RESOURCE UTILIZATION PATTERNS OF REPTILES IN THE TROPICAL DRY MIXED DECIDUOUS FOREST OF ANAIKATTY HILLS, WESTERN GHATS, INDIA

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in

ZOOLOGY

by

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DECLARATION

I, **Debanik Mukherjee** hereby declare that the thesis, entitled "**Resource utilization patterns of reptiles in the tropical dry mixed deciduous forest of Anaikatty Hills, Western Ghats, India**" submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **ZOOLOGY,** is a record of original and independent research work done by me during February 2002–May 2007 under the Supervision and guidance of **Dr. S. Bhupathy,** Senior Scientist, Department of Conservation Ecology, Sálim Ali Centre for Ornithology and Natural History, Coimbatore and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate in any University.

Signature of the Candidate

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SUMMARY

Distribution and ecology of various taxa of the world remain largely unknown. It is estimated that about 15% of the species of the world described till date contains only general taxonomic descriptions. Indian reptiles are most diverse, but poorly studied with respect to their ecology. The Western Ghats is one of the 34 globally recognized biodiversity hot spots. Among the 506 species of reptiles reportedly distributed in India, 165 are distributed in the Western Ghats.

Globally studies on the community ecology of reptiles are scanty. The concept of a biotic community may be defined as an assemblage of various organisms living together and interacting at all trophic level. In the past, in the Western Ghats, no systematic attempt was made to study the reptiles inhabiting the tropical dry mixed deciduous forests. Hence, the present study was under taken with the following objectives: (1) to know the suitability of various techniques for sampling reptiles in tropical mixed dry deciduous forest (2) to study aspects of population of reptiles in the Anaikatty Hills in terms of species richness, diversity and relative abundance, and (3) to understand the patterns of resource use by reptiles at various spatio-temporal levels.

The present study was conducted in Anaikatty Reserve Forest (76° 39'-76° 47' E and 11° 05'-11° 31' N), which is a part of the Nilgiri Biosphere Reserve, Western Ghats, India. Area of the reserve forest is 4448.74 ha, and it falls under Coimbatore Forest Division. Average altitude of the Anaikatty Hills is about 650 m above sea level, and tropical dry mixed deciduous forest covers a major portion of this hill.

This study was conducted from June 2002 to December 2005. Various area (Quadrat, Transect, Road cruising) and time (Visual Encounter Surveys) constrained sampling techniques were used for data collection, and two year sample data (January 2003 to December 2004) was used for rigorous

statistical analyses and hypotheses testing. Various analyses pertaining to population (species diversity, estimators) and community ecology (niche breadth and overlap, species packing) were done using modern statistical packages.

A total of 842 individuals of reptiles belonging to 45 species have been recorded during January 2003 to December 2004 in Anaikatty Hills. Transects yielded the highest 305 individuals followed by Visual Encounter Survey (VES). Quadrat sampling yielded the lowest number (90) of reptiles among various methods used for sampling. However, Road cruising yielded a maximum of 33 species, followed by VES (25 species) and minimum (10 species) in Quadrat sampling. The discovery of two new species (*Cnemaspis anaikattiensis* and *Lycodon flavicollis*) during this study from Anaikatty Hills adds to the conservation value of this area.

As mentioned earlier, including opportunistic observations, a total of 58 reptile species (one species of fresh water turtle, 24 lizards and 33 snakes) were recorded. However, only 45 species were recorded during January 2003 to December 2004, in regular sampling. Jackknife-2 yielded the highest estimated number of species (59 species), which is closer (similar) to the number of species observed during this study including opportunistic observations. Jackknife-2 estimator may be suitable for assessing the number of species in the present study area or a similar habitat with higher number species in the community. The estimated number of species varied among different estimators, and this could be due to the behaviour of species and functions of these estimators. It appears that VES and Road cruising may be suitable for inventorying and monitoring of reptiles inhabiting dry forests.

Various diversity indices showed almost similar trend. Snakes were more diverse (H' = 2.71) compared to lizards (H' = 1.85). Agamids contributed the maximum relative abundance among lizards, whereas it was Colubrids with respect to snakes. Many patterns with respect to size structure in reptiles were observed in Anaikatty Hills, and the reasons for the same are discussed.

Analyses with respect to spatio-temporal use pattern of reptiles were based on 1455 observations in Anaikatty Hills observed during 2002-2005. Lizards and snakes largely used terrestrial microhabitats. Among terrestrial microhabitats, forest floor was used by higher numbers of reptiles. Among lizards, *Calotes versicolor* used almost all microhabitats, whereas the skinks used the least. *Calotes versicolor* and *Hemidactylus frenatus* used various vertical strata, while skinks, geckoes and snakes largely used forest floor (ground).

Activity of various reptile species based on monthly observations showed that maximum and minimum number of them was found during July and May respectively. This may be mostly related to climatic conditions of the study area. Overall pattern showed that most of the lizards and a few species of snakes were active round the year, whereas turtle showed seasonality, active only during a few rainy months. *Calotes versicolor*, *Mabuya carinata* and *Oligodon taeniolatus* were observed year round in Anaikatty Hills, whereas species such as *Geckoella collegalensis*, *Sitana ponticeriana*, *Uropeltis ellioti* and *Liopeltis calamaria* showed seasonality. Various environmental factors and their correlation with observations of reptiles in various months are discussed.

Aspects of community ecology of the reptiles of Anaikatty Hills were analyzed. Analyses using morphometry, parameter such as niche breadth and overlap and species packing were done. Among lizards, *Calotes versicolor* and *Hemidactylus frenatus* showed maximum average niche breadth, both the species were generalists with respect to spatio-temporal resource utilization. Among snakes, Boiga *trigonata* and *Dendrelaphis tristis* were more generalists compared to other species. Among lizards, minimum average niche breadth was obtained by most of the skinks indicating their specialist nature. In the case of snakes, most species were specialized in their resource use.

Overall high overlap was found in spatial (microhabitat, vertical) level compared to monthly (temporal) activity. However, lizards showed low overlap than snakes with respect to microhabitat and vertical position used. Ratio between tail length and snout-vent length showed the suitability of this analysis to assign arboreality in snakes, which was not found useful with respect to lizards.

Clustering with respect to microhabitat use and vertical distribution showed compact species packing compared to temporal use. Overall the species packing in the present study area indicates close packing. Prevailing low intensity anthropogenic activities and contiguity to the plains might have offered opportunities for new niches, which could have resulted in high reptile species diversity in Anaikatty Hills.

CHAPTER - I
INTRODUCTION

1.1. BACKGROUND

Distribution and ecology of various taxa of the world remain largely unknown, and it is estimated that about 15% of the species of the world described till date contains only general taxonomic descriptions (Gaston, 2000). Mammalian and avian species were given relatively more importance with respect to ecology and conservation compared to taxa such as reptiles and amphibians (Vitt, 1987). The extant reptiles include Testudines (Chelonians), Rhynchocephalia (*Sphenodon* spp.), Squamata (Lizards and Snakes) and Crocodylia (Crocodiles). Barring the second taxa, all others are distributed in India.

The Western Ghats is one of the 34 globally recognized biodiversity hotspots (Mittermeier *et al.* 2005). Among the 506 species of reptiles reportedly distributed in India (Das, 2003), about 44% of them are endemic to India. The Western Ghats is the richest region in India with respect to reptiles (Inger and Dutta, 1986) which includes 95 endemic species (Das, 1996). This biogeographic region shares 10 taxa with adjacent biogeographic zones. The unique geographic position, distinct topography, climate and distinct valleys of Western Ghats must have largely attributed to more speciation in case of amphibians and reptiles.

Globally studies on community ecology of reptiles are scanty (Harvey *et al.* 1998; Vitt *et al.* 2003). Frazier (1992) reported that implementation of species conservation plans without understanding their ecology may become futile. Indian reptiles are most diverse, but poorly studied with respect to their ecology (Inger *et al.* 1987; Daniels, 1994). Relatively fewer studies on reptiles in general are mainly due to their cryptic nature, occurrence in low densities, highly seasonal activity and lack of proper sampling techniques (Diller and

Wallace, 1996). Heyer *et al.* (1994) provided various procedures for sampling herpetofauna, but all these methods have largely been tested in temperate conditions mainly in Western countries and their effectiveness or applicability in the tropical ecosystems is not workedout (Pearman *et al.* 1995).

Knowledge on the herpetofauna of India is largely based on information from the surveys and collections over last 130 years. Available information on Asian reptiles are mainly restricted to taxonomy and general distribution (Boulenger, 1890; Wall, 1922; Smith, 1931, 1935 and 1943; Deraniyagala, 1953 and 1955; Swan and Leviton, 1962; Ghalib *et al.* 1976; Whitaker, 1978; Whitaker and Dattatri, 1982; Inger *et al.* 1983 and 1984; Murthy, 1985; Moll and Vijaya, 1986; Murthy, 1990: Auffenberg and Khan, 1991; Das, 1991a and 1991b; Andrews and Whitaker, 1994: Bhupathy and Choudhury 1995; Das, 1995; David and Vogel, 1997; Wüster, 1998a; Wüster, 1998b; Whitaker and Martin, 1999; Das and Bauer, 2000; Das and Sengupta, 2000; Choudhury *et al.* 2000; Pawar and Biswas, 2001; Shrestha, 2001; Bauer, 2002; Daniel, 2002; Utiger *et al.* 2002; Das, 2003; Sharma, 2003).

1.2. ECOLOGICAL STUDIES IN INDIA

Major studies pertaining to population and general ecology, especially community ecology of reptiles, undertaken in Indian region is covered in this section. In the respective chapters, various important literatures based on studies abroad are cited and described in brief.

Studies on aspects of population ecology of Indian reptiles are restricted to a few taxa such as Crocodiles (Andrews and Whitaker, 1994; Vijaykumar *et al.* 1995; Whitaker and Andrews, 2003), turtles and tortoises (Khan, 1982; Kar and Dash, 1984; Moll, 1986; Rao and Singh, 1987; Rao, 1990; Kar, 1992; Frazier, 1992a and 1992b; Bhupathy and Vijayan, 1993; Bhupathy and Choudhury, 1995; Das, 1995; Choudhury *et al.* 2000; Pandav, 2001; Shanker *et al.* 2003; Mukherjee *et al.* 2006; Bhupathy and Saravanan, 2006) and *Varanus bengalensis* (Khan and Whitaker, 1982; Auffenberg, 1986;

Wikramanayake and Dryden, 1993), *Calotes versicolor* (Shanbag, 2003; Radder, 2006) and *Python molurus* (Bhupathy and Vijayan, 1989).

