Vegetation composition and woody species diversity at Chandoli National Park, northern Western Ghats, India

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Woody plant species diversity at Chandoli National Park, an under-explored area from northern Western Ghats, Maharashtra, was assessed in detail by establishing ten transects of 1000 m × 5 m each. All individuals with GBH ≥15 cm were enumerated. A total of 4200 stems were sampled which represented 107 species belonging to 86 genera and 44 families. Shannon's index value ranged from 2.0 to 3.2. We have identified a new subtype *Memecylon–Syzygium–Olea* of previously defined *Memecylon–Syzygium–Actinodaphne* floristic series in the literature. Family importance value of pooled data showed that Melastomataceae was the most dominant family (50.32), followed by Myrtaceae (32.39) and Euphorbiaceae (23.16). The frequency distribution of all the species was highly skewed with *Mememecylon umbellatum*, *Syzygium cumini*, *Olea dioica*, *Catunaregam spinosa* and *Terminalia elliptica* accounting for 50% of the population. Twenty-three species were represented by only one individual in the transects sampled, indicating the underlying log-normal distribution.

Keywords: Chandoli National Park, *Memecylon–Syzygium–Olea* floristic series, vegetation composition, woody species diversity.

THE Western Ghats of India along with neighbouring Sri Lanka is one of the 34 global biodiversity hotspots[1]. It harbours tropical humid forests, known to be amongst the most diverse, most productive and most threatened biological communities of the world[2,3]. It constitutes a chain of mountains running parallel to the west coast of India (approx. 1600 km length and 5–15 km width) and ranges from 8°N to 20°N lat. The northern ranges of the Western Ghats, which lie in Maharashtra, make about one-third of its total length. As elsewhere in the tropical countries, all or most of the original vegetation cover of the Western Ghats has been influenced to varying extents by humankind over thousands of years[4].

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Except for sporadic records that are available regarding quantitative studies[5,6], forest studies conducted so far in northern Western Ghats (NWGs) are largely based on qualitative descriptions (forest type, physiognomy, dominant species, etc.) and taxonomic explorations[7,8]. On the contrary, there are ample records of quantitative inventories on floristics and ecological assessments of the vegetation in general and Protected Areas (PAs) in particular, that are available from southern Western Ghats (SWGs), e.g. Mudumalai Tiger Reserve[9], Kalakad–Mundanthurai Tiger Reserve (KMTR)[10,11] and Agastyamalai Region[12]. The vegetation of NWGs remains understudied in general, which prevented ecologists from generating a holistic picture of plant resources and thereby understanding the forest dynamics over the entire Western Ghats eco-region level. The present work is part of a 4-year on-going study (2004–08) intensively samples plant resources at an entire eco-region level and forms a part of a series of publications to be followed.

Puri *et al.*[13] and Pascal[14] classified the mid-elevation tracts of NWGs under a single *Memecylon–Syzygium–Actinodaphne* (*M–S–A*) type based on the criteria of dominance–abundance–fidelity of species. However, the need and importance of quantitative studies in classifying vegetation types have been emphasized by several workers[15,16]. The idea behind this article emerged from one such quantitative assessment of the KMTR[17]. Also, Ghate *et al.*[15], while working on forests of NWGs, reported existence of another plant community along with the standard *M–S–A* type. In the context of rapid changes a landscape witnesses owing to threats such as forest loss, vegetation is expected to vary over small spatial scale. We investigated in detail the composition, abundance and diversity of woody species (GBH ≥15 cm) at Chandoli National Park (CNP), to provide descriptions of vegetation and species distribution exclusively covering an entire PA from the NWGs. CNP provides an excellent opportunity to study diversity and density estimates for various reasons: (a) It is one of the least explored areas of NWGs because of its rugged terrain and inaccessibility. Till date only one research paper[18] is dedicated towards botanical exploration of a part of this area in 1975 that too before it

was declared a PA and detailed investigations are lacking. (b) The area experienced human disturbance prior to its declaration as a PA. But now it provides an ideal case to study forest dynamics. (c) Recently, CNP along with two other wildlife sanctuaries from NWGs have been proposed as World Heritage Sites to UNESCO. Thus, assessing and understanding conservation potential of the area will help in planning better conservation strategies.

Study area

Northern Western Ghats

The northern ranges of the Western Ghats, popularly known as Sahyadri (15°30′–20°30′N lat., 73°–74°E long.), lie in Maharashtra. The vegetation is more or less in the form of fragmented patches in contrast to continuous stretches of forests in SWGs. Presence of numerous barren, rocky, lateritic plateaus, locally known as 'sadas', is a unique feature of the NWGs. It supports characteristic ephemeral flush vegetation harbouring monotypic genera, many of which show restricted or narrow distribution[19]. However, it is impoverished on account of overall woody species richness, one of the reasons being absence of species-rich forest types, such as *Myristica* swamps and shola forests that are unique to the SWGs.

Chandoli National Park

CNP (earlier declared a wildlife sanctuary in 1985) is located at the junction of four districts, viz. Sangli, Satara, Kolhapur and Ratnagiri, in western Maharashtra. It spreads along the crest line and lies between Koyna and Radhanagari Wildlife Sanctuaries (17°15′N–17°07′N lat. and 73°44′E–73°51′E long.). Its expanse spreads over an area of 317.67 km^2 along the backwaters of Vasant Sagar reservoir (Figure 1). The terrain is inaccessible and hilly; most of the hills are flat-topped with steep slopes sustaining grasslands and scrub vegetation on the hilltops and dense, tall forests on the slopes and valleys. The altitude of CNP ranges from 589 to 1044 m. The underlying rock is the igneous trap – basalt and the superficial rock is laterite in general. The soil is gravelly, red or reddish-brown in colour. The area receives an average annual rainfall of about 6200 mm, most of which is distributed over the period of June–September. The catchment is drained by a number of seasonal and perennial streams.

