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Tree species composition in Koyna Wildlife Sanctuary, Northern Western Ghats of India

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We established belt transects of 1000 m × 5 m in Koyna Wildlife Sanctuary at 12 different localities, to study tree species diversity. A total of 4296 individuals of girth at breast height (GBH) ≥ 15 cm were enumerated belonging to 108 species. A subtype of *Memecylon–Syzygium–Olea* was identified based on dominance from the area previously ascribed to *Memecylon–Syzygium–Actinodaphne* floristic series. Out of 41 families, Melastomataceae, Myrtaceae and Moraceae were found to be dominant families according to the Family Importance Value. Shannon index (H') ranged from 1.5 to 3.03. Taxonomic diversity measured for each sampled locality using normalized simple Avalanche index showed variation between 0.104 and 1.00 and positive correlation with H' . Rarity score for identifying unique tree species composition correlated positively with simple avalanche index. Evergreen forest of *Navja* and *Ozarade* together showed highest population of IUCN-listed tree species. This study shall pave the way for the subsequent ecological research in this area which has recently been declared as a World Natural Heritage Site by UNESCO.

Keywords: Koyna Wildlife Sanctuary, *Memecylon–Syzygium–Olea*, rarity score, simple Avalanche index.

WESTERN Ghats (WGs), one of the 34 global biodiversity hotspots¹, shows remarkable variation in rainfall, dry period length, forest cover and temperature which ultimately govern spatial pattern of its biodiversity. Northern parts of Western Ghats of Maharashtra (NWGs) experience dry period up to 6–8 months² resulting in a peculiar vegetation from evergreen forest in river valleys to highly endemic herbaceous vegetation on the plateaus. Other than few studies^{2–4}, there are no attempts to quantitatively assess the diversity and vegetation composition of NWGs. In contrast, Southern Western Ghats (SWGs) are more explored for vegetation composition, structure and

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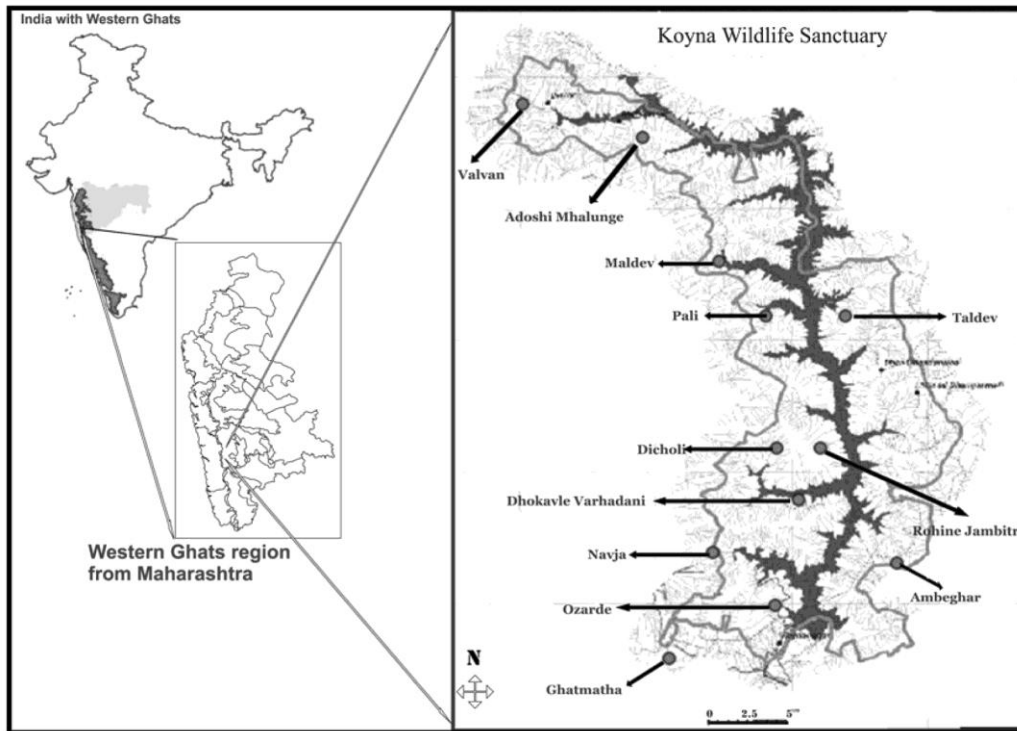


