DIVERSITY AND DISTRIBUTION OF BATS IN THE WESTERN GHATS OF INDIA

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Abstract

In this review, current patterns of distribution of bats in the Western Ghats of India are provided with endemism of species, exclusiveness in various zonesm and possible factors producing these variations. Species checklist from published literature is compiled. The number of species in six zone of 222km each, their endemism at Western Ghats level and exclusiveness at zonal level is presented. Distribution patterns, habits, habitat specificity, threats and conservation measures have been included.

Keywords

Bat, Chiroptera, conservation, distribution, diversity, Western Ghats

Chiroptera constitutes the second most diverse order of mammals. Studies on bats in Western Ghats are focused mainly on taxonomic identifications and species checklist in various localities in Western Ghats, but little research has been done to describe the patterns and processes involved in distribution of bat species in this region. There is a growing body of literature in community ecology describing and analyzing patterns of composition of trees, birds, butterflies, amphibians and freshwater fishes in the Western Ghats (Ghate *et al*., 1998; Kunte *et al*., 1999; Dahanukar *et al*., 2004). Despite the fact that India has 11.6% of world bat species, they have been neglected in these regards (Mistry, 2001). In current imperative of conserving the world's biodiversity, it is important to understand the life-scape that is patterns of distribution of biodiversity in the Western Ghats and underlying processes for changes in these patterns.

This paper focuses on current patterns of distribution of bat species across Western Ghats of India and comments on possible factors producing these variations. This study helps to understand the exclusiveness of bat fauna in various zones of Western Ghats. The conservation status of each bat species is further analyzed in these zones.

Western Ghats

Western Ghats, one of the 34 global biodiversity hotspots (Mittermeier *et al*., 2004) is a mountain chain running north-south and parallel to the western coast of India. It runs rather continuously between 8°-21°N latitudes, covering a distance of approximately 1600km and being interrupted just once by the 30km wide Palghat Gap at around 11°N (Fig. 1). The narrow coastal strip that separates the hill chain from the Arabian Sea in the west varies in width from 30km to 60km; being the narrowest between 14°N and 15°N. Hills are generally of elevations between 600m and 1000m. However, there are hills with 1000m-2000m altitude between 8°N-13°N and 18°N-19°N. Peaks over 2000m are found only in the Nilgiris, Palanis and Anamalais. The Nilgiris and Palanis are spurs from the main hill chain, which extend the Western Ghats eastwards to approximately 78°E (Dahanukar *et al*., 2004).

Annual rainfall on the Western Ghats averages 2500mm (in certain places like Agumbe, between 13°N-14°N, rainfall exceeds 7600mm). The Western Ghats receives much of its rain from the southwest monsoon. Hence, the wettest season generally lies between June and October. The rainy season in the southern latitude is however, often prolonged locally due to premonsoon and winter showers. Thus dry periods in parts of the Western Ghats south of 13°N are the shortest (2 to 5 months), while in the north it varies from 5 to 8 months. Mean temperature ranges between 20°C-24°C. However, it frequently shoots beyond 30°C during April-May (summer) and sometimes falls to 0°C during winter in the higher hills (Dahanukar *et al*., 2004).

Methodology

Species checklist from published literature was compiled. The work by Anderson (1912); Wroughton (1916); Wroughton & Davidson (1920a,b); McCann (1934; 1940); Tate (1941); Brosset (1962a,b,c; 1963); Tiwari *et al*. (1971); Agrawal (1973); Bastawade & Mahabal (1976); Hill (1976); Khajuria (1984); Das (1986); Koopman (1993); Bates *et al*. (1994a,b,c), Bates & Harrison (1997); Pradhan & Kulkarni (1997; 1999); Pradhan & Kurup (2001); Madhavan (2000); Yardi & Korad (2000); Nameer *et al*. (2001); Molur *et al*. (2002); Pradhan (2002); Korad & Yardi (2001; 2002; 2004a,b); Cyriac *et al*. (2005); Vanitharani *et al*. (2003; 2004; 2005) and Vanitharani (2005 a,b) was used for compilation of species checklist. The conservation status of the bats has been adopted from Bates & Harrison (1997); Molur *et al*. (2002) and Molur & Walker (2003).

