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Diversity and regeneration status of tree species in the sacred groves of central western Ghats, India

Shwetha Bharathi[1], AG Devi Prasad[1*]

[1]DOS in Environmental Science, University of Mysore, Manasagangotri, Mysore-570006, Karnataka, India

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Abstract

Tree species diversity and their regeneration status were investigated in three sacred groves of Somwarpet, Central western Ghats using the random quadrat method. A total of 114 arboreal species was identified belonging to 40 families among three sacred groves. Relatively a higher density of 463.44 - 853.44 individuals per hectare and a higher basal area of 62.09 - 82.84 m^2 per hectare were recorded in the sacred groves. *Chrysophyllum roxburghii* with an IVI value of 42.98, *Schleichera oleosa* with an IVI value of 65.96 and *Syzygium caryophyllatum* with an IVI value of 80.43 were found to be dominant in Garwale, Nagarallli and Bettadalli sacred groves respectively. Highest percent of regeneration was observed in the Garwale sacred grove (78.57 % of total tree species) followed by Nagaralli (71.64 %) and Bettadalli sacred groves (56.81%). A greater density of seedlings (188-237.76/100 m2) and saplings (129.14-372.37/ 100m^2) was observed in the study area. The findings emphasize on the protection of sacred groves owing to the potentialities of species for their regeneration. This also necessitates formulating sustainable strategies for utilization and development.

***Corresponding Author:** AG Devi Prasad ✉ agdprasad@yahoo.com

Introduction

Sacred groves are one of the finest examples for informal way of conserving biological wealth. They are nothing but patches of virgin forests left as it is, in the name of local deity and are protected by the local people due to their cultural and religious beliefs and taboos that the deities reside in them (Khan *et al.,* 2008). They represent the last shelter for endemic and endangered plant and animal species as a result of symbiotic relationship between human beings and nature. Sustenance of these sacred groves is mainly associated with the spiritual relation between Indigenous traditional societies and existing physical environment (Khumbongmayum *et al.,* 2005). It is believed that all forms of vegetation in the sacred groves are supposed to be under the protection of reigning deity of that grove, and the removal of even a small twig is a taboo (Varthak and Gadgil, 1973), which is a keystone concept in protecting these forest patches.

Sacred groves are distributed across the globe, acting as an ideal centre for biodiversity conservation. In India, the groves are located in a variety of habitats ranging from resource-rich forested landscapes, such as Western Ghats, north eastern part of the country to extremely resource-poor desert ecosystems in western and central India. Most of the sacred groves reported from India are in the Western Ghats, North Eastern India and Central India (Tripathi, 2001; Khumbongmayum *et al.,* 2005a).

In the course of time, various anthropogenic activities such as deforestation, fragmentation, disruption of habitats and over-exploitation have resulted in the disappearance of these forest patches at an alarming rate, in developing countries particularly in India. These groves are fading away due to many reasons such as; erosion of traditional belief system and nature worship system, spreading of alien religions and sanskritization, lack of interest among the younger generation and poor management. In spite of the global awareness about the importance and significance of sacred groves, meager efforts have been made to unravel the regeneration potentiality of arboreal species and their present status of these forest patches. Therefore, the present study was undertaken to evaluate and asses the same in the three sacred groves of Somwarpet, Central Western Ghats.

Methodology

Study area

The study was made in the three sacred groves of Somwarpet Taluq, Kodagu District, Karnataka, India (Fig. 1). Kodagu district has 1,214 sacred groves covering an area of 2,550 ha, one grove for every 300 ha of land. Considering the number and density, diversity of deities and communities, and forms of worship and management, Kodagu can be called 'hotspot of sacred groves' in the world (Raghavendra and Kushalappa, 2011).

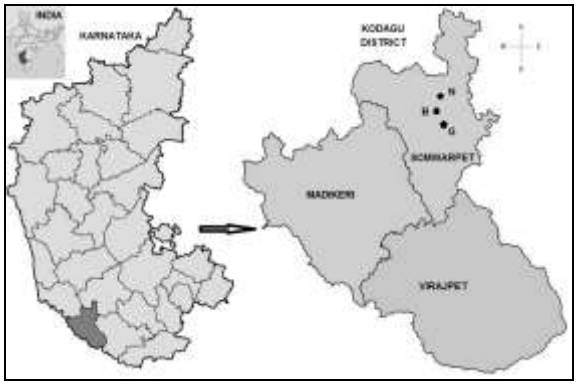

Fig. 1. Study area showing sacred groves studied (G=Garwale sacred grove, N=Nagaralli sacred grove, B=Bettadalli sacred grove).

