HABITAT OCCUPANCY AND INFLUENCE OF ABIOTIC FACTORS ON THE OCCURRENCE OF *Nyctibatrachus major* (BOULENGER) IN CENTRAL WESTERN GHATS, INDIA

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Habitat feature and influence of abiotic factors on the occurrence of *Nyctibatrachus major* in the streams of central Western Ghats was studied by comparing microhabitat variables of the streams inhabited and those streams not inhabited by frogs The study reveals the requirement of low concentration of carbon dioxide, alkalinity and high concentration of dissolved oxygen under low air, water and soil temperatures Further, analysis of abiotic factors and density of the frog reveals that concentration of carbon dioxide in water directly influences on the occurrence of the species, while other factors in combinations determines the suitability of the habitat

Keywords: habitat, *Nyctibatrachus major*, abiotic factors, Western Ghats, India

INTRODUCTION

Modification and changes in habitat quality and subsequent biological imbalance are severe threats to the existence of endemic species, especially to the amphibians The Western Ghats is one of the "hottest hotspots" (Myers et al, 2000) comprises 93 endemic among 218 Indian amphibian species According to recent assessment (BCPP CAMP Report, 1998) among 93 endemics of Western Ghats, 2 species are critically endangered, 16 are endangered, 13 vulnerable and 14 species are listed under low risk near threatened condition. Major threats for these amphibians are, human interference, loss of habitat and habitat fragmentation (Gupta, 1998; Krishnamurthy, 1999). One such ranid frog with high endemism and restricted distribution is *Nyctibatrachus major* (Boulenger). Breeding and adult habitats are the forest streams, filled with litter and organic mulch with slightly acidic pH and low temperature ranging 18 to 24 5°C (Krishnamurthy et al , 1992; Pillai, 1986) Information on the occurrence, altitudinal distribution and habitat feature of *N. major* are available (Daniels, 1992; Krishnamurthy, 1996, 1997; Krishnamurthy et al , 1992; Krishnamurthy and Katre, 1993; Pillai, 1978) Since, they require specific environmental conditions in their microhabitat, they are confined beneath half-submerged rocks during day, owing to its nocturnal activities. From the recent past, indiscriminate and unplanned manmade activities like denudation of forest for timber, fuel wood collection, scraping and collecting organic mulch and loss of canopy cover have increased in the forests of Western Ghats This subsequently caused the shrinkage of habitat of *N major* (Krishnamurthy, 1997). As a result of all these, the species is becoming rare in streams at periphery of the forest Since, the species is highly sensitive, it is felt that information on the microhabitat requirement of the species forms basis for conservation Hence, the present work has been undertaken for in-depth analysis of physical environment and microhabitat requirement of this species in the Western Ghats. Observations made during general survey revealed the absence of this species in forest streams with all visual similarities of habitat components inhabited by *N major*. This has stimulated the hypothesis that occurrence of *N major* is depend-

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ing on the availability of microhabitat and quality of habitat components. The basis for uncovering habitat requirement of a species is recommended by comparing the characters of sites with and without the selected species (Sutherland, 1997). In this paper, we examined various habitat components in eleven streams flowing amidst the Western Ghats and presented comprehensive result focusing on species-specific microhabitat requirement.

MATERIAL AND METHODS

Study was carried out in streams flowing amidst of five notified forests of the central Western Ghats. These forests are Kuvempu Bio-Reserve (KBR); Kudremukh National Park (KNP); Lakkavalli State Forest (LSF); Mudaba State Forest (MSF) and Sringeri Range Forest (SRF), located between 13°10′ – 13°45′ N and 75°05′ – 75°40′ E. Earlier studies (Krishnamurthy 1999; Krishnamurthy and Hussain, 2000; Krishnamurthy et al., 2001a, 2001b) reveal the occurrence and distribution of this species in forest streams of these localities. As an initial study, a thorough stream survey was made in six streams of KNP, five in KBR, three each in LSF and MSF and two streams of SRF. These streams flows in a narrow biogeographic province and the average distance between them are narrow (<1 km) within each locality and were found to be similar in "macro texture" of habitat generally found in those habitats of *N. major*. Selection of streams was made in such a way that one stream in these localities should have recorded the occurrence of *N. major*, while the other stream which do not possess *N. major* but flowing within the short distance from the former. Among these streams two each in KNP, KBR and SRF and one in MSF were horbouring *N. major*, while streams in LSF did not possess *N. major*. Based on the presence and absence of *N. major*, streams are categorized into "Streams with *N. major* (SNM) and without *N. major* (SWNM)." Subsequently, for the habitat analysis of *N. major*, two streams in KNP, KBR and MSF and one stream in SRF were selected.

