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Distribution of tadpoles of large wrinkled frog *Nyctibatrachus major* in central Western Ghats: influence of habitat variables

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Abstract. The relationship between habitat variables and the distribution and abundance of adults and tadpoles of *Nyctibatrachus major* (large wrinkled frog) in 35 forest streams in central Western Ghats is detailed in this paper. Tadpoles were not equally distributed among these streams. Adult frogs and tadpoles were absent from 19 streams. In the remaining 16 streams, adults were found throughout the study period but the density of tadpoles varied considerably. Analysis of habitat variables at streams showed significant relationship with canopy cover over the streams, presence of leaf litter and high relative humidity on the occurrence of tadpoles. Reduction in canopy cover increases light level and air and water temperature of the streams discouraging the occurrence of adult frogs and tadpoles. However, canopy cover in the study area is frequently altered by agriculture related human activities including removal of trees for fuel and timber, pruning of green leaves and twigs for making manure and conversion of forest into commercial plantations. The results suggest that disturbances to forest canopy near streams could have deleterious effects on the occurrence and distribution of tadpoles.

Keywords. Tadpole, *Nyctibatrachus major,* habitat variables, Western Ghats, India.

INTRODUCTION

Understanding the relationships between animal distribution and habitat characteristics plays an important role in designing and developing conservation strategies for threatened species (Boyd et al., 2008). Habitats of most of the endemic anuran amphibians of Western Ghats are being altered or destroyed by different human activities. Despite the distribution of amphibians and their habitat features have been documented in the Western Ghats (Krishnamurthy, 2003), little is known about the factors influencing the distribution of tadpoles. Hence we detail the distribution of tadpoles of the Large Wrin-

kled Frog (*Nyctibatrachus major)* and factors influencing their distribution in evergreen forest patches of central Western Ghats. *N. major* is an endemic frog (IUCN: vulnerable; Anonymous, 2001) that inhabits forest streams with adults generally breeding in the same habitat. Recently, the habitat of the species has been being shrinking due to the extraction of timber, fuel wood, and organic mulch, which cause reduction of canopy and conversion to agricultural land (Krishnamurthy, 1997). In addition, these activities can also cause fluctuations in environmental variables of natural habitats of *N. major*. We conducted this study in order to investigate the influence of the habitat structure on the distribution of *N. major* tadpoles.

MATERIALS AND METHODS

From July 2006 to June 2007, we surveyed 35 streams in central Western Ghats (13˚ 35' - 14˚ 11' N and 74˚ 49' – 75˚ 37' E; altitude 577 – 780 m a.s.l.), which were categorized as "streams with tadpoles" (SWT) and "streams without tadpoles" (SWOT) according to the outcome of surveys. In SWT, tadpoles were sampled in four 1 × 1 m squares randomly selected within a 10 × 10 m area, it also randomly selected along the stream. Since none of the SWT was wider than 3 m, a 10 × 10 m area was chosen that encompassed both the banks across the stream. Tadpoles were sampled using hand nets and were identified following the description of Pillai (1978), whereas adults were caught by hand. Tadpole density in 1 × 1 m sampling squares was calculated following Sutherland (2000), and for each stream we computed a mean tadpole density by averaging the values obtained for the corresponding four 1 × 1 m squares. While the density of adult in each 10 × 10 m area is taken directly for all calculation.

For each of the 35 streams we measured the following environmental variables: the air, water and soil temperatures (using a mercury bulb thermometer, precision 0.1 °C), the water pH (using a portable pH probe, HACH), the light level (using a Lux meter, Kyoritsu, model 5200), the humidity (using a thermo-hygro clock, J412-CTH, Japan), the canopy cover (% above the sampling area using photographic images), the litter thickness, stream width and water depth (using a measuring tape graduated in millimeters), and the tree density. This last variable was recorded on either bank of the stream within an area of 10 × 10 m following the method proposed by Cox (1981), and only trees above 15 cm girth at breast height (GBH) were considered.

In order to detect the environmental variables best predicting the presence or absence of *N. major* tadpoles, we used a simple one-way ANOVA to compare habitat variables between SWT and SWOT streams. The relationship between the habitat variables and the density of tadpoles in SWT were examined using a Pearson correlation. Finally, a stepwise multiple regression analysis was carried out to obtain a model on the selection of different habitat variables for the distribution of adults and tadpoles. We used SPSS version 12.0 for Windows for all statistical analyses.

