

Vegetation dynamics and its dispersal syndrome across size class of tropical montane (shola) forest, Kudremukh, Western Ghats, India.

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ABSTRACT

Tropical montane (shola) forest are recognized to be most threatened ecosystems globally and considered has important hotspot of several endemic species and those are higher vulnerable due to the various factors which often concluded global climatic change or anthropogenic influence. However, assessing the health of the forest ecosystems may also have the forest standing structure and its dispersal syndrome to understand and its ecological constraints may provide greater insights of history of forest recruitments. This paper is to examine the different sized shola's, where how species dispersal syndrome are structured trees communities (>5 cm DBH only tree). The results revealed that species richness shown higher at large-shola (LS) and moderate-shola (MS) than small-shola (SS). Similarly species composition shown significantly higher at LS and MS then least at SS. In LS and MS forest shown higher diversity of species belong to mammals (M) and bat-mammals (BtM). Whereas SS shown passive (Pa) dispersal species shown higher number then bird (B) and bird-mammal (BM). Overall conclusion that size of the shola's play major role in structuring the tree species composition and diverse dispersal syndrome species are limited in SS, it's very important to understand the ecological constraints. The forest managers may have to understand the ecological constraints before getting into intervention of montane (shola's) ecosystem. There is scope for ecological intervention depending upon the size of the shola and species selection based on understanding the ecological constraints of shola, will have greater opportunities to restore back original ecosystem.

Keyword: Dispersal syndrome, ecological restoration; frugivore, shola, Western Ghats

Mathematics Subject Classification: 92D40, 92D25

Journal of Economic Literature (JEL) Classification : Q23, Q57

1. INTRODUCTION

Tropical montane (shola) forest are recognised to be most threatened ecosystems globally (Bunyan et al., 2012) and are considered has hotspot of several endemic species habitats (Narayanan et al., 2013, Robin et al., 2017). These montane forest by its nature isolated and surrounded by grasslands and usually stunted vegetation not exceed 12 – 14 m heights of evergreen trees classified as 'southern montane wet temperate forest' locally known as shola forest (Ranganathan, 1938, Jose et al., 1996a,

Nair and Khanduri, 2001). The vegetation is unique and it is botanically considered as a 'relict' of palaeo-endemic species (Champion and Seth, 1968, Arasumani et al., 2018). Such important ecosystem over many decades' have been influenced due to the anthropogenic factors such as forest fire, invasive species, encroachment and grazing (Chandrashekara et al., 2006). In long run global climate change may also have greater effects on the micro-habitats and its biodiversity of montane ecosystem (Sukumar et al., 1995, Bunyan et al., 2012, Team et al., 2014).

Tropical montane forest has limited understanding of climate change, ecological restoration and invasive species ecology (Robin and Nandini, 2012), however, ecological restoration have to emphasis on multifaceted site specific intervention viewed through land-use history, socio-cultural, political and ecological interface (Higgs, 1997). As part of ecological understanding mainly to know remnant standing of vegetation and its dispersal syndrome provides greater insights to history of successional dynamics and to predict the historical habitat stress shaping those species and proliferation of invasive species (Butler et al., 2007, Robledo-Arnuncio et al., 2014). The studies at sky-island (shola) also showed that how population getting isolated genetically and also limit to the dispersal due to climatic changes have impact on the population and migrations or immigration to the micro-habitats (Robin and Nandini, 2012, Sekar and Karanth, 2013, Robin et al., 2014, Robin et al., 2015). The factors between the grassland and shola interface much debated its dynamics of shola-grassland mosaic to moisture and CO₂ levels (Sukumar et al., 1993), whereas others emphasised the role of frost and soil factors (Vasanthy, 1988) and role of fire sharpened the sholas forest (Ranganathan, 1938).

Human utilization of forest resources often starts with grazing or fuelwood collection, followed by small scale forest clearance for agriculture, then the gradual expansion lead to fragmentation of montane forest in tropics (Chandrashekara et al., 2006, Puyravaud et al., 2010). To understand the extent of human activity by assessing the remnant standing vegetation will provide useful information of health of montane ecosystem, which helps to forest managers to prepare site specific ecological restoration and forest managements.

