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Article

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The importance of conserving fragmented forest patches with high diversity of flowering plants in the northern Western Ghats: an example from Maharashtra, India

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Abstract: The northern Western Ghats (NWG) comprises of a patchy continuum of forests that have been severely fragmented mainly due to anthropogenic activities. We documented tree diversity within a representative fragmented forest patch of the NWG to study the effects of fragmentation on forest structure and composition. The floristic survey was conducted by replicated strip transect sampling method leading to a total sampling area of 0.3ha. A total of 444 individual trees (Girth>10cm) were sampled, which represented 49 tree species belonging to 42 genera and 23 families. Species richness per unit area and tree density were higher than previously reported values from similar forest type in various regions of NWG. These variations, however, could have resulted due to differences in the sampling area, sampling method, and girth classes used across different studies. Nevertheless, various diversity parameters such as N/S ratio, Simpson's index, Shannon's index, and Fisher's α index were comparable with those reported in previous studies in the Western Ghats. The observed species richness was close to species richness estimates such as abundance-based coverage estimate, Chao-1, and Jackknife estimators. The present study also enumerates 108 species of understory flowering plants, which is provided as a checklist. While access restrictions are imposed in protected areas having high conservation priority, such restrictions are not imposed in non-protected areas, which make them much more vulnerable to anthropogenic activities. Hence, this study recommends that owing to their high diversity, the fragmented forest patches of NWG should also be given high conservation priority.

Keywords: Conservation, forest fragmentation, plant diversity.

Abbreviations: APG - Angiosperm phylogeny group; GPS - Global positioning system; NP- National park; NWG - Northern Western Ghats; WG - Western Ghats; WS - Wildlife sanctuary.

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Author contribution: AK, AD, and RP collected the data; RB is a taxonomy expert and helped in identifying the plant species. AK, AD, and RB performed statistical analyses and wrote the initial draft of the manuscript. VG and NK participated in planning and guiding the study, evaluation of interim results, and in providing funding and facilities for the work. All authors participated in writing the final version of the manuscript.

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INTRODUCTION

Biodiversity hotspots have been defined as the areas featuring exceptionally high concentrations of endemic species as well as those experiencing exceptional loss of habitat mainly due to anthropogenic activities (Myers et al. 2000). Currently, 34 biodiversity hotspots have been defined in the world (Mittermeier et al. 2005) and two of these biodiversity hotspots, the Western Ghats/Sri Lanka (WG/SL) and Indo-Burma regions, belong to the Indian subcontinent. The WG/SL is considered one of the eight "hottest hotspots" of biological diversity identified in the world (Gunawardene et al. 2007). WG/SL hotspot, however, is experiencing a rapid loss of habitat and, out of the 190,037km^2 of primary vegetation, only 6.3% area has presently remained as natural intact vegetation (Sloan et al. 2014).

The Western Ghats (WG) refers to a hill chain or escarpment of ~1500km that runs almost parallel to the western coast of the Indian peninsula from the river Tapi (or Tapti) in Gujarat down south to just short of Kanyakumari (Fig. 1). WG covers about 130,500km^2 area (Rodgers et al. 2000); however, the exact area under WG varies from report to report (129,037–164,280 km^2) due to the lack of well-defined boundaries (Reddy et al. 2016). WG, also listed as a world heritage site, is surrounded by one of the most densely populated areas of the world, creating huge anthropogenic pressure on the biodiversity hotspot (Cincotta et al. 2000; Williams 2013). As a result, WG is undergoing severe biodiversity loss, which began with the British colonization era (Chandran 1997) and intensified in the last two decades. In 1920, 95,446km^2 (73.1%) area of WG was under forest cover, of which an estimated 33,579km^2 (35.3%) of forest cover was lost during the period 1920–2013 (Reddy et al. 2016).

WG forms a barrier to the clouds of the southwestern monsoon leading to heavy rainfall up to 7,000mm on the western slopes; due to the rain shadow effect, the eastern slopes are comparatively drier. Similarly, the rainfall is heavier towards the south and extends over eight to nine months a year, while it is lower and restricted to four months of southwestern monsoon in the northern parts of the WG (Gadgil 1996). Most of the rivers of peninsular India originate in the WG and thus it constitutes the 'water tower' of the region (Viviroli et al. 2007). Due to this rainfall regime, WG has a cover of evergreen forest in its western slopes which gradually changes to moist and dry deciduous type forests moving eastwards. Together, these forests host one of the most diverse plant communities with a reported 5,588 native species of flowering plants (Nayar et al. 2014). Plant diversity is higher towards the south and the seasonality, or rather the duration of the raining season, is one of the factors determining the distribution of plant diversity in the WG (Davidar et al. 2005).

Based on the geology of the WG, Pascal (1988) considered three major regions as 'landscape elements' within WG, namely, the northern, central, and southern regions. The northern Western Ghats (NWG) comprises the ~600km stretch of Surat-Goa region of WG (Fig. 1). NWG is homogenous in terms of geology and vegetation compared to the central and southern WG. The vegetation of NWG is considered to be the least resilient among the WG flora, due to a longer dry season and increased anthropogenic activities (Daniels 2011). NWG in Maharashtra State had ~13,500km^2 of forest cover remaining by 2005, comprising dense forest (38.22%), open forest (31.39%), and scrubland (30.39%). Within the period from 1985–1987 to 2005, the overall forest cover of NWG remained more or less unchanged; however, loss of the dense forest cover (~10%) with increased fragmentation has been observed (Kale et al. 2010; Panigrahy et al. 2010).

