

Vegetation Composition across Elevational Gradients of Pushpagiri Wildlife Sanctuary in Kodagu, Western Ghats, India

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Abstract: The present study was carried out in Pushpagiri Wildlife Sanctuary of Kodagu region in the Central Western Ghats. It aimed to understand the changes in the species composition and structure across elevational gradients. The sampling was carried out in 48 quadrats measuring 20 x 20 m were laid covering an area of 1.92 ha in 16 elevational sites. A total of 824 individuals (≥ 30 cm) belonging to 85 species and 37 families were recorded with 36 species being endemic to the Western Ghats. Species richness varied from 8 to 22 species across the elevational sites and was highest at the mid-elevations with 22 species each at 700 m and 1100 m respectively. The forest stand density varied from 250 to 667 /ha and an average basal area of 38.17 m² /ha. *Pallaquium ellipticum* (20.82) followed by *Holigarna arnottiana* (12.23) showed the highest Important Value Index. Shannon Wiener Index ranged from 1.80 to 2.86, Simpson's Diversity Index ranged from 0.81 to 0.93 and Pielou's evenness index ranged from 0.83 to 0.94. Lauraceae contributed the most to the species richness (10 species and 113 individuals). The diversity in the species composition showed that the area harbours a rich flora. This information on species composition can be used in the preparation of management plan and in documentation of tree species. It is thus important to protect these species rich areas to conserve the biodiversity of the region.

Keywords: Conservation, Diversity, Species richness, Vegetation, Western Ghats

1. INTRODUCTION

Tropical forests are one of the most diverse habitats on earth and the diversity varies according to the geography, climate, habitat and disturbance [1]. Mountain regions cover about one-third of the protected areas in the world [2]. Western Ghats are a chain of mountains known for their exceptionally high level of biodiversity and endemism and were declared as one of the biodiversity hotspot's of the World [3]. Although the endemic species are not distributed uniformly along the Western Ghats [4], about 63 % of the tree species in the lower and higher elevations evergreen forests are endemic to this region [5][6]. Topography-based analyses in mountain regions are insightful due to the topography related heterogeneity [7] relative elevation, slope convexity [8] and soil properties [9] which influence the presence of species.

Studies on floristic composition are fundamental for conservation of natural areas [10], understanding the structure of the forest [11][12] distribution patterns of the species [13] comparing the composition of species [14][15][16] biodiversity conservation [17][18] and guidance in the management of the protected areas

[19]. This study was thus carried out to study the structure and composition of the forest in Pushpagiri Wildlife Sanctuary and distribution patterns of endemic species along the elevational gradients which can be incorporated in the wildlife management plan.

2. STUDY AREA

Pushpagiri Wildlife Sanctuary is located in Somwarpet taluk of Kodagu district in the Central Western Ghats. It lies between 12°25' to 12°40' N and 75°39' to 75°45' E and covers an area of 102.92 Km². It was first declared as a Wildlife Sanctuary in the year 1987 but the final notification was issued in the year 1994. According to the forest type classification by Champion and Seth [20], it is composed of Southern Tropical wet evergreen forest, Southern Tropical semi-evergreen forest, Southern hilltop tropical evergreen forest and South Indian subtropical hill savanna. The sanctuary is named after the birthplace of river Lingadhaholle that originates from the Pushpagiri peak. The Sanctuary harbours a variety of flora and fauna and it also has the second highest peak in Kodagu called Pushpagiri Hill (Kumara Parvatha) at an elevation of 1712 m asl [21].

