IMPACTS OF HABITAT CONVERSION ON THE LEAF LITTER ANURAN COMMUNITY OF VARAGALIAR, WESTERN GHATS.

DISSERTATION SUBMITTED TO SAURASHTRA UNIVERSITY, RAJKOT,
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BY
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Wildlife Institute of India

CERTIFICATE

This is to certify that S. U. Saravanakumar of the Wildlife Institute of India has carried out a piece of original research work entitled "Impacts of habitat conversion on the leaf litter anuran community of Varagaliar, Western Ghats" in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under my supervision at the Wildlife Institute of India from November 1994 to July 1995. I also certify that this work has not been submitted for any other degree of any other university.

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SUMMARY

Evergreen forests and teak plantations were sampled to determine the richness and abundance of anurans in the Anamalai hills of the Western Ghats.

Anurans were sampled by plots laid along water sources and at fixed intervals of distance away from water sources. All relevant environmental variables were measured for each plot.

A total of 17 species of amphibians were recorded in the study area, 6 species were recorded only in evergreen forests and 3 species were recorded only in teak plantations. Of the 8 species found in both vegetation types, only *Philautus variabilis* and *Rana beddomii* were seen in all areas of the teak plantations. *Rana keralensis* and *Rana temporalis* were restricted in distribution to the mosaics of natural vegetation found along the streams and the Varagaliar river in teak plantations. The other 4 species were poorly represented in the samples to draw conclusions.

Most amphibians were found at a distance of 0 - 5 m from the water sources.

Evergreen forests were found to have a higher canopy cover and shrub cover. Air temperature, soil temperature and relative humidity were similar in both vegetation types in winter but temperatures were higher and humidity lower in teak plantations in summer. Seventy percent and more of the floor of evergreen forests was covered by leaf litter whereas the floor of teak plantations was dominated by leaf litter and grass.

Canonical Correspondence analysis showed that canopy cover, soil moisture and soil temperature were the most important factors determining the distribution of amphibians. The species separated out into high canopy cover selecting and low canopy cover selecting groups. The high canopy cover selecting species were specialists of evergreen forests and generalist species found in evergreen forests and only in the mosaic of remnant natural vegetation in teak plantations. The low canopy cover selecting species were specialists of teak and a generalist that was predominantly found in teak.

Results indicate that the conversion of evergreen forests to teak plantations would lead to the loss of high canopy cover selecting species. Vegetation tracts along water sources and mosaics of natural vegetation in teak plantations are important habitats for anurans. These habitats enable the survival of some of the high canopy cover selecting species even after large scale habitat conversion.

1. INTRODUCTION

Habitat changes can bring about a reduction in wildlife populations, or in extreme cases the extinction of species (Myers 1986). The extent to which a species or a community is affected is a function of the magnitude of the change. The ability of a species to recolonize an area is dependent on the distance of the source pool, the ability of the species to disperse and its tolerance to changes in habitat (Lovejoy *et al.* 1986).

Amphibians, being poikilothermic, with a very sensitive skin and a bimodal life-history, can be very good indicators of environmental condition. Constraints set by availability of moisture, extremes of temperature and breeding site preference limit their dispersal (Daniels 1992a) and hence restrict their distribution in time and space. Most amphibians have a narrow limit of tolerance, changes in humidity or temperature within a few degrees of their optimum may cause a shift in their habitat use from, say, terrestrial to fossorial (Daniel 1963). The choice of habitats and microhabitats are limited by the sensitivity of each species, some having a wider tolerance limit and hence the ability to occupy more habitats. The availability of critical microhabitat, which may be species specific, generally determines the presence or absence of a species in an area (Daniels 1990).

Amphibian diversity is uneven across India with the highest concentration being in the Western Ghats followed by northeast India (Inger & Dutta 1986). The mountains of the Western Ghats are home to 117 species of frogs and toads (anurans), and caecilians. This constitutes about 60% of the total of 197 species found in India (Dutta 1992). Eighty-nine of the Western Ghats amphibians are endemic to this region (Daniels 1992b). Although amphibians are represented in almost all habitats, natural or man-made, moist evergreen forests contribute most to the amphibian diversity of India (Daniels 1991).

The Western Ghats run continuously north to south between 8°N and 21°N latitudes, a distance of about 1600 km, covering an area of 140,000 km², interrupted only by the 30 km wide Palghat gap. South of the Palghat gap, the Western Ghats widen out into the Nelliampattis in the north and the Anamalais in the east, together forming a basin that holds one of the most extensive tropical moist evergreen forests in the entire region (Nair 1991). However, the Western Ghats have faced a substantial loss of its natural vegetation (Chattopadhyay 1985, Nair 1991), especially evergreen forests and is of concern since there is an associated loss of bio-diversity.

Until the early 1970's the Forest Department of Tamil Nadu had been clearing natural vegetation for planting commercially valuable species, like teak (*Tectona grandis*). This process along with exploitation of the commercially saleable evergreen species of the area, primarily for the production of railway sleepers had brought about changes in habitat, from complete change in vegetation type in the former to conversion from primary to secondary forests in the latter (Wilson 1965). Teak is usually planted after clear-felling of natural vegetation and concentrated artificial regeneration by stumping. The cleared areas are burnt before planting takes place, processes like this are likely to completely wipe out the amphibians, especially the terrestrial and arboreal species. Species close to water bodies have a chance to escape, but what is important is that habitat and microhabitat specialists will suffer the most due to such drastic changes in habitat because their physiology is tuned to certain regimes of the surrounding environment and they have narrower tolerance limits (Myers 1986).

With a taxon that is so sensitive to its immediate environment, one would expect immense changes in amphibian diversity with changes in habitat. Since not much is known about the ecology of amphibians in India (Daniel 1963), studies on their natural history and ecology are necessary for a better understanding of this class of vertebrates and for channelising our conservation efforts. So this study was framed on two basic objectives. The primary objective was to understand the changes in anuran communities, in terms of species richness and abundance, caused by replacement of wet evergreen forests with teak plantations. Since it was important to know the reasons behind the changes, the second objective was to determine the distribution of anurans in relation to habitat structure and microclimate in the two vegetation types.

Research on tropical amphibians has largely been concentrated in two geographic regions, South America and south east Asia (Inger & Colwell 1977, Lloyd *et al.* 1968, Scott 1976, Toft 1985). This trend is probably because these areas are reputed to be rich in amphibian diversity. Besides general ecological studies of particular species, there have also been a few community level studies (Toft 1985, Heyer 1973).

Comparative studies of amphibian communities are few, but interesting. Notable differences were documented when samples of amphibian and lizard fauna were compared between South America and south east Asia (Scott 1976). It was seen that amphibian density was about ten times greater in Costa Rican and Panamanian lowland and upland wet forests than in comparable sites in Borneo and the Philippines. The divergent densities have been speculated to be due to basic differences in the composition of the fauna (densities of predators and/or competitors), or differences in the functioning of the ecosystem. The latter seems to reflect the overall scarcity of small leaf litter vertebrates. Comparisons between similar sites within a region (Duellman 1989, Inger & Voris 1993) have shown that species composition differed drastically, different species being found in different microhabitats. Thus if amphibian communities are expectedly different between similar sites across continents, variation within a region can be remarkable too.