Habitat loss typically leads to fragmentation, the process of division of large, continuous habitats into smaller, more isolated habitat fragments separated by a matrix of human transformed land cover (Haddad et al. 2015). The loss of habitat area, increase in isolation, and increased edge area initiate long-term changes to the composition, richness, and structure of communities of the remaining fragments (Wilson et al. 2016). Effects of fragmentation depend on the size, shape, and distribution of fragments among the landscape as well as the total amount of habitat and nature of non-habitat matrix (Ibanez et al. 2017). Species respond differently to fragmentation based on their population size and the order of succession; thus, late successional species are severely affected while the stress-tolerant pioneer species proliferate (Laurance et al. 2006).

Hence, fragmented forest patches often exhibit a high percentage of pioneer species while retaining the remnants of mature forest communities. As a result, the cumulative species richness of the fragmented patches can be comparable with mature forest communities and represents a significant portion of the overall biodiversity of the region (Arroyo-Rodriguez et al. 2009). This implies that conservation of fragmented forest patches is important to protect the gene pool, prevent species extinction, maintain biodiversity; it would also help in ecological restoration as well as in protecting soil and water resources. Also, the conservation of fragmented patches can establish a network of small conservation areas with flexible structure creating more efficient corridors within intact habitat and conservation network (Kale et al. 2010; Farah et al. 2017). Small-scale inventories in fragmented forest patches are useful to explore the plant community structure and composition as well as to create a baseline for eventual restoration (Castillo-Campos et al. 2008). Hence, the objective of the present study was to systematically document the floristic diversity in one of the representative fragmented forest patches in NWG to understand the actual floristic composition therein and to contribute to its usefulness for biodiversity conservation in the region.

MATERIALS AND METHODS

Study site

The study site was one of the fragmented forest patches of NWG located at 18^{0}32′204″N and 73^{0}25′107″E (Fig. 1), near the village Barpe in Mulshi Taluka, about 45km west of Pune, Maharashtra, India. The study site was roughly a crescent-shaped forested hill slope comprising of ~20ha area with an average elevation of 700m while the hilltop has an elevation of 1,000m. The vegetation of the area is described as a semi-evergreen forest of *Memecylon-Syzygium-Actinodaphne* (*M-S-A*) series (Pascal 1988). The study site is part of a reserved

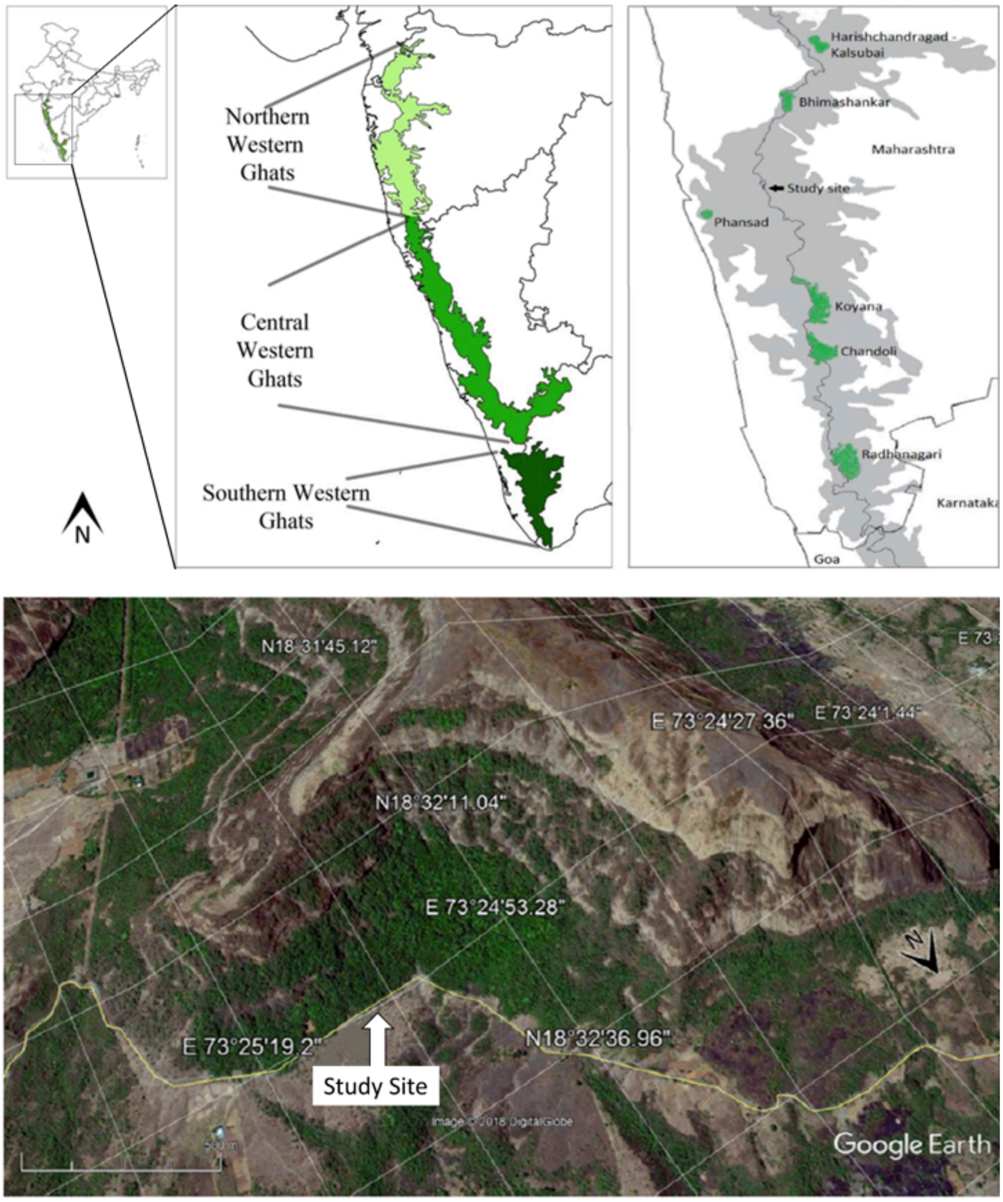

Figure 1. Study site in the northern Western Ghats, India.

