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DISTRIBUTION OF AMPHIBIAN SPECIES IN KUDREMUKH NATIONAL PARK (WESTERN GHATS, INDIA) IN RELATION TO MINING AND RELATED HABITAT CHANGES

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Amphibian communities of Kudremukh National Park in the Western Ghats, India, were examined in relation to a wide range of habitat changes associated with an active iron ore mine. Twenty-six species of amphibian were recorded, comprising 23 anurans (four families) and three apodans (two families). Based on the changes in the quality of habitat, there were considerable differences in the pattern of amphibian distribution at different locations in the National Park. Undisturbed sites yielded 96% of species recorded in the area, while the disturbed sites yielded not more than 50%. Amphibian species richness, with litter-dwelling and semi-aquatic forms predominating, was related to the richness of plant species. Changes in amphibian species-richness and distribution were reflected in three assemblages of decreasing richness, in undisturbed, partially disturbed and heavily disturbed sites.

Key words: amphibian diversity, habitat quality, species composition

INTRODUCTION

Increasing attention is being paid to the effects of environmental changes on the persistence of animal populations at local and regional scales. Amphibians, with their biphasic life cycle and sensitive permeable skin, are considered to be very sensitive to changes in habitat quality. Thus, they are often considered as useful bioindicators of conditions of both terrestrial and aquatic habitats (Lambert, 1997*a,b*). Comparison of amphibian diversity and distribution has been used to assess the impact of anthropogenic disturbance to wetlands (Hecnar & M'Closkey, 1996) and primary rainforest (Kiew *et al.*, 1996; David & Pearman, 1997). Studies pertaining to the impact of man-made activities on amphibian diversity and distribution in the Western Ghats region of India, which contains approximately 123 species, is very limited. The present study is an attempt to assess the impact of habitat changes due to iron ore mining, human habitation and dam construction on the diversity and distribution pattern of amphibians in Kudremukh National Park.

MATERIALS AND METHODS

STUDY AREA

The Kudremukh National Park (KNP) is located in the Central Western Ghats (12° N and 16° N latitude) and spreads over the Tungabhadra State Forest, Naravi and Andar Reserved Forest in Chickmagalur and Udupi Revenue districts of Karnataka State.

The National Park covers a total area of about 600 km^2 and comprises lowland and highland tropical evergreen forests, shola-grassland-savanna and a mosaic of semi-evergreen forests and plantations at the periphery. Altitude of the study area ranges from 300 m (lowland forest) to 1892 m above sea level (highland forest and mountain peaks). The area receives substantial rainfall during the monsoon months of June to October (range: 1700-6350 mm) and is drained by a number of perennial streams, tributaries and rivers (Tunga and Bhadra) that flow through the valleys throughout the year. Except for a few tribal communities and the township of the Kudremukh Iron Ore Company Limited (KIOCL), a public sector enterprise, the area has no legally permanent human settlement (Hussain *et al.*, 1999). The KIOCL township, located in the centre of the National Park, has a population of approximately 10 600 persons involved with iron ore excavation by the contour line method. A dam across the Lakya tributary retains silt generated during the processing of iron ore and supplies water used to transport the concentrated ore to the nearby Mangalore Harbour Pelletization Plant through a gravity-siphon system. This major mining operation and the associated human activities have caused a significant impact on the biota of the National Park, especially in the area immediately surrounding the mines and downstream of the river Bhadra, which flows through the mine area (Hussain *et al.*, 1999).

We selected nine sampling sites from the range of terrestrial/semi-aquatic habitats comprising the study area (Fig. 1). Of these, Kachige Hole (Site 1), Bhagavathi Forest (Site 8) and Naravi Forest (Site 9) were undisturbed habitats, K3 Ridge (Site 2), Ridge I Valley (Site 3) and Store area (Site 4) were located within the mining area, the East shola-Sector IV (Site 5) and Sector II & III (Site 6) were in the Kudremukh township area, and Site 7 constituted the areas of the Lakya Dam (Table 1). All the sampling sites were once typical, tropical evergreen forests with a thick canopy cover. However,