Kodagu is one of the highly wooded Western Ghats regions of Karnataka with 80% of the land area under tree cover. The average temperature varies from 14.2^0 C (winter) to 28.6^0 C (summer). The average annual rainfall is 2,725.5 mm, received mainly from south-western monsoon concentrated during the months of June to September. The study area is mainly composed of moist deciduous species merging into semi-evergreen and evergreen type depending on the rainfall. Soil type of the area varies greatly due to geological heterogeneities, although, clayey, comparatively darker, shallow soil type is found in the

study sites (Keshavamurthy and Yoganarasimhan, 1990). Geographical details of the study sites are given in Table 1.

Table 1. Geographical details of the study area.

Name of the sacred grove	Name of Village	Extent of Area	Latitude and Longitude	Elevation
Sri Povvedi Maadeva Devarakadu	Garwale	32 ha	N12° 34.394' E75° 47.017'	1148 m
Sri Sabbamma Devarakadu	Nagaralli	8.9 ha	N12° 39.968' E75° 47.032'	1215 m
Beera Devara Bana	Bettadalli	3.6 ha	N12° 38.683'E75° 46.286'	1345 m

Sri Povvedi Maadeva Devarakadu (also referred as Garwale sacred grove) in the village of Garwale is surrounded by Revenue forests and coffee plantation. Sri Sabbamma Devarakadu (also referred as Nagaralli sacred grove) in the village of Nagaralli is surrounded by coffee plantations and human settlement. Beera Devara Bana (also referred as Bettadalli sacred grove) in the village of Bettadalli is surrounded by Casuarina plantation on a hillock. All the deities in the three groves are worshipped once a year in the month of March/April.

Data collection and analysis

Field exploration was undertaken during 2013-15 to record the tree species composition of the sacred groves. Quadrats of 20 m x 20 m dimension were laid randomly to enumerate the mature trees covering 5% of total area. Stems having GBH (Girth at Breast Level – 1.34 m height) ≥ 30 cm were counted as adults/trees. Identification of species was made using authentic floras (Saldanha, 1984; Pascal and Ramesh, 1987; Keshavamoorthy and Yoganarasimhan, 1990; Saldanha, 1996; andPoornika *et al.,* 2011) and voucher specimens have been deposited in Biodiversity Conservation Laboratory, DOS in Environmental Science, University of Mysore, Mysore, India. Regeneration studies were carried out by laying down plots of 2 m x 2 m size randomly. In each plot, all tree species ≤ 30 cm GBH were considered as regenerates and enumerated separately into seedlings (< 40 cm height) and saplings (> 40 cm height and <30 cm GBH). Regeneration status of each tree species was evaluated considering the number of seedlings and saplings based on Umashankar (2001), with modifications:

1. Good regeneration, if seedlings > saplings > adults;
2. Fair regeneration, if seedlings > or < saplings > or < adults;
3. Poor regeneration, if the species survives only at sapling stage or only seedlings stage (seedlings and saplings may be less or more or equal to adults);
4. No regeneration, if a species is present only in adult form;
5. Reappearing, if the species has no adults but only seedlings or saplings.

Floristic diversity was measured by using Simpson Index of Diversity (Simpson, 1949) and Shannon and Wiener's Index of Diversity (Shannon and Wiener, 1963). Importance Value Index (IVI) of each tree species was determined (Curtis and McIntosh, 1950) calculating frequency, density and basal area. Similarity among the sacred groves and within the sacred groves was determined by Sorenson's similarity index (Sorenson, 1948). The significance difference in mean values of density, basal area, species richness and diversity indices among the three sacred groves were statistically tested by one-way analysis of variance (ANOVA) and post-hoc tests using SPSS software package 8.0.

Results

A total of 114 tree species belonging to 86 genera and 40 families with an unknown species, were recorded in the study area (Table 2). Of the 40 families recorded, Lauraceae was represented by a maximum of 12 species, followed by Euphorbaceae and Moraceae (10 species each), Anacardiaceae (8

species) and Rubiaceae (7 species). Sixteen families were represented by single species.

Table 2. Density and regeneration status of tree species found in the three sacred groves of Somwarpet.

