Phytosociological analysis of *Myristica* swamp forests of Kulathupuzha, Kerala, India

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The vegetation of *Myristica* swamp forests in Kulathupuzha, southern Kerala, India, was examined with reference to floristic composition, structure and diversity. Quadrates of 100 × 10 m were laid inside (17) and outside the swamps (14), and trees >10 cm girth at breast height were enumerated. A total of 2246 individual trees belonging to 58 species were recorded inside the swamps as against 1203 trees belonging to 89 species from outside the swamps. A total of 1775 shrubs belonging to 46 species and 26 species of herbs with 1082 individuals were recorded from inside the swamps. A total of 3535 shrubs belonging to 83 species and 491 herbs belonging to 30 species were recorded from outside the swamps. The *Myristica* swamp forests showed less diversity when compared to other forest types and was dominated by two Myristicaceae species, *Myristica fatua* var. *magnifica* and *Gymnacranthera farquhariana*. Comparison with *Myristica* swamps in other regions indicates that the Kulathupuzha region has the largest populations of the endangered *M. fatua* var. *magnifica*. Immediate steps for conservation are suggested.

Keywords: Floristic composition, phytosociological analysis, *Myristica* forests, structure and diversity.

THE Western Ghats, one of the 34 'biodiversity hot spots'[1] most threatened with high population density (340/km^2) and positive growth rate[2], is characterized with high species diversity and the presence of several palaeoendemic botanical 'relicts' of ancient and unique vegetation types[3] like the *Myristica* swamp forests[4–18]. These swamps are dominated by trees of the Myristicaceae family which is placed along with other 'living fossil' families of primitive dicots like Magnoliaceae, Annonaceae and Chloranthaceae[19]. These swamps are also a site for unique plant–animal interactions such as pollination[20,21] and secondary seed removal[22]. The swamps are characterized by high endemism[23] of up to 61.11% (ref. 8).

Myristica swamps were first described by Krishnamoorthy[4] and classified by Champion and Seth[3] in the sub-group of tropical freshwater forests (4c/FS1). These forests are highly fragmented and restricted in distribution due to special abiotic conditions required for their survival[5] and systematic destruction which included conversion to plantations and paddy fields[24,25]. They have been reported only in the Western Ghats (Uttara Kannada[9,10], Goa[12]) with maximum patches concentrated in Kulathupuzha, Southern Kerala[5,6,13,14,16], which is considered as a region of high conservation priority in the Western Ghats[26].

Understanding and documenting any or all information about plant communities and their structural and functional dynamics are essential for biodiversity conservation and sustainable management of fragile ecosystems such as the *Myristica* swamp forests[27]. Phytosociological data are essential for assessing biodiversity, and for understanding species assemblages and interactions. This article elucidates the forest structure and floristic composition of the *Myristica* swamp forests of Kulathupuzha region (November 2004–March 2007) and compares it with other forest types.

Materials and methods

Study area

The study area, *Myristica* swamp forest patches of Kulathupuzha and Anchal Forest Ranges and Shendurney Wildlife Sanctuary (8.75°–9.0°N and 76.75°–77.25°E) (Figure 1 *a*), has been described in detail in our previous reports[15,16]. Sixty *Myristica* swamp patches with a cumulative area of 149.75 hectare (ha) (0.01348% of Kerala forest) were mapped[13,16]. Two hundred and twenty-one plant species (79 species of trees, 93 species of herbs/shrubs and 49 climbers constituting 5% of Kerala's flora) belonging to 88 families have been reported from these swamp forests. Eighteen of these species are Red-listed and 49 species are endemic[13–15].

Vegetation sampling

Most of the swamps have an area of less than 5 ha (ref. 16) (Figure 1 *b*), are narrow, constricted, with convoluted outlines and isolated in nature (Figure 2). Hence, relatively small sample plots of 100 m × 10 m (0.1 ha) were laid out in 17 randomly selected swamps in Kulathupuzha Forest Range. Each 100 m × 10 m (0.1 ha) plots

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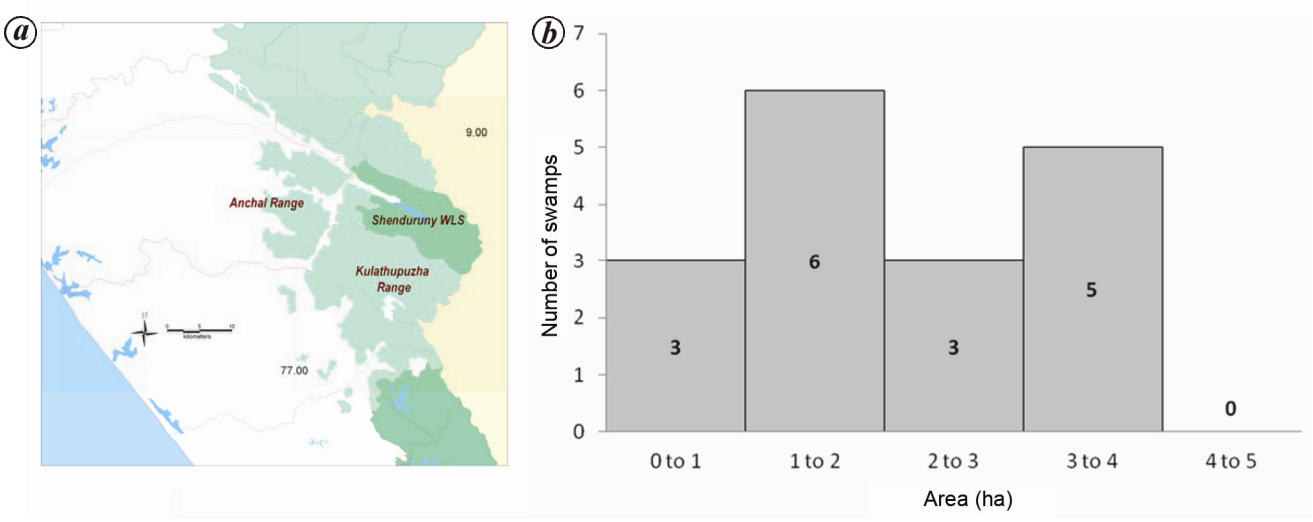

Figure 1. ***a***, Study area. ***b***, Histogram representing the number of swamps in different size classes.

was again divided into ten 10 m × 10 m quadrats. Trees in each quadrat were enumerated, identified and GBH (girth at breast height (1.5 m above ground)) of trees with greater than 10 cm circumference was recorded. For shrubs, sample plots of size 4 m × 4 m were randomly selected within each quadrat (10 m × 10 m). For herbs, sample plots of 1 m × 1 m were randomly taken from each quadrat (10 × 10 m). The shrubs and herbs were also enumerated and identified. Quadrat dimensions conformed to Mueller and Dombois[28]. To compare the natural vegetation composition in *Myristica* swamps and non-*Myristica* swamp areas, sample plots of the same size as taken inside *Myristica* swamps (17 plots, 17,000 m^2) were also taken in the forests outside individual swamp patches (14 plots, 14,000 m^2). Only 14 plots were taken outside the swamps as against 17 inside the swamps because three swamp patches (Poovanthumoodu cluster)[16] lay very close to each other and were flanked on sides by roads and plantations so that only one plot of the required size could be taken from adjacent area with natural vegetation[16].