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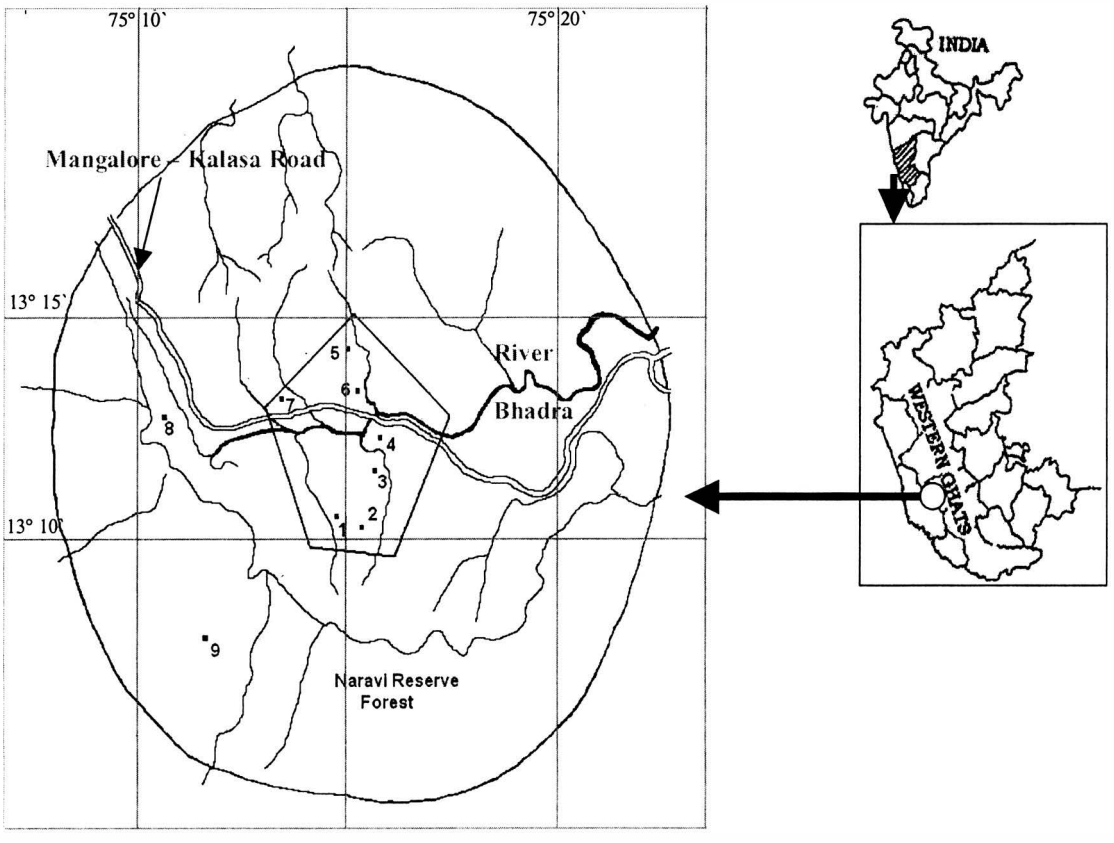

FIG 1. Map showing the study area and sampling sites (numbered 1 to 9).

subsequent to mining and related activities the canopy cover has been reduced in sampling sites 2, 3, 4, 5, 6 and 7. The sampling sites were located between 0.65 km (site 4) and 15 km (site 8) from the iron ore concentration plant. The study area ranges in altitude from 300-660 m asl (site 9: lowland forest) to 1087-1200 m asl (site 2: abandoned mine). In residential areas the canopy was made up of exotic and planted species, while in the vicinity of the mine the topsoil was heavily eroded and the canopy virtually absent.