To study distribution patterns of bats the Western Ghats was divided into divisions of 2° latitude (approximately 222km). The number of species in each zone, their endemism at Western Ghats level and exclusiveness at zonal level was determined by presence or absence of the species in each zone. The 8°-12°N extent of Western Ghats was termed as southern region, 12°-16°N as the central region and 16°-20°N as the northern region. The forest classification for various zones was adopted from Ramesh & Pascal (1997).

Bat species confined to only one of six zones were identified as exclusive. Qualitative data (presence or absence of bat species in each zone) were used to find percent similarity using Bray-Curtis similarity index (McAleece, 1998). Dendrogram was plotted to find out similarity of species in various zones.

The threat status indicated are based on the global assessments for endemics of South Asia, or national assessment

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for India in the case of nonendemic bats following Molur *et al.* (2002) and Molur & Walker (2003).

Scientific names is after Simmons (2005).

Results

Literature records 52 species of bats from Western Ghats of which six species belong to the suborder Megachiroptera and 46 species belong to the suborder Microchiroptera (Table 1).

Species diversity

The bat fauna of Western Ghats belongs to two suborders, eight families and 25 genera (Table 1). Microchiroptera is the largest suborder contributing to 88% of bat species with seven families, of which Vespertilionidae is the most abundant family contributing 40% of the bat fauna of the Western Ghats. Family Hipposideridae (containing leaf nosed bats) is the second dominant family with 14% of total species. Of the 52 species 84% are insectivorous, 12% are frugivorous and 2% are carnivorous (Table 1).

Habitat

Out of 52 species recorded from Western Ghats 47% of roost in caves, 31% roost in crevices, 8% roost in logs of dry trees and 13% roost in trees and foliage. Only one species roosts in bamboo thickets (Table 1).

Colony habits

Roosting places for 27 species (52%) are recorded in man made structures in forests, rural or urban areas in the vicinity of forests, 17 species (31%) are confined to forests of high altitude, mainly found in natural caves. Most of these species are reported in small groups of a few to about 25 roosting under the same shelter. Only 14 species (27%) are gregarious in the true sense forming a colony of few hundreds to thousands (Table 1).

Distribution, endemism and exclusiveness

Table 1 suggests that 13 species are distributed all over the range of Western Ghats. Only *Latidens salimalii* is endemic to the Western Ghats. Western Ghats endemism is confined to zone A, whereas exclusiveness is high in zones A, D and F. The dendrogram suggests that zones C, D, E and F have more similarity in species forming one cluster while Zones A and B are less similar to others forming the second cluster (Fig. 2).

Conservation status

As per Molur *et al.* (2002), 38 species are categorized as Least Concern (LC), seven as Near Threatened (NT), four as Vulnerable (VU), one as Endangered (EN), one as Critically Endangered (CR) and one as Data Deficient (DD) (Table 1) according to the 2001 IUCN Red List Criteria and Categories.

Discussion

Studies on bats in Western Ghats of India have focused mainly on taxonomic identification and listing of species in various localities.

The dendrogram (Fig. 2) shows isolation of zones A and B. Distribution of bats seems to be governed by forest types and bioclimate of these zones. The similarity of species in remaining zones declines as the distance between two zones increases. Same trend has been reported earlier for freshwater fishes in the Western Ghats by Dahanukar *et al.* (2004). Zone B has shown maximum number of forest types (Table 2). This may be the reason for least similarity of this zone with other zones. Furthermore, within these forest types there are variations in bioclimates, which can cause differences in similarity of adjacent zones with same number of forest types (Table 3).

