Final Report (2003 –2004)

on

"Conservation of the *Myristica* Swamps - the highly threatened and unique ecosystem in the Western Ghats, India."

Submitted to

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Submitted by

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Project Summary

Myristica swamps are one of the unique ecosystems in the Western Ghats, a global mega diversity hot spot in India. Located in low-lying poorly drained depressions, these swamps form an extensive network along the watercourses through the primeval forests of the Western Ghats. However, due to human interventions, the swamps today are highly threatened and are highly fragmented.

These swamps, as their name indicate, are the only sites of occurrence of certain members of the ancient family Myristicaceae such as *Myristica fatua* var *magnifica* and *Gymnacranthera canarica.* Besides, the swamps also have many distinct endemic taxa, which remain poorly studied. Recent studies have shown that many of the species endemic to swamps have incredibly small population sizes and have poor regeneration. Consequently a number of the species could be highly threatened and in few cases might also be on the verge of extinction. It is feared that unless immediate measures are taken to restore the populations of these species, many of the species would be faced with the prospect of certain extinction.

In this project an exhaustive distribution map of the *Myristica* swamps in the Western Ghats has been developed. The project facilitated the identification of new habitats (swamps) in the central Western Ghats based on the ecological niche model. A threat map of the swamps has been developed using both qualitative and quantitative threat factors and attempt has also been made to identify the highly threatened swamps. In the stratified set of swamps, floral and faunal diversity were assessed. The status of swampy and non-swampy species across the swamp area and disturbance gradient has been assessed. Based on our results, we propose few conservation strategies and a national agenda to conserve and restore these unique habitats in the Western Ghats.

Aims and Objectives

The over all goal of the proposal is to focus attention on the conservation of the *Myristica* swamps and their species, a unique ecosystem of the Western Ghats, South India.

The specific objectives of the proposal are:

1. To map the network of freshwater *Myristica* swamps in the Western Ghats.

2. To assess the extraneous pressures on the swamps and to generate threat maps of the swamps.

3. To inventorize and determine the demographic profile of the species endemic to the swamps for prioritising species for conservation.

4. To formulate long-term strategies for the restoration and conservation of species endemic to the *Myristica* swamps.

Background and Justification

Freshwater swamps are found in many parts of the world, especially in the valleys of Mississippi and its tributaries, in Sweden, Odzala National Park, Congo, in the Malaysian region, Papua New Guinea, etc. In India, they are reported from the Siwalik and Doon Valley and the Brahmaputra Valley (Rao, 1994), in addition to the Western Ghats. The Western Ghats, which runs parallel to the west coast of India, is one of the global centres of biodiversity hot spots and endemism (Myers, 1998; Nayar, 1996). Among other unique systems, the Western Ghats are home to the *Myristica* swamps, named thus because of the predominant vegetation of the swamps (Krishnamoorthy, 1960).

Even with their little known biota, the *Myristica* swamps are virtually live museum that is of great interest to biologists. They have high watershed value and most of them have been, presumably, exploited through centuries for agricultural purposes. The swamps, which once formed a network along the watercourses through the primeval forests of Western Ghats, have been literally wiped out through ages of anthropogenic interventions. The pressure is however, today, greatly on the last few fragments.

I. Distribution of *Myristica* swamps

Myristica swamp was described as a special type of habitat from the Travancore region of South Indian Western Ghats, four decades ago. Prior references to such swamps are hardly found, nor anything notable added thereafter, more so on swamps north of Travancore, barring a lone location in southern Uttara Kannada. The swamps which would have once formed a network along the water-courses through the primeval forests of Western Ghats have been literally wiped out through ages of agricultural intervention, including shifting cultivation, raising of monoculture plantations of trees and commercial crops, submersion under hydel projects, mining, etc.

The distribution of the *Myristica* swamps as such is rare in Western Ghats. Evergreen trees such as *Gymnacranthera canarica, M. fatua* var. *magnifica, Knema attenuata, Myristica dactyloides* and *M. malabarica* represent Myristicaceae in the Western Ghats. Of these, the first two species are exclusively associated with swampy habitats. The rest are more widely distributed in the non-swampy habitats although *M. malabarica* may sometimes be found in the swamps. Between the Travancore sites (8° to 9°N) and the northernmost site in Uttara Kannada (14°N), Ramesh and Pascal (1997) have shown only a single location for *M. fatua* (at 12°N). Chandran *et al.,* (1999) have identified few swamps having one or the other species in Uttara Kannada. The earlier work of Ramesh and Pascal (1997) on the *Atlas of Endemics* does not show any location for this area (13^0 latitude). Most of the swamps are very small (less than one ha) and might have likely escaped attention during surveys. This highlights the importance of making an exhaustive search for more *Myristica*swamps in the Western Ghats.

II. Threats and the need to study *Myristica* swamps

The *Myristica* swamps may be considered as one of the most threatened ecosystems of India. It is doubtlessly the relic of a primeval ecosystem of the Western Ghats. The presumed widespread loss of perennial freshwater swamps such as the *Myristica* swamps, as evidenced by their present day rarity and fragmentation is perhaps a reminder of the progressive desiccation in the Western Ghats. The swamps of the Western Ghats are threatened with extinction even before much is known about them, such as nutrient cycling, mycorrhizal relationships, plant–animal interactions, species diversity, etc.

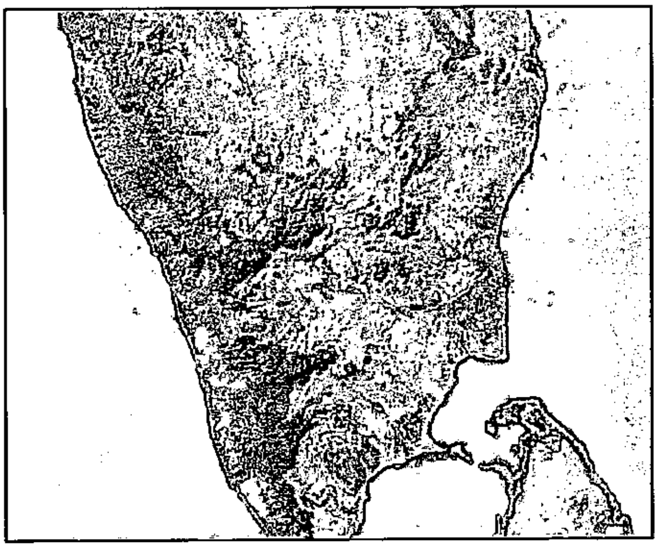
The swamps of the Western Ghats have high degree of endemic plants. The fruits of the *Myristica* are used as spice and also as an ingredient in many drugs, thus affecting the regeneration of the species. *Myristica malabarica, M. dactyloides* and *Gymnacranthera canarica* species are already listed as threatened (FRLHT, 2000, www.iucn.org). Another swampy species *Semecarpus kathalekanensis,* (Anacrdiaceae) a dioecious canopy tree, is restricted to merely four swamps in the Western Ghats with a total population of 91 individuals, of which there are only 42 breeding individuals (Vasudeva *et al,* 2001). Based on the criterion proposed by Frankel and Soule (1981), *S. kathalekanensis* could easily be regarded as a critically endangered species and almost in the verge of extinction.

Many of the tree species in the swamps have population sizes far more precarious than that reported for some of the animals such as the Great Panda, Cheetah and the Grey Wolf. However, largely because of the emphasis on "*charistimatic conservation*" or "*vertebrate chauvinism*", enough attention has not been paid to the conservation of these highly endangered species. Several of these species may face the fate of becoming locally and or globally extinct if immediate measures are not taken to address their conservation concerns.

In summary, the *Myristica* swamps and their constituent endemic and endangered species form a unique ecosystem of the Western Ghats, the loss of which cannot be made good. With mounting pressures and threats to the swamps, there is an urgent need to study them and propose measures to save them from certain extinction.

Study site:

The study has been carried out in the Western Ghats of peninsular India, one of the 18 Biodiversity hot spots of the world. Running along the west coast of peninsular India, the Ghats form a mountain chain about 1500 km long and 100 km wide consisting of over 3000 flowering species with more than 60 per cent of them being endemic to the region (Gadgil *et al.*, 1997). The central Western Ghats in the state of Karnataka account for over 60 % of the entire Ghats and are home to some of the unique swamps in southern India (Davis *et al.*, 1934; Chandran and Mesta, 2001). The Western Ghats is densely inhabited with human settlements that depend upon the forest directly for a number of forest products, and indirectly for a number of ecosystem services such as water, farm nutrients etc.



Forest of Western Ghats, south India

Objective 1

To map the network of freshwater Myristica swamps in the Western Ghats.

Materials and Method:

Information on the distribution of the *Myristica* swamps was obtained from the published literature (flora, forest department records, journals, etc), personal communication and through field survey. Data on distribution was also obtained from Sasya *Sahyadri,* a digital database on plant resources of the Western Ghats (Ganeshaiah *et al.,* 2003). The latitude and longitude of the places of occurrence were obtained and digitized using DIVA GIS and GIS Map Info software.

Results:

Based on the database, spatially explicit map was developed for the *Myristica* swamps in the Western Ghats (Figure 1.1 and 1.2). The *Myristica* swamps usually occur at low altitude (< 200 m) and are distributed through out the Western Ghats. Based on the species that are exclusively associated with the swampy habitat separate maps were developed. Among the tree species endemic to the swamps, *Gymnacranthera canarica* is present in all the *Myristica* swamps where as *Myristica fatua* and *Semecarpus kathalekanensis* are restricted only to a few swamps. The distribution map indicated that *S. kathalekanensis* is completely restricted to the Uttara Kannada district of Karnataka in the central Western Ghats.

Using the primary data of the occurrence of the swamps, we predicted the distribution of the *Myristica* swamps in the Western Ghats (Figure 1.3) using ecological niche models tools. Among the, we used a free ware program, DIVA GIS. The program facilities the prediction of the ecological niche of the species given a sample of actual occurrences of the species (www.diva-gis.org). Following the prediction we validated the findings by undertaking a field survey. We conducted field survey in three stratified regions in the central Western Ghats and found that predictions based on the ecological niche model holds true. Our survey yielded hitherto unknown 8 swamps in the central Western Ghats, all of which were predicted by the model. These initial results have indicated the promise of locating more of these unique habitats in the Western Ghats. Thus the study calls for further rigorous survey of the entire Western Ghats, based on the pointers indicated by the predictive model.

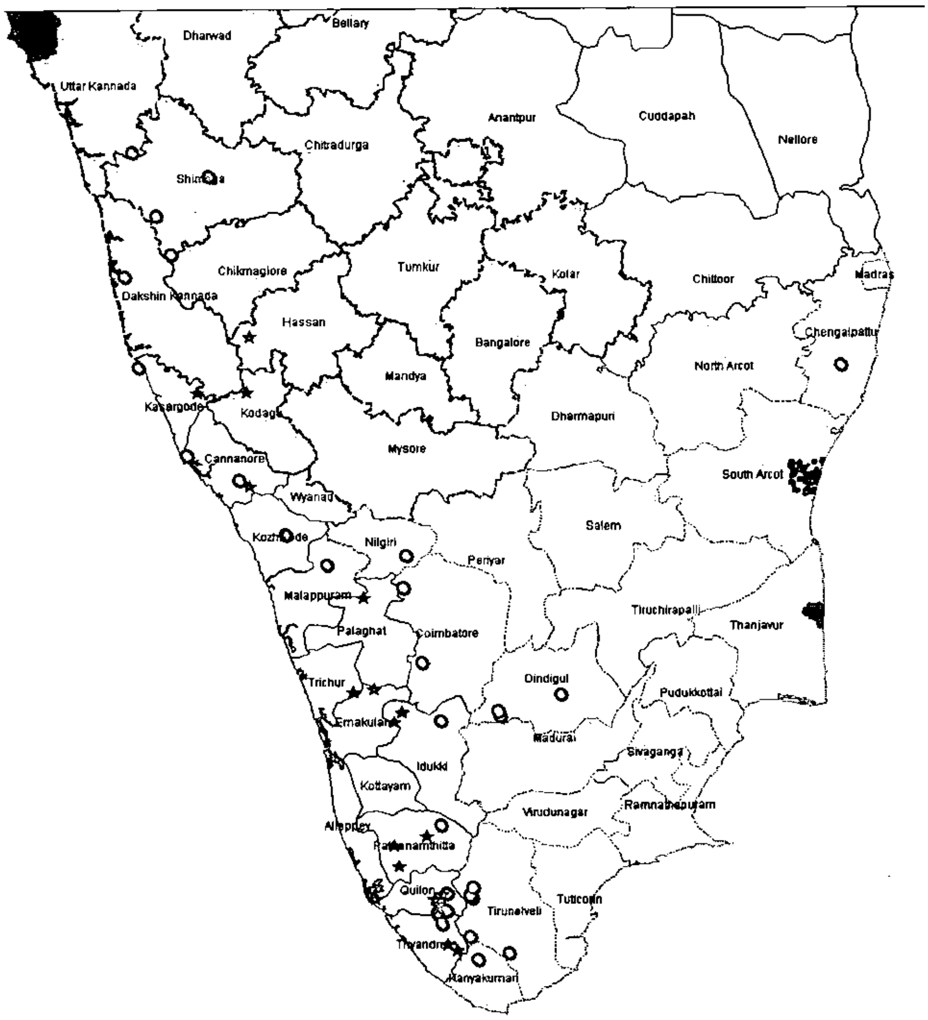


Figure 1.1. Distribution map of swampy species in the Western Ghats, India

(Red-*Gynmacranthera canarica*, Green-*Myristica fatua*)