AMPHIBIAN SAMPLING

We sampled amphibians in fixed quadrats at 30-day intervals, from the beginning of the monsoon season in 1998 until the monsoon of 1999. The size of the quadrat at each site was fixed by increasing its area until a stable number of amphibian species was recorded; this was accomplished during the monsoon, when most species are available. The quadrats covered an area of approximately one-tenth of total area in each site. Thus replicates of quadrat of varying sizes (50 × 50, 75× 100, 75 × 100, 85 × 85, 120× 125, 120 × 125, 200 × 250, 100 × 100 and 100 × 100 m for site 1 to 9, respectively) were used regularly over the period of study and these quadrats were placed in such a way as to cover all possible microhabitats. Sampling was made regularly in the same place using the same quadrat defined for each site. Sampling was done at an average rate of one-man hour per 10 sq. m. The amphibian sampling in all sites was completed within three days from date of the commencement of fieldwork in each month. Searches for amphibians in each quadrat were made following the methods of Sutherland (1996). In all microhabitats "all-out-search" was made by turning the rocks and boulders, scraping the litter, carefully searching the vegetation and bark of the tree, water bodies and also by digging the wet soil for apodans. Night surveys were also made using torchlight and following anuran calls. On-the-spot identifications of the amphibians were made using the field keys of Daniel (1963*a,b*, 1975), Daniel & Sekar (1989) and Daniels (1997*a,b,c*). The number of plant species present in each study site was counted.

DATA ANALYSIS

The similarity between survey sites were calculated in terms of the composition of amphibian assemblages using the Jaccard similarity measure. The similarity values were used to construct similarity matrices for the nine sampling sites. Based on the similarity values a phenogram was constructed using Unweighted Pair Group Method using Arithmetic Averages (UPGMA) method. The Shannon's diversity index was used to compare the sites. These analyses were made using the .programme MVSP ver. 3 for Windows (Kovach computing service). Pearson correlation coefficients were used to relate species richness to the number of plant species.

RESULTS

SPECIES COMPOSITION

The highest amphibian richness was in undisturbed sampling sites, with 22, 18 and 17 species in sites 9, 1

TABLE 1. Description of the study sites.

Sampling sites	Altitude (m asl)	Direction and distance from the concentration plant	Type of terrain and details of habitat
Kachige Hole (Site 1)	890-1030	S-W 3000-3500	Undisturbed shola forest, with a small rivulet flowing in the valley. Prominent siltation on the riverbed.
K3 Ridge (Site 2)	1080-1200	S 3000-3500	Abandoned iron ore mine with exposed inner soil composite, sparsely planted with *Acacia* sp. after the mining.
Ridge I valley (Site 3)	880-1000	S 2100-2500	Remnants of shola forest and a small spring in the middle of active mine. Bed of spring stream is silted and this area is continuously exposed to the vibrations of mine blast and vehicular transport.
Store area of the mining Company (Site 4)	790-835	S-E 650-1200	Absence of natural vegetation, terrain is highly disturbed due mine vehicle activities. Site comprises two check dam to prevent the downward flow of silt during monsoon.
East-shola, Sector IV (Site 5)	770-875	1900-2700	Natural Shola Forests, and rivulets. However, margin of the forest and hill slopes are converted for human habitation (township).
Sector II & III (Site 6)	780-835	N 800-1300	Part of the Kudremukh township.
Lakya Dam & Periphery (Site 7)	900-955	W 2700-3000	Area disturbed during the dam construction and subsequent dumping of the silt. The peripheral area is planted with *Acacia* sp
Bhagavathi Forest (Site 8)	900-1100	W 7000-7500	Undisturbed, thick evergreen forest.
Naravi Forest (Site 9)	500-660	S-W 14000-15000	Undisturbed lowland forest.

and 8, respectively. Of the 26 species encountered in the present study, 24 were recorded from the undisturbed habitats, 13 from residential areas, eight from around the dam (site 7) and nine from the surroundings of the mine (sites 3 and 4). Sites 3 and 4 had six and five species, respectively, while site 2 was devoid of any amphibian species. Among the three apodans recorded in the present study, two species were recorded from site 9 (Naravi) and one from site 8 (Bhagavathi Forest). The pattern of Shannon's diversity index was similar to that of species richness (Table 2). Correlations between Shannon's index and species richness was significant (r=0.90, P=0.001).