Figure 1. Koyna Wildlife Sanctuary map showing sampled localities (source: Koyna WLS map)¹⁰.

disturbance in Protected Areas (PAs)^{5,6}, on forest fragmentation; plant species composition and effect of climatic gradient on plant diversity⁷⁻⁹.

The present study focused on tree species diversity, composition and population structure in Koyna Wildlife Sanctuary (Koyna WLS) of NWGs, which received recognition as a World Natural Heritage Site by UNESCO¹⁰, gaining conservational importance besides being a part of Sahyadri Tiger Reserve.

NWG in Maharashtra state ranging approximately from lat. 15°30'N–20°30'N and long. 73°–74°E, constitutes about one-third of the total length of WGs. This part of WGs experiences longer dry period of 6–8 months as compared to SWGs. Precipitation, mostly due to monsoon, ranges from 2000 to 7000 mm, and decreases as one moves northwards². This zone is covered with lateritic soil till 18°30'N and brown–black soil further north. Rocky plateaus with ephemeral flush vegetation is the characteristic feature of the NWGs. Heavy anthropogenic pressures have fragmented forest in the patches along the rivers, valleys and in informally and formally conserved areas. This study was carried out during 2007–2008 as part of a national level project entitled, 'Mapping and quantitative assessment of geographic distribution and population status of plant resources of Western Ghats', supported by the Department of Biotechnology of Government of India.

Koyna WLS, one of the largest protected areas of Maharashtra, is located in Satara District of Maharashtra (Figure 1). It covers an area of 423.55 sq. km along the

backwaters of 'Shivsagar' (Koyna) Dam. WLS is spread mainly in north–south direction and forms a large corridor between Mahabaleshwar–Pachgani Ecologically Sensitive Area (declared in 2001) in the north and Chandoli National Park (Chandoli NP) in the south. Mean annual rainfall of WLS is around 5000 mm during June–September. Main soil type is red clay. The vegetation in Koyna WLS is classified as Southern Tropical Evergreen Forest and Southern Moist Mixed Deciduous Forest¹¹. These forests are interspersed with grassland harbouring herb diversity in monsoon. Previously occupied private forests and human habitation now exist as grasslands and scrub and/or moist deciduous forests. Owing to its relative inaccessibility and undulating terrain, the sanctuary supports some of the remaining tall evergreen undisturbed forests in the NWGs and hosts important mammals such as *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Cuon alpinus* (wild dogs), *Melursus ursinus* (sloth bear), *Bos gaurus* (Indian gaur), *Cervus unicolor* (sambar), *Tragulus meminna* (mouse deer) and *Muntiacus muntjak* (barking deer). *Pedostibes tuberculosa*, an endemic anuran can be seen in Koyna WLS.

The entire area of Koyna WLS was divided into 12 grids of 6.25 km × 6.25 km each. For a representative sample, a belt transect of 1000 m × 5 m was laid in each of the grids covering 0.01% of total grid area¹². The total area sampled was 6 ha. These transects were so laid as to cover landscape heterogeneity and were identified by their locality name which were used for further analysis. GPS location was marked for each transect. All trees with

Table 1. Summary of the tree diversity across localities

Locality name	Main forest type*	Number of species	Number of individuals**	Number of endemic species	Number of species with IUCN status	Basal area (m ² /ha)
Ghatmatha	MD	35	274	8	5	31.43
Ozarade	EVG	39	242	11	8	58.23
Ambeghar	SCRB	14	84	2	0	6.76
Navja	EVG	37	488	10	6	55.96
Dhokavle–Varhadni	EVG	23	389	4	2	43.43
Dicholi	EVG	38	462	6	6	52.02
Rohine–Jambhitri	EVG	42	496	10	5	33.46
Taldev	SEVG	32	311	8	5	15.71
Pali	EVG	37	544	8	5	36.11
Maldev	SEVG	38	456	5	4	32.54
Adoshi–Mhalunge	SEVG	28	251	5	4	23.02
Valvan	SEVG	29	299	6	5	33.5