Lack of such site specific restoration experiments are the reasons for ecosystem degradation (Bruijnzeel et al., 2010). Understanding vegetation and its dispersal syndrome may have greater implication to forest managers to select appropriate species keeping in view of its association in the ecosystem instead of *ad-hoc* afforestation plan in shola forest and its edge. Hence present study aims at assessing tree species composition across the different size of shola forest, their dispersal syndromes and its implication for ecological restoration.

2. STUDY AREA

The study was carried out in Kudremukh National Park (*henceforth* Kudremukh), which fall within the latitude 12° 55' – 13° 54' N and longitude 75° 01' – 76° 22' E, 1200 m to 1628m asl (Fig. 1). The numerous first and second order streams originate from this remnant shola forest which lead to watershed of Tunga and Bhadra River (Chetana, 2004). The forest largely wet evergreen tropical to moist deciduous

forest and the mean rainfall ranges from 6000-8000-mm. The annual average temperature 23.5⁰ C and higher precipitation during the southwest monsoon in the months of June – September. The major proportion of edaphic are weathered red loams (oxisols) with local occurrences of laterite, underlying rocks and granitic gneisses (Swamy, 1987).

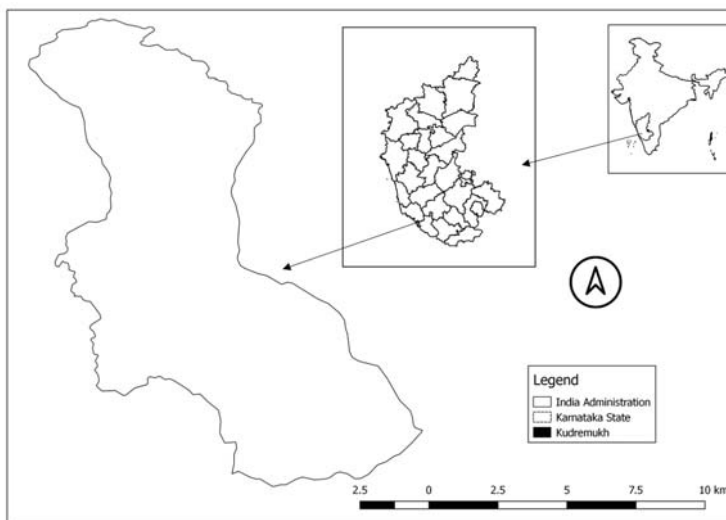


Figure 1. Study area Kudremukh National Park, Karnataka

3. METHODS

The sampling was chosen based on size and altitude at which shola forest situated. Shola were categorized into three types based on size class v/z small-shola (SS; < 2 ha), moderate-shola (MS; 2 to 5 ha), and large-shola (LS; >5ha). Each size of shola 5 replicates of shola were chosen at same altitude minimum 1000 m apart each shola were maintained. The sampling shola were grided 25 x 25 m and vegetation enumeration was done randomly chosen 5 grids at each replicate across the shola size categories, to understand the species composition and vegetation dynamics across. The trees were enumerated > 5 cm Girth at Breast Height (GBH) within each grid. The species were identified using Flora (Gamble and Fischer, 1915–1935, Yoganarasimhan, 1981). The dispersal syndrome of each tree species were identified based on the seed and fruit morphology and classified into bird (B), bat (Bt), bird-mammal (BM), bat-other mammal (BtM), mammal (M) and passive both dehiscent and wind dispersed seeds based on seed morphology (Pa)(Chetana and Ganesh, 2012).

Data analysis

Species richness and abundance was estimated as the cumulative number of species at different sized shola forest (ie. LS, MS, and SS). The Species composition across the shola's forest were examined using single linked clustering (van Tongeren, 1987). Similarity distances were expressed as the Bray-Curtis index. Where similarity of 0% means nothing is common between the two distances classes and 100% means that all the species are common to the two distance classes. Two-factor permutational multivariate ANOVA with shola forests intervals as one independent factors was used to test the differences among species composition. This was done only within replication of shola forest as species

composition is expected to be a subset of shola's. Moreover, PERMANOVA can handle large multiple species datasets (McArdle and Anderson, 2001). Pairwise comparisons based on Monte-Carlo (MC) randomization with 4999 permutations were performed to test for differences among the shola forest size (Chetana and Ganesh, 2012). All the analyses were done using statistical software R 2.12.1 (R Development Core Team) except community composition analysis which was done using PERMANOVA (Anderson, 2001a & 2001b, Chetana and Ganesh, 2012) G-test was performed to see their any significance across the dispersal syndromes.