The area also supports diverse fauna, including the endangered *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Bos gaurus* (gaur), *Melursus ursinus* (sloth bear), *Ratufa indica* (giant squirrel), *Manis crassicaudata* (pangolin), etc. Recently, CNP along with two wildlife sanctuaries, Koyna and Radhanagari, has been proposed as a World Heritage Site (Western Ghats–Sahyadri Sub-Cluster)[20]. Besides, CNP in conjunction with Koyna WLS (423.55 km^2) was proposed to be notified as a Project Tiger Reserve. This will make immense difference in terms of wildlife protection, conservation awareness and tourism, as none of the other three Project Tiger sites in the state, Tadoba, Melghat and Pench, are in the NWGs ranges.

Methods

The entire area of the CNP was divided into ten grids of 6.25 km × 6.25 km each. A belt transect of 1000 m × 5 m was laid in each grid. This amounts to 0.01% of the sampling intensity, which is a standard requirement for such enumerations[21]. Woody species were enumerated for individual height and girth (≥15 cm) estimates. Shrubs were recorded at the beginning and end of the transects by laying sub-plots of 5 m × 5 m. The belts were located such that they incorporate significant environmental gradient of the grid. This is essential to get a representation of the habitat variability. Grids with patchy vegetation were sampled by breaking the entire transect into maximum of four sub-transects of varying lengths. Twenty-six such sub-transects were laid in the entire CNP. All the individuals were identified up to species level. The unidentified specimens were photographed and/or collected and identified later by consulting herbaria and the literature. The overall checklist of the grid, including trees, shrubs and herbs was also prepared.

Two indices were calculated for vegetation analysis: Species importance value (SIV; also popularly known as importance value index) for species and family importance value (FIV) for families.

SIV was calculated as follows:

SIV = Relative frequency + relative density + relative dominance.

Relative frequency = (Number of plots containing a species × 100)/Sum of frequencies of all species.

Relative density = (Number of individuals of a species × 100)/Total number of individuals of all species.

Relative dominance = (Basal area of a species × 100)/Total basal area of all species.

FIV was calculated according to Ganesh *et al.*[17].

FIV = Relative density + relative diversity + relative dominance.

Relative density = (Number of individuals of the species × 100)/Total number of individuals in the sample.

Relative diversity = (Number of species in the family × 100)/Total number of species in the sample.

Relative dominance = (Basal area of the family × 100)/Total basal area in the sample.

The log series distribution model was fitted to the pooled data as given by Magurran[22]. The log series takes the form:

$$\alpha x, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \ldots, \frac{\alpha x^n}{n},$$

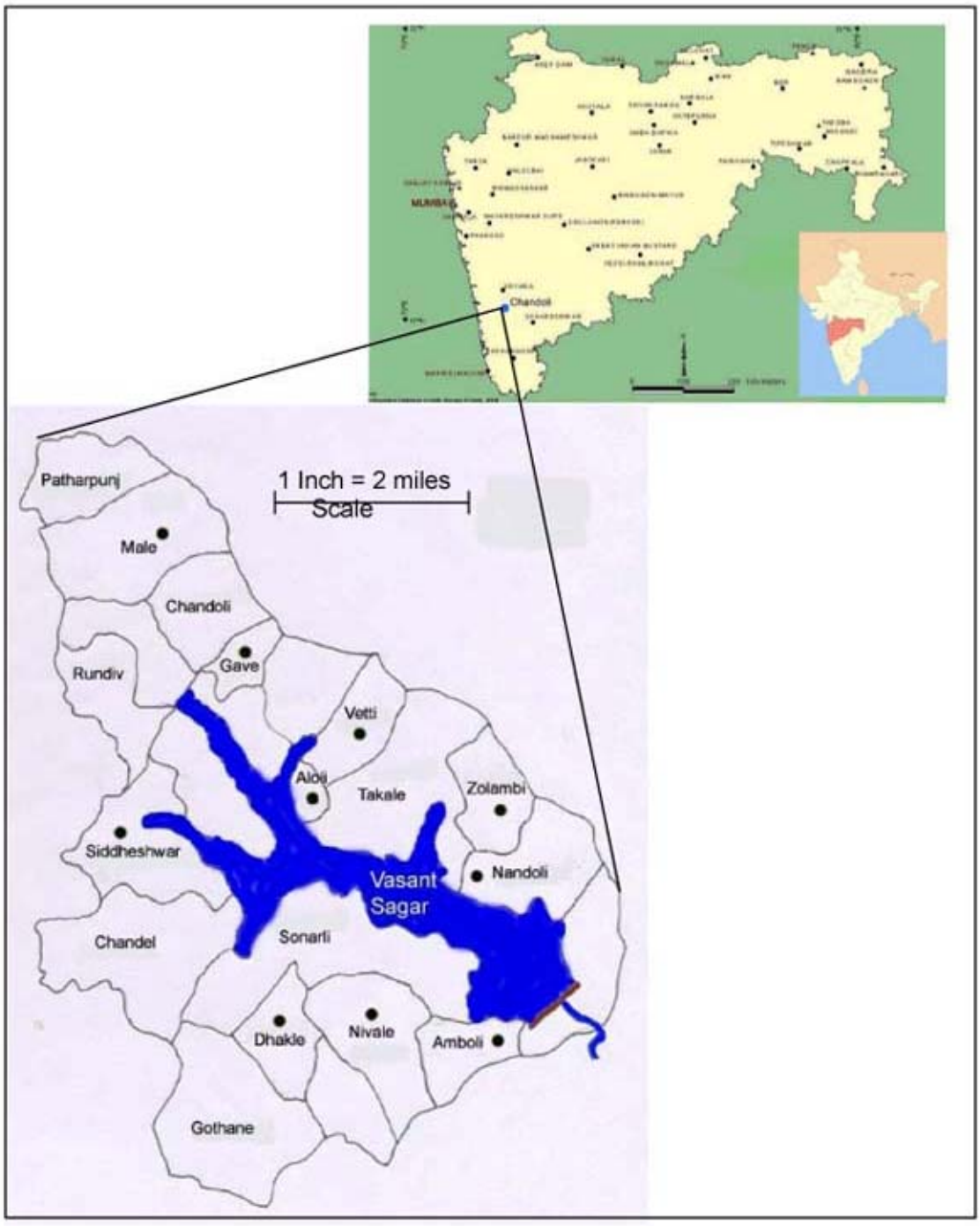


Figure 1. Location map of Chandoli National Park.

