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The Impact of Traditional Conservation Practices on Species Composition and Diversity Patterns of Sacred Swamps in the Central Western Ghats, India

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Abstract

Sacred forests are of immense value for their ecosystem functions. Traditional indigenous conservation practices have helped maintaining biological diversity over centuries and have resulted in the preservation of some of the best patches of natural vegetation. Exclusive taxa find refuge in the micro-climatic conditions of sacred groves and many rare species are found here. Ten sacred swamps and ten non-sacred swamps in the central Western Ghats region, India, with a similar distance from roads, village settlements, or commercial orchards and with nearly the same size, were compared with regard to their species composition, floristic structure, diversity, occurrence of amphibians, odonates and birds. In the sacred swamps, 122 plant species from 99 genera and 58 families occur against 83 species from 72 genera and 47 families in the non-sacred swamps. Tree stem density was 277 individuals/ha in sacred swamps against 158.4 in non-sacred swamps. Average basal area was 47.57 m 2 /ha in sacred swamps and only 14.60 m 2 /ha in non-sacred swamps. Sacred swamps have higher number of endemic species (28%) when compared to non-sacred swamps. We conclude that the traditional belief system of treating the swamps as sacred has helped to protect these ecologically important forests.

Introduction

Sacred groves play a significant role in forest stand survival across the globe (Gadgil and Chandran 1992, Tiwari et al. 1998) and are considered an effective tool in biodiversity conservation (Byers et al. 2001, Campbell 2004, Ramanujam and Kadamban 2001). They are of immense value for the ecosystem services they provide and have survived because of community-based preservation practices (Ceperly et al. 2010, Gadgil and Vartak 1976). Traditional indigenous conservation practices and values integrated with religious knowledge have helped maintaining cultural and biological diversity over centuries and have resulted in the preservation of some of the best patches of natural vegetation (Komanda et al. 2003; Gadgil and Vartak 1976). Although some supporting traditions have weakened by modern influences, sacred groves are frequently more acceptable to local peoples than externally imposed conservation policies (Ntiamoa-Baidu, 1994).

Exclusive taxa find refuge in the micro-climatic conditions of sacred groves and many rare species are found only there (Singh et al. 2011). Numerous studies suggest that the biological spectrum of sacred groves in the tropics closely resembles the typical spectrum of tropical forest biodiversity and that in sacred groves endangered and rare species of flora and fauna are better protected and conserved than elsewhere (Tiwari et al. 1998; Campbell 2004; Shahabuddin and Rao 2010, Shen et al. 2015).

Recurrent human interventions in the forests are known to change habitat fitness for many species leading to a decrease in number of species along the disturbance gradient (Pandey and Shukla 1999). While some species may tolerate disturbance, others may not and disappear (Sagar, 2003). Leigh (1965) suggests that stability increases with the complexity of the ecosystem, i.e. with the number of species and their interactions (MacArthur 1955). Heterogeneous forests may accommodate more species, particularly those requiring specialized microhabitats (Hansen et al. 1991, Pausas & Austin 2001), because they provide greater variety in microclimate, hiding and nesting sites etc., compared to more homogeneous forests (e.g. McArthur and McArthur 1961, Murdoch et al. 1972). Especially the structure of the tree stratum has a central role in determining the ecological processes and habitat characteristics in the forest (Kuuluvainen et al. 1996). Structural complexity of forests is, thus, often a good predictor of overall species diversity (Begon et al. 1986) and can be used to assess the conservation or biodiversity value of forest stands (Hansen et al. 1991).

Whereas forest structure informs biodiversity, information on the latter (i.e., species composition, diversity and population structure) is essential to understand forest ecosystem dynamics at various levels (Giriraj 2008), to provide a conceptual framework and measurable indicators to assess the overall ecosystem condition, and to monitor change (Noss 1990).

Such structural richness and tree species diversity are found in the fresh water swamps of the Uttara Kannada district of the Central Western Ghats, India. Fresh water swamps are marshy areas where water flows in perennial streams at constant level throughout the year (Gupta et al. 2006). Within the climax evergreen forests, they occupy poorly drained depressions that often open into a river or rivulet and have their groundwater level very close to the ground surface. Some of these swamps are sacred. Such sacred swamps today only exist close to commercial gardens, roads and settlements (average distance 100 meters, Hegde et al. 2018).

This paper compares species composition and tree population structure in sacred and non-sacred swamps in order to explore whether the traditional belief systems of treating swamps as sacred are effective in protecting ecologically important forests.

Study Area

The Western Ghats Mountain ranges, running parallel along the west coast of India, constitute one of the eighteen 'hottest global biodiversity hotspots' of the world, because of their large number of endemic biota and the scale and speed of their current habitat loss (Myers et al. 2000). The mountain ranges support - together with Sri Lanka - about 4780 vascular plant and 1073 vertebrate species, of which, respectively, 2180 (i.e., 0.7 % of the world's plant species) and 355 species (i.e., 1.3% of the global vertebrate species) are endemic. At the same time, the region has lost most of its primary vegetation with only 6.8 % of the original vegetation remaining (Myers et al. 2000, Bawa et al. 2007). Uttara Kannada (13.85 º – 15.7166º N, 74.166º – 75.2833º E) is one of the most densely vegetated districts within the Western Ghats and is endowed with rich natural resources. Of its 10,250 km^2 about 81 % is still forest, and only 12 % is used for agriculture.