Comparisons between vegetation types within a small area have shown that distinct assemblages exist in different vegetation types. Inger & Colwell (1977), compared amphibian communities of adjacent areas of broadleaf evergreen forest, deciduous dipterocarp forest and agricultural land in north eastern Thailand and also recorded microhabitat preferences. They found that the three sample areas differed in species richness and relative abundance of species. Differences in species richness could not be explained by differences in microhabitat diversity, mean niche breadth or mean niche overlap. But they did find closer species packing, and larger, and more distinct guilds in the evergreen forest which was richest in species and most predictable in climate. They suggested that unpredictable environments tend to prevent the formation of distinct guilds.

Seasonal changes also affect amphibian communities in numerous ways. Allmon (1991), found that species richness and diversity were highest at approximately the peak of the wet season in central Amazon. Martin & Freeland (1988), found that the relative abundance of species changed seasonally. Frog densities were highest during the dry season. This was explained by the fact that most species used the moister forests as seasonal refuges when the flood plains dried up.

Amphibian research in India was, for quite some time, restricted to the collection and description of species (Boulenger 1890, Daniel 1963, Inger & Dutta 1986). Although detailed ecological studies are lacking the need for documentation is well brought out by the fact that there have been very recent additions to the list of Indian amphibians (Das 1990). However there are two notable studies on the amphibians of the Western Ghats conducted in the past few years.

Inger *et al.* (1987), in a pioneering ecological study on Indian amphibians used data from a collection trip in the Ponmudi hills of Kerala (Inger *et al.* 1984), to construct the community structure of the herpetological assemblage of the area. They used microhabitat information to calculate niche breadth and niche overlap between species. This study was limited by the fact that the data used was collected in a short period of one and a half months, therefore not accounting for factors like changes in microhabitat preference with season.

Daniels (1992b) analyzed the range and patterns of distribution of the amphibians of the Western Ghats by dividing the area into latitudinal and altitudinal classes. He used information on distribution of amphibians from previous studies in the area and his own observations to assign the latitudinal distribution of 98 species and the altitudinal range of a subset of 56 species. The results suggest that the southern half of the Western Ghats (8-13°N) have a representation of almost 95% of the species. The altitudinal range of 800-1000 m was richest in species. This pattern is attributed to the widespread rainfall and shorter dry season in the southern Western Ghats as compared to the north. He was also able to show, although only with a small data set, that the endemics had a restricted distribution, 70% of them being found within a range of 3° latitudes. A general patchiness in the distribution of species was noticeable, and there was a greater representation of moist evergreen forest species among those showing patchy distribution. The reason for the patchiness could be that the moist evergreen forests have suffered the most in terms of destruction for other land use. Loss of forest habitat could have led to the local extinction of some of the species, and hence the patchy distribution (Daniels 1992b).

2. STUDY AREA

The Indira Gandhi Wildlife Sanctuary (Fig.1.), where the study was conducted, is situated in the southern Western Ghats, just south of the Palghat gap. When established in 1972, it was called the Anamalai Wildlife Sanctuary and covered an area of about 958 km^2. The sanctuary was later renamed and its area extended to about 987 km^2 (Kumar 1987).

The Indira Gandhi Wildlife Sanctuary extends for about 45 km north to south and 25 km east to west (76° 49.3'- 77° 21.4'E and 10° 13.2' - 10° 33.3'N). The altitude ranges between 350 msl at the foothills to about 2500 msl. The major vegetation types seen within the sanctuary are the Tropical Evergreen Rain Forests, Mixed Deciduous Forest, Tropical Montane Forests (Sholas), Grasslands and Monocultures (Puri *et al.* 1983).

The Tropical Evergreen Rainforests are distributed from an altitude of 550 m to about 1200 m and are of the *Vateria - Calophyllum* association (Champion & Seth 1968). About 70 km^2 of this vegetation type still remains in the sanctuary (Kumar 1987). At altitudes greater than 1200 m the Tropical Evergreen Rainforests are replaced by Tropical Montane Forests. The Mixed deciduous forest is of the *Terminalia-Anogeissus-Tectona grandis* series. It is characterised by dominant trees which shed leaves between December and April. The monocultures consist of tea, coffee, cinchona and teak plantations.

The Sanctuary receives about 1600 mm of annual rainfall and has on an average 112 rainy days in a year. June and July are the wettest months and the period between December and late April is the driest with very little rainfall (Tamil Nadu Forest Department records). During this study, which was conducted between late November 1994 and end of April 1995, there were only 10 rainy days with heavy rains only on one day in late April. To comprehend seasonal changes, the study period was classified as two seasons; winter which included the months of November, December and January and summer which included February, March and April. The temperature varied from a minimum of 11°c to a maximum of 27°c in winter and a minimum of 17°c to a maximum of 35°c in summer.