where αx is the number of species predicted to have one individual, αx^2 the number of species predicted to have two individuals, and so on. X is estimated by iterating the equation, $S/N = [(1 - x)/x]\cdot[-\ln(1 - x)]$, where S is the total number of species and N the total number of individuals. The iteration involves trying successive values of x until both sides of the equation are equal. α, an index of diversity is estimated using the equation, $\alpha = [N(1 - x)/x]$. The observed and expected data were grouped into octaves or $\log_2$ classes. Then 0.5 was added to the upper boundary of each class to assign the species unambiguously.

Shannon's index (H') and ratio of the number of individuals (N) to the number of species (S) was calculated to

get an insight into diversity. *N*/*S* is a simple yet robust representation of species diversity.

Results and discussion

Species composition and abundance

A total of 120 woody species (approximately 27% of the wild, woody plant species that are found in the Western Ghats, Maharashtra) were recorded from the CNP, of which 107 were encountered on the transects (Annexures 1 and 2). Four thousand and two hundred individuals belonging to 86 genera and 44 families were recorded. *Memecylon umbellatum*, *Syzygium cumini* and *Olea dioica* were the most dominant species, with *Terminalia elliptica* and *Catunaregam spinosa* as codominants. Evergreen forest tracts of NWGs are classified under a single *M–S–A* type[23]. The dominance of evergreen forest species such as *O. dioica* and characteristic under-representation of *Actinodaphne angustifolia* (27 individuals out of 4200 with SIV of 3.06) (Annexure 1), suggests origin of a community differing in composition from the typical *M–S–A* type. Within this type we have identified a new subtype called *Memecylon–Syzygium–Olea* based on abundance. This might be because a comparatively undisturbed forest such as CNP favours preponderance of evergreen forest species over heliophilic pioneers like *A. angustifolia*. Watve *et al.*[6] while studying community dynamics of semi-evergreen forests of Mulshi from NWGs identified *Memecylon–Xantolis–Actinodaphne* type (of degraded semi-evergreen) in addition to the typical *M–S–A* series. Similar abundance-based studies conducted by Ganesh *et al.*[17] identified a subtype of the previously established floristic series from the KMTR. This indicates that the communities are not completely separate but are fragments of a larger forest continuum, where some species became dominant over an area according to local conditions[24,25].

Family-level diversity was studied and compared with similar such studies conducted elsewhere in PAs of SWGs. Euphorbiaceae, Moraceae and Rubiaceae were the most dominant families in terms of species richness in case of CNP. However, FIV index of pooled data showed that Melastomataceae was the most dominant family (50.32), followed by Myrtaceae (32.39) and Euphorbiaceae (23.16) (Figure 2). This is because Melastomataceae is represented by single species, viz. *M. umbellatum*, recorded in high densities (1157 individuals out of total 4200 stems sampled), with SIV of 49.22 (Annexure 1). Myrtaceae was represented by six species. *S. cumini* was the second most dominant species followed by *O. dioica*, with SIV of 25.42 and 14.25 respectively. A study conducted by Ganesh *et al.*[17] at mid-elevation forests of KMTR, reported that Lauraceae, Rubiaceae and Euphorbiaceae were the most dominant families in terms of species richness, whereas Euphorbiaceae, Bombacaceae and Lauraceae turned out to be the most important families based on FIV.

The above-mentioned five species, viz. *M. umbellatum*, *S. cumini*, *O. dioica*, *T. elliptica* and *C. spinosa* represent 50% and 13 other species account for 25% of the total population. Twenty-three species were represented by only one individual in the transects sampled, indicating the underlying log-normal distribution. Gadgil and Vartak[5], while studying the dynamics of forests in Mahabaleshwar, NWGs, reported that four species, viz. *S. cumini*, *A. angustifolia*, *M. umbellatum* and *O. dioica* accounted for more than 70% of the population. Similar observations were recorded by Sukumar *et al.*[9], where few species showed high dominance in a 50 ha plot, in the deciduous forests of Mudumalai Wildlife Sanctuary.

When the species abundance represented in octaves was plotted against the number of species, the population

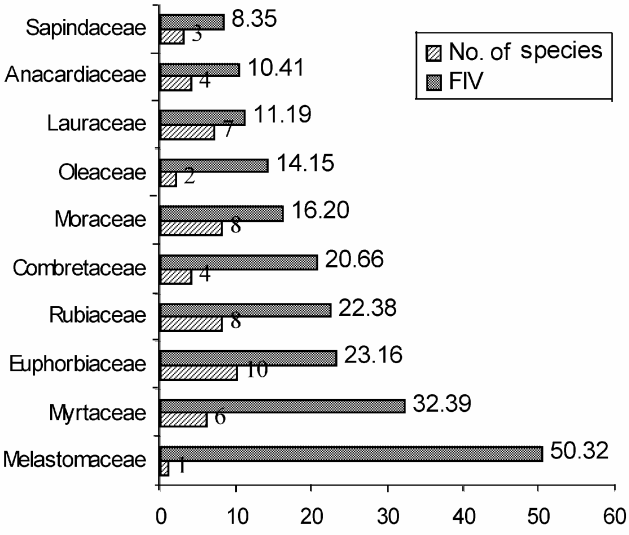


Figure 2. Family-level dominance based on species richness and family importance value (FIV).