*MD, Moist deciduous; EVG, Evergreen; SCRБ, Scrub; SEVG, Semi-evergreen. **Number of individuals per 0.5 ha.

girth at breast height (GBH) ≥ 15 cm were measured for its GBH and height across the transect, and identified in the field and the unidentified specimens were photographed, collected and identified later with the help of taxonomic literature¹³ and experts.

Sampled area can be classified as evergreen, semi evergreen, moist deciduous and scrub^{2,11,14}. Endemic and IUCN Red list status to the species were assigned^{14–16}. Two basic indices were calculated for vegetation analysis: species importance value (SIV) or importance value index (IVI) for species and family importance value (FIV) for families⁵.

IVI was calculated as: IVI = relative frequency + relative density + relative dominance.

FIV was calculated as: FIV = relative density + relative diversity + relative dominance.

Shannon’s diversity index (H') was calculated for each locality. Rarity score of each locality was calculated to gain insights into their unique tree species diversity. It was calculated as

$$\text{Rarity score} = \sum_{1 < i \leq N} 1/c_i,$$

where c_i is the number of grids (0.5 ha) occupied by species i and N is the number of species found in that particular grid¹⁷.

Taxonomic diversity of the area was calculated using avalanche index (AI)¹⁸. AI has two components: the distances among species of the community at taxonomic level and relative abundance of the species. We used only first component of the index which has been called as simple avalanche index (SAI).

SAI is calculated as follows

$$\text{SAI} = \sum_i^S d_{ij},$$

where S is the total number of species in given locality and d_{ij} is the distance between i th and j th species.

For further data analysis, SAI of each locality was normalized by dividing each by highest SAI value among 12 localities and for ease of understanding it was indicated as SAI only. APG III classification system was followed to calculate the taxonomic distance between species.

A total of 108 tree species were recorded from 6 ha of Koyna WLS. Species richness varied from 14 (Ambeghar scrub forest) to 42 species (Rohine–Jambhitri evergreen forest; Table 1). A total of 4296 individuals were encountered from 41 families with highest (544 individuals/0.5 ha) in evergreen forest of Pali and lowest (84 individuals/0.5 ha) in scrub forest of Ambeghar. Five most abundant species were *Memecylon umbellatum*, *Syzygium cumini*, *Xantolis tomentosa*, *Holigarna grahamii* and *Olea dioica*. SIV calculated showed *M. umbellatum*, *S. cumini* and *O. dioica* as three most dominant species of the study area followed by typical evergreen forest species *Dimocarpus longan* and secondary forest member, *X. tomentosa*.

FIV revealed Melastomataceae, Myrtaceae and Moraceae to be the most dominant families. Euphorbiaceae and Moraceae were found to be the most species-rich families represented by 10 species each (Figure 2). Eighteen families encountered during the study were represented by only one species which also included Sapindaceae family represented by one of the dominant species, *D. longan*. Melastomataceae incorporating two species, was recorded as the most dominant family due to presence of *M. umbellatum* which formed 34% of total number of individuals encountered during the study.

Twenty-one tree species endemic to Western Ghats were encountered which were represented by 656 individuals ([Annexure 1; See Supplementary Information online](#)). Endemic species richness varied from two species in scrub forest of Ambeghar to 11 species in evergreen forest of Ozarade. Thirteen species of various IUCN categories were recorded (Table 2), of which *Nothopegia castaneifolia* (status: critically endangered) was found in 8 out of 12 localities, while *Prunus ceylanica*