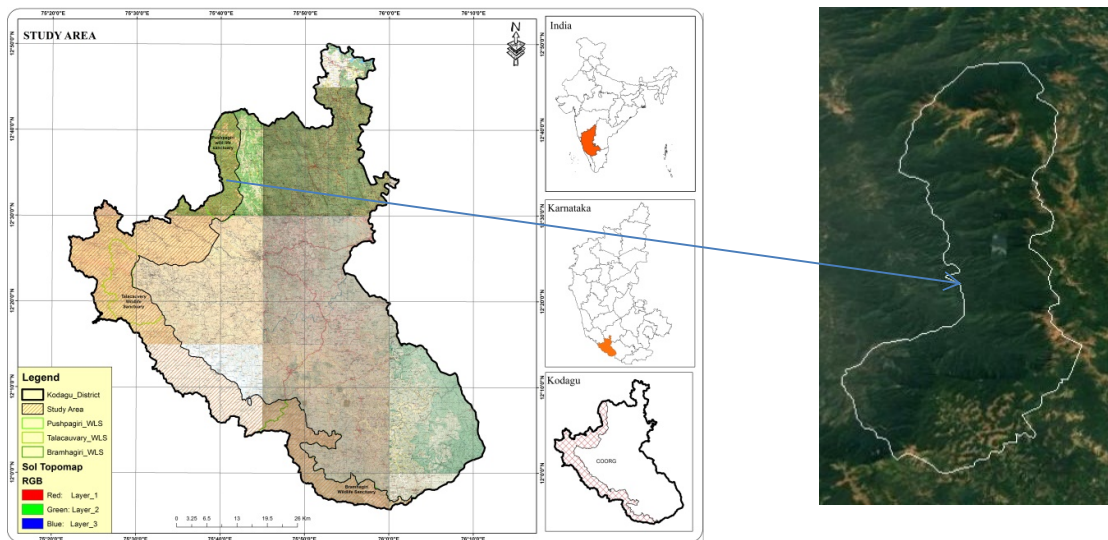


Fig 1: Map of the study area, Pushpagiri Wildlife Sanctuary in Kodagu district, India

3. METHODOLOGY

The vegetation composition of the study area was assessed using quadrat method following the approach of Misra [22]. The study area was divided into 16 elevational sites starting from 200 m till 1700 m at an interval of 100 m which covered an area of 1.92 ha. A total of 48 quadrats were laid, three quadrats measuring 20 x 20 m at 20 m distance from each other were laid at each elevational site. The latitude, longitude and elevation data of each quadrat were obtained using a Global Positioning System (GPS) before laying down the quadrat. The trees with ≥ 30 cm girth at breast height (GBH) was measured and identified with the help of experts, local floras and field guides [23][24][25] for the region. Phytosociological analysis and the floristic structure were analysed following Curtis and McIntosh [26] and Cottam and Curtis [27]. The diversity indices were analysed using the Shannon-Wiener diversity index [28], Simpson's diversity index [29] and Pielou's evenness index [30].

4. RESULTS AND DISCUSSIONS

Species diversity

The study on the natural forest of Pushpagiri Wildlife Sanctuary in the Western Ghats showed a wide diversity in the tree species composition. A total of 824 (≥ 30 cm) individuals belonging to 85 tree species, 64 genera and 37 families were recorded. Out of the 16 study sites, *Holigarna arnottiana* and

Persea macrantha were found to be common in 10 elevations and *Dimocarpus longan* and *Myristica malabarica* were found to be common in 9 elevations. None of the species was found to occur in all the elevational sites. A total of 22 species each were recorded for 700 and 1000 m elevations. It was then followed by 21 tree species each at 200, 300 and 1100 m respectively. Regression drawn between species richness and elevation showed a positive correlation ($R^2=0.44$) (Fig 2a). The species diversity according to the Shannon Wiener Index varied along the 16 elevational sites with values ranging between 1.80 and 2.86. The diversity index was highest at 1100 m with 2.86 and 1700 m had the lowest diversity with 1.80. The Simpson's diversity index which takes into account the number of species present as well as the relative abundance of each species varied between 0.81 at 1700 m and 0.93 at 200 and 1100 m. Pielou's evenness index (E) ranges between 0 and 1 with the value closer to 1 having more evenness in the distribution. The sites at 900 and 1100 m with a value of 0.94 showed a more even distribution in the tree species and the site at 700 m with a value of 0.83 showed the least evenness in the distribution (Table 1).

Endemism

A total of 36 species endemic to the Western Ghats belonging to 431 individuals and 20 families were recorded [6] (Appendix 1). The number of endemic species varied from 3 to 14 across the elevational sites. Endemic species richness was highest at 1000 m

with 14 species and lowest at 1700 m with 3 species. The total number of endemic individuals was highest at 1200 m with 57 and lowest at 400 m with 12 (Fig2b). *Litsea mysorensis* (35) and *Kingiodendron pinnatum* (31) were the dominant individuals. Lauraceae was the dominant family in terms of species richness with 6 species and 76 individuals.