Sl No	Species name	Family	Garwale Sacred Grove		Nagaralli Sacred Grove		Bettadalli Sacred Grove	
			Density/ ha	RS	Density/ ha	RS	Density/ ha	RS
1	*Acrocarpus fraxinifolius* Wight & Arn.	Fabaceae	2.08	None	-	-	-	-
2	*Actinodaphne lawsonii* Gamble.	Lauraceae	1.04	Fair	-	-	-	-
3	*Actinodaphne malabarica* Balak.	Lauraceae	2.08	Fair	-	-	-	-
4	*Alstonia scholaris* (L.)R. Br.	Apocynaceae	3.12	Poor	-	-	-	-
5	*Antiaris toxicaria* Lesch.	Moraceae	-	-	4.54	None	-	-
6	*Aphanamixis polystachya* (Wall.) Parker.	Meliaceae	4.16	Poor	4.54	Poor	-	-
7	*Apodytes dimidiata* E. Meyer ex Arn.	Icacinaceae	1.04	Poor	-	-	-	-
8	*Aporusa lindleyana* (Wight) Baill.	Euphorbiaceae	2.08	None	-	-	-	-
9	*Archidendron monadelphum* (Roxb.) Nielson.	Fabaceae	30.2	Fair	11.36	Fair	17.85	Good
10	*Ardisia pauciflora* Heyne ex Roxb.	Myrsenaceae	-	-	-	-	3.57	None
11	*Ardisia solonaceae* Roxb.	Myrsenaceae	-	-	-	-	3.57	None
12	*Artocarpus heterophyllus* Lam.	Moraceae	20.83	Fair	4.54	Poor	3.57	Fair
13	*Atlantia monophylla* (L.) DC.(E)	Rutaceae	0	Reappearing	0	Reappearing	-	-
14	*Bischofia javanica* Bl.	Euphorbiaceae	7.29	Poor	4.54	Good	-	-
15	*Callicarpa tomentosa* (L.) Murr.	Verbinaceae	14.58	Poor	2.27	Poor	14.28	None
16	*Calophyllum polyanthum* Wall. Ex Choisy.	Clusiaceae	4.16	Fair	-	-	-	-
17	*Canarium strictum* Roxb.	Berseraceae	20.83	Fair	20.45	Fair	-	-
18	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.	Rubiaceae	1.04	Fair	0	Reappearing	71.42	Fair
19	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	1.04	None	-	-	-	-
20	*Caryota urens* L.	Arecaceae	37.5	Fair	15.9	Good	0	Reappearing
21	*Casaeria sps*	Flacourtiaceae	-		-	-	7.14	Poor
22	*Celtis tetrandra* Roxb.	Flacourtiaceae	1.04	Fair	9.09	Fair	14.28	Good
23	*Chionanthus mala-elengi* (Dennst.) Green.	Oleaceae	1.04	None	-	-	-	-
24	*Chrysophyllum roxburghii* G. Don.	Sapotaceae	48.95	Fair	-	-	-	-
25	*Cinnamomum malabatrum* (Burm. F.) Bl.	Lauraceae	15.62	Fair	2.27	None	7.14	Good
26	*Cinnamomum verum* J. S. Presl.	Lauraceae	0	Reappearing	0	Reappearing	-	-
27	*Clausena anisata (Willd.)* Hook. f. ex Benth.	Rutaceae	0	Reappearing	0	Reappearing	-	-
28	*Clerodendron viscosum* Vent.	Verbinaceae	-	-	0	Reappearing	3.57	None
29	*Cryptocarya bourdillonii* Gamble	Lauraceae	-	-	2.27	None	-	-
30	*Debregeasia longifolia* (Burm f.) Wedd.	Urticaceae	-	-	4.54	None	-	-
31	*Dimocarpus longan* Lour.	Sapindaceae	1.04	Fair	-	-	-	-
32	*Diospyros crumenata* Thw.	Ebenaceae	2.08	Poor	-	-	-	-
33	*Diospyros saldanhae* Kosterm.	Ebenaceae	-	-	0	Reappearing	-	-
34	*Drypetes oblongifolia* (Bedd.) Airy Shaw.	Euphorbiaceae	0	Reappearing	-	-	-	-
35	*Elaeocarpus serratus* L.	Elaeocarpaceae	7.29	Poor	4.54	Poor	0	Reappearing
36	*Elaeocarpus tuberculatus* Roxb.	Elaeocarpaceae	2.08	None	4.54	Poor	-	-
37	*Euodia lunu-ankenda* Merr.	Rutaceae	8.33	Poor	-	-	7.14	Fair
38	*Euonymus indicus* Heyne ex Wall.	Celastraceae	1.04	None	-	-	-	-
39	*Excoecaria crenulata* Wight.	Euphorbiaceae	2.08	Poor	13.63	Fair	-	-
40	*Ficus amplissima* J. E. Smith.	Moraceae	-	-	4.54	None	-	-
41	*Ficus callosa* Willd.	Moraceae	1.04	Poor	-	-	-	-
42	*Ficus exasperate* Vahl	Moraceae	-	-	6.81	Poor	-	-

