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Habitat features of an endemic anuran *Micrixalus saxicola* Jerdon, 1853 (Amphibia: Ranidae) in central Western Ghats, India

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Unique features of amphibians such as poikilothermy, cutaneous respiration, bimodal life and requirement of stable environmental temperature have made them highly susceptible to various natural and manmade events operating either singly or synergistically on the species and on the habitat There are many factors listed as a cause for amphibian decline (Blaustein and Wake, 1995; Waldman and Tocher, 1998; Young et al., 2001; Lips and Donnelly, 2002) Among these habitat fragmentation and subsequent changes in the characters of habitat are causing the most severe threats. Parallel to the alarming reports on global amphibian population declines, the Western Ghats amphibian populations are showing the same trend with habitat fragmentation contributing most (around 70%) (Molur and Walker, 1998; Gupta, 1998; Daniels, 1999a and b; Krishnamurthy, 1999) Reports have already indicated a severe threat by habitat fragmentation/destruction to torrent frogs like *Nyctibatrachus* and *Melanobatrachus* (Gupta, 1998) The Western Ghats harbours 60% of recorded Indian amphibian species with a high endemism (72%), including apodan and anuran species. Among the anurans, the genus *Micrixalus* comprises seven species that are endemic to Western Ghats. *Micrixalus saxicola* (Ranidae: Anura) (fig. 1) is a hill stream species confined to the forests of Southern Western Ghats and reported from few localities (Molur and Walker, 1998; Krishnamurthy and Hussain, 2000) The species is distributed between 11° and 14°N latitude in the altitude between 400 and 1400 m msl (Daniels, 1992). The major threats for the species are the loss of habitat, human interference and habitat fragmentation and it is thus listed in the lower risk-near threatened categories of Red Data sheet (Anonymous, 2001) The recent field studies on habitat characters of amphibians made by us in the central Western Ghats revealed the specific range of habitat requirement for this species under natural conditions. We present herewith the detailed habitat preferences of this species, as baseline information for habitat based species conservation

The study was carried out in Kuvempu Bio-Reserve (KBR) (13°35′-13°40N, 75°15′-75°20′E. area: 32.31 km^2) and Kudremukh National Park (KNP) (13°10′-13°26′N 75°5′-75°10′E area: 600 km^2) in the central Western Ghats of India. In the survey the forest streams and adjoining areas were thoroughly searched for the species and they were enumerated using the quadrat and patch sampling techniques of Sutherland (2000) Then the paramel

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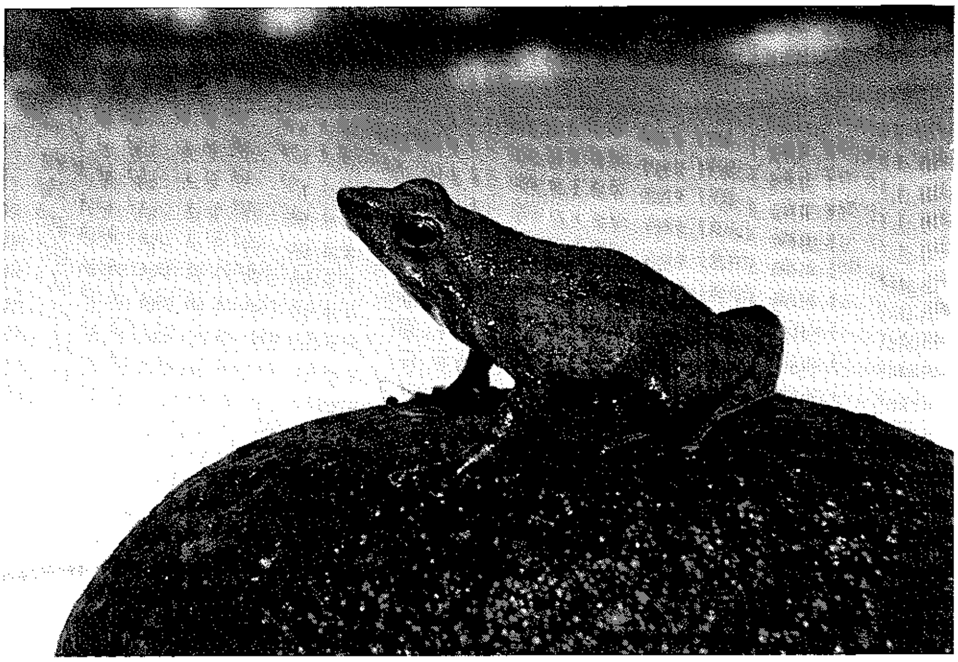

