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Vegetation Structure, Species Diversity and Regeneration Status in Ballavpur Wildlife Sanctuary, West Bengal, India

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ABSTRACT
Vegetation structure of different strata were analysed in dry deciduous forests of Ballavpur Wildlife Sanctuary in lateritic zone of West Bengal. 1212 woody stems $\geq$ 1cm belonging to 21 species, 19 genera and 12 families were enumerated from 25 randomly placed quadrats of 10m x 10m each. *Acacia auriculiformis* obtained the highest stem density and Importance value index while dipterocarpaceae had the highest family importance value. Tree density ranged from 4 to 1498 N ha-1 and they occupied total 22.49 m^2 ha-1 basal area. All the species showed a clumped distribution. Number of species in the tree layer was positively correlated with number of species in the shrub, sapling and seedling layers while herbs showed negative correlation with shrubs and seedlings. Conversion of saplings into trees was satisfactory but success of seedling conversion to sapling was low. This study provides the first report on the vegetation of Ballavpur Wildlife Sanctuary.

Introduction

Biodiversity is essential for human survival and economic well being and for the ecosystem function and stability (Singh, 2002). Tropical forests occupy only 7% of the Earth's land surface but sustain more than half of the planet life-forms (Wilson, 1988). The dry forests owing to a long history of human use (Murphy and Lugo, 1986) are more threatened than moist and wet forests (Gerhardt, 1993). The dry tropical forest accounts for 38.2% of the total forest cover of India (MoEF, 1999) but are rapidly changing into dry deciduous scrub, savanna and grasslands (Champion and Seth, 1968; Singh and Singh, 1989). Despite occupying more area than wet forests, the structure, composition dynamics, diversity and taxonomy of dry forests is not fully unraveled (Hubbel and Foster, 1983).

Trees provide resources and habitat for many species (Canon *et al.*, 1998) and are easy to locate precisely and to count (Condit *et al*., 1996) and are also relatively better known taxonomically (Gentry, 1992). Determining the few essential measurable properties, such as species richness and biomass, that best describe vegetation and its environment, and documenting quantitative relationships among them is a desirable goal of plant ecology (Keddy, 2005). Broad stratification of vegetation into trees, shrubs and herbs is the most prominent feature while characterizing vegetation. Diversity pattern of vegetation strata reveal ecological processes responsible for plant community structure (De, 2007). Further, presence of seedlings, saplings and adult trees indicate successful regeneration of a species (Saxena and Singh, 1984).

Lateritic zone (LZ) of West Bengal comprises Purulia district and western portions of Birbhum, Burdwan, Midnapore and Bankura districts. This zone harbor floristically important Northern Tropical Dry Deciduous forests (Champion and Seth, 1968). Soils are characterized by acidic pH, low NPK content and high iron as reported by many studies (Raychaudhuri, 1980; Choudhury, 1973; Chakraborty *et al.*, 2002). Many plants of this region have immense importance due to their medicinal and dye yielding properties. The minor forest products of the region include lac, sal seeds and leaves, mohua flowers, fibres and flosses, grasses, barks, gums and resins (Mukherjee, 1995).

Forest studies conducted so far in LZ concentrated on floristic and ethnobotanical aspects (Rahaman and Mandal, 1999; Rahaman *et al.*, 2008; Bhattacharya and Mukherjee, 2006; Bouri and Mukherjee, 2011). Bhattacharya *et al.* (2003) tried to reconstruct modern vegetation changes using pollen analysis. Gupta Joshi (2012) made a preliminary quantitative analysis of vegetation structure covering a few sites. Ballavpur Wild Life Sanctuary (BWLS) forms an important part of the tropical dry deciduous forests of the LZ. Forest of the BWLS carries a short but significant historic part and has a management legacy of more than 50 years. It is a typical representative of biogeographic zone 7B – Chotanagpur Plateau (Department of Forests, 2008). BWLS provides an excellent opportunity for vegetation study as it has never been explored earlier.

The objective of the present study is to analyze the vegetation structure, species diversity pattern and regeneration status of a protected forest from LZ which in turn will help to control the forest structure by plantation and better management of the forest flora.

Study Area

The study was conducted in BWLS located in the Birbhum district of West Bengal, India extending between 23˚45′ N latitude and 47˚40′ E longitude (Fig. 1). It is included and managed within the jurisdiction of Bolpur Range

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under Birbhum Forest Division of South East circle. This forest is a created one (creation done between 1953 and 1999 in a phased manner) and some natural regeneration came up gradually as a result of succession. The area of about 200 ha was declared as BWLS in 1977 (Department of Forests, 2008). It harbors a viable population of spotted deer. There are three water bodies within the sanctuary which attract a large number of migratory birds in winter.

