The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under Creative Commons Attribution 4.0 International License unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

Article

The Importance of Conserving Fragmented Forest Patches with High Diversity of Flowering Plants in the Northern Western Ghats: An Example from Maharashtra, India

Amol Kishor Kasodekar, Amol Dilip Jadhav, Rani Babanrao Bhagat, Rakesh Mahadev Pawar, Vidya Shrikant Gupta & Narendra Yeshwant Kadoo

26 May 2019 | Vol. 11 | No. 7 | Pages: 13833–13849
DOI: 10.11609/jott.3296.11.7.13833-13849

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.
THE IMPORTANCE OF CONSERVING FRAGMENTED FOREST PATCHES WITH HIGH DIVERSITY OF FLOWERING PLANTS IN THE NORTHERN WESTERN GHATS: AN EXAMPLE FROM MAHARASHTRA, INDIA

Amol Kishor Kasodekar1,2, Amol Dilip Jadhav2, Rani Banabanrao Bhagat3, Rakesh Mahadev Pawar4, Vidya Shrikant Gupta5 & Narendra Yeshwant Kadoo6

1,2,3,4 Biochemical Sciences Division, CSIR-National Chemical Laboratory, Pune, Maharashtra 411008, India. 1,5,6 Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh 201002, India. 3 Department of Botany, Baburaoji Gholap College, Pune, Maharashtra 411027, India.

Abstract: The northern Western Ghats (NWG) comprises 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.
Flowering plants in northern Western Ghats