Table 1. Diversity and density across localities

Locality	Dominant habitat*	Tree density†	No. of species	*N*/*S*	Shannon's index (*H*′)
Aloli	MD	439	57	7.70	3.2
Amboli	SCRB	333	37	9.00	2.8
Dhakle	SCRB	450	38	11.84	2.4
Gave	SCRB	149	25	5.96	2.5
Male	EVG	657	34	19.32	2.1
Nandoli	SEVG	460	31	14.84	2.0
Nivale	SCRB	470	49	9.59	2.9
Siddheshwar	EVG	513	57	9.00	3.1
Vetti	SCRB	390	35	11.14	2.6
Zolambi	SEVG	391	32	12.22	2.2

*MD, Moist deciduous; SCRB, Scrub; EVG, Evergreen; SEVG, Semi-evergreen.
†Also includes unidentified species.

Table 2. Species with their attributes and uses

Species	E/D[§]	Canopy (C)/ under-storey (U)	Attri-butes[♣,2,4]	Uses[φ,32]	Species	E/D[§]	Canopy (C)/ under-storey (U)	Attri-butes[♣,2,4]	Uses[φ,32]
Acacia auriculiformis	D	C	P	M	*Grewia nervosa*	D	U	P	
*Actinodaphne angustifolia**	E	C	P	M	*Grewia tiliifolia*	D	C	F, P	M, C, E
Aglaia elaeagnoidea	E	C	C	M	*Heterophragma quadriloculare*	D	C		M
Allophylus cobbe	E	Liana	P		*Holarrhena pubescens*	D	U		M, O
Alseodaphne semicarpifolia	E	U	F, R		*Holigarna grahamii**	E	C	C, F	
Anogeissus sp.	D	C	C	C,F	*Homalium ceylanicum*	E	Climber	C	
Artocarpus hirsutus	E	C	F, R	E	*Ixora lanceolaria*	E	U		M, C
Atalantia racemosa	E	U		M	*Ixora nigricans*	E	U		M
Beilschmiedia dalzelli	E	C	C		*Lagerstroemia microcarpa*	D	C	F, P	M
Bombax ceiba	D	C	P	M, C, O, E	*Lannea coromandelica*	D	C	F	M
Bridelia retusa	D	U	P	M, E	*Leea indica*	E	U	F, R	
Bridelia scandens	D	U	P		*Litsea josephii**	E	U	C	
Bridelia sp.	D	C	P		*Macaranga peltata*	E	C	F, P	M, C
Butea monosperma	D	C	P	M, C, E	*Mallotus phillipinensis*	E	C	F, P	M, O
Callicarpa tomentosa	E	U	F, P	M	*Mangifera indica*	E	C	F, R	M, E, C, O
Canthium dicoccum	E	C		M	*Maytenus rothiana**	E	U	F, R, P	
Carallia brachiata	E	C	F, P	M	*Meiogyne pannosa**	E	U	C	
Careya arborea	D	C	F, P, To	M	*Memecylon umbellatum*	E	C		O
Caryota urens	E	C	P, W	E	*Meyna laxiflora*	E	C	P	E, O
Casearia championii	D	U	P	M	*Mimusops elengi*	E	C	F, R	M
Cassia fistula	D	C	F, P	M, E	*Moullava spicata*	E	Climber	F, T	
Catunaregam spinosa	D	C	F, T	MO	*Murraya koenigii*	E	U	P	
Cipadessa baccifera	E	U	P		*Murraya paniculata*	E	U	C, F	M, C, O
Chionanthus mala-elengi	E	C			*Myristica malabarica**	E	C	C, W	M
Cinnamomum verum	E	C	C	O, E	*Neolamarckia cadamba*	D	C		M, O, E
Clausena anisata	D	U			*Neolitsea cassia*	E	U		
Cordia dichotoma	E	C		M, E, C	*Nothapodytes nimmoniana*	D	U	F,R	M
Dillenia pentagyna	D	C	F, P, To	M, C, O, E	*Nothopegia castaneifolia**	E	C	F,R	
Dimocarpus longan	E	C	F, R, C	E	*Olea dioica*	E	C	F, P	
*Dimorphocalyx lawianus**	E	U	C		*Osyris quadripartita*	D	U		
Diospyros ebenum	E	U			*Persea macarantha*	E	C	F, R	
Diospyros montana	D	U	P		*Prunus ceylanica*	E	U		
Diospyros nigrescens	E	U			*Psychotria truncata**	E	U		
Diospyros sylvatica	E	U	C		*Pterocarpus marsupium*	D	C		M, E, O, C
Diospyros sp.	-				*Securinega leucopyrus*	D	U		
*Drypetes venusta**	E	C	C		*Scutia myrtina*	E	U		
Elaeagnus conferta	E	Climber		E	*Schleichera oleosa*	D	C	F, P, To	M, C
Emblica officinalis	D	C	F, P	E, M	*Strombosia ceylanica*	E	C	C, F,	
Erythrina suberosa	D	C	P	M	*Symplocos racemosa*	E	C	C	M
Eucalyptus globulus	D	C	P	C, M, O	*Syzygium cumini*	E	C	F, R, P	M, E, O, C
Eugenia corymbosa	E	C		E	*Syzygium phillyraeoides*	E	U		E
Ficus exasperata	D	C	P		*Syzygium rubicundum*	E	U		
Ficus racemosa	D	C	P	M, O, E	*Syzygium* sp.	E	U		
Ficus microcarpa	E	C	P		*Tabernaemontana alternifolia*	D	U	F, P	
Ficus sp.	D	C			*Terminalia bellirica*	D	C	F, P, To	M, O
Ficus amplissima	E	C			*Terminalia chebula*	D	C	To	M, O
Ficus tsjahela	E	C			*Terminalia elliptica*	D	C	F, P, To	M, C, O
Ficus virens	D	C			*Trema orientalis*	D	U	P	M, E
Flacourtia latifolia	D	U			*Wendlandia thyrsoidea*	E	U	P	
Flacourtia montana	D	U	P	E	*Woodfordia fruticosa*	D	U		O
*Garcinia talbotii**	E	C	C	M	*Xantolis tomentosa*	D	C	F, T, P	
Garuga pinnata	D	C		M	*Xylia xylocarpa*	E	C	To	M
*Glochidion ellipticum**	E	C	P	O	*Ziziphus rugosa*	D	U	F, P, T	E
Gnidia glauca	D	U		M, O					

*Species endemic to the Western Ghats[23].

