Tropical Ecology **59**(1): 119–127, 2018 ISSN 0564-3295

www.tropecol.com

Floristic uniqueness and effect of degradation on diversity: A case study of sacred groves from northern Western Ghats

ABOLI KULKARNI[1], ANURADHA UPADHYE[1], NEELESH DAHANUKAR[2] & MANDAR N. DATAR[1*]

[1]*Biodiversity and Paleobiology Group, M. A. C. S. - Agharkar Research Institute, G.G. Agarkar Road, Pune 411004, Maharashtra, India*

[2]*Indian Institute of Science Education and Research, G1 Block, Dr. Homi Bhabha Road, Pashan, Pune 411008, Maharashtra, India*

Abstract: Western Ghats of India is rich in floristic diversity and endemism. However, being highly threatened with anthropogenic stressors, with only 6.8% of its original vegetation still extant, along with Sri Lanka it is considered as a biodiversity hotspot. It has been suggested that sacred groves in Western Ghats could act as refuge for the relic flora of this region. Sacred groves are the forest patches conserved since centuries due to religious beliefs and are the remnants of the climax vegetation containing endemic and endangered species of plants and animals. However, due to severe deforestation and urbanization, sacred groves are facing serious problems. In present investigation, sacred groves from Pune district, Maharashtra, were studied for their ecological role and their response to physical as well as degradation related parameters. Two hundred ninety six species of plants belonging to 100 families including 45 endemic species were recorded from these groves. Similarity between sacred groves is independent of distances accounting for only 30% for the groves as close as 2.5 km from each other. Physical parameters such as altitude and presence of streams are positively correlated with number of endemic species. Increase in the degradation including cutting, lopping; construction activities have affected the species richness across different sacred groves. Our results show that each sacred grove is unique in terms of biodiversity it contains and demands dedicated conservation efforts.

Key words: Biodiversity, conservation, ecological role, Pune district, sacred groves.

Introduction

Sacred groves, protected in many parts of world due to cultural heritage, are pristine forest pockets, dedicated to local deities. Religious beliefs and myths are largely responsible for their conservation from exploitation for personal and commercial purpose. They are preserved and managed traditionally by local inhabitants and are repositories of biodiversity that once existed in surrounding areas (Gadgil & Vartak 1975; Ghate *et al.* 2004).

Sacred groves exist in many African and Asian countries such as Ghana, Nigeria, Syria, Turkey, and China, Nepal and India (Gajula 2007) and are last remains of primary forests in many parts. Their diversity has been documented as unique example of traditional conservation practices. A large diversity of taxa has been recorded from sacred groves across the world like birds (Kangah-Kesse *et al.* 2009); amphibians (Rathod & Rathod 2013); small mammals (Decher 1997); butterflies (Bossart *et al.* 2006) and even fungi (Kumar & Kaviyarasan 2011). Their conservation potential across globe has been discussed by many workers like Mgumia &