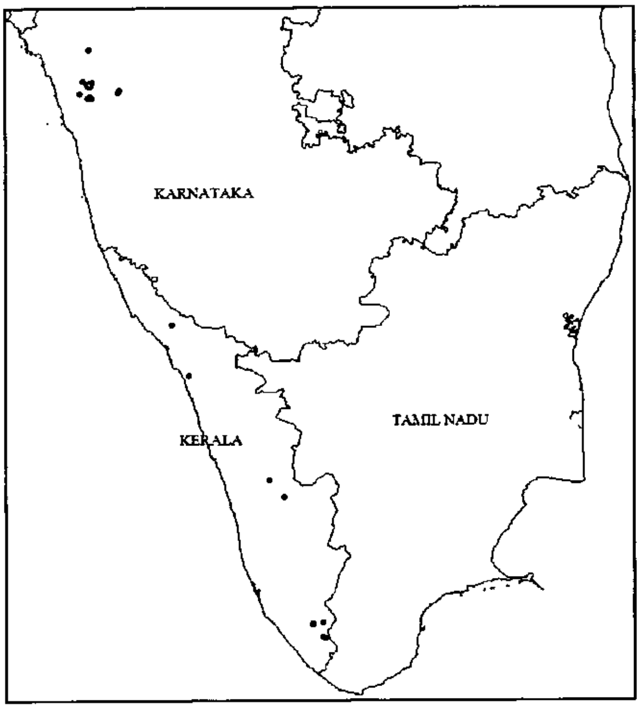


Figure 1.2. Distribution map of *Myristica* swamps based on the primary data points (n=73)

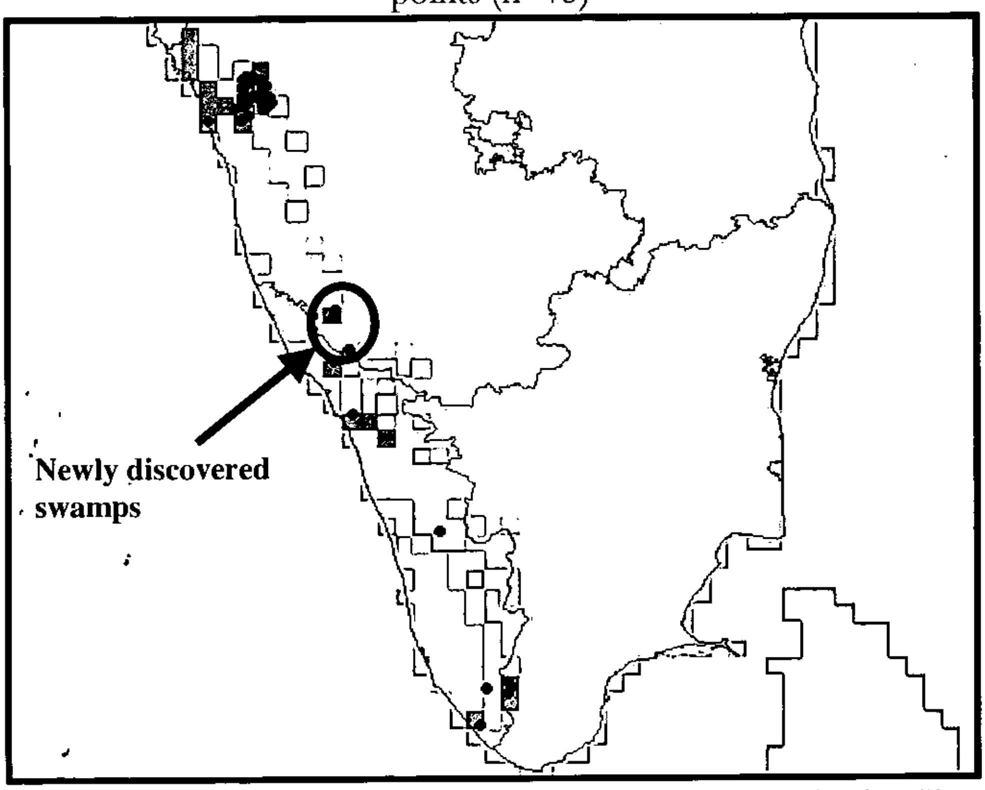


Figure 1.3. Predictive distribution map of *Myristica* swamps in the Western Ghats based on Ecological niche model (DIVA-GIS)

Objective 2:

To assess the extraneous pressures on the swamps and to generate threat maps of the swamps in the central Western Ghats.

As mentioned elsewhere one of the major threats to the swamps is from human induced disturbance either in the form of conversion of the swamps to areacanut plantations and agriculture, diversion of drainages and finally for non-timber forest product use (such as collection of the fruits of *Myristica*). Consequently as documented by earlier workers, a number of swamps have been put to disrepair and many of them have in fact gone extinct. Understanding the various factors threatening the swamps and the sensitivity of swamps of different sizes to these threats could help in formulating mitigating strategies.

Materials and Method:

- The study was located in the central Western Ghats, in the Uttara Kannada district, Karnataka state. Threat assessment was conducted over 56 swamps. For each swamp information on following parameters were recorded: Name of the swamp, area (m^2), Altitude (ft), canopy height (ft), nearest human settlement and cattle population, distance from the cart road (km), distance from the road (km), terrain slope (15^0, 30^0, 60^0 etc), canopy cover (25%, 50%, 75 %), frequency of visitors (high, medium, low), benefits for which the swamps are visited (water, NTFP, fuel, timber, grazing), encroachment (Yes / No), water diversion (Yes / No), felling (Yes / No), track/paths (Yes / No), adjacent vegetation (forest, areca, road, agricultural land), visible decrease in area of swamp (Yes / No) and water source (seasonal / perennial). Based on these parameters a threat index was computed for each of the swamp and a GIS map developed.

Data Analysis:

A). Quantitative data: To arrive at a threat index we computed the following indices, indicating the relative threats.

1. Altitude (ft) is assumed to be inversely related to the threat (Threat = 1/altitude)
2. Human and 3. Cattle population directly proportional to the threat (Threat = log population (# individuals)
4. Distance from road (km) and 5. Path inversely proportional (threat = 1/ distance (km)).

B). *Discrete data (Presence / absence)*

3. Terrain (15^0, 30^0, 60^0) inversely proportional to threat = 1/ 15, 1/30, 1/60)
4. Frequency of visitors Threat value: high=3, medium=2, low=1
5. Benefits (water=1, NTFP=1, fuel=1, timber=1, grazing=1) Mean benefits = (1+1+1+1+1)/5.
6. Adjacent vegetation (Forest, Areca, Road, Agri land) Threat value = Areca=1, Forest = 0, Road=1, Agri land=1.
7. Encroachment (Yes = 1, No=0)
8. Water diversion (Yes=1, No=0)
9. Felling (Yes=1, No=0)
10. Track/paths (Yes=1, No=0)
11. Decrease in swamp area (Yes=1, No=0)
12. Water source (Seasonal=1, Perennial=0)

Threat Index was obtained by computing an arithmetic sum of all the threats, assuming equal weights for the various threat factors. While this is not realistic, in absence of the relative magnitudes of threats by the various factors we assume them to be equal.

Results:

Threats index was developed for a stratified set of swamps based on both quantitative (5) and discrete (10) parameters in Uttara Kannada district, central Western Ghats (Figure 2.1). The frequency distribution of the swamps based on the size (area in m^2) showed a positively skewed distribution (Figure 2.2) indicating that most of the swamps in the study area are small. The threat index developed for the swamps ranged from 8 to 34 across the 56 swamps. There was not relation between the area (or size) of the swamp and their threat index (Figure 2.3). Swamps with perennial source of water are less threatened than those with seasonal source of water (Figure 2.4). We also assessed the threat index of swamps whose size had visibly decreased (certain portion of the swamps had dried-up) compared to those that has not visibly changed in size (Figure 2.5). The former had a higher threat index than the latter indicating that continued threat to them might lead to endangering the swamps.

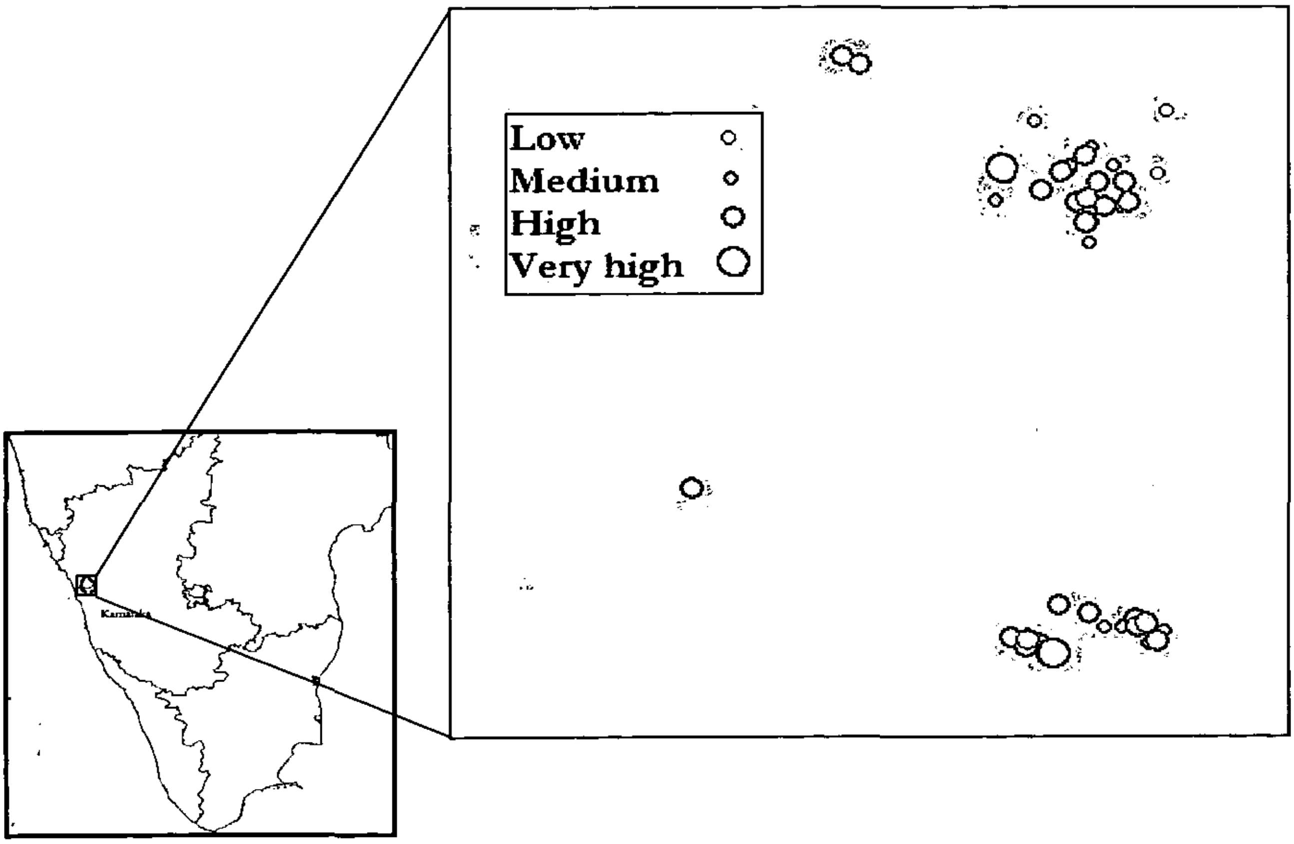


Figure 2.1: Threat map of the *Myristica* swamps in the central Western Ghats (Threat Index: Low= < 10, Medium=< 10 to < 15, High=> 10 to < 20, and Very high= > 25)

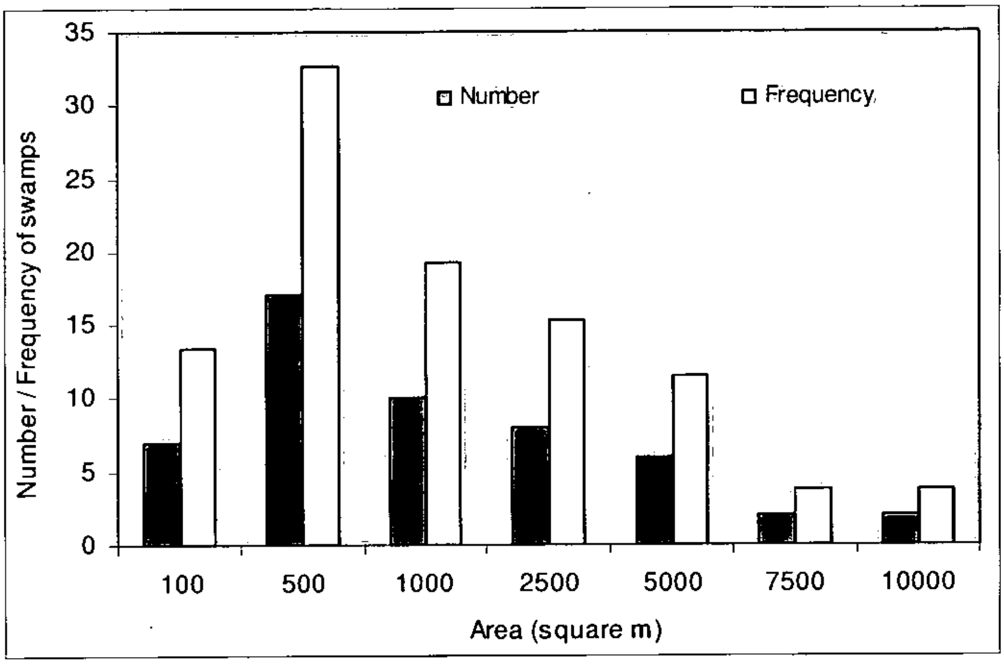


Figure 2.2: Frequency distribution of the area of *Myristica* swamps (n=56) in the central Western Ghats.