Sl No	Species name	Family	Garwale Sacred Grove		Nagaralli Sacred Grove		Bettadalli Sacred Grove	
			Density/ ha	RS	Density/ ha	RS	Density/ ha	RS
43	*Ficus racemosa* L.	Moraceae	1.04	None	-	-	-	-
44	*Ficus hispida* L. f.	Moraceae	-	-	0	Reappearing	-	-
45	*Ficus microcarpa* L. f.	Moraceae	-	-	2.27	None	-	-
46	*Ficus sp tsjahela* Rheede ex Burm. f.	Moraceae	-	-	9.09	None	-	-
47	*Ficus* sps	Moraceae	2.08	Poor	-	-	-	-
48	*Flacourtia Montana* Graham	Flacourtiaceae	-	-	2.27	Poor	21.42	None
49	*Garcinia gummi-gutta* (L.) Robson.	Clusiaceae	14.58	Poor	0	Reappearing	-	-
50	*Glochidion ellipticum* Wight.	Euphorbiaceae	0	Reappearing	9.09	Poor	17.85	Fair
51	*Glochidion zeylanicum* (Gaertn.)	Euphorbiaceae	-	-	0	Reappearing	42.85	Fair
52	*Gnidia glauca* (Fresen.) Gilg.	Thymelaeaceae	-	-	-	-	3.57	None
53	*Goniothalamus cardioupetalus* (Dalz.) Hook. f. & Thoms.	Annonaceae	-	-	0	Reappearing	-	-
54	*Herpullia arborea* (Blanco) Radlk.	Sapindaceae	-	-	4.54	Poor	-	-
55	*Holigarna arnottiana* Hook. f.	Anacardiaceae	1.04	None	2.27	None	-	-
56	*Holigarna ferruginea* Marchand	Anacardiaceae	3.12	None	-	-	-	-
57	*Holigarna grahamii* (Wight) Kurz.	Anacardiaceae	0	Reappearing	6.81	None	-	-
58	*Holigarna nigra* Bourd.	Anacardiaceae	17.7	Poor	0	Reappearing	7.14	None
59	*Hopea canarensis* Hole	Dipterocarpaceae	-	-	-	-	7.14	None
60	*Isonandra lanceolata* Wight	Sapotaceae	-	-	-	-	3.57	None
61	*Ixora brachiata* Roxb.	Rubiaceae	-	-	-	-	0	Reappearing
62	*Lagerstroemia microcarpa* Wight.	Lythraceae	-	-	4.54	Poor	-	-
63	*Leea indica* (Burm. F.) Merr.	Leeaceae	1.04	Fair	0	Reappearing	-	-
64	*Leptonychia caudate* (Wall. ex G. Don) Burrett	Sterculiaceae	-	-	0	Reappearing	3.57	None
65	*Lesianthus jackianus* Wt.	Rubiaceae	0	Reappearing	-	-	0	Reappearing
66	*Litsea bourdilloni* Gamble	Lauraceae	-	-	2.27	Poor	-	-
67	*Litsea floribunda* (Bl.) Gamble	Lauraceae	0	New	2.27	Fair	21.42	Fair
68	*Litsea mysorensis* Gamble	Lauraceae	-	-	0	Reappearing	-	-
69	*Litsea oleoides* (Meissn.) Hook. f.	Lauraceae		-	2.27	Fair	-	-
70	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	23.95	None	4.54	None	32.14	None
71	*Maesa indica* Roxb. DC.	Myrsenaceae	-	-	0	Reappearing	-	-
72	*Magnolia champaka* L.	Magnoliaceae	3.12	None	-	-	-	-
73	*Mallotus philippensis* (Lam) Muell.-Arg.	Euphorbiaceae	0	Reappearing	2.27	Poor	0	Reappearing
74	*Mallotus tetracoccus* (Roxb.) Kurz.	Euphorbiaceae	2.08	None	-	-	10.71	None
75	*Mangifera indica* L.	Anacardiaceae	4.16	Poor	11.36	None	-	-
76	*Melia composita* Willd.	Meliaceae	1.04	Poor	4.54	None	3.57	None
77	*Meliosma pinnata* (Roxb.) Walp.	Sabiaceae	0	Reappearing	2.27	None	-	-
78	*Meliosma simplicifolia* (Roxb.) Walpers	Sabiaceae	3.12	Poor	-	-	-	-
79	*Memecylon malabaricum* (C.B. Clarke) Cogn.	Melastomataceae	-	-	0	Reappearing	157.14	Good
80	*Memecylon talbotianum* Brandis (W)	Melastomataceae	6.25	Poor	-	-	-	-
81	*Mesua ferrea* L.	Clusiaceae	33.33	Good	0	Reappearing	-	-
82	*Meyna laxiflora* Robyns	Rubiaceae	-	-	-	-	3.57	None
83	*Microtropis stocksii* Gamble	Celastraceae	0	Reappearing	-	-	0	Reappearing
84	*Mimusups elengi* L.	Sapotaceae	1.04	None	-	-	-	-
85	*Myristica dactaloides* Gaertn.	Myristicaceae	33.33	Poor	2.27	Good	32.14	None
86	*Neolitsea scrobiculata* (Meis.) Gamble	Lauraceae	2.08	Poor	-	-	-	-
87	*Neolitsea zeylanica* (Nees) Merr, Philip.	Lauraceae	10.41	Fair	6.81	Good	3.57	None
88	*Nothapodytes nimmoniana* (Graham) Mabberley	Icacinaceae	0	Reappearing	0	Reappearing	3.57	Poor
89	*Nothopegia beddomei* Gamble.	Anacardiaceae	10.41	Fair	-	-	-	-
90	*Nothopegia racemoosa* (Dalz.) Ramam.	Anacardiaceae	13.54	Fair	90.9	Good	-	-