[*]*Corresponding Author*; e-mail: mndatar@aripune.org

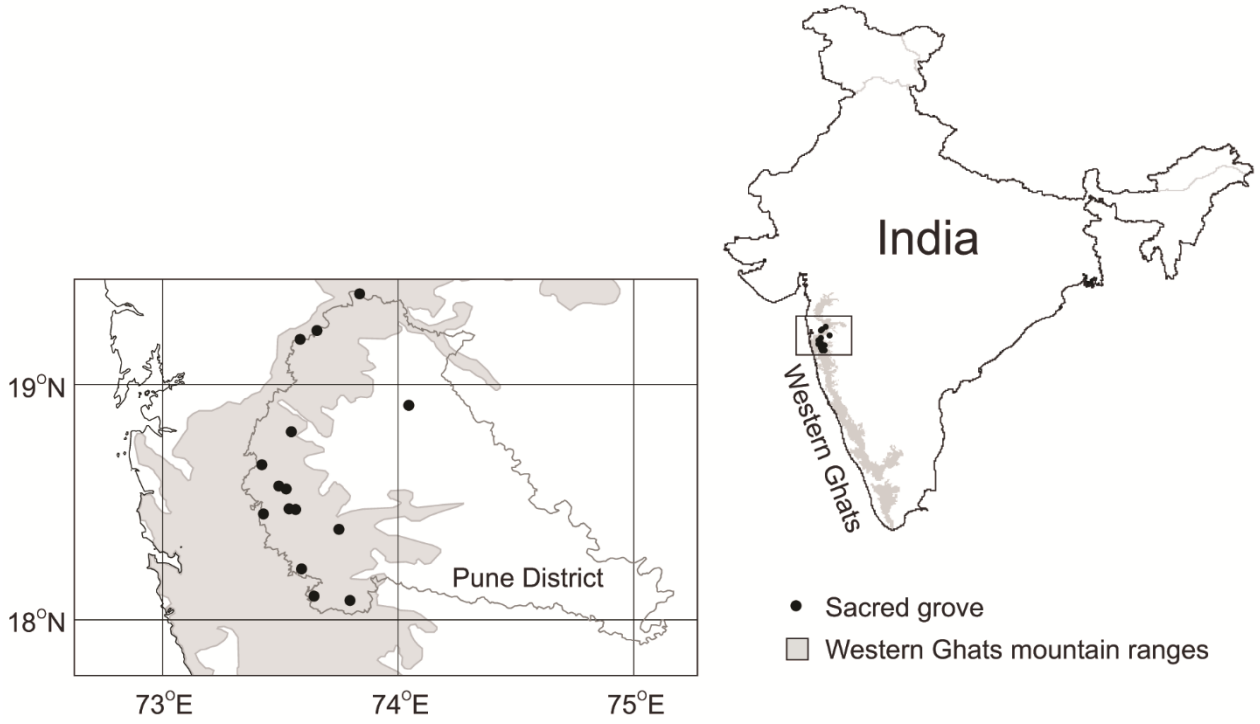

Fig. 1. Study area.

Oba (2003), Schaaf (2003), Gadgil & Vartak (1975). It is believed that they are more effective than government protected areas as they are community managed and cover a wide variety of habitats (Bhagwat & Rutte 2006).

In a developing country like India, this traditional practice might be one of the best ways of biodiversity preservation especially in the threatened biodiversity hotspots like the Western Ghats. Sacred groves are found in almost all agro climatic zones spread across the various states of the country. Maharashtra has 2800 sacred groves covering approximate 35.70 km² of area, most of which are located in Western Ghats or in Konkan which are known to shelter about 800 species of plants (Deshmukh 1999).

Sacred groves have remained in the discussion since long time in designing conservation strategies. They are excellent example of community conservation (Gajula 2007). With increasing anthropogenic activities, there is major problem of deforestation. Sacred groves play a vital role in this respect. Importance of sacred groves have been discussed from many aspects like they shelter rare and endemic flora and fauna and they are refuge and breeding grounds of many animals (Kulkarni *et al.* 2014; Vartak 1983). They are also abodes of wild relatives of cultivated plants, repositories of medicinal plants and source of perennial water.

As far as Maharashtra is concerned, origin of sacred groves dates back to the time of hunter-gatherers and groves are representatives of climax vegetation (Gadgil & Vartak 1975). In some of the groves, cutting or harvesting of plants is a taboo, and in others wood is used for religious purpose. Sacred groves exist in various sizes ranging from few trees up to 0.4 km² or more (Gadgil & Vartak 1976).

Sacred groves not only preserve the plants and animals contained within them, but also help in soil and water conservation (Anupama 2009). Hence, it functions as an ecosystem generating large amount of nutrients which ultimately goes into the adjoining agro-ecosystems like paddy fields (Anupama 2009). Sacred groves of northern Western Ghats have been studied for their floristic composition, socio-economic values and for their importance as repositories of relic vegetation (Ghate *et al.* 2004).

The current study is the an attempt to understand the floristic uniqueness of sacred groves and consequence of different physical and degradation factors on the overall floristic diversity of the groves, especially from the Western Ghats of Maharashtra. Pune is one of the important districts and fastest growing districts of northern Western Ghats and in Maharashtra with rapid industrialization on one side and severe degradation of

Table 1. Details of sacred groves.

Sacred Grove	Latitude	Longitude	Altitude (m)	Area (m^2)	Vegetation type*	Total number of plant species	Endemic species
Ahupe	18°47'23"	73°32'22"	918	43743	MD	42	5
Dhuprahat	18°05'32"	73°38'06"	1018	14168	EVG, SVG	64	10
Durgawadi	19°10'56"	73°34'39"	1138	92932	MD	55	12
Jannapankari	18°12'30"	73°35'01"	676	5310	MD, SVG	38	3
Kambre	18°22'32"	73°44'28"	618	3846	MD	47	6
Koliwade	18°27'29"	73°33'31"	684	416	MD	33	6
Lavarde	18°27'48"	73°31'51"	720	3264	MD	49	4
Manjarmal	19°22'36"	73°49'44"	966	180717	EVG, SVG	46	9
Muleshwar	18°39'03"	73°24'51"	783	14318	SVG	51	11
Nageshwar	18°04'22"	73°47'25"	664	19457	MD	13	1
Nandivali	18°33'37"	73°29'10"	753	18531	MD	34	4
Navlai	19°13'06"	73°38'55"	709	1428	MD	39	0
Sagdara	18°54'08"	74°02'13"	806	4798	DD	51	1
Valane	18°32'52"	73°31'02"	743	3801	MD	30	4
Vardayini	18°26'27"	73°25'22"	638	2879	SVG	29	7

*DD, Dry-Deciduous; MD, Moist-Deciduous; SVG, Semi-Evergreen; EVG, Evergreen

natural resources on the other. Pioneering work on the floristic explorations of the sacred groves of Pune was carried out by Gadgil & Vartak (1980) expressing central idea and importance. This work was carried out in 1970s after which there is a huge gap. Subsequent studies were concentrated more on the phytodiversity explorations.