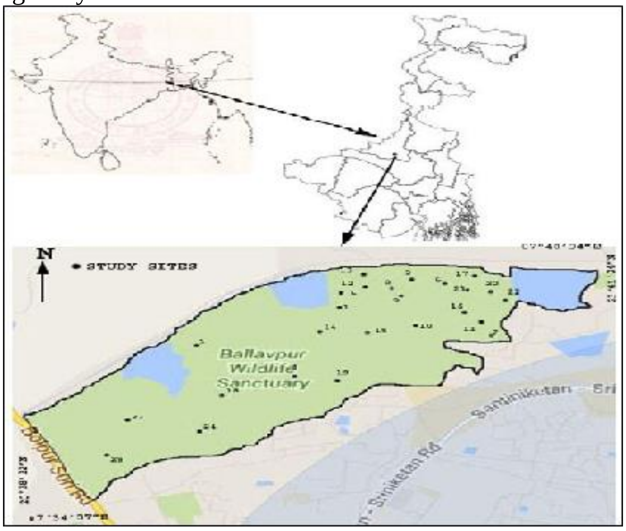

Figure 1. Location of study site.

The whole area is characterized by red lateritic soil with undulating topography. Average annual rainfall is 1300 mm and temperature ranges from 6˚C (minimum) to 45˚C (maximum). This area shows three distinct seasons - winter, summer and rainy.

Methods

Vegetation sampling

The vegetation was sampled randomly by lying 25 quadrats of 10m x 10m each during December 2012 to March 2014 covering all the seasons. This totals to a sampled area of 0.25 ha which is about 0.1% of the sanctuary area. In each quadrat all the trees (dbh≥1cm) were identified and their number and diameter at breast height (dbh) were recorded with the help of a slide caliper. Where dbh measurement was not possible, girth at breast height (gbh) was measured using a meter tape. The shrubs and climbers including tree saplings (< 1cm dbh, height >30 cm) were sampled in two 5m x 5m quadrats, and herbs including tree seedlings (< 1cm dbh, height <30 cm) were sampled in four 1m x 1m quadrats nested within each 10m x 10m quadrat. Plant specimens were collected and identification of the unknown species was done by consulting regional flora (Sanyal, 1994; Guha Bakshi, 1990).

Data analysis

Phytosociological characters like frequency, density, basal area and importance value index (IVI) were calculated for each tree species (Misra, 1968). IVI was calculated by summing up relative frequency, relative density and relative dominance values. Family importance value (FIV) was estimated as the sum of relative density, relative diversity and relative dominance of a family (Ganesh *et. al*. 1996). Dispersion of species was calculated as ratio of abundance to frequency (A/F) Curtis and Cottom, 1956). A species area curve was plotted by using the new species appeared in each of the twenty five 10m x 10m quadrat measured.

Population structure of tree species was studied by determining the number of individuals in different diameter classes starting from 1–5cm to 50-55cm. Species diversity was alculated separately for different vegetation strata – trees, shrubs and herbs. Shannon - Wiener index (H′) was determined from Shannon – Weiner's information function (Shannon and Weaver, 1949). It is most commonly used α diversity measure when random sampling is employed (De, 2007). Concentration of dominance (Cd), known as Simpson's index was measured according to Simpson (1949). Evenness (E) was calculated according to Pielou (1966). Species richness was calculated using Margalef's index of species richness (M) (Margalef, 1968).

$H' = -\sum_{i=1}^{s} pi \ln pi$

$Cd = \sum (pi)^2$

$E = H'/H_{max}$; $H_{max} = \ln(S)$

$M = (S-1)/\ln N$

Where, s=total no of species, pi= ni/N, ni= total no of individual of "ith" species, N= total no of individual of all species, ln= natural log.

The relationships among number of species in different vegetation strata were analyzed by Pearson's Correlation Coefficient. Regeneration status of tree species was studied by performing regression analysis to examine the relationships between number of individuals of trees versus seedlings, saplings versus trees, and seedlings versus saplings. This analysis was done for only those species which were present in both the stages.

Results

Species composition and vegetation structure

A total of 1212 woody individuals (≥1cm dbh) of 21 species (19 genera) from 12 families were recorded from the random quadrats covering 0.25 ha (Table 1). The family Mimosaceae had the greatest number of individuals (373) of single species. The family Meliaceae and family Casuarinaceae were represented by single species having single individual each. The number of species ranged from 1 to 9 per quadrat and individuals from 13 to 110 per quadrat. The number of individuals of various species varied from 1 to 373. Total mean stem density in the area studied was 4848 N ha^{-1}. However, the total density of stems with dbh ≥ 10 cm was 560 N ha^{-1}. Quadratwise the stem density varied from 4 to 1492 ha^{-1} with a mean of 48.48 stems. 12 out of 25 quadrats had stem density more than the mean value.