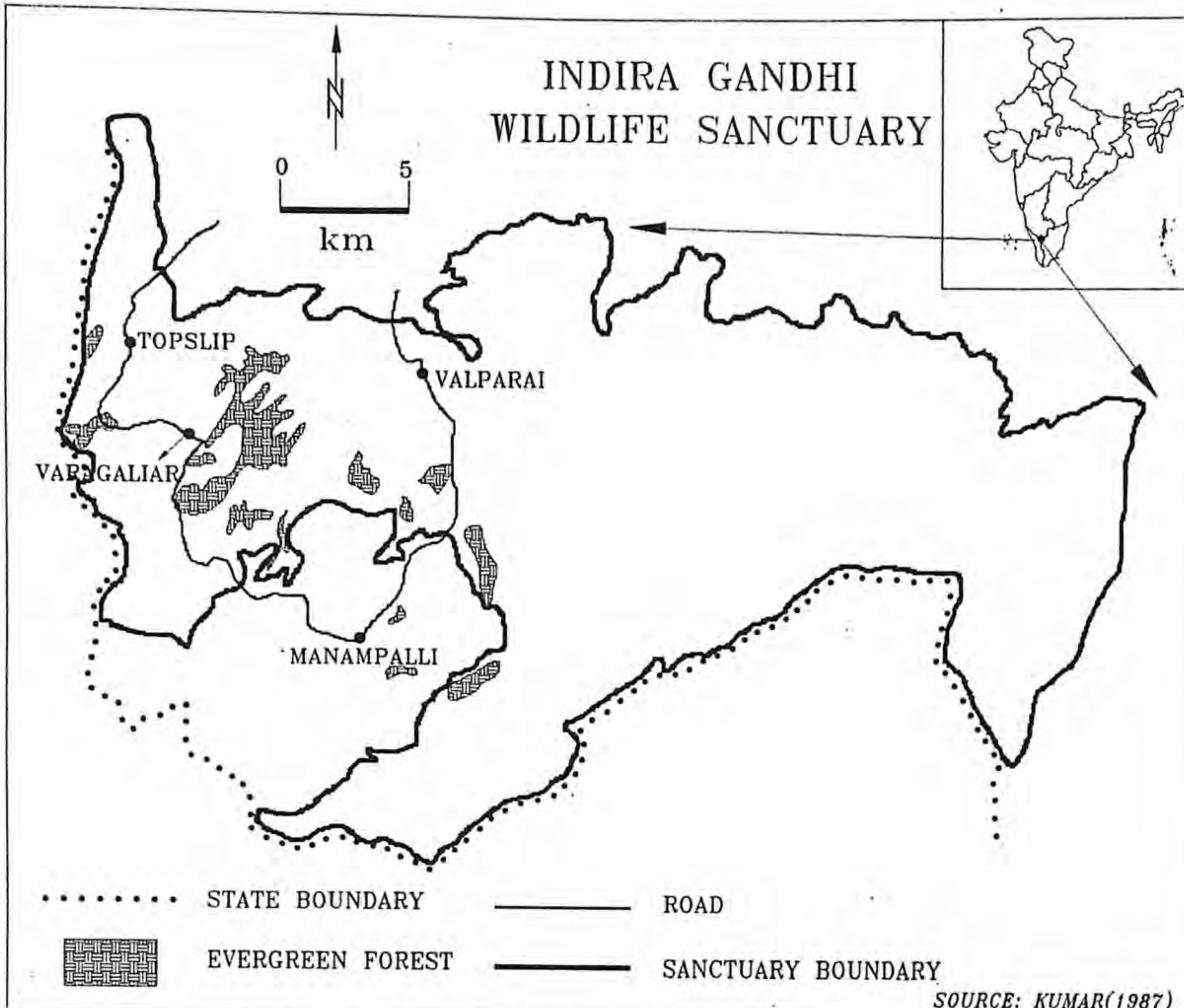

INDIRA GANDHI
WILDLIFE SANCTUARY
0
5
km
TOPSLIP
VALPARAI
VARAGALIAR
MANAMPALLI
STATE BOUNDARY
ROAD
EVERGREEN FOREST
SANCTUARY BOUNDARY
SOURCE: KUMAR(1987)

Figure 1.

Varagaliar, the site of the study, is at an altitude of about 650 m and is situated 10 kms south-east of Topslip which is the Sanctuary headquarters where the major tourist facilities are located.

Varagaliar is the remnant of a once flourishing elephant training camp, where now, only a small number of elephants and their mahouts still remain. The Varagaliar river, from which the camp derives its name runs at the fork of the valley formed by the 'Perunkundru' peak and a few other small hillocks. The river empties into the Parambikulam reservoir. The evergreen patch which was sampled for the study, lies eastward of the camp while the teak plantations are situated westward and downstream. The area around the elephant camp is mainly mixed scrub, forming a convenient separation zone of about 500 m between the teak plantation and the evergreen forests. The teak plantations that were sampled were planted between 1971 and 1974 (Tamil Nadu Forest Department records). This study site was chosen because the river acted as a kind of control, passing through both vegetation types without varying much in its characteristics.

3. METHODS

Sampling was done in the mornings between 0630 and 1000 hours and in the evenings between 1630 and 1900 hours; amphibians have been reported to be most active during the day during this period (Ajith Kumar *pers. comm.*). Even though sampling at night was advisable because some amphibians are nocturnal, night sampling was avoided due to various constraints.

The strategy was to reach the sampling area within each vegetation type before the commencement of the stipulated sampling time and pace out the first sampling point (plot) along the course of the river, this was done after generating random numbers to decide on the number of paces. The first plot was laid along the banks of the river or the stream and the successive plots in a direction perpendicular to it and moving away from it, sampling was done at intervals of 25 m up to a distance of 100 m in this manner. After one such sequence was completed, sampling was restarted from a plot that was 25 m from the first plot along the river and adjacent to it. Since I was also studying the effect of distance from water on amphibian densities, care was taken to avoid the proximity of streams (no other water body was found in the area). Plots were also laid at distances beyond 100 m and along water courses at random points. Places unsuitable for sampling such as rock faces or dense undergrowth were avoided.

Plots of 5 m x 5 m were used as the sampling unit (Allmon 1991). The plots were marked out with a bright coloured nylon rope. Once the plot was laid, microclimate parameters such as air temperature, soil temperature, relative humidity and soil moisture were recorded. Air temperature was measured at the ground level since it was reasoned that this was more likely to affect the amphibians in that strata than at a height from the ground which is how air temperatures are usually recorded. Soil temperature was recorded using a thermometer with a probe. Relative humidity was measured using a digital hygrometer. Soil moisture was subjectively measured giving three categories, dry (no trace of moisture), moist (wet soil with no standing water), and wet (soil with standing water).

The ground cover for the entire plot was estimated in percentage classes. Litter depth was estimated by inserting a sharpened stick into the ground and counting the number of leaves pierced (Ranjit Daniels *pers. comm.*). This was used as an index of litter depth.

Canopy cover was visually estimated above the sampling plot. It was categorised as follows, a completely open canopy (0%), canopy present but with a wide gap (25%), canopy closely packed but gaps still prominent (50%), canopy touching and covered but not much overlap (75%) and dense and completely overlapping canopy (100%).

Any amphibian moving out of the plot as it was being demarcated was recorded as being present in the plot. Any amphibian moving into the plot from outside was either removed immediately or ignored while sampling. The amphibians located within the plot were those that were disturbed from the forest floor when the plot was actively searched. Care was taken not to disturb the region within the plot as any disturbance prior to sampling would bias the data.

The plots were then searched thoroughly for amphibians, logs and stones were overturned and crevices probed. A maximum of one quarter man hour was spent searching in a plot. Three persons searched the plot simultaneously and all amphibians seen were recorded on completion of the search. During the initial period, all amphibians were collected for close examination and identification, but with increasing familiarity collection was restricted to the obscure specimens. Care was taken to avoid double counts of individuals.

Microhabitat descriptions were made at points where each amphibian was first located. The microhabitat is the environment immediately next to the individual occupying it. The nature of the substrate occupied by the amphibian namely on leaf litter, on bare ground, on grass, on shrub, on herb, on logs, under logs, on roots or among the roots, and distance from water was also recorded.

GBH of the trees within each plot was measured. Shrub height was measured and percentage shrub cover was visually estimated.

Each vegetation type was visited once a month and approximately the same general areas were sampled. Thus the information on monthly changes in abundance and distribution of anurans and changes in habitat parameters are comparable.

In addition to quadrat sampling the forests were regularly searched for amphibians, during the day and the early part of the night, adhering more to a general collection method than to any formal sampling strategy. This was done to compile a species list for the area. Observations on the natural history of the amphibians were also noted.

Specimens that were collected were preserved in 10% formalin. All specimens were identified by Dr. Ravichandran of the Zoological Survey of India, Madras.

4. ANALYSIS

Species diversity was calculated using the Shannon-Weiner index:

$$H' = -\Sigma p_i \ln p_i$$

H' = Shannon-Weiner index,

p_i = proportion of individuals found in the *i*th species

And the Simpson's index:

$$D = \Sigma p_i^2$$

D = Simpson's index,

p_i = proportion of individuals in *i*th species.

The Shannon-Weiner index was chosen because it takes into account the evenness of species and the Simpson's index because of its low sensitivity to sample size and use as a dominance measure. The Simpson's index is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness. It is advisable to compare various indices of diversity to check for consistency in the results (Magurran 1988).

Sorensen's and Jaccard's indices of similarity were used for the cumulative amphibian species list of the two vegetation types (Magurran 1988, Kent & Cocker 1992).

$$C_j = j / (a + b - j)$$

$$C_s = 2j / (a + b)$$

C_j = Jaccard's index,

C_s = Sorensen's index,

j = the number of species found in both sites,

a = the number of species in site A,

b = the number of species in site B.

Densities of amphibians between habitats was compared by pairing monthly averages and performing a Wilcoxon matched pair test on the data for the entire study period (Sokal & Rolhf 1981)

Relationships of species with environmental variables was investigated by performing a Canonical Correspondence analysis (Ter Braak 1988) using the program CANOCO. A Monte-carlo permutation test was used to determine the significance of the relationship between canonical axes and environmental variables.