4. RESULTS

Species richness and diversity

A total of 1699 individuals belong to 70 tree species from 51 genera and 35 families were enumerated in the 9.375 ha, of which 44 species were common across LS, followed MS and SS respectively. The dominant families were Euphorbiaceae and Clusiaceae (Appendix I). Total of 932 individuals belong to 69 tree species recorded in LS followed by 561 individuals of 65 species in MS and 206 individuals of 43 species in SS respectively. The species composition indicates that the significant difference across LS, MS and SS ($F = 5.884$, $df = 2$, $P(MC) = 0.0002$), Further, pairwise comparisons among the size of shola shown significance in mean composition between LS and SS ($t = 3.305$, $P_{MC} = 0.0001$) and MS and SS ($t = 2.261$, $P_{MC} = 0.0002$, whereas LS and MS did not showed significance ($t = 1.456$, $P_{MC} = 0.21$).

Bray-Curtis similarity shown 73% of species composition between LS versus MS, and 46% similar between MS versus SS, whereas 32% species across SS versus LS (Fig. 2). The species dominance changed from LS to SS areas, but was remarkably constant across size of shola. In case of LS and MS dominated by *Litsea floribunda*, *Syzygium rubicundum*, followed by *Neolisea zeylanica*, *Mastixia arborea*, *Olea dioica*, and *Daphniphyllum neilgherrense*. In SS species dominated were *Gordenia obtusa*, *Pterocarpus marsupium* and *Macaranga peltataspecies* (Appendix 1).

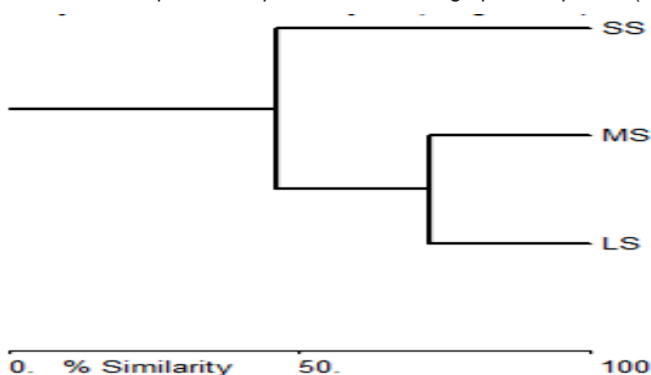


Figure 2. Dendrogram of the three montane: Cluster distances were calculated with the Bray-Curtis similarity index (single link) for the species composition and abundances (Note: SS – small shola, MS – moderate shola, LS – large shola forests).

Dispersal syndromes

In LS and MS forest shown higher diversity of dispersal modes such as bat-mammal (100%), mammals (63%) and bat-birds (94%) respectively. Whereas SS shown Passive dispersal modes shown higher number then bird and dual-dispersal modes of BM were observed. The maximum likelihood G-Test permutation of species dispersal modes shown significant across LS, MS and SS ($G\text{-Test} = 20.726$, df 12, $P=0.05$). The modes of BtM, BtB and Bt species were countable in MS and SS (**Fig. 2**). Whereas Passive modes species shown in SS than LS and MS (**Appendix I**).

