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M. Tadwalkar, A. Joglekar, M. Mhaskar & A. Patwardhan

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COMMUNICATION

Woody species diversity from proposed ecologically sensitive area of northern Western Ghats: implications for biodiversity management

M. Tadwalkar [1], A. Joglekar [2], M. Mhaskar [3] & A. Patwardhan [4]

[1,2,4] Annasaheb Kulkarni Department of Biodiversity, M.E.S. Abasaheb Garware College, Karve Road, Pune, Maharashtra 411004, India.
[1,2,3,4] Research and Action in Natural Wealth Administration (RANWA), 16 Swastishree Society, Ganeshnagar, Kothrud, Pune, Maharashtra 411052, India.
[1] himedhavi@gmail.com, [2] amrutamjoglekar@gmail.com, [3] monali.mhaskar@gmail.com,
[4] ankurpatwardhan@gmail.com (corresponding author)

Abstract: The Western Ghats of India support an array of tropical forests ranging from wet evergreen to scrub formations. Several endemic and threatened plant species are located in areas other than protected areas (PAs). There is an urgent need to understand species diversity in areas other than PAs, for effective management of tropical forests. In this context, reserve forests and informal PAs of Amboli from northern Western Ghats have been investigated. Woody species composition, diversity, and stand structure were assessed by laying quadrats and transects (n=46, area=2.575ha) in closed and open canopy forest patches covering habitat heterogeneity and environmental gradient of the area. A total of 2,224 individuals (of 87 species, 68 genera, and 35 families) was enumerated. *Memecylon umbellatum*, *Syzygium cumini*, and *Diospyros nigrescens* were found to be the most dominant species as per importance value index. Melastomataceae was the most dominant family as per family importance value, whereas Euphorbiaceae and Rutaceae were the most speciose. Fourteen IUCN Red List assessed species and 18 species endemic to the Western Ghats were encountered. Endemic species accounted for nearly 20% of the total number of individuals sampled. Demographic profile exhibited reverse 'J' pattern. Average basal area was 27.02m^2 per hectare. Woody species diversity of Amboli forests was found comparable with other PAs from northern Western Ghats. Amboli and the adjoining area have been proposed as ecologically sensitive and in the wake of anthropogenic and developmental pressures they experience, it calls for urgent conservation attention.

Keywords: Endemicity, protected area comparison, species composition, stand structure

Abbreviations: BMC—Biodiversity Management Committee | DPL—Dry period length | E—Evergreen | ESA—Ecologically sensitive area | FIV—Family importance value | GBH—Girth at breast height | GPS—Global positioning system | IUCN—International Union for Conservation of Nature | IVI—Importance value index | MSL—Mean sea level | NP—National park | NWG—Northern Western Ghats | PA—Protected area | RF—Reserve forest | SWG—Southern Western Ghats | VU—Vulnerable | WG—Western Ghats | WS—Wildlife sanctuary.

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INTRODUCTION

Woody species form an important component of the forest landscape both because of their diversity and biomass. They play a vital role in shaping overall structural dynamics of the forest stands and offer various kinds of 'ecosystem services'. Of the 36 global hotspots of biodiversity, Western Ghats, extending along the western coast of India, along with Sri Lanka comprise the Western Ghats-Sri Lanka hotspot (Conservation International 2019; Myers et al. 2000). Western Ghats of India occupy the fifth position in the world in terms of economic potential of their biological resources (Ganeshaiah & Shaanker 2007). It is globally, an area of high endemism with 1,500 endemic species of which 352 are woody plant species and also houses over 4,000 medicinal plants species. WGs support an array of tropical forest types ranging from wet evergreen to scrub formations covering an area of about 1,64,284km^2 (Kasturirangan et al. 2013). Although nearly 10 percent of the Western Ghats hotspot is under formal protection, it has been pointed out that PAs in this region have historically been established on an ad-hoc basis with little attention to diversity distribution (Bhagwat et al. 2005). There is indeed a growing recognition that PAs cannot be conceived and managed as "islands" isolated from other PAs and from the rest of the landscape context (Laurance et al. 2012). Hence, there is a need to recognize high potential of informal protected areas such as sacred groves for effective conservation management (Bhagwat & Rutte 2006) that can supplement the PA diversity. The conservation management in the region needs to address the following questions: (1) do existing PAs adequately represent the biodiversity? (2) do excluded forest patches sustain more species than PAs? and (3) how many PAs are required to cover the entire gamut of biodiversity? Considering the high endemism, it is necessary and urgent to evaluate conservation potential andecosystem services of the buffer areas surrounding the PAs or other areas not included in formal PA network.

CEPF (2007) report showed that NWG have presence of more fragmented forests patches than the southern Western Ghats (SWG) and are under the pressures of selective logging, excessive grazing, fire, and road construction. Though sporadic records of quantitative inventorization of forest stands from PAs of NWG area available (Kanade et al. 2008; Joglekar et al. 2015), lack of focused studies on diversity that exists outside PAs in fragmented forests is a major challenge in understanding changes in forest community under anthropogenic impacts. Understanding the spatial distribution of these forests, their conservation significance and knowledge of vegetation types thus, becomes essential for outlining effective management strategies.

The forests of Amboli area act as a transition zone between NWG and SWG. CEPF (2007) report identified Amboli region as an irreplaceable site for certain globally threatened species that lack formal protection. Four new faunal species were described from Amboli region in a span of less than five years (Satose et al. 2018). The forests of Amboli experience high developmental pressures owing to growing tourism enterprises, necessitating conservation planning, for which exploration of the region's diversity is necessary. In this paper, we have characterized the woody species diversity, composition and stand structure of Amboli forests from relatively less explored area of NWG.

MATERIAL AND METHODS

Study area

NWGs in Maharashtra range from 15.5°–20.5°N & 73°–74°E. Popularly known as Sahyadri, the forests in this region are highly seasonal (annual rainfall range: 50–7000 mm, dry period length (DPL): 8–9 months, temperature: 10–40 ^{0}C). Amboli (MSL=700m) is located in Sawantwadi Taluka of Sindhudurg District of Maharashtra (Figure 1) in NWG. Although the area lies outside the formal PA network, it includes private forests, reserved forests and community owned forests spread across 659.88ha (Bharmal et al. 2011). Fragmented forests of Amboli form a mosaic of different vegetation and habitat types. Primary vegetation type is evergreen (closed canopy: >60% and height 15–20m), with stunted vegetation around lateritic outcrops (open canopy: 20–40%, height 5–8m) (Image 1). These together harbor endemic and threatened plant species and unique ephemeral flush vegetation that characterize lateritic plateaus. The area is proposed as ecologically sensitive (Maharashtra Government Resolution) and also forms a part of geographically and ecologically important Sahyadri-Konkan Ecological corridor (CEPF 2007).