Based on their density, species were categorized into five classes:

Predominant species (≥ 200 individuals): *Acacia auriculiformis* with highest density (1492 N ha^{-1}) followed by *Shorea robusta* (1340 N ha^{-1}) contributing 58.42 % of the total density, represented this group.

Dominant species (100 to 199 individuals): *Syzygium cumini* with 193 individuals contributing 15.9% of total density belonged to this group.

Common species (25 to 99 individuals): Six species – Cassia seamia, *Terminalia bellerica, Terminalia arjuna, Madhuca longifolia, Buchanania lanzan* and *Xylia xylocarpa* represented this group accounting for 18.9% of total density (229 individuals). Rare species (5 to 24 individuals): five species contributing 5.77% of total density (70 individuals) formed this group – *Pterocarpus marsupium*, *Madhuca indica*, *Anacardium occidentale*, *Butea monosperma* and *Phyllanthus emblica.*

Very rare species (< 5 individuals): seven species with total 12 individuals (0.99% of total density) belonged to this category. Of these four species – *Azadirachta indica, Alstonia scholaris, Casuarina sp* and *Thevetia peruviana* were represented by single individual each.

Table 1. Phytosociological characteristics of tree species.

Species (family)	Total individuals	Density (N ha^{-1}) ± SD	Frequency (%)	Basal area (m^2 ha^{-1})	IVI
Accacia auriculiformis A.Cunn. (Mimosaceae)	373	1492 ± 1392.3	88	5.74	74.79
Shorea robusta Gaertn. f. (Dipterocarpaceae)	335	1340 ± 2032.1	60	6.61	69.63
Syzygium cumini (L.) Skeels (Myrtaceae)	193	772 ± 921.2	68	0.86	34.03
Terminalia bellirica (Gaertn.) Roxb. (Combretaceae)	63	252 ± 341.4	48	2.18	24.96
Pterocarpus marsupium Roxb. (Fabaceae)	22	88 ± 166.6	36	2.11	18.75
Madhuca indica Gmelin (Sapotaceae)	19	76 ± 256.2	24	1.69	14.14
Buchanania lanzan Spreng. (Anacardiaceae)	27	108 ± 249.6	40	0.21	11.57
Cassia siamea Lamk. (Caesalpiniaceae)	44	176 ± 2367.1	12	0.66	9.07
Madhuca longifolia (Roxb.) Macb. (Sapotaceae)	30	120 ± 474.3	20	0.14	7.29
Terminalia arjuna (Roxb.) Wt. & Arn. (Combretaceae)	38	152	4	0.67	6.93
Anacardium occidentale L. (Anacardiaceae)	13	52 ± 54.7	20	0.08	5.63
Xylia xylocarpa (Roxb.) Taub. (Euphorbiaceae)	27	108	4	0.45	5.06
Phyllanthus emblica L. (Euphorbiaceae)	7	28 ± 70.7	8	0.45	4.27
Millettia pinnata (L.) Panigrahi (Fabaceae)	2	8	8	0.29	3.15
Eucalyptus tereticornis Smith. (Myrtaceae)	3	12 ± 70.7	8	0.09	2.31
Butea monosperma (Lamk.) Taub. (Fabaceae)	9	36	4	0.09	1.98
Suregada multiflora (Juss.) Baill. (Euphorbiaceae)	3	12 ± 70.7	8	0.002	1.94
Casuarina equisetifolia J. R. & G. Forst. (Casuarinaceae)	1	4	4	0.16	1.64
Alstonia scholaris (L.) R. Br. (Apocynaceae)	1	4	4	0.02	1.00
Thevetia peruviana (Pers.) K. Schum. (Apocynaceae)	1	4	4	0.01	0.95
Azadirachta indica A. Juss. (Meliaceae)	1	4	4	0.0007	0.93
21 species	1212	4848		22.49	300

The total mean basal area occupied by all the trees was 22.49 m² ha^{-1} and of trees with dbh ≥ 10 cm was 16.48 m² ha^{-1}. Species-wise basal area ranged from 0.0007 m² ha^{-1} to 6.6075 m² ha^{-1}. Largest basal area was occupied by *Shorea robusta* (6.6075 m² ha^{-1}) followed by *Acacia auriculiformis* (5.7401 m² ha^{-1}). These two species accounted for 54.9% (12.35 m² ha^{-1}) of the total basal area. Dipterocarpaceae was the dominant family based on basal area.

Table 2. Family importance value (FIV) based on number of species, density and basal area under different families.