Latitudinal decline of diversity is a ubiquitous phenomenon (Hillebrand, 2004). Tropics at lower latitude harbour relatively more species per unit area than at high latitudes (Gaston, 2000). Previous studies on distribution of amphibians, angiosperms, birds, butterflies and fishes have shown that the southern region is rich in species than central and northern regions (Daniels, 1992; Kunte *et al.*, 1996; Dahanukar *et al.*, 2004). A similar trend can be seen in the distribution of bats of Western Ghats. Unlike endemism, southern and central regions show high exclusiveness as compared to northern region. This may be due to the fact that southern and central regions show high diversity in vegetation type (Fig. 1, Table 2), which probably creates high resource diversity.

The seasonal rain pattern suggests that dry period increases from southern to northern regions. The southern region is dry for 2 to 3 months, central region for 4 to 5 months and the northern region for 5 to 8 months (Daniels, 1992). Variation in this dry period can be one of the possible factors for distribution of bat species in southern and northern regions. Reflection of the above explanation can be seen in high exclusiveness values in southern and northern regions (Table 2).

Fifty-two species of bats included in eight families have been recorded from Western Ghats (Table 1). Most of the bat species have broad distribution, however, *Kerivoula hardwickii*, *K. lenis*, *Harpiocephalus harpia*, *Miniopterus pussilus*, *M. schreibersii*, *Falsistrellus affinis*, *Pipistrellus babu*, *Otomops wroughtoni*, *Rhinolopus pusillus*, *Taphozous theobaldi*, *Rhinopoma microphyllum*, *Eonycterus spelaea and Latidens salimalii* are restricted to only one of the six zones as defined.

The distribution of bat species can also be explained with the help of feeding guild. Frugivore bat species though represent only 12% of total species, their distribution may not be the result of mere frugivory as they show variation in their habitats and their distribution (Appendix 1). *Cynopterus sphinx* feeds on plants of medium height. This species is observed in urban as well as rural areas in all zones. *Pteropus giganteus* is reported near human dwellings but only in spur areas in the northern Western Ghats (Korad & Yardi, 2004a). *Rousettus leschenaulti* prefers caves, tunnels, arches of the bridges, temples and old ruins, where water is available in the vicinity. Insectivore bat fauna is highly specialized in feeding habits. They show feeding activities at various levels from forest canopy to forest floor. Zones D, E and F show more similarity in distribution of insectivore species.