forest as designated in the state forest surveys (PCCF 2013). Certain regions along the edge of the reserved forest, however, have a history of man-made disturbance as observed during the surveys as well as revealed during discussions with the locals.

The study site has a slightly acidic red soil and sandy loam texture. The area receives heavy rainfall (~6,500mm) in monsoon (June–September) followed by a dry spell of eight months including a cool, dry winter (October–February) and a warm moist summer (March–May). The average relative humidity is about 95% in the rainy season (monsoon), but varies from 30% to 70% during the rest of the year; the temperature is reported to vary from a minimum of 4°C in winter to a maximum of 41°C in summer (Watve et al. 2003). Faunal elements like Hanuman Langur *Semnopithecus hypoleucos* and Indian Muntjack *Muntiacus muntjack aureus* are native to the study area and were commonly observed during the study (ZSI 2012).

METHODS

For the present study, several floristic inventories were performed by strip transect sampling in the study site between March 2013 and May 2015, covering all months of the year. Three non-contiguous strip transects of 167m × 06m, spanning from edge to interior were demarcated within the selected forest patch according to Gordon & Newton (2006) and Buckland et al. (2007), and coordinates were recorded using a handheld GPS device (Oregon 550, Garmin, USA) (Fig. 1). Thus, the sampling area was 0.1ha at each strip transect, and the total sampling area was 0.3ha. Tree diversity and abundance encountered within the fixed area of strip transects were documented. Trees with Girth<10cm were excluded while understory plants such as lianas, climbers, shrubs, herbs, and epiphytes were documented. All the specimens were identified using local or regional floras (Sharma et al. 1996; Singh et al. 2001; Yadav & Sardesai 2002) and confirmed by expert taxonomists. Representative plant specimens were identified by comparison with herbarium accessions at the herbarium of the Botanical Survey of India (BSI), Pune, India. The APG IV classification system was followed at the family-level (Chase et al. 2016).

Alpha diversity of the study site was measured as species richness (number of species), species richness indices such as Margalef's index and diversity indices such as Simpson's dominance index, Simpson's reciprocal index, Shannon's index, evenness, equitability, Fisher's alpha index, and Berger-Parker dominance (Magurran 2003) and were calculated using the PAST software (v. 3.11) (Hammer et al. 2001). Species accumulation curve was plotted where X-axis represented the cumulative number of individuals and the Y-axis represented the cumulative number of species (Gotelli & Colwell 2011). Species richness estimates appropriate for abundance data such as Chao-1, abundance-based coverage estimate (ACE), and Jackknife estimators were calculated using EstimateS v. 9.1.0 (Colwell 2013). N/S (ratio of number of individuals (N) to the number of species (S)), a simple parameter to represent species diversity, was also calculated (Watve et al. 2003; Kanade et al. 2008).

RESULTS

Floristic inventories in the study area covering all months of the year resulted in the identification of 157 plant species (including 49 tree species and 108 understory plant species) representing 137 genera and 59 families (Table 1; Images 1–5). The most species-rich family was Fabaceae represented by 12 species, followed by Poaceae (N=11), Apocynaceae (N=9), Asteraceae (N=9), and Acanthaceae (N=8); 31 families were monospecific, i.e., represented by a single species each. Tree diversity of the study area comprised 49 tree species representing 42 genera and 23 families. The number of tree species varied from 33 to 39 among the three strip transects (0.1ha each), and 444 individuals stems (G>10cm) were recorded from the total sampling area of 0.3ha (Table 2).

Memecylon umbellatum Burm.f. (Melastomaceae) (N=77) was the most abundant evergreen tree species followed by *Olea dioica* Roxb. (Oleaceae) (N=32), *Nothapodytes nimmoniana* (J. Grah.) Mabb. (Icacinaceae) (N=31), *Garcinia talboti* Raiz ex Sant (Clusiaceae) (N=23), and *Ixora brachiata* Roxb. (Rubiaceae) (N=19). Members of the genus *Actinodaphne* and *Syzygium* were less abundant than the typical *M-S-A* series forest, suggesting a different community composition. Among the 49 tree species, similar numbers of evergreen (N=23) and deciduous (N=26) species were recorded; however, most individuals were evergreen (N=316, ~71%) while the rest (N=128, ~29%) were deciduous.

The N/S ratio for the total sampling area of 0.3ha was 9.06 while it varied from 3.50 to 4.79 for each strip transect of 0.1ha. Margalef's species richness index for the study site was 7.87, varying from 6.32 to 7.56 per transect. Dominance index (D) of the study site was 0.057, while Simpson's reciprocal index (1/D) was

Image 1 . Plant species observed in the study area: A - *Abrus precatorius* L. | B - *Careya arborea* Roxb. | C - *Dillenia pentagyna* Roxb. | D - *Erythrina stricta* Roxb. | E - *Garcinia talboti* Raiz. ex Sant. | F - *Kydia calycina* Roxb. | G - *Nothapodytes nimmoniana* (J. Grah.) Mabb. | H - *Pinda concanensis* (Dalz.) P. Mukh. & Constance. © Rani Bhagat.