It is the type locality of species like a Caecilian *Gegeneophis danieli* (Giri et al. 2003), Amboli Tiger Toad *Xanthophryne tigerina* (Biju et al. 2009), leaping frog *Indirana chiravasi* (Padhye et al. 2014) and water snake *Rhabdops aquaticus* (Giri et al. 2017). Biologists who studied the diversity of avifauna and Lepidoptera (Bharmal et al. 2011; Satose et al. 2018) concluded that the area is rich in biological diversity. Though the area has been explored in details for faunal diversity,

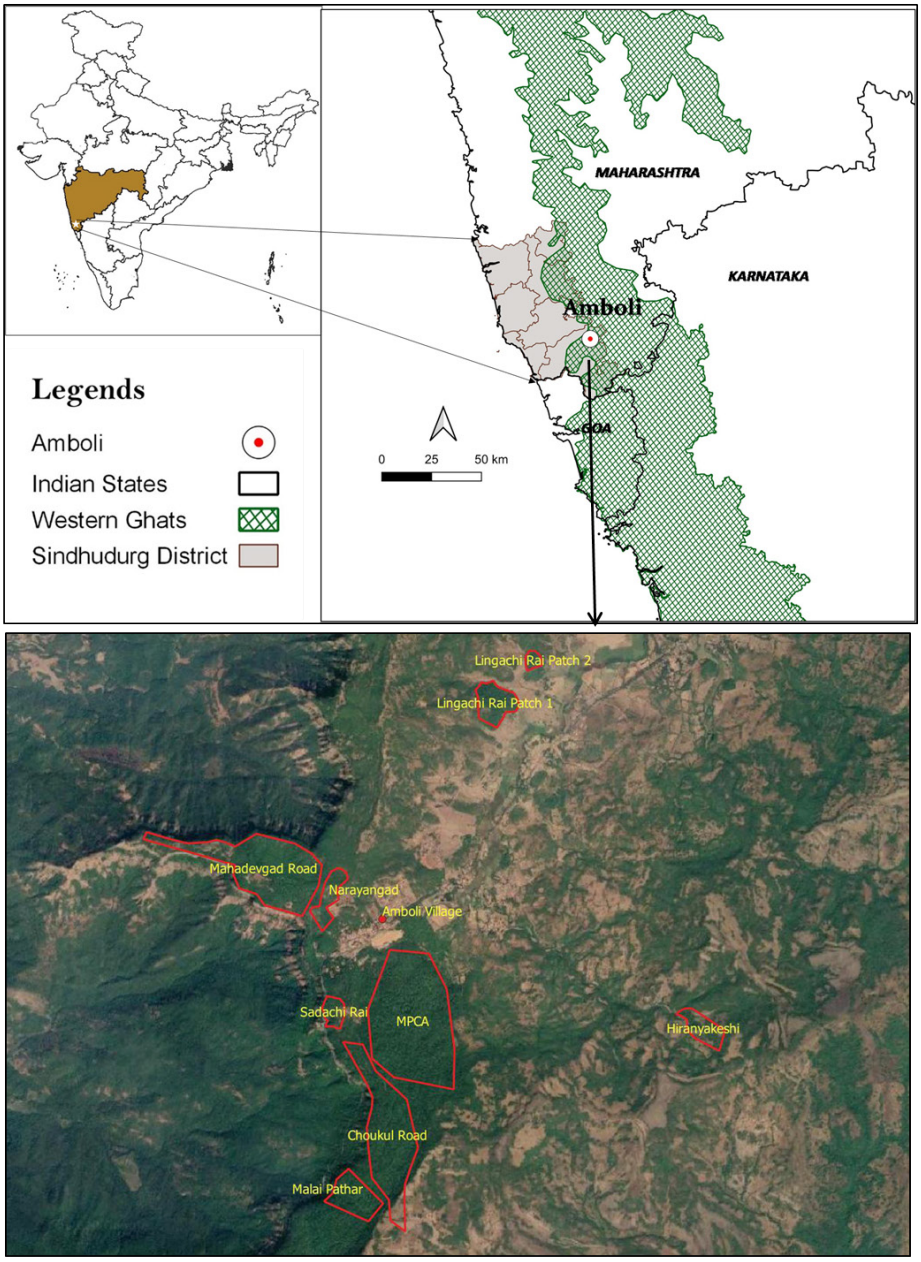

Figure 1. Study area. Source: QGIS Development Team (2019)

comprehensive taxonomic floristic studies are rare (Kulkarni 1988; Almeida 1990). There is dearth of quantitative ecological studies.

Amboli is a famous destination for tourists and naturalists alike due to picturesque landscapes, waterfalls and faunal sightings. But owing to the unplanned and unregulated tourism, the area witnesses encroachment into the forested landscapes, logging, and poorly planned construction.

Sampling design

Standard methods of woody vegetation analysis were followed (Ganesh et al. 1996; Sutherland 2006). Species composition and diversity were assessed by laying quadrats (n=40, size 20 x 20 m) and transects (n=6) in closed and open canopy forest patches covering habitat heterogeneity. It was ensured that the sampling plots cover significant environmental gradient of the area. Transect length varied from 500 x 5 m or 250 x 5 m or 200 X 5m depending on the patch size. Each quadrat and transect was marked by GPS. The total area sampled was 2.575ha and intensity of sampling amounts to 0.39% of sampling, which is more than a standard requirement of 0.01% for such enumerations (Shivraj et al. 2000).

Image 1. Habitat and disturbance in the study area: A—Evergreen forests | B—Lateritic plateaus | C—Open scrub along forest edge | D—Sacred grove | E—Expanding habitation in natural areas | F—Construction debris and littering | G—Tree cutting | H—Roadkill - snake. © Ankur Patwardhan, Medhavi Tadwalkar & Amruta Joglekar.

Vegetation composition, stand structure and diversity assessment

All woody species were enumerated for individual height and girth (≥15cm at 1.3m height above ground) measurements. Species level identification was done using regional flora (Almeida 1990; Singh et al. 2001). Endemicity and IUCN Red List status of the species were assignedby referring to standard literature (Pascal 1988; BIOTIK 2008; Singh et al. 2015; https://www.iucnredlist.org/). Data collected from quadrat and transect sampling were used to understand woody species composition and diversity. For stand structure and basal area estimates data from quadrats was used. Importance value index (IVI) and family importance value (FIV) were calculated as per Ganesh et al. (1996). For the diversity estimates, data from quadrats and transects was pooled. Diversity was estimated using Shannon's index (H') as per Magurran (2004). Compositional similarity between sampled plots was assessed by Bray Curtis similarity index calculated using PAST (version 3). Correlation analysis was performed using the R software (version 3.5.1).

RESULTS

(A) Woody species composition and diversity

A total of 2,224 individuals were sampled during the study representing 87 species spanning across 68 genera and 35 families. Genus *Diospyros* was found to be the most diverse genus with four species followed by *Ixora* and *Ficus* (represented by three species each). Fifty-six genera (82%) were represented by only one species in the sampled area. Figure 2 represents 10 most abundant genera in the sampled area with corresponding abundance.