Loss of habitat and fragmentation of vegetation are two

Table 1. Distribution and status of bats in Western Ghats

Order/ Family/ Species[$]	Feeding Habit	Habitat	Colony habits	Zones A	B	C	D	E	F	Status
Suborder Megachiroptera										
Pteropodidae (5 genera, 6 species)										
Cynopterus brachyotis	F	FL		1	1	1	1	1	1	LC
Cynopterus sphinx	F	T	CN	1	1	1	1	1	1	LC
Eonycteris spelaea	F	CV		1	0	1	0	0	0	LC
Latidens salimalii[#]	F	CV	H	1	0	0	0	0	0	EN
Pteropus giganteus	F	T	G	1	1	1	1	1	1	LC
Rousettus leschenaulti	F	CV	G	1	1	1	1	1	1	LC
Suborder Microchiroptera										
Rhinopomatidae (1 genus, 2 species)										
Rhinopoma hardwickii	I	CV	CN	1	0	0	1	0	0	LC
Rhinopoma microphyllum	I	CV	CN, H	0	0	0	0	0	1	LC
Emballonuridae (2 genera, 5 species)										
Saccolaimus saccolaimus	I	TL	CN	1	1	0	1	0	0	LC
Taphozous longimanus	I	TL	CN	1	0	0	1	1	1	LC
Taphozous melanopogon	I	CV	CN, G	1	1	1	1	1	1	LC
Taphozous nudiventris	I	CV	G	1	1	0	0	0	0	LC
Taphozous theobaldi	I	CV	H,G	0	1	0	0	0	0	VU
Megadermatidae (1 genus, 2 species)										
Megaderma lyra	C	CV	CN, G	1	1	1	1	1	1	LC
Megaderma spasma	I	CV	CN, H	1	1	1	1	1	1	LC
Rhinolophidae (1 genus, 6 species)										
Rhinolophus affinis	I	T	G	1	0	0	0	0	0	LC
Rhinolophus beddomei	I	CV	H	1	1	1	1	1	1	NT
Rhinolophus lepidus	I	CV	CN, H	1	1	1	1	1	1	LC
Rhinolophus luctus	I	CV,TL	CN, FL	1	1	1	0	0	0	NT
Rhinolophus pusillus	I	CV	H	1	0	0	0	0	0	LC
Rhinolophus rouxii	I	CV,TL	H	1	1	1	1	1	1	NT
Hipposideridae (1 genus, 6 species)										
Hipposideros ater	I	CV	CN, H	1	1	0	1	0	0	LC
Hipposideros fulvus	I	CV	CN, G	1	1	1	1	1	1	LC
Hipposideros galeritus	I	CV	CN, H	0	0	1	0	1	0	NT
Hipposideros lankadiva	I	CV	H,G	0	0	1	1	1	0	LC
Hipposideros pomona	I	CV	H	1	1	1	0	0	0	LC
Hipposideros speoris	I	CV	CN, G	1	1	1	1	1	1	LC
Molossidae (2 genera, 3 species)										
Otomops wroughtoni	I	CR		0	0	0	1	0	0	CR
Tadarida aegyptiaca	I	CR	CN	1	0	1	1	1	0	LC
Tadarida plicata	I	CR	CN, G	0	1	0	1	0	1	LC
Vespertilionidae (12 genera, 22 species)										
Falsistrellus affinis	I	CR	CN	0	1	0	0	0	0	NT
Harpiocephalus harpia	I			1	1	0	0	0	0	NT
Hesperoptenus tickelli	I	FL	H	0	0	1	1	0	1	LC
Hypsugo savii	I	CR	CN	0	0	0	1	1	1	VU
Kerivoula hardwickii	I	CV	H	0	0	1	0	0	0	LC
Kerivoula lenis	I	CR		1	0	0	0	0	0	DD
Kerivoula picta	I	F		1	0	1	1	1	1	LC
Miniopterus pusillus	I	CV		0	0	0	1	0	0	VU
Miniopterus schreibersii	I	CV	H,G	1	0	1	0	0	1	LC
Murina cyclotis	I	FL		1	0	0	0	0	0	LC
Myotis horsfieldii	I	CR		1	1	1	1	1	1	LC
Myotis montivagus	I	CR	H	1	1	0	1	0	1	VU
Pipistrellus babu	I	CR	CN	0	0	0	0	0	1	LC
Pipistrellus coromandra	I	CR	CN	1	1	1	1	1	1	LC
Pipistrellus ceylonicus	I	CR	CN	1	1	1	1	1	1	LC
Pipistrellus kuhlii	I	CR	CN	0	0	0	1	1	1	LC
Pipistrellus pipistrellus	I	CR	CN	0	0	0	1	1	1	LC
Pipistrellus tenuis	I	CR	CN	0	1	1	1	1	1	LC
Scotozous dormeri	I	CR	CN	1	0	1	1	1	1	LC
Scotophilus heathii	I	CR	CN	1	1	1	1	1	1	LC
Scotophilus kuhlii	I	CR	CN, G	0	1	1	1	1	1	LC
Tylonycteris pachypus	I	B	G	0	1	1	1	0	0	NT
Total = 52				35	29	30	35	27	30	

Habitats: CV - Roosting in caves; T - Roosting on trees; FL - Roosting in foliage; TL - Roosting in logs of dry trees; CR - Roosting in crevices; B - Roosting in bamboo stem. **Colony habits:** CN - Roosting in man made construction; H - Roosting at high altitude; G - Gregarious species. **Feeding guild:** F - Frugivorous; I - Insectivorous; C - Carnivorous. **Status:** LC - Least concern; EN - Endangered; VU - Vulnerable; NT - Near threatened; CR - Critically Endangered; DD - Data deficient.