Table 1. Plant species recorded in the study area, with their families, habits, and foliar habits (in case of trees). The species endemic to the Western Ghats are indicated by a '*'.

	Family	Species	Habit	Foliar habit
	Gymnosperms			
1	Gnetaceae	*Gnetum ula* Brongn.	Liana	
	Angiosperms			
2	Acanthaceae	*Cynarospermum asperrimum* (Nees) Vollesen	Herb	
3	Acanthaceae	*Eranthemum roseum* (Vahl) R. Br.	Shrub	
4	Acanthaceae	*Haplanthodes verticillata* (Roxb.) R.B. Majumdar	Herb	
5	Acanthaceae	*Hemigraphis latebrosa* (Heyne ex Roth) Nees var. latebrosa	Herb	
6	Acanthaceae	*Justicia diffusa* Willd.	Herb	
7	Acanthaceae	*Lepidagathis cuspidata* Nees	Shrub	
8	Acanthaceae	*Rungia repens* (L.) Nees	Herb	
9	Acanthaceae	*Strobilanthes callosa* Nees	Shrub	
10	Amaranthaceae	*Achyranthes aspera* L. var. aspera	Herb	
11	Anacardiaceae	*Holigarna arnottiana* (Wt.) Kurz*	Tree	Evergreen
12	Anacardiaceae	*Mangifera indica* L.	Tree	Evergreen
13	Apiaceae	*Pinda concanense* (Dalz.) P.K. Mukh. & Constance*	Herb	
14	Apocynaceae	*Anodendron paniculatum* A. DC.	Climber	
15	Apocynaceae	*Carissa congesta* Wight	Shrub	
16	Apocynaceae	*Cryptolepis buchanani* Roem. & Schult.	Shrub	
17	Apocynaceae	*Hemidesmus indicus* (L.) Schult.	Shrub	
18	Apocynaceae	*Hoya wightii* Hook. f.	Climber	
19	Apocynaceae	*Pergularia daemia* (Forssk.) Choiv.	Shrub	
20	Apocynaceae	*Tylophora dalzellii* Hook. f.	Liana	
21	Apocynaceae	*T. indica* (Burm. f.) Merr.	Liana	
22	Apocynaceae	*Wrightia tinctoria* R. Br.	Tree	Deciduous
23	Asparagaceae	*Asparagus racemosus* Willd.	Herb	
24	Asteraceae	*Ageratum conyzoides* L.	Herb	
25	Asteraceae	*Blumea eriantha* DC.	Herb	
26	Asteraceae	*B. lacera* (Burm. f.) DC.	Herb	
27	Asteraceae	*B. laciniata* (Roxb.) DC.	Herb	
28	Asteraceae	*Cyathocline purpurea* (Buch.-Ham. ex D. Don) O. Kuntze*	Herb	
29	Asteraceae	*Laphangium luteoalbum* (L.) Tzvelev	Herb	
30	Asteraceae	*Phyllocephalum scabridum* (DC) Kirkman	Herb	
31	Asteraceae	*Senecio bombayensis* Balakr.	Herb	
32	Asteraceae	*Cyanthillium cinereum* (L.) H. Rob.	Herb	
33	Bignoniaceae	*Heterophragma quadriloculare* (Roxb.) K. Schum.	Tree	Deciduous
34	Boranginaceae	*Cynoglossum zeylanicum* (Vahl ex Hornem.) Thunb. ex Lehm.	Herb	
35	Celastraceae	*Maytenus rothiana* (Walp.) Lobreau-Collen	Shrub	
36	Clusiaceae	*Garcinia indica* (Thou.) Choisy*	Tree	Evergreen
37	Clusiaceae	*G. talbotii* Raizada ex Santapau*	Tree	Evergreen
38	Clusiaceae	*Mammea suriga* (Buch.–Ham. ex Roxb.) Kosterm.	Tree	Evergreen
39	Colchicaceae	*Iphigenia magnifica* Ansari & R.S. Rao	Herb	
40	Combretaceae	*Calycopteris floribunda* (Roxb.) Poir.	Shrub	
41	Combretaceae	*Terminalia chebula* Retz.	Tree	Deciduous
42	Commelinaceae	*Murdannia pauciflora* (G.Brückn.) G.Brückn.	Herb	
43	Convolvulaceae	*Argyreia sericea* Dalz. & Gibs.	Climber	