In the present study, we analyzed fifteen sacred groves primarily for their ecological role and threats they are facing presently. We recorded plant species along with the physical and degradation related factors for each sacred grove that might impact the plant community of the grove. Relationship between plant species and these factors was checked along with the uniqueness of each grove in terms of species they harbor. We also analyzed the effect of forest degradation on the floristic diversity of the sacred groves.

Materials and Methods

Pune district is an important district that lies partly in northern Western Ghats, a biodiversity hotspot which is spread over an area of 16000 km^2. The district has 226 sacred groves (Deshmukh 1999). Fifteen sacred groves spread across the entire length of Pune district were selected for the present study (Fig. 1), fourteen out of which are from northern Western Ghats and one lies on Deccan plateau (Table 1). Sacred groves were selected in such a way that a north-south gradient of the Western Ghats of Pune district is covered. There are very few groves apart from the western region in Pune district. Hence, to show the contrast the one lies on the Deccan plateau was also selected for the study. Selected sacred groves were surveyed for their floristic diversity. Plant species from the sacred groves were collected and identified using local floras (Cooke 1967; Sharma *et al.* 1996; Singh & Karthikeyan 2000, Singh *et al.* 2001). A comprehensive checklist for all plants in the sacred groves was prepared. Plant samples were collected and processed using standard herbarium methods (Jain & Rao 1976) and herbarium specimens were prepared. Identity of the species was confirmed by comparing them with authentic specimens deposited in Herbaria of Agharkar Research Institute, Pune (AHMA) and Botanical Survey of India, Western Regional Center, Pune (BSI). The prepared specimens were deposited in AHMA (accession numbers: AHMA-27597 to AHMA-28659.)

Data was collected for various physical and vegetation parameters for each sacred grove. The total area of each sacred grove was measured by taking the latest imagery of each grove from Google Earth and measuring the area using Axio-Vision software. Degradation related parameters like temple construction, construction of roads, forest cutting and lopping leading to secondary vegetation or barren areas inside the grove were also measured on Axio-Vision, using images acquired from Google Earth.

Statistical analysis of the data was performed in PAST (Hammer *et al.* 2001) and Biplot 1.1 (Smith & Lipkovich 2002). We performed correspondence analysis (CA) to understand the distribution of floristic elements according to plant habit group in different sacred groves. Plants were grouped into different categories such as deciduous trees, evergreen trees, epiphytes, climbers, lianas, herbs and shrubs depending upon their growth habit. Canonical correspondence analysis (CCA) was done to understand the distribution of plant species along various physical parameters, including continuous variables like latitude (ºN), longitude (ºE), altitude (mASL), area (m^2) and percent undergrowth and qualitative variables like presence of semi-evergreen, moist deciduous, dry deciduous forests, and streams, in different sacred groves. Effect of degradation on the floristic diversity was studied using redundancy analysis (RDA) to find the correlations between multiple dependent parameters like number of total species, endemic species, deciduous trees, climbers, herbs, epiphytes, shrubs, lianas and evergreen trees and multiple independent qualitative variables like presence of cutting and lopping, MFP collection, direct presence of humans and construction activities and quantitative variables like area of road (m^2), area of temple (m^2), area of degraded patch (m^2) and percent degradation.

Results

Floristic diversity

Two hundred ninety six plant species belonging to 100 families were recorded from 15 sacred groves. Family Euphorbiaceae was dominant family followed by Rubiaceae and Fabaceae (Table S1). Maximum number of species (S = 64) was recorded from Dhuprahat sacred grove followed by 55 and 51 species from Durgawadi and Sagdara respectively (Table 1). Minimum number of species (S = 13) was recorded from Nageshwar. *Syzygium cumini*, *Terminalia bellirica, Mangifera indica* and *Jasminum malabaricum* were found to be commonly occurring species in sacred grove as they were recorded from more than 50% of the sacred groves under study. About 69% species were recorded only from single sacred grove out of the total species recorded. Some species were found to be restricted to certain sacred groves. Terrestrial orchid species like *Habenaria digitata, Habenaria furcifera, Nervilia* sp. were recorded only from Kambre and Jannapankari sacred groves. Whereas, epiphytic orchid species like *Smithsonia viridiflora, Aerides crispa, Aerides maculosa* were recorded from Vardayini, Manjarmal and Lavarde sacred groves. Sagdara sacred grove located in Rajgurunagar taluka has good population of trees of *Tectona grandis*.

Species such as *Myristica dactyloides, Agrostistachys indica, Canarium strictum, Chukrasia tabularis* and *Tabernaemontana alternifolia* which were recorded from one of these groves showed their northern-most extent with respect to their distribution in Western Ghats (Kulkarni *et al.* 2014).