To compare habitat and microclimate data, samples were drawn randomly from the large data set. Mann-Whitney U' test was used to compare air temperature, soil temperature, humidity, litter depth, canopy cover and ground cover (percentage leaf litter, bare ground, grass, herb, log, and root cover) between the two habitats. Tree densities, shrub cover and shrub height were compared using t-test for independent samples (Sokal & Rolhf 1981). Significance level was set at 0.05.

5. RESULTS

A total of eighteen species of anurans were recorded during the study (Table.1.) Species were classified as generalists and specialists based on their occurrence in the two habitats. A generalist was seen in both habitats while a specialist was seen only in one of the habitats. There were 8 generalist species, 6 specialists of evergreen forests and 3 specialists of teak plantations. Three of these species, *Rana leptodactyla, Polypedates cruciger* and *Philautus spp.* did not occur in the sampling plots and were only seen during the general searches. *Rana limnocharis,* was collected in the scrub area close to the camp. This species was not included for any further analysis.

Similarity in species composition between the two vegetation types was calculated using presence and absence data of species. While the Jaccard's index gave a value of 0.47, the Sorensen's index gave a value of 0.64. The values of these indices vary along a continuum from 0 to 1, with a 0 indicating total dissimilarity and a 1 indicating complete similarity. The results of these indices suggest differences in species composition between the two habitats.

Diversity for each month was calculated separately using the Shannon-Weiner and Simpson's indices and the values for the two vegetation types were compared. There was no significant difference between the two (M-W U'test, $Z = 0.000$, $P = 1.000$ for Shanon-Weiner), (M-W U' test, $Z = 0.400$, $P = 0.689$ for Simpson's index).

Canonical Correspondence Analysis (CCA) was used to investigate the effect of environmental variables on amphibian distribution. The variables used were distance from water, air temperature, soil temperature, soil moisture, canopy cover and leaf litter depth. The eigen values for Axis-1 and Axis-2 are 0.265 and 0.090 respectively. Monte-carlo permutation tests revealed that the first axis was significant (eigen value 0.27, $F = 7.90$, $P = 0.01$). Axes 1 & 2 contribute 57.2% and 76.6% of the variation to the species-environment relationship, the variance on Axis-2 being cumulative.

The correlation matrix of Environmental Axis-1 and Axis-2 (Table. 2) shows the relationship of the environmental variables with the two Axes. The environmental variable which showed the highest correlation with each of the Axes was taken as the parameter that had the strongest influence on species distribution on that axis. Canopy cover shows a strong negative correlation with Axis-1 (correlation coefficient -0.839), and hence its influence on species distribution must be significant. Soil temperature (correlation coefficient 0.5058), and soil moisture (correlation coefficient 0.5058) show a positive correlation with Environmental Axis-2. Hence canopy cover, soil moisture and soil temperature seem to be the most important factors influencing the distribution of anurans in the study area.

The influence of the environmental variables on individual species was investigated. The graphical plot of species with environmental variables (Fig.2) shows that *Rana keralensis*, *Rana temporalis* and *Rana curtipes* occur in areas of high canopy cover, high soil moisture and high soil temperature. The distribution of *Rana temporalis* and *Rana curtipes* is strongly influenced by canopy cover. This is inferred from the proximity of the position of these two species to the canopy vector in the graphical plot. *Philautus nasutus* and *Bufo melanostictus* are found in low cover areas with high soil moisture and temperature while *Philautus pulcherrimus* seems to be unaffected by canopy cover but occurs in high soil moisture and temperature areas. Only one individual of *Philautus nasutus* and *Philautus pulcherrimus* were seen during the study, hence it is difficult to draw conclusions.

Philautus variabilis seems to be a vagrant, not affected much by soil temperature or moisture but occupying areas of low canopy cover.

Rana beddomii and *Rana diplosticta* are placed very close to the origin of the two Axes and are probably not influenced by any of these environmental variables. *Micrixalus gadgili* and *Rana semipalmata* occur in areas with high canopy cover, low soil moisture and soil temperature. Again *Micrixalus gadgili* is represented by only one specimen and conclusions cannot be drawn

It is interesting to note that species occurring on the right hand side of the graph (positive side of Axis-1) are well represented in teak plantations. *Philautus pulcherrimus* and *Philautus nasutus* are specialists of teak while *Philautus variabilis* occurs commonly in teak. *Bufo melanostictus* was however seen in equal numbers in both vegetation types. All the specialist species of evergreen (*Rana curtipes*, *Rana diplosticta* and *Micrixalus gadgili*) are seen on the left hand side of Axis-1 (negative side of Axis-1).

TABLE.1. List of generalist and specialist anurans seen in Varagaliar, Indira Gandhi WLS.

NO	Generalist Species	Specialists of Evergreen	Specialists of Teak Plantations
1	*Rana beddomii*	*Rana curtipes*	*Philautus glandulosus**
2	*Rana cyanophlyctis**	*Rana leptodactyla**	*Philautus pulcherrimus*
3	*Rana brevipalmata**	*Rana diplosticta*	*Philautus nasutus*
4	*Rana temporalis*	*Micrixalus gadgili*	
5	*Rana semipalmata*	*Polypedates cruciger*	
6	*Rana keralensis*	*Philautus sp.*	
7	*Bufo melanostictus*		
8	*Philautus variabilis*		

* - Specimens were seen only along the Varagaliar river.
Rana limnocharis was seen in the scrub area close to the Varagaliar camp.

TABLE.2. Correlation matrix of environmental axes with environmental variables.

DIST WATER	0.4362	0.2255	-0.0396	0.1591
AIR TEMP	0.2765	0.2961	0.0916	-0.7812
SOIL TEMP	0.3130	0.5635*	-0.1283	-0.6805
HUMIDITY	0.1033	0.0891	-0.1239	0.5175
CANOPY	-0.8456*	0.3269	0.1031	-0.0368
LITTER	-0.4034	0.1083	0.4539	-0.4262
SOIL MOIS	0.2659	0.5389*	0.6686	0.2417
	ENV AX1	ENV AX2	ENV AX3	ENV AX4

* - Environmental variables strongly related to the given Axis.