RESULTS

Overall, we found 213 tadpoles and 106 adult frogs in 16 out of the 35 streams surveyed. Air, water and soil temperatures, light intensity and depth of the water column were found to be higher in SWOT than SWT, whereas the opposite was found for the canopy cover, tree density, litter thickness and humidity (see Table 1 for statistics). Both stream width and pH did not differ between SWT and SWOT (Table 1).

Table 1. Habitat variables (Mean ± SD) of streams with (SWT) and without (SWOT) tadpoles of *Nyctibatrachus major.* Values in parenthesis denote the range.

Habitat variables	SWT (Mean ± SD) (n = 16)	SWOT (Mean ± SD) (n = 19)	F_{33}	P
Air temperature (°C)	22.62 ± 0.96 (21.08-24.90)	24.61 ± 1.83 (21.25-27.68)	15.468	0.0001
Water temperature (°C)	22.30 ± 0.56 (21.50-23.68)	23.22 ± 0.84 (21.90-25.08)	14.024	0.001
Soil temperature (°C)	22.22 ± 0.37 (21.78-23.15)	23.15 ± 1.36 (20.51-27.03)	6.978	0.013
Luminosity (Lux)	1061.64 ± 665.42 (277.5-3212.5)	6714.34 ± 7518.62 (1075-33000)	8.942	0.005
Canopy cover (%)	70.94 ± 7.18 (57.5-80.0)	42.76 ± 18.23 (7.5-72.5)	33.675	0.0001
Tree density (no./10m^2)	18.00 ± 4.93 (10-26)	9.53 ± 5.99 (2-22)	20.362	0.0001
Leaf litter thickness (cm)	2.77 ± 1.96 (0.23-7.93)	1.09 ± 0.91 (0.13-3.23)	11.171	0.002
Stream width (m)	1.16 ± 0.46 0.59-2.38)	1.13 ± 0.72 (0.40-3.43)	0.018	0.893
Water depth (cm)	7.34 ± 2.09 (3.53-10.63)	11.95 ± 8.56 (2.38-32.75)	4.414	0.043
Water pH	6.85 ± 0.24 (6.5-7.25)	6.82 ± 0.46 (6.0-7.50)	0.060	0.807
Humidity (%)	89.20 ± 3.06 (84.0-97.25)	79.51 ± 7.52 (67.75-89.75)	23.219	<0.0001

The density of *N. major* tadpoles in the 16 SWTs ranged from 2 to 5 tadpoles/m^2, being on average 3.8 ± 0.7 tadpoles/m^2. All SWTs also harbored adult frogs (Table 2), whose density was on average 6.6 ± 2.3 frogs/10m^2, ranging from 3 to 12.

Both adult frog and tadpole densities varied among the 16 SWT. The correlation analysis showed that the densities of both adults and tadpoles significantly increased according to canopy cover, tree density, litter thickness and humidity, whereas decreased with all other variables (Table 3).

It is very obvious that as tree density increases, canopy cover and leaf litter thickness also increase (r = 0.61, P = 0.018 and r = 0.69, P = 0.012 respectively), and thick forest cover supports higher humidity. Canopy cover, tree density, leaf litter thickness and humidity are positively related to frog density, frogs were confined to undisturbed forest streams. Although these four parameters support tadpole density, tadpole abundance was greater at 60-80% canopy cover with 15-20 trees per 10 m^2, medium litter thickness (2-4 cm), and high humidity of 89-92%, respectively (Fig. 1).

However, the result of multiple regression analysis have revealed influence of water and soil temperature for the adult density (adult density = -3.184-3.662 × [water temperature] + 4.113 × [soil temperature]), while for tadpole density have developed a model

Table 2. Distribution of adult individuals and tadpoles of *N. major* in sixteen streams at the study area.