Out of total 296 species found 45 species are endemic. Out of 15 sacred groves surveyed, 14 groves contain endemic plant species (Table 1). The endemics are either restricted to Western Ghats or broader geographical areas such as peninsular India (Singh & Kartikeyan 2000). Sacred groves selected for study have elevational difference. This elevational difference between the groves seems to affect the number of endemic species found there.

Floristic uniqueness

Out of total 296 species which were recorded during the study, 203 species were restricted to any one of the 15 sacred groves. Floristic similarity between different sacred groves suggested that the maximum similarity was only 30% (Fig. 2a). The similarity between the plant species complex was independent of the distance between the sacred groves, indicating that even geographically closely placed sacred grove holds a unique floral composition. Sacred groves like Valane and Nandivali which are around 2.5 km from each other showed only 30% similarity whereas Koliwade and Lavarde being 3 km from each other showed less than 20% similarity in species composition.

Correspondence analysis (Fig. 2b) suggested that there was a significant association between the sacred grove and the plant habit groups (chi-square = 207.675, df = 84, $P < 0.0001$). Therefore, each sacred grove has a differential proportion of plant groups. Manjarmal, Muleshwar and Dhuprahat showed more number of evergreen trees whereas Valane, Nandivali showed more lianas (Fig. 2b). Even though they have more proportions of Lianas, the species representing it were different in each sacred grove.

We recorded total 45 species endemic to India out of which three are endemic to northern Western Ghats, 30 are endemic to Western Ghats, nine are endemic to peninsular India, and three are wide-

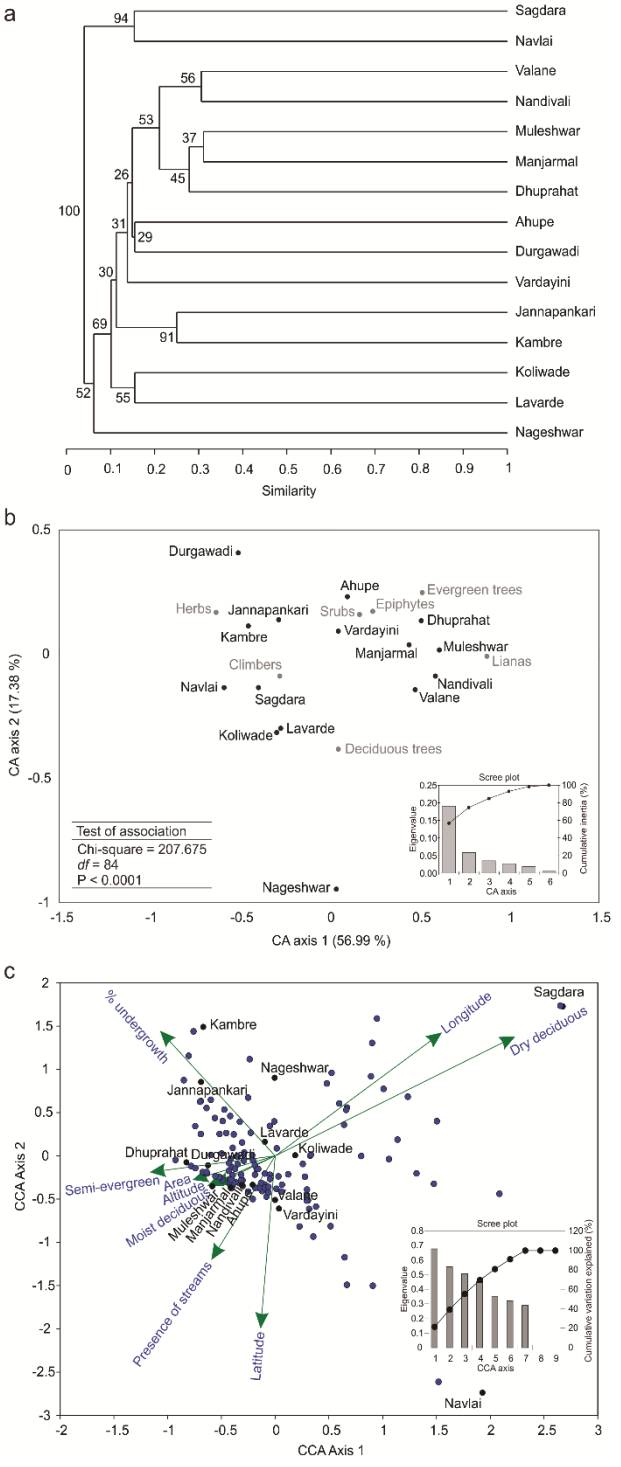

Fig. 2. Floristic uniqueness in sacred groves: (a) Floristic similarity based on Jaccard index, (b) correspondence analysis showing distribution of different plant habit groups in sacred groves and (c) canonical correspondence analysis of floristic diversity along the various physical parameters. For (b) and (c) screen plot is provided in the inset.

spread but endemic to India. Among the endemics, *Smithia purpurea* is restricted to northern Western Ghats. *Ceropegia rollae* is threatened endemic species with threat status as Critically Endangered assigned by Botanical Survey of India (Mishra & Singh 2001). This species is endemic to Ahmednagar and Pune districts of Maharashtra and known only from three to four locations, one of them is a basalt mesa located in Durgawadi Sacred Grove. Epiphytic orchid like *Aerides crispa*, *Aerides maculosa* and *Smithsonia viridiflora* are exclusively endemic to Western Ghats. *Habenaria furcifera*, an endemic orchid to Western Ghats is near threatened as per Kumar *et al.* (2000) occurs in Kambre sacred grove.