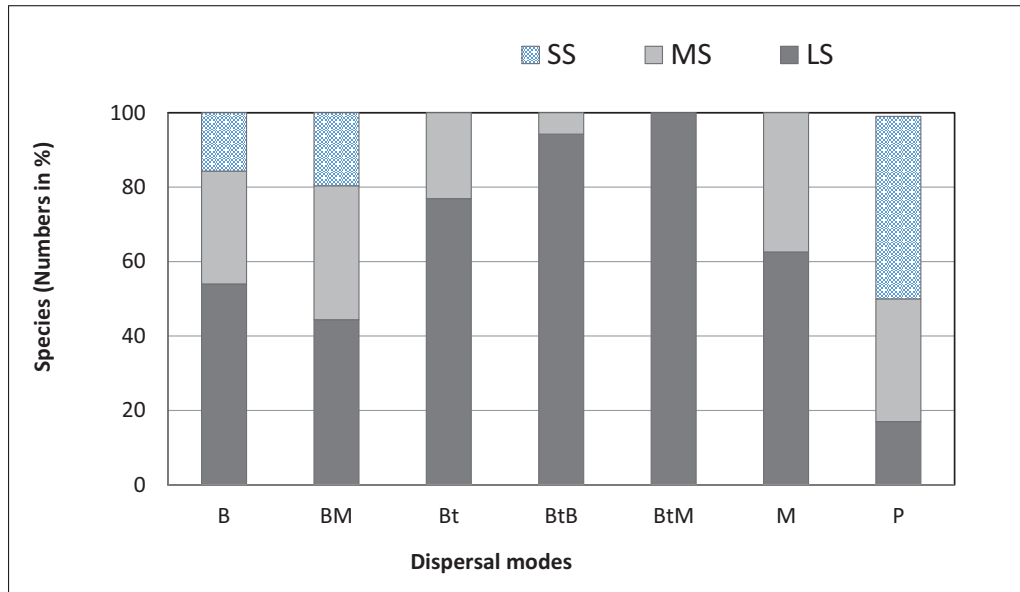


Figure 3. Proportion of species recorded within the different dispersal syndromes in the LS, MS, and SS; Bt – bat, BtM = bat-other mammal, Pa = Passive, M = mammal, B = birds, BM = bird-mammal.

5. DISCUSSIONS

Overall average species richness is 30.6 ± 12.3 ($\bar{x} \pm sd$), similar observation was made at montane forest 31.6 ± 8.9 species in Thaishola permanent plot at Nilgiri Biosphere reserve (Narendran et al., 2001), and 59 species in Kukkal shola in the Palanis (Davidar et al., 2007). The species composition shows that only five dominant species such as *Litsea floribunda*, *Mastixia arborea*, *Neolisea zeylanica*, *Olea dioica*, *Syzygium arnotianum* represented 20% of the stem density and also common across small, moderate and large shola. However, few species such as *Apodytes dimidiata*, *Ficus nervosa*, and *Olea dioica* very are less in number across the shola but relative low in SS. Though Kudremukh shola did not considered during Nair et al., 2001, but later another taxonomical studies by Sringswara (2006), emphasis that based on floristically compositions similar to other part of shola such as *Elaeocarpus tuberculatus*, *Cinnamomum sulphuratum*, *Schefflera rostrata* *Pociloneuron indicum* and *Syzygium arnotianum*. Shola studies from Kerala reveals that human pressure to the local biodiversity altered montane ecosystem due to fuelwood extraction by community to process oil from lemongrass (Chandrashekara, et al., 2006), agricultural encroachments (Joseph et al., 2009) and climate change

over period of centuries (Sukumar et al., 1997). The studies from south-eastern Brazil reveals that smaller fragments had higher contribution from abiotic means of seed dispersers (passive syndrome), whereas larger fragmented forest shown higher contribution from biotic means of seed disperses (Tabarelli et al., 1999). Such pattern had clear indication of many specialised seed disperses or vectors visitation may be absent at SS than MS and LS. The studies done by Fa and Peres (2001), Peres (2001, &1999) in African and Neo-tropical forest-region emphasis that decline in abundance and richness of vertebrate-dispersed plants would almost certainly cause a reduction in vertebrate frugivores. Similar observation were made in present study, where higher passive (abiotic) syndrome species recorded in SS, whereas LS shown higher number of mammals syndrome species (**Fig. 3**). Shola forest lack distinct canopy layers and support lower basal areas (Jose et al. 1996b). However, they are one of the most vulnerable treasures of the hills serving as the prime sources of water and shelter for wildlife (Srivastava, 1994, Mathew and Mohanadas, 2001, Robin and Nandini, 2012). In case of small shola relatively open canopy compare to the moderate and large sholas this could be the reason cryptic small frugivore mammals may have not visit the SS due to the visibility to predator at ground and canopy openness (Chetana and Ganesh, 2007).