[§]E, Evergreen; D, Deciduous.

[♣]The attribute codes are C, Climax; P, Pioneer; T, Thorny; F, Able to be coppiced; R, Relict; W, Wetland; To, Fire-tolerant.

[φ]Uses codes are C, Construction; F, Fuelwood; M, Medicinal; E, Edible; O, Others.

was found to follow the log-series distribution indicating high dominance. The observed values closely followed the expected ones with the chi-square value of 6.325 at $P < 0.05$ (Figure 3). This is supported by FIV and SIV.

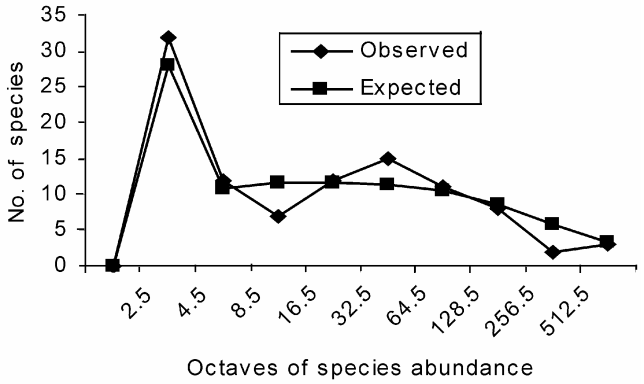
Forest types and diversity indices

The forest types can be classified as medium elevation wet evergreen[23] and southern tropical semi-evergreen[26] in the undisturbed or comparatively less disturbed areas such as Siddheshwar, Male and Nandoli. Some of the evergreen pockets can also be described as the climatic climax of the vegetation in this area[18]. However, vegetation near the villages inhabited in the past is of mixed evergreen, moist deciduous and scrub-type with opened up canopies.

The number of species varied from 25 to 57 per 0.5 ha. The highest number in the evergreen forest was comparable to the 64–82 species recorded/ha during a study conducted by Parthasarathy[27] in the wet evergreen forests of KMTR. The moist deciduous forests of Aloli also showed highest species diversity (Table 1). This is due to the local heterogeneity of the Chandoli catchment. The forest at Aloli spreads over a steep slope and therefore harbours richer diversity than the ridges and the gentle slopes as is found all over the Western Ghats[28]. The *N*/*S* ratio varied from 5.96 to 19.32. The higher *N*/*S* value indicates communities relatively poor in species. Gave, though species-poor (Shannon's index value = 2.5), recorded lower *N*/*S* ratio because of very low tree density. Aloli and Siddheshwar were found to be the best forested areas on the account of lower *N*/*S* and higher species richness values (Shannon's values being 3.2 and 3.1 respectively).

The highest tree density (Table 1) was found in the evergreen forest tracks of Male and Siddheshwar supporting taller forests (maximum height 30 and 20 m respectively) compared to the other areas. Species such as *M. umbellatum*, *S. cumini*, *Dimocarpus longan* and *O. dioica* dominated these evergreen forests. These areas together support 13 endemic tree species (Annexure 1), such as *Myristica malabarica*, *Drypetes venusta* and *Garcinia talbotii*[19] and species exclusive to low disturbance sites such as *Persea macrantha*, *Prunus ceylanica* and *Litsea* sp. Large number of individuals of all size classes of *D. longan* were recorded from Siddheshwar. Such colonizing behaviour of *D. longan* has been noted by Pascal[29] in climax forests.

M. umbellatum, *S. cumini*, *O. dioica* and *T. elliptica* were the most dominant species in semi-evergreen forests while moist deciduous forests were dominated by *M. umbellatum*, *Holigarna grahamii*, *C. spinosa*, *S. cumini* and *Gnidia glauca.* The disturbed forests also showed dominance by *M. umbellatum*, indicating the presence of mixed evergreen forests before degradation. *C. spinosa*, *T. elliptica* and *Glochidion ellipticum* were abundant in these vegetation patches. Slash and burn cultivation that was in practice in the past (as revealed by a discussion with the concerned forest officials and personal observations) led to the highly disturbed patches that are colonized by shrubby and thorny vegetation with hardy species.



Chi-square value: 6.325 at $P < 0.05$

Figure 3. Log-series distribution of species abundance.

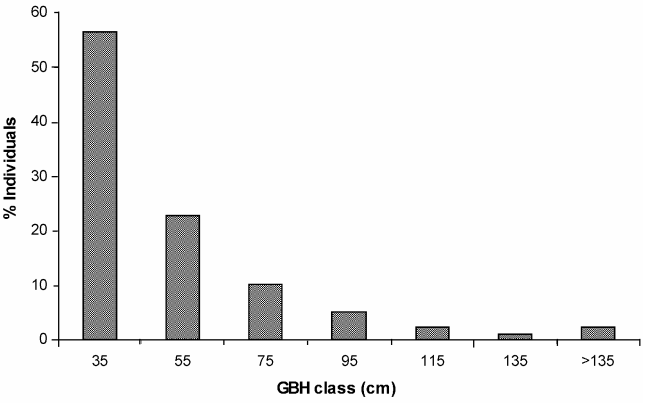


Figure 4. Size class distribution of all individuals in the transects.

