	*Lannea coromandelica*	3.88	0.27	1.80	0.59	0.15	2.22
39	*Litsea glutinosa*	4.31	0.30	0.26	4.56	0.03	0.59
40	*Mallotus philippensis*	60.78	4.26	8.48	1.95	0.56	13.31
41	*Mangifera indica*	0.86	0.06	0.26	0.91	0.01	0.32
42	*Miliusa velutina*	3.02	0.21	1.29	0.64	0.01	1.51
43	*Mitragyna parvifolia*	0.43	0.03	0.26	0.46	0.00	0.29
44	*Neolamarckia cadamba*	0.86	0.06	0.51	0.46	0.01	0.59
45	*Oroxylum indicum*	1.29	0.09	0.51	0.68	0.00	0.61

Table 6. Continued

SL. no.	Scientific name	Stem/ha	RD (%)	RF (%)	RA (%)	RD (%)	IVI
46	*Protium serratum*	32.76	2.30	4.11	2.17	0.18	6.59
47	*Schleichera oleosa*	14.22	1.00	5.14	0.75	0.29	6.43
48	*Semecarpus anacardium*	11.21	0.79	3.08	0.99	0.11	3.98
49	*Shorea robusta*	1,068.97	74.97	14.65	19.84	95.89	185.52
50	*Spondius pinnata*	1.72	0.12	0.51	0.91	0.06	0.69
51	*Sterculia villosa*	0.86	0.06	0.51	0.46	0.00	0.58
52	*Streblus asper*	0.86	0.06	0.51	0.46	0.00	0.58
53	*Suregada multiflora*	0.86	0.06	0.26	0.91	0.00	0.32
54	*Syzygium firmum*	0.43	0.03	0.26	0.46	0.00	0.29
55	*Syzygium fruticosum*	6.47	0.45	1.29	1.37	0.03	1.77
56	*Tamilnadia uliginosa*	0.43	0.03	0.26	0.46	0.00	0.29
57	*Tectona grandis*	0.86	0.06	0.26	0.91	0.15	0.47
58	*Terminalia bellirica*	29.31	2.06	6.68	1.19	0.16	8.90
59	*Terminalia chebula*	4.74	0.33	0.26	5.02	0.02	0.61
60	*Toona ciliata*	0.43	0.03	0.26	0.46	0.00	0.29
61	*Trema orientalis*	0.43	0.03	0.26	0.46	0.00	0.29
62	*Vitex glabrata*	0.86	0.06	0.26	0.91	0.00	0.32
63	*Wendlandia tinctoria*	1.29	0.09	0.77	0.46	0.00	0.86
64	*Wrightia arborea*	2.59	0.18	1.29	0.55	0.01	1.48
65	*Zanthoxylum rhetsa*	2.16	0.15	1.29	0.46	0.01	1.45
66	*Ziziphus rugosa*	1.72	0.12	1.03	0.46	0.01	1.16
	Total	1,425.86	100	100	100	100	300

the forest (Table 5).

The forest is naturally homogeneous in tree species composition. The study revealed that 75% tree individuals were Sal (*Shorea robusta*) and thus it became the single most dominant tree of MNP. The value of Shannon-Weaver's diversity index (Shannon and Weaver 1963) (0.870±0.07) of MNP is much lower than 3.762 of Chunati Wildlife Sanctuary, 2.98 of Sitapahar reserve forest of Chittagong South Forest Division, 3.25 of Tankawati natural forest of Chittagong South Forest Division, 4.45 of Dudhpukuria-Dhopachori WS, 4.27 in Garo Hills of India and 4.37 in Tropical Moist Forests of Mizoram, Northeast India (Nath et al. 2000; Kumar et al. 2006; Motaleb and Hossain 2011; Hossain et al. 2013a; Hossain and Hossain 2014; Devi et al. 2018). Similarly, Simpson Dominance Index (0.634±0.03), Margalef's index (1.482±0.12) and Pielou's species evenness index (0.437±0.02) indicated poor diversity than that's of Chunati Wildlife Sanctuary, Dudhpukuria-Dophachari Wildlife Sanctuary, Tankawati natural forest and tropical evergreen region of Meghalaya, India (Pielou 1966; Motaleb and Hossain 2011; Tynsong and Tiwari 2011; Hossain et al. 2013a; Hossain and Hossain 2014). This poor diversity is due to the higher occurrence of Sal in comparison to associated tree species. The homogeneous topography, climatic and edaphic conditions over the whole MNP area is also the reason for poor diversity and almost homogeneous distribution of the different tree species.