In sampling area, microhabitat characters of the species were recorded using matrix of selected habitat variables (Table 1). These parameters were recorded and analysed following the methods of APHA (1991), Allen et al., (1974), using field kit (Soil and Irrigation Water analysis Kit-1, HACH Inc., USA). Air, water and soil temperatures were measured using mercury and soil thermometers, with a precision of 0.1°C (Make: Jennson). Light penetration as an amount of illuminosity coming through canopy was measured using an illuminometer (Model 5200; Kyoritsu, Japan). With pH Pocket Pal Tester (Electrode Method: Cat No. 44350-00, HACH, USA), water and soil pH were recorded on spot. Water depth was measured by dipping a meter scale (graduated in mm) vertically in the water column. Moisture content of soil was measured following the method of Allen et. al., (1974). A small portion of the soil sample was weighed accurately then heated in a oven for thermal drying at 105 °C. Later the loss of weight (initial weight — weight of soil after thermal drying) multiplied by 100 was recorded as percent moisture content of soil. Similarly, water holding capacity was calculated by measuring the retention of water (ml) in known amount of soil (100 g) after it is thoroughly saturated with water (Allen et al., 1974). All other chemical parameters were analyzed following the methods of APHA, (1991) and Allen et al., (1974). Preferential ranges of these matrices for the species were determined using density of the species as tool to correlate with habitat matrix. For recording the matrix of the habitat variables, two upstream and downstream points stretched along the watercourse comprising an area of 0.25 ha of stream were surveyed for every 30 days over a period of 18 months. Concurrent to the recording of the habitat variable, density of *N. major* was recorded using the methods of Fellers and Freel (1995), Olson et al., (1997), and Sutherland (1997). Density of *N. major* was recorded as number of individuals observed in each quadrat (10 × 10 m) and expressed as the number per 100 m^2. It was carried out by "*all-out*" search method, where in three persons searched entire quadrat for 1 h, by turning boulders, prodding the litter, thoroughly searching the streams and crevices in stream banks. All data were processed using SPSS program (SPSS Inc. 1993, Release 6.0).

RESULTS

Comparison of habitat matrix representing the sites with and without particular species is useful in detecting habitat requirement. Width of streams with *N. major* ranged from 0.6 to 1.8 m (mean: 1.19 ± 0.18 m) and streams without *N. major* ranged from 0.8 to 2.1m (mean: 1.41 ± 0.38 m). But they did not exhibit significant differences ($F = 1.87$, $P > 0.05$). Similarly, current velocity of both types of streams also did not vary considerably (SNM: mean: 0.3 ± 0.25

m/sec; range: 0 0 – 0.6 m/sec, SWNM: mean: 0 34 ± 0 26 m/sec; range: 0 0 – 0 6 m/sec, F = 0 08, P > 0 05). The results of the comparison of other habitat variable of SNM and SWNM are detailed in Table 1 From Table 1, it is clear that the air, water and soil temperature were low in SNM compared to SWNM and are significantly different (ANOVA: air temperature, F = 5 0697, P = 0 003; water temperature, F = 2 719, P = 0 0257, and soil temperature, F = 4 953, P = 0 0004) Similarly, depth of water, carbon dioxide, dissolved organic matter, soil conductivity and light penetration were low in SNM, and are statistically significant compared to SWNM In contrast, values of alkalinity, dissolved oxygen, calcium, phosphate, moisture content and soil alkalinity were high in SNM compared to SWNM. Among these except moisture content of soil all other parameters are significantly different Calcium content, pH of water and soil did not exhibit considerable differences between the sites. In addition, concentration of dissolved organic matter, moisture content and soil alkalinity though exhibited differences between SNM and SWNM, but they are statistically insignificant