Family	No. of species	No. of Trees	Basal area ($m^2 ha^{-1}$)	Relative Density	Relative Diversity	Relative Dominance	FIV
Dipterocarpaceae	1	335	6.61	27.64	4.762	29.38	61.78
Mimosaceae	1	373	5.74	30.78	4.762	25.52	61.06
Combretaceae	2	101	2.84	8.33	9.524	12.63	30.49
Myrtaceae	2	196	0.94	16.17	9.524	4.20	29.89
Fabaceae	3	33	2.49	2.72	14.29	11.07	28.08
Sapotaceae	2	49	1.83	4.04	9.524	8.15	21.72
Euphorbiaceae	3	37	0.90	3.0528	14.29	4.06	21.35
Anacardiaceae	2	40	0.29	3.3003	9.524	1.29	14.12
Caesalpiniaceae	1	44	0.66	3.6304	4.762	2.91	11.31
Apocynaceae	2	2	0.02	0.165	9.524	0.11	9.80
Cassuarinaceae	1	1	0.16	0.0825	4.762	0.71	5.58
Meliaceae	1	1	0.006	0.0825	4.762	0.003	4.85
Total	21	1212	22.49	100	100	100	300

The shrub layer had 83 individuals belonging to 9 species along with 3 climbers having 17 individuals (Annexure 1). All these species exhibited low frequency of below 10% except *Ziziphus oenoplia*, which along with *Clerodendrum viscosum* represented 68.67 % of the shrub population. 52 species of herbs with 5031 individuals composed the ground flora (Annexure 2).

Annexure 1. Frequency and density of shrubs and climbers.

Name of species	Family	Total individuals	Density (N ha^{-1}) ± SD	Frequency (%)
Ziziphus oenoplia (L.) Mill.	Rhamnaceae	27	216 ± 1.75	22
Ziziphus mauritiana Lamk.	Rhamnaceae	2	16 ± 0	2
Hemidesmus indicus (L.) R. Br.	Apocynaceae	10	80 ± 2.51	6
Ichnocarpus frutescens (L.) R. Br.	Apocynaceae	3	24 ± 0.7	4
Rauvolfia tetraphylla L.	Apocynaceae	1	8 ± 0	2
Clerodendrum viscosum Vent.	Lamiaceae	28	224 ± 2.82	4
Lantana camara L.	Verbenaceae	4	32 ± 1.41	4
Carissa spinarum L.	Apocynaceae	4	32 ± 0.57	6
Cassytha filiformis L.	Lauraceae	4	32 ± 0	2
9	5	83	664	