The study area is rich in flowering plants (168 species, 60 families). The undisturbed sites (S1, S8 and S9) had 62, 70 and 76 plant species, the mine and surrounding areas (S2, S3 and S4) had 5, 40 and 39 species. The residential area (S5 and S6) had 66 and 76 species respectively and the dam and surrounding area had 42 plant species.

HABITAT FEATURES

Amphibian species were recorded in all possible microhabitats in the study area and amphibian species richness was correlated with the richness of plant species (r=0.86, P=0.003, Fig. 2). There was no significant correlation between the number of amphibian species and log area of the study sites (r=0.21, P>0.10). Based on habitat and their place of occurrence, amphibians were categorized into litter-dwelling, aquatic, semi-

TABLE 2. Species composition and mean abundance (No/100 m^2/month) of amphibians in different sampling sites of the study. Values in the parenthesis denote the range. Aq, Aquatic; S-Aq, Semiaquatic; T, Terrestrial; A, Arboreal; F, Fossorial; LF, Litter dwelling species.

Species	Habitat	Undisturbed habitats			Mining and surrounding area			Residential area		Dam
		S1	S8	S9	S2	S3	S4	S5	S6	S7
ANURA: RANIDAE										
Micrixalus saxicola	LF, S-Aq	3.3 (0-7)	2.25 (1-5)	0.67 (0-2)		0.50 (0-2)		0.75 (0-3)		
Nyctibatrachus. Major	LF, Aq		1.3 (0-4)	0.67 (0-2)						
N. aliceae	LF, Aq	1.75 (0-5)				0.83 (0-2)				
Rana aurantiaca	LF, S-Aq	1.67 (0-5)	1.08 (0-5)	0.42 (0-2)						
R. limnocharis	S-Aq	2.25 (0-6)	1.58 (0-4)	0.98 (0-3)			0.42 (0-1)	0.58 (0-2)	0.58 (0-2)	0.75 (0-3)
R. beddomii	LF, T	1.17 (0-4)	1.16 (0-4)	0.41 (0-2)						
R. curtipes	LF-T	4.9 (1-12)	0.75 (0-4)	0.25 (0-2)			0.26 (0-1)	0.42 (0-2)	0.34 (0-2)	0.50 (0-2)
R. cyanophlyctis	Aq	1.42 (0-3)	0.5 (0-2)	0.30 (0-1)			0.16 (0-1)		0.16 (0-1)	
R. keralensis	S-Aq	1.7 (0-5)	1.17 (0-5)	0.50 (0-2)						
R. semipalmata	LF, S-Aq	0.75 (0-3)	1.83 (0-6)	1.33 (0-4)				0.24 (0-2)		
R. temporalis	LF, S-Aq	8.4 (4-15)	2.58 (0-6)	1.16 (0-4)				1.08 (0-3)	0.25 (0-1)	
R. tigrina	Aq	0.58 (0-3)	0.75 (0-3)	0.21 (0-2)		0.16 (0-1)		0.33 (0-2)		
Tomopterna braviceps	LF-T			0.50 (0-2)						
T. rufescense	T	1.0 (0-5)		1.25 (0-3)						0.33 (0-1)
ANURA: RHACOPHORIDAE										
Philautus charius	A	1.5 (0-5)	0.33 (0-2)	0.42 (0-2)				0.41 (0-2)		0.17 (0-1)
P. femoralis	A	0.25 (0-2)	0.25 (0-2)	0.51 (0-2)				0.08 (0-1)		
P. glandulosus	A					0.29 (0-1)				0.17 (0-1)
P. leucorhinus	A	1.67 (0-6)	0.83 (0-3)	0.33 (0-1)				0.16 (0-1)		
P. naustus	A					0.41 (0-1)				0.17 (0-1)
Rhacophorus malabaricus	A	0.33 (0-2)	0.35 (0-2)	0.25 (0-1)				0.08 (0-1)		
ANURA: BUFONIDAE										
Bufo beddomei	LF-T	1.08 (0-3)		1.10 (0-3)			0.25 (0-1)	0.25 (0-1)	0.08 (0-1)	0.08 (0-1)
B. melanostictus	LF-T			0.51 (0-1)					0.50 (0-2)	0.42 (0-1)

TABLE 2. Continued...