Figure 1. *Micrixalus saxicola* an endemic species from the Western Ghats of India

ters of the habitat (canopy cover. light penetration light intensity. air water and soil temperatures, water and soil pH conductivity carbon dioxide and dissolved oxygen concentration in water) were recorded on the spot and by processing the water and sediment samples in the laboratory using HACH Kit (Model SIW 1; 24960-00) for soil and water quality test The density of *M. saxicola* was estimated following the methods of Sutherland (1997) and using SPSS programme other statistical calculations were made The habitat use by this species was calculated following the methods of Jacobs (1974)

Among the selected study area, KNP possesses moist evergreen-shola forest, in the altitude ranging 1000-1892 m msl. In KBR, the major forest type is moist semi-evergreen to moist deciduous forest with an altitude of 640-880 m msl Within these two areas, the study was carried out in twelve localities over a period of two years (1998-2000) It was observed that the selected parameters (except the water pH) in these two areas are similar (ANOVA: air temperature; $F = 1.3427$, $P = 0.3703$; water temperature; $F = 0.154$, $P = 0.916$; soil temperature; $F = 0.482$, $P = 0.714$; water pH; $F = 11.6144$, $P = 0.0422$; soil pH; $F = 0.0367$, $P = 0.8603$; light intensity; $F = 0.3824$, $P = 0.7697$; dissolved oxygen; $F = 0.8199$, $P = 0.5648$; carbon dioxide; $F = 2.058$, $P = 0.2243$; canopy cover; $F = 5.00$, $P = 0.1114$; light penetration; $F = 0.2$, $P = 0.685$). Occurrence of *M. saxicola* was restricted to few localities of the study areas An important technique for determining habitat use is to compare the areas where a species occurs with those areas where it is absent, and in case of random distribution the environmental conditions are related to the abundance of the species (Sutherland and Crockford, 1993; Sutherland, 2000). A comparison of physico-chemical variables among the sites with and without *M. saxicola* of the study areas showed that except for the water temperature, dissolved oxygen, light penetration and canopy, all other variables were similar in the sites with and without *M. saxicola* (table 1). The habitat use of *M. saxicola* revealed that the habitats of those sites in Kuvempu Bio-Reserve were rarely restricted (Jacobs Preference Index D = −0.367 to −0.459) compared to habitats in the sites of Kudremukh National Park (D = 0.764 to 1.0).

Only those localities with low air, water and soil temperature were congenial for *M. saxicola*. Low air temperature in general correlates with thickness of canopy (average canopy cover 84.67%, $r = -0.613$; $P = 0.005$). Low water temperatures in different sites also showed significant correlation with canopy cover ($r = -0.51$; $P = 0.457$). Both water and soil pH were found to be slightly acidic to circum neutral (range: 6.14-7.7, and 5.2-6.85 respectively) with high concentrations of dissolved oxygen (range: 5-11.45 mg/L), low concentrations of carbon dioxide (range: 4-9 mg/L) and conductivities of water in the range 99-110 μS. In all the habitats surveyed the light penetration was found to be low (<25%).