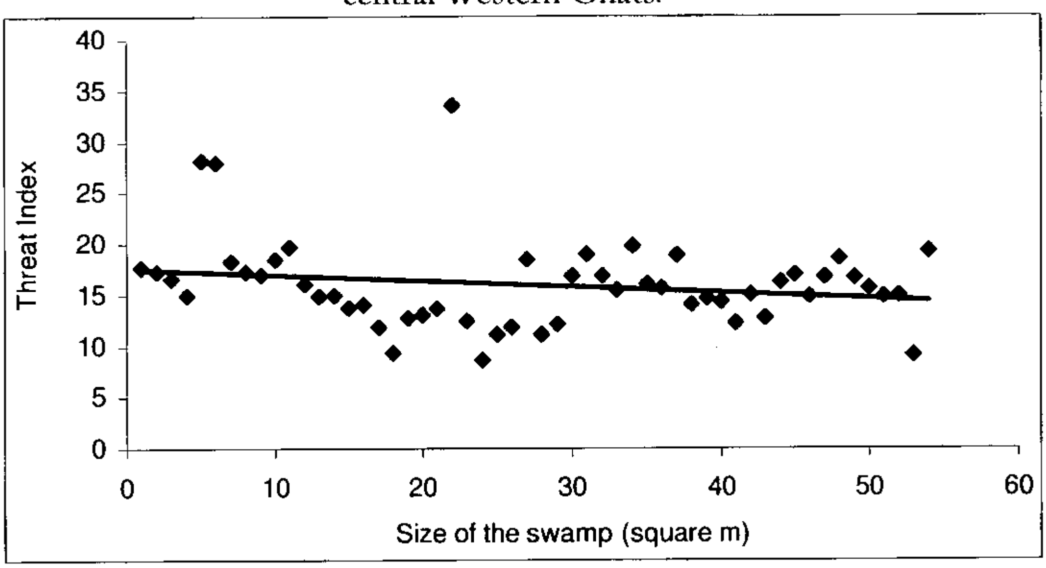


Figure 2.3: Relationship between the threat index and area of the swamps (n=56)

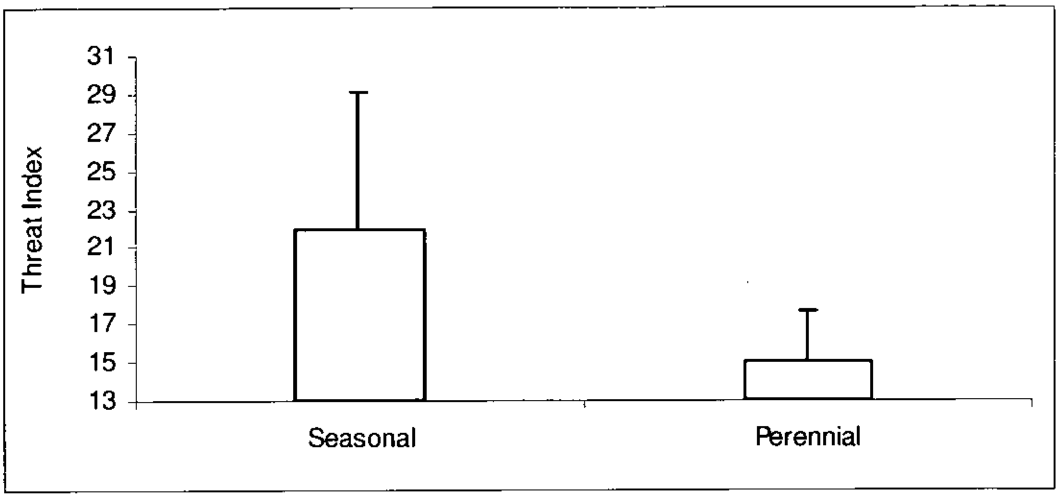


Figure 2.4: Relationship between the water sources of the swamp and threat index (t-test $P<0.05$)

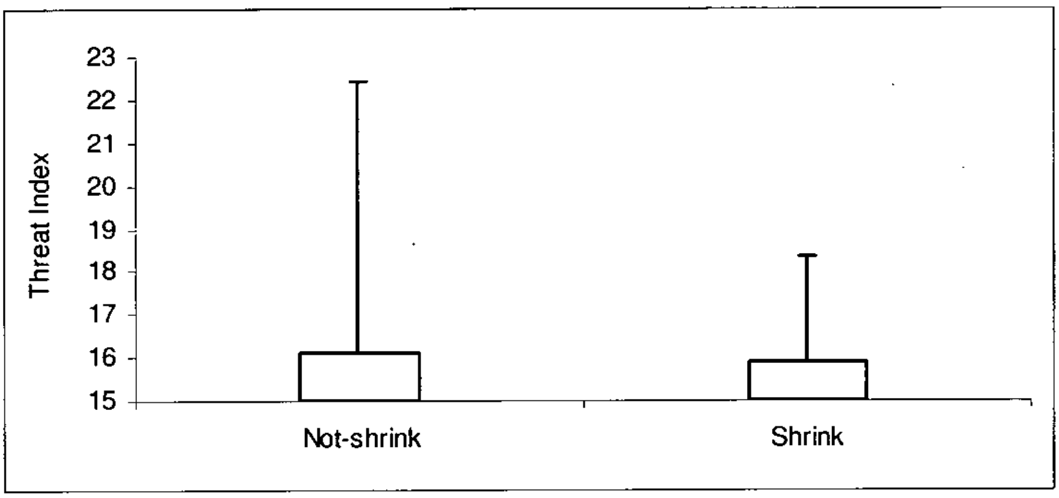


Figure 2.5: Threat index of swamps that had visibly decreased in area (Shrunk) compared to those not (Not shrunk) (t-test=NS).

Objective 3

To inventorize and determine the demographic profile of the species endemic to the swamps for prioritising species for conservation.

Introduction

In the wake of the threats to the swamps, it is likely that several vegetation features such as species richness and diversity might also be affected. Further among the species, it is also likely that certain guilds of species might be more sensitive to the factors threatening the swamps than are others. Poor regeneration or recruitment of species in swamps, which are threatened, could also progressively lead to the local loss of species. In this study we have prepared an exhaustive inventory of the species in the swamps and have addressed questions pertaining to species richness and diversity, sensitivity of species to threat and conservation worthiness of swamps.

Inventory of Floral and faunal diversity of swamps

Materials and Method:

Floral Diversity:

Based on the size and level of threat, eighteen swamps were selected in the central Western Ghats (Table 3.1). For the comparison selected swamps have been classified as small, medium and large based on the area (Table 3.2). In each of the swamps, floral diversity (higher plants) and various demographic parameters (girth class distribution of stems, tree density, regeneration etc.) were measured by laying quadrates of 100 m^2. Depending on the size of the swamp we laid different number of quadrates; in small swamps the entire area was enumerated where as in large swamps maximum of 25 quadrats were laid. In each of the quadrat four 1 m^2 nested quadrates were laid to assess the regeneration status of species.

Analysis:

Girth class distribution of stems: Based on the quadrat data, frequency distribution of the various size classes of stems over all species was arrived at. The frequency distribution of stems was compared across the area of the swamps using Kolgomorov-Smirnov Test (Siegel and Castellan, 1988).

Frequency of species: For each species the frequency of occurrence was computed as the ration between numbers of stems of a given species to the total number of stems of all the species in that swamp.

Richness and Diversity indices: Based on the quadrat data, species richness and diversity parameters were computed following the PopTool (2000) software.

Species richness: The species richness of a swamp was determined by the total number of unique species present in that swamp.

Species richness index : As a measure of species richness (RI) index, Margalef's index (Ludwig and Reynolds, 1988) was computed as:

$$RI = \frac{(\text{Number of species in a swamp} - 1)}{\text{Log (Abundance)}}$$

where, the number of species in a swamp was recorded as the total number of unique species in the swamp and abundance as the total number of individuals in a swamp.

Species Diversity index: The number of individuals of a given species was summed over all the quadrats and their respective proportion computed. Using this proportion, as a measure of the species diversity, Shannon's diversity index was computed as,

$$I = -\sum_{i=1}^{\infty} p_i \log p_i$$

Where, p_i is the frequency of the i^{th} species.

Evenness index: The evenness index (EI) was calculated following two approaches (Ludwig and Reynolds, 1988)

$$EI = \frac{\text{Log (Diversity of a swamp)}}{\text{Log (Total number of species in the same swamp)}}$$

where, diversity of the groves refers to the Shannon's Diversity Index (see above).

Table 3.1. Details of the swamps selected for vegetation analysis

Sl No	Swamp name	Village	Area (m^2)	Status	Latitude ^{0}N	Longitude ^{0}E	Altitude (ft)
1	Harelelekodlu	Harigar	500	SHD	14^{0}25'032"	74^{0}45'736"	1799
2	Hudhottale	Somankuli	300	SHD	14^{0}16'637"	74^{0}46'803"	2001
3	Mundigetota	Hadrimane	600	SHD	14^{0}23'964"	74^{0}45'626"	1611
4	Rinbekodlu	Unchelli	500	SLD	14^{0}24'918"	74^{0}45'037"	2155
5	Tormekodlu (S)	Thorme	800	SLD	14^{0}16'691"	74^{0}46'005"	1854
6	Chikanakodlu	Kanhalli	650	SLD	14^{0}17'108"	74^{0}45'205"	2356
7	Balehaklu	Harigar	800	MHD	14^{0}24'988"	74^{0}46'677"	2219
8	Guledhonda	Harigar	800	MHD	14^{0}25'000"	74^{0}46'121"	1795
9	Manidam (S)	Mastikatte	800	MHD	13^{0}68'725"	75^{0}03'272"	1983
10	Darbejaddi	Unchelli	800	MLD	14^{0}25'967"	74^{0}46'097"	1590
11	Malemane-I	Hejini	1400	MLD	14^{0}16'340"	74^{0}44'652"	1757
12	Malemane-II	Hejini	1700	MLD	14^{0}16'465"	74^{0}44'695"	1735
13	Kathlekhan (D)	Hejini	1325	LHD	14^{0}16'404"	74^{0}44'850"	1829
14	Sirilkhangavi	Somkuli	2150	LHD	14^{0}16'616"	74^{0}46'943"	2005
15	Thormekodlu (L)	Thorme	1700	LHD	14^{0}16'705"	74^{0}46'026"	2823
16	Manidam (L)	Mastikatte	2400	LLD	13^{0}68'725"	75^{0}03'272"	2030
17	Hulikal	Hulikal	2500	LLD	13^{0}71'841"	74^{0}99'821"	2063
18	Kathlekhan (LD)	Hejini	2200	LLD	14^{0}16'444"	74^{0}44'739"	1721

(SHD = Small Highly Disturbed, SLD = Small Less Disturbed, MHD = Medium Highly Disturbed, MLD = Medium Less Disturbed, LHD = Large Highly Disturbed, LLD = Large Less Disturbed)

Table 3.2. Categorization of swamps based on area

Category	Disturbance level	Area
SMALL	High / Low	< 500 m^2
MEDIUM	High / Low	500 m^2 - 2000 m^2
LARGE	High / Low	>2000 m^2

Fauna diversity:

To assess the faunal diversity in the swampy habitat, we adopted different sampling strategies in order to suit the target taxonomic group. In the selected swamps, avifaunal diversity (Birds) was assessed by adopting point sampling method and the details are provided in the table (3.3). To assess the butterfly diversity in the swamps, line transact of variable lengths were laid depending size of the swamps. For amphibians, quadrates of size 100 m^2 were laid and species within the quadrates were enumerated. In order to avoid over or under sampling, the number of quadrates/ transact/ point count were varied in proportion to the area of the swamps sampled.

Table 3.3: Details of sampling method and data analysis of various taxonomic groups

Group	Sampling details	Analysis
Amphibians	■ Quadrats of 10 m were searched in swamp and in the forest floor. ■ All species seen were collected, identified and released back. Doubtful specimens were stored in 70% ethanol. ■ Canopy cover, shrub and herb cover, flow, substratum type etc were recorded ■ Sample size: Large: 6; Medium: 6 and Small: 6	• **Diversity analysis** a) Shannon diversity b) Species richness c) Abundance d) Morisita-Horn Similarity Index • **Basic statistics** a) One way ANOVA between size categories b) Student's T-test between size categories c) KS test for frequency distribution Using software a PopTool
Birds	■ Sampled between 7:00 AM to 10:00 AM ■ Point count of 5 minutes in swamp and in the forest were done ■ Minimum distance of 150 m from each point ■ Minimum of 2 points per swamp ■ Sample size: Large: 6, Medium: 4 and Small: 3	
Butterfly	■ Morning from 10:00 AM to 12:00 noon. ■ Line transect of variable length ■ One transect in swamp and two in forest ■ Sample size: Large: 6; Medium: 4 and Small: 4	

Results:

Does area of the swamp influence the species richness and diversity?

Flora:

A total of 233 species have been identified from, in and around the swamps. Species richness and diversity of the swamp is generally less compared to the adjacent forest. A minimum of 35 species was recorded from the small swamp compared to a maximum of 104 from a large. The mean species richness and diversity tend to increase significantly with area of the swamp (Figure 3.1 and 3.2). However, there was no difference in species richness parameters with respect to levels of disturbances of the swamps. The girth class distribution of stems and evenness index were also found to be similar across the size class of the swamps (Figure 3.3 and 3.4) and across disturbance level (data not shown).

Fauna:

In the study area, 26 species of amphibians, 52 species of birds and 63 species of butterflies have been recorded. The species richness and diversity of the Amphibians (Figure 3.5 and 3.6), birds (Figure 3.7 and 3.8) and butterflies (Figures 3. 9 and 3.10) increased with the area of the swamp though not statistically significantly.