Analysis of data

Importance value index (IVI, which is the sum of relative density, relative frequency and relative basal area), alpha diversity indices (Simpson index, Shannon index (*H*′), Margalef's index (*R*), evenness index 2 (*E*2)) and Hill's diversity indices (*N*0, *N*1, *N*2) were calculated[29,30]. Whittaker's beta diversity (βw) was calculated to ascertain the degree of turnover along plots inside and outside the *Myristica* swamp patches[30]. Jaccard's similarity coefficient based on qualitative data and Morisita Horn coefficient of similarity calculated with quantitative data were determined to assess species turnover between the swamps and the adjacent forests[30]. Species accumulation curves were plotted. Girth class distribution and Raunkiaer frequency classes were determined[31]. Selected environmental parameters (% of swamp area under inundation, average depth of inundation, temperature, relative humidity, % of canopy cover, % of swamp area with litter, average litter depth, % of swamp area with undergrowth, % of gravel, sand, silt and clay in soil, soil pH and organic carbon) were compiled[13] and their relation with tree species was studied for eight swamps (Uthiran Chira, Karinkurinji, Sastha Nada, Pillekode, Marappalam Minor, Marappalam Major, Mottal Mood and Emponge). The results were compared with previous studies in *Myristica* swamps, non-*Myristica* freshwater swamps and other vegetation types.

Results and discussion

Tree composition and structure of Myristica swamps and surrounding forests

A total of 2246 individual trees belonging to 58 species were recorded from 17 transects laid inside *Myristica* swamps. *Gymnacranthera farquhariana* comprised 33.84% of total number of trees, followed by *Myristica fatua* var. *magnifica* which constituted 30.77%. The other major trees were *Lophopetalum wightianum, Vateria indica* and *Holigarna arnottiana*. *G. farquhariana* (87.21) and *M. fatua* var. *magnifica* (73.83) showed the highest IVI values. Non-*Myristica* species with high IVI values were *L. wightianum* (31.35), *V. indica* (17.58), *H. arnottiana* (14.63) and *Syzygium travancoricum* (11.98) (Figure 3 *a*).

A total of 1203 trees belonging to 89 species were recorded from 14 plots covering 14,000 m^2 from forests adjacent to the *Myristica* swamps. *Helicteres isora* and *Aporosa cardiosperma* were the dominant trees found in

