HERPETOLOGICAL JOURNAL, Vol. 15, pp. 167-172 (2005)

VARIATION IN ANURAN ABUNDANCE ALONG THE STREAMS OF THE WESTERN GHATS, INDIA

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In order to test the hypothesis that anuran abundance does not vary between forest and commercial plantations, anurans were sampled along the streams of reserve forests, and adjoining cardamom and coffee plantations on the western slopes of the Western Ghats. The species composition and relative abundance varied significantly between the three habitats. A few species showed complete dependence on the forest whereas many common species were least affected by habitat alterations associated with plantations. Analysis of variance revealed significant differences in the abundance of *R. temporalis*, *Micrixalus saxicolus, Fejervarya limnocharis*, *Euphlyctis cyanophlyctis* and *Bufo melanostictus*, whereas the difference was not significant for *Indirana beddomii*, *Nyctibatrachus* species and *Polypedates* species.

Key words: amphibian, frog, species composition, plantations, stream transects

INTRODUCTION

Amphibian population declines have been reported from various parts of the world (Richards *et al.*, 1993; Fisher & Shaffer, 1996; Lips, 1998; 1999). One of the main reasons for such declines has been found to be habitat modification (Daniels, 1991; Lips, 1998; Lips *et al.*, 2003). Anthropogenic activities such as deforestation (Petranka *et al*., 1993) have been highlighted as an important threat. Amphibians relying on specific microhabitat features may be in danger of declining because of extensive forestry-related disturbances. In southern India, selective logging in the primary forests has converted the original forests to fragmented secondary forests. Such isolation and fragmentation of forests results in drying of the forest floor and altered vegetation composition. Because amphibians show site fidelity and have limited dispersal capabilities, disturbances such as fragmentation, road construction and cutting of trees may disrupt metapopulation systems (Osawa & Katsuno, 2001) and cause local extinction of species (Blaustein *et al*., 1994).

The forests of the Western Ghats are considered to be one of the world's biodiversity hotspots, with endemic plants, butterflies, birds and amphibian species. Until now 196 species of anurans have been reported from India (Daniel, 2002) and approximately 75% of Indian amphibians are endemic to the Western Ghats (Oommen *et al*., 2000). The distributions of amphibians are uneven even across India and within the Western Ghats. The medium elevations are considered to be the richest zone in the Ghats (Daniels, 1992). Most of the ecological works on Indian anurans are restricted to distributional records. The demographic status of anurans in such pristine forests, where there is a concentration of many species, remains anecdotal. Encroachment upon wilderness areas by major anthropogenic activities and habitat modification for establishing new plantations such as coffee and cardamom, diversion of hill streams, and modification of water bodies for farming have resulted in loss of breeding sites in recent years. The synergistic interactions among diverse human activities such as the land use change, climatic changes, habitat degradation, vegetation removal and illegal removal of non timber forest produce (NTFP) has made the conservation of the forest and wildlife a major challenge in these forests.

In the context of global amphibian population decline, it is important to know the situation in one of the world's amphibian diversity hotspots, the Western Ghats. Many researchers have used observational studies and sometimes combined them with historic records to document amphibian declines. However, in areas where historic data do not exist, understanding the population status has become impossible. Regular long-term monitoring of the amphibians in this sensitive area is crucial to plan conservation strategies and management activities to save species from extinction. Our presence/absence survey in one such locality within the area showed the decline in calling frogs during the early monsoon season, especially *Hoplobatrachus tigerinus* during 1999-2000 (personal observations, S.K.N.). Elsewhere the reasons for *Hoplobatrachus tigerina* declines in paddy fields are thought to be due to the indiscriminate use of chemicals in agricultural lands and trading of frog's legs (Dutta & Hejmadi, 1981). The Conservation Assessment and Management Plan for Amphibians of India used the IUCN criteria for status assessment and has already reported the species as vulnerable (Molur & Walker, 1998). The amphibian species preferring cool evergreen forest habitats have patchy distributions, probably due to habitat destruction and fragmentation (Daniels, 1992).

We sampled the streams for anurans in 2001 and 2002, from January to May, when the streams flow is

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less swift and sampling was possible in the difficult sloping terrain of the Western Ghats. There are no pre-existing data on anuran abundance from unmodified habitats that the present data could be compared to. Therefore, only horizontal habitat comparisons can be done to assess the effect of habitat modification on anuran abundance. Here, we report for the first time the abundance of anurans along streams in the forests of the Western Ghats, and provide a measure of comparative species composition and abundance in the two adjoining types of plantations. The objectives of our study were to (1) to establish baseline data on the relative abundance of a few selected riparian species in the pristine forest streams so that the demographic assessments can be done on the basis of present status of anurans for future population monitoring programme; and (2) to understand the effect of habitat modification on the abundance of such species, as it is important for habitat conservation and management implementations.

