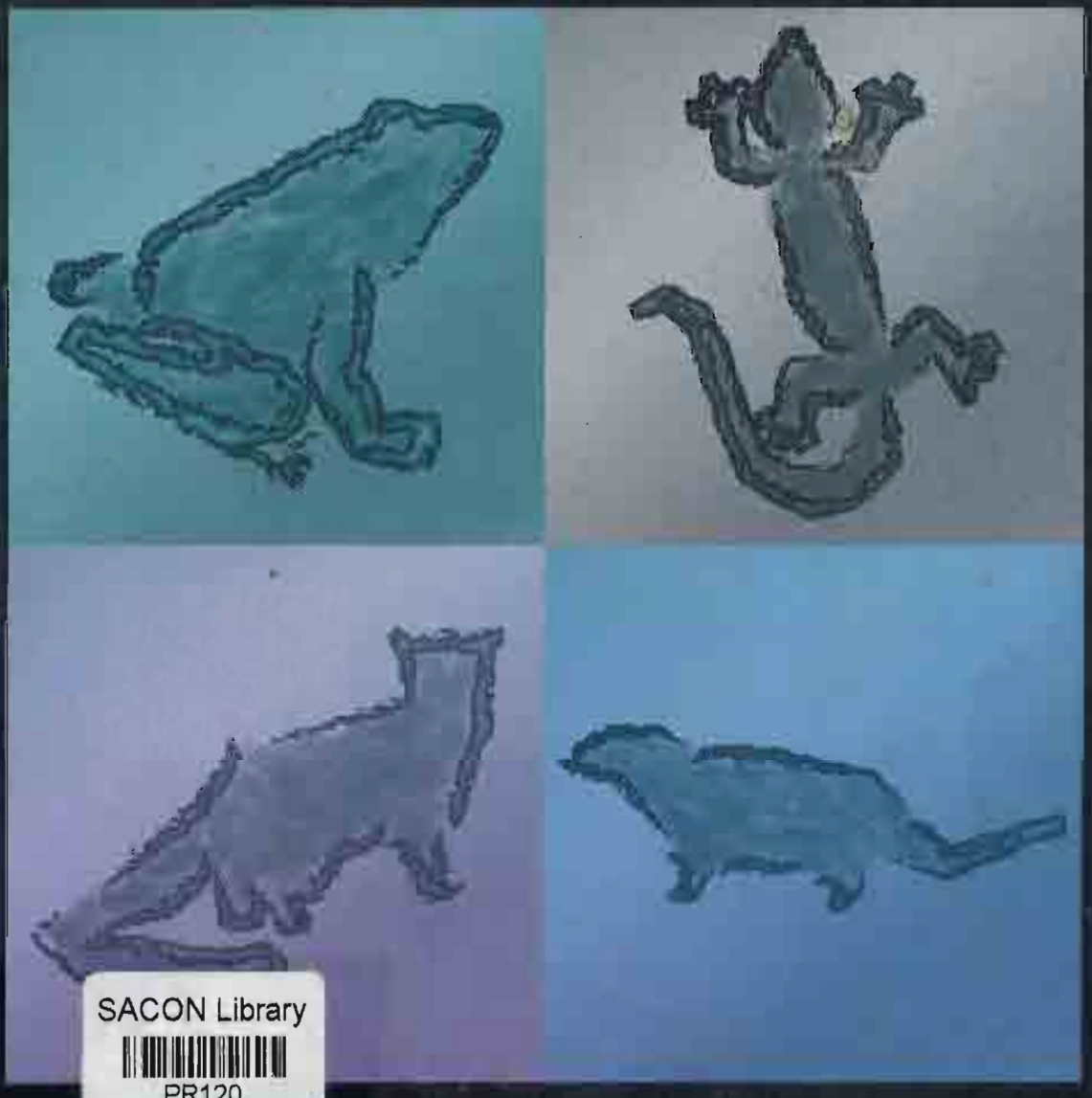
IMPACT OF RAINFOREST FRAGMENTATION ON SMALL MAMMALS AND HERPETOFAUNA IN THE WESTERN GHATS, SOUTH INDIA .



U.S. Fish & Wildlife Service
Wildlife Institute of India
Salim Ali Centre for Ornithology and Natural History

IMPACT OF RAINFOREST FRAGMENTATION ON SMALL MAMMALS AND HERPETOFAUNA IN THE WESTERN GHATS, SOUTH INDIA

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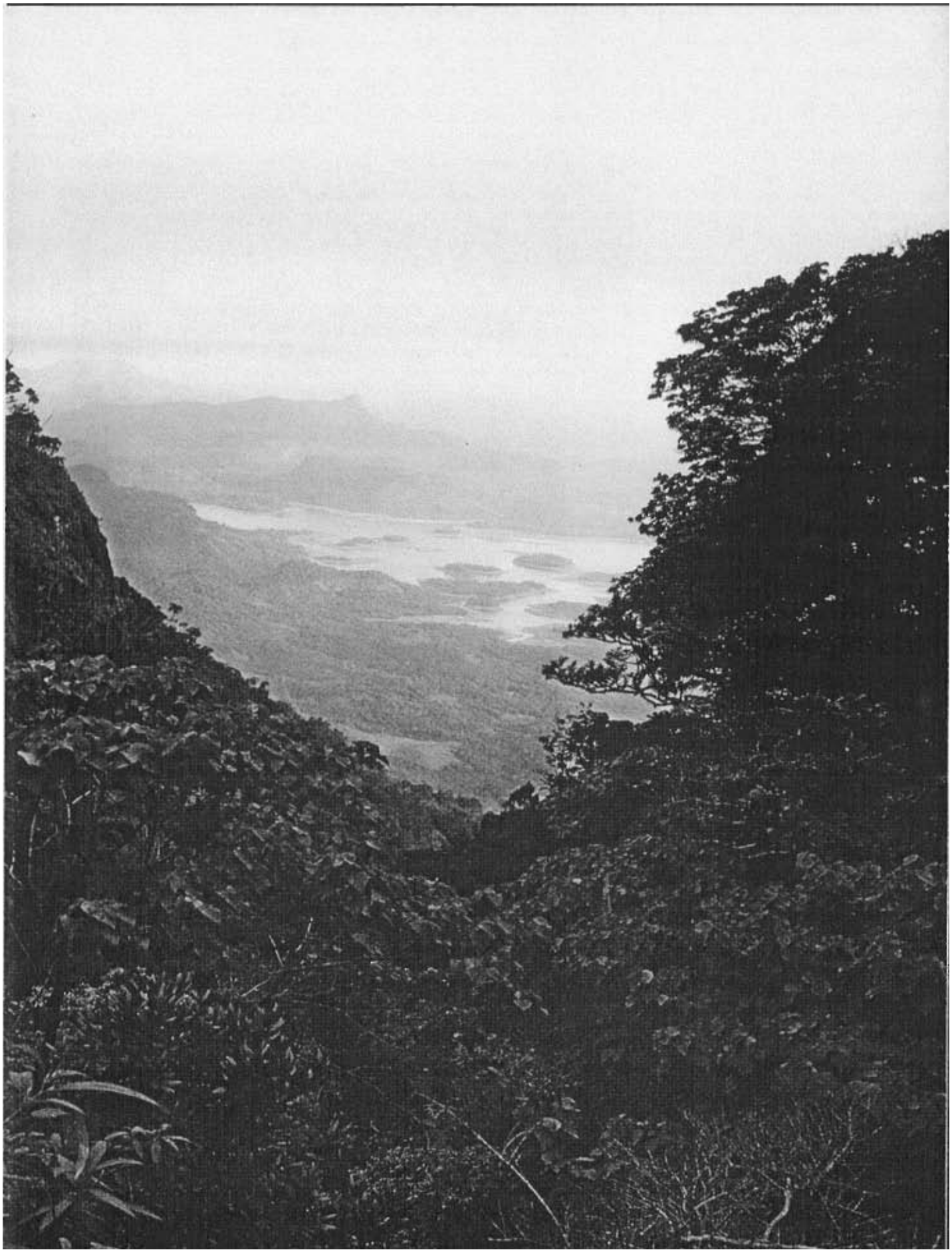
INTRODUCTION