Quantitative structure of the tree species recorded from MNP

The importance Value Index of the tree species indicates the overall dominancy of different species in forest area. However, *S. robusta* was represented by maximum (1,068.97 stem/ha) stem density followed by *Mallotus phillippensis* (60.78 stem/ha). Sal (*Shorea robusta*) is the single plant species which was represented by maximum (74.97%) relative density, maximum (14.65%) relative frequency, maximum (19.84%) relative abundance and maximum (95.89%) relative dominance (Table 6).

The importance value index (IVI) of the species revealed that *S. robusta* has maximum (185.52 out of 300) IVI fol-

lowed by *Mallotus philippensis* (13.31) and *Terminalia bellirica* (8.90) (Table 6). Malaker et al. (2008) revealed *S. robusta* was represented by maximum density (226.67 trees/ha), Total Basal Cover (99.11 m^2ha^{-1}), IVI (72.60), Species Diversity (0.145) in Jaus beat of Madhupur Sal forest and comparatively less in amount with present findings. According to Hossain et al. (2013a) *Dipterocarpus turbinatus* showed highest IVI (13.74) followed by *Lithocarpus acuminate* (10.81). Chowdhury et al. (2018) found *Protium serratum* was a dominant regenerating tree species with highest RD (15.24%), RF (16.30%) and IVI (50.09) in Rampahar natural forest reserve in Rangamati where the values are lower in comparison with present findings.

Structural composition of the tree species in MNP based on diameter class distribution

Structural composition of the tree species was assessed by dividing them into 6 diameter classes based on their diameter at breast height (1.3 m from the base). The diameter (cm) ranges were 5-<15, 15-<25, 25-<35, 35-<45, 45-<55 and ≥55. The lowest diameter range 5-<15 was represented by maximum (75.85%) tree individuals belonging to 62 tree species. Tree individuals of almost all the tree species were found in this diameter range. On the other hand, diameters range of 45-<55 were represented by only two tree species (Ficus sp.) and minimum number of (0.06%) tree individuals. The forest experienced severe encroachment and deforestation in the last few decades by the surrounding people. In the last 5-7 years FD strengthened the protection status of the MNP by involving some local people as community forest workers. However, the joint initiatives for protecting and conserving the forests and forest resources resulted in partial recovery of the forest coverage. The graph representing the number of tree species and tree individuals took the form of reversed-J shape, where both the species and number of tree individuals reduce gradually in the upper diameter classes and is an important feature of natural forests (Fig. 4). It also indicates incidence of illegal felling of comparatively mature trees in National Park area.

Shorea robusta, the flagship plant species of MNP forest, dominated almost all the diameter classes except the ≥ 55 cm class. This plant species singly comprised 74.97% of all the tree individuals followed by *Mallotus phillippensis* (4.26%), *Protium serratum* (2.30%), and *Terminalia bellirica* (2.06%). In addition, only two species of Bot (*Ficus* sp.) were found in the highest diameter class (≥55 cm) in this study.

The previous research findings of similar studies reported that maximum numbers of species (169 species) were found to occur within D.B.H range of 10-<24.5 cm in Dudhpukuria Dhopachori Wildlife Sanctuary, Chittagong, Bangladesh (Hossain et al. 2017). Motaleb and Hossain (2009) found that D.B.H range of 20-<30 cm contains maximum number of species (58 species) in Tankawati Natural Forest Reserve of Chittagong (South) Forest Division, Bangladesh where those results are not agreed with present findings. However, similarity was recorded for Nath et al. (2016) where they recorded 90% trees were belonging to 5-to 15-cm D.B.H class of Chunati Wildlife Sanctuary.