Effect of physical parameters on floristic diversity

Different physical parameters affected the diversity and distribution of plant species (Fig. 2c). First axis of CCA explained 21.52% while the second axis explained 17.60% of the total variation in the data. There was a significant association between various physical parameters on the distribution of the plant species. Jannapankari and Durgawadi have high percentage of undergrowth. Vegetation in Dhuprahat and Durgawadi is dominated by semi-evergreen type whereas; moist deciduous type of vegetation is dominant in Valane, Vardayini. If seen area wise, then Manjarmal is being the largest, followed by Durgawadi and Ahupe. Sacred groves like Sagdara and Navlai showed presence of maximum dry deciduous species hence they are separated from other groves. Species such as *Tectona grandis, Diospyros melanoxylon, Acacia leucophloea* were recorded only from Sagdara whereas, *Diospyros montana, Miliusa tomentosa, Trewia nudiflora* were recorded only from Navlai. Jannapankari and Kambre sacred groves showed little different species composition with presence of ground orchids such as *Nervilia* sp., *Habenaria digitata, Habernaria furcifera* and *Habenaria stocksii*. Other Sacred groves having semi-evergreen and moist deciduous type of vegetation are showing a cluster sharing many species. A significant positive correlation between the altitude and the number of endemic species was observed (Fig. 3). For example, Durgawadi showed highest number of endemic species that is 12 and is located at 1138 m from mASL which is highest amongst the fifteen groves.

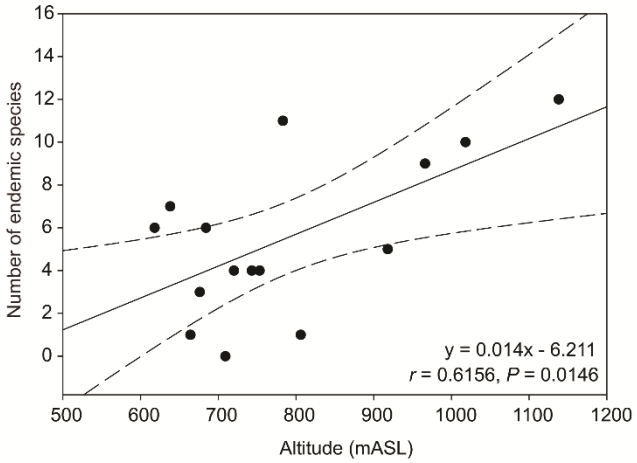

Fig. 3. Effect of altitude on the endemic plant species richness.

Effect of degradation related parameters on floristic diversity

Redundancy analysis suggested that there were negative correlations between the degradation related parameters and floristic diversity in sacred groves (Fig. 4). There was a negative correlation between the total number of plant species and different degradation related parameters. On the second canonical axis, percent degradation was negatively correlated with number of evergreen tree and positively with herbs. There was positive correlation between MFP collection and area of road and number of evergreen trees. Based on their degradation level different sacred groves were separated on the first canonical axis where the least degraded sacred groves had high factor loadings. Dhuprahat and Durgawadi were least degraded areas where as Nageshwer was most degraded. Number of endemic plants decreased significantly with the percent degradation (Fig. 5). As the percentage of degradation of the different sacred groves was not constant the species area curve was influenced by percent degradation as well, where the total number of plants was positively correlated with the area of the sacred grove and negatively with the degradation (Fig. 6).

Discussion

Fifteen sacred groves were surveyed for floristic composition along with physical and degradation related parameters. Due to increased anthropogenic activities and weakening of religious believes in term of conservation of forests sheltered by sacred grove, they are facing many threats such as cutting, MFP collection and construction of roads and temples. Depending upon the level of religious believes associated with each grove and the accessibility, great difference was seen in the species richness as well as the degree of protection. We failed to observe the typical species area curve for the total number of species versus the area of sacred grove although the two variables were positively correlated. The failure to find the relationship, however, could be attributed to the differential degradation in the sacred groves, which had direct negative impact on the total number of species.