Table 3. Basal area comparison across different locations

	Area (ha)	Tree density (>15 cm GBH)	Basal area (m^2/ha)
Rai and Proctor[30]			
Agumbe	0.44	1386	33.7
South Bhadra	0.5	740	48.6
Present study			
Aloli	0.5	439	50.92
Amboli	0.5	333	17.54
Dhakle	0.5	450	25.93
Gave	0.5	149	10.22
Male	0.5	657	57.16
Nandoli	0.5	460	24.24
Nivale	0.5	470	20.04
Siddheshwar	0.5	513	34.55
Vetti	0.5	390	17.72
Zolambi	0.5	391	18.74

Annexure 1. Occurrence and importance value of species encountered in the study area

Species	Locality[#]										Density	Occurrence	Basal area (m^2)	SIV
	A	AL	D	G	M	N	NA	S	V	Z				
Memecylon umbellatum Burm. f.	0	49	182	31	283	48	221	81	98	164	1157	9	1820.58	49.22
Syzygium cumini (L.) Skeels	14	20	32	25	25	93	26	37	75	29	376	10	1300.22	25.42
Olea dioica Roxb.	1	23	1	4	79	10	63	3	35	43	262	10	498.99	14.25
Terminalia elliptica Willd.	90	7	0	2	0	1	39	0	4	13	156	7	649.25	12.49
Catunaregam spinosa (Thunb.) Tirveng	17	5	49	25	2	44	15	2	20	17	196	10	141.63	8.91
Lagerstroemia microcarpa Wight	21	8	18	2	4	14	3	2	4	1	77	10	364.76	8.43
Terminalia chebula Retz.	12	7	2	9	1	17	18	1	6	25	98	10	311.58	8.37
Ficus racemosa L.	0	8	1	1	1	2	0	0	6	0	19	6	560.31	8.01
Gnidia glauca (Fresen.) Gilg	18	2	32	2	7	23	11	6	20	2	123	10	57.08	6.29
Mangifera indica L.	1	4	0	1	0	8	1	6	6	8	35	8	296.05	6.16
Dimocarpus longan Lour.	0	2	0	0	8	1	0	83	0	0	94	4	265.3	6.14
Glochidion ellipticum Wight	0	4	24	13	3	26	11	3	19	7	110	9	79.69	5.94
Xantolis tomentosa (Roxb.) Raf.	0	23	0	8	15	0	2	3	3	5	59	7	199.7	5.44
Careya arborea Roxb.	9	10	1	1	0	4	3	0	4	10	42	8	160.49	4.9
Bridelia retusa (L.) Sperng.	18	6	6	3	0	10	4	1	4	4	56	9	76.91	4.62
Emblica officinalis Gaertn.	4	7	1	0	0	12	4	0	15	23	66	7	93.75	4.49
Heterophragma quadriloculare (Roxb.) K. Schum.	0	1	0	1	8	0	3	1	0	4	18	6	205.41	4.25
Carallia brachiata (Lour.) Merr.	0	0	7	0	32	0	0	5	0	0	44	3	213.07	4.12
Ficus sp.	0	1	0	0	0	1	0	1	0	1	4	4	248.09	3.81
Wendlandia thyrsoidea (R.&S.) Steud.	2	0	1	0	0	71	0	16	0	0	90	4	49.14	3.76
Mallotus phillipinensis (Lam.) Muell.-Arg.	0	10	0	5	11	0	4	13	1	1	45	7	53.66	3.57
Terminalia bellirica (Gaertn.) Roxb.	2	6	0	0	0	0	1	0	0	0	9	3	222.84	3.39
Holigarna grahamii (Wight) Kurz	0	61	0	0	2	0	0	4	0	0	67	3	90.38	3.37
Psychotria truncata Wall.	0	0	0	0	84	0	0	0	22	0	106	2	24.87	3.34
Meyna laxiflora Robyns	13	5	3	3	0	8	3	0	2	0	37	7	34.8	3.18
Atalantia racemosa Wight	0	0	16	3	1	1	4	12	1	0	38	7	30.83	3.16
Actinodaphne angustifolia Nees	0	0	8	1	6	1	4	4	3	0	27	7	46.7	3.06
Allophylus cobbe (L.) Raeusch	1	1	7	1	0	2	4	1	1	1	19	9	6.21	3
Nothapodytes nimmoniana (J. Grah.) Mabberley	0	50	0	0	2	0	1	0	2	0	55	4	32.7	2.76
Flacourtia montana Grah.	19	1	2	0	0	5	3	0	1	0	31	6	22.42	2.63
Canthium dicoccum (Gaertn.) Teijsm. & Binn.	0	3	1	0	0	1	0	6	8	10	29	6	22.35	2.58
Litsea josephii S.M. Almeida	0	0	0	0	48	0	0	9	0	0	57	2	64.02	2.58
Garcinia talbotii Raiz. ex Sant.	0	0	0	0	4	1	0	36	0	0	41	3	69.73	2.54
Macaranga peltata (Roxb.) Muell.-Arg.	3	7	2	0	0	5	2	1	0	0	20	6	29.97	2.45
Diospyros montana Roxb.	0	3	5	1	0	2	4	0	0	2	17	6	34.35	2.42
Nothopegia castaneifolia (Roth) Ding Hou	0	23	0	1	1	0	0	2	0	2	29	5	22.64	2.31
Cinnamomum verum J.S. Presl	0	0	1	0	7	1	0	8	11	0	28	5	23.18	2.29
Bridelia scandens (Roxb.) Willd.	1	1	1	0	0	10	0	0	2	3	18	6	17.34	2.26
Myristica malabarica Lam.	0	0	0	0	2	0	0	16	0	0	18	2	116.2	2.2
Bombax ceiba L.	8	2	0	0	0	0	0	0	0	0	10	2	128.91	2.15
Casearia championii Thwaites	9	0	9	0	0	4	0	1	2	0	25	5	9.72	2.08
Callicarpa tomentosa (L.) Murr.	3	1	0	0	3	4	0	3	0	0	14	5	17.8	1.9
Diospyros nigrescens (Dalz.) Sald.	0	0	1	0	0	5	0	26	0	0	32	3	17.62	1.77
Diospyros ebenum Koen. ex Retz.	0	0	9	0	0	1	0	11	0	0	21	3	37.9	1.73
Symplocos racemosa Roxb.	0	0	0	0	0	3	0	33	0	0	36	2	30.66	1.73
Butea monosperma (Lam.) Taub.	12	0	0	0	0	4	0	0	0	0	16	2	60.74	1.57
Acacia auriculiformis A. Cunn. Ex. Bth.	26	0	0	0	0	0	0	0	0	0	26	1	56.22	1.49
Clausena anisata (Willd.) Hook. f. ex Bth.	0	3	5	1	0	2	0	0	0	0	11	4	11.73	1.49
Cassia fistula L.	6	0	2	0	0	3	0	0	0	1	12	4	8.81	1.48
Drypetes venusta (Wight) Pax & Hoffm.	0	0	0	0	0	0	0	28	0	0	28	1	44.7	1.41
Tabernaemontana alternifolia (Roxb.) Nicols. & Suresh	0	0	8	0	0	9	0	0	1	0	18	3	11.95	1.38
Ficus amplissima J. E. Sm.	0	0	4	0	0	1	0	2	0	0	7	3	34.87	1.36
Ziziphus rugosa Lam.	0	0	0	3	0	0	1	0	4	1	9	4	3.32	1.35
Chionanthus mala-elengi (Dennst.)	0	15	0	0	0	0	0	0	0	7	22	2	22.28	1.31