Methods

Ten sacred swamps (total area 5.60 ha) and ten non sacred swamps (total area 5.71 ha) of similar size were studied. The sacred swamps had an average distance to the nearest road, settlement or commercial orchard of 109 m (standard deviation 19.5), the non-sacred swamps an average distance of 332 m (standard deviation 66.7) (Table 1).

Vegetation was assessed between December 2013 and April 2014 in transects of 5 m wide and variable length (100–1000 m) along the stream, covering a total area of 1.70 ha (sacred swamps) and 1.71 ha (non-sacred swamps). Since the swamps have a linear shape, almost the entire depression part of the swamps was surveyed. The species composition in the catchment area of the swamp forests was assessed in a transect of 50 m x 5 m perpendicular to the edge on either side of each swamp. All plant species were identified using regional and standard floras (Cooke 1903, Talbot 1909, Gamble and Fischer 1935) and keys (Pascal and Ramesh 1987). Tree girth was measured at breast height using a measuring tape. Tree diameters were categorized in 11 diameter classes of 30 cm, with the smallest class having 1–30 cm and the largest ≥ 301 cm diameter at breast height (DBH).

Faunal data were collected in different seasons *viz.*, rainy (June and July 2014), winter (October and November 2014) and summer (April and May 2015). The entire area of the swamps was surveyed for amphibians, selected insect groups and birds. Amphibian species were recorded by a team of four to five people carrying out a detailed search of all possible habitats, including leaf litter, bushes and small trees for arboreal taxa. Torches were used to find and identify amphibians by following their calls at night. Dragonflies, damselflies and butterfly species were recorded through visual observation. Birds were recorded by visual observation and audio identification (by hearing the calls). Faunal documentation took three to five hours per swamp per season and per team. The study of amphibians took nearly 490 person hours of field work, that of dragonflies, damselflies, butterflies and birds in total 660 hours. Field guides (Gururaja 2010, Singh 2011, Subramanian 2009, Kiran and David 2013, Grimmett et al. 2011) were used for *in situ* identification of species, and high-resolution photos (with Canon 600 D camera with Tamron 90 mm macro and Canon 55–250 zoom lenses) were taken for confirmation of the identification.

Table 1
Name, total area (ha), location, distance (meters) of the studied sacred (in italics), and non-sacred swamps

Name	Area	Latitude	Longitude	Average distance to road, settlement or orchard
Chaare	0.18	14.408N	74.736E	98
Birlakaanu Kudgund	0.73	14.293N	74.758E	120
Bogarimakki	0.90	14.387N	74.770E	98
Jaddikodlu Kudegodu	1.03	14.392N	74.754E	138
Keremoole	0.41	14.275N	74.771E	78
Korse Chapparmane	0.89	14.389N	74.757E	138
Kudegodu Devikanu	0.81	14.326N	74.688E	94
Mavingadde	0.48	14.392N	74.695E	103
Nilkund Chowdikanu	0.27	14.449N	74.704E	103
Venkatesh Teertha	0.40	14.547N	74.703E	120
Balehaklu	0.18	14.416N	74.754E	388
Honnekombu	0.24	14.393N	74.756E	363
Hukli	0.73	14.293N	74.788E	375
Mundgetaggu	0.10	14.274N	74.773E	232
Nandisaalu	0.90	14.269N	74.803E	318
Nettikai	1.03	14.416N	74.753E	376
Sashikodlu	0.41	14.326N	74.692E	433
Shingumane	0.89	14.311N	74.732E	318
Sodlekodlu	0.81	14.323N	74.688E	292
Somankuli	0.48	14.270N	74.733E	232

Biomass productivity (stem density and basal area), frequency and importance value index (IVI) of tree species were calculated according to Bonham (2013).

Frequency is the number of times a plant species is present in a given number of quadrats of a particular size or at a given number of sample points. Frequency is usually expressed as a percentage.

Density is an expression of numerical strength of a species in a community. It is calculated as:

$$\text{Density} = \frac{\text{Total number of individuals of all species}}{\text{Total area/quadrats sampled}}$$

The basal area of a stand is the total stem area at breast height of all trees in a plot divided by the total area of that plot (Cain 1959; Chaturvedi and Khanna, 1994):

Basal Area (m^2) = pi * (DBH in cm) ^{2} /40000

The Family Importance Value (FIV) for growing stock (volume of all trees ≥ cm DBH) was calculated as follows;

FIV = Relative density + Relative diversity + Relative dominance

Where,

Relative density = (Number of individuals in family A / Total number of individuals of all families) x 100

Relative diversity = (Number of species in family A/ Total number of species) x 100

Relative dominance = (Basal area of all individuals of family A / Total Basal area of all individuals of all families) x 100

To express both richness (total number of different species) and abundance or evenness (how equally the individuals from each species are represented) into a single numerical value, we used the Shannon (H') and Simpson (D) diversity indices. The Shannon index is expressed as:

$$H' = -\sum_{i=1}^{s}[(ni/N)\ln(ni/N)]]$$

Where, ni= the number of individuals belonging to ‘i’th species;

N= the total number of individuals in the sample;

S= the number of species

The Simpson (D) index is expressed as:

$$D = \sum_{Ii=1}^{n} pi^2$$

pi= the proportion of individuals in the i^{th} species = ni/N

Pi= ni/N, where, ni is the number of individuals belonging to the i^{th} species and N is the total number of individuals in the sample.

The value of the Simpson index varies between 0 and 1. As D increases, diversity decreases (Simpson 1949).