Out of 87 species that were encountered during the study, *Memecylon umbellatum* was found to be the most abundant species in the area (N=501, 22.53%) followed by *Mallotus phillipensis*, *Syzygium cumini*, *Diospyros candolleana*, *Symplocos racemosa*, and *Diospyros nigrescens*. These six species together contributed to 56.11% of the total abundance. A long tail of singleton species was seen where, singleton species and doubleton species contributed to 24.1% (n=21) and 12.6% (n=11), respectively, to the stand structure. *Persea macrantha*, *Homalium ceylanicum*, and *Mitragyna praviflora* were among a few species represented by only one individual and *Euonymus indicus*, *Lagerstroemia microcarpa*, and *Litsea deccanensis* were represented by two individuals. Table 1 depicts various phyto-sociological attributes from the sampled plotsin the study area. The abundance in the sampled plots varied greatly from one individual (OLR2, OMD2) to 384 individuals (CCR3); whereas number of species ranged from 1 (OLR2, OMD2) to 32 (CCR3). Maximum number of woody endemic species (9) was reported from Malai Pathar (CMP4), whereas Mahadevgad road (CMD1) showed highest number of endemic individuals (59). Presence of WG endemic species, *Diospyros candolleana* was a notable feature in this area. Shannon index varied from 0 to 2.86 within sampled plots, '0' being recorded for two open forest plots which were represented by single individual. In order to get insights into the contribution of singleton and doubleton species in overall woody species diversity of the area, Shannon index value was plotted against the proportion of singleton and doubleton species in the sampled plots, depicted in Figure 3 (r=0.798, p<0.001).

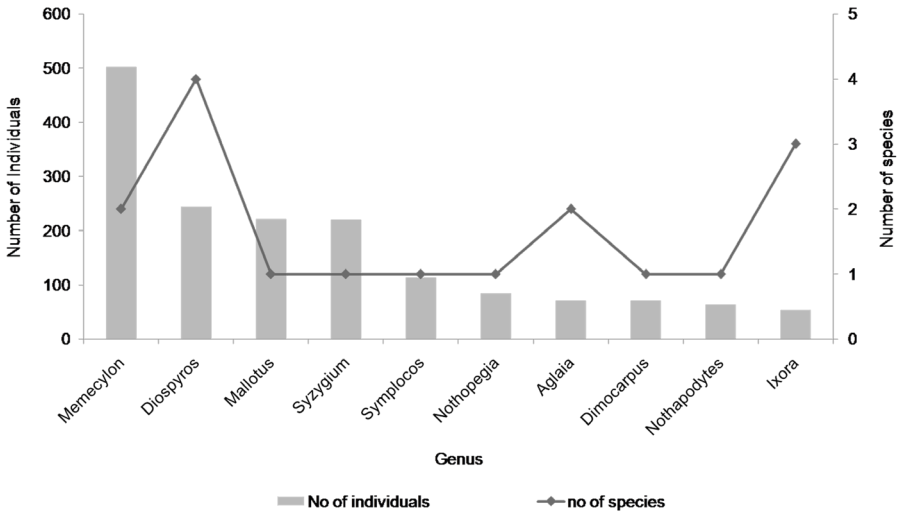

Figure 2. Ten most abundant genera with number of species.

Table 1. Diversity parameters in the sampled plots.

Area	Plot code	No. of species	No. of families	Stem density per sampling unit	Endemic species*	IUCN assessed species	Shannon index
Choukul Road	CCR1	16	13	68	2 (5)	3 (7)	1.97
	OCR1	5	5	8	1 (3)	0	1.39
	CCR4#	17	13	76	4 (23)	4 (15)	2.19
	CCR5	9	9	60	3 (29)	0	1.54
	CCR2	18	14	79	4 (10)	3 (9)	2.39
	CCR3##	32	22	384	6 (35)	3 (32)	2.59
Hiranyakeshi	CHR1	9	7	28	3 (5)	2 (3)	1.53
	OHR2	4	4	5	1 (1)	0	1.33
	CHR3	19	14	50	2 (7)	0	2.14
	OHR4	5	5	8	1 (6)	0	1.49
Lingachi Rai	CLR1	11	9	35	2 (8)	4 (12)	2.04
	OLR2	1	1	1	0	1 (1)	0
	OLR3	11	8	33	7 (16)	5 (15)	2.18
	CLR2	16	11	30	5 (7)	5 (13)	2.54
	CLR3	13	10	42	4 (9)	6 (20)	2.32
	CLR4	13	9	28	5 (11)	4 (14)	2.33
	CLR5	5	4	16	1 (1)	2 (7)	1.13
	CLR6	12	10	28	3 (10)	4 (9)	2.29
	CLR7	13	10	31	5 (11)	4 (14)	2.36
	CLR8	9	7	33	2 (5)	4 (16)	1.87
	OLR1	4	3	5	0	0	1.33
Mahadevgad Road	CMD1	16	11	67	5 (59)	2 (11)	2.41
	OMD1	5	5	16	0	0	1.23
	CMD2	11	9	35	2 (10)	2 (2)	1.67
Malai Pathar	CMP1#	19	15	119	4 (29)	2 (21)	2.44
	CMP2	12	9	39	3 (6)	2 (6)	2.21
	CMP3	15	13	43	6 (8)	2 (2)	2.33
	CMP4##	29	19	209	9 (45)	3 (47)	2.86
MPCA	CCR6###	27	17	124	7 (14)	2 (2)	2.71
	CMC1	12	11	39	3 (5)	1 (2)	2.01
	CMC2	12	10	43	2 (10)	2 (11)	1.98
	CMC3	16	13	47	7 (17)	3 (4)	2.33
	CMC4	6	5	43	3 (13)	1 (5)	1.21
	CMC5#	17	15	99	4 (15)	2 (10)	2.3
Narayangad	OMD2	1	1	1	1 (1)	0	0
	OMD3	4	4	9	2 (5)	0	1.22
Sadachi Rai	CSR1	12	10	24	4 (17)	2 (11)	2.31
	OSR5	8	8	14	3 (6)	0	1.95
	CSR2	15	12	26	3 (9)	3 (10)	2.56
	CSR3	18	13	52	5 (21)	2 (15)	2.49
	CSR4	12	9	29	6 (27)	3 (9)	2.29
	CSR5	14	10	34	6 (9)	2 (13)	2.30
	OSR1	7	6	17	3 (15)	0	1.79
	OSR2	6	6	11	1 (7)	0	1.59
	OSR3	5	5	15	1 (7)	0	1.23
	OSR4	7	7	21	2 (10)	0	1.61

*Values in the parentheses depict the number of individuals encountered
All sampling units are primarily quadrats (20 x 20m, n=40) except # Transects: 250 x 5m (n=3); ##Transects: 500 x 5m (n=2) & ###Transects: 200 x 5m (n=1)

Table 2. Species encountered in the sampled plots and their attributes.