In the selected habitats, *M. saxicola* were recorded at varying densities. The maximum mean densities were recorded in monsoon (June – September) that ranged between 10 and 250 frogs/2500 m^2 (Mean $\pm s_{\bar{x}}$ 167.0 ± 106.97 frogs/2500 m^2) followed by premonsoon (February-May) (range: 2-300; Mean $\pm s_{\bar{x}}$ 98.0 ± 69.83 frogs/2500 m^2) and postmonsoon (October through January) (range: 3-200; Mean $\pm s_{\bar{x}}$ 70.0 ± 44.71 frogs/2500 m^2). The correlations between habitat variables and the density of *M. saxicola* are detailed in table 2. The species inhabited forest streams with some specific physico-chemical habitat components. The association with low air, water, soil temperatures and soil pH were highly significant. The remaining parameters (excluding dissolved oxygen) did not bear any significant correlation with frog density. From comparing the variables between habitats with and without *M. saxicola* (table 1), we expected significant correlation between the

Table 1. Analysis of Variance (Bonferroni Test) of physico-chemical variables calculated for the values of habitat with and without *M. saxicola* of the study area

Parameters	*F*	*P*
Air Temperature (°C)	1.2405	0.3657
Water Temperature (°C)	4.8563	0.0127*
Soil Temperature (°C)	2.6951	0.0800
Water pH	3.6152	0.0523
Soil pH	0.0004	0.9836
Light Intensity (Lux)	0.6981	0.6746
Dissolved Oxygen (mg/L)	9.5125	0.0016*
Carbon dioxide (mg/L)	1.0749	0.4489
Conductivity (μS)	0.0135	0.9091
Light Penetration (%)	9.4307	0.0008*
Canopy Cover (%)	13.6188	0.0003*

* Significant values

among the sites with and without
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of Kudremukh National Park (D =

oil temperature were congenial for
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water temperatures in different sites
$r = -0\ 51$; $P = 0\ 457$) Both water
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l variables calculated for the values of habitat

	P
5	0 3657
3	0 0127*
1	0 0800
2	0 0523
4	0 9836
1	0 6746
5	0 0016*
9	0 4489
5	0 9091
7	0 0008*
3	0 0003*

Table 2 Selected parameters of the habitat of *M saxicola* and their relation with density [Calculated as Karl Pearson correlation (r) with Probability (P)]

Parameters	Mean ± $s_{\bar{x}}$	r	P
Air Temperature (°C)	22 8 ± 2.04	−0 601	0.014*
Water Temperature (°C)	22.0 ± 2 88	0 514	0 042*
Soil Temperature (°C)	21 67 ± 1 744	0 570	0 022*
Water pH	6 59 ± 0 489	0.040	0 881
Soil pH	6 32 ± 0.458	0 55	0.028*
Light Intensity (Lux)	837 05 ± 603 437	0 04	0 888
Dissolved Oxygen (mg/L)	7.54 ± 1 768	−0.30	0 291
Carbon Dioxide (mg/L)	6 05 ± 2 167	0.21	0 461
Conductivity (μS)	99 50 ± 0.459	−0 30	0 264
Light Penetration (% age)	14.2 ± 6 23	−0 01	0 968
Canopy Cover (% age)	84 66 ± 5 164	−0.114	0 686

* Significant values

densities of *M. saxicola* and water temperature, dissolved oxygen, light penetration and canopy cover, but except the water temperature, other parameters did not show any significant correlation. However, interdependencies among air, water and soil temperatures are justifiable with thick canopy and low light penetration

Conservation practices for different species are based on several criteria and planning for most of the amphibian species depends upon habitat and species management At present *M. saxicola* falls in the low risk, near threatened category of the IUCN Red list In the present study *M saxicola* was found to co-occur mostly with *Nyctibatrachus major* (87 5%), and also with *N aliciae*, *Rana beddomi* and *Rana temporalis* (62 5% each). Among these, *N major* is a torrential species and *N. aliciae* is an aquatic species confined to seepage water or the margins of fast flowing water. The remaining two species are litter frogs occurring on the margins of the water bodies The maximum co-occurrence of *M saxicola* with these species depicts the habitat sharing Since the present study reveals specific microhabitat and co-existence of other species with *M saxicola,* deriving a conservation scheme for *M saxicola* will also be useful to conserve other species of the frogs of the same habitat This information could be a tool for conservation and if the habitats are restored to meet the specific ranges of characters required by the species, then it could be conserved and restored even in the marginal zones of forest

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