Family composition

A total of 37 families were recorded from the 16 elevation sites. Lauraceae with 10 tree species (11.76%) was the most dominant family followed by Anacardiaceae with 7 tree species (8.24 %). The family that dominated the stand with the highest number of individuals was Lauraceae (113) contributing to 13.71 % of the total stand density followed by Dipterocarpaceae and Oleaceae (61) with 7.40% (Fig 2c).

Stand density and basal area

The forest stand density in the sites varied from 250 to 667 /ha with a mean stand density of 429 /ha. The stand density was highest at 1200 m with 667 /ha followed by 567 /ha at 1300 m and the lowest stand density was at 1700 m with 250 /ha respectively. The basal area ranged between 5.83 m²/ha and 110 m²/ha with a mean basal area of 38.17 m²/ha (Table 1). The highest basal area was at 1200 m with 110 m²/ha, it can be attributed to the presence of *Pallaquium ellipticum* at 1200 m with a girth size of 5.8 m. *Pallaquium ellipticum* was predominant in this elevation with 20 individuals and contributed to 59.44 m²/ha of the total basal area of 1200 m.

Forest stand structure

The growth of a forest is indicated by the distribution of trees in various girth classes. The girth of the trees were divided into seven classes (30-60 cm, 60-90 cm, 90-120 cm, 120-150 cm, 150-180, 180-210 cm and >210 cm). The 30-60 cm girth class trees comprised of 51.16% of the trees present in the forest, 22.05% in 60-90cm, 10.48 % in 90-120 cm, 6.58% in 120-150 cm, 4.02% in 150-180 cm, 2.19 % in 180 -210 cm and the highest girth class of >210 comprised of 3.90% . The maximum numbers of individuals were in the 30-60 cm and the stand structure of the forest showed a reverse J shape curve (Fig 2d). The Important Value Index (IVI) which gives a measure of the dominance of a species in an area was highest for *Pallaquium ellipticum* (20.77) followed by *Holigarna arnotianna* (12.15) and *Dimocarpus longan* (9.70). The minimum IVI value was recorded for *Cinnamomum sulphuratum* (0.47)(Fig 2f)(Appendix 1).

Tree Canopy

The mature tree species were grouped into three classes based on their height, top canopy (>25 m), mid-canopy (15-25 m) and understory (<15 m) [31]. The results showed that 74 % of the trees are understory trees, 22% of the trees are mid-canopy trees and 3 % constitute the top canopy cover. The most dominant understory tree was *Litsea floribunda*, *Kingiodendron pinnatum* for mid-canopy and *Pallaquium ellipticum* for the top canopy.

The number of species (85) recorded in the study is comparable with the number of species recorded in other parts of the Western Ghats [32][33]. The diversity index (H') values of 1.80- 2.86 from this study is lower than the evergreen forests of Kodagu [34]. It is however, difficult to compare sites based on the diversity index because of the differences in the plot size and the diameter or girth considered for the study. The mean tree density of 429 /ha is greater than that as reported in the Western Ghats [35] but lower compared to studies done in other areas of the Western Ghats with ≥30 cm girth threshold [36][37]. The average basal area of 38.17 m²/ha is higher compared to Dawkin's [38] where he estimated the average basal area for tropical lowland evergreen forest at about 36 m²/ha. It is also higher than the Eastern Ghats [39] but lower than the estimates from studies done in other parts of the Western Ghats [40]. The low tree density and basal area as compared to the other studies can be due to the differences in the sampling size [41], the elevation of the study area, as altitude and slope of a place can affect the species richness and the dispersion behaviour of trees [42]. The species diversity of a place can also depend on the site representativeness, various site attributes and the extent of human interaction in the past and present [43]. The vegetation composition varied along the elevational sites with more species richness in the lower elevations with peak in the mid-altitudes and decreasing higher up the elevations. The girth size of the trees also decreased with elevation with larger girth trees present in the lower elevations and the species richness of the trees also decreased with increase in girth class. The decrease in the species richness is a general trend found in the tropical forests [44][45][46]. The stand structure of the forest which showed a reverse J shape is similar to the pattern found in the studies done by Pascal and Pelisser [47], Ganesh et al., [48] which indicates the undisturbed nature of the forest [49]. It can therefore be said that the sanctuary harbours a growing and a healthy population of trees.