Sl No	Species name	Family	Garwale Sacred Grove		Nagaralli Sacred Grove		Bettadalli Sacred Grove	
			Density/ ha	RS	Density/ ha	RS	Density/ ha	RS
91	*Olea dioica* Roxb.	Oleaceae	8.33	Poor	2.27	None	3.57	Fair
92	*Olea paniculata* R. Br.	Oleaceae	1.04	Poor	-	-	-	-
	Paracroton pendulus (Hassk.) Miq. ssp. *zeylanicus*		-	-	4.54	None	-	-
93	(Thw.) Balakr.& Chakrab.	Euphorbiaceae						
94	*Pavetta indica* L.	Rubiaceae	0	Reappearing	-	-	-	-
95	*Persea macrantha* (Nees) Kosterm.	Lauraceae	0	Reappearing	-	-	-	-
96	*Pittosporum dasycaulon* Miq.	Pittosporaceae	-	-	-	-	14.28	Poor
97	*Pongamia pinnata* (L.) Pierre.	Fabaceae	-	-	0	Reappearing	-	-
98	*Psychotria nigra* (Gaert.) Alston	Rubiaceae	-	-	0	Reappearing	3.57	None
99	*Rapanea wightiana* (Wall. ex A. DC.) Mez	Myrsenaceae	-	-	-	-	89.28	Poor
10 0	*Schefflera racemosa* Harms	Araliaceae	-	-	-	-	32.14	Poor
101	*Schefflera wallichiana* (Wight & Arn.) Harms	Araliaceae	-	-	2.27	None	3.57	None
10 2	*Schleichera oleosa* (Lour.) Oken.	Sapindaceae	58.33	Good	147.72	Good	-	-
10 3	*Scolopia crenata* (Wight & Arn.) Clos	Flacourtiaceae	1.04	None	2.27	Fair	39.28	Fair
10 4	*Spondias pinnata* (L. f.) Kurz.	Anacardiaceae	-	-	6.81	None	-	-
105	*Sterculia guttata* Roxb.	Sterculiaceae	2.08	Good	-	-	3.57	Poor
10 6	*Stereospermum colais (*Buch.-Ham. Ex Dillw.)	Bignoniaceae	1.04	None	-	-	-	-
107	*Symplocos macrophylla* Wall. ex A. DC	Symplocaceae	-	-	0	Reappearing	-	-
10 8	*Syzygium cumini* (L.) Skeels	Myrtaceae	-	-	0	Reappearing	-	-
10 9	*Syzygium hemisphericum* (Wight) Alston	Myrtaceae	-	-	2.27	None	-	-
110	*Syzygium caryophyllatum* (L.) Alston	Myrtaceae	-	-	-	-	128.57	Fair
	Trichilia connaroides (Wight & Arn.)		3.12	Poor	-	-	-	-
111	Bentevelzen	Meliaceae						
112	*Unknown species*	Unknown	-	-	0	Reappearing	-	-
113	*Wendlandia thyrsoidea* (Roth.) Steud	Rubiaceae	-	-	-	-	7.14	None
114	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	-	-	2.27	None	-	-

Of the 114 species documented in the study area, 22 tree species were common to all the three sacred groves. Among the three sacred groves, highest similarity was observed between Garwale and Nagaralli sacred groves (Sorenson's similarity index value=52.55%) followed by Bettadalli and Nagaralli groves (46.84%) and Garwale and Bettadalli (42.10%). Within the three sacred groves, similarity between mature tree species and regenerating tree species was found to be highest in Garwale (Sorenson's similarity index value=75.22%), followed by Bettadalli (66.66%) and Nagaralli (53.19%).