	Family	Species	Habit	Foliar habit
44	Convolvulaceae	*A. elliptica* (Roth) Choisy	Climber	
45	Convolvulaceae	*Strictocardia campanulata* (L.) Merr.	Climber	
46	Cucurbitaceae	*Solena amplexicaulis* (Lam.) Gandhi	Climber	
47	Cucurbitaceae	*Trichosanthes tricuspidata* Lour.	Climber	
48	Cyperaceae	*Cyperus rotundus* L.	Herb	
49	Cyperaceae	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Presl	Herb	
50	Dilleniaceae	*Dillenia pentagyna* Roxb.	Tree	Deciduous
51	Dioscoreaceae	*Dioscorea belophylla* (Prain) Voigt ex Haines	Climber	
52	Dioscoreaceae	*D. bulbifera* L.	Climber	
53	Ebenaceae	*Diospyros montana* Roxb.	Tree	Deciduous
54	Elaeagnaceae	*Elaeagnus conferta* Roxb	Shrub	
55	Eriocaulaceae	*Eriocaulon* sp.	Herb	
56	Euphorbiaceae	*Breynia nivosa* (Bull.) Small	Shrub	
57	Euphorbiaceae	*Euphorbia antiquorum* L.	Shrub	
58	Euphorbiaceae	*Falconeria insignis* Royle	Tree	Deciduous
59	Euphorbiaceae	*Macaranga peltata* (Roxb.) Muell.-Arg.	Tree	Evergreen
60	Euphorbiaceae	*Mallotus philippensis* (Lam.) Muell.-Arg.	Tree	Evergreen
61	Euphorbiaceae	*Securinega leucopyrus* (Willd.) Muell.-Arg.	Shrub	
62	Fabaceae	*Abrus precatorius* L.	Climbers	
63	Fabaceae	*Albizia odoratissima* (L. f.) Bth.	Tree	Deciduous
64	Fabaceae	*Cassia fistula* L.	Tree	Deciduous
65	Fabaceae	*Crotalaria filipes* Benth.	Herb	
66	Fabaceae	*C. hirsuta* Willd.	Herb	
67	Fabaceae	*Dalbergia horrida* (Dennst.) Mabb.	Climbing shrub	
68	Fabaceae	*Entada rheedei* Spreng.	Liana	
69	Fabaceae	*Erythrina stricta* Roxb.	Tree	Deciduous
70	Fabaceae	*Geissaspis cristata* Wight & Arn.	Herb	
71	Fabaceae	*G. tenella* Benth.	Herb	
72	Fabaceae	*Mucuna pruriens* (L.) DC.	Climbing shrub	
73	Fabaceae	*Smithia bigemina* Dalz.	Herb	
74	Gentianaceae	*Canscora diffusa* (Vahl) R. Br. ex Roem. & Schult.	Herb	
75	Icacinaceae	*Nothapodytes nimmoniana* (J. Grah.) Mabb.	Tree	Evergreen
76	Lamiaceae	*Colebrookea oppositifolia* Sm.	Shrub	
77	Lamiaceae	*Leucas ciliata* Benth.	Herb	
78	Lamiaceae	*Pogostemon benghalensis* (Burm. f.) O. Ktze.	Herb	
79	Lamiaceae	*P. heyneanus* Benth.	Herb	
80	Lauraceae	*Actinodaphne angustifolia* Nees*	Tree	Evergreen
81	Lauraceae	*Litsea* sp.	Tree	Evergreen
82	Lecythidaceae	*Careya arborea* Roxb.	Tree	Deciduous
83	Lentibulariaceae	*Utricularia* sp.	Herb	
84	Lythraceae	*Lagerstroemia microcarpa* Wight	Tree	Deciduous
85	Lythraceae	*Woodfordia frutiosa* (L.) Kurz	Shrub	
86	Malvaceae	*Bombax ceiba* L.	Tree	Deciduous
87	Malvaceae	*Ceiba pentandra* (L.) Gaertn.	Tree	Deciduous
88	Malvaceae	*Firmiana colorata* (Roxb.) R. Br.	Tree	Deciduous
89	Malvaceae	*Grewia tiliifolia* Vahl	Tree	Deciduous
90	Malvaceae	*Kydia calycina* Roxb.	Tree	Deciduous
91	Malvaceae	*Sterculia foetida* L.	Tree	Deciduous