Table 2. IUCN listed species encountered in the study area

Species	IUCN status	Number of individuals
<i>Nothopegia castanaefolia</i>	Critically endangered	32
<i>Prunus ceylanica</i>	Endangered	4
<i>Canthium dicoccum</i>	Vulnerable	12
<i>Dimocarpus longan</i>	Lower risk/near threatened	146
<i>Tabernaemontana heyneana</i>	Lower risk/near threatened	3
<i>Holarrhena pubescens</i>	Least concern	5
<i>Aglaia lawii</i>	Lower risk/least concern	37
<i>Aglaia elaeagnoidea</i>	Lower risk/least concern	7
<i>Chukrasia tabularis</i>	Lower risk/least concern	1
<i>Knema attenuata</i>	Lower risk/least concern	1
<i>Myristica dactyloides</i>	Lower risk/conservation dependent	77
<i>Mangifera indica</i>	Data deficient	64
<i>Diospyros ebenum</i>	Data deficient	37

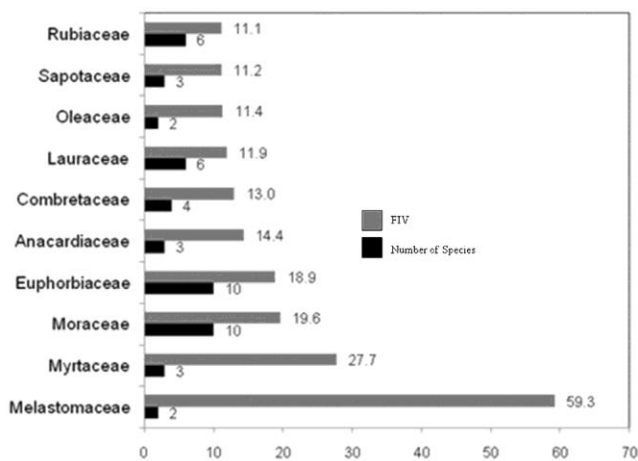


Figure 2. Family dominance based on species richness and family importance value of pooled data.

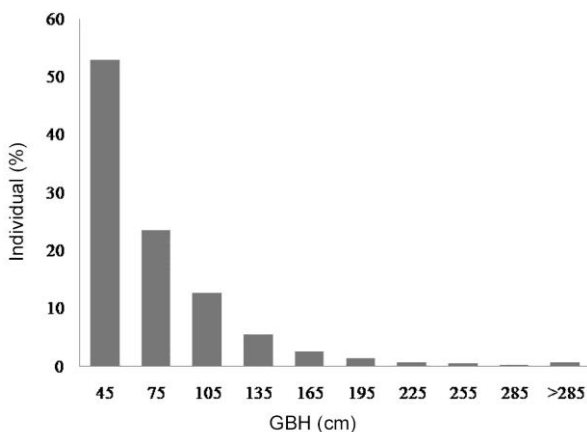


Figure 3. GBH size class distribution of the pooled data.

(status: endangered) was found only at Ghatmatha. *Canthium dicoccum* (status: vulnerable) was found to be distributed in all types of forests except scrub forest. The forests at Navja and Ozarde harboured 8 (out of 13) IUCN listed species and 50% of its total population.

Girth class distribution of 4296 individuals showed typical ‘L’ shaped curve indicating in general the undisturbed nature of forest sampled (Figure 3). Similar pattern was observed when population structure of evergreen, semi evergreen, moist deciduous and scrub forest were considered separately. Basal area showed variation from 6.76 sq. m/ha of scrub forest of Ambeghar to 58.23 sq. m/ha of evergreen forest of Ozarade.

Shannon diversity index varied from 1.5 in Dhokavale–Varhadni to 3.03 in Ozarade (Table 3). Taxonomic diversity for each locality was carried out using SAI that accounts for diversity at seven taxonomic levels.

Significant positive correlation was found between Shannon diversity index and SAI ($r = 0.773$) (Figure 4).