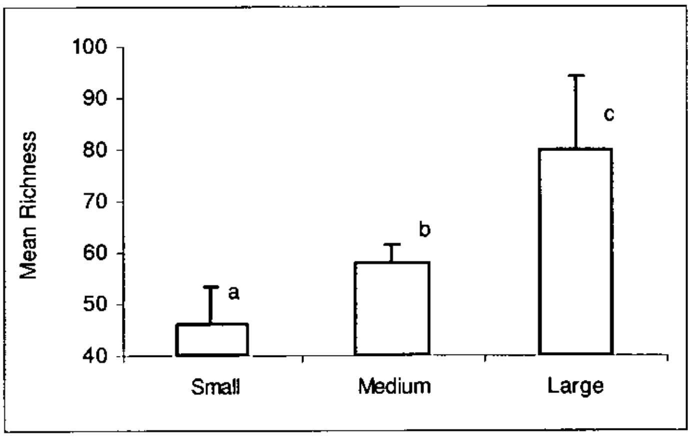


Figure 3.1. Mean plant species richness across the size class of the swamps (Dissimilar letters indicate t-test significant at p<0.05).

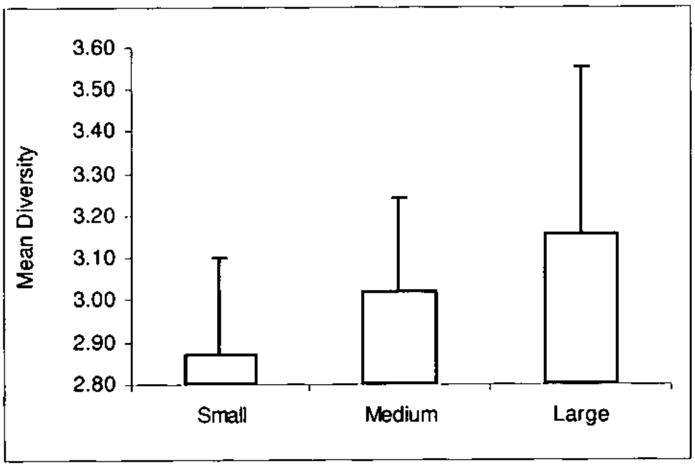


Figure 3.2. Mean Shannon's diversity of species across the size class of the swamps (t-test =NS).

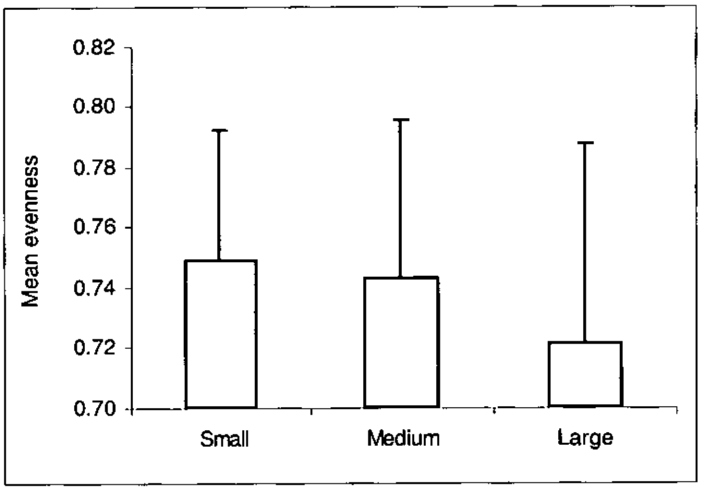


Figure 3.3. Mean evenness index across the size class of the swamps (t-test =NS).

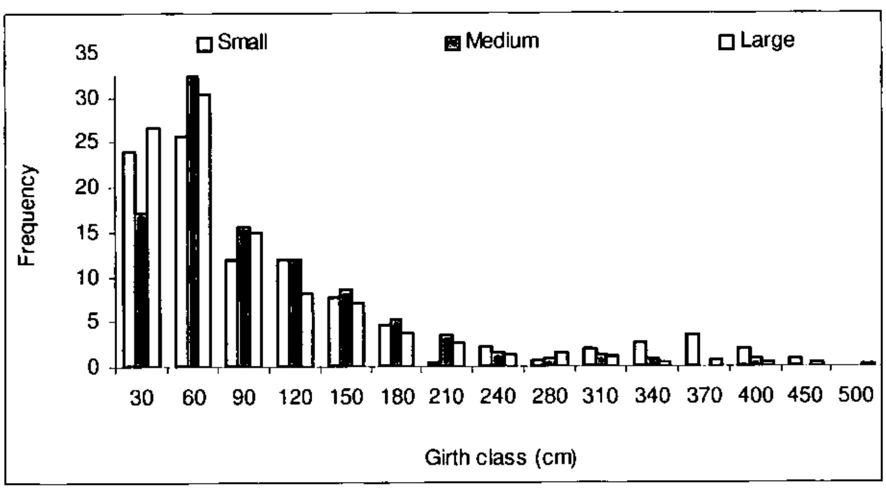


Figure 3.4. Girth class distribution of stems across the size class of the swamps (KS-test=NS)

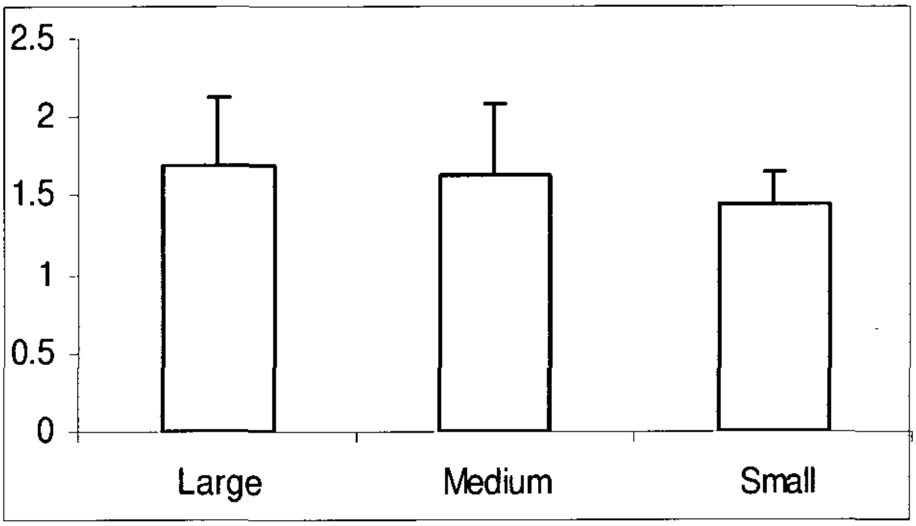


Figure 3.5 Amphibians Shannon's diversity Index (ANOVA F=1.130 P=0.353)

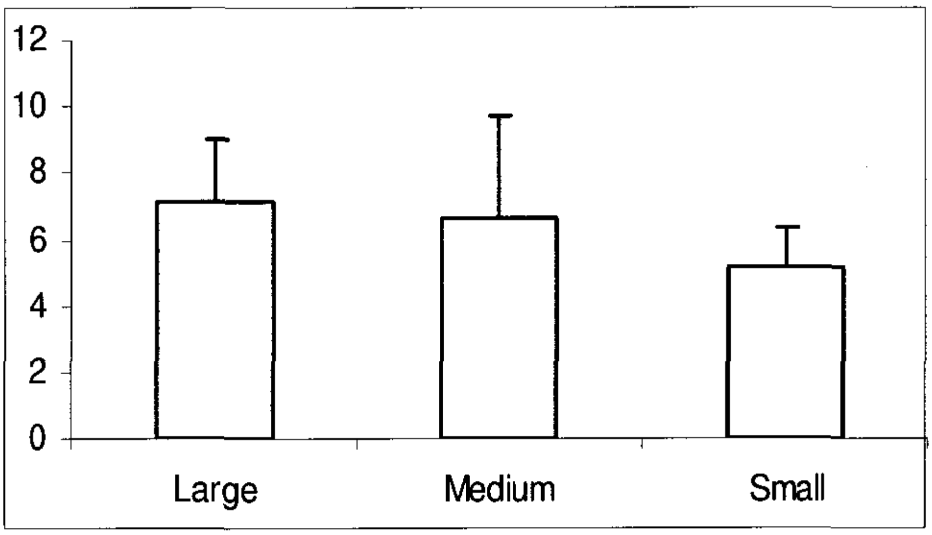


Figure 3.6. Amphibians species richness across the swamp size

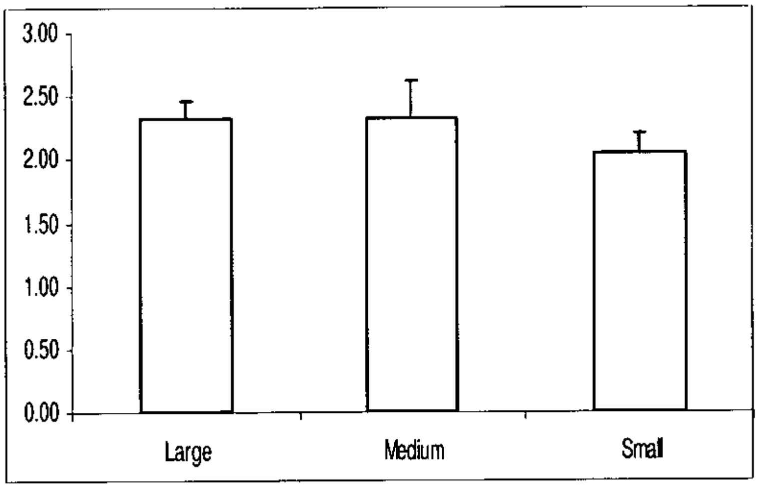


Figure 3.7. Bird's Shannon's diversity Index across swamp size (ANOVA F=2.117 P=0.171)

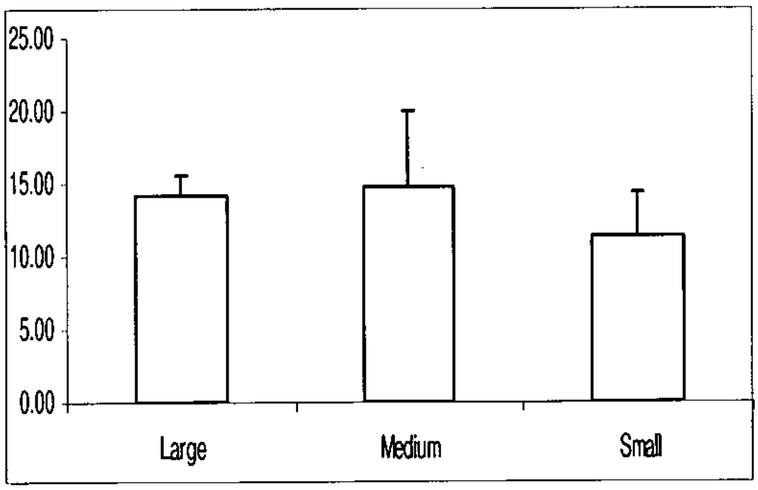


Figure 3.8. Birds species richness across the swamp size (ANOVA F=0.864 P=0.451)

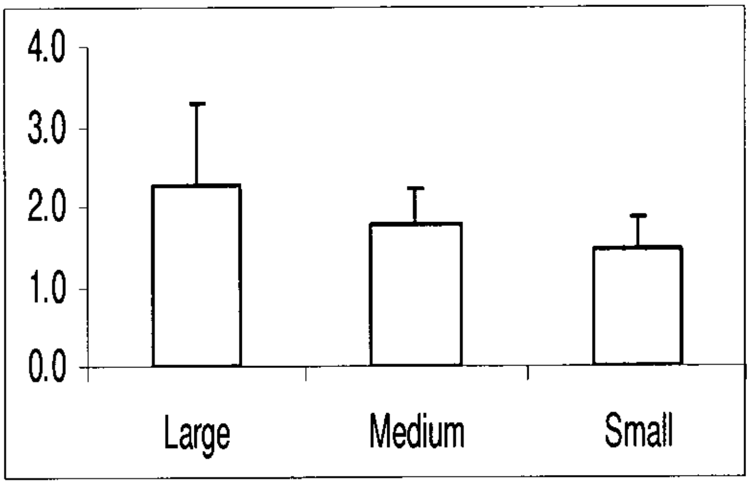


Figure 3.9. Butterflies Bird's Shannon's diversity Index across swamp size (ANOVA F=2.023 P=0.179)

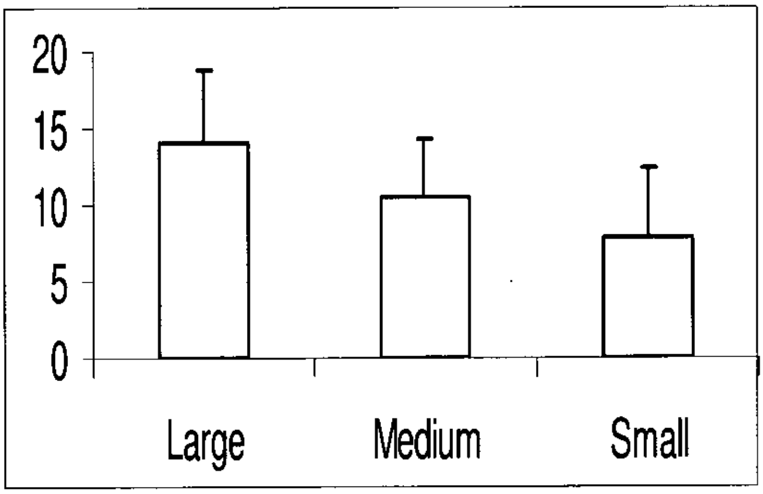


Figure 3.10. Butterfly species richness across the swamp size (ANOVA F=2.573 P=0.121)

Are small swamps similar in their species composition?