Maximum number of species were recorded from Dhuprahat sacred grove. It is less accessible and is a part of a village which is displaced due to Dam construction. Less degraded groves showed more number of species. Species occurrence was specific to sacred grove. Certain ground orchid species were recorded only from two out of 15 groves surveyed. Epiphytic orchid species were recorded from groves having streams in the vicinity. Epiphytic orchid requires high moisture content in the air which might be provided due to presence of the streams. It was also observed that there are more evergreen trees in the groves having seasonal streams. Sacred groves shelter many interesting species whose distribution is patchy due to habitat destruction. Five such species were recorded during our survey of which the sacred grove is the northern most limit based on the present knowledge about the distribution in Western Ghats (Kulkarni *et al.* 2014). It is quite possible that these species once distributed throughout Western Ghats but due to increased deforestation and urbanization they were lost and now remained in such forest pockets. This highlights the importance of groves being important for conservation and sustenance of biodiversity.

Sacred groves may also be providing unique habitat as many endemic plant species were recorded. Altitude and level of degradation seem to be playing important role in endemic species richness. As the altitude increases, number of endemic species was seen to be increasing. However, endemic species number as well as the total species number decreases as the disturbance increases.

Plants were grouped into various categories depending upon their growth habit. The proportion of these habit groups is different in each grove with some being more in one and less in others. Habit groups were represented by different species leading each grove to be unique.

Degradation as well as anthropological disturbances not only change the species composition but

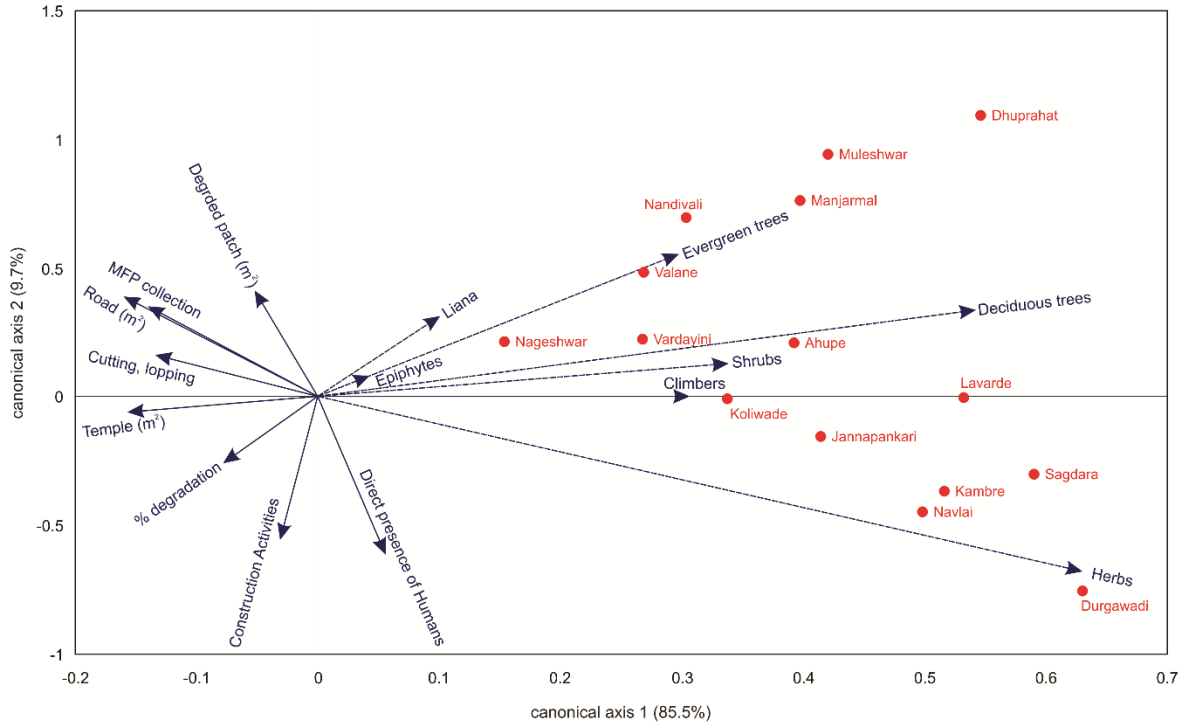

Fig. 4. Redundancy analysis of floristic diversity and disturbance related parameters.

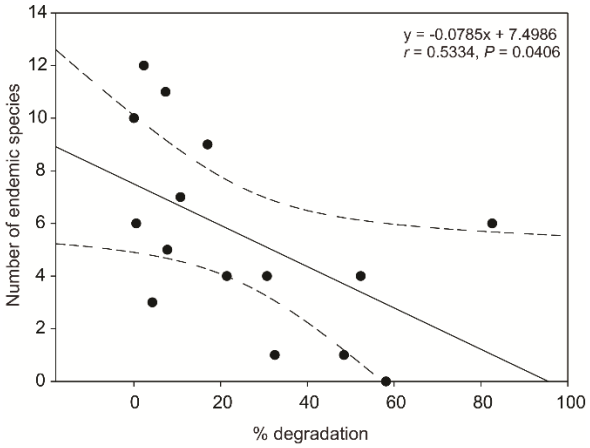

Fig. 5. Effect of percent degradation on the endemic plant species richness.

also affect the whole ecosystem sustained by the grove. Different sacred groves have different types of degradation. Some are threatened by temple construction or other factors due to which forest in the area is being cut down. Sacred groves which have been protected since a very long time often represent a patch of primary forest and are important in view of conservation, as they not only protect the biodiversity but also are offering many ecosystem services such as source of water. Negative correlation between the percent degradation and number of evergreen trees and positive correlation between percent degradation and number of herbs suggests that the evergreen forest patches might be getting replaced by degraded vegetation. Positive relationship between MFP collection and area of road with the number of evergreen trees suggests that evergreen forests are vulnerable from both biological resource use and easy access because of roads.