Annexure 2. Frequency and density of herbs including grasses

Name of species	Family	Total individuals	Density (N m^{-2}) ±SD	Frequency (%)
Melochia corchorifolia L.	Malvaceae	26	0.26 ± 4.08	6
Lyndernia perviflora (Roxb.) Haines	Scrophulariaceae	32	0.32 ± 5.2	4
Saccharum bengalense Retz.	Poaceae	10	0.1 ± 0	1
Oxalis corniculata L.	Oxalidaceae	95	0.95 ± 13.68	8
Alternanthera sessilis (L.) R. Br.ex DC.	Amaranthaceae	1	0.01 ± 0	1
Impreta cylindrica (L.) P. Beauv.	Poaceae	34	0.34 ± 6.5	3
Lindenbergia indica (L.) Ktze.	Scrophulariaceae	3	0.02 ± 0	3
Hyptis suaveolens (L.) Poit.	Lamiaceae	749	7.49 ± 31.51	20
Borreria articularis (L. f.) Will.	Rubiaceae	170	1.7 ± 3.65	36
Andrographis paniculata (Burm. f.) Wall. Ex Nees	Acanthaceae	256	2.56 ± 9.5	29
Evolvulus nummularius (L.)	Convolvulaceae	249	2.49 ± 35.3	14
Evolvulus alsinoides (L.)	Convolvulaceae	117	1.17 ± 4.27	27
Perotis indica (L.) Ktze.	Poaceae	178	1.78 ± 7.65	23
Cynodon dactylon (L.) Pers.	Poaceae	642	6.42 ± 31.23	33
Merremia tridentata (L.) Hall. f.	Convolvulaceae	48	0.48 ± 25.12	3
Sida cordifolia L.	Malvaceae	87	0.87 ± 5.38	21
Mimosa pudica L.	Mimosaceae	10	0.1 ± 1.22	5
Eragrortis trimula (L.) Wolf	Poaceae	32	0.32 ± 5.59	4
Brachiaria ramosa (L.) Stapf.	Poaceae	3	0.03 ± 0	1
Eupatorium odoratum L.	Poaceae	2	0.02 ± 0	1
Eragrostis coarctata Stapf.	Poaceae	1	0.01 ± 0	1
Eragrostis ciliata (Roxb.) Nees	Poaceae	128	1.28 ± 5.05	17
Aristida adscensionis L.	Poaceae	145	1.45 ± 5.7	22
Tephrosia purpurea (L.) Pers.	Fabaceae	33	0.33 ± 3.44	6
Hybanthus enneaspermus (L.) Muell	Violaceae	417	4.17 ± 11.53	41
Sporobolus diander (Retz.) Beauv.	Poaceae	49	0.49 ± 8.1	5
Boerhavia diffusa L.	Nyctaginaceae	10	0.1 ± 2.82	2
Desmodium triflorum (L.) DC.	Fabaceae	517	5.17 ± 25.32	32
Eragrostris tenella (L.) P. Beauv.	Poaceae	23	0.23 ± 2.21	4
Vernonia cinerea (L.) Less.	Asteraceae	63	0.63 ± 4.58	14
Ageratum conyzoides L.	Asteraceae	11	0.11 ± 3.05	3
Oldenlandia corymbosa L.	Rubiaceae	18	0.18 ± 1.39	7
Chrysopogon aciculatus (Retz.) Trin.	Poaceae	46	0.46 ± 11.5	3
Clerodendrum viscosum Vent.	Lamiaceae	14	0.14 ± 2.51	4
Phyllanthus amarus Thonn.	Amaranthaceae	34	0.34 ± 2.67	7
Crotalaria pallida Aiton	Fabaceae	103	1.03 ± 18.16	8
Bothriochloa pertusa (Billd) Maire	Poaceae	126	1.26 ± 23.9	8
Cassia mimosoides L.	Mimosaceae	153	1.53 ± 15.16	15
Tragus racemosus Hk. f.	Poaceae	1	0.01 ± 0	1
Zornia gibbosa Span.	Fabaceae	9	0.09 ± 1.3	5
Ischaemum rugosum Salisb	Poaceae	18	0.18 ± 2.09	6
Cyperus rotundus L.	Cyperaceae	77	0.77 ± 12.12	4
Elephantopus scaber L.	Asteraceae	59	0.59 ± 2.67	18
Eragrostis perpurea Hochst.	Poaceae	44	0.44 ± 0	1
Dactylis glomerata L.	Poaceae	26	0.26 ± 6.13	4
Paspalum paspalodes (Michx.) Scribm.	Poaceae	2	0.02 ± 0	1
Echinochloa colonum (L.) Link	Poaceae	2	0.02 ± 0	1
Scoparia dulcis L.	Scrophulariaceae	1	0.01 ± 0	1
Barleria cristata L.	Acanthaceae	2	0.02 ± 0	1
Vetiveria zizanoides (L.) Nash	Poaceae	77	0.77 ± 17.61	3
Saccharum munja Roxb.	Poaceae	18	0.18 ± 0	1
Fimbristylis aestivalis (Retz.) Vahl	Cyperaceae	56	0.56 ± 8.21	6
52		5027	50.27	495

Quadrat wise basal area varied from 0.2 to 1.96 m² with a mean of 0.92 m²; in 10 quadrats the basal area exceeded the mean value.

The highest IVI was exhibited by *Acacia auriculiformis* (75.12) followed by *Shorea robusta* (69.92). *Azadirachta indica* had the lowest IVI (0.93). Based on family importance value (FIV) Dipterocarpaceae ranked highest among all families followed by Mimosaceae (Table 2).

Distribution pattern for all the species in the area studied was of clumped type (>0.5).