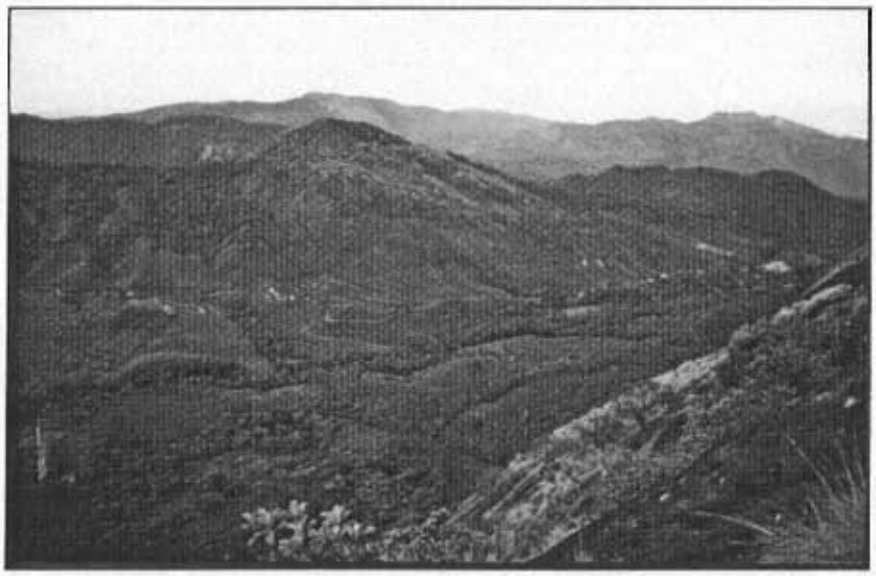
The Western Ghats in peninsular India, a mountain range 1,600 km long, is a biodiversity hot spot, primarily due to the tropical rainforest that it supports. Species richness and endemism are particularly high among plants, small mammals, amphibians, and reptiles. The flowering plants consist of nearly 5,000 species with 30% endemism. A similar level of endemism also occurs among the small mammals consisting of murid rodents, shrews, and small carnivores. Endemism among the amphibians (about 75% of 120 species) and reptiles (50% of nearly 190 species) is even greater. Nearly 65 rivers originate in the Western Ghats, and riparian organic nutrients from here support riverine and mangroves-fisheries in the east and west coasts of southern India.

The forest in the Western Ghats has been severely fragmented due to human activities, especially clear felling for tea, coffee, and teak plantations during 1860 to 1950. Even between 1920 and 1970 nearly 40% of forest cover was lost with a 4-fold increase in the number of forest fragments. Due to habitat fragmentation and high human densities, the Western Ghats is considered one of the 8 most threatened biodiversity hot spots of the world.



FRAGMENTATION

Habitat fragmentation is a significant threat to conservation due to two major reasons. First, it leads to the fragmentation of contiguous, large populations into several small and isolated populations. These small populations are prone to extinction from several threats that are well known. Second, the habitat fragments decay in the long run due to changes in the macro- and micro-habitat conditions. This process is often further aggravated by human activities. The impact of habitat fragmentation differs among species depending on their biology, ecology and social behaviour. Species that are rare, endemic and habitat specialists are more adversely affected and tend to be lost faster than other species. Similarly, more complex and species rich habitats like the tropical rainforest are much more adversely affected than other habitats.



Rainforest fragments in Munnar, Kerala

This project aimed to assess the changes in the communities of amphibians, reptiles, murid rodents, shrews and small carnivores in the rainforest in the Western Ghats due to habitat fragmentation.

Sherman trap (left), Stream sampling (centre) Forest transects (right)

OBJECTIVES

Since the target taxa were ecologically unknown, in the first phase of the project (1996-2000) we attempted to understand their distribution and ecology in the continuous stretch of rainforest in Kalakad-Mundanthurai Tiger Reserve. The second phase (1997-2000) was a study in rainforest fragments in the Anamalai Hills. The specific objectives of the project were:

- To examine the community structure and ecology of the target taxa in relatively undisturbed forests in terms of *species richness, abundance,* and *relative abundance,* and factors governing them.
- To identify the nature and extent of changes in communities in forest fragments and habitat correlates of such changes.
- To identify implications for conservation and research.

Taxa	Methods	KMTR	Anamalai Hills
Amphibians	Quadrats (5 x 5 m)	648	638
	Stream transects (100 m)	63 (6)	51 (6)
Reptiles	Quadrats (5 x 5 m)	631	524
	Forest transects (250 m)	162 (18)	297 (33)
Rodents & shrews	Live trap nights	9,613	12,699*
Small carnivores	Camera trap nights	112	95
	Track plot nights	177	295
	Survey hours	35	105
	Radio collared animals	7	---
	Phenology trees	450	---
	Vegetation plots	200	250

*Table 1. Sampling effort for the target taxa in the continuous rainforest in Kalakad-Mundanthurai Tiger Reserve (KMTR) and in the fragmented rainforest in Anamalai Hills. The numbers in parenthesis are the number of transects which were replicated. * includes trapping effort by Kumar et al. (1998).*

METHODS

Sampling methods included quadrat searches (for forest floor amphibians and reptiles), forest transects (for arboreal reptiles), stream surveys (for stream amphibians and reptiles), live trapping (murid rodents and shrews), and camera trapping and track plots, radio-telemetry, plant phenology and vegetation plots (for small carnivores, Table 1).

Photo : Divya Mudappa

Camera trap picture of common palm civet (Paradoxurus hermaphroditus)

STUDY AREAS

Continuous rainforest in the Kalakad-Mundanthurai Tiger Reserve

The Kalakad-Mundanthurai Tiger Reserve (KMTR) is at the southern extremity of the Western Ghats, and covers about 895 sq.km in area, and 50 m to 1,700 m in altitude. The rainforests occur above 600 m. KMTR and the adjoining Wildlife Sanctuaries in Kerala State have about 400 sq.km of relatively undisturbed and continuous rainforests, one of the few such areas left in the Western Ghats. In KMTR, the sampling centered on three sites - Kannikatti (700 m), Sengaltheri (1,000 m), and Kakachi (1,300 m), which represented the altitude and climatic regime in the Reserve.

Anamalai Hills is a typical representative of the extent to which the rainforest has been lost and fragmented in the Western Ghats. Clear felling, initially for planting tea, began in the 1860's and continued up to the 1970's. Most of the remaining rainforest fragments fall either within the Indira Gandhi Wildlife Sanctuary (987 sq.km), or in privately owned coffee and tea estates that almost entirely cover the Valparai valley. Nearly 30 such fragments were identified, of which 14 were selected for sampling, representing the variability in area, matrix around the fragment and disturbance levels. These fragments were in an altitudinal range of 700 m to 1,500 m, and ranged from 1 ha to 2,500 ha in area.

Rainforest fragments in the Anamalai Hills.

In both the sites, annual rainfall ranges from 1,500 mm on eastern slopes to over 3,000 mm in the western parts, and the daytime temperature in the rainforest ranges between 19° C in January and 24° C in April-May at mid-elevations. There are three distinct seasons in both the sites: the dry season (February to May), south-west monsoon (June to September), and north-east monsoon (October to January). In both sites, the mid-elevation rainforest is of the *Cullenia exarillata - Mesua ferrea - Palaquium ellipticum* type.

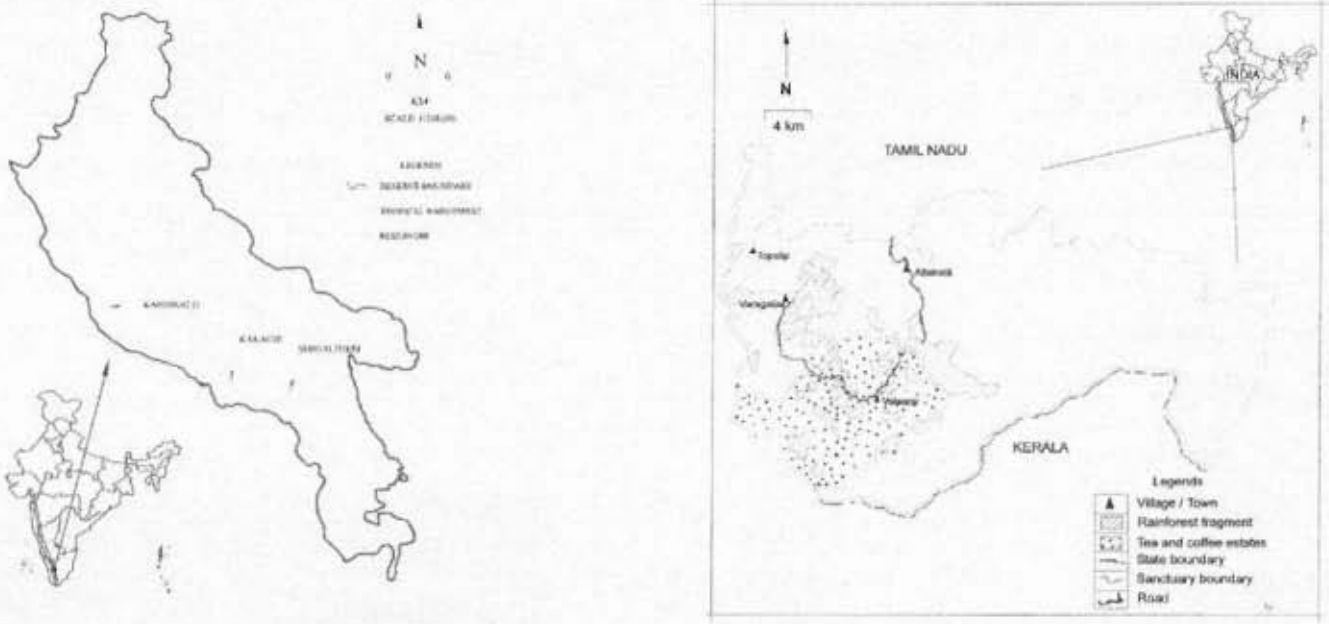


Figure 1. Kalakad-Mundanthurai Tiger Reserve showing continuous forest (left) and Indira Gandhi Wildlife Sanctuary showing rainforest fragments (right)

MURID RODENTS AND SHREWS

Mammalian diversity in the Western Ghats is relatively low, with about 122 of the 420 species of Indian mammals occurring in this region, with 22 endemics. Two monotypic genera, *Latidens* (a bat) and *Platacanthomys* (a rodent), are unique to the Western Ghats. The mammalian fauna of KMTR includes 76 species, of which 8 are endemic to the Western Ghats. In addition, at least 17 bat species also occur in KMTR. The mammalian fauna in the Anamalai Hills is very similar to that in KMTR.