METHODS

Bisale reserve forest (12^0 15'N and 75^0 33'E) is managed by the Karnataka State Forest Department. The forest is wet evergreen secondary forest. Three different sites were selected for the study, one undisturbed forest and two modified habitats (plantations). Care was taken while selecting the plantation so that they were all located adjacent to each other, so that elevation and other physical parameters remained almost same. The forest site was at a higher elevation on the crest of the western slopes of the Western Ghats at an elevation of 840 m above sea level. The Western Ghats in this area receive an average of 5500 mm rainfall annually from the south-west monsoon rains. This in turn had turned the Western Ghats into a main watershed for the Indian Peninsula, with many streams and rivers. Many hill streams in the study area feed the west flowing river Kumaradhara that in turn joins Arabian Sea. The vegetation is semi-evergreen (Champion & Seth, 1968) and classified as *Dipterocarpus indicus – Kingiodendron pinnatum–Humboldtia brunonis* forest type (Pascal, 1988). The edges of reserve forests in this region are circled by numerous small private land holdings. These private lands, which were once forested, are being modified for the cultivation of commercial crops, paddy fields and plantations. The main large-scale plantations in the area are cardamom and coffee estates.

The second site was in Hosagadde, a cardamom estate (28^0 slope) located on the hill ranging from 840-920 m elevation, adjoining the Bisale Reserve Forest on the eastern side. The annual average temperature during 2002 was recorded to be 21.11^0 C, the humidity was 62.89% and annual total rainfall was 4790 mm. The cardamom (*Elettaria cardamomum*) is grown on the cool slopes of hills where there is heavy rainfall and more moisture, whereas coffee requires less rain and drier weather to produce seeds. The cardamom plantations in these areas were grown under the canopy, without clearing the undergrowth. Neither fertilizer nor insecticides were sprayed.

The third site was a coffee plantation, 3 km to the north-east of the forest site. Although the coffee plantations were developed on contours, the general terrain was less undulating when compared to cardamom and forested sites (Table 1). However, coffee (*Coffea arabica*) plants were grown in a completely modified habitat. Coffee plantations need more open canopy and clear ground. Hence the canopy cover is removed off on a yearly basis and the undergrowth cleared. Coffee plants were fertilized every year and the spraying of insecticide was used as part of the cultivation practice.

Streams were treated as special transects (Inger & Colwell, 1977) and were sampled for the occurrence of anurans. The data were collected from early morning transects (0530 to 0700 hr) along fixed segments (500-820 m) of the streams and sampled repeatedly. The streams selected were flowing in curves and covered the entire habitat of our interest. Therefore, the stream surveyed was representative of the entire riparian habitat of the areas in forest and plantations. Five volunteers, one in the middle of the stream, two on either sides very close to the edge of the stream and two on the shores, moved forward and made a systematic search of the area. We monitored all the stream transects by scanning the banks and marginal vegetation after flushing out frogs by sticks, scanning emergent rocks, uprooting the stones, sticks and litters within the streams. Care was also taken to release the captured frogs well behind the survey line so that recounting of the same individual was avoided. We recorded data from 820 m segments of the

TABLE 1. Site characteristics for the three habitats studied.

Site characteristics	RF Stream	Cardamom stream	Coffee stream
Elevation	< 850 m	920-840 m	900 m
Topography	Hilly	Hilly	Flat
Vegetation	Secondary forest	Plantation	Plantation
Canopy cover	Covered	Covered	Clear
Streams: Width (m)	4–5.8 m	4–7 m	6–9 m
Gradient/Clarity	Steep/clear	Steep/clear	gentle/clear
Bottom	Rocky	Rocky	Rocky & few mud bottom pools

stream in the forest and cardamom habitats and sampled them 13 and 24 times respectively. In the coffee estate, we marked a 500 m stream segment and sampled five times (Inger & Voris, 1993). Stream width varied from 6.1 to 10.2 m and the mid-stream depth varied from 0.7 to 1.3 m. Intervals between the sampling periods varied from five to eight days.

As the transect length varied between habitats, abundance was measured as the total number of frogs observed per 500 m transect. Anuran abundance variations along the streams running in three different habitats were compared using chi-square tests. Within-species comparisons of abundance in three different habitats were done using multiple comparisons available in one-way ANOVA. Tukey HSD post-hoc tests were used to compare the relative abundance of each species between the habitats to identify the homogenous habitats ($\alpha = 0.05$).