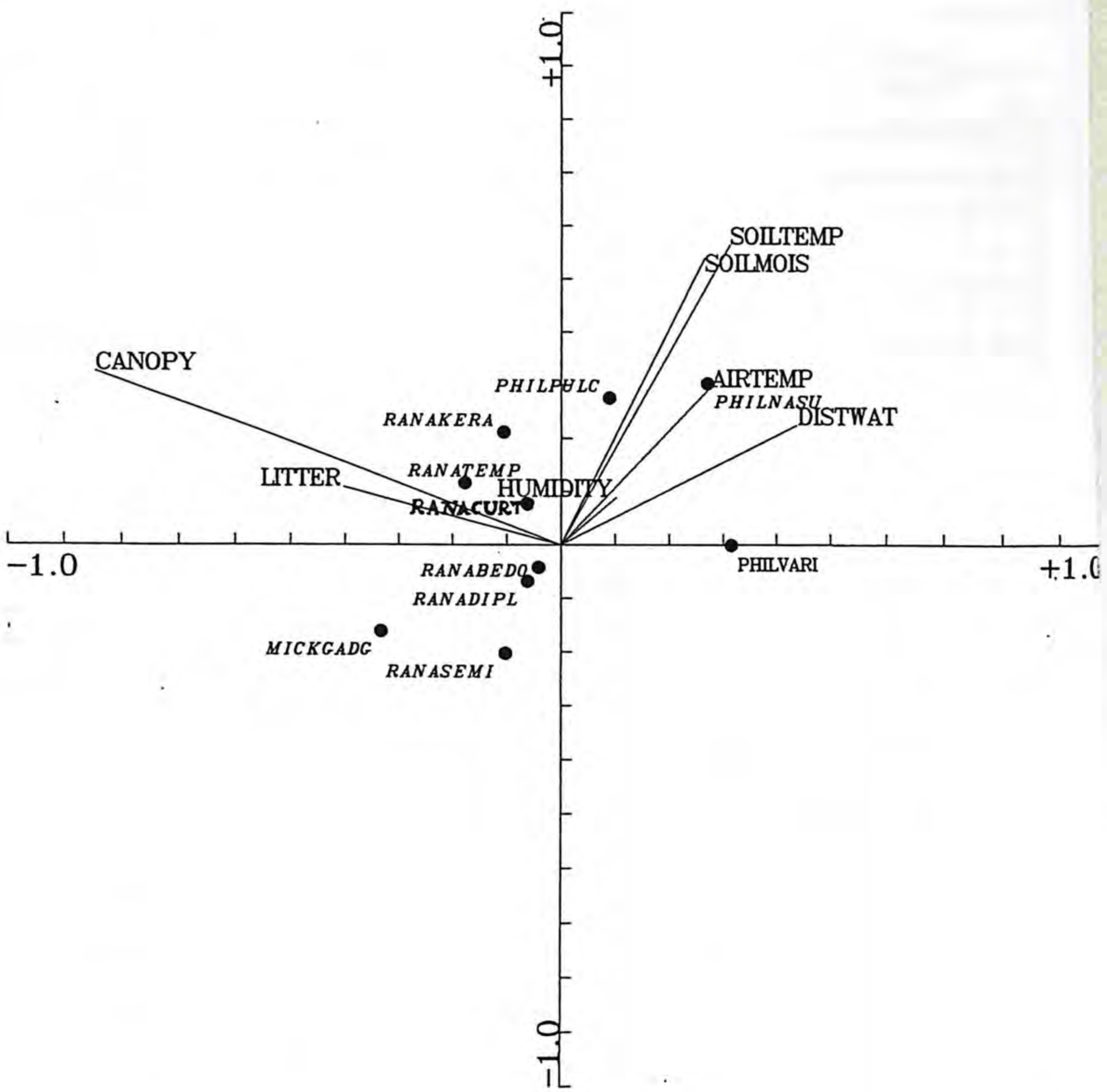

+1.0
SOILTEMP
SOILMOIS
CANOPY
PHILPULC
AIRTEMP
PHILNASU
RANAKERA
DISTWAT
RANATEMP
LITTER
HUMIDITY
RANACURT
−1.0
RANABEDO
PHILVARI
+1.0
RANADIPL
MICKGADG
RANASEMI
−1.0

Figure 2.

The environmental and microclimate variables were compared between the two vegetation types. Among the three important variables identified by CCA, it was found that canopy cover was significantly higher in evergreen (P = 0.00, Table.3). Soil temperatures were not significantly different between the two vegetation types in winter (P = 0.814) but was significantly higher in teak plantations in summer(P = 0.021, Table.4). Soil moisture was found to be significantly higher in teak plantation in winter(P = 0.027) but showed no difference between the two vegetation types in summer(P = 0.511).

The comparison of environmental variables of the two vegetation types has been summarised in Tables. 3, 4 and 5. In general evergreen forests have comparatively more vegetation cover and a stable microclimate with marginal seasonal variation.

The distribution of anurans in both the habitats is restricted to the proximity of the water sources (0 - 5 m), streams and the Varagaliar river. A few specimens were recorded away from the water sources in the months of November and December in both the vegetation types but none were recorded away from water in the rest of the months. The average density in the plots next to the water source for evergreen forests was 3.355 adult anurans per plot and 3.41 adult anurans per plot in teak plantations. Figures 3 & 4 graphically represent the densities of anurans in evergreen and teak respectively for the study period. The graphs also give densities of juveniles in the two areas. Since the identity of many of the juveniles was obscure, only their densities have been considered for the analysis.

It is seen from Fig.2 that *Rana temporalis* and *Rana keralensis* which have been classified as generalists also select high canopy areas. Since teak plantations have very little canopy cover, since this is contrary to what is observed it requires an explanation. The areas along the streams and the Varagaliar river in teak plantations still have remnants of natural vegetation. These form a kind of mosaic with a few patches of natural vegetation surrounded by teak. Almost all specimens of *Rana temporalis* and most of the specimens of *Rana keralensis* were seen in these areas of natural vegetation. To ascertain this, densities of these two species in teak plantations were calculated and then recalculated after eliminating plots that were laid in the mosaic of natural vegetation. These were then compared with densities calculated for evergreen forests. Both species did not show significant differences in density when the complete data set was considered (Wilcoxon MP, P = 0.105 for *Rana temporalis* and P = 0.0796 for *Rana keralensis*, Table.6.). But densities in teak were significantly lower when the data set after elimination of plots with natural vegetation were considered (Wilcoxon MP, P = 0.0431 for both the species, Table.7.). Thus even though these species do occur in teak plantations their distribution is concentrated in the mosaics of natural vegetation.

Rana beddomii and *Philautus variabilis* do not show significant differences even after the plots with natural vegetation were removed (refer Tables. 6 & 7. for statistical values). This shows that these two species are found in equal densities in other areas in the teak plantations.

TABLE.3.Comparison of ground cover and canopy cover between Evergreen and Teak vegetation types at Varagaliar, Indira Gandhi WLS.

Parameter	Mean		N	Z	p
	Evergreen	Teak			
Litter depth in winter	1.99	1.67	32	2.001	0.045
Litter depth in summer	2.98	2.18	36	3.463	0.001
% Leaf litter in winter	70	41.90	21	4.478	0.00
% Leaf litter in summer	72	48.03	28	3.343	0.001
% Bare ground in winter	16.9	14.04	21	0.491	0.624
% Bare ground in summer	7.67	15.53	28	1.229	0.219
% Grass cover in winter	0.24	33.57	21	4.981	0.00
% Grass cover in summer	0	30.17	28	4.351	0.00
% Herb cover	2.38	9.52	21	1.585	0.133
% Log cover	3.33	0.476	21	1.296	0.195
% Root cover	5	0	21	3.421	0.001
Canopy cover in winter	92.96	29.68	32	6.633	0.00
Canopy cover in summer	94.44	38.19	36	6.025	0.00

TABLE.4.Comparison of microclimate variables between Evergreen and Teak Vegetation types at Varagaliar, Indira Gandhi WLS.

Parameter	Mean		N	Z	p
	Evergreen	Teak			
Air temp. in winter	19.35	19.36	32	0.074	0.941
Air temp. in summer	19.73	22.75	36	2.697	0.007
Soil temp. in winter	19.42	19.74	32	0.235	0.814
Soil temp. in summer	19.81	21.77	36	2.309	0.021
Relative Humidity in winter	76.62	75.81	32	0.228	0.819
Relative Humidity in summer	73.44	63.27	36	2.630	0.009
Soil moisture in winter	1.28	1.61	38	2.213	0.027
Soil moisture in summer	1.46	1.41	38	0.657	0.511

TABLE.5. Comparison of vegetation structure between Evergreen and Teak vegetation types in Varagaliar, Indira Gandhi WLS.