	Family	Species	Habit	Foliar habit
92	Malvaceae	*Triumfetta rhomboidea* Jacq.	Shrub	
93	Melastomataceae	*Memecylon umbellatum* Burm. f.	Tree	Evergreen
94	Meliaceae	*Turraea villosa* Benn.	Shrub	
95	Menispermaceae	*Anamirta cocculus* (L.) Wight & Arn.	Liana	
96	Menispermaceae	*Diploclisia glaucescens* (Bl.) Diels	Climbing shrub	
97	Menispermaceae	*Tinospora sinensis* (Lour.) Merr.	Climbing shrub	
98	Molluginaceae	*Glinus oppositifolius* (L.) A. DC.	Herb	
99	Molluginaceae	*Mollugo pentaphylla* L.	Herb	
100	Moraceae	*Ficus amplissima* J.E. Sm.	Tree	Deciduous
101	Moraceae	*F. arnottiana* (Miq.) Miq.	Tree	Deciduous
102	Moraceae	*F. microcarpa* L.f.	Tree	Evergreen
103	Moraceae	*F. nervosa* B. Heyne ex Roth	Tree	Evergreen
104	Moraceae	*F. racemosa* L.	Tree	Deciduous
105	Moraceae	*F. talbotii* King	Tree	Evergreen
106	Moraceae	*F. virens* Ait. var. *virens*	Tree	Deciduous
107	Musaceae	*Ensete superbum* (Roxb.) Cheesm.	Herb	
108	Myrtaceae	*Syzygium* sp.	Tree	Evergreen
109	Oleaceae	*Jasminum malabaricum* Wight	Climbing shrub	
110	Oleaceae	*Olea dioica* Roxb.	Tree	Evergreen
111	Orchidaceae	*Aerides maculosa* Lindl.	Epiphyte	
112	Orchidaceae	*Dendrobium barbatulum* Lindl.	Epiphyte	
113	Orchidaceae	*Oberonia recurva* Lindl.	Epiphyte	
114	Piperaceae	*Piper* sp.	Climbing shrub	
115	Plantaginaceae	*Mecardonia procumbens* (Mill.) Small	Herb	
116	Poaceae	*Arundinella pumila* (Hochst. ex A. Rich.) Steud	Herb	
117	Poaceae	*Arundinella spicata* Dalz.	Herb	
118	Poaceae	*Bambusa bambos* (L.) Voss	Herb	
119	Poaceae	*Eragrostiella bifaria* (Vahl.) Bor	Herb	
120	Poaceae	*Eragrostis cilianensis* (All.) Vignolo-Lutati ex F.T. Hubb.	Herb	
121	Poaceae	*Heteropogon contortus* (L.) P.Beauv. ex. R. & S.	Herb	
122	Poaceae	*Isachne globosa* (Thunb.) O.Ktze. var. *globosa*	Herb	
123	Poaceae	*Ischaemum tumidum* Stapf ex Bor	Herb	
124	Poaceae	*Jansenella griffithiana* (C. Muell.)Bor	Herb	
125	Poaceae	*Oplismenus burmannii* (Retz.) P. Beauv.	Herb	
126	Poaceae	*Themeda triandra* Forssk.	Herb	
127	Primulaceae	*Maesa indica* (Roxb.) A. DC.	Shrub	
128	Ranunculaceae	*Clematis heynei* M.A. Rau	Climber	
129	Rubiaceae	*Catunaregam spinosa* (Thunb.) Tirveng.	Tree	Deciduous
130	Rubiaceae	*Hymenodictyon obovatum* Wall.	Tree	Deciduous
131	Rubiaceae	*Ixora brachiata* Roxb.	Tree	Evergreen
132	Rubiaceae	*Ixora nigricans* R. Br. ex Wight & Arn.	Shrub	
133	Rubiaceae	*Pavetta indica* Andr.	Shrub	
134	Rubiaceae	*Psydrax dicoccos* Gaertn.	Tree	Evergreen
135	Rutaceae	*Atalantia racemosa* Wight	Shrub	
136	Rutaceae	*Glycosmis pentaphylla* (Retz.) DC.	Shrub	
137	Rutaceae	*Murraya koenigii* (L.) Spr.	Tree	Evergreen
138	Rutaceae	*M. paniculata* (L.) Jack	Tree	Evergreen
139	Rutaceae	*Paramignya monophylla* Wight	Liana	

	Family	Species	Habit	Foliar habit
140	Rutaceae	*Zanthoxylum rhetsa* (Roxb.) DC.	Tree	Deciduous
141	Santalaceae	*Osyris quadripartita* Salz. ex Decne.	Shrub	
142	Sapindaceae	*Allophylus cobbe* (L.) Raeusch.	Tree	Deciduous
143	Sapindaceae	*Dimocarpus longan* Lour.	Tree	Evergreen
144	Sapindaceae	*Sapindus laurifolius* Vahl	Tree	Deciduous
145	Sapotaceae	*Xantolis tomentosa* (Roxb.) Raf.	Tree	Evergreen
146	Scrophulariaceae	*Rhamphicarpa fistulosa* (Hochst.) Benth.	Herb	
147	Scrophulariaceae	*Striga gesnerioides* (Willd.) Vatke	Herb	
148	Smilacaceae	*Smilax zeylanica* L.	Climber	
149	Solanaceae	*Solanum anguivi* Lam.	Shrub	
150	Thymelaeaceae	*Gnidia glauca* (Fresen.) Gilg.	Shrub	
151	Ulmaceae	*Celtis cinnamomum* Lindl. ex Planch	Tree	Evergreen
152	Urticaceae	*Boehmeria macrophylla* Hornem.	Shrub	
153	Urticaceae	*Girardinia diversifolia* (Link) Friis	Herb	
154	Vitaceae	*Cissus elongata* Roxb.	Climber	
155	Vitaceae	*C. repens* Lamk	Climber	
156	Vitaceae	*Leea indica* (Burm. f.) Merr.	Shrub	
157	Vitaceae	*L. setuligera* C.B. Cl.	Shrub	

Table 2. Diversity parameters of the study area.

	Present study	Watve et al. 2003*	Muthuramkumar et al. 2006	Kanade et al. 2008	Joglekar et al. 2015
Study area	Mulshi Forest area, NWG	Mulshi Forest area, NWG	Valparai Plateau, SWG	Chandoli NP, NWG	Koyana WS, NWG
Unit sampling area	0.1ha	0.05–0.1 ha	0.8ha	0.5ha	0.5ha
Total sampling area	0.3ha	0.635ha	4ha	5ha	6ha
Girth class	G>10cm	G>10cm	G>30cm	G>15cm	G>15cm
Number of families	23 (19–21)	31 (9–16)	-	44	41
Number of genera	42 (28–34)	45 (11–20)	-	86	-
Number of species (S)	49 (33–39)	52 (12–20)	144 (38–73)	120 (25–57)	108 (14–42)
Number of individuals (N) per area	444 (133–158)/ 0.3ha	633–1720.0/ 1.0ha	307–453/ 0.8ha	149–657/ 0.5ha	84–544/ 0.5ha
N/S	9.06 (3.5–4.79)	3.92–6.36	-	5.96–19.32	-
Margalef's index	7.87 (6.32–7.57)	6.67–9.14	-	-	-
Simpson's dominance index	0.057 (0.052–0.078)	0.11–0.31	-	-	-
Simpson's reciprocal index (1/D)	17.48 (12.76–19.08)	3.23–9.09	-	-	-
Berger-Parker dominance	0.17 (0.13–0.20)	-	-	-	-
Shannon's index	3.36 (2.97–3.26)	2.77–3.43	-	2.0–3.2	1.5–3.03
Evenness	0.59 (0.59–0.68)	-	-	-	-
Equitability	0.86 (0.85–0.90)	0.63–0.84	-	-	-
Fisher's α index	14.07 (12.7–17.8)	-	11.42–24.62	-	-
Abundance based coverage estimate (ACE)	51.78 (39.99–48.04)	-	-	-	-
Chao-1	51.49 (39.99–48.04)	-	-	-	-
Jack 1	54.33	-	-	-	-
Jack 2	53.50	-	-	-	-

Note: Figures in parentheses indicate the range of values in individual strip transects; *Density extrapolated to 1ha; NWG - northern Western Ghats, SWG - southern Western Ghats.