About 70 species of murid rodents, which include the rats, mice, voles and dormouse (Order: Rodentia: Family Muridae) occur in India of which 17 occur in the Western Ghats. Seven species of ground shrews (Order Insectivora; Family Soricidae) occur here, out of 26 species in India. Being small and specialized in their diet, murid rodents and shrews would be more sensitive to habitat fragmentation than many other mammals.

Species richness and abundance of these two taxa were assessed by live-trapping using standard Sherman traps. Traps were set up on the forest floor in grids of 7x7 m, at 10 m intervals. In the Anamalai Hills, the matrix consisting of tea, coffee, and cardamom plantations, around or adjacent to the fragments was also sampled in order to identify dispersal-shy species and species not adversely affected by man-modified habitats.

During a total of 9,613 trap-nights in KMTR, 204 individuals of 5 species were captured. *Mus famulus* and *Suncus etruscus* were seen in KMTR, but not trapped. The list of species along with their capture rates in KMTR, matrix, and the fragments is given in Table 2. A total of 71 individuals of 5 species were captured in 2,104 trap-nights in the matrix. In an earlier study (Kumar *et al.* 1998), 572 individuals of 8 species were trapped during 10,595 nights of trapping in the forest fragments in Anamalai Hills.

Malabar spiny dormouse (*Platacanthomys lasiurus*)

Species	KMTR		Matrix		Rainforest Fragments *	
	CR	RF	CR	RF	CR	RF
Rattus rattus wroughtoni	1.71	80.39	0.71	21.13	2.62	48.52
Platacanthomys lasiurus	0.21	9.81	0.0		0.06	1.11
Funambulus tristriatus	0.12	5.88	0.71	21.13	N.d	N.d
Suncus sp.*	0.07	3.43	0.38	11.27	1.52	28.15
Mus sp.	0.01	0.49	1.38	40.85	0.10	1.85
Golunda ellioti	0.0		0.19	5.63	0.05	0.92
Mus booduga	0.0		0.0		0.95	17.59
Cremnomys blanfordi	0.0		0.0		0.05	0.92
Vandeleuria oleracea	0.0		0.0		0.05	0.92

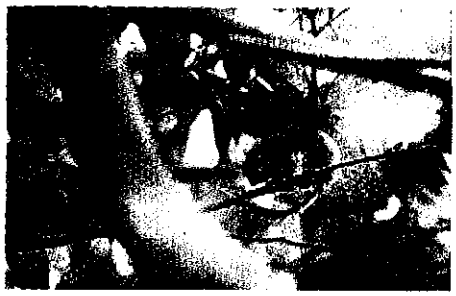
CR = animals/100 trap nights; RF = % of total animals trapped; N.d = No data.

*Table 2: The community structure of murid rodents and shrews in KMTR, rainforest fragments and matrix around them in Anamalai Hills. The capture rate of the Western Ghats squirrel (Funambulus tristriatus) is also given. *from Kumar et al. (1998)*

The capture rate in the continuous rainforest was low (2.14/100 trap nights). *Rattus rattus wroughtoni* (white-bellied wood rat) was the most abundant species in KMTR contributing to 80% of the captures, followed by *Platacanthomys lasiurus* (Malabar spiny dormouse, 9.8%), *Funambulus tristriatus* (Western Ghats striped squirrel, 5.9%), *Suncus* sp. (ground shrews, 3.4%), and *Mus* sp. (mouse, 0.5%, Table 2). The shrews trapped in KMTR were *Suncus montana* and *S. murinus*. The sites from where the endemic dormouse was trapped had a greater canopy cover (c. 98%) and height (27 m), and more lianas and climbers (mean = 7.3), than sites where they were not captured.

The forest fragments and the matrix in the Anamalai Hills had greater capture rates (5.4 and 3.5/100 trap nights, respectively) as well as more species than KMTR (Table 2). Even though the capture rate of the white-bellied wood rat was greater in the fragments, its relative abundance was much lower compared to KMTR, due to the presence of other species. The largest fragment (Akkamalai) had the highest species richness. The medium sized fragments (Korangumudi and Puthuthotam), which had low species richness but the highest capture rates, had coffee and cardamom as understorey. The alteration in the fragment and matrix reduces the habitat complexity affecting the composition of the small mammal community.

The structural changes in the rodent and shrew community in fragments include the invasion of human commensals, loss of endemics, and changes in abundance. The loss of Malabar spiny dormouse, an endemic, is related to the loss of specific habitat features such as woody lianas, buttressed trees, and canopy cover and height. While shrews were associated with rocky areas and high litter depth, the white-bellied wood rat was ubiquitous in microhabitat selection.



Malabar spiny dormouse on lia

SMALL CARNIVORES

Carnivora is a species-rich mammalian Order with about 272 species worldwide. About 54% of the species, belonging to the Families Herpestidae, Viverridae, and Mustelidae, are commonly referred to as small carnivores. Small cats (Felidae) are sometimes included along with these species, when small carnivore community is considered in its entirety.

Photo : Divya Mudappa

The endemic and frugivorous brown palm civet *(Paradoxurus jerdoni)*

Small carnivores form diverse assemblages in tropical forests, and are critical to the functioning of natural ecosystems because of the key roles that they play as predators, prey, and seed dispersers. Thirty species of small carnivores occur in India, with two major centres of diversity; north-east including Eastern Himalaya and the Western Ghats. The latter has 13 species: 4 civets, 4 mongooses, and 5 mustelids. The four species of viverrids are the common palm civet (*Paradoxurus hermaphroditus*), brown palm civet (*P. jerdoni*), small Indian civet (*Viverricula indica*), and Malabar civet (*Viverra civettina*). The four species of herpestids are the ruddy mongoose (*H. edwardsii*), stripe-necked mongoose (*H. vitticollis*), and brown mongoose (*H. fuscus*). The mustelids are the Nilgiri marten (*Martes gwatkinsi*), ratel (*Mellivora capensis*), smooth-coated otter (*Lutrogale perspicillata*), small-clawed otter (*Amblonyx cinereus*) and common otter (*Lutra lutra*). The small cats that occur in the region are the leopard cat (*Prionailurus bengalensis*), jungle cat (*Felis chaus*), rusty spotted cat (*P. rubiginosus*), and fishing cat (*P. viverrinus*).

The brown palm civet, an arboreal frugivore and a major seed disperser, dominated the small carnivore community in the continuous forest in KMTR, forming about 80 % of the

sighted small carnivore during the daytime was the Nilgiri marten. Other species sighted in the rainforest included small Indian civet, brown mongoose, stripe-necked mongoose, and leopard cat.

Nearly 90% of the scats of the brown palm civet contained fruit remains. Over three and a half years, they fed on fruits of 53 species, mostly trees and lianas. Due to intra- and inter-annual variation in the diet, no species formed >10% of the overall diet, although some species formed 25-75% of the diet in certain months. Most fruits were drupes or berries, with moderately thick and watery pulp. Fourteen fruit species important to the brown palm civet is given in Appendix 1.

Photo : Divya Mudappa

The largely nocturnal brown mongoose *(Herpestes fuscus)*

Photo : Divya Mudappa

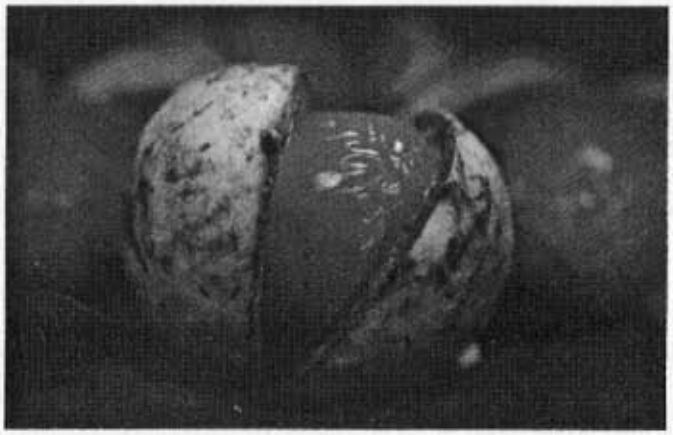
The widely distributed small Indian civet (*Viverricula indica)*

Fruits of nearly 53% of all the trees in the study area were eaten by the brown palm civet, showing its importance as a seed disperser.