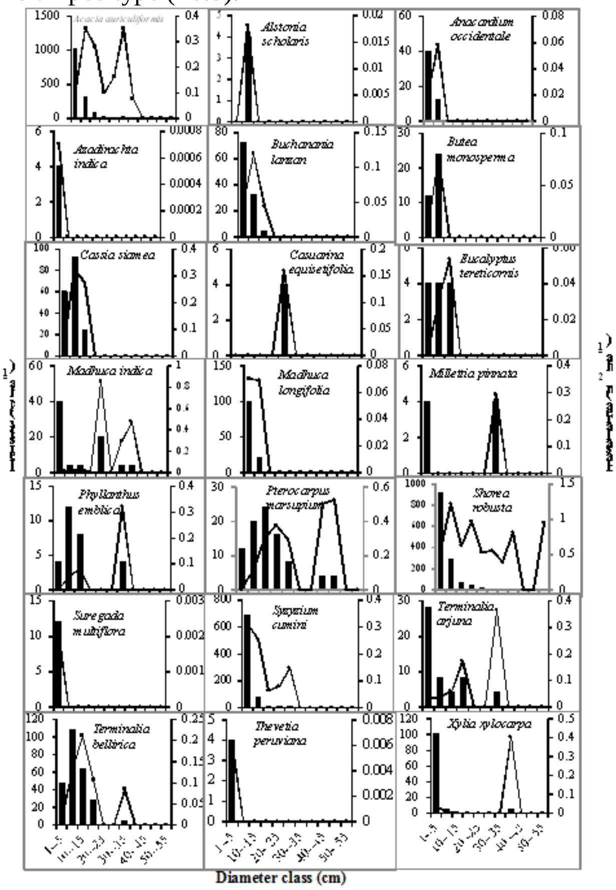

Figure 2. Diameter class distribution of tree species based on density (N ha^{-1}) (column) and basal area (m^2 ha^{-1}) (line).

The distribution of tree density in different diameter classes revealed a reverse J shaped distribution by most of the species (Fig. 2). The maximum diameter recorded was 55 cm (for *Shorea robusta*). The most preferred diameter class was 1-5 cm with density ranging from 4 to 1028 stems ha-1 except a few species where 5-10 cm was most preferred. In some species the larger dbh classes occupied highest basal area with reduced density as in *Madhuca indica, Terminalia arjuna, Phyllanthus emblica, Pterocarpus marsupium* and *Xylia xyloarpa*. Smaller dbh classes recorded high basal area in *Acacia auriculiformis* and *Shorea robusta* because of extremely high density of their small sized stems. The mean stand dbh was 5.1 cm and 1572 stems exceeded the mean value. However, the 30-35 cm dbh class had the highest basal area of 9.32 m2 ha-1 (41.47%) as well as the highest number of species (Table 3).

Species diversity pattern

Shannon-Wiener Index or heterogeneity (H´) for tree species was 2.84. Evenness was low with high concentration of dominance (0.2) (Table 4). Species richness was high leading to high heterogeneity value. Shrub layer had lower species richness but higher evenness than trees leading to heterogeneity value of 2.44. Species richness, heterogeneity and evenness values were highest in the herb layer.

Regeneration status of trees

Total 1780 saplings of 17 tree species and 659 seedlings of 15 tree species were recorded. *Acacia auriculiformis* had highest number of saplings (765) and seedlings (182) followed by *Shorea robusta* (581 saplings and 73 seedlings). We did not get any saplings or seedlings for 6 tree species (*Alstonia scholaris, Casuarina equisetifolia, Butea monosperma, Thevetia peruviana, Suregada multiflora* and *Millettia pinnata*) while *Ficus recemosa* occurred only as sapling and *Phoenix sylvestris* occurred only as seedling and sapling. Seedlings were absent in *Madhuca indica* and *Eucalyptus tereticornis*, and their proportion was less than 6% in *Terminalia arjuna, Anacardium occidentale, Buchanania lanzan* and *Pterocarpus marsupium* (Fig. 3). Seedling percent was highest (68%) for *Cassia siamea* but sapling percent was very low. Sapling percent was highest for *Azadirachta indica* but tree percent was lowest. Significant linear relation existed between number of saplings and number of trees, and also between number of trees and number of seedlings (Fig. 4). The relation between number of seedlings and number of saplings was less significant but improved after exclusion of data for *Syzygium cumini* and *Cassia siamea*.

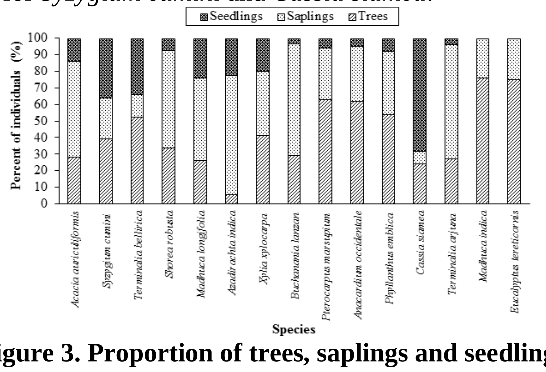

Figure 3. Proportion of trees, saplings and seedlings in different species.