To record the regenerating species, two plots (quadrates) of 5 x 5 m were laid out; one at the 50^{th} and another at the 100^{th} meter of each transect of varying length along the river. Trees (seedlings) with less than 30 cm DBH were considered as the regenerating potential of the species. The natural regenerates were grouped into following regeneration classes for further analysis (Puttaswamy et al. 2010):

0 – 30 cm height————————Class I

31 – 60 cm height———————Class II

61 - 90 cm height and < 10 cm GBH (Girth at Breast Height) ——Class III

91 - 120 cm height and 10-30cm GBH—Class IV

The population structure was described as the number of individuals of each tree species in the different diameter classes. The species richness refers to the number of different species represented in a sample (Magurran 1998). Evenness (E) was calculated following Pielou (1996) as:

E= H´/ln(S)

Where, H’= Shannon’s index

S = Species richness

Results

In the sacred swamps 122 species from 99 genera and 58 families were found against 83 species from 72 genera and 47 families in the non-sacred swamps (Fig. 1, Fig. 2, Table 2). Lauraceae, Apocynaceae, Anacardiaceae, Moraceae, Myristicaceae and Rubiaceae were the most species-rich families in the sacred swamps, whereas in the non-sacred swamps Euphorbiaceae, Anacardiaceae, Arecaceae, Apocynaceae, Celastraceae, Dipterocarpaceae, Lauraceae and Myristicaceae.

Table 2
Plant functional types, IUCN Red List species, and total numbers of plant species, genera and families in the total studied area of sacred (1.70 ha) and non-sacred (1.71 ha) swamps.

Plant functional types		**Sacred swamps**	**Non sacred swamps**
Climber species		5	4
Epiphyte species		1	1
Fern species		6	2
Herb species		7	7
Liana species		8	3
Shrub species		14	12
Tree (excl. palm) species		74	49
Palm species		4	5
Status in IUCN Red List*	Vulnerable species	8	9
	Endangered species	4	3
Total species		122	83
Total genera		99	72
Total families		58	47

* http://www.iucnredlist.org/ accessed on 23 December 2015.

Table 3
Diversity, stand density and basal area of trees in the total studied area of sacred (1.70 ha) and non-sacred (1.71 ha) swamps

Properties	**Sacred swamp**	**Non-sacred swamp**
No. of individuals > 30 cm DBH	437	215
Simpson index	0.579	0.615
Shannon index	1.312	1.377
Species richness	2.78	3.61
Evenness index	0.73	0.83
Frequency	16.3	13.66
Stem density (individuals/ha)	277	158.4
Average basal area (m^2/ha)	47.57	14.60

Myristicaceae have the highest Family Importance Value both in the sacred (99.14 %) and in the non-sacred swamps (61.2). Other important families are the Anacardiaceae (26.16%) and the Celastraceae (20.54%) in the sacred, and the Arecaceae (45.6%) in the non-sacred swamps (Figs. 3 and 4).

Most trees with a GBH > 30 cm fall in the 30–60 cm category both in the sacred (68.4 %) and in the sacred swamp swamps (51.8 %, Fig. 5). 28% of the plant species are endemic to the Western Ghats in the sacred against 23% in the non-sacred swamps (annex 1).

Table 4
Occurrence of amphibian, bird, butterfly and odonata species in the studied sacred and non-sacred swamps.

Species	**Number of species**		**Number of individuals**	
	Sacred swamp	Non sacred swamp	Sacred swamp	Non sacred swamp
Amphibian	25	21	182	119
Birds	26	15	44	18
Butterflies	16	15	27	35
Odonata	15	15	63	57

Number of species and individuals from amphibian, birds, butterflies and odonata are found to be higher in the sacred swamps compared to the non-sacred swamps (Table 4).

The Simpson index for all fauna was 0.40 in the sacred and 0.36 in the non-sacred swamps, whereas the Shannon index was − 1.1 and − 1.2, respectively.

Three critically endangered amphibian species from the IUCN Red List, *Nyctibatrachus dattatreyaensis*, *Pseudophilautus amboli* and *Micrixalus kottigeharensis*, were found to occur in both sacred and non-sacred swamps, however, non-sacred swamps were represented by only 6 individuals where as it was 22 individuals in sacred swamps. (Table 5).

Table 5

Occurrence of threatened species of amphibians according to the IUCN Red List in the studied sacred (1.70 ha) and non-sacred swamp transects (1.71 ha). See for details appendix 2.

IUCN Category	Sacred swamps		Non sacred swamps	
	Number of species	Number of individuals	Number of species	Number of individuals
Critically endangered	3	22	3	6
Endangered	4	56	2	8
Vulnerable	1	1	0	0
Near threatened	2	21	1	45

Discussion

Consistently more species (122 species with 58 plant families) were found to occur in the sacred compared to the non-sacred swamps (87 species and 47 families). Higher species numbers have also been recorded in sacred compared to non-sacred non-swamp sites in the south-eastern coastal belt of India near Pondicherry (Ramanujan and Kadamaban 2001).

Although the number of plant species in the swamps is low compared to well-watered (but not waterlogged) land, the occurring species are often site or habitat specific and endemic and contribute significantly to the regional biodiversity of the Western Ghats (Chandran et al. 1999; Chandran and Mesta 2001; Roby and Nair 2006).