Table 1: Floristic richness and diversity indices for Pushpagiri Wildlife Sanctuary, Kodagu.

Characteristics	Elevational sites (m)																Overall
	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	
Species richness	21	21	20	20	16	22	19	16	22	21	12	19	19	15	12	8	85
Number of families	18	15	15	15	13	17	15	12	11	14	9	15	13	8	9	6	37
Number of genera	20	19	20	20	16	21	18	14	19	21	11	17	16	12	11	8	64
No of Endemic species	8	12	8	10	7	10	9	6	14	10	8	9	11	5	5	3	36
Stand density/ha	383	417	442	450	450	550	500	308	475	308	667	567	417	283	400	250	429
Basal area (m ² /ha)	50.57	33.24	22.62	29.7	36.71	28.29	40.95	23.21	66.83	92.14	110.34	26.79	24.32	11.69	7.53	5.83	38.17
Shannon –Weiner Index(H')	2.82	2.64	2.67	2.77	2.46	2.58	2.53	2.60	2.79	2.86	2.16	2.63	2.72	2.48	2.08	1.80	-
Simpson's Diversity (D)	0.93	0.89	0.91	0.90	0.90	0.88	0.89	0.91	0.92	0.93	0.86	0.91	0.92	0.90	0.84	0.81	-
Pielou's Evenness Index (E')	0.93	0.87	0.89	0.93	0.89	0.83	0.86	0.94	0.90	0.94	0.87	0.89	0.92	0.92	0.84	0.87	-

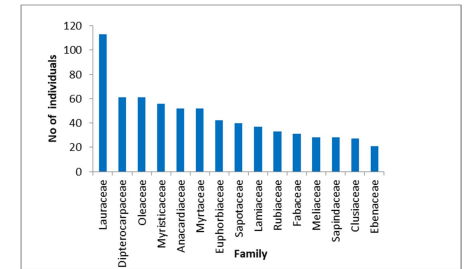
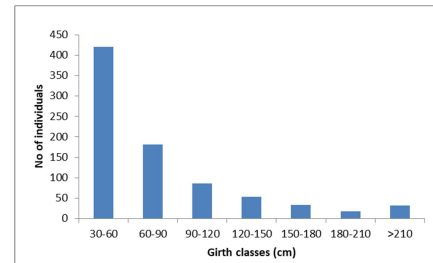
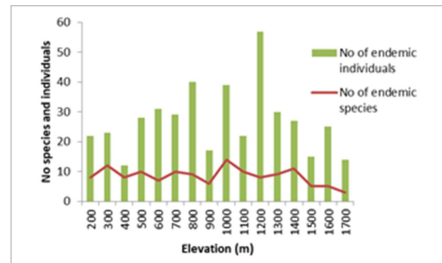
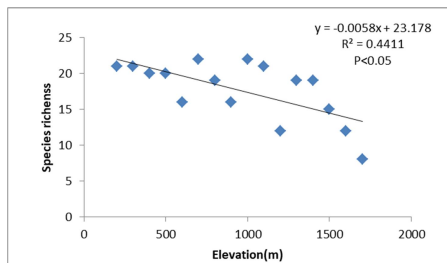
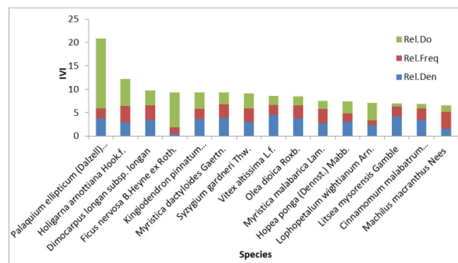


Fig 2: a) Elevational gradient of Species richness b) Elevational gradient of endemic species & individuals c) Girth class distribution

d) Top 15 Family wise distribution of the number of individuals



f) IVI of the top 15 species in Pushpagiri Wildlife Sanctuary, Kodagu.