Introduction

Myristica swamps are one of the unique ecosystems, usually hidden in the wet evergreen forests of the Western Ghats. The swamps are of size ranging from a few square meters to few hectares. The specific habitat requirements and specialized species composition of swamps are distinct from the adjacent forest. The swamps generally, behave as islands in the wet evergreen forest of Western Ghats. The Island Biogeography theory (IBG) predicts that as island size increases the number of species in an island also increases depending on the carrying capacity. However, it does not provide information on species composition of the islands. In order to maximize the conservation efforts and conserve the greater diversity, in this regard Ganeshaiah et al (1997) predicted and showed that a set of smaller islands would harbour great diversity among them selves than a set of larger islands. Thus few small islands together would help to conserve more species than a collection of large swamps. In this section, we test the predictions of Ganeshaiah et al (1997) with regard to the species composition of the swamps.

Materials methods:

Proportion of species shared: The proportion of species shared between any given pair of swamps was computed as the ratio of number of species common to a given pair of swamps to the total number of species from the same pair of swamps. (Ganeshaiah *et al*, 1997).

Similarity Index (Correlation coefficients of the frequencies of species): The similarity Index or correlation coefficients between the frequencies of the species between any two swamps of a given size category was analyzed to indicate the extent of similarity between the swamps. (Ganeshaiah *et al*, 1997).

Frequency distribution of the proportion of species shared and similarity index: The frequency distribution of the proportion of species shared for small, medium and large swamps was arrived at and statistically compared using the Kolgomorov-Smirnov Test (Siegel and Castellan, 1988).

Results:

Proportion of species shared: The mean proportion of species shared among the set of large swamps was higher compared to the smaller swamps (Table 3.4). On an average, the proportion of species shared among large swamps was 40 per cent compared to about 28 per cent among the small swamps. These results indicate that smaller swamps are more diverse among themselves in terms of their species composition compared to larger swamps (Figure 3.11).

Similarity index: Based on the frequency of species occurrence, similarity index was calculated within each size class of the swamps. The mean similarity index was also found to higher among larger swamps compared to that among smaller and medium sized swamps (Table 3.4). In other words, a given pair of larger swamps is more similar with respect to each other compared to a pair of smaller swamps (Figure 3.12).

Frequency distribution of proportion of species shared and similarity index: The frequency distribution for the proportion of species shared and similarity index (i.e. correlation for the frequency of species occurrence) for each size class of the swamp was computed. The frequency distribution of proportion of species shared was positively skewed for the smaller swamps indicating the smaller swamps are more diverse among themselves with respect to the proportion of species shared. On the other hand, the frequency distribution for the proportion of species shared was negatively skewed for larger swamps (Figure 3.13). However, the pattern was not very clear for the frequency distribution of the similarity index among swamps (Figures 3.14). The frequency distribution of both similarity index and proportion of species shared was compared across the size using the KS test (Table 3.5).

Table 3.4. Similarity index and proportion of species shared among the swamps of similar size.

				Proportion of species shared		Similarity index	
	No. of swamps	No. of pairs	Size (m^2)	Mean	SD	Mean	SD
Small	6	15	< 500	0.2775	0.0479	0.3696	0.1736
Medium	6	15	500 to 2000	0.2944	0.0667	0.3295	0.2082
Large	6	15	> 2000	0.4001	0.0696	0.4554	0.2174

Table 3.5. Results of KS-test and D max values for similarity index and proportion of species shared.

	Proportion of species shared	Similarity index
Small Vs Large	0.72 (< 0.05)	0.17 (NS)
Medium Vs Large	0.60 (< 0.05)	0.23 (< 0.05)
Medium Vs Small	0.17 (NS)	0.21 (< 0.05)

A long-standing debate in conservation of fragments has been the classic several small or single large (SLOSS) issues. In this study we have addressed a slightly different debate – that of a collection of small versus a collection of large swamps. As mentioned elsewhere, our study has shown that the proportion of species shared and the correlation for the frequency of species increased with the size of fragments. Further the co-efficient of variation for the proportion of species shared and similarity index decreased with the fragment size. That is, in contrast to the existing intuitive notion that small fragments (swamps) may not be conservation worthy, our study indicates that, smaller swamps are more diverse among themselves with respect to their species composition than the larger swamps. Hence we argue that conservation of few smaller swamps that will conserve more diversity is, if not more, equally important as is the conservation of larger fragments (swamps).

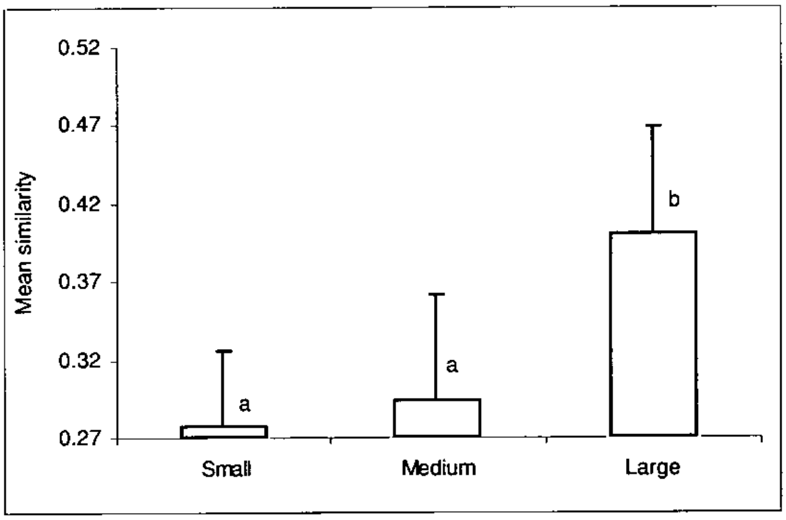


Figure 3.11. Proportion of species shared across the size class of the swamps (Dissimilar letters indicate t-test significances at $p<0.05$)

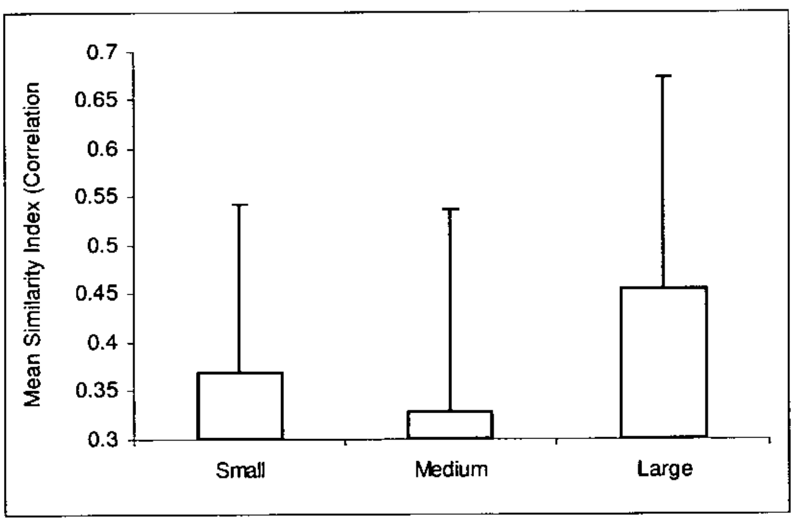


Figure 3.12. Mean correlation for the frequency of species across the size class of the swamps (t-test=NS)

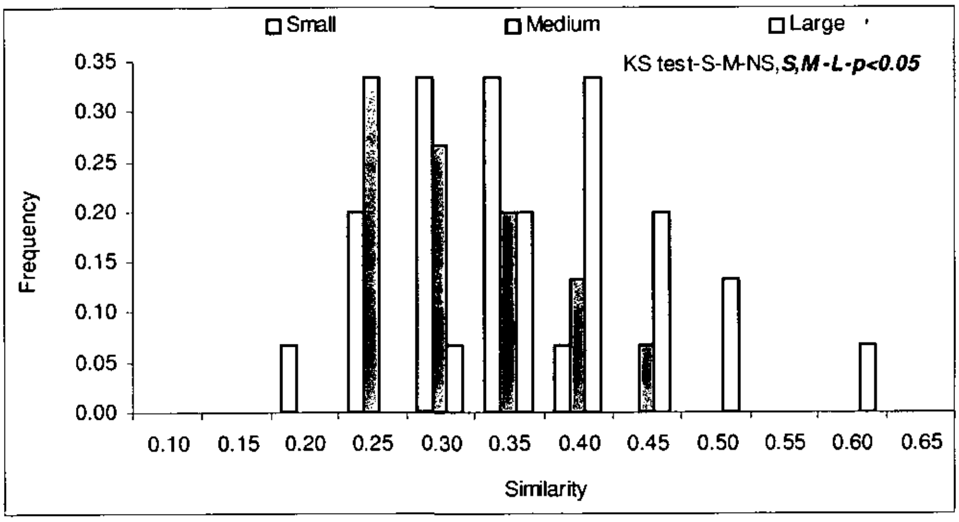


Figure 3.13. Frequency distribution of proportion of species shared across the size class of the swamps

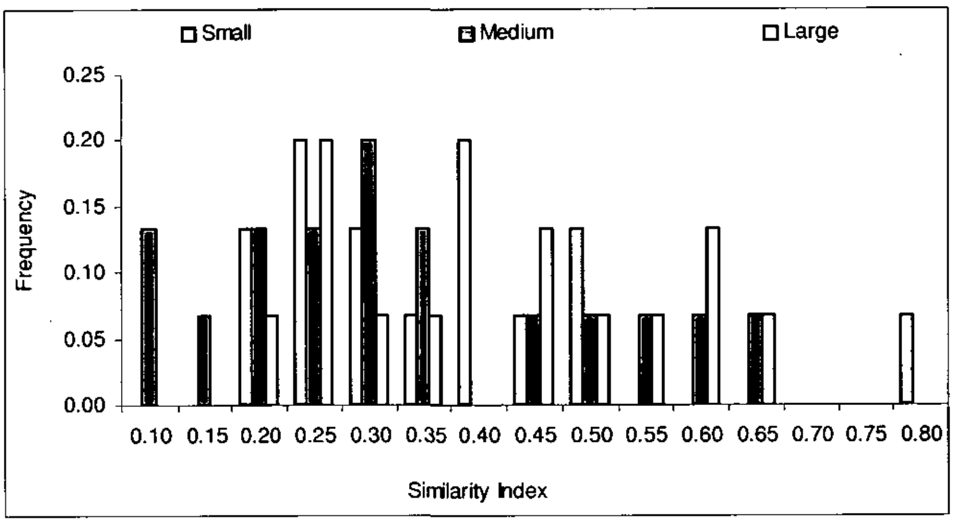


Figure 3.14. Frequency distribution similarity index (correlation for the frequency of species) across the size class of the swamps.

Are swampy species threatened?

Introduction

Myristica swamps harbor some of the rare-relic floristic composition comprising a large number of threatened plant species in the Western Ghats (Vasudeva *et al*, 2001). Many of the tree species in these swamps are highly restricted in their distribution and have several physiological and structural modifications to survive in the anaerobic conditions. However, because of pressure on land many of these swamps have been over the years subjected to extensive destruction and are converted to either arecanut plantations and/or for paddy cultivation (Krishnamoorthy, 1960, Champion and Seth, 1968, Chandran *et al*, 1999, Chandran and Mesta, 2001). Ramesh *et al* (1997) have reported that many potential swamps have been converted into rice fields, oil palm and teak plantations. Since these tree species are highly adapted to the swampy conditions, drying of swamps would lead to extinction of these species (Nair and Daniel, 1986). Drying up of soil in certain parts of the swamp has led to many of the swamps being invaded by other non-swampy species. Many of these non-swampy species have successfully established in these swamps. In this section we examine and compare the structure and status of swampy and non-swampy species across the swamp area.

Materials and method:

The vegetation composition of the swamp was enumerated by laying 100 m^2 quadrats; vegetation in the adjacent forest was recorded by laying 10 X 50 m transact (i.e. 100 m^2 5 quadrats in a series) in three directions starting from the periphery of the swamp. Totally, 204 quadrats were laid in selected 18 swamps and 250 quadrats outside or adjacent to the swamps (non-swampy habitat). Frequency of occurrence for each species (mentioned earlier) was computed by pooling the data over all the quadrats (separately for swamps and non-swampy habitat). To identify the obligate swampy species, per cent swampyness for each species was computed using the formula as follows;

$$\text{Per cent Swampyness} = \frac{\text{Frequency of species (in swamp - outside the swamp)}}{\text{Frequency of species in swamp}} \times 100$$

Girth class distribution of swampy and non-swampy species across the area of swamps: The per cent swampyness for each of the species was computed and obligate swampy species were short listed. The girth class distribution of swampy (i.e. species that has > 90 %

swampyness index) and non-swampy species was computed and the distribution pattern of stems was compared across the size class of the swamp.

Per cent distribution of swampy species across the area of swamp and level of disturbance: The number of stems in each swamp was categorized as swampy and non-swampy based on per cent swampyness. Per cent distribution of swampy and non-swampy individuals was computed for each of the swamps and compared across the size and level of disturbances.

Results:

Swampyness: Based on the frequency of species in the swampy habitat and in the adjacent non-swampy habitat, swampyness of the species was arrived at. If a species occurs only in the swampy habitat and not under non-swampy conditions it was regarded as obligatory swampy. On the other hand if a species occurs only in the adjacent non-swampy area and not within the swamps, it was regarded as non-swampy. Species that located themselves in either of the habitats (swampy and non-swampy) were regarded a facultative and the degree of their affiliation is defined by their frequency abundance in the respective habitats. (Table 3.6).

Girth class distribution of swampy and non-swampy species: Girth class distribution of swampy and non-swampy species indicated that, in swamps only the swampy species exits with higher girth class (KS-test $p<0.05$; Figure 3.15). The pattern seems to be consistent across the size class of the swamps (Figure 3.16 and 3.17). Intriguingly, with increase in area of the swamps there was a decrease in regeneration of swampy species. However the per cent saplings (or pole stage) increased with area of the swamps (Figure 3.18).