	Species	Family	Number of Individuals	Dispersal Mode#	E/D Habit$	Forest strata*	Endemicity	IUCN Red List category##
1	*Aglaia lawii*	Meliaceae	54	Z	E	C		LC
2	*Aglaia* sp.	Meliaceae	17	Z	E	C		
3	*Allophylus cobbe*	Sapindaceae	2	Z	E	Liana		
4	*Alstonia scholaris*	Apocynaceae	1	An	E	C		LC
5	*Ardisia solanacea*	Myrsinaceae	3	Z	E	U		
6	*Artocarpus hirsutus*	Moraceae	2	Z	E	C		LC
7	*Atalantia racemosa*	Rutaceae	28	Z	E	M		
8	*Beilschmiedia dalzellii*	Lauraceae	23	Z	E	C	WG	
9	*Blachia denudata*	Euphorbiaceae	10	At	E	U	WG	
10	*Bridelia retusa*	Euphorbiaceae	3	Z	D	M		
11	*Callicarpa tomentosa*	Verbenaceae	3	Z	E	U		
12	*Canthium anguistifolium*	Rubiaceae	1	Z	E	Liana		
13	*Canthium dicoccum*	Rubiaceae	1	Z	E	M		VU
14	*Canthium rheedei*	Rubiaceae	1	Z	E	U		
15	*Carallia brachiata*	Rhizophoraceae	3	Z	E	C		
16	*Careya arborea*	Lecythidaceae	6	Z	D	M		
17	*Carissa congesta*	Apocynaceae	1	Z	E	U		
18	*Carissa inermis*	Apocynaceae	9	Z	E	Liana		
19	*Caryota urens*	Arecaceae	10	Z	E	C		LC
20	*Casearia graveolens*	Flacourtiaceae	1	Z	E	U		
21	*Casearia* sp.	Flacourtiaceae	5	Z	E	U		
22	*Catunaregam spinosa*	Rubiaceae	28	Z	D	C		
23	*Celtis timorensis*	Ulmaceae	3	Z	E	C		
24	*Cinnamomum verum*	Lauraceae	6	Z	E	C		
25	*Clausena anisata*	Rutaceae	2	Z	E	C		
26	*Clausena indica*	Rutaceae	9	Z	E	U		
27	*Combretum extensum*	Combretaceae	1	An	D	Liana		
28	*Combretum ovalifolium*	Combretaceae	1	An	D	Liana		
29	*Connarus wightii*	Connaraceae	1	At	E	Liana		
30	*Dichapetalum gelonioides*	Dichapetalaceae	10	Z	E	U		
31	*Dimocarpus longan*	Sapindaceae	71	Z	E	C		NT
32	*Dimorphocalyx lawianus*	Euphorbiaceae	18	At	E	U	WG	
33	*Diospyros candolleana*	Ebenaceae	115	Z	E	C	WG	VU
34	*Diospyros montana*	Ebenaceae	16	Z	D	C		
35	*Diospyros nigrescens*	Ebenaceae	112	Z	E	M	WG	
36	*Diospyros* sp.	Ebenaceae	1	Z	E	M		
37	*Drypetes venusta*	Euphorbiaceae	10	Z	E	M	WG	
38	*Dysoxylum binectariferum*	Meliaceae	11	Z	E	C		
39	*Euonymus indicus*	Celastraceae	2	Z	E	C	WG	
40	*Ficus exasperata*	Moraceae	1	Z	D	U		LC
41	*Ficus racemosa*	Moraceae	7	Z	D	C		
42	*Ficus* sp.	Moraceae	1	Z	E	C		
43	*Flacourtia indica*	Flacourtiaceae	2	Z	D	U		
44	*Garcinia indica*	Clusiaceae	4	Z	D	M	WG	VU
45	*Garcinia talbotii*	Clusiaceae	20	Z	E	M	WG	

	Species	Family	Number of Individuals	Dispersal Mode[#]	E/D Habit[$]	Forest strata*	Endemicity	IUCN Red List category[##]
46	*Glochidion ellipticum*	Euphorbiaceae	17	At	E	C	WG	
47	*Glycosmis pentaphylla*	Rutaceae	5	Z	E	U		
48	*Heterophragma quadriloculare*	Bignoniaceae	11	An	D	C		
49	*Holigarna grahamii*	Anacardiaceae	29	Z	D	C	WG	
50	*Homalium ceylanicum*	Flacourtiaceae	1	Z	E	C		
51	*Hymenodyction obovatum*	Rubiaceae	1	Z	D	M		
52	*Ixora brachiata*	Rubiaceae	37	Z	E	M	WG	
53	*Ixora nigricans*	Rubiaceae	4	Z	E	U		
54	*Ixora* sp.	Rubiaceae	13	Z	E	U		
55	*Knema attenuata*	Myristicaceae	1	Z	E	C	WG	LC
56	*Lagerstroemia microcarpa*	Lythraceae	2	An	D	C	WG	
57	*Leeaindica*	Leeaceae	29	Z	E	U		
58	*Lepisanthes tetraphylla*	Sapindaceae	18	At	E	M		
59	*Ligustrum perrottetii*	Oleaceae	18	Z	D	M	WG	
60	*Litsea deccanensis*	Lauraceae	2	Z	E	U		
61	*Litsea stocksii*	Lauraceae	4	Z	E	M	WG	
62	*Mallotus philippensis*	Euphorbiaceae	221	Z	E	C		
63	*Mangifera indica*	Anacardiaceae	24	Z	E	C		DD
64	*Meiogyne pannosa*	Annonaceae	3	Z	E	U	WG	
65	*Memecylon umbellatum*	Melastomataceae	501	Z	E	C		
66	*Memecylon wightii*	Melastomataceae	1	Z	E	U		
67	*Mimusops elengi*	Sapotaceae	9	Z	E	C		LC
68	*Mitragyna parviflora*	Rubiaceae	1	At	D	C		
69	*Moullava spicata*	Caesalpineaceae	2	At	E	Liana		
70	*Murraya koenigii*	Rutaceae	2	Z	E	U		
71	*Murraya paniculata*	Rutaceae	1	Z	E	U		
72	*Myristica dactyloides*	Myristicaceae	31	Z	E	U		VU
73	*Neolitsea cassia*	Lauraceae	1	Z	E	U		
74	*Nothapodytes nimmoniana*	Icacinaceae	64	Z	D	M		
75	*Nothopegia castaneifolia*	Anacardiaceae	84	Z	E	M		
76	*Olea dioica*	Oleaceae	31	Z	E	C		
77	*Oxyceros rugulosus*	Rubiaceae	1	Z	E	Liana		
78	*Persea macrantha*	Lauraceae	1	Z	E	C		
79	*Salacia chinensis*	Celastraceae	2	Z	E	U		
80	*Scutia myrtina*	Rhamnaceae	12	Z	E	Liana		
81	*Symplocos racemosa*	Symplocaceae	114	Z	E	C		
82	*Syzygium cumini*	Myrtaceae	185	Z	E	C		
83	*Syzygium hemisphericum*	Myrtaceae	35	Z	E	C		
84	*Tabernaemontana alternifolia*	Apocynaceae	14	Z	D	U	WG	NT
85	*Terminalia chebula*	Combretaceae	8	Z	D	C		
86	*Xantolisto mentosa*	Sapotaceae	46	Z	E	C		
87	*Ziziphus rugosa*	Rhamnaceae	2	Z	E	U		

[#] Dispersal mode category: Z—Zoochory | At—Autochory | An—Anemochory |[$] E/D habit: E—Evergreen | D—Deciduous | *Forest Strata: C—Canopy species | M—Middle Storey Species | U—Under storey |[##] IUCN category: DD—Data Deficient | NT—Near Threatened | LC—Least Concern | VU—Vulnerable.