The basal area of tree species in the sacred swamps was much higher (47.57 m^2/ha) compared to that in the non-sacred swamps (14.6 m^2/ha). A high basal area indicates the presence of old and huge trees. The highest basal area in sacred forests in the Kakachi forests was reported to be 42.03 m^2/ha (Ganesh et al. 1996) and 47.01 m^2/ha for the Uppinangala forest (Pascal and Pelissier 1996).

The average density of trees above 30 cm GBH in the (natural) forests of the Western Ghats ranged from 446 to 1576 stems/ha (Ganesh et al. 1996; Ayyappan and Parthasarathy 1999, Parthasarathy 2001). Sukumaran (2008) recorded a stem density of 100 / ha in the sacred groves of Astheeshwaram of Southern peninsular India, whereas in our study the density in sacred and non-sacred swamps was 277 and 156 stems per hectare, respectively. The rather small biomass productivity (stem density and basal area) in our samples could be due to the constant water level throughout the year. Conner (1976) and Brinson et al. (1981) found that seasonally flooded open systems are generally more productive than stagnant closed ones. Productivity was approximately double in wetlands subject to periodic flooding, compared to stagnant or slowly flowing systems (Mitsch 1991). Further, area of both sacred and non-sacred swamps was small compared to other studies, which are in the terrestrial ecosystems.

In the study sites, tree cutting intensity was high in the non - sacred swamps, which is evident from the presence of cut stumps and cutting of knee roots of *Gymnacranthera canarica*. We did not find evidence of cutting in the sacred swamps. The cultivated species *Musa paradisiaca* and *Areca catechu* were found only in non-sacred swamps, indicating attempts to convert them into commercial orchards.

Sacred swamps had 28% of endemic species while non-sacred swamps had 23%. Vasanthraj and Chandrashekhar (2006) reported that 37% of the species from Charmady reserve forest are endemics of the Western Ghats, whereas the average endemism for evergreen forests of the Western Ghats is around 41% (Ghate et al. 1998).

Only few species, i.e. *Myristica fatua var. magnifica* and *Gymnacranthera canarica*, can survive in the depression part of the swamp forests with permanently water-logged conditions because their stilt and aerial roots provide anchoring and breathing capacity. These species along with facultative swamp species like *Vateria indica, Dipterocarpus indicus*, *Dysoxylum binecteriferum*, *Myristica malabarica, Mastixia arborea, Lophopetalum wightianum* and *Calophyllum apetalum* (Annex 1) are very old in origin ('palaeoendemics' - relic plants with ancient pedigree) and indicator species of evergreen climax forests, and important shelter and food plants for rare and endangered species like lion tailed macaque (*Macaca silenus*, Ramachandran and Joseph 2000) and great pied hornbill (*Buceros biornis*), (Ali et al. 2006).

The interaction between forest disturbance, regeneration and succession determines the size and age distribution of trees (Kuuluvainen et al. 1996). Biological quality ('health') of forests is often indicated by their size class distribution and regeneration ability, with a large proportion of seedlings and saplings reflecting a growing population (Murali et al. 1996). With regard to diameter classes, the sacred swamps show a clear 'reverse J' shape distribution curve, in contrast to the non-sacred swamps, which show a much lower prevalence of the lowest (Fig. 6) and the complete absence of trees in the highest girth classes (Fig. 5).

Amphibian assemblages are good indicators of environmental health (Hager 1998, Gibbs 1998) as amphibians are sensitive to environmental change (Blaustein 1994, Pearman 1997, Daniels 1999). In our study, sacred swamps have a higher number of amphibian species and a higher number of threatened species when compared to non-sacred swamps. Diversity and richness of bird, butterfly and odonata species were, however, only marginally higher in the sacred swamps. Higher species richness and composition in non-sacred swamp is an effect of mild disturbance that favours the early invaders and the deciduous species essentially increases the species richness. However, the studies of Murali and Setty (2001) have observed high species richness as well as forest stand in the plots with mild disturbance than the less disturbed plots. Methachen (2002) reported that the disturbed evergreen forests of Uttara Kannada district were floristically more rich compared to undisturbed evergreen forest in terms of species richness as well as diversity indices complying to the 'mild disturbance' theory.

Conclusions

Our study shows that the species composition and diversity patterns - tree population, stem density, and the basal area of tree species – are higher in sacred swamps compared to non-sacred swamps. Regeneration of swampy species is much better in sacred swamps. Both natural and human activities have an effect on species diversity, population structure, and natural regeneration of a forest ecosystem. Vegetation characteristics make it clear that sacred swamps act as safe zones for the in-situ conservation of many endemic and red listed species of the Western Ghats. This condition is made possible, only because the local community restricts anthropogenic activities. This social fencing, i.e. the most viable form of protection in the field, is based on traditional values of local communities, evolved over long time. Such community behaviour requires a socio-cultural ecosystem to nourish it and local forest dwelling communities must be given credit for ensuring survival of these biodiverse habitats. We conclude that the traditional practices of protecting the swamp forests play an important role in biodiversity conservation.