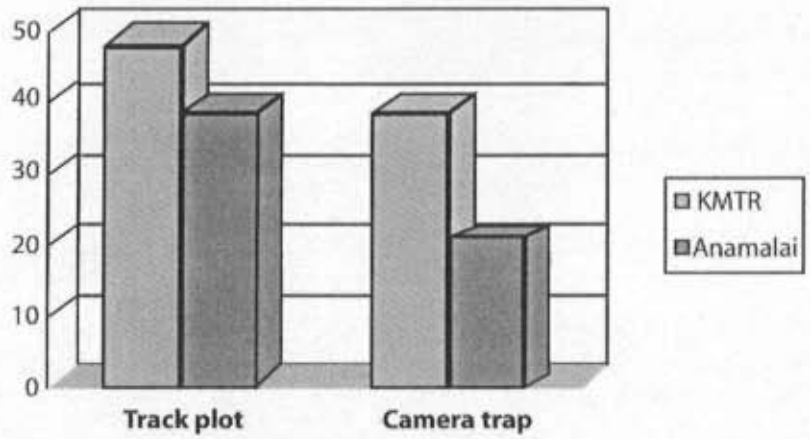
The home ranges of 5 males and 2 females radio-tracked for 12 to 238 days, varied from 6 ha to 57 ha, substantially smaller than that of related species elsewhere. Individuals in areas with higher tree density, tree species, and basal area, had smaller home ranges. The civets were active 79% of the night-time, and mostly used nests of the Malabar giant squirrel (*Ratufa indica*) for day-bedding. The day-beds were on trees that were large in girth and height, and also had high canopy contiguity.

Changes in the small carnivore community in the rainforest fragments included a decline in the overall abundance of small carnivores, a decline in the absolute and relative abundance of the brown palm civet, and an increase in the terrestrial small carnivores (brown mongoose and small Indian civet, Figure .2). These changes were related to habitat features other than fragment area. The brown palm civet occurred in

Elaeocarpus munronii - an important food resource in the mid-elevation rainforests.



Knema attenuata - an important brown palm civet food in the lower altitude rainforests in KMTR.



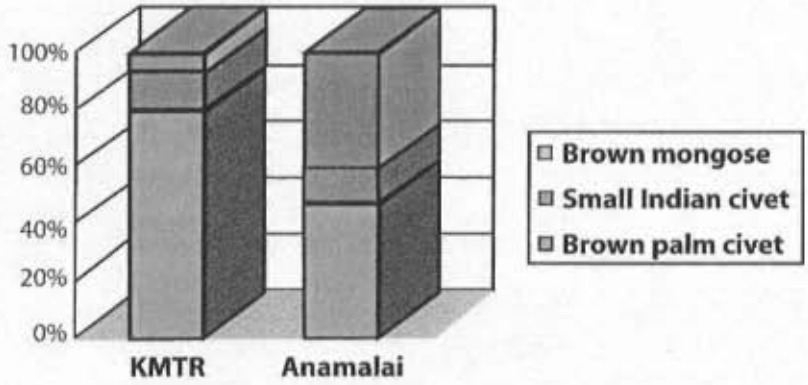


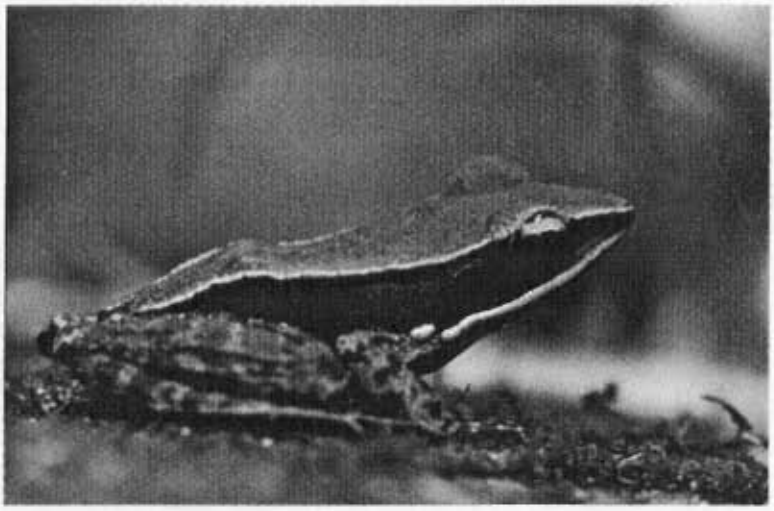
Figure 2. The community structure of small carnivores in continuous forests in KMTR and forest fragments in the Anamalai Hills: (above) the percentage of track plots and camera traps in which small carnivores were recorded, and (below) the percentage of three species in track plots and camera traps.

some highly disturbed rainforest fragments due to the abundance of food trees, some of them exotic, and the protection of relatively large (200 ha) fragments in an otherwise highly disturbed landscape.

Therefore, in a fragmented landscape, conservation efforts should include the maintenance of relatively undisturbed and large tracts of forests with high diversity of native trees and lianas. At the same time, efforts should be made to protect even small forest fragments that hold wild populations of many endemics, including the brown palm civet. Restoration efforts can also be made to improve the quality of highly degraded fragments. The brown palm civet can play a major role in this regard due to its seed dispersal abilities.

AMPHIBIANS

Out of the 219 species of amphibians in India, 120 species occur in the Western Ghats, with 93 endemics. Species richness and endemism are notable among some taxa e.g. 14 of 16 species of limbless amphibians (caecilians), 29 out of 35 species of rhacophorids or gliding frogs, and 35 out of nearly 50 species of ranids. A majority of the species are found in the rainforest and almost all the endemics are confined to it. It is being increasingly realised that the amphibians, along with other lower vertebrates and invertebrates, might have considerable patchiness in their distribution. This patchy and restricted distribution makes them highly susceptible to extinction, and also has major implications in the context of habitat fragmentation.



Rana temporalis

Micrixalus fuscus (in amplexus)

Thirty two species of amphibians were recorded from KMTR (Appendix 2). The forest floor amphibians occurred as discrete clusters of 6 to 8 animals, with an overall density of 348 animals/ha, comparable to sites in south-east Asia and South America. The density, however, shows a very sharp decline with increasing distance from streams. The densities as well as species composition varied considerably among the three sites in KMTR (Kannikatti, Sengaltheri, and Kakachi). In Sengaltheri, the community was dominated by one species (*Rana temporalis*), which occurred in high densities (Figure 3a). Even though densities were lower, the communities were more species rich in Kannikatti and Kakachi, the latter with *Micrixalus* as the dominant genus.

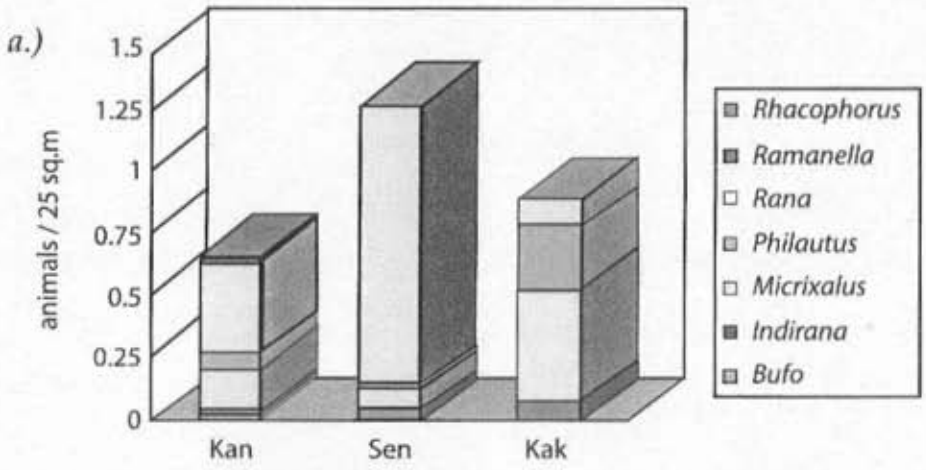


Figure 3a :Spatial variation in amphibian community: The density of rainforest floor amphibians in 3 sites in KMTR (Kannikatti, Sengaltheri and Kakachi)

The spatial differences in community composition were more evident in the case of stream amphibians (Figure 3b). The similarity in species occurrence and relative abundance was highest between stream segments within a drainage, followed by stream segments in different drainages, while stream segments in different hill ranges (Ashambu Hills and Anamalai Hills) had the lowest similarity. Thus, data from both forest floor and stream amphibians strongly suggest a turn over of species from one drainage to another. The hilly nature of the Western Ghats, the dependence of amphibians in the Western Ghats on streams for breeding, and even Pleistocene glaciation might all be reasons for the high turn over of species. This results in a low alpha or local diversity, but high beta and gamma, or regional diversity.