Table 3. Importance Value Index of the species from the study area.

	Species	Frequency	Relative frequency	Density	Relative density	Basal area (m^2)	Relative dominance	IVI
1	*Memecylon umbellatum*	32	7.862	334	27.512	447.083	26.221	61.596
2	*Syzygium cumini*	22	5.405	75	6.178	264.011	15.484	27.067
3	*Diospyros nigrescens*	23	5.651	72	5.931	31.495	1.847	13.429
4	*Aglaia lawii*	16	3.931	54	4.448	85.247	5.000	13.379
5	*Dimocarpus longan*	14	3.440	45	3.707	81.107	4.757	11.903
6	*Holigarna grahamii*	12	2.948	26	2.142	101.144	5.932	11.022
7	*Diospyros candolleana*	18	4.423	48	3.954	38.110	2.235	10.612
8	*Mangifera indica*	9	2.211	24	1.977	107.012	6.276	10.464
9	*Nothopegia castaneifolia*	21	5.160	47	3.871	13.787	0.809	9.840
10	*Mallotus philippensis*	10	2.457	42	3.460	28.339	1.662	7.579
11	*Beilschmiedia dalzellii*	9	2.211	22	1.812	57.208	3.355	7.379
12	*Ixora brachiata*	13	3.194	34	2.801	14.830	0.870	6.865
13	*Symplocos racemosa*	9	2.211	35	2.883	22.388	1.313	6.407
14	*Catunaregam spinosa*	11	2.703	23	1.895	29.089	1.706	6.303
15	*Syzygium hemisphericum*	7	1.720	13	1.071	42.462	2.490	5.281
16	*Garcinia talbotii*	9	2.211	19	1.565	22.757	1.335	5.111
17	*Xantolisto mentosa*	9	2.211	20	1.647	18.739	1.099	4.958
18	*Atalantia racemosa*	11	2.703	17	1.400	5.826	0.342	4.445
19	*Nothapodytes nimmoniana*	6	1.474	28	2.306	11.032	0.647	4.428
20	*Caryota urens*	7	1.720	10	0.824	20.474	1.201	3.744
21	*Ligustrum perrottetii*	6	1.474	18	1.483	7.783	0.456	3.413
22	*Terminalia chebula*	7	1.720	8	0.659	16.206	0.950	3.329
23	*Ficus* sp.	1	0.246	1	0.082	47.130	2.764	3.092
24	*Glochidion ellipticum*	7	1.720	10	0.824	7.979	0.468	3.012
25	*Heterophragma quadriloculare*	7	1.720	11	0.906	6.233	0.366	2.992
26	*Dysoxylum binectariferum*	6	1.474	8	0.659	14.603	0.856	2.990
27	*Olea dioica*	6	1.474	9	0.741	7.341	0.431	2.646
28	*Drypetes venusta*	4	0.983	10	0.824	14.087	0.826	2.633
29	*Diospyros montana*	4	0.983	8	0.659	14.816	0.869	2.511
30	*Mimusops elengi*	5	1.229	9	0.741	7.271	0.426	2.396
31	*Ficus racemosa*	5	1.229	5	0.412	12.846	0.753	2.394
32	*Myristica dactyloides*	2	0.491	6	0.494	22.084	1.295	2.281
33	*Tabernaemontana alternifolia*	5	1.229	9	0.741	3.461	0.203	2.173
34	*Careya arborea*	5	1.229	6	0.494	5.774	0.339	2.061
35	*Lepisanthes tetraphylla*	5	1.229	6	0.494	2.792	0.164	1.886
36	*Scutia myrtina*	4	0.983	9	0.741	2.222	0.130	1.854
37	*Carissa inermis*	4	0.983	8	0.659	1.414	0.083	1.725
38	*Dimorphocalyx lawianus*	2	0.491	5	0.412	8.572	0.503	1.406
39	*Blachia denudata*	2	0.491	8	0.659	2.318	0.136	1.286
40	*Cinnamomum verum*	2	0.491	3	0.247	8.343	0.489	1.228
41	*Clausena indica*	1	0.246	9	0.741	2.175	0.128	1.115
42	*Carallia brachiata*	3	0.737	3	0.247	1.481	0.087	1.071
43	*Persea macrantha*	1	0.246	1	0.082	12.560	0.737	1.065

	Species	Frequency	Relative frequency	Density	Relative density	Basal area (m^2)	Relative dominance	IVI
44	*Dichapetalum gelonioides*	3	0.737	3	0.247	0.358	0.021	1.005
45	*Callicarpa tomentosa*	2	0.491	2	0.165	5.160	0.303	0.959
46	*Clausena anisata*	2	0.491	2	0.165	2.835	0.166	0.822
47	*Meiogyne pannosa*	2	0.491	3	0.247	1.005	0.059	0.797
48	*Bridelia retusa*	2	0.491	2	0.165	1.130	0.066	0.722
49	*Euonymus indicus*	2	0.491	2	0.165	0.674	0.040	0.696
50	*Neolitsea cassia*	1	0.246	1	0.082	6.243	0.366	0.694
51	*Leea indica*	1	0.246	5	0.412	0.574	0.034	0.691
52	*Ardisia solanacea*	2	0.491	2	0.165	0.184	0.011	0.667
53	*Glycosmis pentaphylla*	2	0.491	2	0.165	0.181	0.011	0.667
54	*Salacia chinensis*	2	0.491	2	0.165	0.167	0.010	0.666
55	*Artocarpus hirsutus*	1	0.246	2	0.165	2.033	0.119	0.530
56	*Lagerstroemia microcarpa*	1	0.246	1	0.082	3.267	0.192	0.520
57	*Celtis timorensis*	1	0.246	1	0.082	2.377	0.139	0.467
58	*Ziziphus rugosa*	1	0.246	2	0.165	0.537	0.031	0.442
59	*Moullava spicata*	1	0.246	2	0.165	0.411	0.024	0.435
60	*Flacourtia indica*	1	0.246	2	0.165	0.362	0.021	0.432
61	*Allophylus cobbe*	1	0.246	2	0.165	0.182	0.011	0.421
62	*Murraya koenigii*	1	0.246	1	0.082	1.583	0.093	0.421
63	*Casearia* sp.	1	0.246	2	0.165	0.171	0.010	0.420
64	*Alstonia scholaris*	1	0.246	1	0.082	1.016	0.060	0.388
65	*Garcinia indica*	1	0.246	1	0.082	0.723	0.042	0.371
66	*Murraya paniculata*	1	0.246	1	0.082	0.430	0.025	0.353
67	*Knema attenuata*	1	0.246	1	0.082	0.407	0.024	0.352
68	*Mitragyna parviflora*	1	0.246	1	0.082	0.246	0.014	0.343
69	*Combretum extensum*	1	0.246	1	0.082	0.152	0.009	0.337
70	*Diospyros* sp.	1	0.246	1	0.082	0.152	0.009	0.337
71	*Memecylon wightii*	1	0.246	1	0.082	0.152	0.009	0.337
72	*Canthium anguistifolium*	1	0.246	1	0.082	0.138	0.008	0.336
73	*Connarus wightii*	1	0.246	1	0.082	0.126	0.007	0.335
74	*Carissa congesta*	1	0.246	1	0.082	0.091	0.005	0.333
75	*Casearia graveolens*	1	0.246	1	0.082	0.091	0.005	0.333
76	*Combretum ovalifolium*	1	0.246	1	0.082	0.091	0.005	0.333
77	*Oxyceros rugulosus*	1	0.246	1	0.082	0.085	0.005	0.333
78	*Litsea deccanensis*	1	0.246	1	0.082	0.080	0.005	0.333

The results showed highly significant relation indicating contribution of rare speciesin the overall diversity of the study area.