Species-rich evergreen forest of Rohini–Jambhriti showed highest SAI (1.00), which indicates higher diversity at different taxonomic levels compared to tree species community at other locations. Lowest SAI was recorded for Ambeghar scrub forest (0.104). SAI showed highly significant positive correlation with species richness ($r = 0.984$) and endemic richness of the locality ($r = 0.802$). Rarity score of the evergreen forest of Ozarade was found to be highest (12.4), while Ambeghar scrub forest showed lowest (3.10). Taxonomic diversity, SAI, showed positive relation with rarity score, $r = 0.908$ (Figure 5).

This study showed variation in species richness from minimum of 14 to maximum of 42 per 0.5 ha. Studies in Chandoli NP³ following similar methodology recorded 25–57 species per 0.5 ha where liana and shrubs were also considered. The stand density of Koyna WLS was between 84 and 544 individuals per 0.5 ha sampled as against 149–657 individuals per 0.5 ha of Chandoli NP³.

The mid-elevation tracts of NWGs are classified under *Memecylon–Syzygium–Actinodaphne* (M–S–A) type of floristic study^{14,19}. The vegetation composition studies in Chandoli NP³ emphasized the poor representation of *Actinodaphne angustifolia* and identified a new subtype *Memecylon–Syzygium–Olea*. This study also identified the same subtype, i.e. *Memecylon–Syzygium–Olea* due to

Table 3. Diversity indices of the localities

Locality name	Number of species	Shannon index (H')	Simple avalanche index	Simple avalanche index (normalized)*	Rarity score
Ghatmatha	35	2.68	3079	0.66	8.22
Ozarade	39	3.03	3847	0.82	12.4
Ambeghar	14	1.66	486	0.10	3.1
Navja	37	2.95	3661	0.78	11.36
Dhokavle–Varhadni	23	1.5	1300	0.28	5.41
Dicholi	38	1.95	3612	0.77	9.38
Rohine–Jambhatri	42	2.59	4687	1.00	12.09
Taldev	32	2.24	2558	0.55	10.94
Pali	37	2.64	3581	0.76	11.08
Maldev	38	2.4	3709	0.79	10.34
Adoshi–Mhalunge	28	2.17	1990	0.43	5.34
Valvan	29	2.1	2186	0.47	8.34

*Normalized values of SAI used for data analysis.

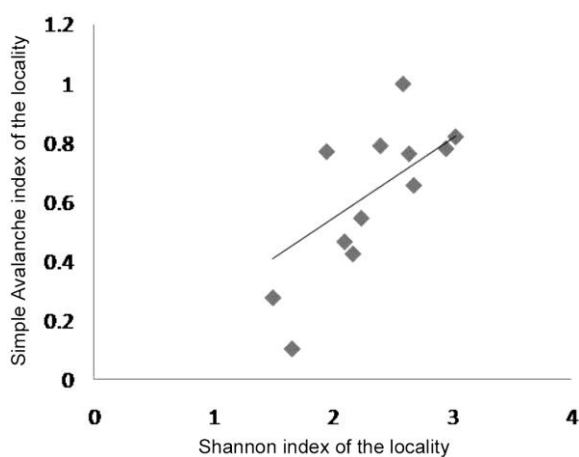


Figure 4. Relation between Shannon diversity index and simple avalanche index ($r = 0.773$).

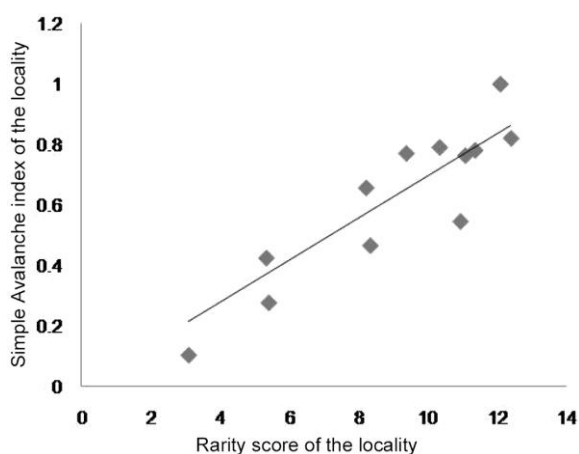


Figure 5. Relation between normalized simple avalanche index and rarity score of the locality ($r = 0.908$).

