Distribution of forest floor reptiles in the rainforest of Kalakad–Mundanthurai Tiger Reserve, South India

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This paper examines the distribution, density and community structure of forest floor reptiles in the rainforests in three sites (Kannikatti, Sengaltheri and Kakachi) within the Kalakad–Mundanthurai Tiger Reserve (KMTR). The forest floor reptiles were sampled at an altitudinal range of 700–1300 m, during southwest and northeast monsoons and summer, between June 1997 and May 1998. We used adaptive cluster sampling, with 5 m × 5 m quadrats. A total of 173 reptiles of 17 species was recorded from 426 primary and 363 secondary quadrats. Only 14.8% of the primary quadrats had reptiles, showing their sparse distribution. Moreover, most of the clusters were small (58.7% were only single quadrats), had less than two animals (57%) and only one species (60.3%). The overall density of forest floor reptiles was 0.2559 animals/quadrat. There were differences among the three sites in the abundance of clusters, densities and community structure. Lizards were most abundant in Kannikatti, geckos in Sengaltheri and skinks in Kakachi. It is very likely that this variation in community structure is due to an altitudinal gradient in reptile communities. Including other sampling methods, we recorded only 55 species in KMTR out of nearly 180 species reported from the Western Ghats. Inadequate sampling of some taxa (e.g. fossorial forms), absence of some taxa from the rainforests (e.g. some lizards and geckos) and altitudinal restriction of sampling (to 700–1300 m) are all reasons for the low species richness. Since species turnover is mainly along the altitudinal gradient, complete altitudinal coverage of protected areas is required for reptile conservation in the Western Ghats.

OUT of 484 species of reptiles reported from India[1], 180 species are known to occur in the Western Ghats, of which nearly 50% are endemic to these hill ranges[2]. This makes the Western Ghats the richest biogeographic zone for reptiles in India. Species richness and endemism is particularly high in some taxa; e.g. nearly all the 34 species of uropeltid (shield tail) snakes; pit vipers (7 species), and agamid lizards (7 species) occur in the Western Ghats. As in the case of amphibians, many reptiles in the Western Ghats have highly restricted distribution, a major reason for many of them (63 species) being threatened[2]. Despite this high degree of endemism and threat, there have been only a few studies on the distribution, abundance, habitat preference, and community structure of reptiles in the Western Ghats[3–9]. As in the case of amphibians, many species still remain as single locality records.

Being almost at the southernmost end of the Western Ghats and close to the equator, the Kalakad–Mundanthurai Tiger Reserve (KMTR) is a major centre of species richness of plants[10] and animal taxa[11]. Besides this, the vast expanse of over 400 km^2 of relatively undisturbed rainforest makes the Reserve an ideal locality to study the ecology of reptiles. In this paper we examine (a) pattern of spatial distribution, abundance and community structure of the forest floor reptiles in the rainforests in three sites within the Reserve, and (b) species richness in reptiles in the rainforest of the Reserve, in relation to species richness of the entire Western Ghats. The community structure of the arboreal reptiles in the Reserve is examined elsewhere[9]. This study is part of a larger study that aims to understand the factors that influence the distribution of reptiles in rainforests of the Western Ghats and to assess the impact of rainforest fragmentation on the reptilian community.

Study area

The KMTR (895 km^2, 8°25′ to 8°53′ N and 77°10′ to 77°35′ E) is the southernmost Tiger Reserve in India. The altitude of the Reserve ranges from about 50 m to 1800 m, but the rainforests are mostly between 700 m and 1600 m above sea level. The mean temperature in the rainforest ranges from 24° to 30°C. This area receives rainfall from both the southwest (June to September) and the northeast (October to January) monsoons, the annual rainfall ranging between 750 mm in the rain shadow eastern slopes to over 3,000 mm in the western parts. The tropical rainforest in the medium elevations (of 900 m to 1200 m) is of *Cullenia–Mesua–Palaquium* series[10]. The Reserve has one of the largest contiguous tracts of tropical rainforests

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remaining in the Western Ghats, over 400 km^2, including the forests in the adjoining state of Kerala[11].