Density of *N major* varies in study sites and ranges from 1 to 15 individuals per 100 m² Density did not exhibit any significant differences between the seasons (MANOVA, F = 1 65, P = 0 269) This frog is a continuous breeder in its adult microhabitat. Therefore, insignificant seasonal differences in densities indicate its permanent occupancy to the specific microhabitat Taking density of the species as a tool, favorable microhabitat can be analyzed. Since, SNM and SWNM are exhibiting significance differences for air, water and soil temperatures, water depth, alkalinity, dissolved oxygen, carbon dioxide, calcium, phosphate, soil moisture content and water holding capacity, it made us to assume that these factors either singly or in combination favors the occurrence of *N. major* The partial correlation calculated for these factors under density as a control reveal significant positive correlation between air and water temperature (r = 0 7194, P = 0 029), air and soil temperature (r = 0 7773, P = 0 014) While air temperature possess significant correlation for water depth and dissolved oxygen (r = –0 7664, P = 0 016, and r = –0 7649, P = 0.016, respectively) Water temperature possesses significant correlation with phosphate (r = –0 7796, P = 0.016) and soil temperature with water holding capacity (r = –0 7149, P = 0 03) In addition, alkalinity and carbon dioxide of water ex-

TABLE 1. Physicochemical Parameters (mean ± SEσ) of Streams with and without *N major*

Parameter	SNM, mean ± SEσ	SWNM, mean ± SEσ	F	P
Air temperature, °C	23 10 ± 0 52 (18 70 – 27 90)	26 55 ± 0 41 (19 8 – 31 6)	5 0697	0 0003*
Light penetration, lux	867 60 ± 276 07 (32 00 – 9600 00)	5188 46 ± 1346.06 (120 – 40000)	5 2863	0 0001*
Water parameters				
Temperature, °C	20.98 ± 0 41 (18 50 – 25.50)	22 79 ± 0 42 (18 1 – 30 2)	2 7197	0 0257*
Depth, cm	3 70 ± 0 48 (90 90 – 15 00)	7 29 ± 0 97 (0 5 – 33)	4 806	0 0001*
pH	6 76 ± 0 09 (5 90 – 7 90)	6 66 ± 0 076 (5 4 – 8)	0 0871	0 9167
Alkalinity, mg/liter	78.48 ± 9.74 (34 00 – 184 00)	68.24 ± 8 0 (18 – 270)	2 6031	0 0141*
Dissolved oxygen, mg/liter	6 29 ± 0 33 (1 63 – 8 98)	5 18 ± 0 19 (0.38 – 9 11)	23 796	0 0001*
Carbon dioxide, mg/liter	7 26 ± 0 52 (3 99 – 16 00)	17 38 ± 1 89 (3 99 – 50)	10 4164	0 0001*
Calcium, mg/liter	9 04 ± 1 248 (0 57 – 22 04)	8 82 ± 2 18 (0.57 – 52 91)	5 7368	0 0003*
Dissolved organic matter, mg/liter	6 62 ± 1 37 (0 60 – 34 00)	7.47 ± 1 59 (1 – 35 48)	0 9459	0 4973
Phosphate, mg/liter	0 55 ± 0 09 (0 09 – 1.30)	0 31 ± 0 04 (0 09 – 0 85)	6 3072	0.0168*
Soil Parameters				
Temperature, °C	21 28 ± 0 33 (18 50 – 26 10)	24 30 ± 0 52 (18 -36 8)	4 9532	0 0004*
pH	6 09 ± 0 14 (4 70 – 6 90)	5 92 ± 0 08 (4.3 – 6 9)	0 5177	0 6001
Moisture content, % age	25 00 ± 2 05 (11 00 – 43 50)	19 08 ± 1 8 (0 – 48)	1 4085	0 2339
Water holding capacity ml/100 g	46 13 ± 2 46 (30 00 – 71 00)	45.84 ± 1 29 (30 – 71)	2 5035	0 0236*
Electric conductivity, µS	101 36 ± 1 78 (83.63 – 136 60)	221 32 ± 52.97 (99 – 2000)	397 1463	0 0001*
Alkalinity, mg/100 g	53 98 ± 16 24 (2 40 – 320 00)	32 91 ± 2 2 (11 25 – 90)	2 5538	0 16
Calcium, mg/100 g	5.71 ± 0.562 (1.60 – 9.62)	6.67 ± 0.84 (1.6 – 25.65)	1.0197	0.4365