Table 3. The proportion of tree species, stem density and basal area in different diameter classes

S .No.	dbh class (cm)	No. of species	No. of stems ha^{-1}	% of stems ha^{-1}	Basal area (m^2 ha^{-1})	% of basal area
1	1 to 5	3	3276	67.57	0.002	0.008
2	>5 to 10	4	1012	20.88	0.33	1.45
3	>10 to 15	3	288	5.94	0.95	4.23
4	>15 to 20	0	120	2.48	0	0
5	>20 to 25	2	60	1.24	1.02	4.53
6	>25 to 30	0	36	0.74	0	0
7	>30 to 35	5	28	0.58	9.33	41.47
8	>35 to 40	2	20	0.41	2.14	9.52
9	>40 to 45	1	4	0.08	2.11	9.37
10	>45 to 50	0	0	0	0	0
11	>50 to 55	1	4	0.08	6.61	29.38
	Total	21	4848	100	22.48	99.97

Table 4. Diversity values of tree, shrub and herb layer

Vegetation stratum	H'	E	Cd	M
Tree	2.84	0.93	0.2	2.81
Shrub	2.44	1.11	0.24	1.81
Herb	4.47	1.13	0.07	6.1

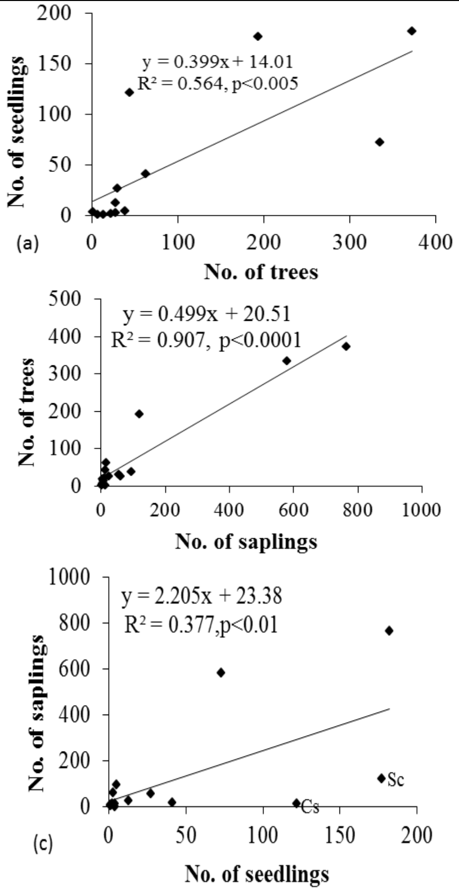

Figure 4. Species-wise relationship between (a) number of seedlings and number of trees, (b) number of trees and number of saplings and (c) number of saplings and number of seedlings. In (c) the significance level improved after excluding data for *Cassia siamea* and *Syzygium cumini* (y=4.462x+4.111, R^2 = 0.848, p<0.0001).

Discussion

No two dry tropical forest communities could be closely identical with respect to vegetation composition and structure (Murphy and Lugo, 1986). Occurrence of 21 tree species with 1212 individuals in 0.25 ha area is relatively a good number. Presence of two evergreen species, *Syzygium cumini* and *Xylia xylocarpa* in the deciduous forest indicates planting preference. Similar studies in other tropical dry forests covering 1-2 ha area have reported considerably higher number of species like 57 in the Eastern Ghats (Sahu *et al*., 2012), 4 to 23 in central India (Sagar and Singh, 2006), 93 in Rajasthan (Kumar *et al*., 2010), 46-133 in Karnataka (Sukumar *et al*., 1992; Krishnamurthy *et al*., 2010), and 50 in Puerto Rico (Murphy and Lugo, 1986a).

Previous study in adjacent natural forests reported the dominance of *Shorea robusta* (Gupta Joshi, 2012). In the present study *Acacia auriculiformis* was the dominant species. As the study area is a created or manmade forest, the results indicate the preference in its plantation. However, *Shorea robusta* occupied the largest basal area followed by *Acacia auriculiformis*. The total basal area occupied by the tree species is comparable to the earlier studies including 1.31 to 13.78 m^2 ha^{-1} from Vindhyan highlands (Sagar and Singh, 2006); 7 - 23 m^2 ha^{-1} from certain dry forest communities in India (Jha and Singh, 1990), 10.79 - 20.44 m^2 ha^{-1} for a tropical dry evergreen forest of southern India (Parthasarathy and Sethi, 1997).

In the present study a reverse J-shaped diameter density distribution of trees indicate a younger regenerating forest with dominance of small sized individuals. Nearly half of the species were present with small sized stems only with preferred diameter class upto 10 cm. *Xylia xylocarpa* and *Millettia pinnata* exhibited discontinuous distribution. Only two species represented 58% of the total tree population. This high dominance by few species has been reported from other deciduous and evergreen forests of India (Sukumar *et al.*, 1992; Kanade *et al.*, 2008). Mean tree density of 276 - 980 stems ha^{-1} has been reported in other tropical dry forests with preferred diameter classes ranging from 20-50 cm (Pandey and Shukla, 2001; Sagar and Singh, 2006; Sahu *et al*., 2007, 2012; Bhadra *et al*., 2010; Krishnamurthy *et al*., 2010). In some other tropical deciduous forests, A-shaped curve suggested medium age of forests (Parthasarathy and Sethi, 1997; Kumar *et al*., 2010).