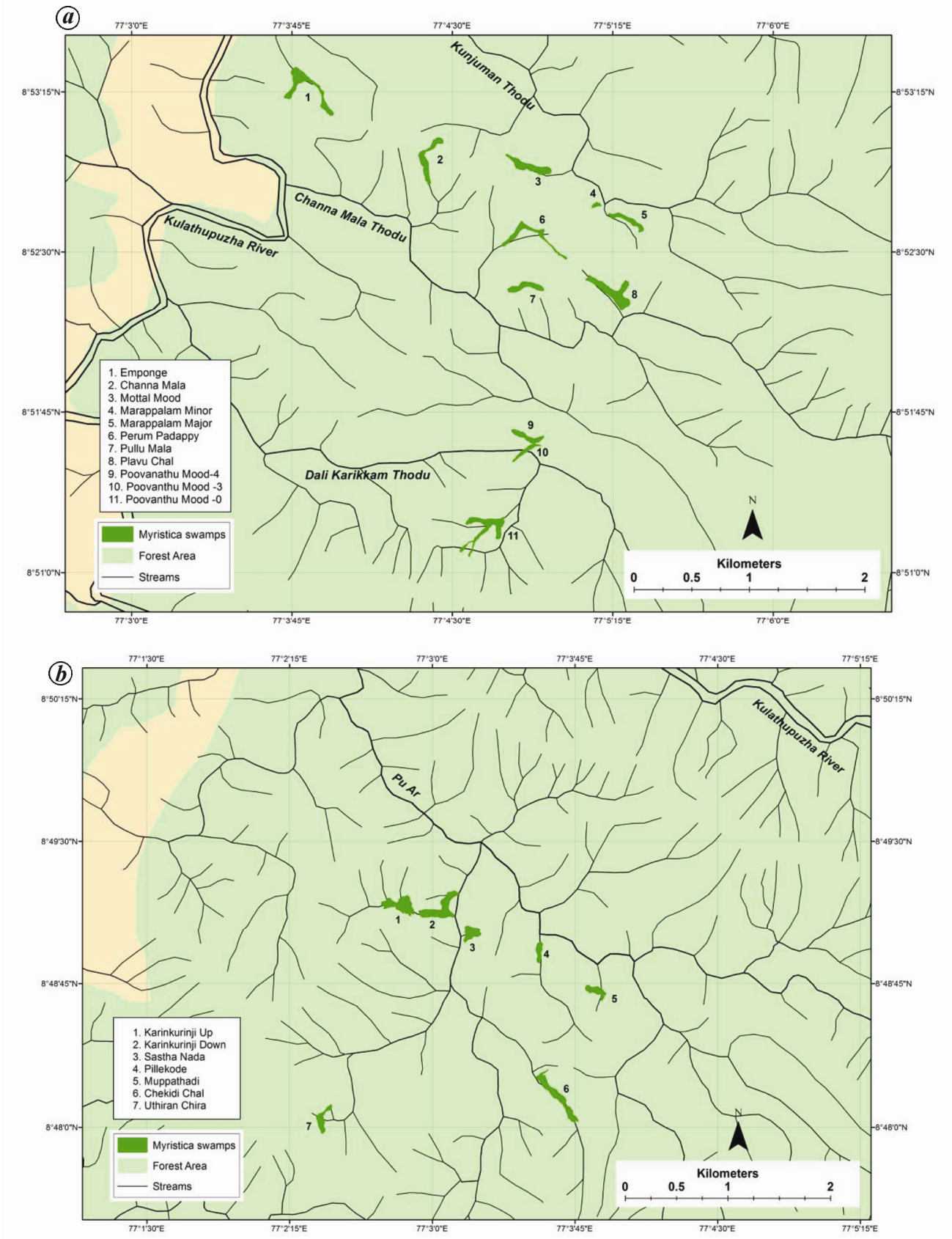

Figure 2. ***a***, Insularity of swamps situated along Kunjuman Thodu, Channa Mala Thodu, Dali Karikkam Thodu (tributaries of Kulathupuzha River in Kulathupuzha region, Kerala). ***b***, Insularity of swamps situated along Pu Ar (tributary of Kulathupuzha River in Sasthanada region, Kerala).

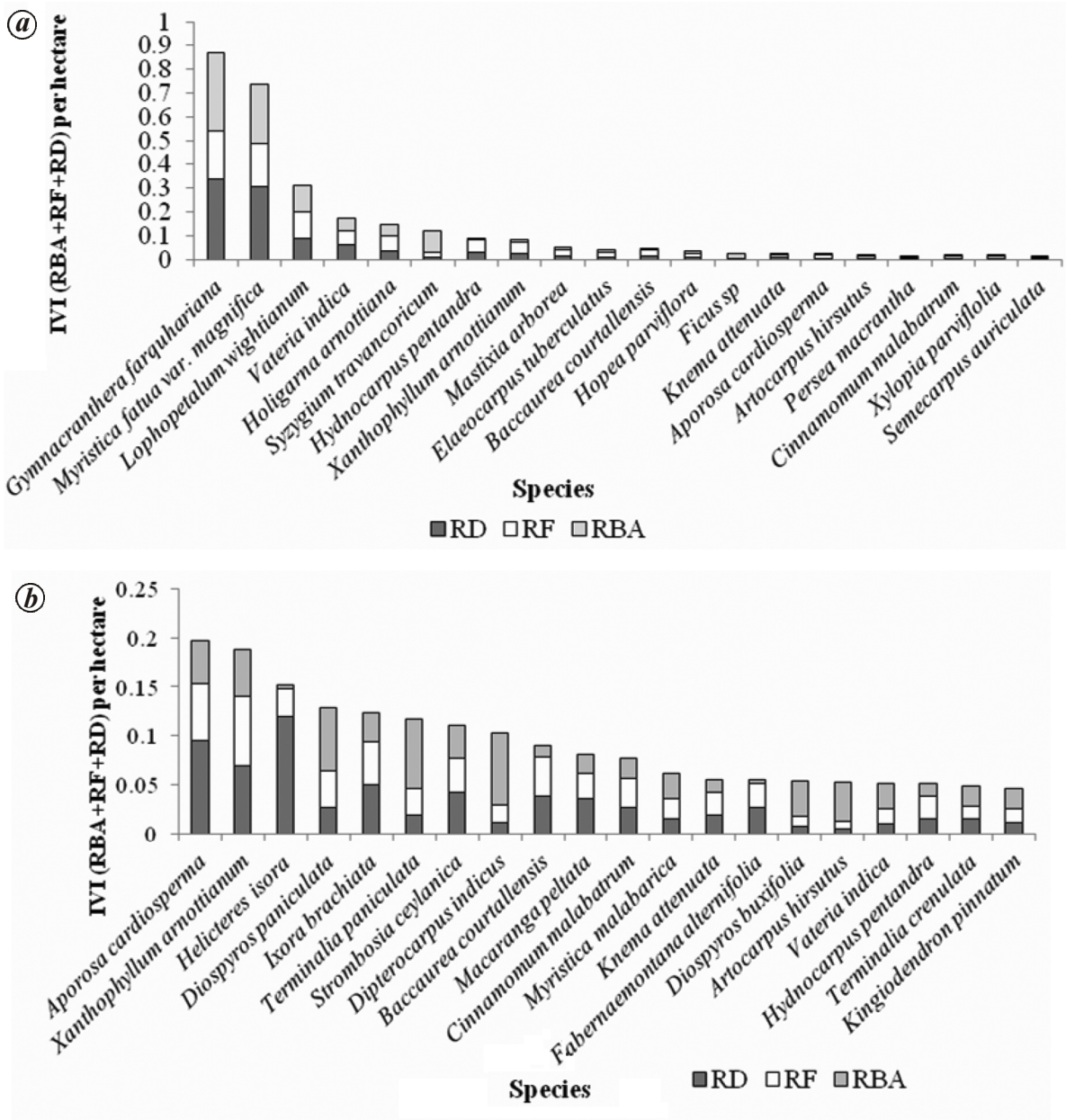

Figure 3. ***a***, Details of tree composition of *Myristica* swamps. ***b***, Summary of tree vegetation in forests adjacent to the *Myristica* swamps. All values for the most abundant 20 species have been converted to value per hectares. RD (relative density) + RF (relative frequency) + RBA (relative basal area) = IVI (importance value index).

the plots outside the swamps and constituted 11.97% and 0.0956% of the total number of the trees respectively. *H. isora*, usually a shrub, attained small tree size in this area. *Xanthophyllum arnottianum* and *A. cardiosperma* were the most frequent species in the plots, followed by *Ixora brachiata* and *Baccaurea courtallensis*. The tree species *A. cardiosperma* (19.66) and *X. arnottianum* (18.85) had the maximum IVI (Figure 3 *b*).

Species accumulation curve plotted for tree species inside the swamps reached a plateau after sampling 16 plots, whereas the accumulation curve for tree species outside the swamps reached an asymptote with the *x*-axis at 13 plots and showed a much steeper slope in its ascending phase as well as a more abrupt following out (Figure 4). Trees in *Myristica* swamps fall under 38 families. The family Euphorbiaceae is most represented with eight species followed by Myristicaceae with five species[15]. The family Myristicaceae constitutes the maximum number of individual trees and makes up 65.54% of the total number of the trees in the *Myristica* swamps. It includes five species, namely *G. farquhariana*, *M. fatua* var. *magnifica*, *M. malabarica*, *K. attenuata* and *M. dactyloids*. Within Myristicaceae, *G. farquhariana* makes up 52% and *M. fatua* var. *magnifica* 47%. Other

dominant families are Celestraceae, Dipterocarpaceae, etc. (Figure 5).