The studies on forest floor reptiles were carried out for a period of one year, from June 1997 to May 1998. Three sites were selected representing the altitude and rainfall regimes in the reserve: Kannikatti (760 m), Sengaltheri (980 m) and Kakachi (1200 m). Sampling was carried out in three seasons that were identified based on rainfall pattern: southwest monsoon (June to September), northeast monsoon (October to January) and summer (February to May). Sampling was restricted to rainforest within an altitudinal range of 700 m to 1300 m.

Methods

Forest floor reptiles were sampled using adaptive cluster sampling, which gives better estimates of the density of animals that show patchy distribution[12]. The basic sampling unit was 5 m × 5 m randomly laid quadrats. If an animal was sighted in one of these quadrats (called primary quadrats), additional quadrats (called secondary quadrats) of the same dimension were searched on four sides of the primary quadrat. There was a 1 m gap between the primary and secondary quadrat. If any of these quadrats had animals, further quadrats were laid around them until the quadrats with animals were bounded or surrounded by quadrats without animals. The quadrats with the animals then become a cluster. If the primary quadrat did not have any animals, the sampling was carried out in the next randomly selected primary quadrat. The search procedure in a quadrat followed Inger[13]. To minimize the chances of missing animals during search, two observers searched the quadrat from opposite sides towards the centre of the plot. The following parameters were estimated from these data:

1) The number of primary quadrats with animals: An indicator of the abundance of clusters.
2) Cluster size: The number of quadrats with animals in a cluster, an indicator of the area occupied by a cluster of animals.
3) Species richness in a cluster: An indicator of species assemblages in the area.
4) Density: This is the mean of the densities in clusters, including primary quadrats without animals (density of zero).
5) Community composition: The percentage of animals in a taxon out of the total number of animals recorded from quadrats.

During the study, reptiles were also sampled along forest transects (for arboreal reptiles) and stream transects (for stream dwelling nocturnal reptiles especially pit vipers and cat snakes). Records on opportunistically sighted reptiles were also maintained. Species recorded using these methods are also included in the total species richness of the area.

Voucher specimens were collected for all species. Species identification was based on published keys[14–16] and consultation with taxonomists, especially I. Das and S. K. Dutta.

Results

Distribution pattern

A total of 426 primary quadrats and 363 secondary quadrats were sampled during the study, and 173 reptiles belonging to 17 species were recorded (Table 1). Out of 426 primary quadrats sampled, only 63 (14.8%) had reptiles showing their patchy distribution. Of the 63 clusters with reptiles, 58.7% had a cluster size of only one quadrat, indicating that reptiles do not form large clusters. The proportion of clusters with 2, 3, and 4 animals was 20.6%, 15.9% and 4.8% respectively. The number of reptiles per cluster varied from 1 to 8, with a mean of 2.75, and a median of 2. Nearly 57% of the clusters had less than 2 reptiles, showing their sparse distribution (Figure 1). The overall density of reptiles for all sites together was 0.2559 animals per quadrat. Reptiles were not likely to form multi-species assemblages, with 60.3% of the clusters having only one species, and 30.2% having two species. Only 10% of the clusters had 3 or 4 species. Thus, the forest floor dwelling reptiles were sparsely distributed, and also occurred as small clusters of a few animals belonging to one or two species.

In all sites, the percentage of primary quadrats with reptiles was highest during summer and lowest during the northeast monsoon (Figure 2 *a*). When pooled over all sites, 21.4% of the primary quadrats had reptiles in the summer, 15.8% in the southwest monsoon and 11.1% in the northeast monsoon. Cluster size did not show any

Table 1. Sampling effort and the number of individuals and species (in parenthesis) recorded in four major taxa in three sites in Kalakad–Mundanthurai Tiger Reserve