One-way ANOVA and post hoc tests have revealed a significant difference in the mean values of density ($F_{2,30}$=30.359; p=0.000) between Bettadalli and Nagaralli sacred groves, and Bettadalli and Garwale sacred groves and also in the mean values of species richness ($F_{2,30}$=5.376;p=0.010) between Bettadalli and Nagaralli sacred groves. No significance difference was observed in the mean values of basal area ($F_{2,30}$=1.618;p=0.215) among the three sacred groves. A low value of significance (not significant) was recorded between Nagaralli and Garwale sacred groves in terms of mean values of Shannons index ($F_{2,30}$=3.858;p=0.032) and Simpsons index ($F_{2,30}$=3.402;p=0.047).

Garwale sacred grove

Tree species distribution

A total of 70 tree species belonging to 57 genera and 31 families were identified in Garwale sacred grove.

Lauraceae was represented by a maximum of eight species, followed by Euphorbiaceae and Anacardiaceae (seven species each). Fourteen families were represented by single species. Shannon's Diversity Index (H') showed a value of 3.307 and Simpson's Diversity Index (1-D) showed a value of 0.9473. Density and basal area of the grove found to be 508.11 individuals per hectare and82.84 m² per hectare respectively. *Chrysophyllum roxburghii* scored highest value of 42.98 for Importance Value Index. Second highest value for IVI was recorded by *Schleichera oleosa* (28.83), followed by *Canarium strictum* (19.83), *Myristica dactyloides* (17.92) and *Mesua ferrea* (16.89). Of all the tree species recorded in Garwale, *Schleichera oleosa* was found to be dominatingin the area with 58.33 individuals per hectare, while, *Chrysophyllum roxburghii* had highest basal area (21.62 m²/ha) with 48.95 individuals per hectare. Seventeen species were represented by single individual.

Regeneration status

A reverse j-shaped curve for four regeneration classes was observed in the study area (Fig. 2). Out of 70 tree species recorded in the study area of sacred grove, 78.57 % (41 species) were regenerating. Twenty two species had poor regeneration and sixteen had fair regeneration condition. Only three species- *Schleichera oleosa, Mesua ferrea* and *Sterculia guttata* showed good regeneration. Fourteen tree species have reappeared in the sacred grove with no mature individuals. Fifteen tree species have shown no regeneration at all. An interesting observation was made with *Macaranga peltata* that with 23.95 mature individuals per hectare, it did not show any regeneration. Overall, 237.76 regenerates/100 m² were recorded at seedling stage and 360.67 regenerates/100 m² at sapling stage. *Schleichera oleosa* species recorded the highest density of regenerates in the study area: 144.53 seedlings/100 m² and 128.38 saplings/100 m², followed by, *Mesua ferrea* (32.81 seedlings and 29.16 saplings /100 m²) and *Nothopegia beddomei* (20.05 seedlings and 24.47 saplings /100 m²).

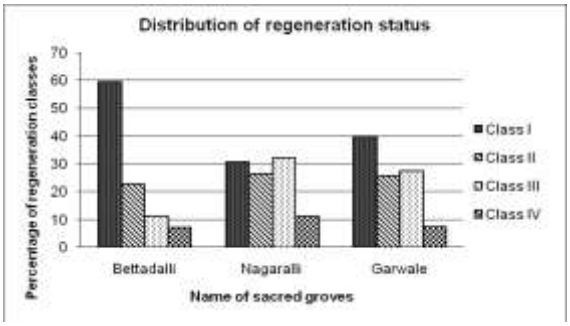

Fig. 2. Distribution of four regeneration classes in the three sacred groves.

Nagaralli sacred grove

Tree species distribution

Nagaralli sacred grove recorded a total of 67 tree species belonging to 54 genera and 32 families. Lauraceae is represented by a maximum of 8 species, followed by Euphorbiaceae and Moraceae (7 species each) and Anacardiaceae (6 species). Seventeen singleton families were recorded in the study area. Shannon's diversity index value and Simpson's evenness index value for Nagaralli sacred grove were 2.735 and 0.8512 respectively. Tree density of the grove was recorded to be 463.44 per hectare with 65.65 m² per hectare of basal area. Highest IVI value was recorded for *Schleichera oleosa* (65.96), followed by *Nothapegia racemosa* (36.83), *Canarium strictum* (25.76), *Mangifera indica* (19.06) and *Celtis tetrandra* (10.15). Highest density and basal area was contributed by *Schleichera oleosa* with a value of 147.72 individuals per hectare and 15.0538 m² per hectare. Seventeen singleton species were recorded during the study.