Shrub–herb composition of Myristica swamps and surrounding forests

Shrubs and herbs in the *Myristica* swamps represent 48 families. Rubiaceae is represented by 10 species followed by Zingiberacae and Melastomataceae each represented by six and five families respectively[15]. A total of 1775 shrubs belonging to 46 species were recorded from 17 plots covering 17,000 m^2 of *Myristica* swamp patches. *Ochalandra travancorica*, *Piper nigrum* and *Barleria courtallica* were the most dominant shrubs with 27.38% and 9.24% respectively, of the total number of shrubs sampled. Twenty-six species of herbs and 1082 individuals were recorded from plots laid inside the swamps with *Lagenandra ovata* (36.60%), *Selaginella brachystachya* (17.10%) and *Ophiorrhiza pectinata* (12.29%) making up more than 65% of the total number of herbs.

A total of 3535 shrubs belonging to 83 species were recorded from 14 plots covering 14,000 m^2 from forests adjacent to *Myristica* swamp patches. *Psychotria flavida* (16.44%), *O. travancorica* (9.87%), *Dracaena terniflora* (9.65%) were some of the prominent shrubs found in the plots outside the swamps. Of the 491individuals belonging to 30 herbs species recorded from outside the swamps, various grass species (41.75%), followed by *Zingiber zerumbet* (12.42%) and *Alpinia malacensis* (10.79%) were dominant.

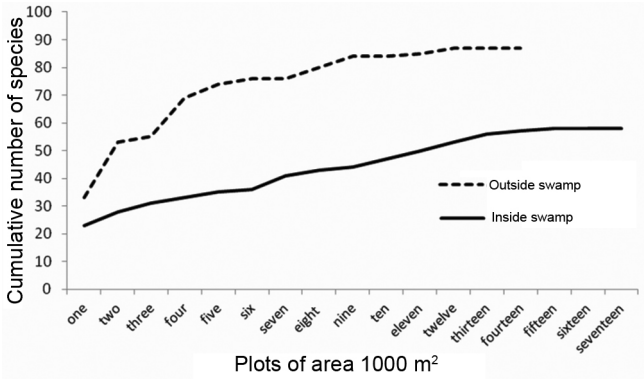

Figure 4. Species accumulation curve of tree species from inside and outside the *Myristica* swamps.

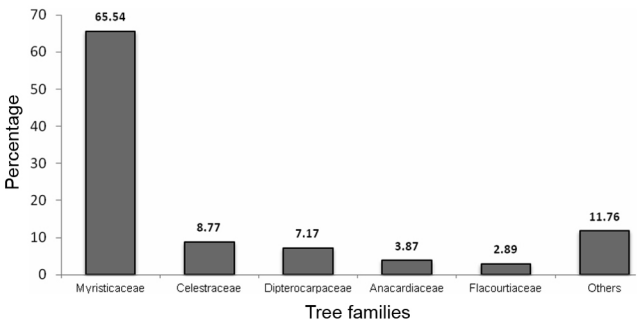

Figure 5. Percentage of stems in tree families of *Myristica* swamps.

Alpha diversity indices of Myristica swamps and surrounding forests

All diversity indices obtained from the plots outside the swamps were higher than those obtained inside the swamps. The dominance of a few trees and lesser diversity inside the swamps are supported by the relatively lower alpha diversity figures ($R = 7.39$, $H = 2.05$, $N1 = 7.80$, $N2 = 4.46$) and number of species (58), but a higher Simpson's dominance index (0.22) and number of stems (2246) inside the swamps when compared with the corresponding values obtained from the forests adjacent to the swamps (Table 1). The evenness value outside the swamps ($E2 = 0.46$) is almost three and a half times higher than that inside the swamps ($E2 = 0.13$). The diversity indices calculated from outside the swamps for shrubs were also higher than the values calculated from inside the swamps (Table 1).

The number of species (S) and total number of individuals (N) of shrubs were higher for the forests adjacent to the swamps. In the case of herbs, S value was higher for the forests adjacent to the swamps, while N value was higher inside the swamps due to higher number of stems of specialists like *L. ovata*.

The number of species of trees and shrubs was predictably higher outside the swamps. The complete dominance of Myristicaceae species in the swamps and the totally different vegetation communities (mixed forest, moist deciduous, semi-evergreen, evergreen, plantation, etc.) with diverse species in the area adjoining the swamp patches were reflected in the relatively higher diversity and evenness values obtained from the plots outside the swamps, but higher dominance values were obtained from inside the swamps.

Beta diversity and similarity indices

Whittaker's beta diversity to ascertain the degree of turnover along plots was 3.02 inside the *Myristica* swamp patches and 2.51 for the vegetation adjacent to the *Myristica* swamps.

Jaccard's coefficient of similarity based on qualitative data showed up to 53% similarity (Jaccard measure 0.5263) in the tree species composition outside and inside the swamps. Morisita–Horn coefficient of similarity calculated with quantitative data showed just 4% similarity (Morisita–Horn measure 0.0411). Beta diversity values indicated a higher degree of turnover along plots in the swamps than those in the forests adjacent to the swamps.

Table 1. Alpha diversity indices calculated for trees, shrubs and herbs of *Myristica* swamps and adjacent forests (pooled values)

	S	*N*	*R*	Simpson's	*H*	*N*1	*N*2	*E*2
Trees								
Myristica swamps (17,000 m^2)	58	2246	7.3864	0.2240	2.0536	7.7962	4.4641	0.1344
Adjacent *Myristica* swamps (14,000 m^2)	89	1203	12.4073	0.0416	3.7122	40.9440	23.9809	0.4600
Shrubs								
Myristica swamps	46	1775	6.0148	0.1113	2.7598	15.7963	8.9841	0.3434
Adjacent *Myristica* swamps	83	3535	10.1568	0.0699	3.2203	25.0349	14.3044	0.2980
Herbs								
Myristica swamps	26	1082	3.5783	0.1947	2.0620	7.8617	5.1352	0.3024
Adjacent *Myristica* swamps	30	491	4.6801	0.2151	2.0797	8.0017	4.6484	0.2667

S, Total no. of species; *N*, Total no. of individuals; *R*, Margalef's index; *H*, Shanon–Weiner index, *N*1, *N*2. Hill's diversity indices and *E*2, Buzas' evenness.