Site	Primary plots	Secondary plots	Geckos	Skinks	Agamids	Snakes	Reptiles
Kannikatti	131	139	37 (3)	15 (2)	14 (2)	3 (2)	69 (9)
Sengaltheri	142	137	46 (3)	17 (2)	1 (1)	5 (3)	69 (9)
Kakachi	153	87	12 (2)	21 (2)	0	2 (1)	35 (5)

variation among seasons. Animals per cluster also did not show seasonal variation, with 55.6% to 61.9% of the clusters having only one animal, and 16.0% to 23.8% having two animals per cluster ($c^2 = 1.35$, $df = 6$, $P = 0.969$). When data from sites were pooled, seasonal variation in the number of species per cluster was nearly significant ($c^2 = 11.86$, $df = 6$, $P = 0.065$), with summer having greater species richness (1.55 species per cluster), followed by the southwest monsoon (1.5) and the northeast monsoon (1.42).

Among the three sites, Kakachi had the lowest occurrence of reptiles, the percentage of primary quadrats with a reptile being the lowest in all the three seasons (Figure 2 *a*). Kannikatti had the highest occurrence in two seasons. However, the difference among sites was not significant, even when pooled across seasons ($c^2 = 3.0$, $df = 2$, $P = 0.224$). There was no difference among the sites in cluster size, with more than 70% of the clusters having only one or two quadrats. The mean number of species per cluster was highest in Kannikatti (1.71), followed by the Sengaltheri (1.59) and Kakachi (1.11), the difference being nearly significant (ANOVA, $F = 2.72$, $df = 2$, $P = 0.074$). In Kakachi, nearly 82% of the clusters had only one species. In contrast, 44.2% of the clusters in Kannikatti and 41.9% in Sengaltheri had two to four species (Figure 2 *b*). Thus species richness in a cluster, although generally low, showed spatial and temporal variation. Among sites it was highest in Kannikatti and lowest in Kakachi, and among seasons it was highest in summer and lowest in the northeast monsoon. The percentage of primary quadrats with reptiles had a similar variation. In contrast, cluster size did not show any spatial and seasonal variation.

Community composition

The abundance of many of the 17 species recorded during cluster sampling was very low. Therefore, analysis of community composition is based on four taxa, namely agamids, geckos, skinks and snakes (Table 2). All three sites together, geckos were the most common taxon, occurring at a density of 0.1318 animals/quadrat and accounting for 51.5% of the total reptile community. Skinks were the next most common (0.0776 animals/quadrat), forming 30.3%. Agamids (0.0292 animals/quadrat)

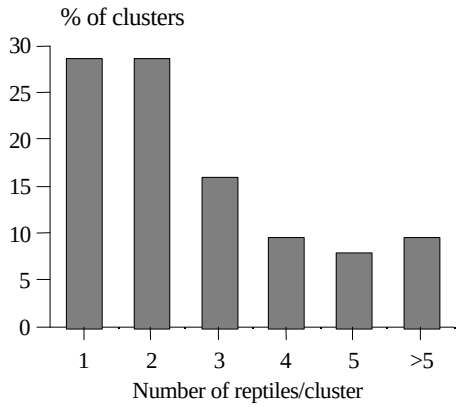

Figure 1. Frequency distribution of the number of individuals in a cluster in the forest floor reptiles in Kalakad–Mundanthurai Tiger Reserve.