5. CONCLUSION

The findings from this study showed that the forest structure and composition changed along the elevational gradients. The lower elevations had higher species diversity as compared to the higher elevations. The study showed the dominance of *Pallaquium ellipticum* along riparian areas in the lower elevations. Pushpagiri Wildlife Sanctuary harbors a diverse flora along with a high number of endemic species. Thus, continued conservation efforts and site specific management plans needs to be implemented to conserve the biodiversity of the Sanctuary.

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Appendix 1: Basal area and IVI of the tree species in Pushpagiri Wildlife Sanctuary, Kodagu
(*Endemic to the Western Ghats)

Sl.No	Species name	Family	Basal area (m ² /ha)	IVI
1	Actinodaphne bourdillonii Gamble*	Lauraceae	0.06	2.17
2	Aglaia elaeagnoidea (A. Juss.) Benth.*	Meliaceae	0.31	2.38
3	Aglaia simplicifolia (Bedd.) Harms.*	Meliaceae	0.12	3.43
4	Agrostistachys borneensis Becc.	Euphorbiaceae	0.26	1.76
5	Antidesma menasu (Tul.) Miq. ex Muell.-Arg.	Phyllanthaceae	0.01	0.51
6	Antidesma montanum Blume.	Phyllanthaceae	0.02	0.53
7	Aporosa lindleyana (Wight) Baill.	Euphorbiaceae	0.24	4.46
8	Archidendron bigeminum (L.)I.C.Nielsen	Mimosoideae	0.16	1.85
9	Artocarpus heterophyllus Lam.	Moraceae	0.98	3.05
10	Artocarpus hirsutus Lam.*	Moraceae	0.01	4.07
11	Calophyllum apetalum Willd.*	Calophyllaceae	0.51	3.01
12	Carallia brachiata (Lour.) Merr.	Rhizophoraceae	0.13	0.81
13	Caryota urens L.	Arecaceae	0.14	1.43
14	Celtis philippensis wightii (Planch.) E. Soepadmo	Cannabaceae	0.08	0.81
15	Chionanthus mala-elengi (Dennst.) P.S.Green	Oleaceae	0.25	4.96
16	Chukrasia tabularis A. Juss.	Meliaceae	0.01	0.50
17	Cinnamomum malabratrum (Burm. f.) Presl*	Lauraceae	0.39	6.89
18	Cinnamomum sulphuratum Nees*	Lauraceae	0.00	0.48
19	Cinnamomum verum J. S. Presl	Lauraceae	0.17	0.91
20	Croton laccifer L.	Euphorbiaceae	0.01	0.98
21	Cryptocarya wightiana Thw.	Lauraceae	0.01	1.57
22	Dillenia pentagyna Roxb.	Dilleniaceae	0.09	0.70
23	Dimocarpus longan subsp. longan	Sapindaceae	1.22	9.78
24	Diospyros assimilis Bedd.	Ebenaceae	0.04	0.59
25	Diospyros ebenum J.Koenig ex Retz.	Ebenaceae	0.04	1.53
26	Diospyros paniculata Dalzell*	Ebenaceae	0.11	1.86
27	Diospyros sp.	Ebenaceae	0.27	3.34
28	Dipterocarpus indicus Bedd.*	Dipterocarpaceae	0.30	2.92
29	Drypetes oblongifolia (Bedd.) Airy Shaw*	Putranjivaceae	0.27	1.44
30	Dysoxylum malabaricum Bedd. ex C. DC.*	Meliaceae	0.08	1.65
31	Erythroxylum sp.	Erythroxylaceae	0.01	0.50
32	Ficus nervosa B.Heyne ex Roth.	Moraceae	2.83	9.31
33	Garcinia gummi-gutta (L.) Robs.*	Clusiaceae	0.41	5.38
34	Garcinia indica (Thouars) Choisy.*	Clusiaceae	0.24	3.12
35	Glochidion ellipticum Wight *	Euphorbiaceae	0.14	3.71
36	Gordonia obtusa Wall. ex Wight & Arn.*	Theaceae	0.07	1.74
37	Grewia tiliifolia Vahl. var. tiliifolia	Malvaceae	0.38	1.47
38	Holigarna arnottiana Hook.f. *	Anacardiaceae	2.21	12.23
39	Holigarna grahamii (Wight) Kurz*	Anacardiaceae	0.13	1.53
40	Hopea canarensis Hole	Dipterocarpaceae	1.70	6.37
41	Hopea parviflora Bedd.*	Dipterocarpaceae	0.71	4.49
42	Hopea ponga (Dennst.) Mabb.*	Dipterocarpaceae	1.01	7.44
43	Humboldtia brunonis Wall. *	Fabaceae	0.01	0.50
44	Hydnocarpus pentandra (Buch.-Ham.) Oken*	Flacourtiaceae	1.11	3.87
45	Ixora brachiata Roxb.*	Rubiaceae	0.44	5.84