[#] - Species endemic to Western Ghats; [$] - Taxonomic status adopted from Bates & Harrison (1997); Molur *et al.* (2002); Molur & Walker (2003); Simmons (2005)

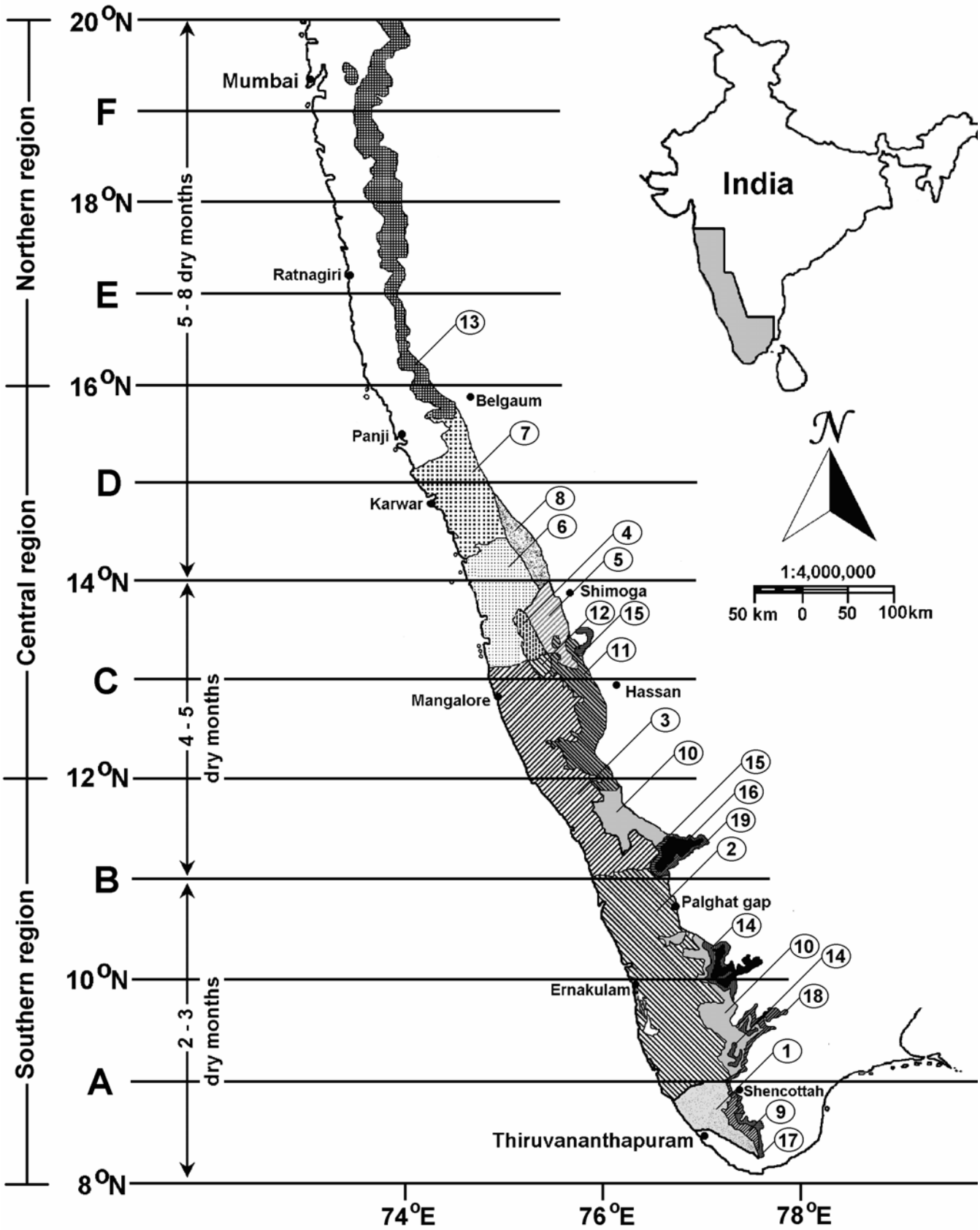


Figure 1. Major forest types and bioclimate of the Western Ghats. Map modified from Ramesh and Pascal (1997). For legends of forest types refer Table 3