RESULTS

Eight common species representing three families (Ranidae, Bufonidae and Rhacophoridae) accounted for more than 90% of frogs observed along the streams at forest sites. The rare sightings included a single individual of *Ansonia ornata* within the stream of forests. The streams of cardamom estate and forest showed equivalent species composition. However, the stream transects in coffee habitat revealed only six anuran species. Anuran abundance varied between the three habitats (χ^2=1882.1, df=16, *P*=0.001). They showed significantly varied patterns of distribution in all the three different habitats (Table 2). Few species showed complete dependence on the forest streams. However many common species were least affected by habitat alterations caused by plantations. The ANOVAs revealed significant differences in mean abundance in four species, but the difference was not significant in *Indirana beddomii* ($F_{2,39}$=1.07, *P*=0.352), *Nyctibatrachus* sp. ($F_{2,39}$=1.64, *P*=0.205) and *Polypedates* sp. ($F_{2,39}$=0.82, *P*=0.446). The cardamom estate and the forest formed a single group for five species and due to the significant variation in their abundance, the coffee estate was singled out from the group. But the abundance of three species did not significantly vary between the habitats (Table 2 and Table 3).

INDIVIDUAL SPECIES ACCOUNTS

Rana temporalis. This is a medium sized, bronze coloured, nocturnal frog. They are active both day and night (Daniel, 2002) and retreat into rocky or mud crevices in the banks of streams. Sometimes we have observed them basking on the rock outcrops of streams. The species has long legs and leaps over considerable distances when disturbed. The juveniles are always found to inhabit the sandy banks close to water. We never sighted them away from the water source.

Rana temporalis showed an uneven pattern of distribution, with 75% abundance in the coffee estate stream, but only 12.3% and 25.3% abundance along forest and cardamom streams, respectively. The mean number of frogs per transect was significantly higher in the coffee and cardamom estate streams than in the forest ($F_{2,39}$=449.98, *P*=0.0001). Although the variation in mean numbers of *R. temporalis* in the streams of forest and cardamom estates was significant and formed a common subset, their abundance was extremely high in the streams of the coffee estate and therefore that habitat formed a different subset (Table 2, 3).

TABLE 2. Mean numbers and *F*-values for anuran abundance in forests and two adjoining plantations of Bisale Reserve forests. Ranges are given at 95% confidence interval for Mean. *N*=number of sampling episodes.

Species	Reserve Forest stream Mean ±SE Range (*N*=13)	Cardamom stream Mean ±SE Range (*N*=24)	Coffee stream Mean ±SE Range (*N*=5)	*F*	*P*
Rana temporalis	6.03±1.7 (2.23-9.918)	23.9±3.9 (15.83-31.99)	271.2±13.19 (234.56-307.83)	449.9	0.001
Bufo melanostictus juv	0	0.33±0.15	4.6±0.4 (3.48-5.71)	100.9	0.001
Micrixalus saxicolus	19.69±3.57 (11.89-27.49)	22.79±2.38 (17.86-27.72)	0	8.18	0.001
Fejervarya limnocharis	2.53±0.74 (0.9-4.1)	3.95±0.65 (2.59-5.31)	30.2 ± 4.22 (18.47-41.92)	90.4	0.001
Indirana beddomii	9.53±2.50 (4.08-14.99)	15.25±2.91 (9.22-21.27)	16.2 ± 1.3 (12.43-19.96)	51.07	0.332
Nyctibatrachus sp.	8.61±2.00 (4.24 -12.99)	27.66±8.04 (11.02-44.30)	19.20±0.96 (16.50-21.89)	1.64	0.205
Euphlyctis cyanophlyctis	0	0.12	3.20±0.8 (0.97-5.42)	48.09	0.001
Polypedates sp. juv.	0.46±0.26 (0.12-1.04)	0.62±0.22 (0.16-1.08)	0	0.82	0.44

TABLE 3. Post-hoc Tukey HSD test showing homogeneous habitats. Means for group in homogeneous subsets are displayed for three habitats, R.F., species along the stream of Reserve forest, Cardamom, species along the stream of Cardamom estate; Coffee, species along the streams of the coffee plantation.