There is huge area dedicated to temple in the groves like Durgawadi, Navlai and Nageshwar. In Navlai sacred grove almost one third of the forest has been cut down for the construction of temple. Ahupe is threatened by presence of large road which divides the grove into two parts. There is huge amount of cutting, lopping leading to large degradation in Jannapankari and Durgawadi sacred grove. Dhuprahat and Manjarmal are comparatively protected groves, as they are less accessible.

Today sacred groves are the forest pockets remaining in the urbanized landscape acting as refuge for wild plants and animals. They shelter many endemic, endangered species. A lot of species now have distribution limited to sacred groves. The Western Ghats along with Sri Lanka is considered as a hottest hotspot for biological conservation because of high level of anthropogenic threats

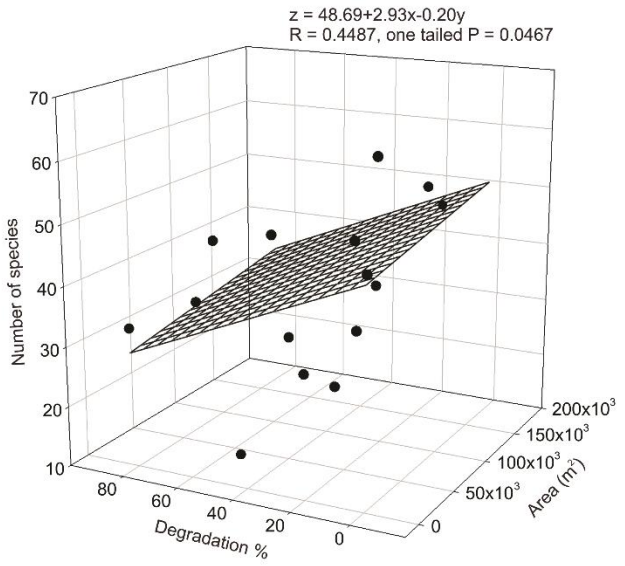

Fig. 6. Effect of area of the sacred grove and percent degradation on total number of species.

(Myers *et al.* 2000). With rapid deforestation in the Western Ghats, it has been estimated that only 6.8% of the total primary forests exists today (Myers *et al.* 2000). The deforestation is a continuous process and in the last 22 years 26% of the forest cover has vanished from the area (Jha *et al.* 2000). With these rapid declines in the forested areas, sacred groves can be considered as a refuge to the threatened and endemic plants in the Western Ghats. Contradicting to a current mindset of protecting one forest patch and surrendering others for development, our results are showing that each sacred grove is unique and needs to be protected. In our study we found that sacred groves as close as 2.5 kilometers shares only about 30% similarities in their species composition. This is an interesting aspect which strongly recommends a need to protect each and every sacred grove. Further, the fact that each sacred grove is unique also points to a need for design and implementation of sacred grove specific management action plans.

Acknowledgements

ASK, ASU and MND are thankful to Director Agharkar Research Institute, Pune for providing necessary facilities for research work and for constant encouragement. They are also grateful to Chief Conservator of Forest and Silviculturist, Maharashtra State Forest Department for funding the research work (Grant no SP: 209) and in-charge Herbarium, Botanical Survey of India, Western Regional Centre, Pune for allowing to consult herbarium specimens. They also thank Mr. Umesh Awasarkar for assistance in the field work. ND is supported by DST-INSPIRE Faculty Fellowship.

References

Anupama, C. 2009. *Ecological Studies on Selected Sacred Groves of Malabar*. Ph.D. Thesis. University of Calicut, Calicut, Kerala.

Bhagwat S. A. & C. Rutte. 2006. Sacred groves: potential for biodiversity management. *Frontiers in Ecology and the Environment* **4**: 519–524.

Bossart J. L., E. Opuni-Frimpong, S. Kuudaar & E. Nkrumah. 2006. Richness, abundance, and complementarity of fruit-feeding butterfly species in relict sacred forests and forest reserves of Ghana. pp. 319–345. *In:* D. L. Hawksworth & A. T. Bull (eds.) *Arthropod Diversity and Conservation*. Springer Netherlands.

Cooke, T. 1967. *Flora of Presidency of Bombay*. Botanical Survey of India, Calcutta.

Decher J. 1997. Conservation, small mammals, and the future of sacred groves in West Africa. *Biodiversity & Conservation* **6**: 1007–1026.