Species	Habitat	Undisturbed habitats			Mining and surrounding area			Residential area		Dam
		S1	S8	S9	S2	S3	S4	S5	S6	S7
ANURA: MICROHYLIDAE										
Microhyla ornata	S-Aq	0.67 (0-3)	0.83 (0-3)	0.83 (0-2)		0.17 (0-1)	0.16 (0-1)			
APODA: ICHTHYOPHIDAE										
Ichthyophis beddomei	F, S-Aq		0.32 (0-2)							
I. bombayensis	F, S-Aq			0.25 (0-1)						
APODA: CAECILIDAE										
Gegeneophis carnosus	S-Aq			0.17 (0-1)						
Total abundance		34.39	17.86	13.02	0	2.36	1.25	4.88	1.91	2.59
Species richness		18	17	22	0	6	5	11	6	8
Shannon's Index		2.523	2.639	2.923	0	1.160	1.541	2.146	1.627	1.878

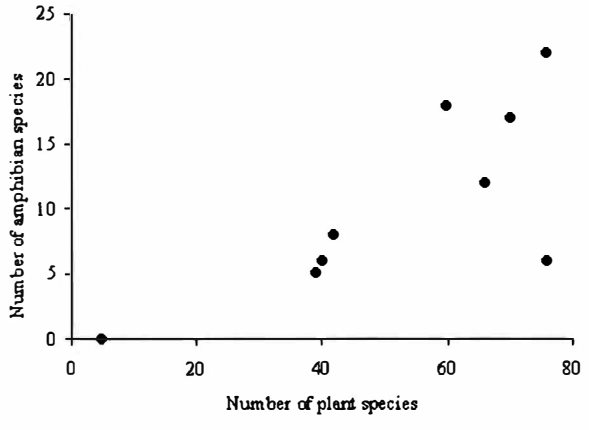

FIG. 2 Numbers of amphibian and plant species at different sampling sites.

aquatic, terrestrial, fossorial and arboreal species (Table 3). Interestingly, litter-dwelling species predominated in the undisturbed sites and accounted for 25-31% of the amphibian species richness, followed by semi-aquatic (20-32%), terrestrial (0-28.6%) and arboreal species (0-25%). Sites with undisturbed habitats (S1, S8 and S9) contained high species richness and exhibited significant similarity. Site 5 of the residential area exhibited high similarity with undisturbed habitats. Site 6 was similar to site 4 (Table 4). Other sampling sites had low species richness and the lowest similarity index. The UPGMA phenogram reveals the formation of distinct clusters of S1, S8 and S9, S6 and S4 (Fig. 3).

DISCUSSION

Because of their biphasic life style and membranous and permeable skin, amphibians are considered to be environmental indicators that can provide an early warn-

TABLE 3. Numbers of amphibian species in different habitats at each sampling site (total no. of species in each type of habitat is denoted in the parenthesis)

Habitat	Undisturbed habitats			Mine surroundings			Residential area		Dam area
	Site 1	Site 8	Site 9	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Litter (n=11)	8	7	10	0	2	2	5	4	3
Aquatic (n=4)	3	3	3	0	2	1	2	1	0
Semi-aquatic (n=10)	7	8	8	0	2	2	4	2	1
Terrestrial (n=6)	4	2	6	0	0	2	2	3	4
Fossorial (n=3)	0	1	2	0	0	0	0	0	0
Arboreal (n=6)	4	4	4	0	2	0	4	0	3

TABLE 4. Jaccard's coefficient of similarity between the sampling sites.