The concept of a biotic community may be defined as an assemblage of various organisms living together and interacting at all trophic level (Heatwole, 1982). The spatial and temporal parameters play an important role in structuring ecological communities, but studies on this aspect especially pertaining to herpetofauna is scanty (Harvey *et al.* 1998).

Studies on the community ecology of Indian herpetofauna are very few. Inger *et al.* (1987) studied the herpetofaunal community, especially resource utilization pattern in the Ponmudi hills, Kerala, and showed that a high proportion of amphibians and reptiles used forest floor. Brown (1992a and 1992b) studied the reptile communities of south Indian forests. This study revealed the inter-relationships among various lizards and snakes with respect to utilization of spatial niche such as microhabitat. The result showed formation of distinct arboreal and terrestrial guilds among various species with respect to specific microhabitat use. Bhupathy and Kannan (1997) studied the habitat and microhabitat use by various agamid lizards of the Western Ghats. The effect of habitat fragmentation on the herpetological communities of Mizoram, North-east India was studied by Pawar (1999). This study provided information on the impact of rain forest fragmentation and age of the plantation on the herpetofaunal communities. Ishwar *et al.* (2001) and Kumar *et al.* (2002) studied the effect of fragmentation of tropical evergreen forest on smaller mammals and herpetofauna in the Western Ghats. It is reported that most of the terrestrial or forest floor community was dominated by skinks and geckoes, whereas arboreal community by agamid lizards. Nixon (2005) provided information regarding resource utilization patterns of reptiles in Upper Nilgiris, Nilgiri Biosphere Reserve (NBR), especially, which inhabit the montane shola and grasslands.

Overall review shows that ecological research on Indian reptiles is still in infancy, compared to the diversity it harbours. Regarding taxonomy and distribution areas such as northeast India, Western and Eastern Ghats and

Bay islands of Andaman and Nicobar have not been fully explored (Das, 1996). In the past, no systematic attempt was made to study the reptiles of Anaikatty Hills, Western Ghats or tropical dry mixed deciduous forests. Hence, the present study was under taken with the following objectives.

1.3. OBJECTIVES

Major objectives of the present study were to;

(1) examine the suitability of various techniques for sampling reptiles in tropical mixed dry deciduous forest,

(2) study aspects of population of reptiles in the Anaikatty Hills in terms of species richness, diversity and relative abundance, and

(3) understand the patterns of resource use by reptiles at various spatio-temporal levels.

This dissertation is organized in six Chapters.

Chapter-I provides information on the background, a brief review on studies undertaken in India on population and resource use by reptiles and objectives of the present work.

Chapter-II describes the biotic and abiotic factors of the Western Ghats in general and Anaikatty Hills in particular.

Chapter-III provides descriptions on various reptile sampling techniques and their suitability with respect to sampling in tropical mixed dry deciduous forest compared.

Chapter–IV explains aspects of population ecology (species richness, diversity, relative abundance and size structure of selected species) of reptiles of this area.

Chapter-V describes various spatial and temporal resource use by the reptiles of Anaikatty Hills. Aspects such as microhabitat and vertical strata use by reptiles and their monthly activity pattern are covered.

Chapter–VI provides information on the niche utilization by reptiles in the Anaikatty Hills. Niche breadth, overlap and species groupings are described with respect to spatio-temporal resource use.

CHAPTER - II
STUDY AREA

2.1. WESTERN GHATS

The Western Ghats, known as *Sahyadris* is one of the 34 biodiversity hotspots of the World (Mittermeier *et al.* 2005), and is one of the four tropical moist forest zones available in Southeast Asia. Several studies during the last few years have corroborated the importance of the areas as global priorities (Rodrigues and Gaston, 2001; Das *et al.* 2006). A total of 165 species of reptiles has been reported from Western Ghats, of which 58% (species) are endemic to this hill range (Das, 1996). This chain of mountains runs parallel to the West Coast from the river Tapti in Gujarat (in north) to Kanyakumari in Tamil Nadu, the southernmost tip of the peninsular India. Though Western Ghats constitutes only five percent of the total land area of India, it harbors about 30% of India's biological species (Rodgers and Panwar, 1988). The Western Ghats is being threatened by various anthropogenic activities. However, about one third of its area is still covered by natural vegetation, including about 20,000 Km^2 rain forests (Collins, 1990).

Currently, eight National Parks and 40 Wildlife Sanctuaries are declared in the Western Ghats (Kothari *et al.* 1989; Amarnath *et al.* 2003). The Anamudi (2,695 m) in Kerala, is the highest peak in the Western Ghats. The southern parts of the hill range receive high rainfall during the southwest monsoon (June-August), and over 7,450 mm annual precipitation has been recorded in some areas. Important peninsular Indian rivers such as the Godavari, Krishna, Cauvery, Tambiraparani and their tributaries have their origin in the Western Ghats.

It is reported that the Southwestern Indian coast should have been alongside the Eastern coast of Madagascar during pre-continental drift period, and is supported by the great resemblance between the geology of Madagascar and Travancore-Ceylon with Archaean gneisses, Schists and Charnockites (Krishnan, 1953 and 1968). This geographic region contains various rock types such as Charnockite-Khondalite associations, Crystalline Limestones and Granulitic metamorphites with garnet, spinel, pyroxene, sillimanite, cordierite and staurolite (Krishnan, 1953 and 1968).

The unique geographic position and distinct physiographic, edaphic and climatic gradients of the Western Ghats aid to harbour a wide array of habitats that support distinct plant and animal assemblages. Various topography and climatic conditions of this mountain range reportedly regulate allopatric speciation in small bodied, habitat specific, sedentary terrestrial reptiles (Hora, 1953; Inger *et al.* 1987; Das, 1996).

2.2. NILGIRI BIOSPHERE RESERVE (NBR)

The Nilgiri Biosphere Reserve (76°- 77°15' E and 11°15' - 12°15' N), Western Ghats encompasses about 5520 km^2 covering Karnataka (1527.4 km^2), Kerala (1455.4 km^2), and Tamil Nadu (2537.6 km^2; Figure 2.1) is the first (declared) Biosphere Reserve in India by the Man and Biosphere Reserve programme of the UNESCO.

A wide range of rainfall zones between 500 and 7000 mm (annually) have been reported from here (Legris and Blasco, 1969). NBR is covered with tropical thorn forest in the lower altitude, and forest types vary according to altitudes. High altitudes (2000-2500 m) are covered with wet temperate forests (Champion and Seth, 1968).

The Nilgiri Biosphere Reserve falls under the biogeographic region of the Malabar rain forest (ENVIS, 2006). It holds well-known protected areas such as Mudumalai, Wyanaad Wildlife Sanctuaries and Bandipur, Nagarhole, Mukuruthi and Silent Valley National Parks. Of the reported 285 endemic vertebrate species from the Western Ghats, 156 occur in NBR, including 60 endemic reptiles (ENVIS, 2006).

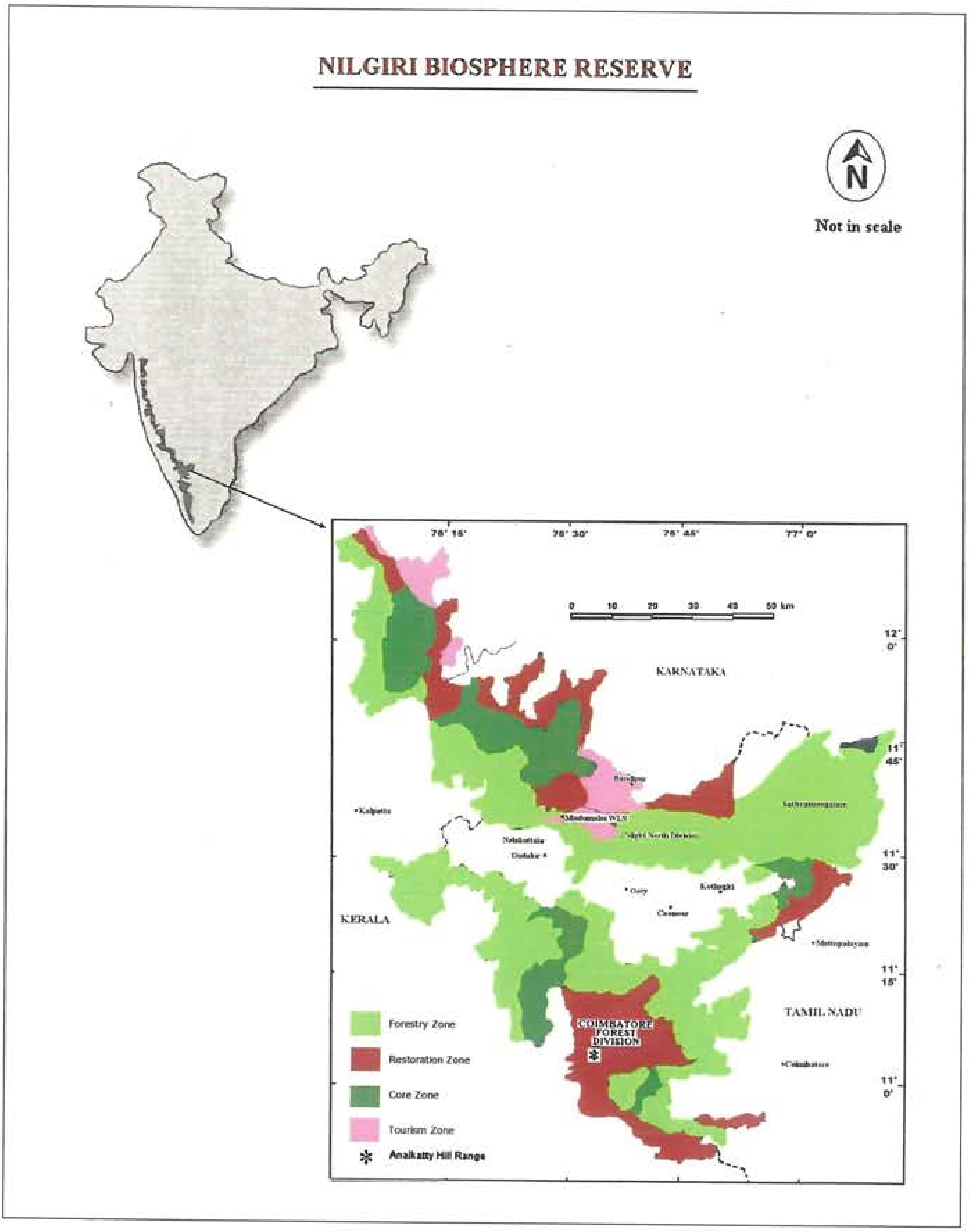


Figure 2.1. Map showing the location of the Nilgiri Biosphere Reserve, Western Ghats, India.