Parameter	Mean ± σ		t	df	p
	Evergreen	Teak			
Tree density	4.72 ± 2.92	1.72 ± 1.55	5.13	47	< 0.001
Shrub cover	37.28 ± 28.37	16.87 ± 20.97	3.27	57	0.002
Shrub height	148.87 ± 109.56	92.69 ± 79.96	2.34	57	0.023

TABLE.6. Comparison of densities of the commonly occurring generalist species between Evergreen and Teak vegetation types in Varagaliar, Indira Gandhi WLS.

SPECIES	MEAN DENSITY IN EVERGREEN	MEAN DENSITY IN TEAK	N	Z	P
P. variabilis	0.254	1.148	5	-2.022	0.0431
R. beddomii	2.162	1.27	5	-0.674	0.50
R.keralensis	0.662	0.078	5	-1.752	0.079
R.temporalis	0.746	0.036	5	-1.618	0.1056

Densities are in individuals per 5 m x 5 m plot.
N refers to the number of samples in this case months.

TABLE.7.Comparison of densities of the commonly occurring generalist species between Evergreen and Teak vegetation types after removal of plots laid in the natural vegetation mosaic in Teak plantations in Varagaliar, Indira Gandhi WLS.

SPECIES	MEAN DENSITY IN EVERGREEN	MEAN DENSITY IN TEAK	N	Z	P
P. variabilis	0.254	1.108	5	-2.022	0.043
R. beddomii	2.162	1.078	5	-0.674	0.50
R. keralensis	0.662	0.526	5	-2.022	0.043
R. temporalis	0.746	0.432	5	-2.022	0.043

Densities are in individuals per 5 m x 5 m plot.
N refers to the number of samples in this case months.

FIG 3 DENSITIES OF ANURANS ALONG STREAMS
EVERGREEN FORESTS IN VARAGALIAR,
INDIRA GANDHI WLS.

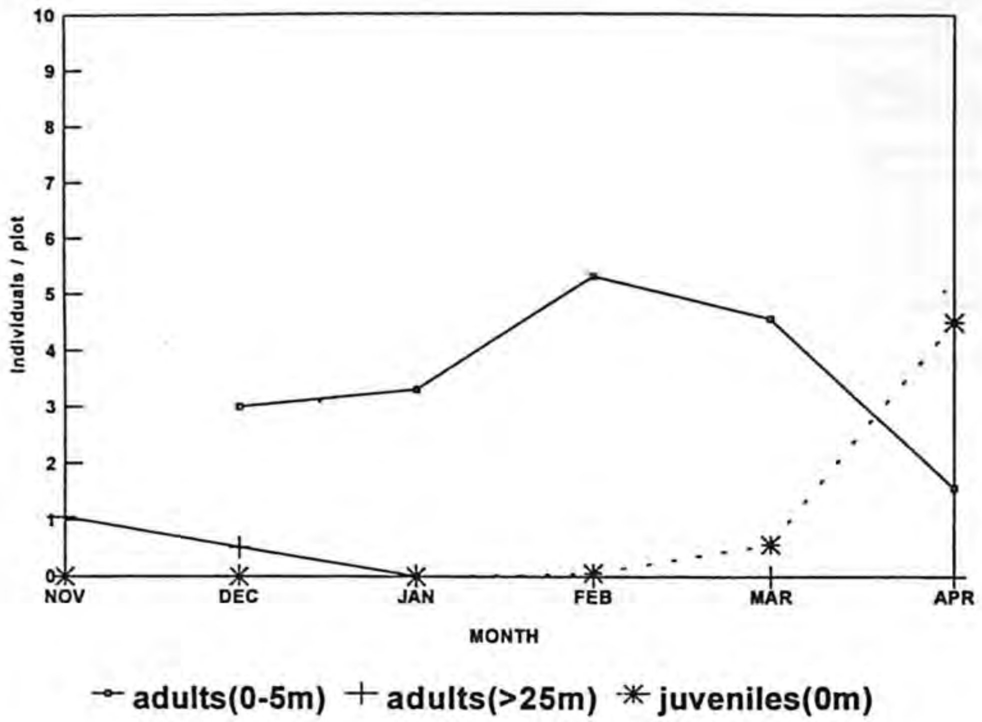
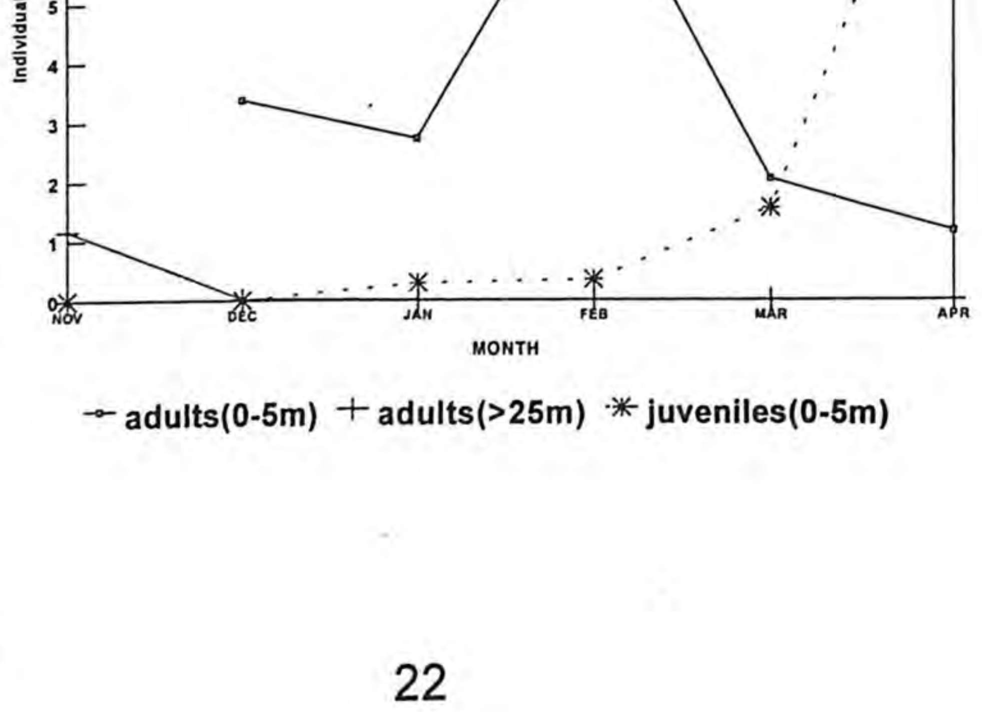


FIG 4 DENSITIES OF ANURANS ALONG STREAMS
IN TEAK PLANTATIONS IN VARAGALIAR
INDIRA GANDHI WLS.



6. DISCUSSION

Studies on tropical avifauna (Johns 1991) have shown that communities in disturbed habitats were dissimilar to that of undisturbed forests, the degree of difference being proportional to the extent of disturbance. The differences were reflected both in species richness and relative abundance. In my study the disturbance factor is a complete change in habitat, which probably lies at the extreme end of a continuum of disturbances. Such profound changes in habitat would prompt us to expect vast differences in the anuran communities of the two vegetation types.