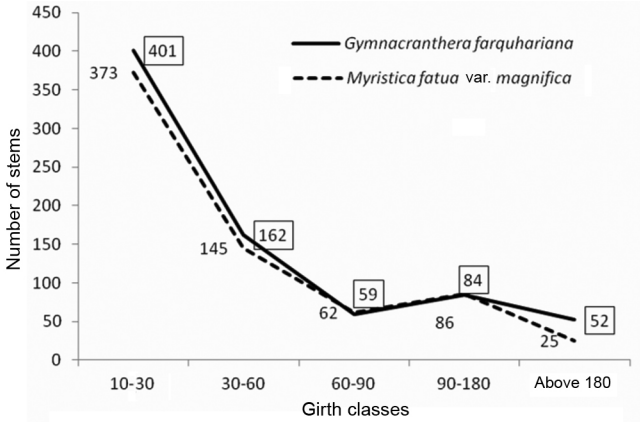

Figure 6. Girth class distribution of *Gymnacranthera farquhariana* and *Myristica fatua* var. *magnifica*.

Jaccard's coefficient of similarity based on qualitative data showed up to 45% similarity (Jaccard measure 0.4588) in the shrub species composition outside and inside the swamps. In the case of herbs, Jaccard's coefficient of similarity was 22% (Jaccard measure 0.2174). Morisita–Horn coefficient of similarity calculated with quantitative data showed 36% similarity (Morisita–Horn measure 0.3648) in the case of shrubs and 22% similarity (Morisita–Horn measure 0.2232) in the case of herbs.

The environmental conditions in *Myristica* swamps have resulted in the complete dominance of a few species. The dominant vegetation in all the swamp patches was the same (Myristicaceae species), causing high species turnover within the swamps. However, the forests adjoining the swamp patches were completely different (mixed forest, moist deciduous, semi-evergreen, evergreen, plantation, etc.), therefore causing a lower species turnover along the adjacent plots.

Some non-swampy species which are found in the adjacent forests may be present in few numbers in the swamps, thereby showing higher Jaccard similarity (qualitative-based on species presence–absence) when compared to Morisita–Horn similarity (quantitative-based on number of individuals/species). This is true in the case of herbs also, where *L. ovata* makes up 36.60% of the total number of herbs in the swamps. In the case of shrubs, *O. travancorica* is present in large numbers both outside and inside the swamps leading to higher qualitative and quantitative similarity.

Girth class structure of Myristica swamp trees

The girth class distribution of dominant species belonging to the Myristicaceae family was recorded from the tree plots in the swamps. *M. fatua* var. *magnifica* and *G. farquhariana* showed an almost reverse J-shaped curve, except for the slight bulge in girth class 90–180 caused by more individuals when compared to the succeeding and preceding classes (Figure 6).

Girth class analysis of all the trees in the swamps showed an almost perfect inverted J (healthy regeneration and stable population), though a slight distortion in the 90–180 girth class indicated some disturbance in the past (Figure 7). Girth class analysis of selected species also gave similar results except for two species, namely *M. malabarica* and *S. travancoricum*. This could be because *M. malabarica* is not exclusively restricted to lowland swamps[32–35] and showed complete absence of saplings and large trees, while *S. travancoricum* had very few trees in the lower girth classes[36]. Girth class analysis inside and outside the swamps showed that the overall number of trees recorded in all girth classes was higher inside the swamps, especially in the 10–30, 30–60 and above 180 classes, where the number of individuals in the swamps was almost double that in the adjacent plots. Regeneration was also higher in the swamps when compared to the adjacent forests. It may be hypothesized that tree species with low timber value, lesser human access, specialized environmental conditions leading to lesser possibilities of conversion to plantations, therefore less human disturbance, lesser undergrowth and high canopy may have allowed the shade-tolerant Myristicaceae to thrive better in swamps than the trees in adjacent areas.

There are many factors which influence the vegetation composition and life cycle of a community. Each species

Table 2. Correlation of selected tree species with environmental parameters

Variables	*Myristica fatua* var. *magnifica*		*Semecarpus auriculata*		*Gymnacranthera farquhariana*	
	N	IVI	*N*	IVI	*N*	IVI
Inundation area	0.94*	0.94*	0.68	0.76*	0.15	–0.06
Inundation depth	0.89*	0.85*	0.70	0.78*	0.27	0.22
Temperature	–0.90*	–0.92*	–0.68	–0.73*	–0.02	0.11
Humidity	0.88*	0.78*	0.59	0.80*	0.47	0.29
Canopy cover	0.87*	0.80*	0.62	0.63	0.38	0.20
Litter area	–0.93*	–0.82*	–0.63	–0.79*	–0.45	–0.27
Litter depth	–0.86*	–0.85*	–0.82*	–0.96*	–0.23	–0.05
Undergrowth cover	–0.43	–0.14	0.23	0.06	–0.72	–0.35
Coverage stilt root	0.77*	0.61	0.35	0.45	0.30	0.14
Coverage knee root	–0.66	–0.68	–0.34	–0.34	0.14	0.27
Percentage of gravel in soil	–0.29	–0.48	–0.51	–0.61	–0.28	–0.22
Percentage of sand in soil	–0.69	–0.59	–0.47	–0.77*	–0.44	–0.28
Percentage of silt in soil	–0.61	–0.52	–0.23	–0.39	–0.71	–0.46
Percentage of clay in soil	–0.88*	–0.81*	–0.50	–0.64	–0.61	–0.35
Soil pH	–0.61	–0.35	–0.04	–0.39	–0.56	–0.32
Soil organic carbon	0.80*	0.65	0.40	0.70	0.63	0.42

*Significance level $\alpha = 0.05$. *N*, Total number of individuals/stems; IVI, Importance value index.

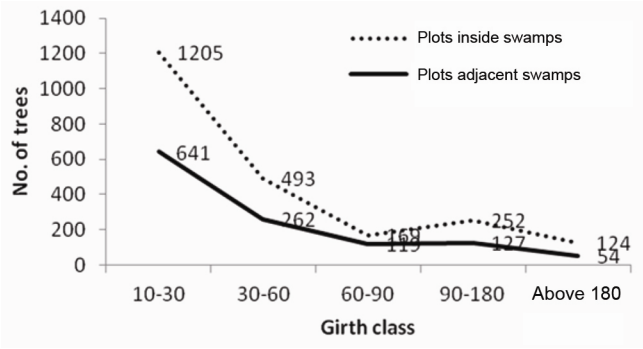

Figure 7. Girth class distribution of trees in and adjacent to *Myristica* swamps.