Notes. Values in the parenthesis denote the range * Significant values

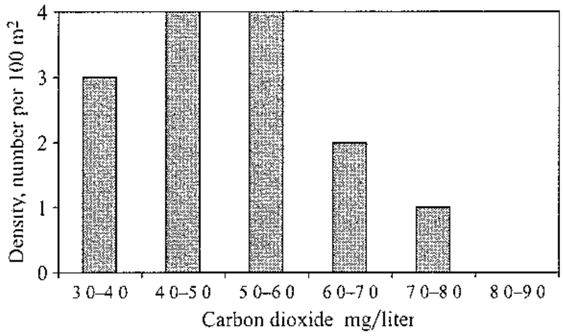

Fig. 1. Density of *N. major* plotted against carbon dioxide concentration

hibit significant (r = –0.7322, P = 0.025 and r = –0.702, P = 0.024, respectively). But except the carbon dioxide none of these variables exhibit direct significant correlation with the density. This is further depicted by multiple regression analysis (Table 2), where in carbon dioxide content exhibited significant values indicating the reduction of *N. major* density with an increase in carbon dioxide concentration of water. Density of *N. major* (Fig. 1) is maximum between 4 and 6 mg/liter of carbon dioxide. Therefore, this frog could inhabit in such streams with low carbon dioxide but the synergistic influence of other variables could also be a determining factor.

DISCUSSION

Animal species maintain their viable populations in specific places possessing favorable physical environment. Physical environments of an organism in association with biotic interactions are primary determining factors for survival and distribution. Considering the influence of abiotic factors alone, many ecologists have explained the habitat, distribution and abundance of some of the animal species (Dunson and Travis, 1991). As abiotic environments influence the efficiency of physiological function of a species, these factors not only determine quality of habitat but also explain viability of population over a range of habitat components.

TABLE 2. Multiple Regression Analysis Calculated for Density of *N. major*

Parameters	R^2	T	P
Air temperature	0.044	0.028	0.978
Water temperature	0.031	–1.311	0.231
Soil temperature	0.282	–0.759	0.473
Depth	0.0001	–0.305	0.769
Dissolved oxygen	0.110	0.915	0.391
Carbon dioxide	0.492	–2.784	0.024*
Water calcium	0.11	0.169	0.871
Water alkalinity	0.000008	–2.003	0.085
Phosphate	0.358	–0.404	0.699
Water holding capacity	0.109	0.432	0.679

* Significant values

N. major is an endemic anuran confined to undisturbed forest streams of Western Ghats. This species occur in a narrow range of microhabitat components. The character of microhabitat of the species and precise reason for its dependence on specific microhabitat are wanting (Krishnamurthy, 1997). For understanding habitat requirement, Sutherland (1997) has advocated comparison of habitat components of sites with and without that species. In the present study, comparisons of habitats were made using physicochemical characters of soil and water. Interpretation of observations described in this paper were made with a great caution, as the differences between the values of parameters of SNM and SWNM were narrow and the former possess narrow fluctuations.

The habitat selection and utilization was studied for many species of anurans and salamanders of temperate and tropical countries (Corsetti, 1999; Denton and Beebee, 1996; Diller and Wallace 1999; Hale and Guyer 2000; Pyke and White, 1996; Sugalsky and Claussen, 1997; Welsh and Lind, 1995, 1996). The distribution of Salamanders (*Plethodon cinereus*) was affected by soil moisture, pH and light intensity. Similarly, movement and microhabitat of *Bufo marinus* was affected by soil moisture, soil temperature and relative humidity (Seebached and Alford, 1999; Sugalsky and Claussen, 1997). Canopy cover and moisture contents were the influential factors for occurrence and distribution of Salamanders and different age class were known to respond at varying degree (Grover, 1998). However, earlier studies on *N. major* reveal only the occurrence and habitat feature (Inger et al., 1984; Krishnamurthy, 1996, 1997; Krishnamurthy et al., 1992; Pillai, 1986). Present study indicates that the *N. major* opts low light intensity; relatively low air and water temperature, low calcium carbonate in water with a high concentration of oxygen. Differences between concentrations of these tested parameters of SNM and SWNM are statistically significant (Table 1) and fluctuations of values recorded for SNM was very narrow. This indicates the specific microhabitat requirement. Multiple regression analysis calculated for the parameters those distinguish between SNM and SWNM reveal significant relation between density and carbon dioxide. However the concentration of the carbon dioxide also exhibits partial correlation with alkalinity of water. In addition, air, water and soil temperature, water depth, dissolved oxygen, water calcium, phosphate and water holding capacity of soil also exhibited partial correlation with density. Field studies confirm that *N. major* occurs at narrow ranges of these parameters. Therefore, concentration of the carbon dioxide in water in forest habitat is an influencing factor on the occurrence of *N. major*. But, synergistic influence of the other factors those distinguish SNM from SWNM cannot be ruled out.

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