Table 2 gives various species attributes of the study area. Fourteen IUCN assessed species together accounted for 15% of the total number of individuals encountered. *Diospyros candolleana*, listed in the Vulnerable (VU) category, was found to be one of the dominant species in the study area. Evergreen (E) is the dominant habit represented by 78% of species which are mainly distributed in closed forest patches. Eighty-six percent of species showed zoochory as a dispersal mode. An attempt has also been made to assign species status (canopy / middle storey / understorey) as per the vegetation strata observed in the study area.

Cluster analysis (Figure 4) revealed that maximum species similarity of the plots was observed to be ca. 74%. Quadrats laid in Lingachi rai sacred grove area (a community owned forest), formed a cluster. This cluster exhibits low similarity with the other quadrats taken in reserve forests, private forests and Sadachi rai (a sacred grove situated in the reserved forests). It is interesting to note here that these quadrats despite being laid in the closed forests exhibit different patterns. Open forest patches showed lowest (2% to 20%) species compositional similarity with closed forest patches.

(B) Importance Value Index (IVI) and Family Importance Value (FIV)

Data collected through quadrat sampling (S=78, N=1213) was used for the estimation of IVI and FIV. *Memecylon umbellatum* was found to be the most dominant species as per IVI (Table 3). Though represented by only 6% of individuals, *Syzygium cumini* was found to be second most important species due to its high basal area followed by *Diospyros nigrescens, Aglaia lawii*, and *Dimocarpus longan*. Family Melastomataceae represented by the genus *Memecylon* in the study area, showed the highest FIV (56.38) due to its abundance as well as the basal area. Families Myrtaceae, Anacardiaceae, Ebenaceae, and Euphorbiaceae were found to be the other most important families as per FIV (Figure 5). Euphorbiaceae and Rutaceae were the most speciose families with six species each followed by Lauraceae and Rubiaceae (5 species each).

(C) Stand structure

The girth class distribution showed typical reverse 'J' shaped curve (Figure 6). First three GBH classes, i.e., 15–30cm, 30–45cm, and 45–60 cm contributed to 73% of the individuals (no. of species=70) (Figure 7). Less than 1% individuals were represented in GBH class > 210cm. They were comprised by species such as *Holigarna grahamii, Persea macrantha, Syzygium cumini*, *Mangifera indica*, and *Memecylon umbellatum*. Total basal area recorded was 43.23m^2. GBH classes (45–120 cm) contributed to highest basal area (40.99%), however, it should be noted that maximum number of individuals was found among lower GBH classes with subsequent GBH classes showing steady decrease in number of individuals (Figure 7). Basal area decreased with increasing GBH which was depicted by very low abundance. Stand basal area of *Memecylon umbellatum* and *Syzygium cumini* was around 41% of the total basal area.

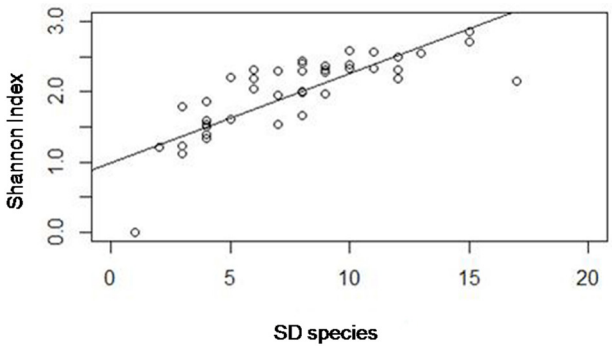

Figure 3. Relation of singleton and doubleton species (SD species) with the Shannon diversity index.

(D) Endemic species diversity and abundance

Of the total number of species recorded, 18 species were Western Ghats endemics and accounted for nearly 20% of the total number of individuals sampled. Genus *Diospyros* (represented by two endemic species – *D. candolleana* and *D. nigrescens*) comprised of 51.8% of the endemic individuals. *D. candolleana* (VU) was also found to be one of the dominant species in the study area as revealed from IVI. *Drypetes venusta, Knema attenuata*, and *Meiogyne pannosa* were encountered only in the sacred groves. Sacred groves also showed presence of *H. grahamii* (>195cm) and *Beilschmiedia dalzellii* (>180cm). Such hefty individuals of these species were seldom seen elsewhere highlighting the significance of protection of sacred groves in biodiversity conservation. Endemic species richness also exhibited highly significant relation with Shannon diversity ($r=0.766$, $p<0.001$) (Figure 8).