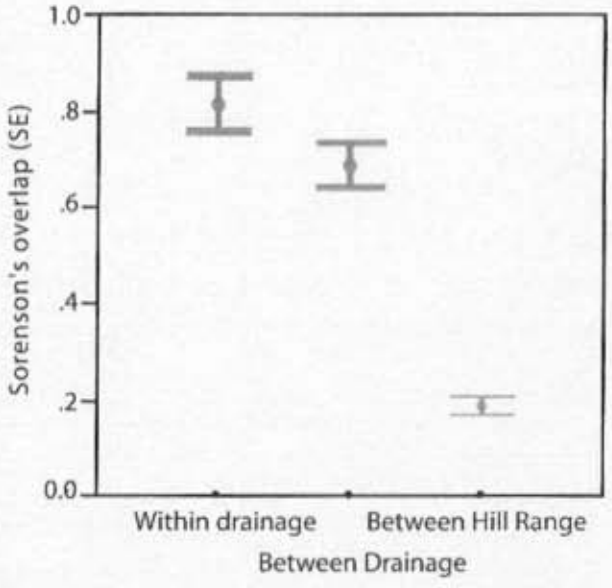


Figure 3b :Spaital variation in amphibian community: The overlap in species composition of stream amphibians in three scales.

In KMTR, litter depth, canopy cover and height, and soil temperature were important habitat features that affected the local distribution of different amphibian taxa.

A total of 40 species were recorded from the rainforest fragments in the Anamalai Hills (Appendix 2). Apart from area and time since isolation, habitat disturbance had a negative impact on the species richness in the rainforest fragments in the Anamalai Hills. Moreover, the densities of different genera were not correlated with fragment area but with different habitat features, especially disturbance (Figure 4). This indicates the need for active management of these remnant rainforest fragments and the intervening matrix in the Western Ghats.

The occurrence of many species in a rainforest fragment depends on periodic recolonization from large undisturbed forest fragments in the landscape. The probability of recolonization is low due to the matrix of inhospitable tea plantations that surround many forest fragments. The scenario might change with the change in the dominant plantation crop.

The 'core area' of a fragment may be extremely small due to edge effects. The effective area habitable to amphibians in rainforest fragments might be, thus, far less than the area of the fragment.

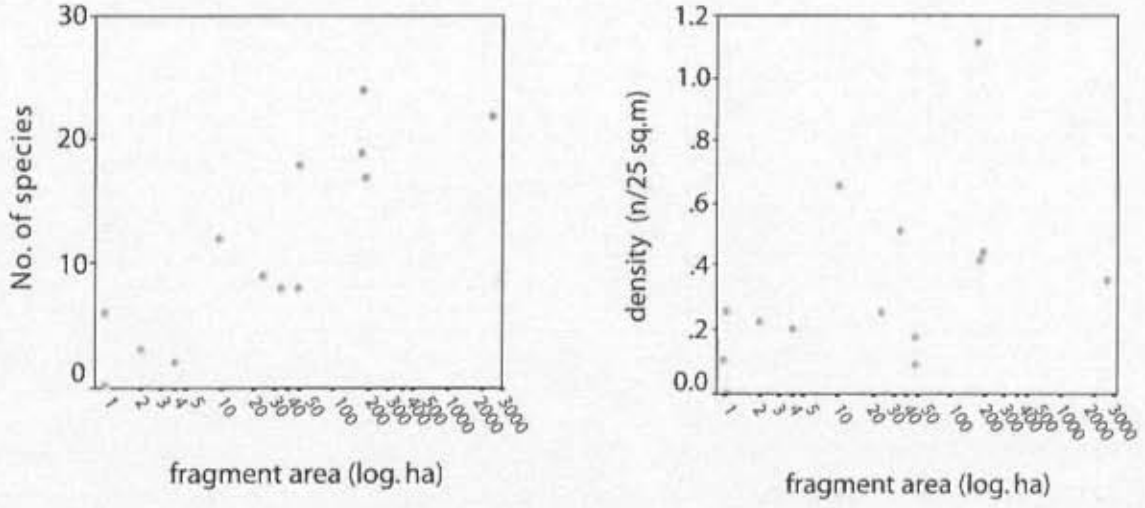
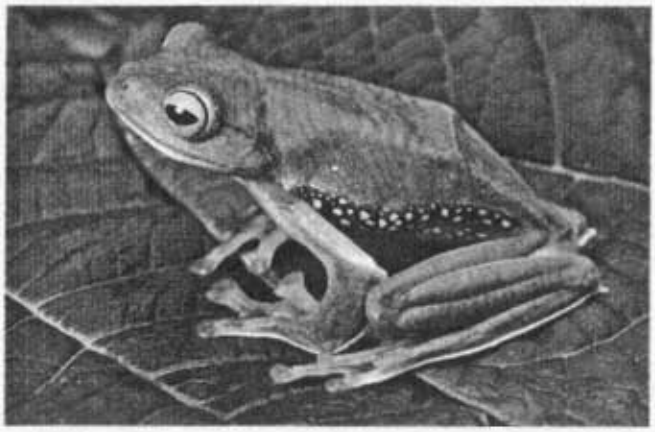


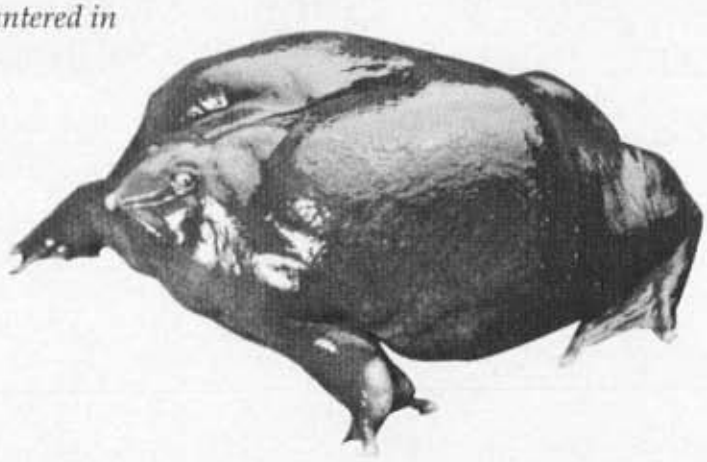
Figure 4. The influence of fragment area on amphibian species richness (left) and



Rhacophorus pseudomalabaricus - A new species to science

The large turn over of species indicates that the amphibian fauna in the Western Ghats has been poorly inventoried and that even small patches of forest might contain exclusive species. This is indicated by the discovery of several new species in this study, some of them confined only to a few forest fragments.

Some interesting amphibian species encountered in this study remain to be identified.



REPTILES

Out of nearly 490 species of reptiles reported from India, at least 197 occur in the Western Ghats, and about 130 of these are restricted to the rainforests. Some taxonomic groups show very high endemism, (e.g. all 33 species of uropeltids or shield tailed snakes, and 40 out of about 62 species of geckos, skinks and agamids). Many endemics are known from single locality records. Despite these high levels of endemism among reptiles in the Western Ghats, detailed studies on their distribution, community structure, and conservation are very few.

Reptiles are highly diverse in their morphology and ecology. In trying to understand the patterns of reptilian communities it has been necessary to group certain similar forms of reptiles. Thus, the Order Squamata has been grouped into three taxa; the geckos (Family: Gekkonidae, Genera: *Cnemaspis* and *Hemidactylus*), the skinks (Family: Scincidae, Genera: *Mabuya, Ristella* and *Scincella*), and the agamids (Family: Agamidae, Genera: *Calotes, Draco, Psammophilus* and *Salea*). The Order Serpentes has been retained as a single unit due to very low detection even at Family levels.

Mabuya beddomii - a skink

Salea anamallayana - an agamid

Cnemaspis sp. - a gecko

A total of 54 reptile species were recorded from KMTR (Appendix 3). Geckos and skinks dominated the forest floor assemblage. Unlike amphibians, reptiles did not form single or multi-species assemblages, and had an overall density of 112 animals/ha. There were major differences among the three sites in KMTR in overall density as well as those of the four taxa (Figure 5). Kannikatti and Sengaltheri had high densities, and were dominated by agamid lizards, while Kakachi had low densities and was dominated by skinks. The density of snakes was also higher in Kakachi, compared to the other two sites.