Stream number	Latitude – Longitude	Altitude (m a.s.l.)	Density of adult frogs (mean n/10m^2 ± SD)	Density of tadpoles (mean n/m^2 ± SD)
1	13° 51' 41.0" N - 75° 03' 12.2" E	580	11.7± 2.1	4.7 ± 0.6
4	13° 43' 04.8" N - 75° 00' 03.6" E	581	7.6 ± 1.1	3.5 ± 0.6
5	13° 43' 04.3" N - 74° 59' 52.3" E	577	8.2 ± 1.3	4.5 ± 0.6
8	13° 55' 38.5" N - 75° 07' 44.0" E	623	4.8 ± 2.3	2.8 ± 0.5
9	14° 09' 11.3" N - 74° 49' 05.8" E	611	3.4 ± 1.6	3.3 ± 0.2
10	14° 09' 55.0" N - 74° 49' 01.1" E	619	4.3 ± 1.1	4.0 ± 0.8
15	13° 44' 07.8" N - 75° 00' 45.5" E	586	8.1 ± 2.0	3.7 ± 0.6
16	13° 47' 05.9" N - 75° 00' 17.9" E	620	7.3 ± 1.2	4.8 ± 0.5
17	13° 55' 50.4" N - 75° 08' 05.8" E	646	4.3 ± 1.2	3.5 ± 0.6
23	13° 36' 13.6" N - 75°18' 07.6" E	655	6.2 ± 1.3	3.8 ± 1.0
24	13° 38' 08.5" N - 75°17' 51.7" E	650	7.1 ± 2.0	4.3 ± 1.0
25	13° 35' 55.5" N - 75°19' 31.5" E	717	5.7 ± 1.2	3.0 ± 0.8
26	13° 36' 55.4" N - 75°19' 29.3" E	732	5.8 ± 3.0	4.0 ± 0.8
27	13° 36' 57.2" N - 75°19' 30.8" E	730	4.2 ± 2.3	2.5 ± 0.7
28	13° 36' 33.9" N - 75°19' 35.1" E	732	8.3 ± 1.7	4.8 ± 1.0
29	13° 36' 19.8" N - 75°19' 06.2" E	692	9.1 ± 1.9	4.0 ± 0.8

Table 3. Influence of habitat variables (as indicated by Pearson Correlation coefficient) on adult individuals and tadpoles of *Nyctibatrachus major*.

Habitat variables	Adult frogs		Tadpoles	
	r	*P*	*r*	*P*
Air temperature (°C)	-0.49	0.003	-0.55	0.001
Water temperature (°C)	-0.60	0.0001	-0.57	0.001
Soil temperature (°C)	-0.36	0.037	-0.41	0.016
Luminosity (Lux)	-0.41	0.015	-0.45	0.007
Canopy cover (%)	0.65	0.0001	0.69	0.0001
Tree density (n/10m^2)	0.54	0.001	0.58	0.0001
Leaf litter thickness (cm)	0.47	0.004	0.47	0.004
Water depth (cm)	-0.32	0.064	-0.34	0.044
Humidity (%)	0.57	0.0001	0.62	0.0001