2.3. ANAIKATTY HILLS

2.3.1. Location

The present study was conducted in Anaikatty Reserve Forest (Figure 2.2; 76°39' - 76°47' E and 11°05' - 11°31' N). Area of the reserve forest is 4448.74 ha, and it falls under Coimbatore forest division, located about 25-km northwest of the Coimbatore City. The average altitude of the area is about 650 m above sea level. The Perumalmudi is the highest peak (1,500 m asl) of the general area.

2.3.2. History

In the ancient Tamil literature, area under Coimbatore, Periyar and Salem districts was known as Kongu country. In the first three centuries of Christian era, Kongu country was ruled by the tribes; Mavelar, Kasar and Kongar. In course of time this area changed hands from one to another. In 1700 AD, the whole area was governed by the Mysore rulers Hyder Ali and Tippu Sultan. Tippu had intimate knowledge about the forests of Coimbatore district. During his dynasty sandal trees were treated as royal forest item and he started protecting these valuable trees. After Tippu Sultan, the Coimbatore District came under the control of East India Company in 1799.

In 1859 Madras Forest Department constituted and allowed free removal of fuel wood and other forest products. According to the Jungle Conservancy Rule (1860) sandalwood was not allowed to exploit. Under the Forest Act (1882), all the jungles in this district were transferred into regular Reserve Forests. During 1906-1907 "Located felling" were continued in Mangarai and they were expanded year after year depending up on demand. The Tamil Nadu Forest Department had implemented afforestaion programme in 1990. The existing forest is largely a secondary growth that was formed by succession (Sundarapandian, 1992). A part of this hill area is privately owned.

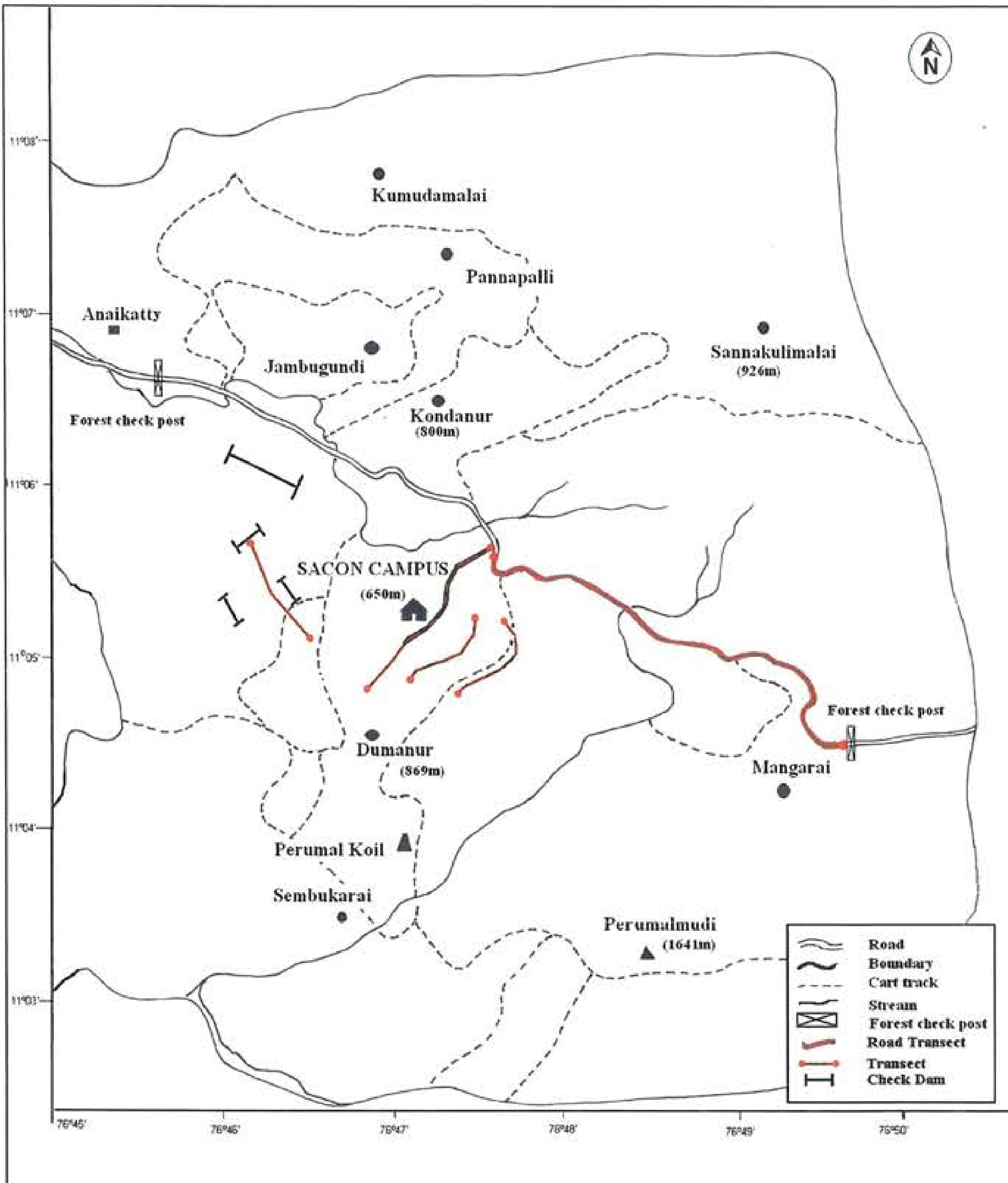


Figure 2.2. Map showing the details of the study area; Anaikatty Hills, Western Ghats.

2.3.3. Soil

Anaikatty Hills is comprised of various types of rocks largely Archean origin. Among the minerals Mica, Quartzite, Talc, Amethyst, Garnetite, Calcite, Feldspar, Hematite, etc. have been observed from the region (Ranjini, Pers. Comm.). In most parts, soil is hard gravel and in some places it is red loamy. The reddish brown soil and clay are mostly found in the plains. In general, most parts of the area have soil devoid of humus.

2.3.4. Climate

In general, climate of the Anaikatty Hills is moderate for most of the year except summer (March to May). This hill receives precipitation from both Southwest (May to August) and Northeast (September to November) monsoons (Figure 2.3). The Northeast monsoon contributes more than half of the total annual rainfall of the Anaikatty Hills. The average rainfall of the area during past 10 years was 668 mm.

During this study, the highest rainfall was observed in October and the lowest in December. The mean of monthly minimum and maximum rainfall was 0.5 and 288.8 mm respectively. The mean maximum (36.3°C) and minimum (17.3°C) temperature was recorded during April and December respectively (Figure 2.4). Mean relative humidity of the area varied between 81 and 88%. The maximum humidity was recorded during November and minimum during June (Figure 2.5).

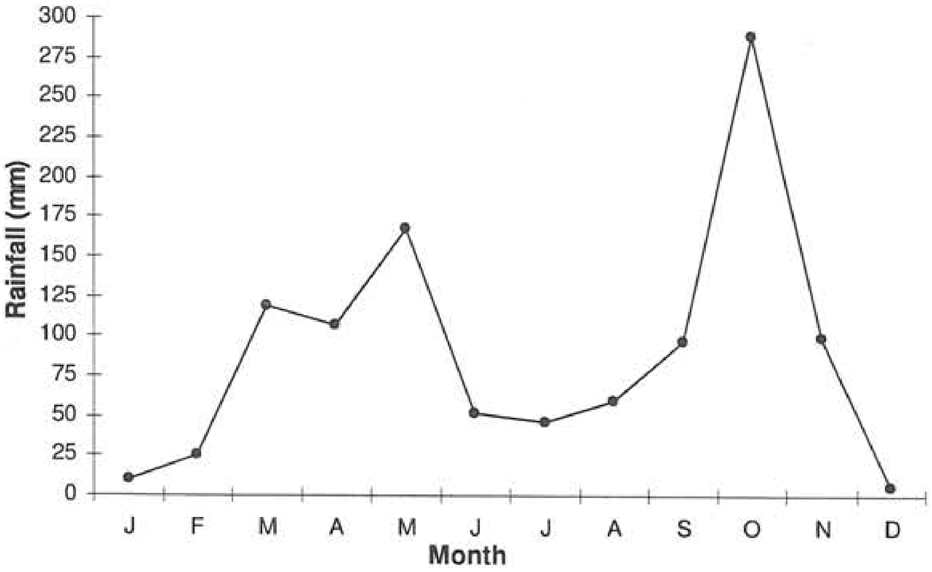


Figure 2.3. Monthly rainfall pattern of the Anaikatty Hills (2003-2005).

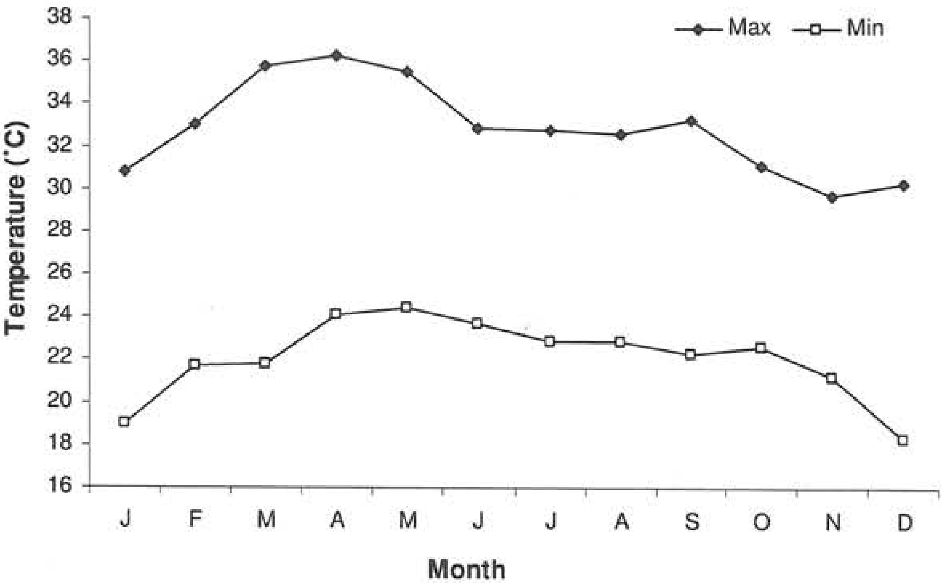


Figure 2.4. Monthly (maximum & minimum) temperature recorded during 2003-2005 in the Anaikatty Hills.