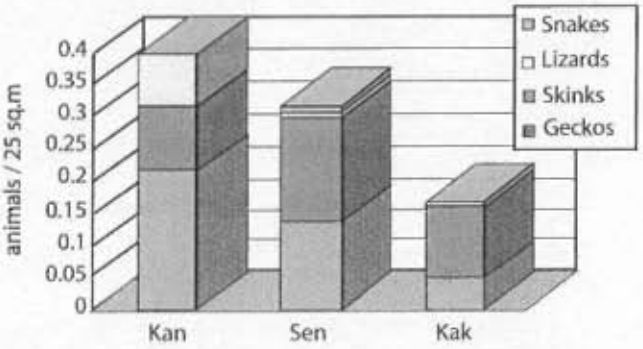
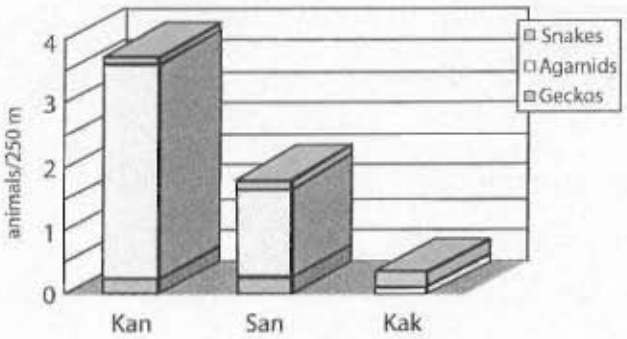


Figure 5: The variation in reptile community among three sites (Kannikatti, Sengaltheri, and Kakachi) in KMTR: (above) Density of rainforest floor reptiles; (below) The encounter rate of arboreal reptiles.



There were considerable differences among the 18 transects in KMTR in the abundance and composition of arboreal reptiles. The overall encounter rate was 1.94 animals/250 m, about 51% of which was of the gliding lizard (*Draco dussumieri*) and about 28% of another endemic, *Calotes ellioti*. Snakes were the most species rich taxon (8 species), although only 38 individuals were sighted. Sengaltheri had greater species richness while Kannikatti had greater abundance in the arboreal reptile community. In both the leaf litter and arboreal assemblages, the high altitude site of Kakachi had a unique assemblage in terms of species richness, composition and abundance (Figure 5).

Species richness of arboreal reptiles along transects in KMTR showed a quadratic or unimodal relationship with altitude while abundance showed a linear decline with an increase in altitude (Figure 6). Individual taxon varied in its response to altitude. Thus, the abundance of agamid lizards showed a sharp decline with altitude, while geckos and skinks reached highest abundance and species richness at mid altitude, and snakes were more abundant in the higher altitudes. The similarity between transects in species occurrence and relative abundance also decreased with increasing difference in altitude

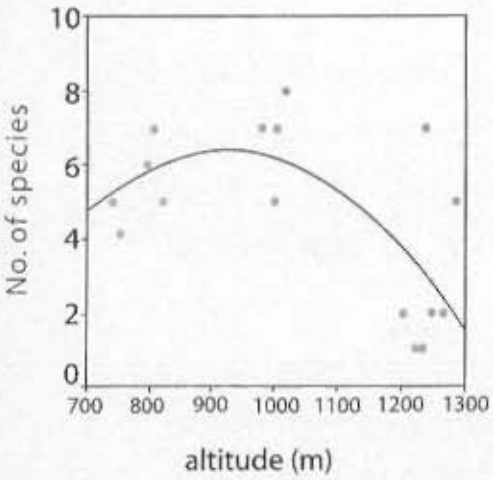
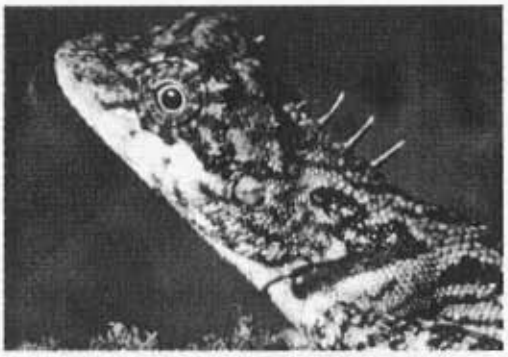


Figure 6. The variation of species richness in arboreal reptiles with altitude of the transect, in the rainforest of KMTR.



Calotes ellioti - a commonly encountered endemic forest lizard

Draco dussumieri gliding lizard

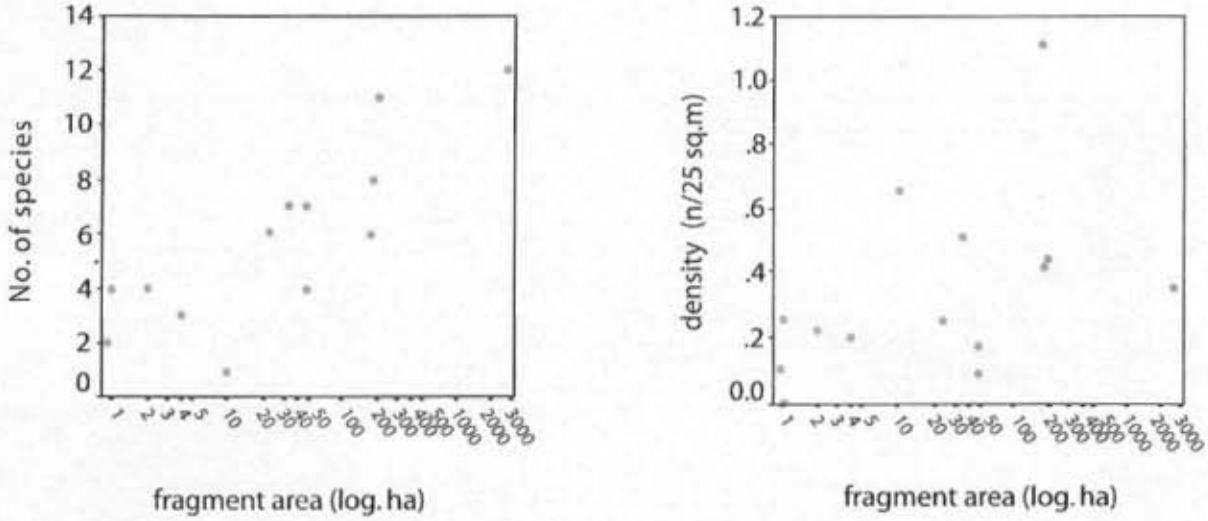


Figure 7. The influence of fragment area on reptile species richness (left) and densities (right), in 14 rainforest fragments in the Anamalai Hills.

Atmospheric and substrate temperature influenced only the abundance, and not species richness. Thus altitude was a major determinant of reptile richness, composition and abundance, even at higher taxonomic levels.

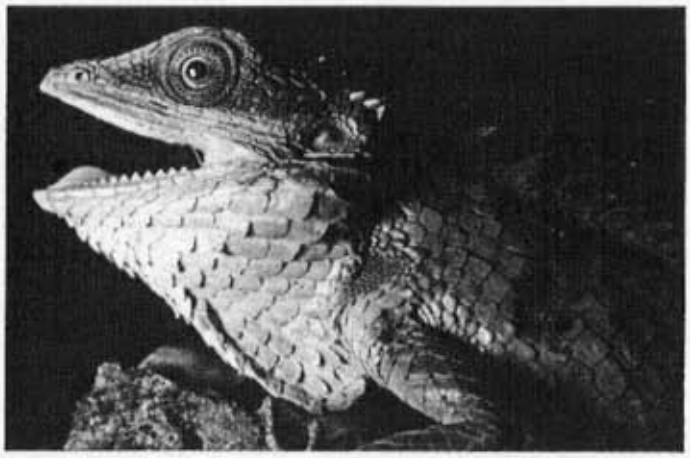
A total of 40 species of reptiles were recorded from the Anamalai Hills (Appendix 3). Skinks and geckos dominated the leaf litter assemblage in the rainforest fragments in the Anamalai Hills also, while agamid lizards dominated the arboreal assemblage. The overall density of floor reptiles in fragments (148 animals/ha) was greater than in KMTR, mainly due to an increase in non-endemic and habitat generalist species. Although the encounter rate of arboreal reptiles in fragments (1.84 animals/250 m) was comparable to that in KMTR (1.94), there were major changes in species composition.

Although species richness was highly correlated with fragment area, time since isolation was also an important factor. As in the case of the amphibians, the density of forest floor reptiles overall as well as that of individual taxon showed no correlation with fragment area, but was related to

different habitat features, especially those that measured human disturbance. Unlike amphibians, however, disturbance had a positive effect on reptile abundance.