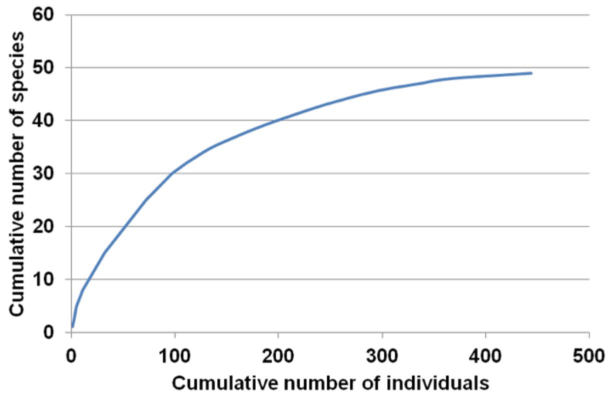

Figure 2. Species accumulation curve.

17.48. Berger-Parker dominance index, which indicates the dominance of most abundant species, was 0.17. Shannon index (H) of the study site was 3.36, while evenness and equitability indices were 0.59 and 0.86, respectively. Fisher's alpha diversity index for the study site was 14.07. The species richness estimators such as Chao-1 and ACE index of the study site were 51.49 and 51.78, respectively. Similarly, Jackknife estimators of species richness Jack 1 and Jack 2 were 54.33 and 53.50, respectively (Table 2). Species accumulation curve (Fig. 2) showed a typical hyperbola-shaped curve reaching approximately to asymptote; the estimated species richness was close to observed species richness (49).

DISCUSSION

Protected areas such as wildlife sanctuaries (WS) and national parks (NP) have high conservation priorities; presently, there are 10 WSs and two NPs within the auspices of NWG, covering an area of 2,151.93km^2. The remaining forest area (~11,350km^2) of NWG, however, does not fall under the protected area network and is mostly composed of discontinuous forest patches that are highly vulnerable to anthropogenic activities (Kale et al. 2010). In the 20th Century, several dams were constructed on the rivers originating in NWG, which created water bodies covering 1,681.33km^2, contributing further to the loss of forest cover of NWG (Panigrahy et al. 2010). Collectively, NWG is under intense pressure of further habitat loss and, together with its topology and anthropogenic activities, the landscape matrix has become a mosaic of disjunct forest patches, dams, agricultural lands, and villages. Habitat loss typically leads to fragmentation; however, fragmented forests often retain mature forest communities. Hence, the cumulative species richness of fragmented patches can be comparable with that of mature forests. This implies that the fragmented forest patches should also be conserved to protect the gene pool, to prevent species extinction, and to maintain forest biodiversity. In view of this, small-scale inventories in fragmented forest patches are very important to document the plant community structure and to create a baseline for the restoration of diversity.

The present study documented the floristic composition of a representative fragmented forest patch of NWG and reported 157 species of flowering plants including 49 tree species from the area of 0.3ha. The number of tree species recorded in the present study constitutes ~11% of the total native tree species of Maharashtra (Ghate & Datar 2009). The number of tree species recorded per unit area was higher than that previously reported in various regions of the WG: 12–20 species in 0.05–0.1 ha in Mulshi Forest area, NWG (Watve et al. 2003); 25–57 species in 0.5ha in Chandoli NP, NWG (Kanade et al. 2008); 14–42 species in 0.5ha in Koyana WS, NWG (Joglekar et al. 2015), and 38–73 species in 0.8ha in Valparai plateau, southern WG (Muthuramkumar et al. 2006). The higher species richness observed in the present study could partly be due to the differences in sampling method and sampling area across different studies since species richness is affected by these two factors and different species maybe over- or under-represented in different locations (Gotelli & Colwell 2001).

The species accumulation curve reached approximately to the asymptote and the observed species number was close to the estimated species richness. Extensive sampling of the whole study area might result in an addition of a few species, reaching estimated species richness and reducing the number of monospecific families. Higher species richness per area indicates a low level of disturbance at the study site; however, very few endemic species were observed. Species reported in the present study are comparable with a previous study in the same area (Watve et al. 2003), and most of the species found were pioneer species (e.g., *Memecylon umbellatum* Burm.f.) with a few climax species (e.g., *Holigarna arnottiana* (Wt.) Kurz). This observation correlates with that of Arroyo-Rodriguez et al. (2009), who reported a high percentage of pioneer species along with remnant species of the mature forest communities in the rain forest fragments in Los Tuxtlas, Mexico.

Tree density of 444 individual trees (G>10cm) from the area of 0.3ha was higher than previously

Image 2. Plant species observed in the study area: A - *Actinodaphne angustifolia* Nees | B - *Anodendron manubriatum* Merr. | C - *Eranthemum roseum* (Vahl) R. Br. | D - *Hemigraphis latebrosa* (Heyne ex Roth) Nees | E - *Memecylon umbellatum* Burm.f. | F - *Murraya paniculata* (L.) Jack | G - *Olea dioica* Roxb. | H - *Turraea villosa* Benn. © Rani Bhagat.