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 190,037km² 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 130,500km² area (Rodgers et al. 2000); however, the exact area under WG varies from report to report (129,037–164,280 km²) 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, 95,446km² (73.1%) area of WG was under forest cover, of which an estimated 33,579km² (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 peninsula 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 ~13,500km² 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°32′204″N and 73°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...
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 167 m × 06 m, 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 0.1 ha at each strip transect, and the total sampling area was 0.3 ha. Tree diversity and abundance encountered within the fixed area of strip transects were documented. Trees with Girth<10 cm 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 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 (Watte 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 (0.1 ha each), and 444 individuals stems (G>10 cm) were recorded from the total sampling area of 0.3 ha (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 0.3 ha was 9.06 while it varied from 3.50 to 4.79 for each strip transect of 0.1 ha. 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 talbotii* 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      | Gnetaceae Gnetum ula Brongn.                 | Liana     |              |
| Angiosperms      | 2 Acanthaceae Cynarospermum asperarimum (Nees) Vollesen | Herb     |              |
|                  | 3 Acanthaceae Eranthemum raseum (Vahl) R. Br. | Shrub     |              |
|                  | 4 Acanthaceae Haploanthodes verticillata (Roxb.) R.B. Majumdar | Herb |              |
|                  | 5 Acanthaceae Hemigraphis latebrosa (Heyne ex Roth) Nees var. latebrosa | Herb |              |
|                  | 6 Acanthaceae Justicia diffusa Wild.         | Herb     |              |
|                  | 7 Acanthaceae Lepidagathis cuspidata Nees    | Shrub     |              |
|                  | 8 Acanthaceae Rungia repens (L.) Nees        | Herb     |              |
|                  | 10 Amarantaceae 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 Cryptopeis 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 daeżeli Hook. f.    | Liana     |              |
|                  | 21 Apocynaceae T. indica (Burm. f.) Merr.    | Liana     |              |
|                  | 22 Apocynaceae Wrightia tinctoria R. Br.     | Tree      | Deciduous   |
|                  | 23 Asparagaceae Asparagus racemosus Wild.    | Herb     |              |
|                  | 24 Asteraceae Ageratum conyzoides L.         | Herb     |              |
|                  | 25 Asteraceae Blumea eriantha DC.            | Herb     |              |
|                  | 26 Asteraceae B. lacera (Burm. f.) DC.       | Herb     |              |
|                  | 27 Asteraceae B. lacinia (Roxb.) DC.         | Herb     |              |
|                  | 28 Asteraceae Cyathochine purpurea (Buch.-Ham. ex B. Don) O. Kuntze* | Herb |              |
|                  | 29 Asteraceae Laphangium lutealbum (L.) Texlev | Herb |              |
|                  | 30 Asteraceae Phyllocephalum scabridum (DC) Kirkman | Herb |              |
|                  | 31 Asteraceae Senecio bombayensis Balak.     | Herb     |              |
|                  | 32 Asteraceae Cynanthis cineria (L.) H. Rob. | Herb     |              |
|                  | 33 Bignoniaceae Heterophragma quadriloculare (Roxb.) K. Schum. | Tree     | Deciduous   |
|                  | 34 Boranginaceae Cynoglossum zeylonicum (Vahl ex Hornem.) Thunb. ex Lehm. | Herb |              |
|                  | 35 Celastraceae Maytenus rothiana (Walp.) Lobel-Collin | 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 Calycophyllum 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                    |                |                      |
| 45                | Convolvulaceae                    |                |                      |
| 46                | Cucurbitaceae                     |                |                      |
| 47                | Cucurbitaceae                     |                |                      |
| 48                | Cyperaceae                        |                |                      |
| 49                | Cyperaceae                        |                |                      |
| 50                | Dilleniaceae                      |                |                      |
| 51                | Dioscoreaceae                     |                |                      |
| 52                | Dioscoreaceae                     |                |                      |
| 53                | Ebenaceae                         |                |                      |
| 54                | Elaeagnaceae                      |                |                      |
| 55                | Elaeocaulaceae                    |                |                      |
| 56                | Euphorbiaceae                     |                |                      |
| 57                | Euphorbiaceae                     |                |                      |
| 58                | Euphorbiaceae                     |                |                      |
| 59                | Euphorbiaceae                     |                |                      |
| 60                | Euphorbiaceae                     |                |                      |
| 61                | Euphorbiaceae                     |                |                      |
| 62                | Fabaceae                          |                |                      |
| 63                | Fabaceae                          |                |                      |
| 64                | Fabaceae                          |                |                      |
| 65                | Fabaceae                          |                |                      |
| 66                | Fabaceae                          |                |                      |
| 67                | Fabaceae                          |                |                      |
| 68                | Fabaceae                          |                |                      |
| 69                | Fabaceae                          |                |                      |
| 70                | Fabaceae                          |                |                      |