Table 2. Latitudinal distribution of bats

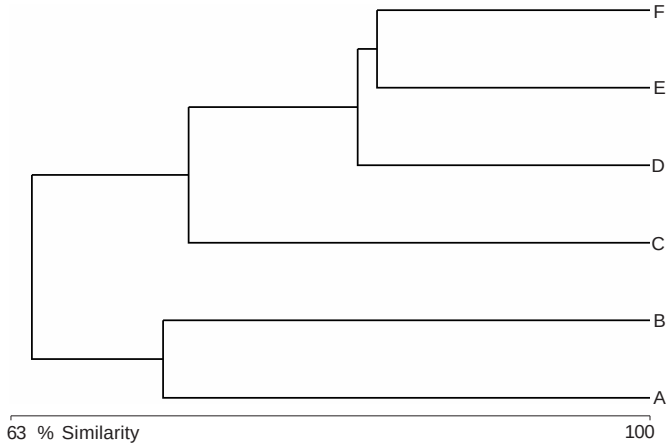
Zone	Latitude	Families		Genera		Species		Endemic Species (%)	Exclusive Species (%)
		Mega-chiroptera	Michro-chiroptera	Mega-chiroptera	Michro-chiroptera	Mega-chiroptera	Michro-chiroptera		
A	08-10	1	7	5	14	6	29	1 (1)	5 (7)
B	10-12	1	6	3	11	4	25	0	1 (1)
C	12-14	1	6	4	12	5	25	0	1 (1)
D	14-16	1	7	3	15	4	31	0	2 (4)
E	16-18	1	6	3	9	4	23	0	0 (0)
F	18-20	1	7	3	12	4	26	0	0 (0)

Table 3. Relationship between Bioclimate[+] and zonal distribution of forest types

Forest type [#]	Rainfall (mm)	Temp[*]	Dry-season	Zones A	B	C	D	E	F
1	2000-5000	>23	2-3	+	-	-	-	-	-
2	2000-5000	>20	2-3	+	-	-	-	-	-
3	2000-6000	>20	4-5	-	+	+	-	-	-
4	5000-8000	>20	4.5-5.5	-	-	+	-	-	-
5	>2000	>20	5-6	-	-	+	-	-	-
6	3500-7000	>20	5-6	-	-	+	+	-	-
7	2000-6000	>23	6-7	-	-	-	+	-	-
8	1500-2000	23-24.5	6-7	-	-	+	+	-	-
9	2000-5000	16-23	2-3	+	-	-	-	-	-
10	2000-5000	16-23	2-4	+	+	-	-	-	-
11	2000-5000	17-22	4-5	-	-	+	+	-	-
12	5000-7000	18-20	4-5	-	-	+	-	-	-
13	5000-6500	17-23	5-7	-	-	-	+	+	+
14	3000-5000	13.5-16	2-3	-	+	-	-	-	-
15	[3] 2000	13.5-17	3-6	-	+	+	-	-	-
16	900-6000	<13.5	0-4	-	+	-	-	-	-
17	1200-1500	>23	4-6	+	-	-	-	-	-
18	1200-1500	>23	4-5	+	-	-	-	-	-
19	1200-1500	16-23	4-6	+	+	-	-	-	-

[+] - Bioclimate as mentioned by Ramesh and Pascal, 1997; [#] - Forest type as mentioned in circle in Figure 1; [*] - Temperature = Mean temperature of the coldest month

Figure 2. Dendrogram of the relationship among various zones drawn from similarity of bat species diversity. The similarity seems to be decreasing as the distance between zones increases



major contributors to population decline and further restrictions on distribution of bats (Nameer *et al*., 2001). Groups of bats, which reside in caves, crevices, tree logs, trees and foliage (90% of total) face considerable threat due to the above mentioned activities. The worst affected among all species might be *Tylonycteris pachypus and Kerivoula lenis* (Bates & Harisson, 1997; Vanitharani *et al*., 2003). These species require bamboo thickets for shelter and all over the Western Ghats there is heavy cutting of bamboo for commercial purpose.