(*Contd*)

Annexure 1. (*Contd*)

Species	Locality[#]										Density	Occurrence	Basal area (m^2)	SIV
	A	AL	D	G	M	N	NA	S	V	Z				
Strombosia ceylanica Gardn.	0	13	0	0	0	0	1	1	0	0	15	3	12.3	1.31
Ficus tsjahela Burm. f.	0	0	0	0	0	1	1	2	0	0	4	3	32.43	1.26
Neolamarckia cadamba (Roxb.) Bosser	0	0	0	0	0	3	0	0	0	0	3	1	67.66	1.06
Ficus microcarpa L. f.	0	1	0	0	0	2	0	0	0	0	3	2	36.08	1
Grewia tiliifolia Vahl	3	0	0	0	0	1	1	0	0	0	5	3	3.8	0.99
Ficus exasperata Vahl	1	0	1	0	0	1	0	0	0	0	3	3	4.16	0.94
Maytenus rothiana (Walp.) Lobreau-Collen	0	0	0	0	2	1	1	0	0	0	4	3	0.88	0.93
Mimusops elengi L.	0	0	1	0	0	1	0	1	0	0	3	3	3.25	0.93
Aglaia elaeagnoidea (A. Juss.) Bth.	0	3	0	0	0	0	0	1	0	0	4	2	10.09	0.75
Caryota urens L.	0	6	0	0	0	0	0	0	0	0	6	1	31.1	0.75
Flacourtia latifolia (Hook. f. & Thoms) T. Cooke	0	0	0	2	0	0	0	0	4	0	6	2	3.9	0.73
Syzygium rubicundum Wight & Arn.	0	0	0	0	0	0	0	2	0	0	2	1	37.12	0.71
Syzygium phillyraeoides (Trim.) Sant.	0	0	0	0	0	0	0	6	0	0	6	1	26.84	0.7
Dillenia pentagyna Roxb.	1	1	0	0	0	0	0	0	0	0	2	2	3.31	0.63
Ixora nigricans R. Br. ex Wight & Arn.	0	1	0	0	0	0	0	2	0	0	3	2	0.66	0.63
Leea indica (Burm. f.) Merr.	0	2	0	0	0	0	1	0	0	0	3	2	0.61	0.63
Meiogyne pannosa (Dalz.) Sinclair	0	1	0	0	0	0	0	1	0	0	2	2	0.53	0.6
Persea macrantha (Nees) Kosterm	0	0	0	0	0	0	0	7	0	0	7	1	9.76	0.55
Prunus ceylanica (Wight) Miq.	0	0	0	0	1	0	0	0	0	0	1	1	19.81	0.51
Eucalyptus globulus Labill.	3	0	0	0	0	0	0	0	0	0	3	1	12.77	0.48
Ficus virens Ait	0	0	0	0	0	0	0	1	0	0	1	1	15.83	0.47
Beilschmiedia dalzelli (Meiss.) Kosterm.	0	0	0	0	0	0	0	3	0	0	3	1	10.9	0.46
Cordia dicotoma Forst. f.	2	0	0	0	0	0	0	0	0	0	2	1	13	0.46
Anogeissus sp.	0	6	0	0	0	0	0	0	0	0	6	1	3.27	0.45
Dimorphocalyx lawianus (Muell.-Arg.) Hook. f.	0	0	0	0	0	0	0	6	0	0	6	1	3.15	0.45
Syzygium sp.	0	0	0	0	2	0	0	0	0	0	2	1	11.88	0.45
Bridelia sp.	0	2	0	0	0	0	0	0	0	0	2	1	8.91	0.42
Eugenia corymbosa Lam.	0	0	0	0	0	0	0	1	0	0	1	1	10.41	0.41
Artocarpus hirsutus Lam.	0	0	0	0	0	0	0	1	0	0	1	1	6.27	0.37
Murraya paniculata (L.) Jack	0	0	0	0	3	0	0	0	0	0	3	1	1.9	0.37
Xylia xylocarpa (Roxb.) Taub.	1	0	0	0	0	0	0	0	0	0	1	1	5.46	0.36
Murraya koenigii (L.) Spr.	0	0	3	0	0	0	0	0	0	0	3	1	0.74	0.35
Grewia nervosa (Lour.) Panigr.	0	1	0	0	0	0	0	0	0	0	1	1	3.58	0.34
Diospyros sp.	0	0	0	0	0	0	0	2	0	0	2	1	0.79	0.33
Diospyros sylvatica Roxb.	0	0	0	0	0	0	0	2	0	0	2	1	0.47	0.33
Holarrhena pubescens (Buch.-Ham.) Wall.	2	0	0	0	0	0	0	0	0	0	2	1	1.07	0.33
Erythrina suberosa Roxb.	0	0	1	0	0	0	0	0	0	0	1	1	2.09	0.32
Garuga pinnata Roxb.	1	0	0	0	0	0	0	0	0	0	1	1	2.26	0.32
Homalium ceylanicum (Gardn.) Bth.	0	0	0	0	0	0	0	1	0	0	1	1	1.71	0.32
Moullava spicata (Dalz.) Nicols.	0	1	0	0	0	0	0	0	0	0	1	1	1.71	0.32
Pterocarpus marsupium Roxb.	1	0	0	0	0	0	0	0	0	0	1	1	2.09	0.32
Lannea coromanedelica (Houtt.) Merr.	0	1	0	0	0	0	0	0	0	0	1	1	0.65	0.31
Woodfordia fruticosa (L.) Kurz	0	1	0	0	0	0	0	0	0	0	1	1	0.84	0.31
Alseodaphne semicarpifolia Nees	0	1	0	0	0	0	0	0	0	0	1	1	0.34	0.3
Cipadessa baccifera (Roth.) Miq.	0	1	0	0	0	0	0	0	0	0	1	1	0.41	0.3
Elaeagnus conferta Roxb	0	0	0	0	0	0	0	0	0	1	1	1	0.28	0.3
Ixora lanceolaria Colebr.	0	1	0	0	0	0	0	0	0	0	1	1	0.17	0.3
Neolitsea cassia (L.) Kosterm	0	0	0	0	1	0	0	0	0	0	1	1	0.34	0.3
Osyris quadripartita Salz. ex Dence.	0	0	0	0	0	0	0	0	0	1	1	1	0.52	0.3
Schleichera oleosa (Lour.) Oken	0	0	1	0	0	0	0	0	0	0	1	1	0.22	0.3
Scutia myrtina (Burm. f.) Kurz	0	0	0	0	0	0	0	0	0	1	1	1	0.25	0.3
Securinega leucopyrus (Wild.) Muella.-Arg.	0	0	0	0	0	0	0	0	1	0	1	1	0.31	0.3
Trema orientalis (L.) Bl.	0	1	0	0	0	0	0	0	0	0	1	1	0.28	0.3
Total	325	423	448	149	648	468	460	507	385	387	4200		9483.59	300