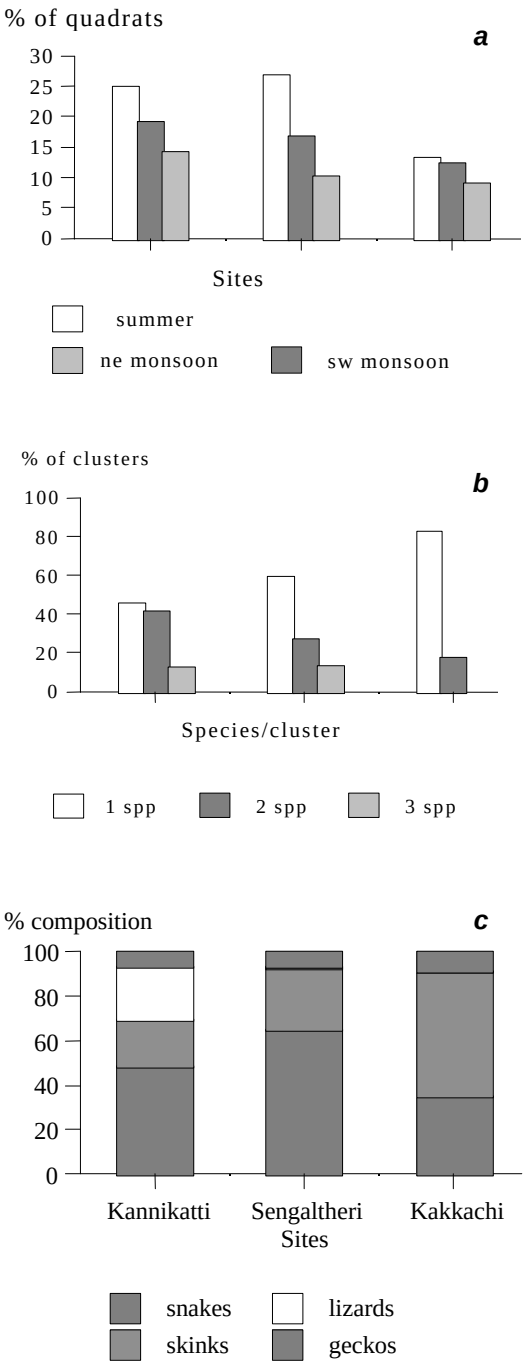

Figure 2. ***a***, The percentage of primary quadrats with forest floor reptiles in three sites in three seasons in KMTR; ***b***, Frequency distribution of the number of species in a cluster of forest floor reptiles in three sites in three seasons in KMTR; ***c***, Percentage composition of geckos, lizards, skinks and snakes in the forest floor reptiles in three sites in KMTR.

formed 11.4% while snakes accounted only for 6.7% (0.0173 animals/quadrat).

There were considerable differences among the three sites in the density (Table 2) and relative abundance of the four taxa (Figure 2 *c*). Total reptile density was highest in the low altitude site (Kannikatti) and lowest in the high altitude site (Kakachi). The composition of the community also differed among the three sites, at a broad taxa level, as well as at the species level. Geckos were the most abundant taxa in Kannikatti (0.1737 animals/quadrat) and Sengaltheri (0.1684 animals/quadrat). This taxon formed 48.9% and 64.8% of the reptiles, respectively, in the two sites. However, two different species dominated in the two sites, *Cnemaspis mysoriensis* in Kannikatti and *C. indica* in Sengaltheri. Skinks were the most common taxon in Kakachi (0.0861 animals/quadrat) forming 56.4% of the reptiles, largely dominated by *Scincella travancoricum*, which was restricted to this site. Lizards (mostly *Calotes ellioti*) formed 24% of the reptiles in Kannikatti but were rare in Sengaltheri (only 0.88%) and absent in Kakachi. The snakes were represented by two species each of Uropeltids, Colubrids and Viperids. The density of snakes was highest in Kannikatti (Table 2), however, as a percentage of the community it was highest in Kakachi. In Kannikatti, the Beddome's keelback, *Amphiesma beddomei*, was the most common snake, while in Kakachi it was the large-scale pit viper, *Trimeresurus macrolepis.*

Species richness

In spite of intensive sampling that included 789 quadrats, only 17 species of forest floor reptiles were recorded from the rainforest. These included four species of geckos (Family Gekkonidae) and skinks (Scincidae), three species of lizards (Agamidae), and six species of snakes, two each from three families (Uropeltidae, Colubridae and Viperidae). When species records from other sampling methods were also included a total of 55 reptile species were recorded from the three study sites together. Among the new records for the Western Ghats were *Calotes andamanensis*[17], a possible new species of wolf snake (*Lycodon* spp.), and more than two species of dwarf geckos (*Cnemaspis* spp.). Among the taxa that were not recorded at all are turtles and tortoises (eight species in the Western Ghats), crocodile (one species), and chameleon (one species).