The similarity indices have detected a certain amount of differences between the two habitats. But a comparison of the diversity indices shows that the two vegetation types are not different in their diversity, when one would actually expect very significant differences. Both the vegetation types have anuran communities that were dominated by one generalist species *Rana beddomii*, which contributes most to the total number of anurans seen (83% of all anurans seen in evergreen forests and 55% of all anurans seen in teak). Also the specialists are extremely rare with only one specimen each of *Micrixalus gadgili* (evergreen), *Philautus pulcherrimus* and *Philautus nasutus* (teak), seen. Three of the specialists of evergreen, *Rana leptodactyla, Polypedates cruciger* and *Philautus. spp.* have not been included in the analysis since they did not occur in the sampling plots. Hence the results shown by the diversity indices need to addressed with care.

The Canonical Correspondence analysis, however, separated out the anurans into two distinct groups based on their distribution with respect to canopy cover (Fig.2.). *Rana curtipes*, *Rana diplosticta*, *Micrixalus gadgili*, *Rana keralensis*, *Rana temporalis* and *Rana semipalmata* are species found in areas with high canopy cover. Of these the first three are specialists of evergreen. The rest of the species mentioned above are found in both vegetation types, but their distribution in teak plantations is restricted to the mosaics of natural vegetation along the streams and riverine areas. The specialist anurans of teak plantations select areas with low canopy cover. Conversion of evergreen forests to teak would hence lead to a loss of specialist communities of evergreen forests and cover loving species and would be replaced by species preferring low cover.

Conversion of evergreen forests seems to have the following consequences. Habitat structure is changed in the form of a loss in canopy cover and shrub cover (shrub cover in teak plantations is largely contributed by *Lantana. spp.*). Thus teak plantations are much more open and hence the floor is relatively more exposed (Table.3.).

In winter, the two vegetation types are not significantly different in air and soil temperature and relative humidity, but in summer, teak plantations are hotter and less humid (Table.4.). So species found in relatively open areas in teak plantations have to be tolerant to a higher range of temperature and humidity (18°c - 37°c and 33% - 82% respectively for minimum and maximum air temperature and humidity in summer in teak while in evergreen it is 17°c - 29°c and 47% - 85% in summer).

It may be surprising to note that in winter, teak plantations have a higher soil moisture than evergreen forests. This is because, in winter there is dew in the mornings. The relatively larger surface area of teak leaves probably act as a better condensation medium than the smaller leaves of the evergreen species. The relatively open canopy also allows the condensed dew to drip to the ground while in evergreen forests much of it is caught up in the canopy.

The only species commonly found in areas away from the mosaics of natural vegetation in teak plantations are *Philautus variabilis* and *Rana beddomii.* These two species are probably tolerant to higher variation in temperature and humidity. Most amphibians lack a cutaneous barrier to evaporation and consequently experience severe water loss (Spotila and Berman 1976). However reduced evaporative loss has been well documented for several arboreal anuran species. Experiments on the genus *Hyla*, a genus related to *Philautus*, have shown that they can withstand water loss up to about 31-45 % of their body weight. They also have the ability to accumulate water in their lymph sacs and body cavity and such stored water resources increase their ability to withstand desiccation (Main & Bentley 1964). Some species such as *Hyla arborea* have granules in the epidermis which are structurally similar to mammalian lamellar granules that provide water proofing in mammalian skin and probably perform the same function (Bani *et al.* 1985, Wertz and Downing 1982). The genus *Philautus* also possess a granular skin. They probably share these adaptations against water loss which would help them survive in drier areas such as teak plantations.

The restricted distribution of *Rana curtipes* to evergreen forests is probably because of its microhabitat needs. It was seen in moist areas with dense cover. Since its skin is smooth and without granules, they probably cannot withstand water loss. This species is sluggish and an awkward mover. It was also observed to be a poor swimmer, which is further established by the lack of webbing on the hind limbs (Daniel & Sekar 1989, *pers. obs.*). Its poor mobility especially its swimming abilities have probably prevented its movement to the mosaics in teak plantations. The tadpoles of *Rana curtipes* were seen in deep rocky pools with flowing water, in the Varagaliar river. None were seen in sandy pools even in evergreen forests. The entire stretch of the Varagaliar river in teak plantations is sandy and the probable lack of appropriate development sites for tadpoles could be another reason for the absence of *Rana curtipes* in teak. Daniel & Sekar (1989), recorded this species only in evergreen and semi-evergreen forests, which matches with the observations of this study.

Among the other evergreen forest specialist *Rana diplosticta* was seen on leaf litter very close to the water sources in evergreen forests. Inger *et al.* (1984) had also collected specimens in evergreen and gallery forests. They were seen on dead leaves and bare soil. *Rana leptodactyla* and *Micrixalus gadgili* were collected next to a stream, on leaf litter under good canopy cover. *Polypedates cruciger* was collected on leaf litter about 30 m away from water, with moderate cover.

Rana keralensis and *Rana temporalis* can be considered more of an evergreen species because their distribution even in teak plantations is restricted to the natural vegetation mosaics. Inger *et al.* (1984) and Daniel & Sekar (1989) had recorded *Rana temporalis* mostly in evergreen forests and very few in moist deciduous and moist semi-evergreen forests. Similarly *Rana keralensis* was more often seen in evergreen forests though it occupied a variety of habitats including secondary forests, moist deciduous and rubber plantations (Inger *et al.* 1984), and in humid areas close to water in evergreen forests and semi evergreen (Daniels 1992c). These records suggest that the kind of habitats used by these species in the study area are similar to what was observed elsewhere.

It is quite probable that the floor of teak plantations have a less predictable environment than evergreen forests because of its greater exposure to the external environment. Species in climatically predictable environments have a greater tendency to form organised communities or guilds (Inger &

Colwell 1977), on the other hand the continual perturbation inflicted by a less predictable environment would prevent the formation of guilds. The organisation of a community permits a greater total number of species to coexist, given an equal array of resources, because interspecific competition for resources are weak and only intraspecific interactions are strong. Thus the species of a guild show an overlap in resource at a very broad scale but are unique at a finer resolution. The greater number of species in evergreen forests is probably because of better guild formation. We should not consider *Rana temporalis* and *Rana keralensis* as species found in teak plantations because of their restricted presence in the mosaic of natural vegetation which is probably more predictable than the rest of the plantation.

During the month of November, species such as *Rana beddomii, Rana keralensis*, *Rana temporalis* and *Rana curtipes* were encountered away from water. But after mid December no anurans were seen beyond about 10 m from water. In November, Varagaliar received heavy rains and the soil was still moist. Since soil moisture plays an important role in the distribution of amphibians, it should have influenced the observed patterns of distribution. Since there was no rain after November there must have been a reduction in the soil moisture which caused the amphibians to move closer to water sources.

A look at the graphs of anuran densities (Fig.3 & 4.) across the months show that there is a gradual increase in the densities, in plots close to water, up to the month of March after which there is a sharp decline in both vegetation types. I speculate that the increase in density close to water is because of the movement of the dispersed amphibians towards water as soil moisture and humidity levels decrease. The sharp drop in density is difficult to interpret. The need to aestivate does not arise since there is a permanent water source (Daniel 1963). There is an observed increase in the juvenile density (of *Rana temporalis, Rana keralensis* and *Rana curtipes*), which parallels the decrease in the adult density.

Thus areas next to streams and the river support high densities and act as a refuge to the adult and juvenile amphibians during the dry season. Hence the tracts next to water sources are the most important habitats for anurans in the time between late December up to end of April. The strong affinity of most species towards high canopy cover and soil moisture is also well demonstrated in this study.

Hence areas close to water sources with good cover are absolutely essential for the survival of amphibians in Varagaliar.