Percentage of swampy and non swampy species: The percentage of stems belonging to swampy and non-swampy species was assessed, and compared across the size class of the swamps. Our results indicated that, across the size of the swamps there is no observable change with respect to the number of stems of swamp species (Figure 3.19). Per cent swampyness of swamps was also compared with respect to level of disturbance. There was no significant difference in the per cent abundance of stems of swampy species across the different levels of disturbance (Figure 3.20).

Table3. . List of few species with their swampyness index

Sl. No.	**Species**	**% Swampyness**
1	*Myristica fatua* var. *magnifica*	100
2	*Gymnacranthera canarica*	98
3	*Semecarpus kathalekanensis*	98
4	*Calamus laciferus*	97
5	*Mastigxia arborea*	97
6	*Elaeocarpus tuberculatus*	89
7	*Calophyllum apetalum*	79
8	*Symplocos racemosa*	78
9	*Fern sp.1*	78
10	*Zingiberaceae*	75
11	*Fern sp.2*	72
12	*Mesa indica*	68
13	*Pinnaga dicsonii*	62
14	*Panadanus sp*	58
15	*Lophopetalum wightianum*	54
16	*Fern sp.3*	42
17	*Calophyllum polyanthum*	31
18	*Holigarna arnotiana*	31
19	*Strobilanthus sp*	28
20	*Macaranga peltata*	27
21	*Calamus sp*	23
22	*Hopea ponga*	12
23	*Leea indica*	3
24	*Unidentified (A)*	3
25	*Humboldtia sp*	1

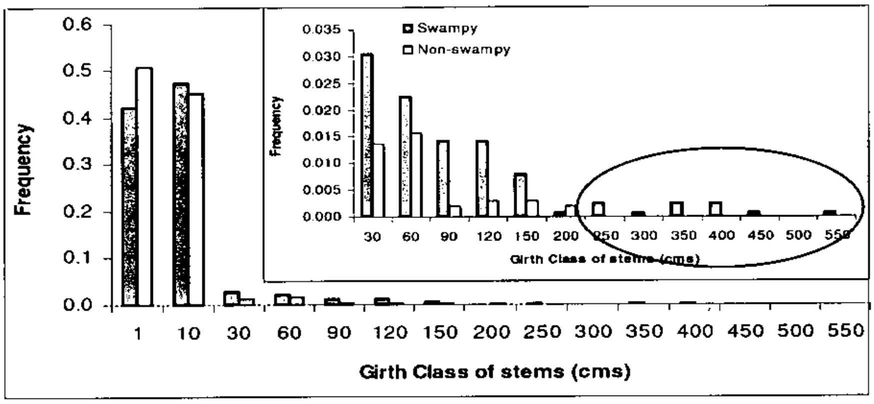


Figure 3.15. Girth class distribution of swampy and non-swampy species stems in small swamps.

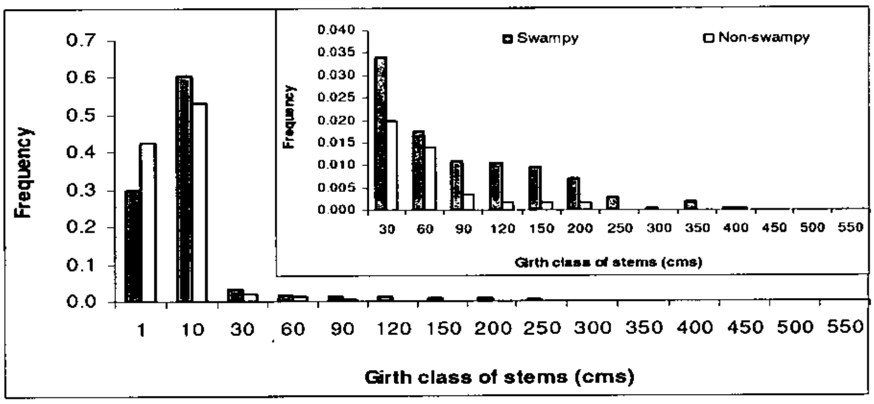


Figure 3.16. Girth class distribution of swampy and non-swampy species stems in medium swamps.

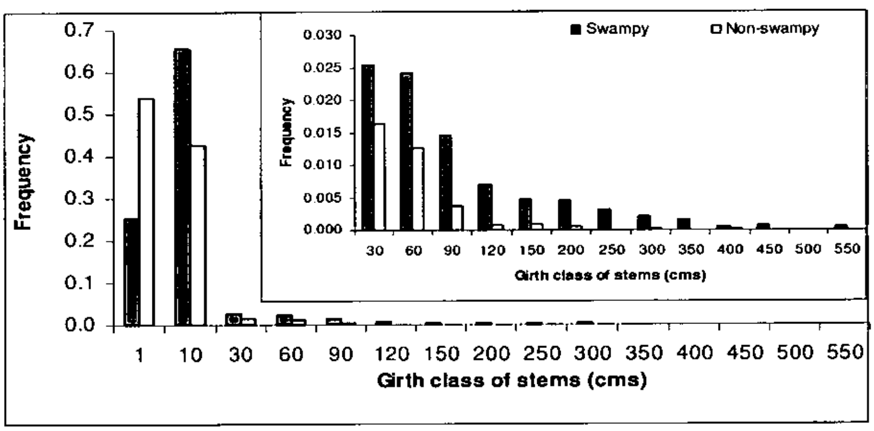


Figure 3.17. Girth class distribution of swampy and non-swampy species stems in large swamps.

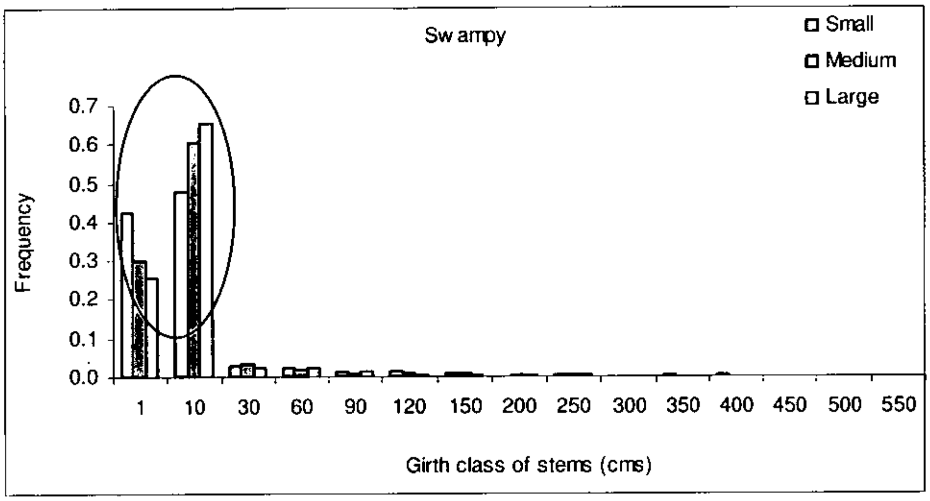


Figure 3.18. Girth class distribution of swampy species across the swamp size.

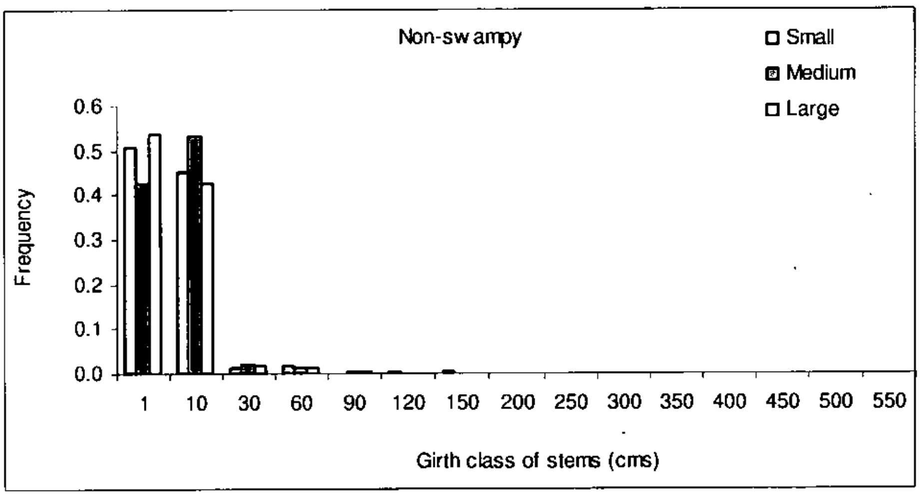


Figure 3.19. Girth class distribution of non-swampy species across the area of the swamp.

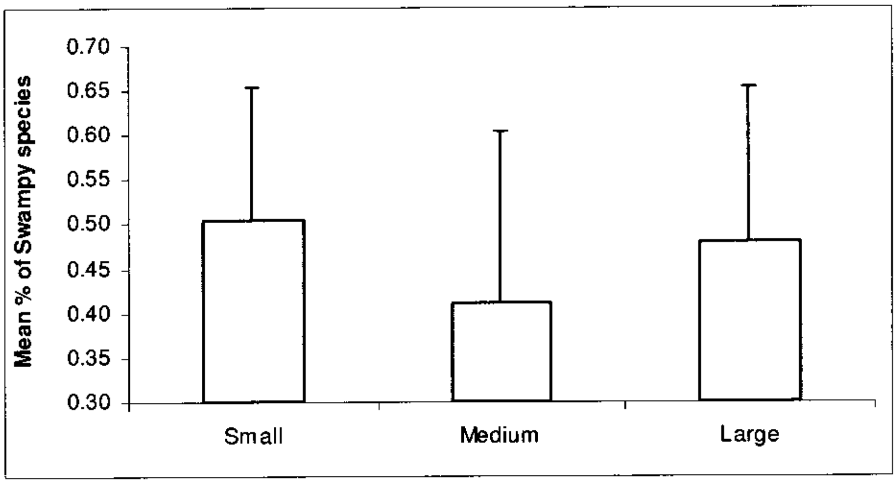


Figure 3.20. Percentage abundance of swampy species across the size class of the swamps in the central Western Ghats (t-test=NS).

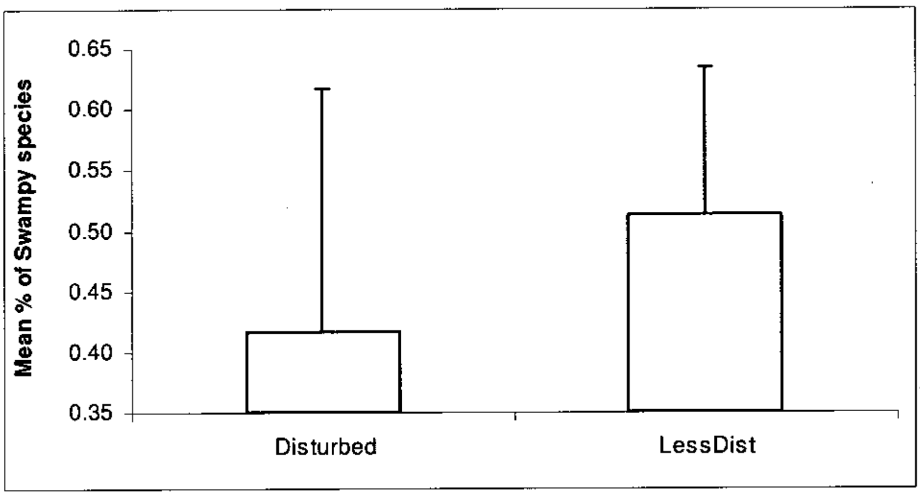


Figure 3.21. Percentage abundance of swampy species in disturbed (n=9) and less disturbed (n=9) swamps in the central Western Ghats (t-test=NS).

Objective 4

To formulate long-term strategies for the restoration and conservation of species endemic to the Myristica swamps.

The *Myristica* swamps are one of the oldest and unique habitats in the Western Ghats of south India harboring some of the most endemic species of the family Myristicaceae and Anacardiaceae. Besides these plants, the freshwater swamps are home to a number of fauna especially amphibians, reptiles and birds. In fact immediately preceding our work in the swamps, a new frog species, *Philatus* sp. was reported from these habitats. The swamps offer critical ecosystem services, including facilitating a high water table. In recent years however the swamps have been threatened and endangered due to encroachments, conversion of the swamps into the highly prized areacanut plantations and paddy fields, extraction of non-timber forest products including the arils of the *Myristica* fruits and finally diversion of the drainages for domestic and irrigation purposes. Indeed over the last couple of decades alone, it is feared that scores of the swamps have been lost to arecanut plantations and many more dried up due to diversion of the water drainages.

In the light of these concerns, our study offered to make a comprehensive understanding of the threats to the swamps and their species to arrive at strategic plans for the restoration of the unique habitats and their species. Some of the key findings that hold important implications for developing a conservation plan for the swamps are summarized here.

- ***Are there more swamps and where are they?***

One of the approaches to alleviating the problem faced by the threat to the swamps is finding out if there are indeed more swamps (than is known now) in the Western Ghats and where might be they located. Using recently available GIS software that offers predictions on the ecological niche of a species we have been able to delineate the probable occurrence of swampy habitat in the Western Ghats. A pilot exercise to test the prediction was performed and consequently 8 more new swamps of varying sizes were identified in the central Western Ghats.

The technique employed has opened up a rich possibility of discovering more of such unique habitats in the Western Ghats than has been known so far. Another successful finding that could be attributed to this modeling tool is the discovery of the 6th population of the species, *Semecarpus kathalekanensis* in the swamps of the central Western Ghats.

Implication: The implication of this work is self evident. We propose that such modeling tools could be used to carefully predict the potential niches for the swamps in the Western Ghats and attempt be made to ground truth them. This process could also lead to the discovery of newer populations of the swampy species as has been demonstrated by the discovery of the population of *Semecarpus* sp.