Regeneration status

In Nagaralli sacred grove, a reverse J-shaped curve was recorded for different regeneration classes. Of the 67 species, 71.64% of species showed regeneration and 28.35 % showed no regeneration. Six species have shown good regeneration followed by 7 species with fair regeneration and 12 species with poor regeneration. Only 34.32% of tree species were in reappearing status without any mature individuals. Overall, 164.68 regenerates/100 m² were recorded at seedling stage and 372.37 regenerates/100 m² at

sapling stage. *Schleichera oleosa* species recorded the highest density of regenerates with 66.47 seedlings/100 m² and 163.63 saplings/100 m², followed by, *Nothapegia racemosa* (142.04 seedlings and 86.36 saplings /100 m²) and *Leptonychia caudata* (5.68 seedlings and 113.06 saplings /100 m²).

Bettadalli sacred grove

Tree species distribution

Forty four tree species belonging to 40 genera and 25 families were observed in Bettadalli sacred grove. A maximum of 6 species belonging to Rubiacae were recorded, followed by Euphorbiaceae (5 species), Flacourticaceae (4) and Myrsenaceae and Lauraceae (3 species each). A total of 17 families were represented by single species. Shannon's diversity index value and Simpson's evenness index value for Bettadalli sacred grove were 2.908 and 0.9131 respectively. A density of 853.44 individuals per hectare and a basal area of 62.09 m² per hectare were recorded. *Syzygium caryophyllatum* was counted for highest IVI score with a value of 80.43, followed by *Memecylon malabaricum* (32.50), *Rapanea wightiana* (26.33), *Canthium dicoccum* (16.92) and *Scolopia crenata* (12.99). *Memecylon malabaricum* recorded the highest number of individuals (157.14 /ha) with a basal area of 3.96 m², followed immediately by *Syzygium caryophyllatum* with 128.57 individuals per hectare with a basal area of 35.80 m². A total of 15 singleton species were recorded in the study area.

Regeneration status

A reverse J-shaped curve for four regeneration classes was observed in the study area. Among the tree species recorded, 56.81% were observed to be regenerating, while 43.18% had no regeneration. Six tree species showed poor regeneration and four species showed good regeneration. Six species had no mature trees and hence are considered as reappearing. Overall, 188 regenerates/100 m² were recorded at seedling stage and 129.14 regenerates/100 m² at sapling stage. *Memecylon malabaricum* recorded the highest density of regenerates in the study area (127.67 seedlings/100 m² and 22.32 saplings/100 m²) followed by, *Archidendron monadelphum* (63.39 seedlings and 2.67 saplings /100 m²) and *Cinnamomum malabatrum* (25.89 seedlings and 22.32 saplings /100 m²).

Discussion

Distribution of tree species

A fundamental approach for conservation of plant diversity is to map the distributional patterns and look for concentrations of diversity and endemism (Devi and Yadav, 2006). Hence studies on floristic composition and structure of forests become instrumental in the sustainable management of forests since they play a major role in the conservation of plant species and the management of ecosystem as a whole (Addo-Fordjour *et al.,* 2009). In this regard, the present investigation undertaken to know the diversity and distribution of tree species in the sacred groves would be helpful in conservation of floristic diversity. The results of such study would throw a light on the present status of tree species in the sacred groves. The occurrence of good number of species, density, basal area and regeneration in the three sacred groves studied are the results of prolonged protection from the local communities in the name of local deities.

In the present study Sorenson's similarity index showed a high similarity between Garwale and Nagaralli groves. Similar results were shown by ANOVA for the same groves. These could be attributed to the landscape similarity between them. However significant variation was observed in Sorenson similarity index value and ANOVA result in Bettadalli grove as it embraces shola vegetation, though it is present in the same bio-geographical area.

Shannon's diversity index value ranged from 2.73 to 3.70 among the three sacred groves studied. Similar observations have been made by Jayakumar and Nair

(2013) who reported a range of 2.79 to 3.67 for New Amarambal reserve forest of Nilgiri Biosphere Reserve, Kerala: Vasanthraj and Chandrashekar (2006) reported a value of 4.9 for Charmadi reserve forest, Karnataka, Kanade *et al.* (2008) recorded 2.58 for Chandoli National Park, North Western Ghats, Maharastra, and Gunaga *et al.* (2013) recorded a range of 2.55 to 3.48 in the Kaans of Uttara Kannada district, Karnataka. Highest values for both Shannons and Simsons indices were recorded at Garwale sacred grove and lowest at Nagaralli sacred grove indicating variations between species richness and evenness between them. Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictabilities of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favorable and more predictable (Putman, 1994). In the present case, it could be pointed out that Nagaralli sacred grove is relatively more accessible to anthropogenic activities than the other groves.