(E) Woody species diversity across various PAs vis-a-vis vegetation at Amboli

Table 4 represents various ecological attributes from

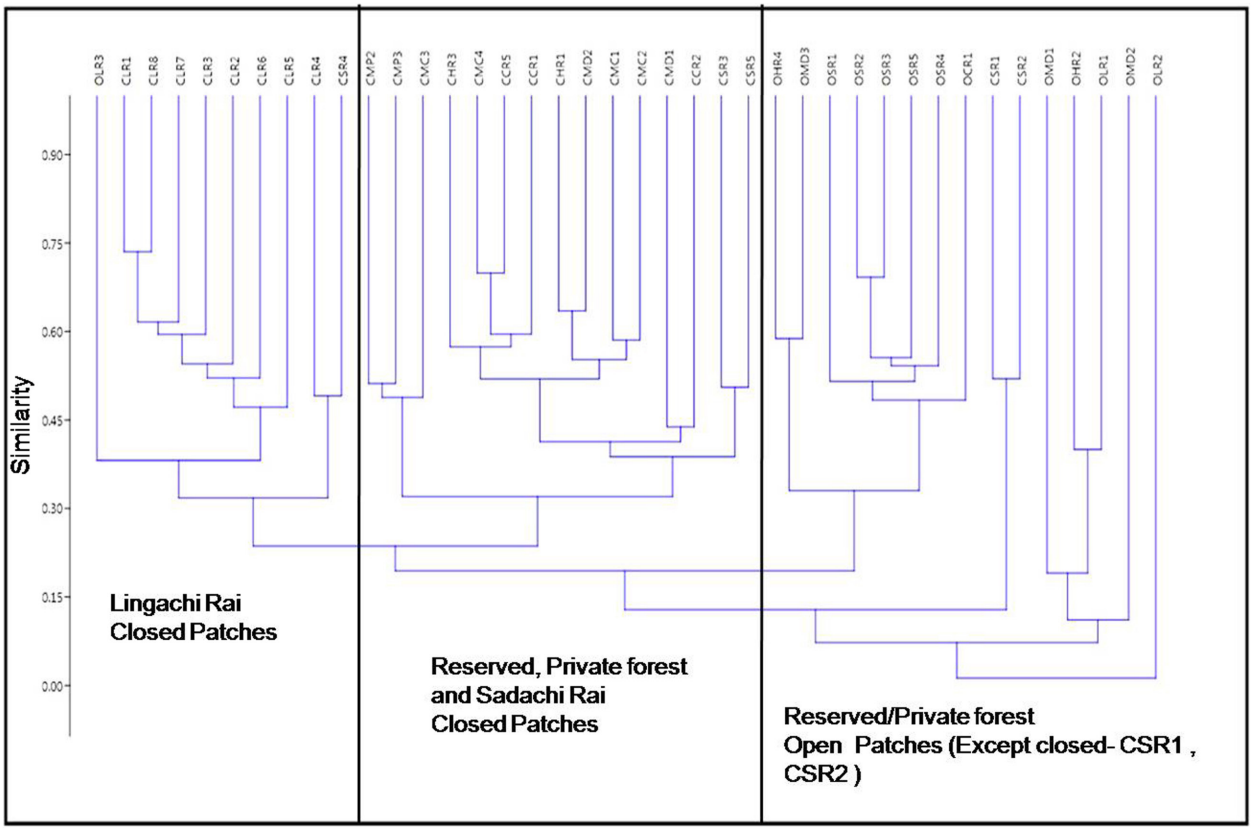

Figure 4. Bray-Curtis similarity plot based on species composition.

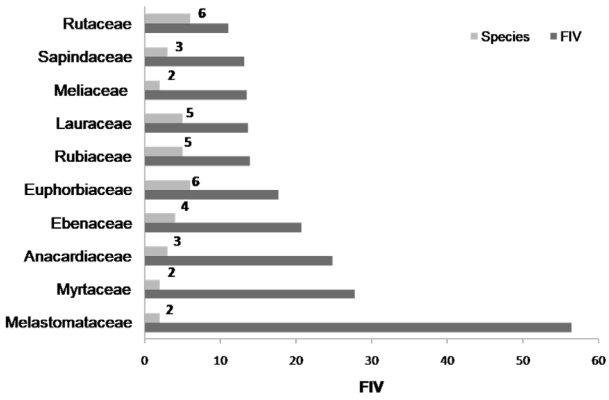

Figure 5. Family dominance based on FIV.

study area and compares it with similar such studies conducted elsewhere inside PAs and reserve forests of NWG.

DISCUSSION

Present study provides systematic account of woody species composition of Amboli forests. In comparison with studies from protected areas from NWG, the sampled area showed high species richness and abundance (Table 4). Out of 35 families, Euphorbiaceae and Rutaceae were found to be diverse families of Amboli forest followed by Lauraceae and Rubiaceae. Though highly diverse, Lauraceae and Rubiaceae showed lower FIV values due to its lower density and lower basal area as similar to studies conducted in Kalakad-Mundanthurai forests of SWGs by Ganesh et al. (1996). As per FIV, Melastomataceae was found to be the most dominant family which is very similar to family dominance in Chandoli NP (Kanade et al. 2008) and Koyna WS (Joglekar et al. 2015). Puri et al. (1983) and Pascal (1988) assigned *Memecylon-Syzygium-Actinodaphne* (M-S-A) floristic series to evergreen forests of NWG based on the criteria of dominance–abundance–fidelity. Current study revealed *Memecylon-Syzygium–Diospyros* type which is found to be different from *Memcylon-Syzygium-Olea* type found in protected areas of NWG (Table 4). *M. umbellatum,* the most dominant species

Table 4. Woody plant species diversity in Amboli vis-à-vis PAs and RF from northern Western Ghats.

Study area	Present study Amboli forest	Mulshi forest (Watve et al. 2003)	Chandoli NP (Kanade et al. 2008)	Koyna WS (Joglekar et al. 2015)	Radhanagari WS (Unpublished data)	Fragmented forest of Mulshi Taluka (Kasodekar et al. 2019)
Location	15.95°N & 74°E	18.43°N & 73.42°E	17.12°N & 73.85°E	17.42°N & 73.77°E	16.40°N & 73.98°E	18.53°N & 73.42°E
Annual Rainfall (mm)	7000	6500	6200	5000	5000	6500
Altitude (m)	600–700	500–1000	589–1044	740–1005	579–853	700–1000
Dry period length	7 months	8–9 months	8–9 months	8–9 months	8 months	8–9 months
Forest type	Evergreen	Semi evergreen	Evergreen, semi evergreen	Evergreen, semi evergreen, moist deciduous	Evergreen, semi evergreen, moist deciduous	Semi evergreen forest
Area sampled (ha)	2.575	0.635	5	6	6.5	0.3
Species encountered	87	52	107	108	165 (Includes unidentified species)	49
Girth class measured	≥15cm	≥10cm	≥15cm	≥15cm	≥15cm	>10cm
Total no. of individuals	2224	-	4200	4296	4754	444
Density	1213 individuals/1.6ha	633–1720 individuals/ha	149–657 individuals /0.5ha	84–544 individuals /0.5ha	140–648 individuals /0.5ha	-
No. of endemic species	18	-	13	21	17	4
IUCN assessed species	14	-	-	13	-	-
Basal area	27.02m²/ha	14.5–72.9 m²/ha	10.22–57.16 m²/ha	6.76–58.23 m²/ha	20.33m²/ha	-
Floristic series	Memecylon-Syzygium-Diospyros	Dimocarpus-Aglaia-Ficus nervosa	Memecylon-Syzygium-Olea	Memecylon-Syzygium-Olea	Memecylon-Syzigium-Olea	-
Shannon index	0–2.86	2.1–3.83	2.0–3.2	1.5–3.03	2.52–3.47	2.97–3.26

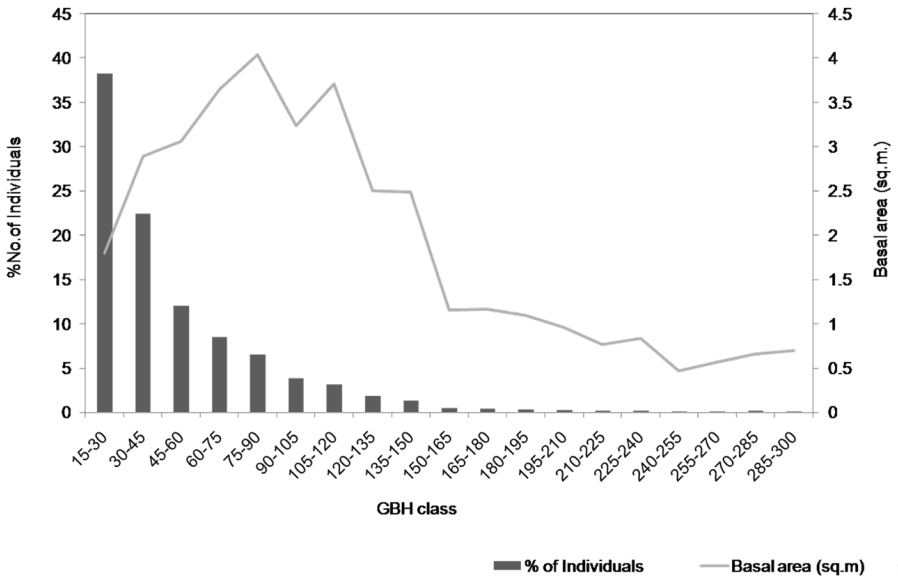

Figure 6. Number of individuals and corresponding basal area across GBH.