• *Drivers of threats to swamps*

One of the features that predispose the swamps to varying levels of threats is the fact that often a kaleidoscope of human activities is placed in close proximity to the swamps. Thus adjoining the swamps, there are either paddy field or other agricultural lands, plantations, human settlements, cattle grazing etc. Certain topographical features such as the altitude and distance from the nearest roads could secondarily modify and vary the threats received from human activities. Understanding these drivers might help influence plan the conservation in a way that can be long lasting and not succumb to the immediate threats. Using over 16 factors that could potentially threaten the swamps, we have arrived at a threat index for each of the swamp and have identified broad patterns of the levels of threats faced by the swamps. Thus while it might be expected that size of the swamp could be an important factor influencing a swamp's sensitivity to threat, there was no such clear pattern. Thus swamps, irrespective of their size were more or less equally prone to being threatened. An important finding was that swamps fed by seasonal waters were more threatened than are those with perennial source of water. Swamps that had visible signs of having decreased in size faced a greater degree of threat than those not having any such signatures.

Implications:

The assessment of threat to the swamps has led us to identify not only the major drivers of threat but also to prioritize swamps that are threatened and might be restorable. At important finding is that swamps are best restored and maintained at sites that are either farthest from the roads and in higher altitudes; these swamps would be relatively inaccessible for conversion to agricultural fields and perhaps also may ensure an uninterrupted drainage system. In fact perennial swamps stand a better chance of being conserved than the swamps fed by seasonal waters.

Are small swamps any worth conserving?

Small fragments compared to large fragments are often considered unworthy of conservation. The arguments stems from the assumption that small fragments may be more vulnerable to edge effects, genetic drift processes and above all being more prone for disturbances. While much of this assumption have been demonstrated in many fragment systems, a hitherto aspect of the small *vs* large fragments has escaped serious debate and consideration from the point of view of setting up conservation priorities. Island biogeography(IBG) theory proposed that small fragments compared to large would harbour a smaller number of species and thus perhaps the former may not compare with that of the larger as far as conservation plans go. However an important point not considered in the IBG is the composition of the small species pool. Ganeshaiah et al. (2001) showed that a group or collection of small fragments would be more diverse among themselves with respect to species composition compared to say a collection of large fragments. In other words they argued that from the point of holding on a greater diversity of species, a collection of smaller fragments indeed might be much more conservation worthy than a collection of large fragments. We tested this hypothesis in the swamp system using the plant species diversity as a case in point. Our studies showed that indeed a collection of small swamps harboured a greater diversity of swampy species (both obligate and facultative) than a collection of large swamps. Thus it appears that small swamps that otherwise might appear to be sensitive to extraneous pressures could be as conservation worthy than only the large swamps.

Implications:

The implication of this study is far reaching. Swamps are generally small. In fact the frequency distribution of the size of 56 swamps in the central Western Ghats was sharply positively skewed. In the light of our finding it makes a good argument to not neglect these swamps in favor of a few large ones. Rather the study offers a sound platform to seriously consider the conservation of a collection of small swamps, even though their management may be tedious.

Are swampy species threatened?

Being in close proximity and adjoining the forest and agricultural landscape, the species in the swamps are fraught with the danger of being usurped by the non-swampy species. Thus while the swamps might themselves be vulnerable to extraneous pressures, the species in them could be vulnerable due to competition from the non-swampy species. We examined the relative abundance of the swampy and non-swampy species in swamps in the Western Ghats. While substantial inroads have been made by non-swampy species, it appears that because of their adaptability, the swampy species are still by far the most abundant of the plants in the swamps. An intriguing feature however was that the relative abundance of the swampy species decreased with the size of the swamp. Species in small swamps were in fact less prone for invasion compared to those in large swamps. The underlying reason for this seems to be that smaller swamps usually are swampier than the larger ones which not infrequently have a number of less swampy patches.

Implications:

Swampy species by themselves do not seem to be under serious threat either due to lack of regeneration or being out competed by non-swampy species. In that context, the conservation of the swampy species might not be as challenging as that facing the conservation of the swamps themselves. However the study does point to the fact that in the larger swamps or in swamps that are drier there might be a real danger of extinction of the swampy species.

Strategies for restoration and conservation: National agenda for the conservation of unique and critically endangered habitats and their species.

Based on the outputs of the study several strategies for the restoration and conservation of the *Myristica* swamps are in order. We briefly discuss these and highlight the initiatives that have already been taken in the project period.

One of the major strategies for the restoration and conservation of the swamps is to develop a National agenda for the conservation of unique and critically endangered habitats and their species in the country. We argue that only under such an institutional authority can effective conservation be implemented. The national agenda will help develop a comprehensive strategy and action plan for the long-term conservation of swamps and their genetic resources in the central Western Ghats. The specific tasks that can be charged for the restoration and conservation of the swamps are:

- *Discovery of newer swamps and species occurrence:* As mentioned earlier, there is little documented information on the occurrence of the *Myristica* swamps in the Western Ghats. It is proposed that an exhaustive mapping of the swamps be undertaken that shall provide spatially explicit information on the distribution of the swamps in the Western Ghats.

- *Development of corridors between fragmented swamps:* From studies such as ours, several examples of swamps have been found that have been fragmented either due to diversion of drainages or encroachment. It is suggested that where possible, such swamps be identified and enable corridors between the swamps. This would require the mediation of the local forest department and the local communities.

- *Development of restoration protocols for the swampy tree species:* For the purposes of restoration there is a need to develop restoration protocols for the endemic swampy species. In fact the need is all the more urgent in case of endemic tree species. Protocols for the multiplication of the species will be an essential prerequisite for the conservation of the species.

• *Recreation of swamps in the Western Ghats:* As a possible step in aiming at the long term conservation of both the habitat and the swampy species it is suggested that locations be identified where the swamps could be recreated and the species conserved. This strategy could possibly avert in the long run the threats to the swamp and their species.

• *Process involving the local community:* As most of the existing swamps have a proximate and heavy interface of the local community, a strategic alliance would be to create awareness in the local community of the need to conserve the swamps and if need be to institute some incentive to conserve.

Initiatives towards conservation of swamps

Based on our findings and interaction with the local communities several initiatives have already been taken. A brief overview of these initiatives is presented here.

Restoration of critically endangered species of Myristica swamps in the central Western Ghats.

We have initiated a restoration program in the Kudremukh Iron Ore Company Limited in the central Western Ghats (13^0 01'00" to 13^{0}29'17" and 75^0 00'55" to 75^0 25'00"). The forests in this region act as water shed for two major rivers, Tunga and Bhadra, and accordingly could be home to a potentially large number of swamps.

Based on the suitability of the habitats, three sites in the forest have been identified. Eleven species including three endemic and swampy species *viz. Myristica fatua, Gymnacranthera canarica, Semecarpus kathalekanensis* have been selected for being restored in the three sites. To date, over 6000 seedlings/saplings have been raised in nurseries and the first phase of the restoration is shortly going to be taken up.

Dialogue with the forest department and the local community:

As a means to transmit the urgency of the need to conserve the swamps several meetings and interactions have been had with the local forest department and the local community impressing on both the need to conserve the swamps. These interactions have been very fruitful and people have started to look at the issue enthusiastically, though no tangible outcome has so far emerged.

Personnel:

1. ***Project leader.***
   Bhausaheb Tambat (28)
   Research Scholar, Department of Crop Physiology
   University of Agricultural Sciences
   Bangalore - 560 065, India.
   Experienced in field studies on plants, statistical analysis and an expert in molecular marker techniques such as RAPD, CAPs and Allozymes

2. ***Co-Project leader.***
   Dr. Ravikanth G. (30)
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3. ***Team members***
   a. Dr. Nageswara Rao M. (29)
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      Expert in molecular marker techniques like Isozymes, RAPD, CAPs, AFLP, Microsatellites and protein chemistry.

   b. Chaithra G. N. (24)
      Research Scholar, Department of Bio-Sciences, Mysore
      Expert in molecular marker techniques such as Isozymes, RAPD, CAPs, SDS page and chromatographic techniques.

   c. Ramesh B. T. (22)
      Master Degree in Science, Department of Crop Physiology University of Agricultural Sciences
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      Experienced in molecular marker techniques like RAPD and CAPs

Research Advisor:

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Public awareness:

The project outputs will be presented to the Government and other related Non-government agencies concerned. The results of the study will be shared with the scientific communities in the form of proceedings, reports and research papers. General awareness to the local community with regard to conservation of *Myristica* swamps has been carried out through interaction meeting at Sirsi, Forestry College and Local Village Panchayath office. Further, using the mass media the awareness with regards to the conservation of swamps shall be continued.

Salient findings:

1. Discovery of new swamps in the central Western Ghats
2. Discovery of an additional population of *Semecarpus kathalekanensis*
3. Recreation of three swamps in central Western Ghats
4. Identification of new *Gymnacranthera canarica* mutant.
5. Nursery multiplication of 6000 saplings of 12 swampy species for restoration
6. Identified drivers of threats to swamps
7. Swamps with seasonal water source are more threatened than those fed by perennial water source.
8. A set of small swamps are as conservation worthy as are a collection of larger swamps
9. Demographic profile of swampy and non-swampy species assessed across size and disturbance gradient of swamps.
10. Creation of awareness of the ecosystem services of swamps
    - Ground water table
    - Fauna and flora
    - Soil and water conservation
    - Breeding grounds for many amphibians and reptiles
11. Graduate students of Forestry College, Ponnampet, UAS Bangalore and Forestry College, Sirsi, UAS Dharwad have been trained in field sampling techniques and GIS technology.

Local participation and Approval

The project has support from the Forest Department officials and University of Agricultural Sciences, Bangalore and Dharwad. Besides, the team has

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Statement of Expenses for the projet tilted " Conservation of Myristica Swamps -The highly threatened and unique ecosystem in the Western Ghats, India

ITEMS	BUDGET IN POUNDS	TOTAL APPROVED BUDGET IN US DOLLARS	FUNDS RECEIVED (IN US DOLLARS)	EXPENDITURE (IN US DOLLARS)	BALANCE
			A	B	(A-B)
CONSUMABLES					
Stationery	500	755	566	773	-207
Computer accessories, internet charages, phone etc	300	453	340	441	-101
Acquirng maps, data from consemed Departments	400	604	453	647	-194
and resource personnel					
SALARIES AND WAGES					
Field assistanats and local guide	400	604	453	619	-166
FIELD EXPENSES					
Personel cost	800	1207	905	1197	-292
Vehicle rent and accomadation	400	604	453	593	-140
EQUIPMENTS					
Data logger and acessories, GPS, Digital Camera,	2950	4452	3339	4385	-1046
other minor equipments					
DOCUMENTATTION					
Documentation and Report writing	300	452	340	486	-146
ADMINISTARATIVE OVERHEAD					
15% of the total budget	908	1369	1027	1369	-342
Total	**6958**	**10500**	**7875**	**10510**	**-2635**

Gladwin Joseph
Dr. Gladwin Joseph
Director

T.R.Gopi
T.R.Gopi
Senior Accountant

Date: 10-3-2005

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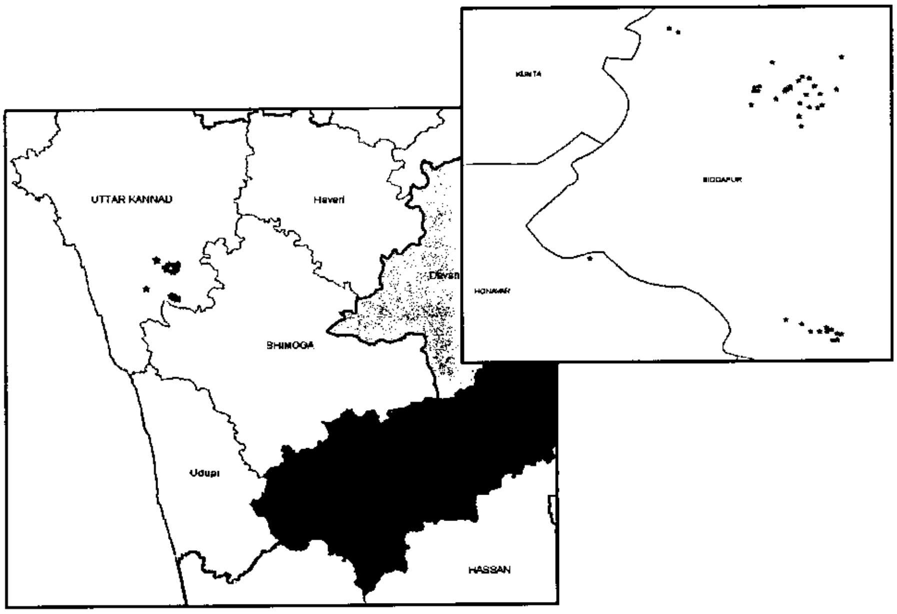
Appendix 1. Various diversity and richness indices of the selected swamp