Conclusions and Conservation way-forward

Density of trees species positively correlated with the size of the montane (shola) forest. The smaller the size of shola needs special attention for intentional restoration of those species which are specialised dispersal syndrome such as M and BtM in case of this study. The management should focus on ecological intervention wherever such small shola forest because these are higher chance of passive syndrome species mono-dominance or could also proliferate invasive or exotic species. Also edge of the shola need to be restored using light demanding and fire resistant species to avoid the seedling mortality during fire. We observed *Acacia auriculiformis* plantation on edge of shola, which need to be thinning-out to facilitate native species regeneration. Further, post-monsoon controlled fire-line need to be undertaken with utmost precaution on not to damage seedling on shola edge.

6. ACKNOWLEDGEMENTS

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Appendix-I. List of species recorded within the Sholas forest gradients: dispersal syndromes - Bt – bat, BtM = bat-other mammal, P = passive, M = mammal, B = birds, BM = bird-mammal and L: large shola forest, M: moderate Shola forest, and S: small shola forest.

Sl.No.	Species	Family	Dispersal syndrome	Gradients
1	<i>Daphniphyllum neilgherrense</i> (Wight) K. Rosenth	Lauraceae	B	LS/MS/SS
2	<i>Agrostistachys indica</i> Dalz.	Euphorbiaceae	B	LS/MS/SS
3	<i>Alangium salvifolium</i> Wang.	Alangiaceae	M	LS/MS
4	<i>Antidesma menasu</i> (Tul.) Miq.	Euphorbiaceae	BM	LS/MS/SS
5	<i>Apodytes dimidiata</i> E. Meyer ex Arn.	Icacinaeae	BM	LS/MS/SS
6	<i>Bischofia javanica</i> Bl.	Euphorbiaceae	B	LS/MS
7	<i>Callicarpa tomentosa</i> (L) Murray	verbenaceae	B	LS/MS
8	<i>Carallia brachiata</i> (Lour.) Merr.	Rhizophoraceae	M	LS/MS
9	<i>Careya arborea</i> Roxb.	Barringtoniaceae	M	LS/MS
10	<i>Celtis philippensis</i> Blanco	Cannabaceae	B	LS/MS/SS
11	<i>Chrysophyllum lanceolatum</i> (Bl.) DC	Sapotaceae	M	LS
12	<i>Cinnamomum malabatum</i> (N. Burman) Blue	Lauraceae	B	LS/MS/SS
13	<i>Cleistanthus collinus</i>	Euphorbiaceae	M	LS/MS
14	<i>Dillenia pentagyna</i> Roxb.	Dilleniaceae	M	LS/MS
15	<i>Diospyros angustifolia</i>	Ebenaceae	M	LS/MS
16	<i>Diospyros crumenata</i> Thw.	Ebenaceae	M	LS/MS
17	<i>Diospyros saldanhae</i> Koesterm.	Ebenaceae	M	LS/MS
18	<i>Elaeocarpus tuberculatus</i>	Elaeocarpaceae	Bt	LS
19	<i>Elocarpus serratus</i> L.	Elocarpusaceoc	BtM	LS
20	<i>Ervatamia heyneana</i> (Wall.) Cooke	apocynaceae	M	LS/MS
21	<i>Euodia lunu-ankenda</i> (Gaertn.) Merrill	Rutaceae	B	LS/MS
22	<i>Euonymus indicus</i> Heyne ex Wall.	Celastraceae	B	LS/MS
23	<i>Eurya nitida</i> Korth	Pentaphylacaceae	M	LS/MS
24	<i>Ficus callosa</i> Willd.	Moraceae	BM	LS
25	<i>Ficus nervosa</i> Heyne ex roth	Moraceae	BM	LS/MS/SS
26	<i>Ficus tsajela</i> Burm.	Moraceae	BM	LS
27	<i>Garcinia gummi-gutta</i> (L.) Robs.	Clusiaceae	M	LS/MS
28	<i>Garcinia morella</i> (Gaertn.) Desr.	Clusiaceae	M	LS/MS
29	<i>Glochidion ellipticum</i> Wight	Euphorbiaceae	B	LS/MS
30	<i>Gochidion zeylanicum</i>	Euphorbiaceae	B	LS/MS/SS
31	<i>Gordonia obtusa</i> Wall ex Wight Arn.	Theaceae	P	LS/MS/SS
32	<i>Holigarna grahamii</i> (Wt.) kurz	Anacardiaceae	M	LS/MS
33	<i>Holigarna ornattiana</i>	Anacardiaceae	M	LS/MS
34	<i>Hopea canarensis</i>	Dipterocarpaceae	P	LS/MS/SS
35	<i>Knema attenuata</i> (Hk. & Thoms.) Warb	Myristicaceae	B	LS/MS/SS
36	<i>Ligustrum</i> sp.,	Oleaceae	B	LS/MS/SS
37	<i>Litsea floribunda</i> (Blume) Gamble	Lauraceae	B	LS/MS/SS
38	<i>Litsea ghatica</i> Saldanha.	Lauraceae	B	LS/MS/SS
39	<i>Litsea mysorensis</i>	Lauraceae	B	LS/MS
40	<i>Lophopetalum wightianum</i> Arn.	Celastraceae	P	LS/MS/SS
41	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.	Euphorbiaceae	B	LS/MS/SS