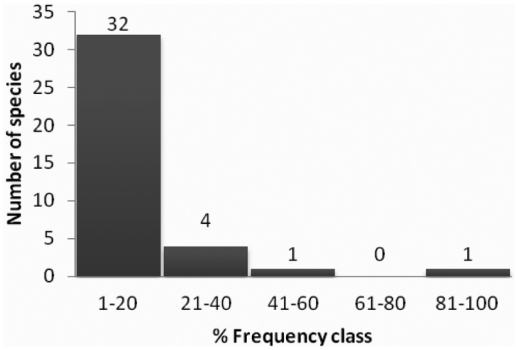

Figure 8. Histogram showing the number of species in Raunkiaer frequency classes.

may respond differently to various environmental variables. In contrast to faunal composition which keeps changing with the short-term changes in the environment, plant communities are shaped by centuries of climatic and geological shifts.

Raunkiaer's law

Figure 8 shows the number of species in each Raunkiaer frequency class recorded from the tree plots laid in the *Myristica* swamps. The number of species in frequency class A is greater than that of class B, B is greater than in C; C is greater, or equal or lesser than in D, while class D is lesser than class E, and is in agreement with Raunkiaer's law. The tree community of *Myristica* swamps follows the general trend of most natural communities, i.e. species with low frequency value are higher in number than those with higher frequency value. The decrease in the number of species within successive 20% frequency class intervals but increase in 80–100% class has been interpreted as a community characteristic indicating homogeneity[37].

Correlation with environmental variables

The size of the swamp patches showed no significant relationship to the presence/absence of any species or the number of stems per species. It did not significantly affect the number of tree species or number of stems in a swamp. Temperature, humidity and soil characteristics also did not show any significant effects[13] (Table 2). The area of a swamp under inundation showed significant negative correlation with the number of species present in that swamp ($r = –0.73$, $P < 0.05$). The number of *Elaeocarpus tuberculatus* and *Mastixia arborea* trees were also negatively correlated to area under inundation ($r = –0.71$, $P < 0.05$). The only tree which showed a significant positive correlation with the area under inundation in a swamp was *M. fatua* var. *magnifica* ($r = 0.94$, $P < 0.05$).

The number of *M. fatua* var. *magnifica* trees was positively correlated with typical swamp conditions of high area and depth of inundation, low temperature, high humidity, low litter cover and undergrowth and high canopy cover, etc. (Table 2).

Of the 58 tree species recorded from the swamps only 2, namely *M. fatua* var. *magnifica* (*N* and IVI) and *Semecarpus auriculata* (IVI only) showed high affiliation to pure swampy conditions. Other species, even those belonging to Myristicaceae, including *G. farquhariana* (which had the highest IVI) showed no significant correlation to swampy conditions. This confirms with our visual observations during field work that while *M. fatua* var. *magnifica* was always found in high numbers in perennially inundated swamps or in lower numbers in the inundated areas of drier swamps, *G. farquhariana* was found in all swamps, especially in relatively drier areas where inundation was neither too deep nor perennial. A pristine patch of *Myristica* swamp may be a deterrent for many plant species and supports only specialists, but the drier swamps and swamp ecotone while retaining the characters of evergreen forests provide the habitat requirements of other tree species.

Dominance of Myristicaceae

As the name implies, *Myristica* swamp vegetation is dominated by Myristicaceae species. The first two dominant tree species in the swamp (*M. fatua* var. *magnifica* and *G. farquhariana)* contribute a combined IVI of 161.03, which is more than 50% of the cumulative IVI of any ecosystem (300). Family importance value (FIV) of Myristicaceae is 164.64. Only six other species have IVI more than 10. This indicates the complete dominance of Myristicaceae in the swamp ecosystem.

Some non-*Myristica* species like *L. wightianum* (31.35), *V. indica* (17.58), *H. arnottiana* (14.63) and *S. travancoricum* (11.98) also seem to thrive in the swamp conditions. The vegetation composition outside the swamps is entirely different from that of inside the swamps, but some species such as *X. arnottinum*, *Hydnocarpus pentandra*, *Baccaurea courtallensis*, etc. are present both inside and outside the swamps. It is notable that while the combined IVI of the first six dominant species inside the swamps is 236.57, it is only 90.64 in the forests adjacent to the swamps, further indicating the specialization of vegetation species in the swamps.

Table 3. Comparison of Shannon index for different forest types with *Myristica* swamp forests in this study

Forest type	Shannon index
Moist deciduous forest[41]	3.07
Teak plantations[41]	1.6
Tropical semi-evergreen forests[41]	3.87
Subtropical hill forests[41]	3.58
Subtropical savannahs[41]	2.59
Montane forests[41]	3.15
Myristica swamp forests[#]	2.13
Forest adjacent to *Myristica* swamp forests[#]	3.17

[#]Present study.

Comparison with other studies

When compared to other forest communities, the *Myristica* swamps have very less diversity ($H = 2.05$), just higher than a teak plantation ($H = 1.6$) (Table 3) and lower than earlier reports on other freshwater forest studies in the Western Ghats (Table 4), except for the values reported from Uttara Kannada[9].

Environmental conditions such as flooding which permit only a few species to colonize the swamp area[38], cause a situation where only one or a few species thrive. A previous report has validated this using species abundance distribution studies[39], where the removal of rare tree species (not true swamp residents) led to a log-normal distribution, indicating the transient and resident trees (six species) of the *Myristica* swamps.

Our results while showing much similarity vary from an earlier study in this region[6], which can be explained by the difference in sampling area and effort. The authors[6] reported 16 tree families, with Myristicaceae being the dominant with an IVI of 179. *G. farquhariana*, *M. fatua* var. *magnifica* and *L. wightianum* were the dominant species in both studies. However, their study lists *M. malabarica* as a species with IVI of above 20, whereas our study found *V. indica*, *H. arnottiana* and *S. travancoricum* as the other dominant species (Figure 3 *a*). Both studies report Celestraceae, Flacourtiaceae, Dipterocarpaceae and Anacardiaceae as other dominant families. FIV of Myristicaceae in Agasthyamalai region was reported as 148.82 (ref. 7). The other dominant families were Lauraceae and Clusiaceae. *G. farquhariana* and *M. dactyloides* were reported as the dominant species[7]. The shrub–herb composition was also notably different.