The policy of the Tamil Nadu Forest Department to retain the natural vegetation along streams and riverine areas in teak plantations has enabled the survival of species such as *Rana keralensis* and *Rana temporalis*, which would have otherwise perished due to the gross changes in habitat.

7. CONCLUSION

The conversion of evergreen forests to teak plantations results in gross changes in habitat structure and microclimate. These changes cause the local extinction of anuran species that select habitats with high canopy cover and favour those species that select more open areas. Tracts of natural vegetation along streams and rivers in teak plantations are important habitats for anurans and help in the survival of species that select high canopy cover, even in teak plantations.

REFERENCES

ALLMON, W. D. 1991. A plot study of forest floor litter frogs, Central Amazon, Brazil. Journal of Tropical Ecology. 7:503-522.

BANI, G., R. CECCHI, AND S. BIANCHI. 1985. Skin morphology in some amphibians with different ecological habits. A light and electron microscopical study. Z. mikrosk.-anat. Forsch., Leipzig 99:455-474.*

BOULENGER, G. A. 1890. Fauna of British India. Reptilia and Batrachia. London.

CHAMPION, H. G.,AND S. K. SETH. 1968. A revised survey of the forest types of India. Manager of Pubication, New Delhi.

CHATTOPADHYAY, S. 1985. Deforestation in parts of the Western Ghats region (Kerala), India. Journal of Environmental Management, 20: 219-230.

DANIEL, J. C. 1963. Field guide to the amphibians of Western India, Part 1 and 2. J. Bombay nat. Hist. Soc. 60: 415-438, 690-702.

DANIEL, J. C., AND A. G. SEKAR. 1989. Field guide to the amphibians of Western India, Part 4 . J. Bombay nat. Hist. Soc. 86: 194-202

DANIELS, R. J. R. 1990. Habitat and microhabitat preference of some tropical frogs and toads. Vijnana Parichaya, Publication of the Indian Institute of Science, Bangalore. pp. 8-10.

DANIELS, R. J. R. 1991. The problem of conserving amphibians on the Western Ghats, India. Current Sci. 60: 630-632.

DANIELS, R. J. R. 1992a. Habitat selection in the Western Ghats amphibia: Implications for species conservation. Paper presented at the first International Conference of the IUCN SSC-ISRAG, Bhubaneshwar. Report.

DANIELS, R. J. R. 1992b. Geographical distribution patterns of amphibians in the Western Ghats, India. J. Biogeog. 19: 521-529.

DANIELS, R. J. R. 1992c. Geographic range and ecology of the Verrucose frog (Rana keralensis). J. Bombay nat. Hist. Soc. 89: 199-203.

DAS, I. 1990. Amphibians from India - some further species. J. Bombay nat. Hist. Soc. 87:310-311.

DUELLMAN, W. E. 1989. Tropical herpetofaunal communities: patterns of community structure in Neotropical rainforests. *in*: Ecological Studies 69 (eds) M. L. Harmelin-Vivien and F. Bourliere, Springer-Verlag, New York.

DUTTA, S. K. 1992. Amphibians of India: Updated species list with distribution record. Hamadryad 17: 1-13.

HEYER, W. R. 1973. Ecological interactions of frog larvae at a seasonal tropical location in Thailand. J. Herpetology. 7: 337-362.*

INGER, R. F., AND R. K. COLWELL. 1977. Organisation of contiguous communities of amphibians and reptiles in Thailand. Ecological Monographs. 47: 229-253

INGER, R. F., AND S. K. DUTTA. 1986. An overview of the amphibian fauna of India. J. Bombay nat. Hist. Soc. 83: 135-146

INGER, R. F., H. B. SHAFFER, M. KOSHY, AND R. BAKDE. 1984. A report on the collection of amphibians and reptiles from Ponmudi, Kerala, South India. J. Bombay nat. Hist. Soc. 81:406-427, 551-570.

INGER, R. F., H. B. SHAFFER, M. KOSHY, AND R. BAKDE. 1987.Ecological structure of a herpetological assemblage in South India. Amphibia-Reptilia. 8: 189-202.

INGER, F. I., AND H. K. VORIS. 1993. A comparison of amphibian communities through time and from place to place in Bornean forests. J. Trop. Ecol. 9: 409-433.

JOHNS, A. D. 1991. Responses of Amazonian rainforest birds to habitat modification. J. Trop. Ecol. 7: 417-437.

KENT, M., AND P. COCKER. 1992. Vegetation Description and Analysis: A Practical Approach. CRC press and Belhaven press. pp. 363.

KUMAR, A. 1987. The ecology and population dynamics of the Lion-tailed macaque (*Macaca silenus*) in South India. Ph.D dissertation, University of Cambridge.

LLOYD, M., R. F. INGER, AND F. W. KING. 1968. On the diversity of reptile and amphibian species in Bornean rain forest. Am. Nat. 102: 497-515.

LOVEJOY, T. E., BIERREGAARD, R. O., RYLANDS, A. B., *ET AL.* 1986. Edge and other effects of isolation on Amazon forest fragments. *in*: Conservation Biology; The Science of Scarcity and Diversity.(ed) Soule, M. E., pp. 237-256. Sinauer Associates, MA.

MAGURRAN, A. E. 1988. Ecological Diversity and its Measurement. Croom Helm. pp. 179.

MAIN, A. R., AND P. J. BENTLEY. 1964. Water relations of Australian burrowing frogs and tree frogs. Ecology. 45: 379-342.

MARTIN, K. C., AND W. J. FREELAND. 1988. Herpetofauna of a northern Australian monsoon rain forest: seasonal changes and relationships to adjacent habitats. J. Trop. Ecol. 4: 227-238.

MYERS, N. 1986. Tropical deforestation and a mega-extinction spasm, *in*: Conservation Biology; The Science of Diversity And Scarcity. (ed) Soule, M. E. pp 394-426. Sinauer Associates, MA.

NAIR, S. C. 1991. The Southern Western Ghats: A biodiversity conservation plan.Indian National Trust for Art and Cultural Heritage, New Delhi.pp. 92.

PURI, G. S., V. M. MEHER-HOMJI, R. K. GUPTA, AND S. PURI. 1983. Forest Ecology: Phytogeography and Forest Conservation. Oxford and IBH Publishing Co. Pvt. Ltd.

SCOTT, N. J., JR. 1976. The abundance and diversity of the herpetofaunas of tropical forest litter. *Biotropica* 8: 41-58.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry. The principles and Practices of Statistics in Biological Research. Second edition. W. H. Freeman and Co., New York.

SPOTILA, J. R., AND E. N. BERMAN. 1976. Determination of skin resistance and the role of the skin in controlling water loss in amphibians and reptiles. Comp. Biochem. Physiol. 157: 423-427.*

TER BRAAK, C. J. F. 1988. CANOCO - a FORTRAN program for canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal component analysis and redundancy analysis (version 2.1). Technical Report: LWA-88-02. Agricultural Mathematics group, Wageningen, The Netherlands.*

TOFT, C. A. 1985. Resource partitioning in Amphibians and Reptiles. Copeia. 1: 1-21.

WERTZ, P. W., AND D. T. DOWNING. 1982. Glycolipids in mammalian epidermis: Structure and function in the water barrier. Science. 217: 1261-1262.*

WILSON, J. 1965. Revised working plan for the Coimbatore South Forest Division- 1965-66 to 1974-75.

* - Not referred in original.