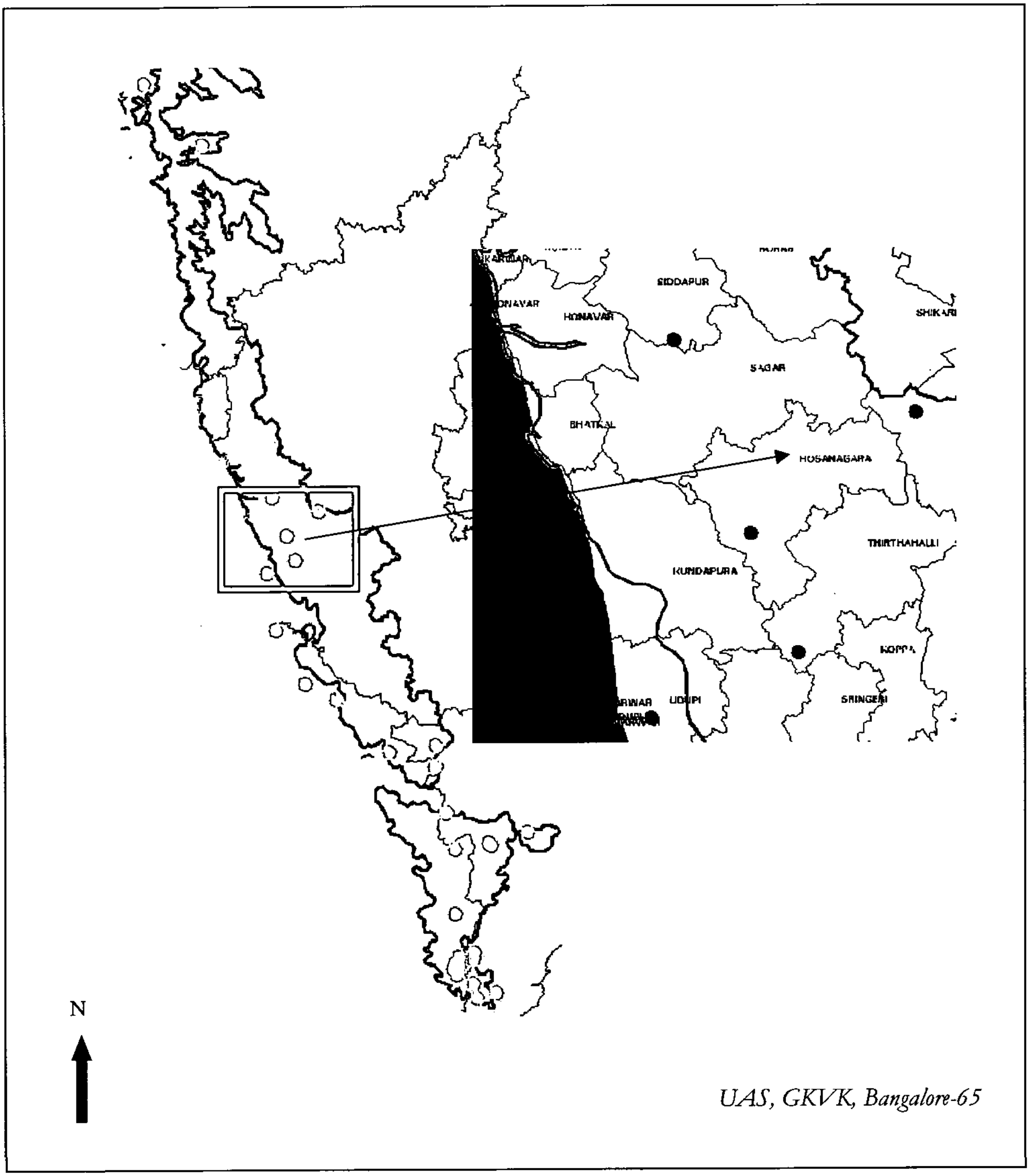
Sl. No.	Swamp	# Quadrates	Size category	Shannon-Wiener Index	Margalef's Index	Evenness Index	Simpson's Dominance	Simpson's Diversity(1 - Dominance)	Richness	Abundances
1	Kathlekan_Disturbed	12	Large	2.9124	6.5579	0.6902	0.1042	0.8958	68	1325
2	Shirlkhangavi	21	Large	3.9064	9.9010	0.8411	0.0305	0.9695	104	2150
3	Thorme (L)	17	Large	2.8072	7.6085	0.6443	0.1537	0.8463	78	1700
4	Hulikal	25	Large	3.1172	6.1387	0.7388	0.0617	0.9383	68	2500
5	Kathlekan_Good	21	Large	3.2168	8.0778	0.7167	0.0756	0.9244	89	2200
6	Manidam (L)	24	Large	2.9902	6.5470	0.6992	0.0924	0.9076	72	2400
7	Balehaklu	8	Medium	3.3125	6.1635	0.8158	0.0558	0.9442	58	800
8	Guledahonda	8	Medium	2.9613	5.6139	0.7424	0.0835	0.9165	54	800
9	Manidamsmall	8	Medium	3.2764	6.6299	0.7970	0.0673	0.9327	61	800
10	Darbejaddi	8	Medium	2.7879	5.8413	0.6926	0.1518	0.8482	56	800
11	Malemale1	8	Medium	2.8809	5.7688	0.7126	0.1067	0.8933	57	1400
12	Malemale2	9	Medium	2.9048	6.0389	0.7011	0.1136	0.8864	63	1700
13	Haralelekodlu	3	small	2.6774	4.0900	0.7531	0.1077	0.8923	35	550
14	Hudotathale	6	small	2.9448	5.1619	0.7691	0.1040	0.8960	46	600
15	Mundigethaggu	6	small	2.9338	5.8207	0.7389	0.0950	0.9050	53	600
16	Chikankodlu	6	small	3.0908	6.1560	0.7785	0.0824	0.9176	53	650
17	Rinbekodlu	4	small	3.0662	5.8680	0.7879	0.0795	0.9205	49	500
18	Thorme (S)	6	small	2.4973	4.8780	0.6681	0.1710	0.8290	42	800

Appendix 2. Species selected for enrichment planting

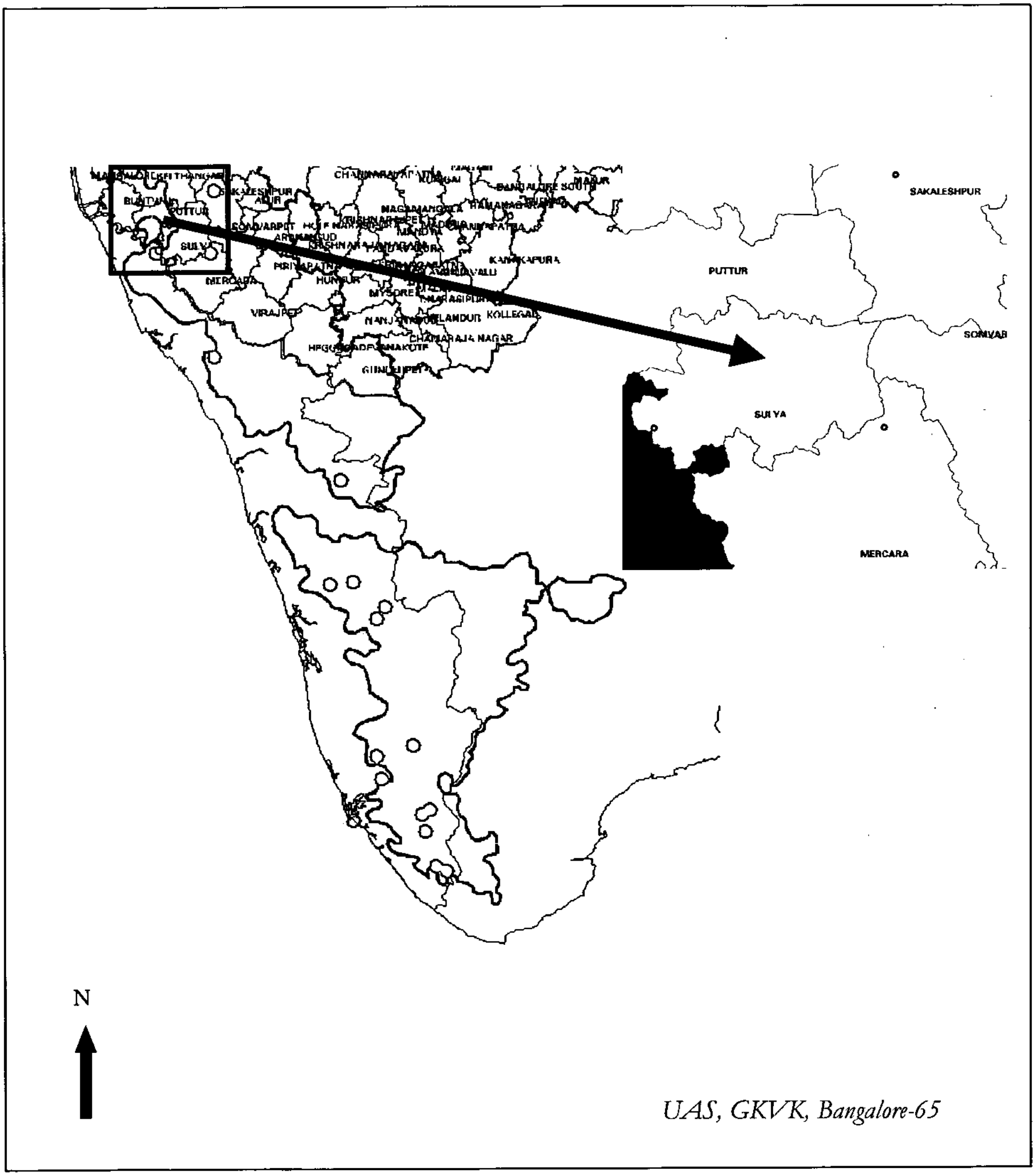
Sl. No.	Species
1	*Caryota urens*
2	*Garcinia indica*
3	*Gymnacranthera canarica*
4	*Holigarna arnotianna*
5	*Holigarna grahamii*
6	*Hopea ponga*
7	*Ixora species*
8	*Knema attentuata*
9	*Lophopetalum weightianum*
10	*Mastigxia arboria*
11	*Myristica fatua* var. *magnifica*
12	*Myristica malabarica*
13	*Semecarpus kathalekanensis*
14	*Syzygium spp.*



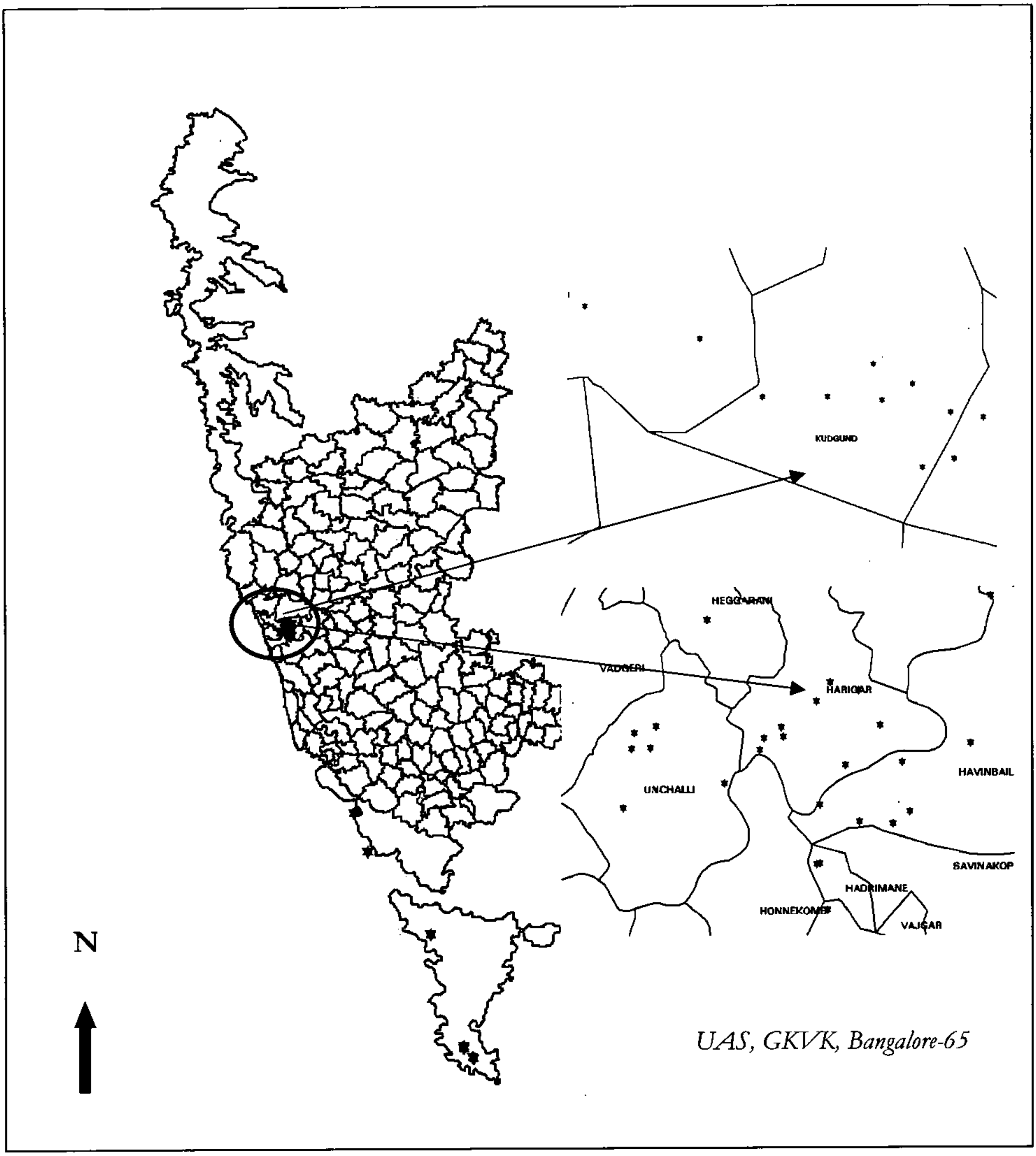
Appendix 3. Distribution Map of *Myristca* swamps in the Western Ghats based on filed survey in the Uttara Kannada district in the central Western Ghats.



Appendix 4. Distribution of *Myristica fatua* var. magnifica along the Western Ghats



Appendix 5. Distribution of *Gymnacranthera canarica* along the Western Ghats



Appendix 6. Distribution of *Myristica* Swamps along the Western Ghats