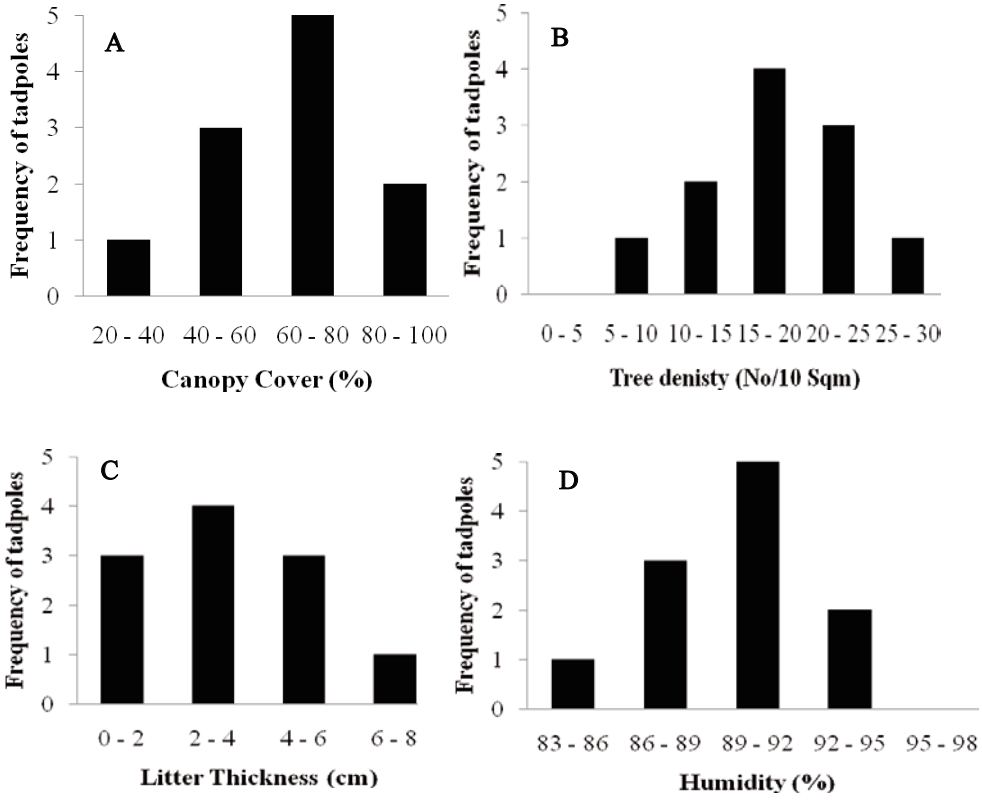

Fig. 1. Frequency distribution of tadpoles of *Nyctibatrachus major* against canopy cover (A), tree density (B), leaf litter thickness (C) and humidity (D).

(Tadpole density = 5.223 + 0.06474 × [canopy cover] - 0.1040 × [tree density] - 0.1274 × [leaf litter thickness] - 0.04241 × [humidity]) that is not statistically significant ($R^2 = 0.21$, $P = 0.58$).

DISCUSSION

A comparison of the habitat variables of sites that shelter and do not shelter *N. major* within a locality was used to decipher the habitat preferences. With the increase of light intensity, air, water and soil temperatures gradually raised. Probably for this reason, streams which run at open sites on forest borders do not shelter adult individuals of *N. major* or their tadpoles. This could be also a clear indication of sensitivity of the species to these variables. *Nyctibatrachus major* occurs at places with a thick canopy, high tree density, deep leaf litter and high humidity. In earlier studies of Gururaja et al. (2003), it was found that adult individuals of this species require low air and water temperature. This

study shows that, in addition to adult distribution, the tadpoles of *N. major* also require a narrow range of habitat variables.

Modification of the landscape generally alters the spatial structure of habitats and affects the distribution of organisms (Weins et al., 1993). Habitat preservation and protection are important steps in maintaining amphibian populations. Baseline information on species distribution, abundance, and habitat requirements are needed, especially in the case of poorly known and/or threatened species to clarify the extent and pattern of population declines (Parris, 2002). Analysis of habitat variables can help to elucidate the distribution, habitat requirements and preferences of a particular amphibian species. *Nyctibatrachus major* is a threatened endemic frog confined to the native forest streams of Western Ghats. This frog forages and breeds in a very narrow range of microhabitats, whose availability may influence on the survival, reproduction and viability of its populations. The influence of habitat variables on the distribution of tadpoles of *N. major* may help to conserve the species population in the local scale.

Various herpetological researchers conducted studies on habitat quality, habitat requirement, distribution and factors influencing different species of frogs and salamanders (Hollis, 1995; Gillespie and Hollis, 1996; Welsh and Lind, 1996; Grover, 1998; Harper and Guynn, 1999; Wilkins and Peterson, 2000; Parris, 2001; Lecis and Norris, 2004; Casatti et al., 2006; Muenz et al., 2006). The distribution and abundance of the cascade tree frog *Litoria pearsoniana* was found to be greatly influenced by stream size and mesic mid-storey vegetation in the riparian zone (Parris, 2001). In Brazil, stream volume, arboreal vegetation cover at stream margins and microhabitat diversity were shown to influence the distribution of adult frogs and tadpoles (Eterovick and Barata, 2006). Canopy cover and leaf litter in bodies of water have influenced the abundance and species richness of frogs and performance of tadpoles (Binckley and Resetarits, 2007; Williams et al., 2008). In the present study, the tadpoles of *N. major* were found to be abundant in streams with thick canopy cover.

Populations of *N. major* could be threatened by a number of factors, including extensive anthropogenic pressures such as litter and mulch collection, timber extraction, stream modification, construction of check dams, deforestation. These man-made activities are known to reduce the population size of a congeneric species (*N. aliciae)* in Western Ghats (Krishnamurthy and Reddy, 2008). Increased human activities (e.g. collection of timber wood, fuel wood and organic mulch, pruning of green leaves) in the forest areas of central Western Ghats alter light, temperature and moisture regimes (Krishnamurthy, 1996). These activities might gradually change the structure and composition of mid and understory vegetation, resulting in more open canopies in the forest, possibly increasing fluctuations in habitat variables of stream.

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