From colony habits 52% of species have roosting places in urban constructions. This group faces major threats because of various man made activities. It has been reported earlier by Addline *et al*. (2004) that many megachiropteran and microchiropteran bats get killed during renovations of old constructions. Along with this, killing of bats for food, medicine or as pest also pose a threat to bat fauna.

Frugivorous bats are considered to be pests of orchards, but actually these bats play an important role in pollination and in turn increase fruit yield (McCann, 1940). Insectivorous bats are primary consumers of nocturnal insects and play an important role in insect control on large scale (Kunz, 1982).

Since the work on bat ecology is ongoing and much needs to be understood, Korad (2005) mentions current threats to bat fauna in the central Western Ghats of Maharashtra. There is need for more surveys exclusively for bat fauna in the entire Western Ghats region for monitoring purposes, and for ecological studies of specific bat species to understand the process of forestation and the role of bats in the food web of forest ecosystem. The bat fauna has tremendous potential as bioindicator to judge the ecological stresses in the forest ecosystem. This type of study will prove vital to frame conservation measures in forest areas. The small mammal fauna in inhabiting only high altitude forests is highly specific in selecting suitable habitat. This rigidity in preference has made them vulnerable to disturbances. Most cave species of bats are experiencing ecological stresses.

Nearly 35% of the bat fauna of the Western Ghats are threatened globally or nationally. Conservation measures to protect this fauna are thus essential. The information for species occurrence in different parts of the mountain range is still incomplete due to patchy studies and inconsistent efforts and methodologies. The recent work by Juliet Vanitharani and team who recorded several bats for the first time from Kalakkad-Mundathurai Tiger Reserve is a good eye opener for what is still unknown in the Western Ghats. Nameer *et al*. (2001) suggests certain conservation measures and stresses the requirement of more studies of these small mammals to understand the distribution and various effects of human intervention.

Human activities should be restricted at least in regions of remarkable bat populations. Plantation of native bamboo varieties should be encouraged to provide homes for bats as well as livelihoods for craftsmen in the area. Natural caves of

all kinds should be systematically documented and all human activities in the caves should be banned.

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INCLUSIVE PLANNING AND ALLOCATION FOR FOREST CONSERVATION THROUGH RURAL SERVICES: AN EXPERIENCE

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The Gir National Park and Sanctuary is one amongst the seven protected areas selected for biodiversity conservation through Eco-Development Project funded by World Bank. One of the major steps taken was restricting the inhabitants of this forest to enter the National Park and thus rehabilitating them to the fringes of the protected areas. This has also enacted a restriction in using the forest resources and thus has created an unsaid conflict between the forest and its dwellers. Over the years however, it has been realized that for effective management of the protected area is not possible without addressing the legitimate needs of the locals.

To protect the natural resource, eco development project was a commitment in transforming the way services are planned and financed; a new association between the local governments, NGOs and private sector agencies are being created. Much attention has focused on adoption of various techniques with special emphasis on people's participation, through which direct and intensive involvement of locals can be encouraged in decentralized planning. This trend was critically examined and potential unintended consequences are highlighted. A broader concept of accountability is outlined to illustrate a more inclusive approach to planning and allocation for more equity and sustainability in rural services.

Sloganeering about 'participation in development', which has now become mandatory to attract and passing policies, however, no longer goes without challenge. Tallying up the once-hidden vices of participation alongside its known virtues, a recent review concluded that participatory development is an 'essentially contested concept' (Cernea, 1985). Yet it is clear that delivery of sustainable, equitable and affordable rural services is helped if service users are involved in choices about priorities and delivery options. They tend to be more prepared to invest their own resources and sometimes, though not as often as hoped, this involvement makes those services more accessible to vulnerable sections of the population (Cernea, 1985).

In developing countries, it is often argued that this kind of participation is constrained by the representative political process. The political, economic and social, connections between elected leaders and their constituency is simply too great for voices to be heard and participation to be effective. Thus special measures are welcomed. In response it has been agreed that intensive community consultation techniques (such as found in the 'PRA toolbox' much popularised by Robert Chambers and associates) can greatly improve the quality of local service planning decisions. Most donors now insist that these techniques are adopted and

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