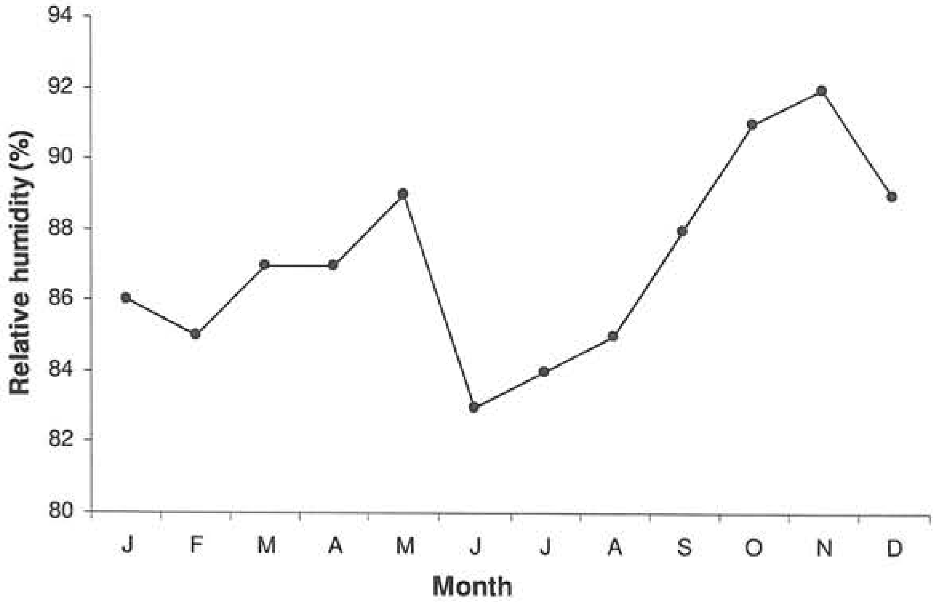


Figure 2.5. Relative humidity (%) recorded during 2003-2005 in the Anaikatty Hills.

2.3.5. Vegetation

The Coimbatore Forest Division is largely covered with Southern tropical mixed dry deciduous forests (47%, Plate 1a) and Southern tropical thorn forest (29%). Tropical semi evergreen (8%) and wet evergreen (2%) forests are found on hilltops (Champion and Seth, 1968).

The tropical thorn forest (Scrub jungle) largely dominates the lower part or the foothills of this Reserve Forest. Common vegetation of the area is *Lantana camara*, *Lantana wightiana*, *Chromolaena odorata*, *Clausena indica*, *Flacourtia indica*, *Paretta indica* and *Mundulea sericea*. Succulents such as *Opuntia dillenii* and *Euphorbia antiquorum* are also fairly common.

Trees such as *Acacia leucophlea*, *Ziziphus mauritiana*, *Albizia amara*, *Albizia lebbeck*, *Tamarindus indica*, *Cassia fistula*, *Santalum album* and *Commiphora caudata* dominate the mixed dry deciduous forest. Bamboo (*Bambusa bamboos* and *Dendrocalamus strictus*) is common in riverine habitats of the area. The hilltops of the area harbour tropical semi evergreen forests. Major tree species on hilltops includes *Neolitsea scrobiculata, Ziziphus xylopyrus, Syzygium cumini* and *Nothopegia racemosa.*

The inhabitants of the surrounding villages (Doomanur, Sembukkarai, Kondanur, Alamaramedu, and Moongilpallam) collect firewood, bamboo, honey and minor forest products. The Anaikatty Reserve Forest has been highly degraded because of the unlimited exploitation of the forests, forest fire, cattle grazing and the rapidly burgeoning brick industries.

2.3.6. Wildlife

Amphibians and Reptiles

Ten species of amphibians were observed during this study, among them Common Indian toad (*Bufo melanostictus*), Marbled balloon frog (*Uperodon systoma*), Red microhylid (*Microhyla* sp.), Skittering frog (*Euphlyctis cyanophlyctis*) and Indian bull frog (*Hoplobatrachus tigerinus*) were frequently observed. Fifty-eight species of reptiles were observed in Anaikatty Hills during this study (Appendix I).

Birds

A total of 187 species of birds were observed in this area by Nirmala (2002). A few common bird species include Red-whiskered Bulbul (*Pycnonotus jocosus*), Red-vented Bulbul (*Pycnonotus cafer*), Indian Robin (*Saxicoloides fulicata*), Yellow–billed Babbler (*Turdoides affinis*) and Indian Peafowl (*Pavo cristatus*). Endemic and rare bird species of the area include Rufous Babbler (*Turdoides subrufus*), Yellow-throated Bulbul (*Pycnonotus xantholaemus*), Great Hornbill (*Buceros bicornis*) and Malabar Parakeet (*Psittacula columboides*).

Mammals

Common herbivorous mammal species includes, Black-naped hare (*Lepus nigricollis*), Gaur (*Bos gaurus*), Spotted deer (*Axis axis*), Sambar (*Cervus unicolor*) and Asian elephant (*Elephas maximus*). Among the carnivores Brown mongoose (*Herpestes brachyurus*), Indian wild dog (*Cuon alpinus*)

Leopard (*Panthera pardus*) and Omnivore species Wild boar (*Sus scrofa*) were sighted occasionally. Man animal conflict includes occasional reports of elephants attacking human and raiding crops.

2.4. ECOLOGICAL STUDIES IN ANAIKATTY HILLS

Anaikatty Hills is poorly understood in terms of the biodiversity and ecology. Aspects of ecology of bird communities of the area have been worked out by Nirmala (2002). Description on aspects of ecology and seasonality of insects of the area is available in Eswaran and Pramod (2004) and Eswaran (2006). Information on the reptile fauna is scanty and largely anecdotal (Rathinasabapathy and Gupta, 1995; Kannan and Bhupathy, 1997). Hence, the present study was initiated.

CHAPTER - III

REPTILE SAMPLING TECHNIQUES

3.1. INTRODUCTION

Herpetofauna (amphibian and reptiles) have been relatively uncommon subjects of study compared to birds and mammals (Vitt, 1987). This is mainly due to their small size, cryptic nature, highly seasonal activity, low density and lack of standard sampling techniques. Among the major herpetofaunal sampling techniques, Visual Encounter Survey (VES), Quadrat, Transect, Pitfall and Cover boards are widely used in monitoring herpetofauna (Heyer *et al.* 1994). Heyer *et al.* (1994) further advocated using a combination of techniques to survey a habitat to obtain reasonable results with respect to herpetofaunal diversity. However, consequence of different techniques may vary and the results are often incomparable. This may be mainly due to the limitations of methods; by using a single method all the species in a given area may not be detected and secondly the response or behaviour of species may be different with respect to each method. Hence, standardization of sampling techniques and their revisions may be useful.

In India, during recent years, several attempts have been made to use Visual Encounter Survey (VES), Quadrat and Transect for sampling herpetofauna (Bhupathy and Kannan, 1997; Ishwar *et al.* 2001; Giri and Chaturvedi, 2001; Ishwar *et al.* 2003; Bhupathy and Nixon, 2004; Nixon, 2005). Noon *et al.* (2006) tested the efficiency of adaptive cluster sampling in detecting terrestrial herpetofauna in tropical rain forests of Western Ghats. Pitfall traps and artificial / cover-boards were largely attempted in temperate areas (Campbell and Christman, 1982; Corn and Bury, 1990; Heyer *et al.* 1994). The suitability of these methods have not been tested and validated in tropics. The Pitfall traps yielding better results in tropics may be doubtful due to high rainfall, run off and siltation. Cover-board or artificial retreat may not be suitable to study reptiles in the tropics, as the same have a diversified forest type with relatively larger number of natural retreats such as crevices and boulders. Hence, the probability of yielding desired results in tropical conditions using this method is doubtful. In the present study, an attempt was made to use of various sampling techniques and understand their merits and limitations.

3.2. METHODOLOGY

The fieldwork was conducted from June 2002 to December 2005. However, only two years data (January 2003-December 2004) was used to test the suitability of sampling methods in the present study. All methods were consistently used on fortnightly basis for sampling. During fortnightly sampling two persons were involved in all surveys. Brief data collection procedure with respect to each method is given below.

3.2.1. Visual Encounter Survey (VES)

VES is a time-constrained sampling technique (Campbell and Christman, 1982; Corn and Bury, 1990). It needs a systematic search through an area or habitat for a prescribed time period (Campbell and Christman, 1982). The result of VES is measured against the time spent for search. VES technique is one of the simplest methods, and an appropriate technique for both inventory and monitoring Herpetofauna (Heyer *et al.* 1994). VES is often considered to be the best method to survey species that are rare. Among the various drawbacks of this sampling technique, not all the microhabitats or strata could be sampled with equal success due to variation in visibility and differential habitat and microhabitat use by various species.

Field surveys were conducted on fortnightly basis and two field personnel were involved during all bouts of VES. Sampling was done on three hours bout, during 0600-0900 and the other at 1600-1900hrs. This resulted in six-man hours search in the morning and evening totaling to 12 hours survey in a fortnight.

3.2.2. Quadrat Sampling

Quadrat sampling consists of laying out a series of squares (Quadrats) within a habitat and thoroughly searching for target species. Each quadrat should be placed apart to avoid pre-sampling disturbances (Heyer *et al.* 1994). In this sampling technique field researcher should examine all possible microhabitats present within the Quadrat. The results from Quadrats can be used to determine the species present in an area, their relative abundance and density. Forest floor species can be sampled more effectively using this method. Quadrat sampling has been used in tropical forests to determine density, species diversity and relative abundances of amphibians and reptiles (Heyer *et al.* 1994).

This sampling technique looses effectiveness in habitats with dense ground cover and irregular or steep terrain, where it is difficult to place quadrats. Sampling of the subterranean or fossorial and arboreal or scansorial species may not be effective using this method.

In the present study, 10x10m quadrats were used and two persons examined the same searching all microhabitats. Fortnightly, 35 quadrats were examined during 0600-1000 and 1600-1900 hrs.

3.2.3. Strip Transect

Strip transect includes cruising along the transect line searching for target species (Heyer *et al.* 1994). This sampling technique is useful in determining relative abundance of species across habitat gradients. This technique is useful in determining intra and interspecific changes in populations. As microhabitats are not examined, species found active above ground can be encountered with this method.

In the present study, four transects of one kilometer each was monitored fortnightly during 0700-0800 and 1630-1730 hrs. Fixed width of 2m was used in all transects. Among them, two transects, were monitored during night (between 2000 and 2100 hrs).

3.2.4. Road Cruising

Cruising the road that crosses the forest at regular intervals provides information on species richness and relative abundance of species present in the area (Heyer *et al.* 1994). Klauber (1939) used this technique for making inventory of nocturnally active snakes. Habitat specific species may be poorly represented in road cruising. The quality of the data depends on the activity of the animals and traffic density of the area. Nevertheless, the data obtained from this method would give indication of the reptile composition of the area.