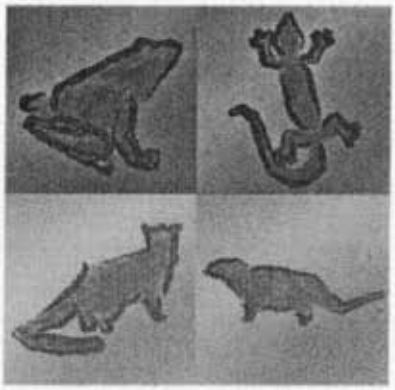
Five of 14 species of agamid lizards in the Western Ghats were recorded from rainforest fragments. *Calotes elliotti* was the most dominant species in all fragments (40-45% of all agamids), while *C. rouxii*, a secondary forest species, was more common (22.6%) in small fragments. The relative abundance of two rainforest endemic species (*C. grandisquamis* and *C. nemoricola*) declined from the large (22%) to small fragments (7.5%), while that of the flying lizard (*Draco dussumieri*) was highest in the medium sized fragments (37.5%). *C. elliotti* was associated with a wide variety of microhabitats, probably the reason for its insensitivity to habitat fragmentation. In contrast, *C. grandisquamis* and *C. nemoricola* were associated with structurally complex vegetation with minimal human disturbance, explaining their decline in abundance in small fragments. The flying lizard was associated with areas with low tree densities and greater basal area.

Calotes nemoricola



Calotes grandisquamis

Calotes andamanensis - A species that was thought to be restricted to Andamans was discovered in the higher elevation rainforests of KMTR during the study



IMPORTANT CONCLUSIONS

- The murid rodent and shrew community in the undisturbed forests had low species richness and abundance. While species richness and abundance increased in the rainforest fragments due to the intrusion of some commensal species, the endemics were more abundant in the undisturbed forests in KMTR.
- The brown palm civet, an arboreal frugivore and a major seed disperser, dominated the small carnivore community in KMTR. Changes in the small carnivore community in the fragmented landscape included a decline in the absolute and relative abundance of this species and an increase in the more terrestrial brown mongoose and small Indian civet. These changes were related to habitat features rather than fragment area.
- There were major differences among sites within the continuous rainforests in KMTR in the density, composition and relative abundance in the amphibian and reptile communities. The distribution of amphibians is especially narrow, with drainages having different species assemblages. This is the major reason for low local, but high regional, species richness. In reptiles, the turnover of taxa is primarily related to altitude.
- There is an overriding influence of fragment area on species richness in amphibians and reptiles. However, overall species richness and densities of different taxa respond to habitat features other than area, especially human disturbance.
- Most amphibians and reptiles were rare in continuous and fragmented forests. The forest fragments together contained more species than the continuous forest and the largest fragment. This results from the patchy distribution of many species, especially amphibians, and the intrusion of secondary forest species into fragments, especially reptiles and rodents.
- Many species unique to the Anamalai Hills are confined to forest fragments, some of them privately owned and managed for production of coffee and cardamom.

CONSERVATION IMPLICATIONS

1. The patchy distribution of herpetofauna has important conservation implications. For example, Protected Areas in the Western Ghats need to enclose ecological gradients and drainage systems. Even forest fragments in hitherto un-surveyed drainages are likely to contain several species unknown to science. This is evident from the discovery of several new species during this project, including a taxonomically unique amphibian species.

2. Since the abundance of many taxa respond to specific habitat features, rather than fragment area, it should be possible to manage fragments to retain such taxa. Specific measures would depend on the taxa and their conservation importance.

3. Since many forest fragments are privately owned and managed for production of cash crops under natural shade, conservation of many endemics in these fragments would depend on the integration of conservation and production goals through appropriate policies and other incentives. Many of the forest fragments require habitat restoration in order to support resident populations of species such as the brown palm civet.

4. Forest fragments are a dominant feature in the Western Ghats landscape, and are often surrounded by or adjacent to Protected Areas. Such forest fragments are often the stepping-stones for the dispersal and seasonal movement of medium and large sized mammals, birds, and a few reptiles within and between Protected Areas. The retention of these fragments is therefore critical to the conservation of such animals, apart from resident populations of several endemics.

RESEARCH IMPLICATIONS

1. The patchy distribution of amphibians and reptiles, and the turn over of species with drainage and altitude suggest that systematic surveys of drainages and altitude zones would discover several new species. The discovery of several new species in this project, and many more by others in recent years is an indication of this.

2. A systematic survey of lower vertebrates and small mammals in the Western Ghats is needed in order to identify gaps in their coverage in the Protected Area network.

3. Taxonomic uncertainties are a major handicap in the studies on amphibians, reptiles, murid rodents and shrews.

4. Privately owned rainforest fragments are critical to the conservation of several endemics as well as wide ranging species in a fragmented landscape. Management measures, appropriate policies and economic incentives that would promote conservation of such forest fragments need to be identified.

5. The data collected need to be examined in the context of landscape level processes which might add substantially to our understanding of the factors that govern the survival of species in forest fragments.

Appendix 1. Food plant species of the brown palm civet in Kalakad-Mundanthurai Tiger Reserve (important food species are in green.)

1 Acronychia pedunculata
2 Annonaceae sp.
3 Antidesma menasu
4 Artocarpus heterophyllus
5 Bentinckia codapanna
6 Bischofia javanica *
7 Calamus sp. (L)
8 Canthium dicoccum
9 Caryota urens
10 Chrysophyllum lanceolatum
11 Cullenia exarillata
12 Dimocarpus longan *
13 Diospyros sylvatica
14 Diospyros sp.2.
15 Elaeocarpus munronii
16 E. serratus *
17 Eleagnus kologa (L)
18 Embelia sp. (L)
19 Ensete superbum (S) *
20 Erycibe wightiana (L)
21 Euonymus angulatus
22 Fagraea ceilanica
23 Ficus sp.*
24 Filicium decipiens *
25 Gnetum ula (L) *
26 Holigarna nigra *
27 Knema attenuata
28 Lepisanthus decipiens
29 Liana sp.1. (L)
30 Ligustrum perrottetii
31 Nothopegia beddomei *
32 Olea dioica
33 Palaquium ellipticum *
34 Pandanus sp. *
35 Pinanga dicksoni
36 Rutaceae sp. (L)
37 Sapotaceae sp.
38 Semecarpus auriculata
39 Solanum sp.
40 Strychnos colubrina (L)
41 Strychnos sp.2.
42 Syzygium cumini/mundagam
43 Syzygium zeylanicum
44 Tricalysia apiocarpa *
45 Viburnum punctatum *
46 Vitaceae sp. (L) *
47 Zizyphus sp.
48 Banana (P)
49 Eletteria cardamomum (P)
50 Coffea arabica (P) *
51 Psidium guajava (P)
Two unidentified species

** Species viable even after ingestion by brown palm civets, L - liana, P-Planted, S-shrub*

Appendix 2. List of amphibian species recorded during this study

Munnar Division (February-March 2001)

FAMILY: BUFONIDAE
1. Bufo sp.

FAMILY: RHACOPHORIDAE
2. Polypedates pleurostictus
3. P sp.
4. Philautus leucorhinus
5. P sp.1.
6. P sp.2.
7. P. pulcherrimus
8. P. charius
9. Rhocophorus sp.

FAMILY: RANIDAE
10. Limnonectes nilagirica
11. Indirana leptodactyla
12. I. beddomi
13. I. phrynoderma
14. Micrixalus silvaticus
15. M sp.

Nelliampathy Division (April-May 2001)

FAMILY: BUFONIDAE
1. Bufo melanostictus

FAMILY: RHACOPHORIDAE
2. Philautus temporalis
5. Rhacophorus malabaricus

FAMILY: RANIDAE
6. Limnonectes brevipalmata
7. Euphlytis cyanophlictis
8. Rana aurantiaca
9. R. temporalis
10. Indirana brachytarsus
11. I. beddomi
12. Micrixalus gadgili
13. M. fuscus
14. Nyctibatrachus sp.

Thenmalai Division (June 2001)

FAMILY: BUFONIDAE
1. Bufo melanostictus

FAMILY: RHACOPHORIDAE
2. Philautus temporalis
3. P. pulcherrimus
4. P. leucorhinus
5. Rhacophorus malabaricus

FAMILY: RANIDAE
6. Limnonectes brevipalmata
7. Euphlytis cyanophlyctis
8. Indirana semipalmata
9. I. beddomi
10. Micrixalus nudis

Kalakad-Mundanthurai Tiger (May 1996 -August 1997)

FAMILY: ICHTHYOPHIDAE
1. *Ichthyophis* sp.1.
2. *Ichthyophis* sp.2.

FAMILY: URAEOTHYPHLIDAE
3. *Uraeotyphlus malabaricus*

Ichthyophis.sp.

FAMILY: BUFONIDAE
4. *Bufo melanostictus*
5. *B. beddomi*
6. *B. microtympanum*

Bufo parietalis

FAMILY: MICROHYLIDAE
7. *Melanobatrachus indicus*
8. *Ramanella triangularis*

Ramanella sp.