Declarations

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Figures

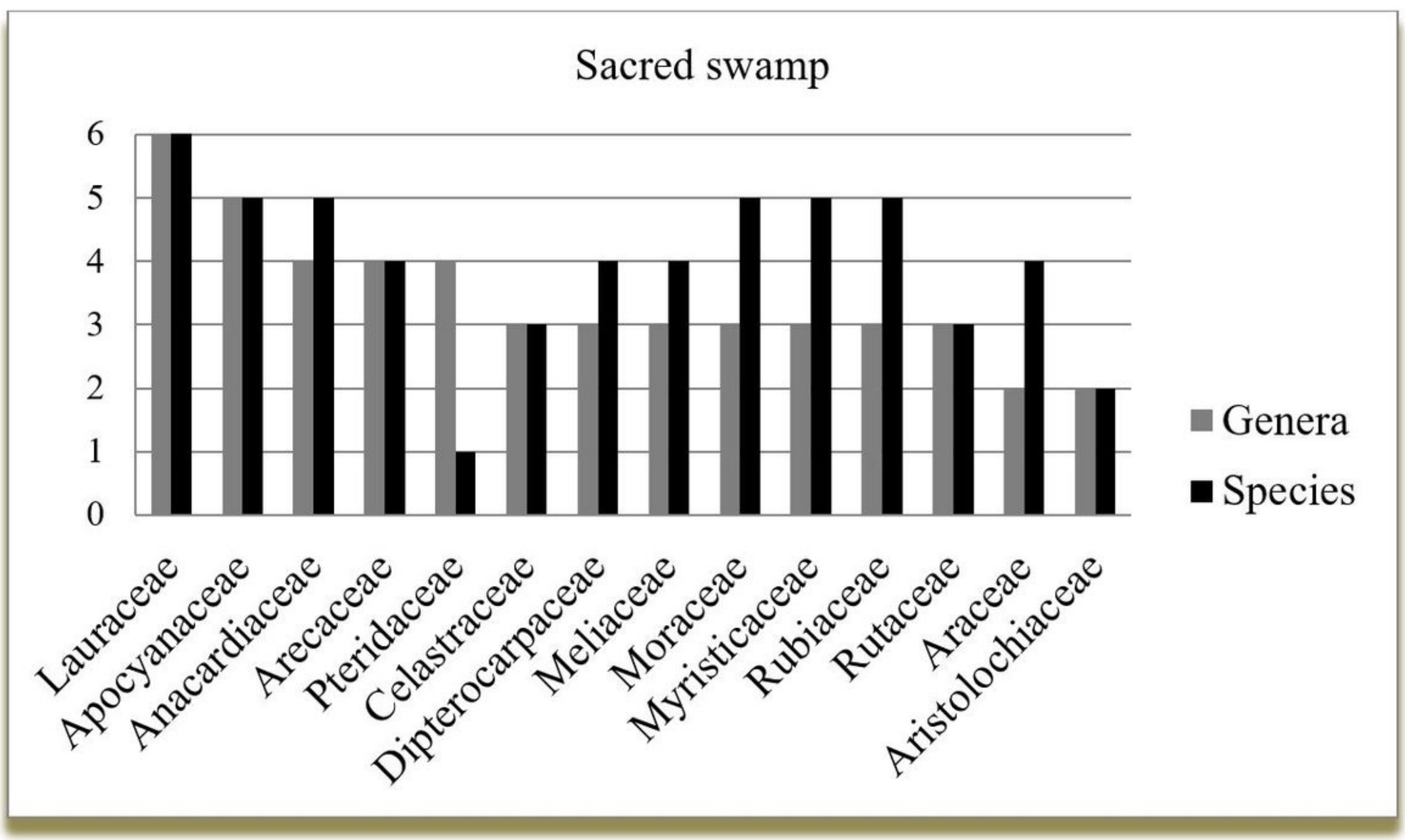

Figure 1

Number of genera and species per family in the studied 1.70 ha of sacred swamps.