Fortnightly, four kilometers of Anaikatty-Coimbatore State Highway (No.63, Plate 1b) was sampled for reptiles during 0700-0800 and 1700-1800 hrs.

Reptile identification and nomenclature was following (Smith,1931, 1935,1943 and Das, 1995, 2002, 2003). Varification of doubtful species was done comparing specimens at the National Museum, Zoological Survey of India, Kolkata.

3.2.5. Data Analyses

The following analyses were done.

Species richness

A) Number of species observed during the study was considered as species richness of the area.

B) Species richness using non-parametric estimators such as first and second order Chao, first and second order Jackknife, Bootstrap and Cole rarefaction were used to determine the estimated reptile species richness in the present study. EstimateS, version 7 software (Colwell, 2004) was used to estimate species number.

(1) First order Chao (1984) derived from

$$\hat{S}_{max} = S_{obs} + (a^2/2b)$$

where,

S_{obs} = actual number of species in the sample

a = number of species found only in one sample

b = number of species found only in two samples

If all species have been observed more than twice, $\hat{S}_{max} = S_{obs}$

(2) Second order Chao - the observed number of species in a sample, combined with the number of species appearing in only one or two samples;

(3) Burnham and Overton (1978) and Heltshe and Forrester (1983) developed first order Jackknife estimator:

$$\hat{S}_{max} = S_{obs} + a\,(n\text{-}1\,/n)$$

where,

n = number of samples

a = the number of species found only in one sample

(4) Second order Jackknife estimate is based on the number of species that occur in only one sample, as well as the number in exactly two samples.

(5) Bootstrap estimate of species richness can be calculated as

$$S_{boot} = S_{obs} + \Sigma\,(1\text{-}P_k)^m$$

where,

P_k = proportion of m samples with species k and the summation is across all

S_{obs} = species in the pooled samples.

(6) Rarefaction allows standardization of sampling effort. It gives the heterogeneity or patchiness of a sample.

Representative species in each family with maximum number of individuals were considered as common species in the present analysis.

3.3. RESULTS

Data from all the sampling techniques on fortnightly basis was considered for analyses. Sampling intensity using various field methods during two years of this study (2003-2004) is given in Table 3.1. Including night survey, transects covering a total of eight kilometers were sampled during each fortnight. Similarly, eight kilometers were covered during morning and evening for road cruising. With respect to quadrat sampling, 35 quadrats (0.35 ha) were sampled in each fortnight. Among 1,700 quadrats examined, 71 had species. In each fortnight VES was conducted twice (morning and evening), three hours each. This worked out to be 12 hours survey in each fortnight.

Table 3.1. Sampling intensity using various methods from January 2003 to December 2004 in Anaikatty Hills.

Method	Unit / Bout	Fortnightly Sample	Total
Transect (day)	3 (each 1 km, morning & evening)	6 km	288 km
Transect (night)	2 (each 1 km)	2 km	96 km
Road Cruising	1 (each 4 km, morning & evening)	8 km	384 km
Quadrat	35 (10X10 m)	0.35 ha	16.8 ha
Visual Encounter Survey	2 (six hours each)	12 hrs	576 hrs

A total of 842 reptiles were recorded during the present study using various sampling techniques, which includes 42 turtles. Since turtles were mostly aquatic and all the sampling techniques used in the present study largely were applicable for terrestrial animals; the same was not excluded from analysis. Transects yielded the highest number of 305 reptiles and Quadrat sampling the lowest (Table 3.2). However, highest density (5.4/ha) of reptiles was obtained by Quadrat sampling and minimum (0.50/ha) by Road cruising (Table 3.2). With respect to number of species observed, the order of the sampling techniques, which resulted number of species in decreasing order are as follows: Road Cruising (33 species) > VES (25) > Transect (11) > Quadrat (10) (Table 3.2).

Table 3.2. Number of Reptile species observed using various sampling techniques in Anaikatty Hills.

Methods	Sampling	No. of Species	No. of Reptiles	Species/ Effort	Number/ Effort
Transect (day & night)	153.6 ha	11	305	0.07 /ha	2/ha
VES	576 hrs	25	271	0.04/hrs	0.5/hrs
Road Cruising	268.8 ha	33	134	0.12/ha	0.50/ha
Quadrat	16.8 ha	10	90	0.59/ha	5.4/ha
Total	-	44	800	-	-

Overall results showed that a large number of lizards were detected by all methods used in this study with a maximum species in VES (Figure 3.1). Higher number of snake species were observed in Road cruising and none in Quadrat sampling. Number of snakes observed in transects and VES was low (Figure 3.2).

Lizard taxa observed at family level in various methods are given in Figure 3.3a. Road cruising detected maximum (5) lizard taxa, whereas Quadrat yielded only three (Figure 3.3a). Agamids, Scincids and Gekkonids were detected by all sampling methods. Chamaeleonids was not sighted in quadrat, whereas Varanids in Road cruising only (Figure 3.3a).

Analysis with respect to the various snake taxa at family level is given in Figure 3.3b. As in lizards, Road cruising yielded maximum (6) snake taxa, whereas Quadrat did not yield any snakes (Figure 3.3.b). Boidae and Colubridae were detected by all other sampling methods barring Quadrat. Typhlopid was detected in VES and Road cruising, whereas Uropeltid, Elapids and Viperids were found only in Road cruising. The order of the sampling techniques with respect to decreasing number of snake taxa observed is as follows: Road Cruising > VES > Transect (Figure 3.3b).

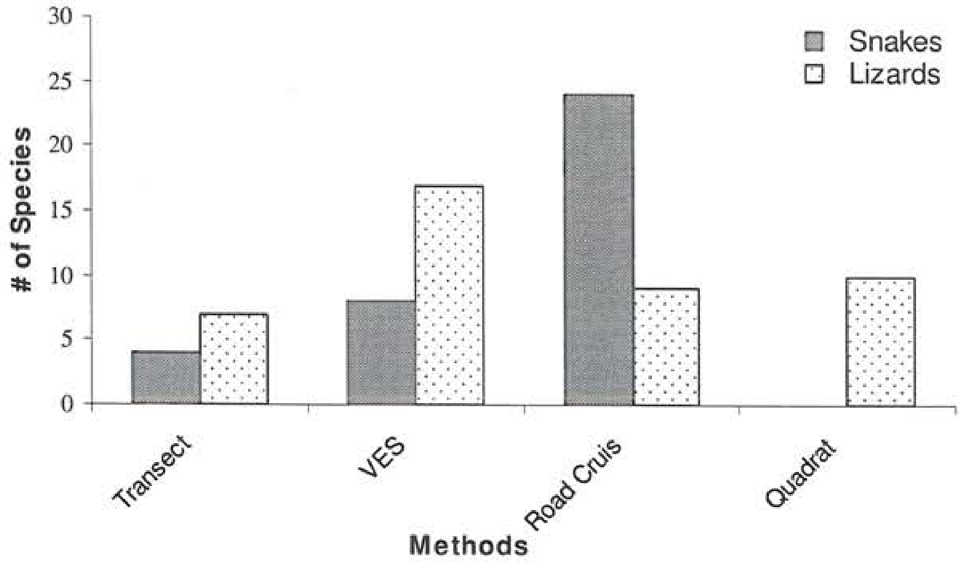


Figure 3.1. Detection of lizards and snakes by various sampling techniques observed in the Anaikatty Hills.

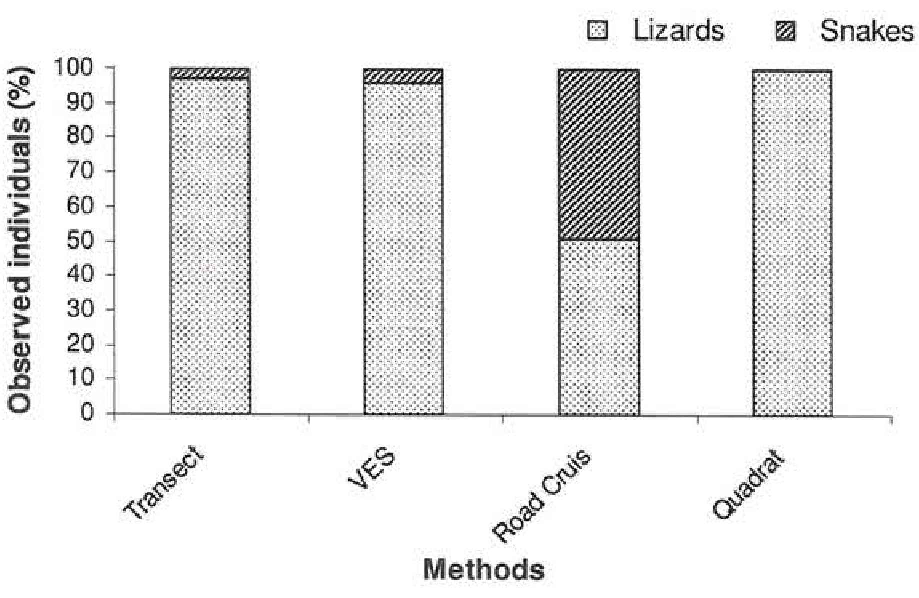
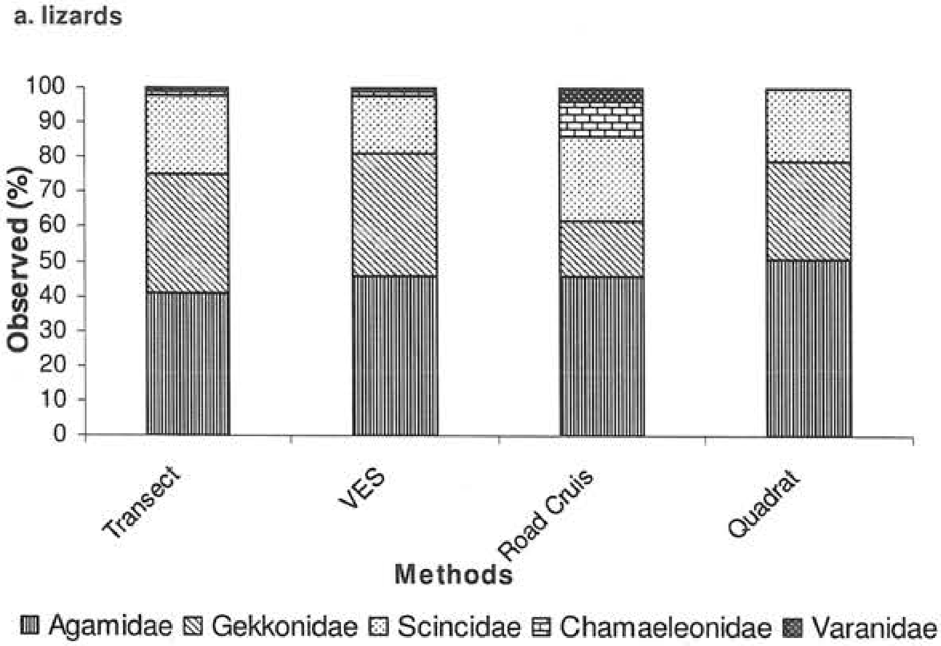


Figure 3.2. Detection of lizards and snakes by various sampling techniques observed in the Anaikatty Hills.