46	Kingiodendron pinnatum (DC.)Harms*	Fabaceae	1.35	9.31
47	Knema attenuata (Hook. fil. & Thoms.) Warb.*	Myristicaceae	0.03	1.04
48	Ligustrum perrottetii A.DC.*	Oleaceae	0.08	1.67
49	Litsea bourdillonii Gamble*	Lauraceae	0.03	0.55
50	Litsea floribunda (Bl.) Gamble *	Lauraceae	0.70	3.63
51	Litsea mysorensis Gamble*	Lauraceae	0.21	6.92
52	Lophopetalum wightianum Arn.	Celastraceae	1.40	7.05
53	Macaranga indica Wight	Euphorbiaceae	0.28	4.65
54	Mallotus philippensis (Lam.) Müll.Arg.	Euphorbiaceae	0.31	2.49
55	Mangifera indica L.	Anacardiaceae	0.14	1.32
56	Meiogyne pannosa (Dalzell) J. Sinclair*	Annonaceae	0.27	2.13
57	Memecylon umbellatum Burm. f.	Melastomataceae	0.14	3.14
58	Mesua ferrea L.	Calophyllaceae	0.51	2.30
59	Mimusops elengi L.	Sapotaceae	0.75	4.82
60	Murraya paniculata (L.) Jacq.	Rutaceae	0.01	0.63
61	Myristica dactyloides Gaertn.	Myristicaceae	0.99	9.30
62	Myristica malabarica Lam.*	Myristicaceae	0.64	7.54
63	Neolitsea zeylanica (Nees & T. Nees) Merr.	Lauraceae	0.26	4.04
64	Nothapodytes nimmoniana (J. Grah.) D.J. Mabberley	Stemonuraceae	0.28	3.13
65	Nothopogia beddomei Gamble	Anacardiaceae	0.05	1.20
66	Nothopogia travancorica Bedd. ex Hook. f.*	Anacardiaceae	0.17	2.00
67	Olea dioica Roxb.	Oleaceae	0.71	8.44
68	Palaquium ellipticum (Dalzell) Baill.*	Sapotaceae	5.69	20.82
69	Persea macrantha (Nees) Kosterm.	Lauraceae	0.53	6.50
70	Psychotria sp.	Rubiaceae	0.01	0.50
71	Psydrax umbellata (Wight)Bridson	Rubiaceae	0.10	2.28
72	Rapanea wightiana (Wall. ex DC.) Mez	Myrsinaceae	0.06	1.94
73	Schefflera sp.	Araliaceae	0.05	0.96
74	Schefflera wallichiana (Wight & Arn.) Harms	Araliaceae	0.01	0.51
75	Semecarpus travancorica Bedd.*	Anacardiaceae	0.35	3.08
76	Spondias pinnata (L. f.) Kurz	Anacardiaceae	0.10	1.34
77	Symplocos cochinchinensis (Lour.)	Symplocaceae	0.06	0.63
78	Syzygium sp.	Myrtaceae	0.09	1.78
79	Syzygium cumini (L.) Skeels	Myrtaceae	0.42	2.18
80	Syzygium densiflorum Wall. ex Wt. & Arn.*	Myrtaceae	0.24	3.77
81	Syzygium gardneri Thw.	Myrtaceae	1.25	9.15
82	Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	0.44	2.57
83	Terminalia travancorensis Wight & Arn.*	Combretaceae	0.40	4.17
84	Vateria Indica L.*	Dipterocarpaceae	0.55	4.07
85	Vitex altissima L.f.	Lamiaceae	0.76	8.61
	Total		38.17	300