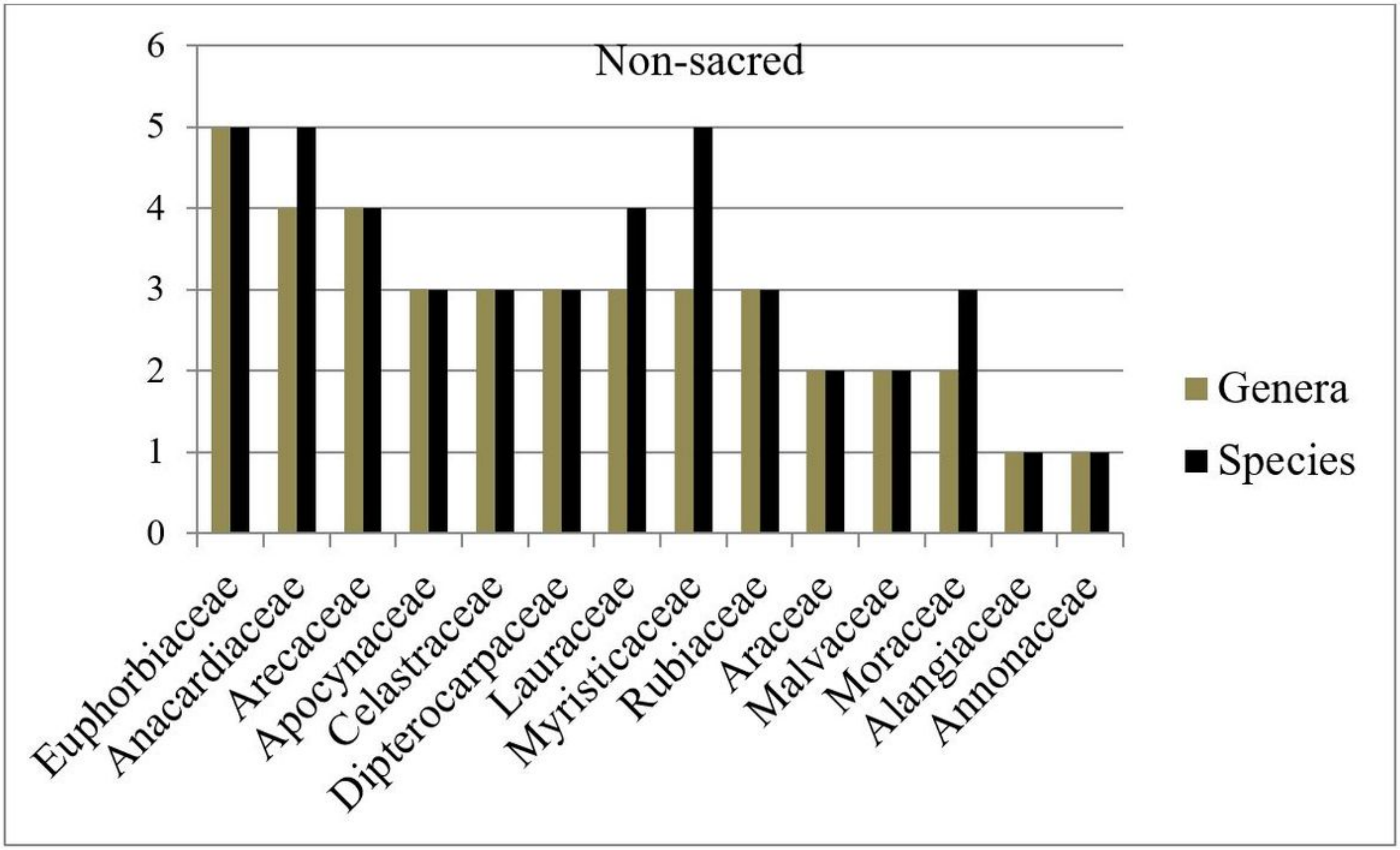

Figure 2

Number of genera and species per family in the studied 1.71 ha of non-sacred swamps