Detectability of five common lizard species regarding various sampling techniques revealed that *Calotes versicolor* and *Mabuya carinata* were detected in all four methods (Figure 3.4a). Four out of five species were found in Transects, VES and Road Cruising and three species, namely *Calotes versicolor*, *Mabuya carinata* and *Cnemaspis mysoriensis* in Quadrat sampling (Figure 3.4a). Species such as *Chamaeleo zeylanicus* was detected only during Road cruising in this study.

Five out of six species of common snake species of the area were found in Road cruising (Figure 3.4b). VES revealed three and transect two species. Quadrat did not yield any snake species (Figure 3.4b). Road Cruising yielded species such as *Uropeltis ellioti*, *Liopeltis calamaria* and *Ahaetulla nasuta.*

Results showed that sampling methods were biased towards various taxa. For instance, Road cruising yielded more snakes, while other methods were biased towards lizards (Figure 3.1). With respect to snake species, maximum 24 species were observed from the Road cruising and no snakes in Quadrat. The order of the sampling techniques with respect to the number of snake species observed was Road cruising > VES > Transect > Quadrat. With respect to the number of lizard species, VES yielded the maximum of 17 species and minimum of six species in transects. The order of detection of lizards in various sampling methods was, VES > Quadrat > Road cruising > Transect.



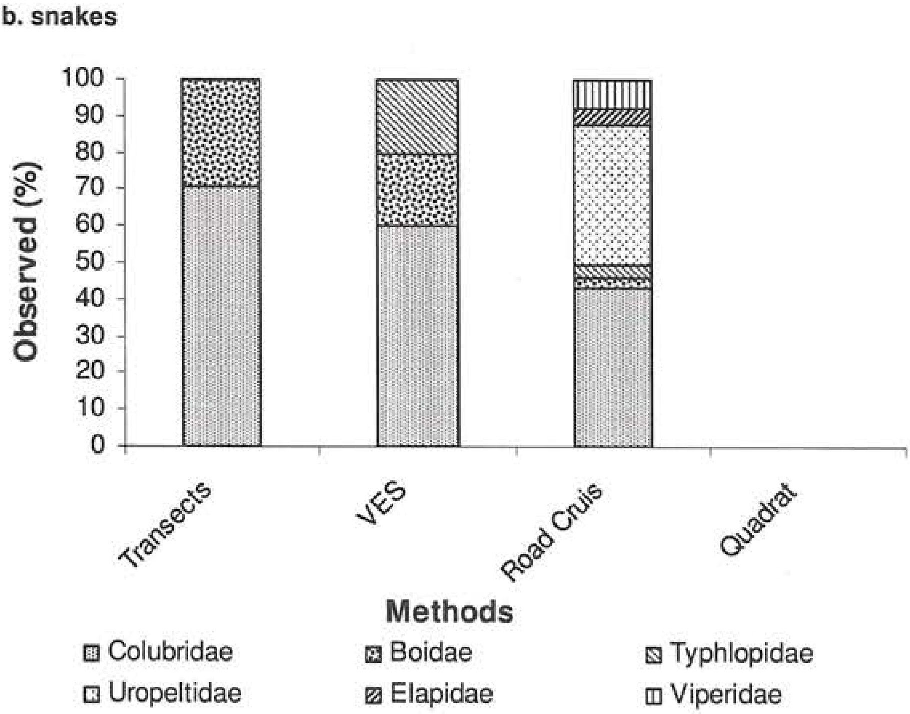


Figure 3.3. Detection of various lizards and snakes at family level by various sampling techniques.

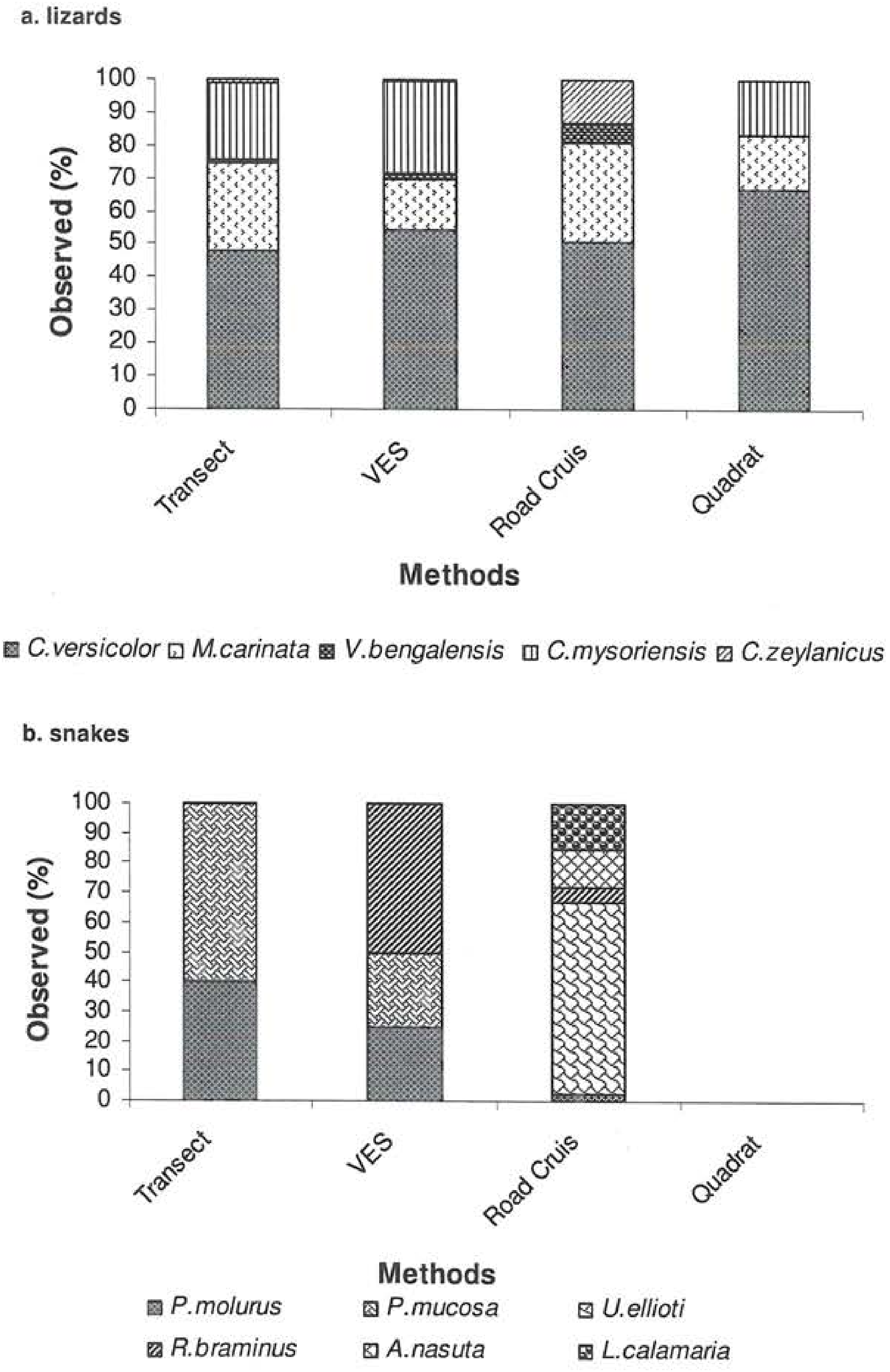


Figure 3.4. Detectability of few lizard and snake species with respect to various sampling techniques.

Species Richness

Overall, including opportunistic records a total of 58 species were observed during the present study (Appendix I). Thirty-three species were observed in Road cruising, the second order Jackknife yielded the maximum (60.7 species) and Cole rarefaction the minimum 33.8 species (Table 3.3). Twenty-five species were observed in Visual Encounter Surveys (VES), the second order Jackknife yielded the highest of 46.7 and the Cole-rarefaction the lowest (25.9 species). Rarefaction gave almost similar number of species as observed in VES (Table 3.3) and all other estimators yielded more species than the observed number. In Transect 11 species were observed and the first order Jackknife estimated highest 13 species. In Quadrat 10 species were observed and first order Jackknife yielded highest of 11 species (Table 3.3).

Table 3.3. Estimated number of species obtained using different estimators based on data collected using various methods.

Estimators (mean)	Road Cruising	VES	Transect	Quadrat
Chao1	54.2	33.2	12.06	10
Chao2	54.2	42.9	12.06	10.06
Jackknife 1	49.8	37.9	13	11
Jackknife 2	60.7	46.7	12.01	10
Bootstrap	40.9	30.9	12.7	10.7
Cole-rarefaction	33.8	25.9	12	10
No. of species observed	33	25	11	10

Remaining all estimators yielded almost similar number of species as observed in Quadrat. The estimated number of species was mostly higher than the observed species in Road cruising and VES, while it did not vary much from the observed one in case of Transect and Quadrat (Table 3.3). Although the second order Jackknife contributed highest number of species in Road cruising and VES, first order Jackknife estimated maximum species for other methods and Cole-rarefaction obtained minimum species in all methods. The result showed that the highest number of species was observed using Road cruising followed by VES, Transects and Quadrat (Table 3.3).

3.4. DISCUSSION

Heyer *et al.* (1994) suggested various herpetofaunal sampling techniques, but all those have largely been untested in tropics (Pearman *et al.* 1995). In the present study, various methods were used for sampling and results were compared. The result using Road cruising yielded better output for snakes compared to lizards with respect to number of species. Road cruising yielded rare and nocturnal snake species, which were undetected by other methods (Andrews, 2004; Andrews and Gibbons, 2005). However, the main drawback regarding Road cruising is that the result largely depends upon vehicular traffic density, activity of the species and swiftness in their movement. Compared to tetrapod lizards most of the snakes move slowly and are likely to get killed by the passing vehicles. Road is relatively smoother compared to natural substrates, and that makes the movement of snakes difficult.