Deshmukh, S. V. 1999. *Conservation and Development of Sacred groves in Maharashtra*. Final Report of the World Bank aided Maharashtra forestry project, Department of Forest, Government of Maharashtra and Bombay Natural History Society, Mumbai.

Gadgil, M. & V. D. Vartak. 1975. Sacred groves of India: A plea for continued conservation. *Journal of Bombay Natural History Society* **72**: 314–320.

Gadgil, M. & V. D. Vartak. 1976. The sacred groves of Western Ghats in India. *Economic Botany* **30**: 152–160.

Gadgil, M. & V. D. Vartak. 1980. The sacred groves of Maharashtra: An inventory. pp. 289–294. *In:* S. K. Jain (ed.) *Glimpses of Indian Ethnobotany*. Oxford & IBH Publishers, Delhi.

Gajula, G. 2007. Sacred grove lore and laws: On the beliefs of ecologists, environmentalist-historians, and others. *Indian Folklife* **26**: 19–24.

Ghate, V. S., H. D. Sane & S. S. Ranade. 2004. (eds.) *Focus on Sacred Groves and Ethnobotany*. Prism Publications, Mumbai.

Hammer, O., D. A. T. Harper & P. D. Ryan. 2001. PAST: Paleontological Statistics Software Package for education and data analysis. *Palaeontologia Electronica* **4**: 9. http://palaeoelectronica.org/2001_1/past/issue1_01.htm (accessed 15 May 2015).

Jha, C. S., C. B. S. Dutt & K. S. Bawa. 2000. Deforestation and land use changes in Western Ghats, India. *Current Science* **79**: 231–237.

Jain, S. K., and R. R. Rao. 1977. *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers & Publishers, New Delhi.

Kangah-Kesse, L., D. Attuquayefio, E. Owusu & F. Gbogbo. 2009. Bird species diversity and abundance in the Abiriw sacred grove in the eastern region of Ghana. *West African Journal of Applied Ecology* **11**: 38–44.

Kulkarni, A. S., M. N. Datar, U. Awasarkar & A. S. Upadhye. 2014. Northernmost distribution of five tree species to the Western Ghats from sacred groves of Pune district, Maharashtra, India. *Journal of Threatened Taxa* **6**: 6090–6100.

Kumar, M. & V. Kaviyarasan. 2011. A rare agaric (Agaricomycetes: Agaricaceae) from a sacred grove of Eastern Ghats, India. *Journal of Threatened Taxa* **3**: 1778–1781.

Kumar, S., B. V. Shetty, D. Bennet & S. Molur. 2000. *Report of the Conservation Assessment and Management Plan Workshop on Endemic Orchids of the Western Ghats*. Zoo Outreach, Organization & CBSG South Asia, Coimbatore, India.

Mgumia, F. H. & G. Oba. 2003. Potential role of sacred groves in biodiversity conservation in Tanzania. *Environmental Conservation* **30**: 259–265.

Mishra, D. K. & N. P. Singh (eds.). 2001. *Endemic and Threatened Flowering Plants of Maharashtra*. Botanical Survey of India, Calcutta.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. Da Fonseca & J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.

Rathod, S. & P. Rathod. 2013. Amphibian communities in three different coffee plantation regimes in the Western Ghats, India. *Journal of Threatened Taxa* **5**: 4404–4413.

Schaaf, T. 2003. UNESCO's experience with the protection of sacred natural sites for biodiversity conservation. pp. 13–20. *In:* C. Lee & T. Schaaf (eds.) *The Importance of Sacred Natural Sites for Biological Conservation*. Proceedings of the international workshop on the importance of sacred natural sites for biodiversity conservation, Kunming and Xishuangbanna Biosphere Reserve, Peoples Republic of China. 17–20 February 2003.

Sharma, B. D., S. Karthikeyan & N. P. Singh. (eds.) 1996. *Flora of Maharashtra State. Monocotyledones*. Botanical Survey of India, Kolkata.

Singh, N. P. & S. Karthikeyan. 2000. *Flora of Maharashtra State. Dicotyledonous. Vol. I.* Botanical Survey of India, Kolkata.

Singh, N. P., P. Lakshminarasimhan, S. Karthikeyan & P. V. Prasanna. 2001. *Flora of Maharashtra State. Dicotyledones. Vol II.* Botanical Survey of India, Kolkata.

Smith, E. P. & I. A. Lipkovich. 2002. Biplot 1.1: Excel add in freeware. Statistics Department of Virginia Tech, Blacksburg, VA U.S.A.

Vartak, V. D. 1983. Observations on rare, imperfectly known and endemic plants in the sacred groves of Western Maharashtra. pp. 169–178. *In:* S. K. Jain & R. R. Rao (eds.) *Assessment of Threatened Plants of India.* Botanical Survey of India, Kolkata.

(Received on 03.06.2016 and accepted after revisions, on 12.03.2018)

Supporting Information

Additional supporting information may be found in the online version of this article.

Table S1. Species composition across sacred groves.