Table 4. Comparison of diversity indices of freshwater swamp forests of Karnataka and Kerala with those of *Myristica* swamp forests in this study

Study site	Area sampled (m^2)	Number of species	Number of individuals	Shanon index
Kulathupuzha[6]	5000	21	891	2.53
Anchal[6]	5000	21	682	3.69
Shendurney[6]	5000	14	1012	2.46
Kathlekane[36]	2000	63	681	4.04
Unchalli[9]	2800	5.57	110	1.28
Kudgund[9]	5200	16	214	1.97
Hemgar[9]	1600	6.5	55	1.41
Malemane[9]	5200	7	222	1.43
Agasthyamalai[7,8]	1000	18	–	2.50
Present study	17,000	58	2246	2.05

Table 5. Comparison of Myristicaceae in freshwater swamp forests of Karnataka and Kerala with that of *Myristica* swamp forests in this study

Study site	FIV	IVI and position of *Gymnacranthera farquhariana*	IVI and position of *Myristica fatua* var. *magnifica*
Kulathupuzha[6]	179	99.47,1	86.09,2
Kathlekane[36]	102.63	57.83,1	38.49,2
Uttara Kannada[11]	111.93	89.02,1	19.63,4
Agasthyamalai[7,8]	148.82	38.15,1	23.02,6
Present study	164.64	87.21,1	73.82,2

Our results also vary slightly from those of studies conducted in the Uttara Kannada swamps[9]. These differences could be due to the combined effects of latitudinal gradient in species richness, climatic, evolutionary and anthropogenic factors other than differences in sampling methods and efforts.

In the swamps of Uttara Kannada[11], trees with the highest IVI were *G. farquhariana* (89.02), *M. arborea* (38.37), *L. wightianum* (23.90) and *M. fatua* var. *magnifica* (19.63). Myristicaceae (FIV 111.93) was the most dominant family forming 32% of the total number of trees. Within Myristicaceae, *G. farquhariana* accounted for 78%, followed by *M. fatua* var. *magnifica* (19%).

When compared with similar studies, FIV of Myristicaceae was maximum in Kulathupuzha region (Table 5). While *G. farquhariana* was the dominant tree in all the study sites, *M. fatua* var. *magnifica* was the second most dominant tree in Kulathupuzha and Kathlekane. However, it was only in Kulathupuzha where *G. farquhariana* and *M. fatua* var. *magnifica* were almost co-dominants.

Floristic studies from *Myristica* swamps of other regions indicated that *M. fatua* var. *magnifica* was relatively less in those swamps[7,8,11,18,40]. All studies in *Myristica* swamps, except in the Agasthyamalai region[7] reported high-regeneration based on girth class analysis.

Conclusion

According to Krishnamoorthy[4], the dominant species of these freshwater swamp forests were *M. fatua* var. *magnifica* (very frequent) and *G. farquhariana* (frequent) followed by other allied species. The present study indicates that by 2010 (40 years since Krishnamoorthy's pioneering work), *G. farquhariana*, which is also dominant in the swamps of other regions, has overtaken *M. fatua* var. *magnifica* as the most frequent and dominant tree. Does this indicate the slow desiccation of the *Myristica* swamps of Kulathupuzha region?

The Kulathupuzha region has been considered as high conservation priority in the Western Ghats[26] and Rodgers and Panwar[24,25] had called for Priority I level implementation of *Myristica* swamp Wildlife Sanctuary almost three decades ago. The conservation value of *Myristica* swamps is not in its high diversity, but in its ability to provide specialized conditions for the survival of certain endemic and endangered plants.

The conservation of this rare ecosystem must be prioritized for the sake of all the endemic and rare plants flourishing in it and especially because it is the exclusive habitat to the largest population of the endangered *Myristica fatua* var. *magnifica*.

1. Myers, N., Biodiversity hotspots revisited. *Bioscience*, 2003, **53**, 916–917.
2. Cincotta, R. P., Wisnewski, J. and Engleman, R., Human population in the biodiversity hotspots. *Nature*, 2000, **404**, 990–992.
3. Champion, H. G. and Seth, S. K., *A Revised Survey of the Forest Types of India*, Government of India (GoI), New Delhi, 1968, pp. xxiii + 404.
4. Krishnamoorthy, K., *Myristica* swamps in the evergreen forests of Tranvancore. *Indian For.*, 1960, **86**(5), 314–315.
5. Varghese, V., Vegetation structure, floristic diversity and edaphic attributes of the freshwater swamps forests in southern Kerala. Dissertation (B Sc) submitted to College of Forestry, Kerala Agricultural University, Mannuthy, Kerala, 1992, pp. 113 + iv.
6. Varghese, A. V. and Kumar, B. M., Ecological observations in the freshwater swamp forests of Southern Kerala, India. *J. Trop. For. Sci.*, 1997, **9**, 299–314.
7. Varghese, A. O. and Menon, A. R. R., Floristic composition, dynamics and diversity of *Myristica* swamp forests of southern Western Ghats, Kerala. *Indian For.*, 1999, **125**, 775–783.
8. Varghese, A. O. and Menon, A. R. R., Ecological niches and amplitudes of rare, threatened and endemic trees of Peppara Wildlife Sanctuary. *Curr. Sci.*, 1999, **76**(9), 1204–1208.
9. Chandran, M. D. S., Mesta, D. K. and Naik, M. B., Inventorying and conservation of the *Myristica* swamps of Uttara Kannada. Final Report, FRTI, Bangalore, 1999.
10. Chandran, M. D. S. and Mesta, D. K., On the conservation of the *Myristica* swamps of the Western Ghats. In *Forest Genetic Resources: Status, Threats, and Conservation Strategies* (eds Uma Shaanker, R., Ganeshaiah, K. N. and Bawa, K. S.), Oxford & IBH, New Delhi, 2001, pp. 1–19.
11. Chandran, M. D. S. and Mesta, D. K., *Myristica* swamps. *Sahyadri E-News*, 2005, issue 13; http//wgbis.ces.iisc.ernet.in/biodiversity/sahyadrienews/mewsletter/issue13/index.htm (accessed on 23 January 2017).
12. Santhakumaran, L. N., Singh, A. and Thomas, V. T., Description of a sacred grove in Goa (India), with notes on the unusual aerial roots produced by its vegetation. *Wood*, 1995, 24–28.
13. Nair, P. V., Ramachandran, K. K., Swarupanandan, K. and Thomas, T. P., Mapping Biodiversity of the Myristica swamps in Southern Kerala, Research Report No. 326, KFRI, Peechi, 2007, p. 255.
14. Roby, T. J., Floristic structure and diversity of *Myristica* swamps at Kulathupuzha in a GIS perspective, Ph D thesis, Forest Research Institute (Deemed) University, Dehradun, 2011, pp. 148 + xxxi.
15. Roby, T. J., Jose, J. and Nair, P. V., Checklist of flora of *Myristica* swamps – a critically endangered freshwater ecosystem of southern Western Ghats of Kerala, India. *Indian For.*, 2014, **140**(6), 608–616.
16. Roby, T. J., Nair, P. V. and Jose, J., GIS techniques for mapping highly fragmented ecosystems – a case study on the *Myristica* swamp forests of southern Kerala, India. *Res. J. Rec. Sci.*, 2014, **3**(ISC-2013), 110–119.
17. Prabhugaonkar, A., Mesta, D. K. and Janarthanam, M. K., First report of three redlisted tree species from swampy relics of Goa State, India. *J. Threatened Taxa*, 2014, **6**(2), 5503–5506.