44	<i>Mallotus philippensis</i> (Lam.) Muell.	Euphorbiaceae	B	LS/MS/SS
42	<i>Mangifera indica</i> L.	Anacardiaceae	M	LS/MS
43	<i>Mastixia arborea</i> (Wt.) Bedd	Cornaceae	M	LS/MS
45	<i>Memecylon wallichii</i>	Melastomataceae	M	LS/MS
46	<i>Mesua nagassarium</i> (Burman)Kosterm.	Calophyllaceae	M	LS/MS
47	<i>Myristica dactyloides</i> Gaertn.	Myristicaceae	BM	LS/MS/SS
48	<i>Myristica fatua</i> Houtt. var. <i>magnifica</i> (Bedd.) Sinclair	Myristicaceae	B	LS/MS
50	<i>Neolitsea zeylanica</i> (Nees) Merr.	Lauraceae	BM	LS/MS/SS
49	<i>Nothapodytes foetida</i> L.	Icacinaceae	M	LS/MS
51	<i>Nothapodytes nimmonica</i> (Grah) Mabber	Icacinaceae	M	LS/MS
52	<i>Olea dioica</i> Roxb.	Oleaceae	BM	LS/MS/SS
53	<i>Palaquium ellipticum</i> (Dalz.) Baillon	Sapotaceae	Bt	LS/MS
54	<i>Persea macrantha</i> (Nees) kosterm.	Lauraceae	B	LS/MS/SS
55	<i>Phoenix sylvestris</i> (L) Roxb	Arecaceae	M	LS/MS
56	<i>Pithecellobium dulce</i> (Roxb.)Bebtg	Fabaceae	B	LS/MS/SS
57	<i>Poeciloneuron indicum</i> Bedd.	Clusiaceae	P	LS/MS/SS
58	<i>Pterocarpus marsupium</i> Roxb.	Fabaceae	P	LS/MS/SS
59	<i>Rapanea striata</i>	Primulaceae	BM	LS/MS/SS
61	<i>Scheffera rostrata</i> (Wt.) Harms	Araliaceae	M	LS/MS
62	<i>Symplocos cochinchinensis</i> (Lour.) Moore subsp.	Symplocaceae	BM	LS/MS/SS
63	<i>Symplocos</i> sp	Symplocaceae	BM	LS/MS
64	<i>Symplocos racemosa</i> Roxb	Symplocaceae	BM	LS/MS/SS
65	<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	BM	LS/MS
66	<i>Syzygium lanceolatum</i> (Lam.) Wt. & Arn.	Myrtaceae	B	LS/MS
67	<i>Syzygium arnottianum</i> (Wight) Walp	Myrtaceae	BtB	LS
68	<i>Toona ciliata</i> M. Roem. var. <i>ciliata</i>	Meliaceae	B	LS/MS/SS
69	<i>Trema orientalis</i> (L.) Blume	Ulmaceae	BtB	LS/MS
70	<i>Trichilia connaroides</i> (W. & A.) Benth.	Meliaceae	B	LS/MS/SS