	Undisturbed habitats			Mine surroundings			Residential area		Dam area
	Site1	Site 8	Site 9	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Site 1									
Site 8	0.750								
Site 9	0.739	0.696							
Site 2	0	0	0						
Site 3	0.200	0.150	0.120	0					
Site 4	0.278	0.222	0.227	0	0.100				
Site 5	0.611	0.556	0.500	0	0.133	0.231			
Site 6	0.263	0.211	0.273	0	0	0.571	0.308		
Site 7	0.238	0.136	0.250	0	0.167	0.300	0.267	0.40	

ing of environmental deterioration that may not be perceived by humans (Halliday & Heyer, 1997). Hence, increasing attention has been devoted to understanding the dynamics of these ecologically pivotal species (Hecnar & M'Closkey, 1996). Previous studies in relation to other taxa suggested that the loss of forest cover has led to erosion of forest species in the Western Ghats, (Daniels *et al.,* 1995). However, in India, and especially in the Western Ghats, there is a dearth of information needed to use amphibians as a gauge for assessing habitat deterioration. Study areas in the Western Ghats have mega-hydroelectric projects, open cast-contour mining and monoculture-plantations, all reported to cause the shrinkage of habitat and decline of amphibian populations (Krishnamurthy, 1997; Gupta, 1998). The present study is an attempt to understand the impact of one such activity, open cast-contour line iron ore mining, which was initiated in 1973 at Kudremukh in a 5 km^2 stretch of land amidst dense moist evergreen forests.

The results of previous studies, within the vicinity (Krishnamurthy & Shakunthala, 1993; Bhatta, 1998; Krishnamurthy, 1997; 1999; Krishnamurthy & Hussain, 2000) have revealed a good number of amphibian species. In the present study, sites located in the buffer zone around the mine (undisturbed habitats) and in partially disturbed habitats were shown to have comparable species richness, whereas diversity decreased towards the active mine. Decline of amphibian populations in response to habitat degradation has been discussed for a variety of locations elsewhere (Corn & Vertucci, 1992; Daniels, 1992; Blaustein & Wake, 1995; Delis *et al.*, 1996; Fisher & Shaffer, 1996). Delis *et al.*, (1996) considered that differences in population structures between urban development and park were the result of habitat degradation. Hadden & Westbrooke (1996), while studying the impact of habitat alteration recorded a significant relationship between herpetofaunal richness, level of grazing pressure and vegetation understory structure and predicted amphibian richness in relation to the soil type in Victoria, Australia. Observations in the present study have revealed that habitat alteration has resulted in patchy distribution with decreased richness within a relatively small locality amidst the unique environment of moist evergreen forest. Litter-dwelling, semi-aquatic, terrestrial, arboreal and aquatic species were found in the undisturbed habitats, while aquatic and terrestrial species predominated in the residential areas. In the present study, there was a significant relationship between amphibian species richness and the number of plant species. Sites with more natural plant species were associated with rich amphibian communities. Hence the reduction in species diversity in the study area could be attributed to the development of a township around the mine, lack of topsoil and an absence of a surface litter layer. The UPGMA phenogram reflects the possibility of three assemblages of amphibian species representing undisturbed, partially disturbed and heavily disturbed habitats. Occupants of the disturbed habitats were widespread. This reflects the sharing by very few species in both assemblages and species of disturbed sites would be a subset of species complement of undisturbed sites.

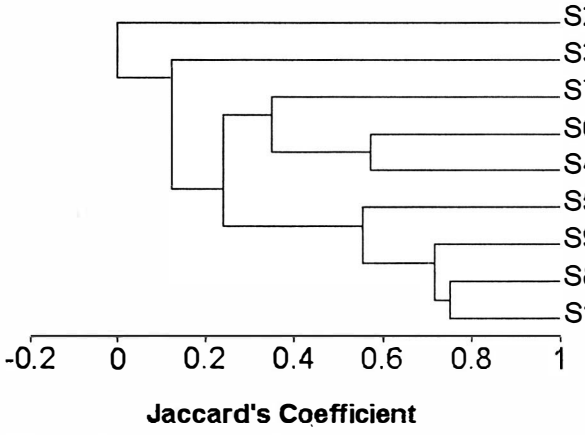

FIG. 3. Cluster analysis of the nine sampling sites examining the similarity of their amphibian richness.

The present study suggests that mining, human settlements and developmental activities have damaged habitats, resulting in the decline of amphibian populations in and around the KIOCL mine in the Kudremukh National Park.

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