Other techniques such as Transect, VES and Quadrat were largely biased towards lizards, which may be because lizards are largely terrestrial and could be easily detected by these methods. Variations in the results by different sampling techniques, most probably due to the responses of different taxa to various methods, which affirmed that a single sampling technique may not be suitable for detecting all reptile taxa in a given area (Corn and Bury, 1990; Pearman *et al.* 1995). Various reptile species were restricted to their specific habitats or microhabitats, which may be one of the reasons for this difference. Not only habitat or microhabitat but also behaviour or habit of certain species may vary depending on its ambient environment (Cloudsley-Thompson, 1999; Pough *et al.* 1999). Based on the present study it is suggested that a combination of VES and Road Cruising technique may be useful for preparing inventory of reptiles in other forest areas having similar cover, especially for monitoring purpose.

As mentioned earlier, of the 133 individuals that were killed by vehicular traffic on the Coimbatore-Anaikatty state highway (No.63) during the sampling, 65 (49%) were snakes and remaining 68 individuals were lizards (51%). However, with respect to the number of species, the highest 24 snake species were detected compared to other methods. The impact of road traffic on the herpetofauna is poorly understood in the Western Ghats (Gokula, 1997; Vijayakumar *et al.* 2001). Studies on the herpetofaunal mortality in the Anamalai Hills, Western Ghats by Vijayakumar *et al.* (2001) showed that more than 80% of the road kills comprised snakes. The vulnerability of various snake species to vehicular traffic is probably because the snakes may use roads as substrates for thermoregulation (Vijayakumar *et al.* 2001). Andrews (2004) reported that snakes are ideal taxa for investigating the generality and interspecific differences of both direct and indirect road impacts. Swift moving species such as *Ptyas mucosa* and *Naja naja* and few arboreal and aquatic species such as *Dendrelaphis tristis*, *Ahaetulla pulverulenta* and *Xenochrophis piscator* were poorly represented in Road cruising. Opportunistic observations and Road cruising were used for sampling by several researchers (Sullivan, 1981; Andreone *et al.* 2003). Heyer *et al.* (1994) reported that opportunistic records and road survey in conjunction with other sampling techniques may provide complete species richness of a given area and the present study augments this view.

Lloyd *et al.* (1968) reported that snakes were less abundant in Quadrat sampling. Under-representation of snakes in Quadrats during this study is similar to that of the findings of Das and de Silva (1998). Quadrat sampling in the present study did not yield any snake species. Heinen (1992) pointed out the pre-sampling disturbance such as low frequency ground-borne vibrations could be one of the reasons associated with under-representation of snakes in quadrat sampling.

Nixon (2005) obtained 282 reptiles in 2,706 quadrats laid in the Upper Nilgiris during 2000 to 2002, which yielded 10.42 reptiles/ ha, a total of 136 quadrats with species; which comprised of 5.02% of total quadrats laid. In comparision only 5.3 reptiles/ ha were observed in the present study. Among 1,700 quadrats laid only 4.1% quadrats had species. Higher density of reptiles in Upper Bhavani compared to Anaikatty may be due to the variation in geographical location such as altitude and changes in factors such as temperature and microhabitats. Due to the adverse winter temperature most species in Upper Bhavani might have suffered from thermoregulatory adjustment and remained lethargic, which could be only solved by enhanced basking. All these factors would have resulted in higher observations of reptiles in the Upper Nilgiris (Nixon, 2005). On the other hand, reptiles in warmer areas such as in Anaikatty Hills may be relatively fast moving, active and would escape detection (Andrews, 1990; Bonnet *et al.* 1999).

Comparison of various sampling techniques has largely been untested. Lips (1999) and Toral *et al.* (2002) used VES to study the population of anurans in Western Panama and Ecuador. Various researchers used VES in India (Bhupathy and Kannan 1997; Giri and Chaturvedi, 2001; Bhupathy and Nixon, 2004). Nixon (2005) reported both quadrat and VES methods show largely similar trend in species detection in Upper Nilgiris, when sample size is high. However, Nixon (2005) further reported that data from Quadrat and VES might not be comparable as they differed in quality (Quadrat yields number of reptiles / unit area and VES yields number of reptiles / unit effort).

One of the primary objectives of the field studies in ecology in terms of population is to estimate how many species of a given taxon occur in an area (Ugland *et al.* 2003). Species accumulation analysis may be important as all species in a study area especially that of reptiles may not be detectable all times. These analyses may provide information on the completeness or shortcomings in the sampling effort. Southwood and Henderson (2000) reported that perhaps all the estimators could show differential magnitude with respect to the observed species such as in the present study. In such cases to avoid misleading results, it would be a sound practice to estimate those population or other variables by more than one estimator. It has been well experienced that simple species richness or the total number of species observed in samples underestimates richness in a given area. Estimators allow the reduction of the underestimation associated with sampling (Krebs, 1989; Southwood and Henderson, 2000).

Hellmann and Fowler (1999) stated that where sample size is small the second order Jackknife may be used. However, Walther and Morand (1998) found that in similar data set first order Jackknife performed better. The present study contained large data set and the better results from both Jackknife-2 did not support Hellmann and Fowler (1999). Species richness estimation using data collected from various methods showed that Jackknife 2 obtained better results in case of Road cruising and VES, whereas Transect and Quadrat, Jackknife-1 yielded better results compared to other estimators. According to Zahl (1977), Quadrats generally yield independent samples, which may be jackknifed for diversity estimation. Colwell and Coddington (1994) suggested that second order Jackknife clearly provided the least biased estimates followed by the first order Jackknife. Overall result from Jackknife estimator in the present study supports Colwell and Coddington (1994).

Both Jackknife and Bootstrap may reduce the biases associated with species richness. Jackknife can reduce the underestimation of the true number of species in an assemblage based on the number represented in a sample. The Jackknife estimates species richness based on the number of species that occur in only one or two samples and that functions on the number of rare species found in a community (Burnham and Overtone, 1978, 1979; Heltshe and Forrester, 1983). In all, including opportunistic observations, a total of 58 species were recorded during this study. This is closer to the highest estimated number (59 species). Hence, the estimated number of species by Jackknife may be relatively a true picture of the species richness of the present area (Chapter IV- Population).

According to Southwood and Henderson (2000), if the data set comprised of presence or absence data, then the Chao may be the only suitable method, and this estimator can perform well when most species are infrequent. Colwell and Coddington (1994) reported that Chao performs well if most of the information in the sample is concentrated on relatively rare species. The Chao estimator uses the observed number of species in a sample, combined with the number of species appearing in only one and two samples.

In the present study, Chao1 and Chao2 did not yield better results in estimating overall species richness. The first and second order Chao obtained 46.5 and 48.8 species respectively, the results yielded only few more species than that of the observed number. Even with respect to each sampling technique Chao1 and 2 did not perform well in case of Transect and Quadrat. It estimated almost same number of species, which was observed during the field sampling. However, Chao1 and 2 yielded better results in Road cruising and VES. This is because many species including rare species was found in these two methods. Number of species observed was very few in Transect and Quadrat, and hence these methods did not yield better results in the present study.

Rarefaction or Coleman curves are basically not estimators of richness but it can be used for the heterogeneity test (Southwood and Henderson, 2000). It estimates species richness based on all species actually discovered during the study. Sanders (1968) proposed that rarefaction method standardized all samples to a common size and can estimate the number of species expected in random samples. A sample with taxonomic similarity could give better result in Rarefaction. In the present study, overall the Rarefaction did not perform well probably because the Anaikatty Hills harbored higher taxonomic diversity (turtles, lizards and snakes). Sanders (1968) argued that rarefaction curve could not be extrapolated beyond the number of individuals in a sample. The mean species accumulation curve with the Coleman (or rarefaction) curve permits a rough evaluation of sample heterogeneity (patchiness). In the present study, Cole-rarefaction estimated lower number of species than the observed one, both in method and overall estimation of species richness in Anaikatty Hills. It is probably because of the incapability of the estimator to extrapolate the total number of species from the samples. Nixon (2005) reported that variations in the estimated number of species could be due to the behaviour and functional aspects of various estimators.

The present study concludes that a combination of methods may be suitable to study the reptile community in general and dry deciduous forest in particular.

3.6. SUMMARY

- Various area (quadrat, transect, Road) and time (VES) constrained sampling techniques were used and compared in the present study for data quantification during January 2003-December 2004.
- Barring turtles, a total of 800 individuals of reptiles belonging to 44 species were recorded during the sampling. Transects yielded the highest (305 individuals) followed by VES (271) and Quadrat sampling yielded the lowest number (90) of reptiles among the methods used for sampling.
- Road cruising yielded maximum of 33 species followed by VES (25 species) and minimum (10 species) in Quadrat sampling.
- The study reveals that VES and Road cruising are suitable for sampling reptiles inhabiting dry forests.
- Maximum 5.4 reptiles/ha and minimum 0.50/ha were observed in Quadrat and Road cruising respectively. Density of reptiles with respect to number of species observed in each method resulted in the highest of 0.59 species/ha in Quadrat.
- Among various estimators used, Jackknife yielded maximum species. This estimator may be suitable for assessing number of species, where the community is speciose. Variations among different estimators with respect to methods could be due to the behaviour of species and functions of each estimator.

CHAPTER - IV
POPULATION

4.1. INTRODUCTION

Population may be defined as a group of organisms of the same species, which live together in one geographical area in the same time (Odum, 1971; Yablokov, 1986; Chapman and Reiss, 2000). Population ecology focuses on the multi species patterns such as species richness, relative abundance, absolute and relative density, sex ratio and juvenile adult ratio. Major factors that determine species richness of an area include physical (geographic position, productivity, and climate) and biological (predation and competition) factors (Odum, 1971). The count of species at a given site or species richness is the simplest means of expressing species diversity. Comparative studies over broad geographic scales reveal that the species richness of Herpetofauna varies greatly from place to place (Pough *et al.* 1998) and may be correlated with factors such as altitude, climate and resource availability (Schall and Pianka, 1977). It has been observed that the species richness of lizards is positively correlated with mean sunshine and negatively correlated with mean annual precipitation, whereas species richness of snakes is positively correlated with both annual rainfall and mean temperature (Pough *et al.* 1998).

Data generated from population studies on reptiles may be useful to develop conservation and management plans for an area as these species are highly parochial and depend on local resources (Whiting *et al.* 1997). Population studies on the herpetofauna are urgently needed, as our knowledge of vertebrate population ecology is largely based on studies on fish, birds and mammals (Turner, 1960), which is true for India as well. Aspects of population of the reptiles of Mundanthurai Kalakad Tiger Reserve and Upper Nilgiris of Western Ghats are available (Ishwar *et al.* 2001, 2003; Nixon, 2005). Species diversity and relative abundance of Agamid lizards of this hill range is also available (Bhupathy and Kannan, 1997).

The present chapter deals with aspects of population such as species richness, diversity, relative abundance and size structure of selected species of reptiles observed in Anaikatty Hills, Western Ghats.