[#]A, Amboli; AL, Aloli; D, Dhakle; G, Gave; M, Male; N, Nivale; NA, Nandoli; S ,Siddheshwar; V, Vetti; Z, Zolambi.
*Endemic species of the Western Ghats[23].

Annexure 2. Addendum to woody species list of CNP

Mammea suriga (Buch.-Ham. ex Roxb.) Kosterm.
Garcinia indica (Thou.) Chois.
Spondias pinnata (L.f.) Kurz
Embelia ribes Burm. f.
Albizia chinensis (Osb.) Merr.
Bridelia hamiltoniana Wall. ex Muell.-Arg.[#]
Zanthoxylum rhetsa (Roxb.) DC.
Litsea deccanensis Gamble
Agrostistachys indica Dalz.
Ziziphus zylopyra (Retz.) Willd.
Ficus arnottiana (Miq.) Miq.
Gnetum ula Brongn.
Pongamia pinnata (L.) Pierre
Garcinia xanthochymus Hook. f. ex T. And.[#]
Maytenus senegalensis (Lam.) Excell

[#]Species recorded by Mahajan and Vaidya[18].

Species attributes

A list of species with their various ecological attributes is given in Table 2. These include endemism status, habit (evergreen/deciduous), preferred habitat (e.g. climax/ pioneer) and utility value (medicinal, timber, fuelwood, edible, etc.). Out of the total 107 woody plant species recorded on the transects, 16% belonged to the climax forest and 56% was of human utilitarian value.

Basal area distribution

The girth class distribution from pooled data shows a typical L-shaped curve, indicating the undisturbed nature of the forests (Figure 4). We compared the basal area distribution patterns of the present study with those conducted by Rai and Proctor[30] from rainforests of Karnataka (Table 3). Interestingly, though the density recorded during the present study was on lower side, basal area was comparable with the forest sites from SWGs. The basal area varied from 10.22 m^2/ha at the disturbed sites to 57.16 m^2/ha at the comparatively undisturbed sites. These values are more or less in comparison with the lowland rainforests of Africa (23–37 m^2/ha)[31], South America (30–40 m^2/ha)[32] and Sarawak (28–57 m^2/ha)[33].

Conclusion

Lack of uniform methodology has always been a concern for drawing meaningful insights into outlining structural complexities leading to conservation strategies. In the wake of the ever increasing forest loss, such studies highlighting distribution of plant resources at an entire Western Ghats eco-region will be vital. Besides, application of standard methodology will help in analysing and interpreting data at larger spatial scale.

Forests at the CNP possess high level of diversity comparable to species-rich forests from SWGs. We have also recorded a new subtype (*Memecylon–Syzygium–Olea*) of the already existing floristic series in the literature. Though the expanse of the CNP is less than 1% of the geographical area of Maharashtra, it supports nearly 30% of the total number of woody species recorded from the Western Ghats of Maharashtra. Understorey species contribute to the 38% of the total species diversity. Canopy species contribute more to human utility compared to the understorey species. Undisturbed patches of evergreen forests at Siddheshwar and Male though very small in expanse, are the origin of many perennial streams and river Varana, besides having high proportion of endemic species, thereby making the conservation of such tracts important.

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ACKNOWLEDGEMENTS. We thank the Department of Biotechnology, New Delhi, for financial support. We also thank the two anonymous referees for critically evaluating the manuscript. Thanks are also due to Mr Majumdar, PCCF (WL), Maharashtra; Mr Saiprakash, CF, Working Plan, Aurangabad; Mr M. K. Rao, CF (WL), Kolhapur and Mr Zure, RFO, CNP for their cooperation. Dr Milind Sardesai helped in the identification of the specimens. We thank Dr R. Ganesan who critically commented on the manuscript. We also thank our colleagues, Shantanu Shukla, S. Raghavendra, M. Chandrasekar, Jahnavi Joshi, Kedar Champhekar, Shamika Mone, Sarita Bhawalkar, Rujuta Bhagwat and Aditi Sancheti for help during on-field data collection.

Received 10 January 2008; revised accepted 9 July 2008