Species	Subset for α=0.05			
	1		2	
Rana temporalis	R. F.	6.07	Coffee	271.2
	Cardamom.	23.91		
Bufo melanostictus juv.	R. F.	0.0	Coffee	4.6
	Cardamom	0.3		
Micrixalus saxicolus	Coffee	0.0	R. F	19.69
			Cardamom	22.79
Fejervarya limnocharis	R. F.	2.53		
	Cardamom	3.95	Coffee	30.2
Euphlyctis cyanophlyctis	R. F.	0.0	Coffee	3.2
	Cardamom	0.12		
Indirana beddomii	R. F.	9.53		
	Cardamom	15.25		
	Coffee	6.2		
Nyctibatrachus sp.	R. F.	8.61		
	Cardamom	19.2		
	Coffee	27.66		
Polypedates sp. juv.	R. F.	0.0		
	Cardamom	0.46		
	Coffee	0.62		

Bufo melanostictus. This is the only common toad encountered in the area. The toad has been observed to retreat in the crevices during the dry summer day. In 3 cases we also noticed more than four individuals using the common retreat sites, under a rock. Although the adults are rarely found near the water the juveniles were often encountered near the streams in coffee and cardamom estate streams. The relative abundance of the species in coffee plantation was estimated to be 1.09 % were as in cardamom it was 0.3%. We did not sight any juveniles nor the adults toads along the forest streams.

Micrixalus saxicolus. This stream frog is mostly found adhering on to the surface of rocky outcrops within the streams. Black tadpoles of this species were observed to adhere firmly by oral suckers to the submerged rock surfaces within the fast flowing torrential streams. This frog was the most abundant species with 43.95% relative abundance in forest streams. On the other hand, it was completely absent from the streams of the coffee estate, and less abundant (23.38%) in the cardamom habitat (Fig. 1).

Fejervarya limnocharis. Commonly known as the cricket frog, this species was found to be more abundant in the coffee estate streams than in the other two habitats ($F_{2,39}$=90.41, P =0.0001). The species breeds during the early rain from June to August in the pools and streams that flow less rapidly.

Indirana beddomii. This is a litter frog that sometimes occurs along the streams. The frog has a habit of urinating when disturbed and jumps to a considerable distance. Adults are found resting on the stem buttress of the larger trees in the cooler habitats. Although information on their habits is sparse, the species has been reported to be extremely common elsewhere (Daniel, 2002)

We observed the species to be more abundant along the forest streams (relative abundance of 18.8%), followed by the cardamom habitat (16.1%). Although the mean number of frogs did not vary significantly between the three habitats ($F_{2,39}$ =1.073, P=0.352), the coffee habitat recorded the lowest abundance of the species (4.12%).

Euphlyctis cyanophlyctis. The skipper frog was found mostly found along the coffee estate streams, but in relative low numbers (relative abundance= 0.55%). They were always sighted inside the pools of stream water. They were seldom found in swift flowing stream waters. They were never sighted in the forest streams and their number in cardamom estate streams was very low (Table 2).

Polypedates pseudocruciger. This is among the least studied species of the Western Ghats. Except for a distribution report (Daniels & Ravichandran, 1995), there is no other information on this species. We observed adults of this species along the streams in the rainy season. We recorded the calls of eight individuals from shrubs overhanging water bodies in two locations in the forest at 940 m elevation. We sighted 15 individuals

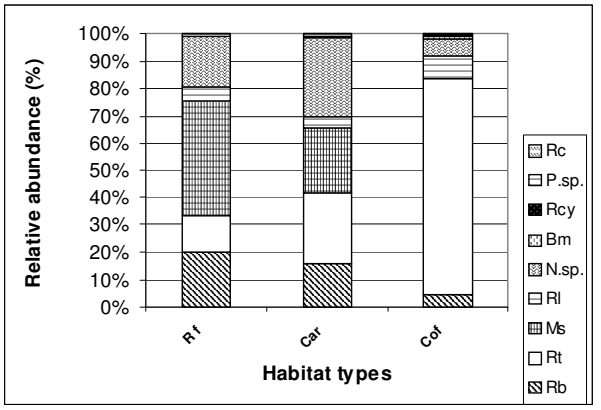

FIG 1. Relative abundance of frogs along the streams of Reserve forests (Rf), Cardamom estate (car), and Coffee estate (Cof) in the western slopes of evergreen forests of Western Ghats, Karnataka. Rc, *Rana curtipes*; P. sp., *Polypedates pseudocruciger*; Rcy, *Euphylyctis cyanophyctis*; Bm, *Bufo melanosticus*; N. sp., *Nyctibatrachus* sp.; Rl, *Fejervarya limnocharis*; Ms, *Micrixalus saxicolus*; Rt, *Rana temporalis*; Rb, *Indirana beddomii.*

along the stream in the cardamom estate and six individuals along the forest stream. We never sighted them along the stream transects of the coffee plantation.