A very high value for basal area and density was observed in the present study among the three sacred groves as compared toother tropical forests of Western Ghats, such as; New Amarambal reserve forest of Nilgiri Biosphere Reserve, Kerala (132–855 individuals/ha and 23.4–48.0 m^2/ha), Chandoli National Park, North Western Ghats, Maharastra (149-657 individuals/ha and 10.22–57.16 m^2/ha basal area) and, Kaans of Uttara Kannada district, Karnataka (254 -387 individuals/ha and 22.60 – 48.80 m^2/ha basal area).Of all the three sacred groves, in Bettadalli sacred grove greater density and minimum basal area were recorded with large number of mature individuals (58.75%) falling in a GBH range of 30-60 cm.

It was observed that significant difference was found between the tree species of first and second highest scores with regards to IVI values. This difference clearly indicated the predominant and co-dominant species in the study area. Similar observations were reported by Gunaga *et al.*, (2013) that *Artocarpus hirsutus* (IVI=59.71), *Garcinia morella* (26.86) and *Aporusa lindleyana* (26.61) were the predominant tree species in higher rainfall sacred groves, where as *Syzygium gardneri* (147.77), *Diospyros crumenata* (50.45) and *Saraca asoca* (42.38) were dominant ones in low-rainfall sacred groves of Shimoga, Central Western Ghats. Also, *Memecylon umbellatum* (IVI=49.22) and *Syzygium cumini* (25.42) were reported to be dominant and co-dominant tree species in the Chandoli national Park, northern Western Ghats (Kanade *et al.,* 2008).

Regeneration status

Forests depend on adequate regeneration of tree species to be healthy and sustainable. Regeneration of a species in turn is dependent on the internal community process and exogenic disturbances (Barker and Patrick, 1994). Micro-environment and characteristics of local canopy are important for the germination and survival of seedlings and sprouts (Khan *et al.,* 1986). Environmental factors such as fire, light, grazing, canopy density, soil moisture, soil nutrients and anthropogenic activities also affect the process of regeneration (Welden *et al.*, 1991). Hence it is difficult to pinpoint the exact cause of regeneration and its status of a forest community.

In the present study, a minimum similarity was observed between mature and regenerating tree species in Nagaralli grove. Chauhan *et al.* (2008) opined that the regeneration of a species does not account for its adult density: meaning there is no linear relationship between seedling density and adult density of a species. Jones *et al.,* (1994) opined that seedling layer in various forests differs in composition from their respective overstories.

A reverse J-shaped curve for different regeneration classes was observed in all three sacred groves, meaning maximum number of regenerated counted for class I and minimum number of regenerates for class IV. This reverse J-shaped curve is an indication of sustainable regeneration in a forest ecosystem. A

population structure characterized by the presence of sufficient number of seedlings, saplings and young trees implies satisfactory regeneration behaviour, while inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration (Nazir *et al.,* 2013). Assessment of regeneration status of each species in the three sacred groves revealed a possible change in the tree species composition of Garwale and Bettadalli sacred groves in the near future as they recorded poor (31.42% in Garwale and 13.63 % in Bettadalli) and no (36.36% in Garwale and 43.42 % in Bettadalli) regeneration for large number of species. Nagaralli grove accounted for highest number of tree species without any mature individuals in the study area. This could be attributed to anthropogenic activities observed in the grove such as; firewood collection, presence of mud roads, soil and litter removal, selective logging for temple construction causing canopy openings which possibly can invite new species colonization. Whittaker (1975) and Connell (1978) have pointed out that mild disturbance provides greater opportunity for species turnover, colonization and persistence of high species richness. Khumbongmayum *et al.* (2005) opined that creation of natural light gaps cause better growth and survival of species than in the understory and concluded that natural gaps sustain natural regeneration and maintain the species composition. The species with poor or no regeneration in the study area are neither dominant nor co-dominant species which is a cause of concern as their survival in the near future is at risk. Nazir *et al*., (2013) opined that once these species vanish from the forests due to population pressure, threat will be on dominant species placing the stability of the ecosystem in jeopardy.

Relatively a high density of seedlings and saplings was observed in the study area with a value ranging from 188 – 237.76 seedlings/100 m^2 and 129.14 – 372.37 saplings/100 m^2. Nazir *et al.,* (2013) reported a seedling density ranging from 11.36 to 18.74 seedlings/100 m^2 and sapling density from 8.84 to 15.2 saplings/100 m^2 in the sacred groves of Garhwal Himalayas. Chauhan *et al.,* (2010) recorded 158.7 seedlings and 496.0 saplings per hectare respectively in Terai-Bhabhar of Sohagibarwa Wildlife Sanctuary, India.

Conclusion

The above studies thus reveal that higher density of regenerates and species richness is because of the protection of sacred groves by the local communities due to their religious beliefs and hence the conservation of species too. Though, the species composition in the sacred groves might change in the future as the results indicate, these pristine forest patches can be conserved if sustainable strategies of protection and management are implemented.

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