18. Chandran, M. D. S. and Sivan, V. V., Myristicaceae. Classroom Lifescape Series, Part II. *Resonance*, 1999, **72**, 10–12.
19. Ravikanth, G., Vasudeva, R., Ganeshaiah, K. N. and Uma Shaanker, R., Molecular analysis of *Semecarpus kathalekanensis* (Anacardiaceae) – a newly described species from the *Myristica* swamps of Western Ghats, India. *Indian For.*, 2004, **130**(1), 101–104.
20. Sharma, M. V. and Kundaranahalli, R. S., Pollinators, pollination efficiency and fruiting success in a wild nutmeg, *Myristica dactyloides*. *J. Trop. Ecol.*, 2011, **27**(04), 405–412.
21. Sharma, M. V. and Armstrong, J. E., Pollination of *Myristica* and other nutmegs in natural populations. *Trop. Conserv. Sci.*, 2013, **6**(5), 595–607.
22. Krishna, S. and Somanathan, H., Secondary removal of *Myristica fatua* (Myristicaceae) seeds by crabs in *Myristica* swamp forests in India. *J. Trop. Ecol.*, 2014, **30**(3), 259–263.
23. Ramesh, B. R. and Pascal, J. P., *Atlas of the Endemics of the Western Ghats (India). Distribution of Tree Species in the Evergreen and Semi-evergreen Forests*, French Institute, Pondicherry, 1997, p. 403.
24. Rodgers, W. A. and Panwar, H. S., Planning wildlife protected area network in India. State summaries. A report prepared for the Department of Environment, Forests and Wildlife, GoI, Wildlife Institute of India, 1988, vol. II, p. 267.
25. Rodgers, W. A. and Panwar, H. S., Planning wildlife protected area network in India. The report. A report prepared for the Department of Environment, Forests and Wildlife, GoI, Wildlife Institute of India, 1988, vol. I, p. 341.
26. Dasa, A. J., Krishnaswamya, K. S., Bawaa, M. C., Kirana, V., Srinivas, N., Samba Kumar, K. and Ullas, K., Prioritisation of conservation areas in the Western Ghats, India. *Biol. Conserv.*, 2006, **13**(3), 16–31.
27. Swamy, S. L., Dutt, C. B. S., Murthy, M. S. R., Mishra, A. and Bargali, S. S., Floristics and dry matter dynamics of tropical wet evergreen forests of Western Ghats, India. *Curr. Sci.*, 2010, **99**(3), 353–364.
28. Mueller, D. and Dombois, H. E., *Aims and Methods of Vegetation Ecology*, John Wiley, London, 1974, pp. xix + 547.
29. Sivaram, M., Sasidharan, N., Ravi, S. and Sujanapal, P., Computer aided inventory analysis for sustainable management of non-timber forest product resources. *J. Non-Timber For. Prod.*, 2006, **13**(4), 237–244.
30. Magurran, A. E., *Ecological Diversity and its Measurements*, Chapman and Hall, London, 1988, p. x + 178.
31. Raunkiaer, C., *The Life Forms of Plants and Statistical Plant Geography*, Oxford University Press, Oxford, UK, 1934, p. 632.
32. Sasidharan, N., Biodiversity documentation for Kerala, Part 6: flowering plants, KFRI Handbook No. 17. KFRI, Peechi, 2004, p. 702.
33. Sasidharan, N., *Forest Trees of Kerala*, KFRI, Peechi, 2004, p. viii + 166.
34. Sasidharan, N., Illustrated manual on tree flora of Kerala supplemented with computer aided identification, KFRI Research Report No. 282, KFRI, Peechi, 2006, p. 502.
35. Sasidharan, N., Tree ID: Tree identification key for Kerala (CD). KFRI Handbook No. 17, KFRI, Peechi, 2007.
36. Roby, T. J., Jose, J. and Nair, P. V., *Syzygium travancoricum* (Gamble) – a critically endangered and endemic tree from Kerala, India – threats, conservation and prediction of potential areas; with special emphasis on *Myristica* swamps as a prime habitat. *Int. J. Sci. Environ. Technol.*, 2013, **2**(6), 1335–1352.
37. Gleason, H. A., The individualistic concept of the plant association. *Bull. Torrey Bot. Club*, 1926, **53**, 7–26.
38. Leigh Jr, E. G., Wright, S. and Herre, E. A., The decline of tree diversity on newly formed isolated tropical islands: a test of null hypothesis and some implications. *Evol. Ecol.*, 1993, **7**, 76–102.
39. Jose, J., Roby, T. J., Ramachandran, K. K. and Nair, P. V., Species abundance distribution of selected communities in the *Myristica* swamp forest of southern Kerala. *Curr. Sci.*, 2014, **107**(3), 447–453.
40. Bhatt, P. R. and Kaveriappa, K. M., Ecological studies on *Myristica* swamp forests of Uttara Kannada, Karnataka, India. *Trop. Ecol.*, 2009, **50**(2), 329–337.
41. Sharma, J. K. *et al.*, Studies on the biodiversity of New Amarambalam reserved forests of Nilgiri Biosphere Reserve. KFRI Research Report No. 247, KFRI, Peechi, 2002. p. 230.

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