We observed that anuran abundance in the natural forest and two human modified habitats varied significantly for most of the species (Table 2). *Rana temporalis* and *B. melanostictus* show significant variation in abundance between the three habitats, whereas *M. saxicolus, F. limnocharis* and *Euphlyctis cyanophlyctis* exist in almost equal numbers in the forest and cardamom streams. However, their abundance along the forest streams differed from that of coffee streams. The least affected species were *Nyctibatrachus, Indirana beddomii* and *Polypedates* (Table 2).

DISCUSSION

Rana temporalis, *Euphlyctis cyanophlyctis*, *Micrixalus saxicola* and *Nyctibatrachus sp.* are strictly aquatic. All the species listed in Table 2 breed in streams, and therefore the juveniles are found on stream banks. Hence, our observations of dry season sampling include the juvenile counts of *Bufo melanostictus*, *Polypedatus* sp., and *Indirana beddomii*. However, juveniles remain along the stream for a brief period. Once the area starts receiving monsoon rains, they disperse into the forests, which are their feeding grounds, and therefore, adults are rarely found along the streams.

Our study shows that anuran species composition and relative abundance varied between the three habitats. The terrain and the general physical conditions of cardamom plantations were similar to that of the forest. The luxuriant growth and flowering of cardamom plantations is dependent on high rainfall, canopy cover for their soft tissues and a sloping terrain. The canopy cover and the litter cover are maintained intact for the retention of ground moisture in areas of cardamom cultivation. On the other hand, the coffee plantations need more sunlight and therefore the canopy is cleared every year. The understory is removed and herbs are cleared in order to fertilize the coffee plants. The forests are modified completely in coffee cultivations and only a few trees are left intact. Due to the opening of the canopy, the annual mean temperature is high and the humidity is low in the coffee plantations when compared to the forest and cardamom plantations. Monthly average temperature ranges from 20.10^0 C to 24.03^0 C in the forest and the cardamom plantations, whereas the monthly average temperature in coffee plantations lies between 24^0C and 28^0 C. The woody coffee plants are also susceptible to different insect stem borers. Therefore, these plantations are sprayed annually with insecticides such as Rogor, Nuvacron and Metasid (Daniels, 1991). Due to the slopping terrain and high rainfall, the residual insecticides may drain into the streams, which are used by anurans as breeding and retreat sites. Our results indicate that some species such as *Ansonia ornata*, *Micrixalus* sp. and *Polypedates* sp. are absent in such streams (Table 1). *Bufo melanostictus* was not encountered along the streams in cardamom and forest habitats. However, in the coffee estate, they were found to occur along the streams. This suggests that the climatic changes such as increased temperature and reduced humidity might result in a preference for cooler areas along the streams in the coffee estate. In concurrence with the observation of Dutta & Hejmadi (1981), we observed that *H. tigerina* was absent from all the three habitats studied (N=42 transects). It is possible that modified habitats such as coffee plantations, where opening of the canopy increases the temperature and reduces the atmospheric humidity, and with insecticide residues, might be detrimental for the existence of these species. Anurans like *R. temporalis* and *R. limnocharis* can be considered as hardy species, and are still more abundant in coffee estate streams than other two habitats.

The monoculture plantations, which have fragmented the forests and occupied the hilltops, except in the rainy season, do not support amphibian diversity (Krishnamurthy, 1999). Based on our data, we suggest that the monoculture plantations involving large-scale habitat modifications – as in case of coffee – affects anuran species composition and relative abundance in the rain forests of the Western Ghats. However, crops such as cardamom, when cultivated without modifying the natural habitat and grown as an intercrop in the forests of the Western Ghats, would form a suitable habitat for anurans. However, these natural forests in the area are under high human pressure. The present water crisis in the eastern plains has forced the state Government to propose projects for the diversion of water from the Western Ghats. Road constructions are exposing more forested and streams in the areas. This progressive habitat modification will convert the present forests into a drier zone and therefore many endemic species might go

extinct. Hence, it is vital to monitor anuran diversity and abundance in these modified forested areas. Further, the survival of anurans in the future could be assisted by managed forests in the form of cardamom estates.

ACKNOWLEDGEMENTS

We thank the Karnataka Forest Department and the estate owner Mr Umesh, for their support in conducting the field observations. We thank H. Venkatesh, T. O. Sajith, and Anil Kumar for their field assistance. We acknowledge the assistance of students of Bioscience Department, Hemagangothri, Hassan, during the data collection. We are grateful to Mark Wilkinson, W. Wüster and two anonymous reviewers who provided useful comments on an earlier version of the manuscript. The financial support was provided by Declining Amphibian Populations Task Force, through the award of Seed Grant to S. N. K.

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Accepted: 1.10.04