| 71                | Fabaceae                          |                |                      |
| 72                | Fabaceae                          |                |                      |
| 73                | Fabaceae                          |                |                      |
| 74                | Gentianaceae                      |                |                      |
| 75                | Icacinaceae                       |                |                      |
| 76                | Lamiaceae                         |                |                      |
| 77                | Lamiaceae                         |                |                      |
| 78                | Lamiaceae                         |                |                      |
| 79                | Lamiaceae                         |                |                      |
| 80                | Lauraceae                         |                |                      |
| 81                | Lauraceae                         |                |                      |
| 82                | Lecythidaceae                     |                |                      |
| 83                | Lentibulariaceae                  |                |                      |
| 84                | Lythraceae                        |                |                      |
| 85                | Lythraceae                        |                |                      |
| 86                | Malvaceae                         |                |                      |
| 87                | Malvaceae                         |                |                      |
| 88                | Malvaceae                         |                |                      |
| 89                | Malvaceae                         |                |                      |
| 90                | Malvaceae                         |                |                      |
| 91                | Malvaceae                         |                |                      |
| Family                  | Species                          | Habit   | Foliar habit   |
|-------------------------|----------------------------------|---------|----------------|
| Malvaceae               | *Triumfetta rhomboidea* Jacq.    | Shrub   |               |
| Melastomataceae         | *Memecylon umbellatum* Burm. f.  | Tree    | Evergreen     |
| Meliaceae               | *Turrara villosa* Benn.          | Shrub   |               |
| Menispermaceae          | *Anamirta cocculus* (L.) Wight & Arn. | Liana  |               |
| Menispermaceae          | *Diplolcisia glaucescens* (Bl.) Diels | Climbing shrub |          |
| Menispermaceae          | *Tinospora sinensis* (Lour.) Merr. | Climbing shrub |          |
| Molluginaceae           | *Glinus oppositifolius* (L.) A. DC. | Herb   |               |
| Molluginaceae           | *Molluga pentaphyla* L.         | Herb    |               |
| Moraceae                | *Ficus ampulissima* J. E. Sm.    | Tree    | Deciduous     |
| Moraceae                | *F. arnottiana* (Miq.) Miq.     | Tree    | Deciduous     |
| Moraceae                | *F. microcarpa* L.f.            | Tree    | Evergreen     |
| Moraceae                | *F. nervosa* B. Heyne ex Roth   | Tree    | Evergreen     |
| Moraceae                | *F. racemosa* L.                | Tree    | Deciduous     |
| Moraceae                | *F. taihotai King*              | Tree    | Evergreen     |
| Moraceae                | *F. virens* Ait. var. virens    | Tree    | Deciduous     |
| Musaceae                | *Ensete superbum* (Roxb.) Cheesm. | Herb   |               |
| Myrtaceae               | *Syzygium* sp.                  | Tree    | Evergreen     |
| Oleaceae                | *Jasminum malabaricum* Wight    | Climbing shrub |          |
| Oleaceae                | *Olea dioica* Roxb.             | Tree    | Evergreen     |
| Orchidaceae             | *Aerides maculosa* Lindl.       | Epiphyte|               |
| Orchidaceae             | *Dendrobium barbatulum* Lindl.  | Epiphyte|               |
| Orchidaceae             | *Oberonia recurva* Lindl.       | Epiphyte|               |
| Piperaceae              | *Piper* sp.                     | Climbing shrub |          |
| Plantaginaceae          | *Mecardonia procumbens* (Mill.) Small | Herb |               |
| Poaceae                 | *Arundinella pumila* (Hochot. ex A. Rich.) Steud | Herb |               |
| Poaceae                 | *Arundinella spicata* Dalz.     | Herb    |               |
| Poaceae                 | *Bambusa bambos* (L.) Voss      | Herb    |               |
| Poaceae                 | *Eragrostiella bifaria* (Vahl.) Bor | Herb |               |
| Poaceae                 | *Eragrostis ciliennis* (All.) Vignola-Lutati ex F.T. Hubb. | Herb |               |
| Poaceae                 | *Heteropogon contortus* (L.) P.Beauv. ex. R. & S. | Herb |               |
| Poaceae                 | *Isachne globosa* (Thumb.) O.Ktze. var. globosa | Herb |               |
| Poaceae                 | *Ischaemum tumidum* Stapf ex Bor | Herb |               |
| Poaceae                 | *Jansenella griffithiana* (C. Muell.) Bor | Herb |               |
| Poaceae                 | *Oplismenus burmannii* (Retz.) P. Beauv. | Herb |               |
| Poaceae                 | *Themeda triandra* Forssk.      | Herb    |               |
| Primulaceae             | *Maesa indica* (Roxb.) A. DC.   | Shrub   |               |
| Ranunculaceae           | *Clematis heynei* M.A. Rau      | Climbing |              |
| Rubiaceae               | *Catunaregam spinosa* (Thunb.) Tirveng. | Tree | Deciduous     |
| Rubiaceae               | *Hymenodictyon abovatum* Wall.  | Tree    | Deciduous     |
| Rubiaceae               | *Ixora brachiata* Roxb.         | Tree    | Evergreen     |
| Rubiaceae               | *Ixora nigricans* R. Br. ex Wight & Arn. | Shrub |               |
| Rubiaceae               | *Pavetta indica* Andr.          | Shrub   |               |
| Rubiaceae               | *Psychotria dicoccos* Gaertn.   | Tree    | Evergreen     |
| Rutaceae                | *Atalanta racemosa* Wight       | Shrub   |               |
| Rutaceae                | *Glycosmis pentaphylla* (Retz.) OC. | Shrub |               |
| Rutaceae                | *Murraya koenigii* (L.) Spr.    | Tree    | Evergreen     |
| Rutaceae                | *M. paniculata* (L.) Jack       | Tree    | Evergreen     |
| Rutaceae                | *Paramignya monaphylla* Wight   | Liana   |               |
Table 2. Diversity parameters of the study area.