Structural composition of the tree species of MNP based on height class distribution

Tree species of the MNP are distributed in few strata. In

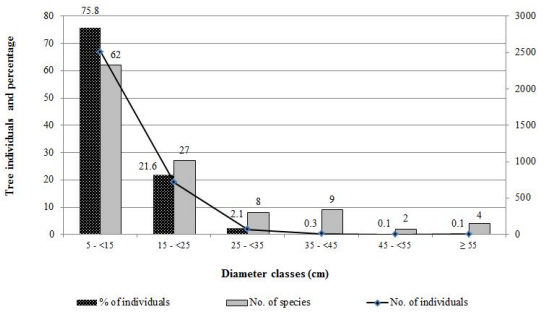

Fig. 4. Distribution of tree species and tree individuals into different diameter classes.

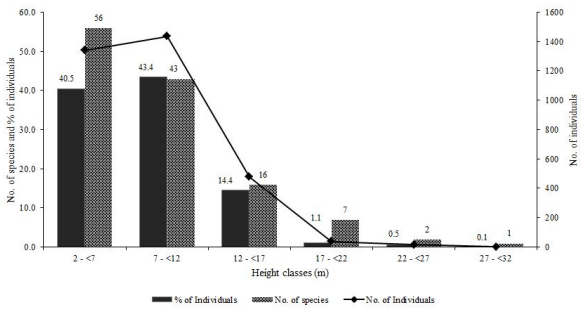

Fig. 5. Distribution of tree species and tree individuals into different height classes.

the study we considered 6 height classes considering total height of the tree individuals of different species with interval of 6 m. The 6 height classes were, 2-＜7 m, 7-＜12 m, 12-＜17 m, 17-＜22 m, 22-＜27 m, and 27-＜32 m. The lowest height of the tree species were recorded 2.3 m for habitually small trees, but for convenience in calculation the lowest height class was started from 2 m. The study revealed that the number of species was maximum (56 species) in the height range of 2-＜7 m followed by 7-＜12 m (43) and 12-＜17 m (16). The number of species was reduced gradually in the upper height classes where the relative number of individuals were increased slightly in the second height class (2-＜7) then gradually reduced with the increase of height growth. In the higher height ranges of 22-＜27 m and 27-＜32 m the tree species and individuals were very few. The relative distribution of both tree individuals and species indicates that tree species of MNP were distributed in mainly 3 strata i.e. 2-7 m, 7-＜12 and 12-＜17 m (Fig. 5).

Tree species distribution within the different height classes revealed that *S. robusta* (24.70%) and *Mallotus philippensis* (2.60%) were very common in the lowest height ranges. In the 7-＜12 m height range *S. robusta* (35.52%) was very common and *Mallotus philippensis* (1.45%) and *Protium serratum* (1.15%) were found in comparatively higher number. There were *S. robusta* (0.45%) and planted *Tectona grandis* (0.03%) occurred in the 22-＜27 m height class whereas only *S. robusta* occurred in all the height classes.

Study on similar kind of results found by Bhuju and Yonzon (2001) where they recorded, highest frequency of all the species were within the range of 4-10 m height. On the contrary, Hossain et al. (2015) revealed the number of tree species, tree individual percentage and their number were highest (97 species, 77.99%, 404 individuals respectively) in the height range of 4.5-14.4 m. However, the structural composition of present study indicates their potential regeneration status in this area but threats to anthropogenic disturbances. Hence, regular diameter and height distribution should be maintained for maximum wood production, biodiversity conservation and optimal financial return from the National Park area.

Conclusion

The MNP harbors our traditional Sal forest where the area contains substantial number of local people directly and indirectly involved for their livelihood generation. Because of increasing community growth within the forest area, natural flora of forest was disturbed by exotic species plantation in and around the national park. As a consequence, population of natural associates of Sal is being changing also. In case of present study, Shannon-Weaver, Simpson, Margalef's and Pielou's diversity indices indicated poor diversity in the natural forest patches which is supposed due to biological disturbances (Margalef 1958; Pielou 1966). Expansion of commercial cultivation, haphazard trails causing easy access, conflict of interest between Garo ethnic and Bangladesh Forest Department, poaching, forest resource extraction by locals, road killing of animals due to vehicle collision, and robbery were seemed to be major threats of MNP. It is recommended to control expansion of commercial crop cultivation (pineapple, banana etc.) while establish some PSP (Permanent Sample Plot) and ANR (Assisted Natural Regeneration) plots, adopt species specific conservation measures to enhance regeneration status and tourism potentiality of MNP. Therefore, further information on tree species richness and overall status is needed for taking management decisions and new policy development of the Madhupur National Park.

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