Table 2. Densities (animals/25 m^2) of four major taxa in the forest floor in the rainforest in three sites in Kalakad–Mundanthurai Tiger Reserve

	Kannikatti		Sengaltheri		Kakachi	
Site	Mean	SE	Mean	SE	Mean	SE
Geckos	0.1737	0.0467	0.0534	0.0218	0.1684	0.0414
Skinks	0.0732	0.0268	0.0861	0.0288	0.0734	0.0263
Agamids	0.0852	0.0338	0.0000	0.0000	0.0023	0.0002
Snakes	0.0229	0.0229	0.0131	0.0009	0.0158	0.0008
Reptiles	0.3550	0.0775	0.1525	0.0387	0.2600	0.0526

Discussion

Community structure

The study has revealed that forest floor reptiles are sparsely distributed within the rainforests, with cluster abundance being far lower (14.8% of the primary quadrats) compared to amphibians (50%) in the same area[18]. Moreover, the forest-floor reptiles form very small clusters consisting of a few animals, mostly of one species. There is, however, considerable variation in the cluster abundance among the three sites, being highest in the low altitude site (Kannikatti) and lowest in the high altitude site (Kakachi). There are also considerable differences among the sites in the density and community structure of forest floor reptiles in the rainforests.

One of the possible reasons for the above variation in community structure is the response of reptiles to environmental gradients[19,20]. For example, reptile communities change along altitudinal gradients, responding primarily to temperature[19]. Reptiles might also respond to the overall productivity of the habitat, which is often greater in mid-elevation[21]. The arboreal reptiles in the rainforests of the Reserve showed a linear decline in abundance with altitude (between 700 m and 1300 m). However, species richness showed a nonlinear relationship with altitude, being highest in mid elevation (1000–1100 m)[9]. There is thus an altitudinal gradient in the abundance, species richness and assemblage composition of reptiles in the Reserve. This altitudinal gradient implies restricted distribution of many species, thus explaining differences in the reptile communities among the three sites, located in different altitudes. What is perhaps more interesting is the replacement at higher taxa levels, lizards dominating in the low altitudes, geckos at the mid-altitudes and skinks at higher altitudes. A majority of these species are endemic to these forest types.

Restricted distribution could arise due to other factors such as drainages, which could form barriers to the dispersal of animals. In the Western Ghats, amphibian communities have been reported to vary from one drainage to another and across hill ranges[18,22]. Being independent of water for completing their life cycles, reptiles might not be limited by drainage, unlike amphibians. The data on arboreal reptiles in KMTR did not show any significant differences between drainages in species assemblages and composition[9].

Species richness

The rainforest in the Ashambu Hills, being the southernmost point in the Western Ghats, and closest to the equa-

tor, is believed to be a centre of species richness and endemism within the Western Ghats[11]. In spite of intensive sampling for more than one year, we have been able to record only 55 species of reptiles (including one new record to the Western Ghats and three unidentified probably new species) from the rainforests of the KMTR. This forms only about 30% of the nearly 180 species of reptiles reported from the Western Ghats. Three factors might have contributed to the low number of reptile species that we recorded. First, in spite of intensive sampling, some of the taxa were clearly under-sampled, mainly due to the lack of appropriate sampling methods. For example, out of the 34 species of burrowing shield tail snakes or uropeltids in the Western Ghats, only six were recorded. Similarly, other fossorial snakes and skinks and canopy reptiles also may have been under-sampled. Secondly, many species reported from the Western Ghats may occur in other vegetation types, and not in rainforests. Typical examples are *Psammophilius dorsalis* (the rock agama) and geckos of the genus *Hemidactylus*, which may be mostly confined to the drier forests. Similarly, most of the turtles occur in water bodies at lower altitudes. Even when we exclude such species, we are still left with nearly 130 species, only about 42% of which have been recorded in our study.