| Study area                | Present study | Wate et al. 2003* | Muthuramkumar et al. 2006 | Kanade et al. 2008 | Joglekar et al. 2015 |
|---------------------------|---------------|-------------------|---------------------------|-------------------|--------------------|
|                           | 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                       | 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.
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 2,151.93km². The remaining forest area (~11,350km²) 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 1,681.33km², 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 (Watte 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 *Memecylon-Xantalis-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 (Watte 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). Watte 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 (Watte 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.

**REFERENCES**

Arroyo-Rodríguez, V., E. Pineda, F. Escobar & J. Benítez-Malvido (2009). Value of small patches in the conservation of plant-species diversity in highly fragmented rainforest. Conservation Biology 23(3): 729–739. [https://doi.org/10.1111/j.1523-1739.2008.01120.x](https://doi.org/10.1111/j.1523-1739.2008.01120.x)

Buckland, S.T., D.L. Borchers, A. Johnston, P.A. Henrys & T.A. Marques (2007). Line transect methods for plant surveys. Biometrics 63(4): 989–998. [https://doi.org/10.1111/j.1541-0420.2007.00798.x](https://doi.org/10.1111/j.1541-0420.2007.00798.x)

Castillo-Campos, G., G. Halfcter & C.E. Moreno (2008). Primary and secondary vegetation patches as contributors to floristic diversity in a tropical deciduous forest landscape. Biodiversity and Conservation 17(17): 3557–3575.
Viviroli, D., H.H. Dürr, B. Messerli, M. Meybeck & R. Weingartner (2007). Mountains of the world, water towers for humanity: typology, mapping, and global significance. Water Resources Research 43(7): W07447. https://doi.org/10.1029/2006WR005653

Watte, A., R. Gandhe & K. Gandhe (2003). Vegetation structure and composition of semi-evergreen forest fragments in Mulshi area of northern Western Ghats. Annals of Forestry 11(2): 155–165.

Williams, J.N. (2013). Humans and biodiversity: population and demographic trends in the hotspots. Population and Environment 34(4): 510–523. https://doi.org/10.1007/s11111-012-0175-3

Wilson, M.C., X.Y. Chen, R.T. Corlett, R.K. Didham, P. Ding, R.D. Holt, M. Holyoak, G. Hu, A.C. Hughes, L. Jiang, W.F. Laurance, J. Liu, S.L. Pimm, S.K. Robinson, S.E. Rosso, X. Si, D.S. Wilcove, J. Wu & M. Yu (2016). Habitat fragmentation and biodiversity conservation: key findings and future challenges. Landscape Ecology 31(2): 219–227. https://doi.org/10.1007/s10980-015-0312-3

Yadav, S.R. & M.M. Sardesai (2002). Flora of Kolhapur District. Shivaji University Press, Kolhapur, India, 679pp.

Author details: Mr. AMOL K. KASODEKAR is a PhD fellow registered with AcSIR (Academy of Scientific and Innovative Research) and working at Biochemical Sciences Division, CSIR -National Chemical Laboratory (CSIR-NCL), Pune, India. Mr. AMOL D. JADHAV was working as Project Assistant at Biochemical Sciences Division, CSIR-NCL, Pune. Dr. RANI B. BHAGAT is a taxonomy expert and Assistant Professor in Department of Botany, Baburaoji Gholap College, Pune, India. Dr. RAKESH M. PAWAR was working as Research Associate at Biochemical Sciences Division, CSIR - NCL, Pune. Dr. VIDYA S. GUPTA is Emeritus Scientist at Biochemical Sciences Division, CSIR - NCL and Professor at AcSIR, Ghaziabad, India. Dr. NARENDRA Y. KADDO is Principal Scientist at Biochemical Sciences Division, CSIR - NCL and Associate Professor at AcSIR, Ghaziabad, India.
**Articles**