under-representation of *A. angustifolia* (34 individuals out of 4296; SIV = 3.71) and dominance of *O. dioica* (SIV = 11.71). Plant assessment studies in mid-elevation

evergreen forest of Kalakad Mundanthurai Tiger Reserve of WGs also suggested a new subtype to original plant series as a result of total absence of one of the plant species in the preexisting series⁵. Watve *et al.*⁴ identified *Memecylon–Xantolis–Actinodaphne* type in addition to typical M–S–A series of semi-evergreen forests of Mulshi from NWGs and also revealed non-*Memecylon* communities with dominance of *D. longan* of small girth sizes indicating growth after moderate disturbance to climax forest community. Patchy vegetation of Mulshi recorded dominance of typical evergreen forest species such as *H. grahamii* and *Aglaia* sp., which suggests an origin from community differing in composition from typical M–S–A community⁴. This study recorded abundance of *D. longan* and *H. grahamii*, especially in evergreen forests, which might occur due to presence of undisturbed evergreen forest community. Limited accessibility to various forest patches due to ‘Shivsagar’ dam backwater since decades might have played an important role in maintenance of healthy evergreen forest patches in Koyna WLS. The evergreen forests of Ozarade (near Ozarade Waterfall) is the only location where one can come across adult and regenerating individuals of *Canarium strictum* Roxb., which is seldomly seen elsewhere in the entire NWGs of Maharashtra. Species such as *Turpinia pomifera* and *Chrysophyllum roxburghii* also find refuge here; whereas, Navja forest tracts showed healthy and pocketed population of Red-listed *Embelia ribes* Burm.f. Change in sequence of dominance of the plant community in certain areas might be the result of continuous changes in the original community due to natural and/or human-made disturbance.

Families namely Melastomataceae, Myrtaceae and Moraceae were found to be dominant in Koyna WLS, whereas Chandoli NP³ recorded Melastomataceae, Myrtaceae and Euphorbiaceae as dominant families according to FIV. Ganesh *et al.*⁵ found Euphorbiaceae, Bombacaceae and Lauraceae as dominant families in mid-elevation tracts in PA of SWGs. The most diverse families were

Euphorbiaceae and Moraceae with 10 species and dominance of Melastomataceae was mainly governed by the stand density of *M. umbellatum*. GBH distribution of pooled data showed 'L' shaped curve similar to forest of Chandoli NP³ and patchy vegetation of Mulshi⁴. The low density of higher girth classes indicated early seral stages of communities⁴. The basal area variation in this study (6.76–58.23 sq. m/ha) was found to be comparable with Chandoli (10.22–57.16 sq. m/ha)³. Vegetation studies of forest patches in Mulshi⁴ recorded basal area in the range of 14.5 to 72.9 sq. m/ha. Species level diversity was revealed by Shannon index while biological heterogeneity among species (considering seven taxonomic levels) was revealed by SAI. SAI values of the localities showed a positive correlation with the species richness and endemic species richness. Endemic species richness reflected subsequent increase in the SAI value, which substantiates that endemic species are geographically restricted ones which add to the biological heterogeneity of the area. Rarity score was calculated to gain insights into an area which harboured species that occurred less frequently/rarely across the area sampled. The rarity scores thus achieved showed a positive correlation with the SAI value which suggest contribution of rare species composition in taxonomic heterogeneity within the community.

Koyna WLS along with Chandoli NP forms part of Sahyadri Tiger Reserve (STR) and was recently declared as a World Natural Heritage Site¹⁰. *Ozarde* and some areas of *Navja* belong to the 'tourism zone' of STR. In a country such as India where tourism is oriented primarily towards charismatic wildlife such as tiger, elephant or one horned rhinosorus, Koyna WLS in general and *Ozarde* and *Navja* forest beats in particular can provide excellent opportunity for directed and planned 'rare plant species tourism'. Koyna WLS and similar forests depict *in situ* conservation of natural habitats, which entail detailed scientific studies of such areas. Such studies then become even more imperative in the under-studied areas.

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