FAMILY: RHACOPHORIDAE
9. *Philautus temporalis*
10. *P. variabilis*
11. *P. pulcherrimus*
12. *P. charius*
13. *P. glandulosus*
14. *P* sp.1.
15. *Polypedates maculatus*
16. *Rhacophorus calcadensis*

Rhacophorus calcadensis

Philautus sp.

FAMILY: RANIDAE
17. *Euphlyctis cyanophlyctis*
18. *Indirana beddomi*
19. *I. brachytarsus*
20. *I. leptodactyla*
21. *I. diplostictus*
22. *Limnonectes keralensis*
23. *Micrixalus fuscus*
24. *M. saxicola*
25. *M* sp.
26. *Nyctibatrachus aliceae*
27. *N. major*
28. *N. vasanthi*
29. *N. beddomi*
30. *Rana aurantiaca*
31. *R. curtipes*
32. *R. temporalis*

Rana curtipes

Nyctibatrachus sp.

Micrixalus sylvaticus

Anamalai Hills (November 1997-January 1999)

FAMILY: ICHTHYOPHIDAE
1. *Ichthyophis* sp.1.

FAMILY: URAEOTHYPHLIDAE
2. *Uraeotyphlus menoni*
3. *Uraeotyphlus narayani*
4. *Uraeotyphlus malabaricus*

FAMILY: BUFONIDAE
5. *Bufo melanostictus*
6. *B. beddomi*
7. *B* sp.
8. *B. parietalis*
9. *Pedostibes tuberculosus*

FAMILY: MICROHYLIDAE
10. *Melanobatrachus indicus*
11. *Ramanella triangularis*

FAMILY: RHACOPHORIDAE
12. *Philautus variabilis*
13. *P. temporalis*
14. *P. pulcherrimus*
15. *P. charius*
16. *P. signatus*
17. *P* sp.1.
18. *P* sp.2.
19. *P* sp.3.
20. *Polypedates maculatus*
21. *Rhacophorus calcadensis*
22. *R. pseudomalabaricus*
23. *R* sp.

FAMILY: RANIDAE
24. *Euphlyctis cyanophlyctis*
25. *Indirana beddomi*
26. *I. brachytarsus*
27. *I. leptodactyla*
28. *Limnonectes keralensis*
29. *L. limnocharis*
30. *Micrixalus fuscus*
31. *M. silvaticus*
32. *M. gadgili*
33. *M* sp.
34. *Nyctibatrachus beddomi*
35. *N. deccanensis*
36. *N* sp.1.
37. *N* sp.2.
38. *Rana aurantiaca*
39. *R. temporalis*
40. Unidentified Ranid

Appendix 3. List of reptiles recorded during this study.

Anamalai Hills (1998-1999)

No	Species	AKK	AND	MAN	SAN	IYE	PUT	KOR	TAF	PAN	VA1	VA2	VA3	VA4	TA2	Total
	Geckos (GECKONIDAE)															
1	*Cnemaspis indica***		X		X		X						X	X		5
2	*C.mysoriensis***	X	X	X	X				X				X			6
3	*C.ornatus**	X		X					X						X	4
4	C sp.1. *(white belly)***	X	X	X			X									4
5	C sp. 2. *(yellow throat)***	X	X	X	X	X	X	X		X		X				9
6	C sp. 3. *(red eye)***	X						X							X	3
7	C sp. 4. *(total black)***	X	X	X	X			X	X	X		X				8
8	C sp. 5. *(black throat)***	X	X	X				X								4
9	C sp. 6. *(?)***	X		X	X	X		X		X						6
	Lizards (AGAMIDAE)															
10	*Calotes ellioti**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
11	*C.grandisquamis***	X	X	X	X	X	X		X	X		X	X			10
12	*C.nemoricola***	X	X	X	X	X		X				X				7
13	*C.rouxii*		X	X	X	X			X		X	X	X	X	X	10
14	*Draco drussumeri**	X	X	X	X	X	X	X	X	X	X	X	X	X		13
15	*Salea anamallayana***	X														1
	Skinks (SCINCIDAE)															
16	*Mabuya beddomii*	X	X	X	X	X	X	X	X	X	X	X	X	X		13
17	*M.carinata*		X		X	X		X					X		X	6
18	*Ristella guntheri***	X	X		X	X	X		X	X						7
19	*Scincella travancoricum***	X		X		X	X		X	X						6
20	*Scincella* sp.**	X														1

	Monitor lizard (VARANIDAE)															
21	*Varanus bengalensis*	X	X	X				X	X				X			6
	Blind snake (TYPHLOPIDAE)															
22	*Typhlops* sp.**	X				X	X			X						4
	Snakes (UROPELTIDAE)															
23	*Melanophidium punctatum***	X														1
24	*Uropeltis nitida***						X									1
25	*U.ocellata***	X		X	X		X	X		X						6
26	*U.rubromaculatus***	X					X	X								3
	Snakes (COLUBRIDAE)															
27	*Ahaetulla nasutus*	X	X	X		X	X		X				X			7
28	*Amphiesma beddomei**	X	X	X	X	X	X	X	X	X		X				10
29	*Boiga ceylonensis***	X	X	X	X	X										5
30	*Coluber mucosus*	X	X	X	X	X	X	X		X						8
31	*Coluber* sp.*						X									1
32	*Dendrelapis tristis*				X	X										2
33	*Elaphae Helena*				X	X										2
34	*Lycodon* sp.**	X	X	X												3
35	*Oligodon arnensis*				X	X										2
36	*Xenochrophis piscator*	X														1
	Snakes (ELAPIDAE)															
37	*Calliophis melanurus nigrescens**	X	X	X	X							X				5
	Snakes (VIPERIDAE)															
38	*Hypnale hypnale*		X													1
39	*Trimeresurus macrolepis**	X	X	X		X						X				5
40	*T.malabaricus**		X		X			X	X	X			X			6
	Total number of species	30	24	23	22	20	17	16	14	14	4	11	11	5	5	

* Endemic to the Western Ghats ** Endemic to the rainforest of Western Ghats

Fragments : AKK- Akkamalai AND- Andiparai MAN- Manamboli shola SAN- Shankarankudi IYE- Iyerpadi
PUT- Puthuthotam Estate KOR- Korangumudi Estate TAF- Tata Finley Estate PAN- Pannimedu
VA1- Varattuparai I VA2- Varattuparai II VA3- Varattuparai III VA4- Varattuparai IV TA2-Tata II

Kalakad-Mundanthurai Tiger Reserve

FAMILY: BATAGURIDAE
1. Melanochelys trijuga


Melanochelys trijuga

FAMILY: GEKKONIDAE:
2. Cnemaspis indica **
3. C.ornatus *
*4. C.beddomei***
5. Cnemaspis sp.1.**
6. Cnemaspis sp.2. *(yellow throat)***
7. Cnemaspis sp.3. *(Red eyed gecko)***
*8. Hemidactylus anamallensis = (Dravidogecko anamallensis)***


Hemidactylus sp.

FAMILY: AGAMIDAE:
9. Calotes andamanensis **
10. C. calotes
11. C. ellioti *
12. C. grandisquamis **
13. C. nemoricola **
14. C. rouxii
15. Draco dussumieri *
16. Otocryptis beddomii **
17. Psammophilus blanfordanus
18. P. dorsalis


Otocryptis beddomii


Uropeltis sp.

FAMILY: UROPELTIDAE:
25. Brachyophidium rhodogaster *
26. Melanophidium punctatum **
*27. Uropeltis arcticeps**
*28. U. ellioti**
29. U. ocellata *
30. Uropeltis sp.**

FAMILY: SCINCIDAE:
19. Mabuya beddomii
20. M. carinata
21. M. macularius
*22. Scincella travancoricum (= Liolopisma travancoricum)***
23. Ristella sp.**


Dasia halianus


Ahaetulla nasutus

FAMILY: COLUBRIDAE:
*31. Ahaetulla dispar**
32. Ahaetulla nasutus
33. Ahaetulla perroteti **
34. Ahaetulla pulverulentus
35. Amphiesma beddomei *
36. Boiga ceylonensis **
37. B. forsteni
38. Coluber mucosus
*39. Dendrelaphis grandoculis**
40. D. tristis
41. Lycodon aulicus
42. L. travancoricus **
43. Lycodon sp.*
44. Macropisthodon plumbicolor
45. Oliogodon arnensis
46. O. brevicaudus *
47. Xenochropis piscator

FAMILY: VARANIDAE:
24. Varanus bengalensis


Lycodon travancoricus


Calliophis melanurus

FAMILY: ELAPIDAE:
48. Calliophis melanurus nigrescens *
49. Ophiophagus hannah


Trimeresurus macrolepis

FAMILY: VIPERIDAE:
50. Hypnale hypnale
51. Trimeresurus gramineus
52. T. macrolepis **
53. T. malabaricus *
54. T. strigatus

FAMILY: BOIDAE
55. Python molurus

* Endemic to the Western Ghats ** Endemic to the rainforest of Western Ghats