**Cats, canines, and coexistence: dietary differentiation between the sympatric Snow Leopard and Grey Wolf in the western landscape of Nepal Himalaya**
– Anil Shrestha, Kanchan Thapa, Samundra Ambuhang Subba, Maheshwar Dhakal, Bishnu Prasad Devkota, Gokarna Jung Thapa, Sheren Shrestha, Sabita Mall & Kalai Thapa, Pp. 13815–13821

**Genetic diversity among the endemic barb *Barbodes tumba* (Teleostei: Cyprinidae) populations from Mindanao, Philippines**
– Onaya P. Abdulmalik-Labe & Jonas P. Quilang, Pp. 13822–13832

**The importance of conserving fragmented forest patches with high diversity of flowering plants in the northern Western Ghats: an example from Maharashtra, India**
– Amol Kishor Kasodekar, Amol Dilip Jadhav, Rani Babanrao Bhagat, Rakesh Mahadev Pawar, Vidya Shrikant Gupta & Narendra Yeshwant Kadoo, Pp. 13833–13849

**Communications**

**First assessment of bird diversity in the UNESCO Sheka Forest Biosphere Reserve, southwestern Ethiopia: species richness, distribution and potential for avian conservation**
– Mattias Van Opstal, Bernard Oosterlynck, Million Belay, Jesse Erens & Matthias De Beenhouwer, Pp. 13850–13867

**Roadkill of animals on the road passing from Kalaburagi to Chincholi, Karnataka, India**
– Shankerappa Shantveerappa Hatti & Heena Mubeen, Pp. 13868–13874

**Ceriagrion chromothorax** sp. nov. (Odonata: Zygoptera: Coenagrionidae) from Sindhudurg, Maharashtra, India
– Shantanu Joshi & Dattaprasad Sawant, Pp. 13875–13885

**The diversity and distribution of polypores (Basidiomycota: Aphylloraphales) in wet evergreen and shola forests of Silent Valley National Park, southern Western Ghats, India, with three new records**
– C.K. Adarsh, K. Vidyasagar & P.N. Ganesh, Pp. 13886–13909

**Short Communications**

**Recent photographic records of Fishing Cat *Prionailurus viverrinus* (Bennett, 1833) (Carnivora: Felidae) in the Ayeyarwady Delta of Myanmar**
– Naing Lin & Steven G. Platt, Pp. 13910–13914

**Rediscovery of Van Hasselt’s Mouse-eared Bat *Myotis hasseltii* (Temminck, 1840) and its first genetic data from Hanoi, northern Vietnam**
– Vuong Tan Tu, Satoru Arai, Fuka Kikuchi, Chu Thi Hang, Tran Anh Tuan, Gábor Csorba & Tamás Görföl, Pp. 13915–13919

**Notes on the diet of adult Yellow Catfish *Aspistor luniscutis* (Pisces: Siluriformes) in northern Rio de Janeiro State, southeastern Brazil**
– Ana Paula Madeira Di Beneditto & Maria Thereza Manhães Tavares, Pp. 13920–13924

**Waterbirds from the mudflats of Thane Creek, Mumbai, Maharashtra, India: a review of distribution records from India**
– Omkar Dilip Adhikari, Pp. 13925–13930

**Moths of the superfamily Tineoidea (Insecta: Lepidoptera) from the Western Ghats, India**
– Amit Katewa & Prakash Chand Pathania, Pp. 13931–13936

**Winter season bloomer Hairy Bergenia *Bergenia ciliata* (Haw.) Sternb. (Saxifragales: Saxifragaceae), an important winter forage for diverse insect groups**
– Aseesh Pandey, Ravindra K. Joshi & Bhawana Kapkoti Negi, Pp. 13937–13940

**Notes**

**Kerala state bird checklist: additions during 2015 – May 2019**
– Abhinand Chandran & J. Praveen, Pp. 13941–13946

**What is in a name? The birthright of *Oxyopes nilgiricus* Sherriffs, 1955 (Araneae: Oxyopidae)**
– John T.D. Caleb, P. 13947

**Book Review**

**Study on biological and ecological characteristics of mudskippers**
– Ali Reza Radkhah & Soheil Eagderi, Pp. 13948–13950