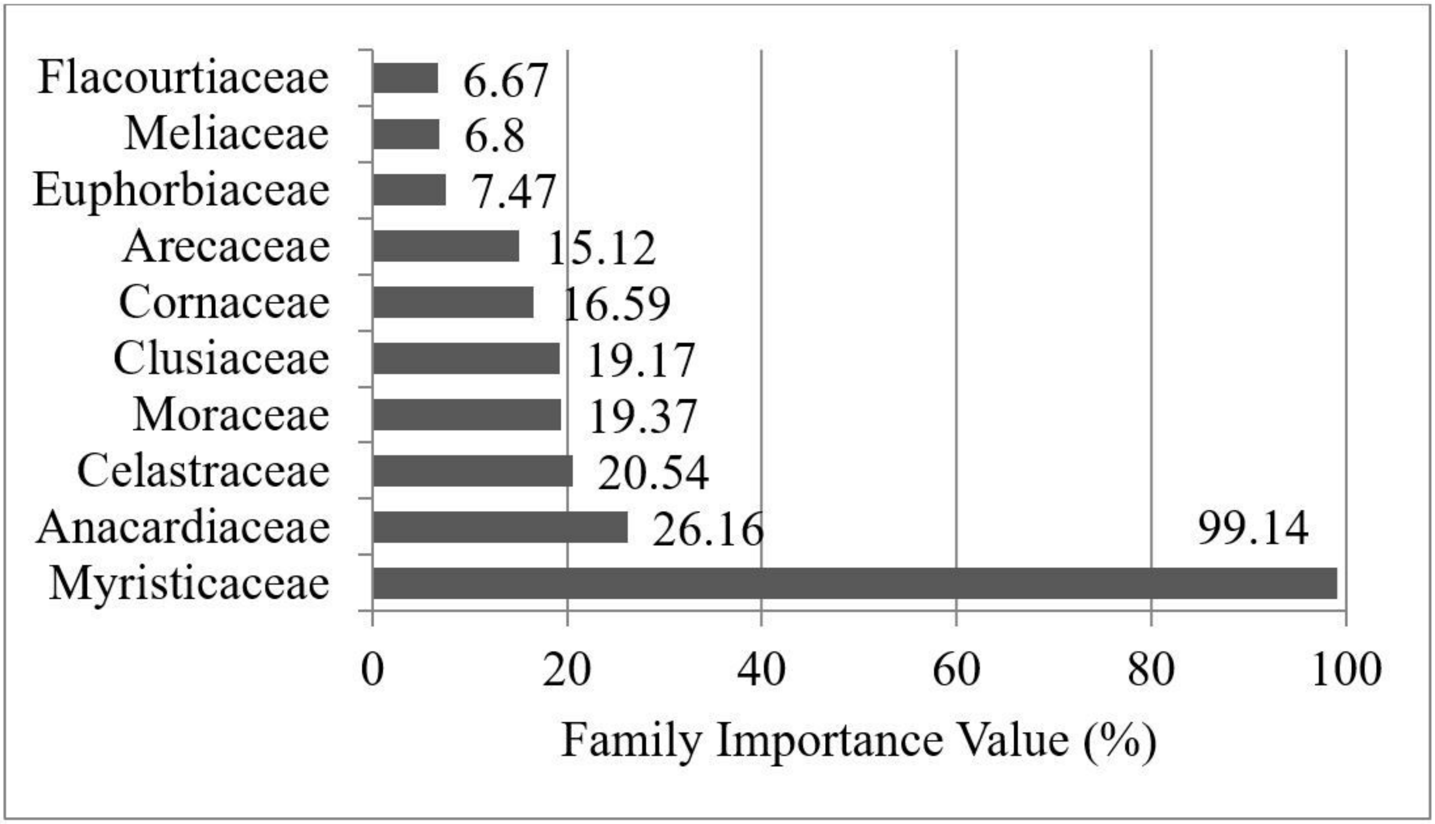

Figure 3

Family Importance Value for the tree species in the studied sacred swamps

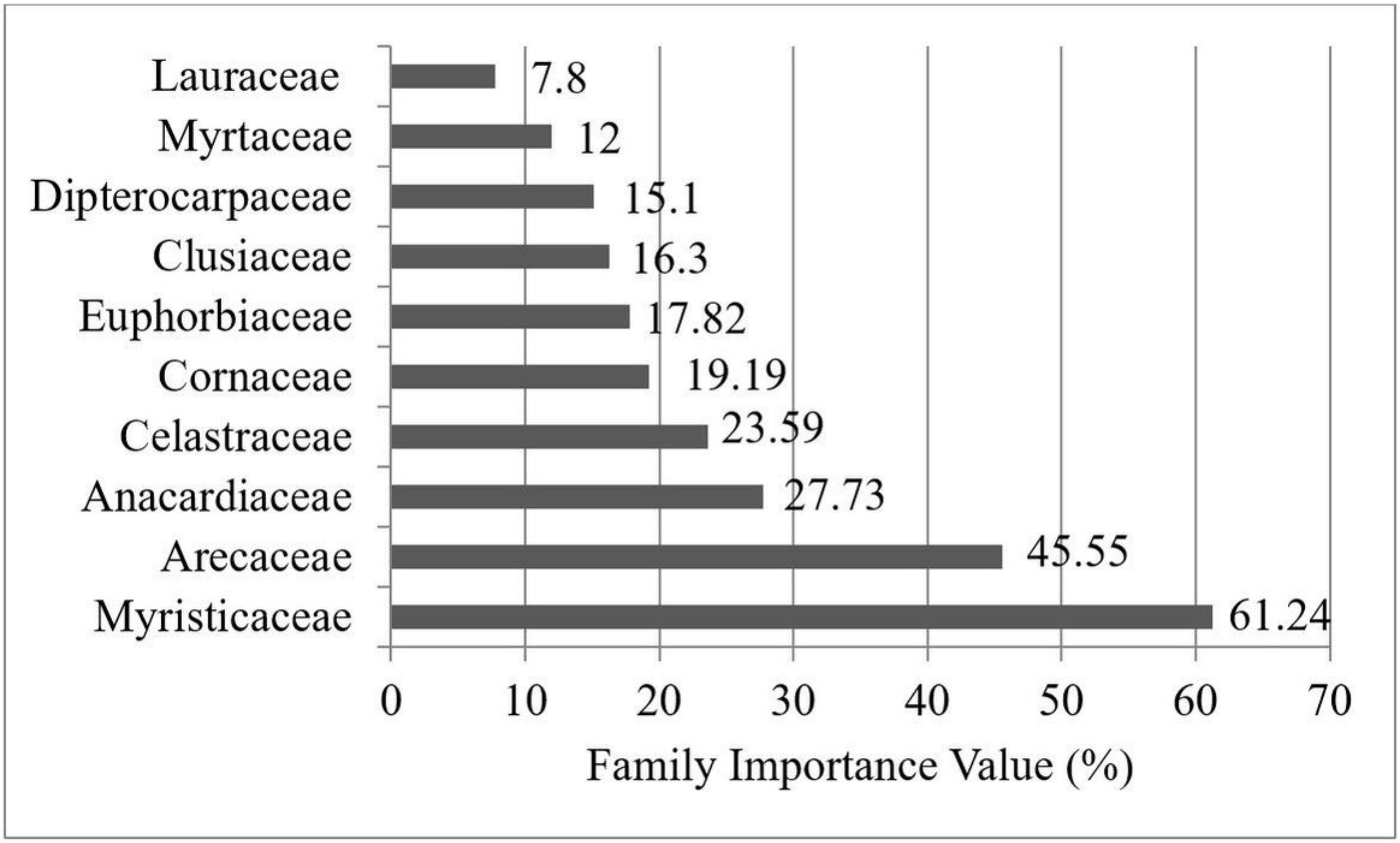

Figure 4

Family Importance Value for the tree species in the studied non-sacred swamps

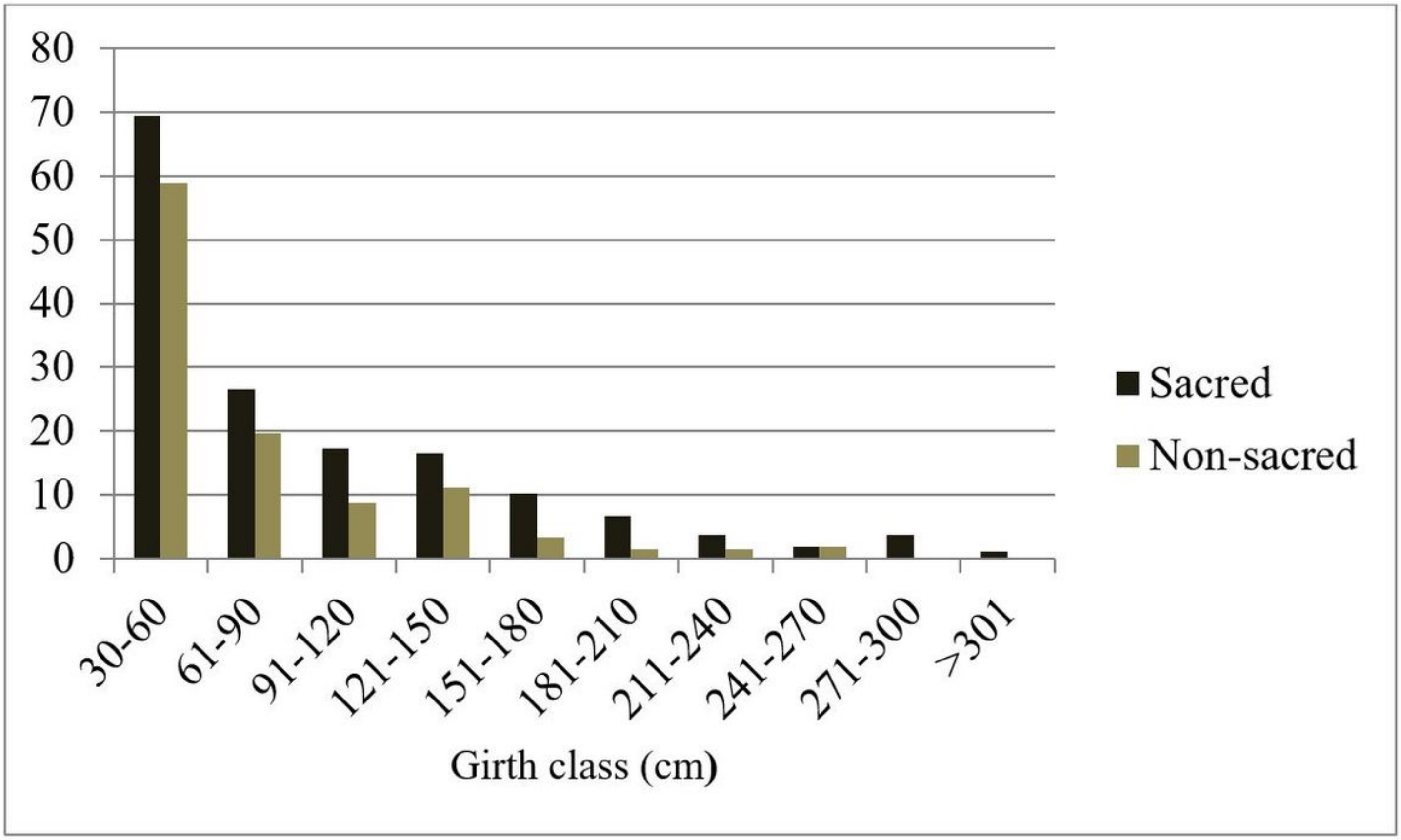

Figure 5

Size class distribution of trees in girth classes >30cm DBH in the studied sacred and non-sacred swamps

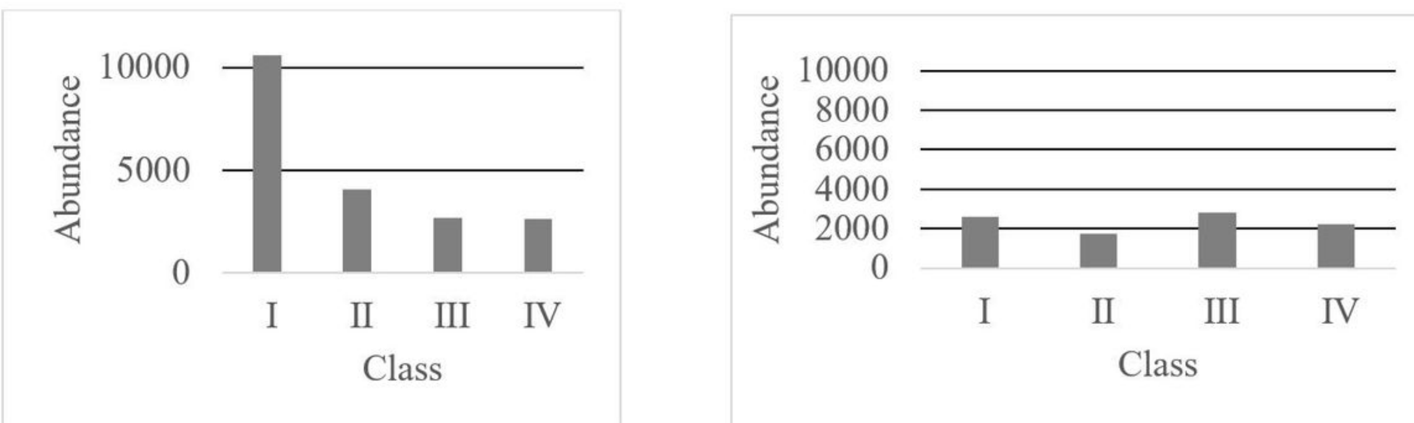

Figure 6

Abundance of regenerated trees (N) in the studied sacred swamp (1.70 ha, left) and non-sacred swamp areas (1.71 ha, right). Class I: 0 – 30 cm height, II: 31 – 60 cm; III: 61 - 90 cm height and < 10 cm GBH, IV: 91 - 120 cm height and 10-30cm GBH.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Annex1Listofplantspecies.docx
- Annex2Listofamphibnianspecies.docx
- Annex3Listofodonataspecies.docx
- Annex4Listofbuterflies.docx
- Annex5Listofbirdspecies.docx
- Fundingsources.docx