Number of species per quadrat (1 to 9) in the present study is similar but number of individuals per quadrat (13 to 110) was higher than 1 to 12 individuals per quadrat reported for the Vindhyan dry forests (Sagar *et al.*, 2003). Majority of quadrats had upto 5 species and upto 60 individuals. This indicates two things- a patchy distribution of species and a high density of individuals that must have been possible because of their small size. All the species showed clumped distribution which is very common in nature (Odum, 1971) due to patchy distribution and coppice forming, insufficient mode of seed dispersal or gap formation encouraging recruitment and growth of numerous saplings or vegetative reproduction by suckers (Roy and Singh, 1994; Richards, 1996).

Tree density and species richness were negatively related with the tree basal area in this study. This indicates dominance of small sized stems of a few species with low equitability of distribution of individuals among species. This contrasts the theory of positive relationship between basal area (or productivity) and diversity (Odum, 1971), also reported in some dry deciduous forest where disturbance did not permit concentration of biomass or stems in only a few strong competitors (Sagar and Singh, 2006). On the contrary low species richness at high biomass levels is caused by dominance by a few strong competitors (Keddy, 2005). Protection from disturbance or preference in planting or both might be responsible for this observation in the present study.

The 21 tree species recorded in this study reflected only a part of overall tree diversity as the species area curve continued to climb steadily at the end of 0.25 ha of sampling. During vegetation survey an important decision to make is whether to have a single large plot or a number of small random plots. Several small plots have potential to represent different ‘vegetation types’ and encompass more species while clumped distribution of species make it necessary to study a large area (Sukumar *et al.*, 1992). Clumped distribution of all the species might be responsible for the unsaturated species area curve in present study as the sampling intensity of 0.1% fulfils the standard requirement of such enumerations (Kanade *et al.*, 2008).

We selected the minimum cut-off size of plants for enumeration as 1cm dbh according to Sukumar *et al.* (1992). Traditionally foresters have looked at only trees above 10 cm dbh. With a 10 cm dbh cut-off we would have lost six species and 86.7% of individuals from enumeration.

The values of Shannon-Wiener Index (H´) and Simpson's concentration of dominance (Cd) are in the reported range for tropical dry forests. Diversity (H′) range of 0.83 - 4.1 and concentration of dominance range of 0.10 – 1 has been reported for tropical dry forests (Rasingam and Parthasarathy, 2009; Shukla, 2009; Tripathi and Singh, 2009; Krishnamurthy *et al*., 2010; Sahu *et al*., 2012; Kumar *et al*., 2010). The diversity values (H′ and M) showed an initial decrease and then increased greatly as we moved from the trees to the herbs. Concentration of dominance was highest for the shrubs followed by the trees.

We found negative correlation between number of species of herbs and seedlings, and between number of species of herbs and shrubs, although statistically insignificant (Table 5). In the field seedlings were poor in places having good herbaceous cover; also herbs were poor where shrub layer was dense. The number of species of trees was significantly positively correlated with number of species of shrubs, saplings and seedlings; and number of species of shrubs with number of species for seedlings. Correlation was highest in case of trees and saplings while correlation between trees and seedlings was low. Regression analysis also suggested significant relationship between saplings and trees indicating satisfactory conversion of saplings into trees, but success of seedling conversion to sapling was lower. Density dependent mortality of seedlings or grazing or some adverse condition of substratum might be responsible for low recruitment of saplings that needs further investigation. The removal of *Syzygium cumini* and *Cassia siamea* improved the relationship between seedlings and saplings. Occurrence of six tree species without any regeneration indicates their declining population.

Table 5. Correlation of species number among different vegetation strata.

	Shrub	Herb	Sapling	Seedling
Tree	0.49 ($p<0.01$)	0.08	0.61 ($p<0.001$)	0.54 ($p<0.005$)
Shrub		-0.03	0.22	0.61 ($p<0.001$)
Herb			0.10	-0.20
Sapling				0.34

Conclusions

The present work is the first report on vegetation study in the BWLS since its creation in 1977 and provides a baseline database. Subsequent sampling and monitoring will provide additional data on forest structure and diversity. As a protected area, it harbors a viable population of spotted deer besides having a diverse flora. Small forest fragments are reported to provide a safety net for a significant number of species and their genetic diversity (Turner and Corlett, 1996). Even small forest patches of less than 1 ha could play a major role in maintenance of regional diversity (Pither and Kelman, 2001). Although it is artificially created and encompass a small area of 200 ha, the tree species richness, density and basal area of BWLS are comparable to other dry deciduous forests. However lack of regeneration in some tree species requires urgent management attention.

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