Image 3. Plant species observed in the study area: A - *Asparagus racemosus* Willd. | B - *Cissus elongata* Roxb. | C - *Ensete superbum* (Roxb.) Cheesm. | D - *Ixora nigricans* R. Br. ex Wight & Arn. | E - *Leucas ciliata* Benth. | F - *Macaranga peltata* (Roxb.) Meull. - Arg. | G - *Oberonia recurva* Lindl. | H - *Solena amplexicaulis* (Lam.) Gandhi. © Rani Bhagat.

Image 4. Plant species observed in the study area: A - *Argyreia sericea* Dalz. & Gibs. | B - *Boehmeria macrophylla* Hornem. | C - *Celtis cinnamomum* Lindl. ex Planch. | D - *Entada rheedei* Spreng. | E - *Geissaspis tenella* Bth. | F - *Pavetta indica* Andr. | G - *Tylophora dalzellii* Hook.f. | H - *Xantolis tomentosa* (Roxb.) Raf. © Rani Bhagat.

Image 5. Plant species observed in the study area: A - *Canscora diffusa* (Vahl) R. Br. ex R. & S. | B - *Colebrookea oppositifolia* Sm. | C - *Heteropogon contortus* (L.) P.Beauv. ex R. & S. | D - *Ficus talbotii* King | E - *Jasminum malabaricum* Wight | F - *Osyris quadripartita* Salz. ex Decne. | G - *Psydrax dicoccos* Gaertn. | H - *Sterculia foetida* L. © Rani Bhagat.

reported from various regions of WG (Watve et al. 2003; Muthuramkumar et al. 2006; Kanade et al. 2008; Joglekar et al. 2015). These variations, however, might be caused due to differences in the sampling method and girth classes used in different studies. Nevertheless, the N/S ratio for the study site was comparable with the values previously reported for similar forest type in Mulshi Forest area (Watve et al. 2003) and Chandoli NP (Kanade et al. 2008). Similarly, Margalef's index of species richness was comparable with the values reported at Mulshi Forest area (Watve et al. 2003).

A higher Berger-Parker dominance index was the result of relative dominance of a single species (e.g., *Memecylon umbellatum* Burm.f.). Simpson's dominance index (1/D) was higher compared to a previous study in Mulshi Forest area (Watve et al. 2003); however, this index is known to be affected by the presence of singleton species. Shannon index of the study site was comparable with the values reported for similar forest type at Mulshi Forest area (Watve et al. 2003), Chandoli NP (Kanade et al. 2008), and Koyana WS (Joglekar et al. 2015). Equitability values for the study site suggest a low level of dispersion of species within the study site and were comparable to a previous study at Mulshi Forest area (Watve et al. 2003). Fisher's α index for the study site was within the range of values reported for the forest fragments at Valparai plateau, southern WG (Muthuramkumar et al. 2006).

Under the dominance of *Syzygium* spp. and *Actinodaphne* spp. observed, the present study suggests that the community composition is different than the typical *M-S-A* series forest. A previous study (Watve et al. 2003) in the Mulshi Forest area, NWG, also reported a similar observation for a few locations, where species composition differs from *M-S-A* type and the composition pattern of *Memeylon-Xantolis-Actinodaphne* was reported. Other studies in NWG suggested a subtype of *M-S-A* series forest composed of *Memecylon-Syzygium-Olea* based on abundance (Kanade et al. 2008; Joglekar et al. 2015). These communities, however, are not completely separate since most of the species are shared by both the types. This observation indicates the fragments of a larger forest continuum, where some species became dominant over a small area as per local biotic and abiotic conditions (Watve et al. 2003; Kanade et al. 2008).

In the present study, similar numbers of evergreen and deciduous species were recorded; however, evergreen trees were numerically dominant as compared to deciduous trees. Deciduous tree species were found either alongside streams and upper slopes of the study site having shallow soil depth or at the edge of the forest fragments. The mosaic of evergreen and deciduous tree species along the streams (e.g., *Ficus arnottiana* Miq.) or upper slopes may be explained by habitat heterogeneity and microhabitat preference (Fang et al. 2017). While the occurrence of deciduous tree species at the forest edge (e.g., *Bombax ceiba* L.) may be the result of fragmentation. Edge effect promotes a shift in the functional composition near the forest edge, with the local dominance of pioneer and small-seeded wind-dispersed species (Mendes et al. 2016). Watve et al. (2003) suggested the dependence of these species on germplasm from scrub areas surrounding the forest patches.

CONCLUSIONS

Forest fragmentation has become a global phenomenon and much of the Earth's remaining forest fragments are individually less than 10ha in size while 70% of the world's remaining forests are now found within 1km of the forest edge (Haddad et al. 2015). While some habitats like NWG are patchy by nature, the patchy continuum of forests has further been severely fragmented due to anthropogenic activities (Watve et al. 2003). The large area of NWG is composed of discontinuous and fragmented forests and these patches are categorized as either reserved forest or, occasionally, unclassified forest. While protected areas like WSs and NPs have a high priority for conservation with access restrictions, such restrictions are not being imposed on non-protected areas, which makes them much more vulnerable to anthropogenic activities. The present study revealed that even such small fragmented forest patches could also harbour a high diversity of flowering plants and that they need to be conserved by increasing awareness of the local communities and vigilance for destructive activities. This would aid in conserving the biodiversity of the entire region as a whole.

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