in the study area was represented by >20% of the total number of individuals. Similar trend was found in studies conducted in Chandoli NP and Koyna WS where *M. umbellatum* was represented by 27% and 34% individuals, respectively. The study area harbored 18 species endemic to the WG that accounted for around 20% of the individuals sampled. It is interesting to note that some endemic species represented in the study

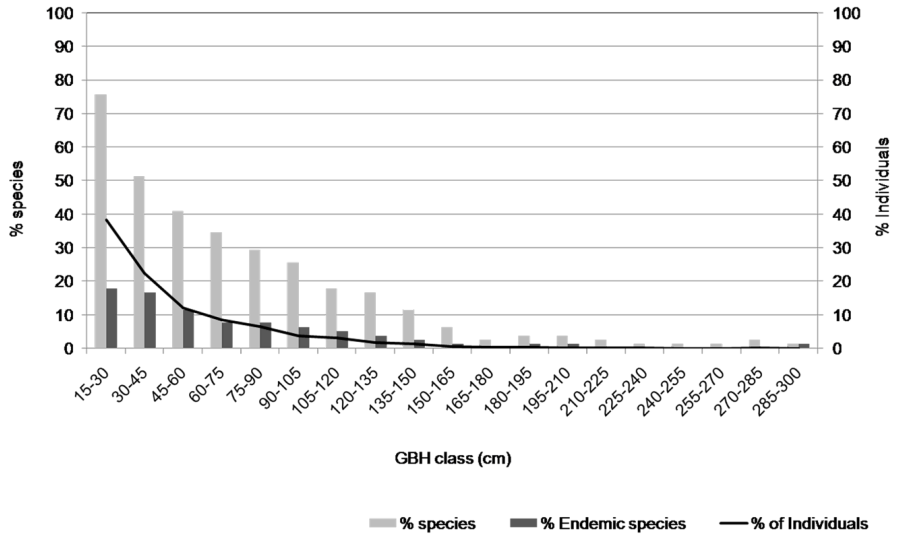

Figure 7. Number of species and individuals across GBH classes.

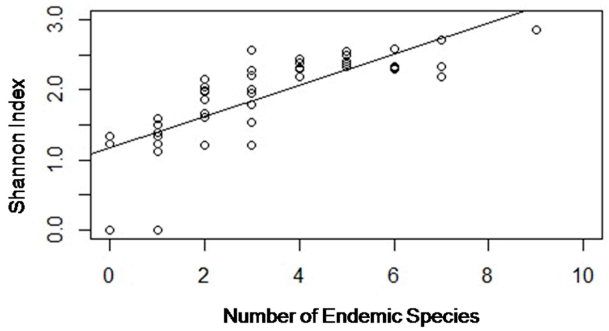

Figure 8. Relation between endemic species richness and Shannon diversity.

area are among the most important species according to IVI. These include *D. nigrescens* (IVI 13.43), *Holigarna grahamii* (IVI 11.02) and *D. candolleana* (IVI 10.61). This underlines the importance of the study area in sustaining the population of endemic woody species. High proportion of endemic species was also reported by Kanade et al. (2008) from undisturbed evergreen forest patches of Chandoli NP. Similar findings were reported from Koyna WS which showed presence of 23 endemic species represented by 656 individuals (15.27%). The dominance of typical evergreen forest species such as *Holigarna grahamii* and *Aglaia lawii*, both endemic species, suggest an origin from a community differing in composition from the typical M-S-A types (Watve et al. 2003). Amboli forests showed presence of 14 IUCN assessed species (six species being VU or NT) with 15% of total individuals sampled which is comparable to Koyna WS that recorded 13 IUCN assessed species and 9% of total number of individuals (Joglekar et al. 2015).

Since the area under consideration is relatively small, we may expect high similarity among the species in the sampled plots, however, clustering with Bray-Curtis similarity plot reveals that there are unique species conferring unique composition to the plots. Closed forest patches of Lingachi rai form a separate cluster as against other closed reserved forest patches and Sadachi rai. Species like *Artocarpus hirsutus*, *Blachia denudata*, *Beilschmiedia dalzellii*, and *Caryota urens* were present in Lingachi rai with low/no occurrence in other closed forest patches. Average stand basal area of Amboli forests was 27.02m^2/ha which was found to be comparable with other studies conducted in protected areas of NWG (Table4). Present study also showed reverse 'J' pattern of the stand structure with highest number of species and individuals in lowest GBH class (15–30 cm) (Kanade et al. 2008; Joglekar et al. 2015) while higher basal area was found to be between 45–120 cm. Typical evergreen endemic forest species like *Aglaia lawii*, *Beischmedia dalzellii*, *Holigarna grahamii* and ecologically important species like *Ficus* sp., *Dimocarpus longan* were present in higher GBH classes (above 180cm) indicating healthy nature of vegetation.

CONCLUSION

Studies on the vegetation analysis and biodiversity pattern are of utmost importance especially in the forest areas outside the PA network. Such areas in tropics are actively managed and modified by humans. Unplanned and uncontrolled tourism especially during monsoon, poorly planned construction and logging are some

of the disturbance drivers affecting floral and faunal diversity of Amboli (Image1). Floristic surveys form the primary step for carrying out ecological restoration of a particular area (Mota et al. 2017) and provide the inputs which feed large scale databases.

In this context, present study forms an important step in establishing the baseline data about woody plant diversity of the region. Closed forest patches with dominance of endemic and rare species emphasized the importance of conservation of Amboli forests in patchily distributed forests of NWG. It also revealed that the woody plant diversity in Amboli forest is comparable to other PAs from NWG. The information thus generated can be used effectively by BMC formed under the provisions of Biological Diversity Act (2002). Conserving this unique landscape rich in flora and fauna involving BMC and other stakeholders such as local community and forest department will reveal new facets of participatory conservation model that can be replicated elsewhere in the adjoining areas.

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Author details: Medhavi Tadwalkar is Assistant Professor at Annasaheb Kulkarni Department of Biodiversity, MES Abasaheb Garware College and research associate at RANWA. Her research interests include forest ecology, plant phenology pattern and biodiversity studies. Amruta Joglekar is a research scholar at Annasaheb Kulkarni Department of Biodiversity, MES Abasaheb Garware College and research associate at RANWA. Her research interests include forest ecology, seed biology and socio-ecological studies. Monali Mhaskar is a research associate at RANWA. Her research interests include forest ecology and understanding human wildlife interaction. Ankur Patwardhan is Head and Associate Professor at Annasaheb Kulkarni Department of Biodiversity, MES Abasaheb Garware College and Honorary secretary at RANWA. His research interests include plant resources study, bioprospecting and conservation of threatened plant taxa from northern Western Ghats, and documenting traditional knowledge and community conservation practices.

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