The third reason for the low species richness might be that many of the rainforest species might have highly restricted distribution, even within rainforest. The distribution of various reptile species in the Western Ghats is very poorly known except for two species of agamid lizards, *Salea horsfieldii* and *S. anamallayana*. The former is known to be restricted to the higher elevation shola grassland in the Nilgiris, and the latter to the same habitat in Anamalai Hills[4]. In a recent assessment of the conservation status of Indian reptiles using the revised IUCN criteria, restricted distribution was stated as a reason for the endangerment of most of the 63 species of threatened reptiles in the Western Ghats[2]. The major differences in the forest floor reptile communities among the three sites in this study, and a similar difference in the arboreal reptiles in the same area[9] strongly suggest an altitudinal restriction in the distribution of many species. If this is true, then a major reason for the low species richness that we recorded was the restriction of sampling to altitudes between 700 m and 1300 m.

Scincella travancoricum, an endemic species of the southern Western Ghats, occurs in the higher altitude rainforest in KMTR. (Photo: S. U. Saravanakumar)

Conservation implications

The pattern of distribution of reptiles, especially the altitudinal gradient, has important conservation implications especially in the Protected Area (PA) networks. Unlike the amphibians in which the geographical spread of PAs is necessary to cover more species[18,22], what is important for reptiles might be altitudinal coverage. This is because species turnover in reptiles is not across drainage as in amphibians, but along the altitudinal gradient. In order to conserve the reptilian fauna of the Western Ghats, it is necessary to conserve habitats in the entire altitudinal range of the Western Ghats. Historically, low elevation forests were the first to be lost in the Western Ghats[23], and only small remnants are scattered along the Malabar coast, either as sacred groves or as reserved forests. Given the pattern of reptile distribution in the Western Ghats, it is very likely that many species probably as yet unknown, have become extinct or are nearly so in the low elevation forests. The high elevation forests are the next most altered natural vegetation in the Western Ghats, for plantation of cardamom, tea, eucalyptus and wattle. For example, in the Nilgiri Hills as much as 80% of the original shola grassland complex has been lost[24]. The low and high elevation habitats are likely to have unique reptilian assemblages, which are under serious threat and hence need better protection. In comparison, the loss of mid-elevation rainforest has been relatively less, in the past but presently they are under pressure due to anthropogenic reasons. Our studies show that it is at mid-elevations that reptile species richness is the highest, and hence it is necessary to conserve these forests too.

Appendix 1. List of reptiles recorded from the rainforests of Kalakad–Mundanthurai Tiger Reserve during 1996–1998.

Family: Bataguridae
Melanochelys trijuga

Family: Gekkonidae
*Cnemaspis indica**
*C. ornatus**
C. beddomei
*C. mysoriensis**
Cnemaspis sp. 1 (unidentified)
Red eye gecko (unidentified)
*Hemidactylus anamallensis**

Family: Agamidae
Calotes andamanensis
C. calotes
*C. ellioti**
*C. rouxii**
C. nemoricolor
C. grandisquamis
*Draco dussumieri**
Otocryptis beddomii
Psammophilus blanfordanus
P. dorsalis

Family: Scincidae
*Mabuya macularicus**
M. carinata
*M. beddomii**
*Scincella travancoricum**
Ristella sp.* (unidentified)

Family: Varanidae
Varanus bengalensis

Family: Uropeltidae
*Brachyophidium rhodogaster**
*Melanophidium punctatum**
Uropeltis arcticeps
U. ellioti
U. ocellatus
Uropeltis sp. (unidentified)

Family: Colubridae
Ahaetulla dispar
A. nasutus
A. perrotetti
A. pulverulenta
*Amphiesma beddomei**
A. monticola
Boiga ceylonensis
B. forsteni
Dendrelaphis grandoculis
D. tristis
Lycodon aulicus
*L. travancoricus**
Lycodon sp. (unidentified)
Macropisthodon plumbicolor
Oligodon arnensis
O. brevicaudus
Coluber mucosus
Xenochropis piscator

Family: Elapidae
Ophiophagus hannah
Calliophis melanurus nigrescens

Family: Viperidae
*Hypnale hypnale**
Trimeresurus gramineus
T. malabaricus
*T. macrolepis**
T. strigatus

*Species recorded during this study using adaptive cluster sampling.

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