4.2. METHODOLOGY

The fieldwork was conducted from June 2002 to December 2005. Data collected for two years (January 2003 to December 2004) were considered for comparison and analysis. Field sampling was done on fortnightly basis and two persons were involved in every sampling. Various field methods, Quadrat, Transects, Visual Encounter Survey (VES) and Road cruising have been used for data collection. Descriptions on sampling methods are presented in Chapter III.

Relative abundance of lizards and snakes were calculated using data generated from all methods (Quadrat, Transect, VES and Road Cruising) during January 2003 to December 2004. Linear measurements such as snout-vent length (SVL) were taken using a metal scale (accuracy 1mm) in the case of lizards, and a nylon thread or flexible measuring tape for snakes. SVL of each species was classified into various size classes. Species with more than 15 observations were considered for this analysis. Data on morphometry taken all through this study (June 2002 to December 2005) including opportunistic observations were considered for analysis.

4.2.1. Data Analyses

The following analyses were done,

1) Various estimators were used to know the reptile species richness of the area, and descriptions of estimators and their limitations are described in Chapter III, Sampling technique.

2) Species Diversity

   Shannon-Wiener, Hill's diversity and Equitability indices were used to estimate generic and species diversity of the reptiles of the area.

(i) Shannon-Wiener Index (H')

$$H' = -\sum_{i-1}^{s} p_i \log_e p_i$$

$\log e \; p_i$ = ni / N,

where, H' = Diversity,

S = Number of species,

p_i = the proportion of individuals of the total sample belonging to the i' th species.

$\log e \; p_i$ = Natural log of p_i

(ii) Hill's diversity (N_1)

$$N_1 = e^{H'}$$

where,

H′ = Shannon- Wiener species diversity

(iii) Equitability or evenness J

$$J = H / \log (S)$$

where,

H′ = the observed Shannon-Wiener index,

Log (S) = maximum value

S = total number of species in the habitat

II) Relative Abundance

$$\text{Relative abundance} = \frac{\text{Number of observations of a species}}{\text{total observation of all species}} \times 100$$

Number of species obtained from fortnightly data based on all methods clumped together was analysed for estimating overall species richness of the area. Apart from the overall estimate of species richness, the estimated species richness with respect to each method was also calculated. This provided indication on the efficiency of sampling techniques used in the present study.

4.3. RESULTS

4.3.1. Taxonomic Diversity

Taxonomic diversity may provide information on the richness at various levels such as Family, Genus and Species of a particular taxon such as reptiles in the present context. Including turtles, overall 842 reptiles belonging to 12 families, 32 genera and 45 species were recorded during January 2003 to December 2004. This includes one species of freshwater turtle, 11 genera and 18 species of lizards and 20 genera and 26 species of snakes (Figure 4.1). Two new species, one each gecko (*Cnemaspis anaikattiensis*) and snake (*Lycodon flavicollis*) were recorded during this study (Mukherjee *et al.* 2005; Mukherjee and Bhupathy, 2007). Papers published during this study are given in Appendix (IV to VII). Colubridae contributed the maximum number of species 17 (38%) followed by Gekkonidae. Families such as Bataguridae, Chamaeleonidae, Varanidae, Typhlopidae and Uropeltidae were represented each by single species.

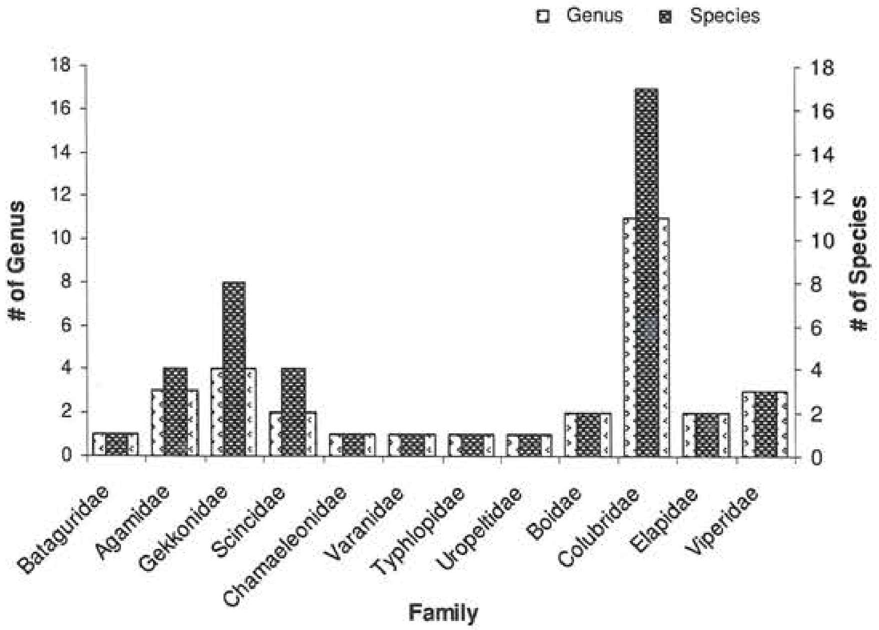


Figure 4.1. Distribution of reptiles at generic and species level in Anaikatty Hills.

4.3.2. Species Richness

As mentioned earlier, including inventory a total of 58 species of reptiles were observed during June 2002 to December 2005, whereas a total of 45 species were recorded using various methods. Overall, the accumulation curve attained only partial asymptote, which indicates more efforts yielding higher number of species (Figure 4.2).

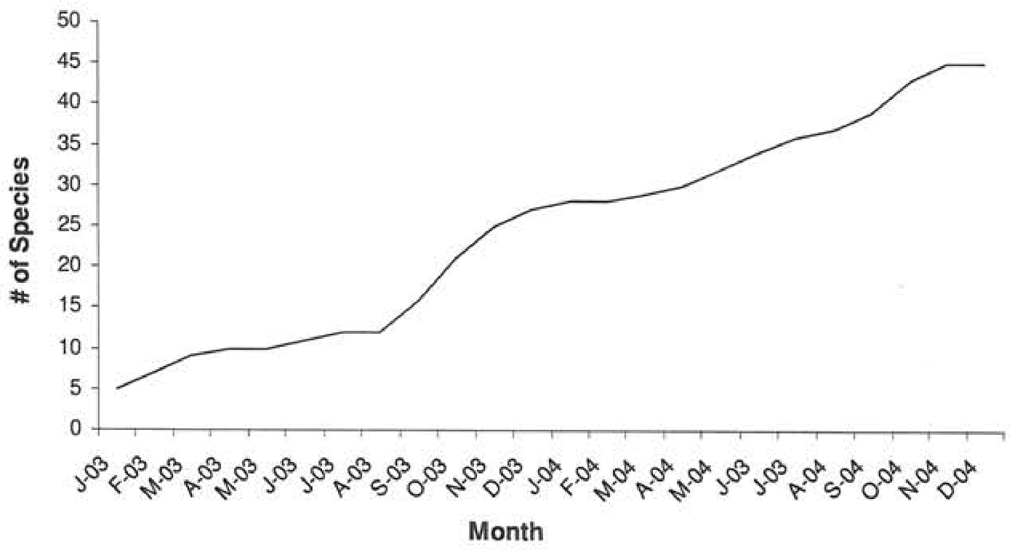


Figure 4.2. Cumulative species accumulation pattern of reptiles based on various sampling methods in Anaikatty Hills.

Among various estimators used to find out the species richness of the area, the Jackknife-2 yielded the highest of 59 species followed by Jackknife-1. Minimum of 37 species was estimated by Cole-rarefaction (Table 4.1). Among all estimators, Jackknife 1 and 2, Chao 2 yielded more species compared to number of species actually observed during this study. Estimators such as Chao yielded almost closer to the observed number of species. Estimators such as Bootstrap and Cole-rarefaction underestimated the number of species occurred in the area (Table 4.1). It is to be noted that overall observed and estimated species richness is almost closer.

Table 4.1. Estimated species richness of reptiles in Anaikatty Hills using various statistical estimators based on monthly data from January 2003 to December 2004.

Estimators (mean)	No. of species
Overall observed species richness	58
No. of species observed in methods	45
Chao1	46.5
Chao2	48.8
Jackknife 1	52
Jackknife 2	59
Bootstrap	43.6
Cole-rarefaction	37

4.3.3. Diversity

The calculated reptile species diversity of Anaikatty Hills using various indices is given in Table 4.2. The pattern of overall species diversity (turtle, lizard and snake), and lizard and snake diversity using Shannon Wiener, Hills and Equitability indices showed almost similar trend. For instance Shannon Wiener index (H') and Hill's diversity with respect to overall reptile species, lizard and snake species diversity was 2.32, 1.85 and 2.71 and 10.26, 6.39 and 15.17 respectively. It is observed that in all cases diversity of snakes were higher than lizards (Table 4.2).

Table 4.2. Reptile species diversity of Anaikatty Hills, Western Ghats.

Diversity Index	Lizard	Snake	Overall
Richness	18	26	45
Shannon Wiener	1.85	2.71	2.32
Hill's Diversity	6.39	15.17	10.26
Equitability	0.65	0.83	0.62

4.3.4. Relative Abundance

Relative abundance may provide an idea on the number of common or rare species in the community. The relative abundance of 18 species of lizards and 26 species of snakes are given in Table 4.3 and 4.4. Analysis showed that relative abundance of lizards was higher 85%, than snakes (9.7%) and turtles (4.9%; Figure 4.3 a).

Among the various lizards, relative abundance of Agamids was the highest (45%) and Varanids contributed the lowest (1.1%; Figure 4.3 b). The order of sequence with respect to relative abundance of various lizard taxa is as follows: Agamidae >Gekkonidae > Scincidae > Chamaeleonidae > Varanidae.

Among snakes, the highest relative abundance (47.5%) was obtained by Colubridae (Figure 4.3 c) and lowest by Elapidae (4%). Barring Colubridae and Uropeltidae, other families relatively contributed low relative abundance of snake families in the order of Colubridae > Uropeltidae > Boidae > Typhlopidae > Viperidae > Elapidae.

Relative abundance of the lizards at species level showed *Calotes versicolor* contributed highest (39.9%) and lowest (0.28%) by *Calotes calotes* and *Hemidactylus leschenaultii* (Table 4.3). The relative abundance of species such as *Mabuya carinata* and *Cnemaspis mysoriensis* was over 10%, whereas several species such as *Geckoella collegalensis*, *Hemidactylus triedrus*, *Hemidactylus maculatus*, *Hemiphyllodactylus aurantiacus*, *Chamaeleo zeylanicus* and *Varanus bengalensis* was more than 1%, but lower than 5%. Relative abundance of species such as *Mabuya macularia*, *Lygosoma punctata* and *Hemidactylus leschenaultii* was lower than 1%. (Table 4.3).

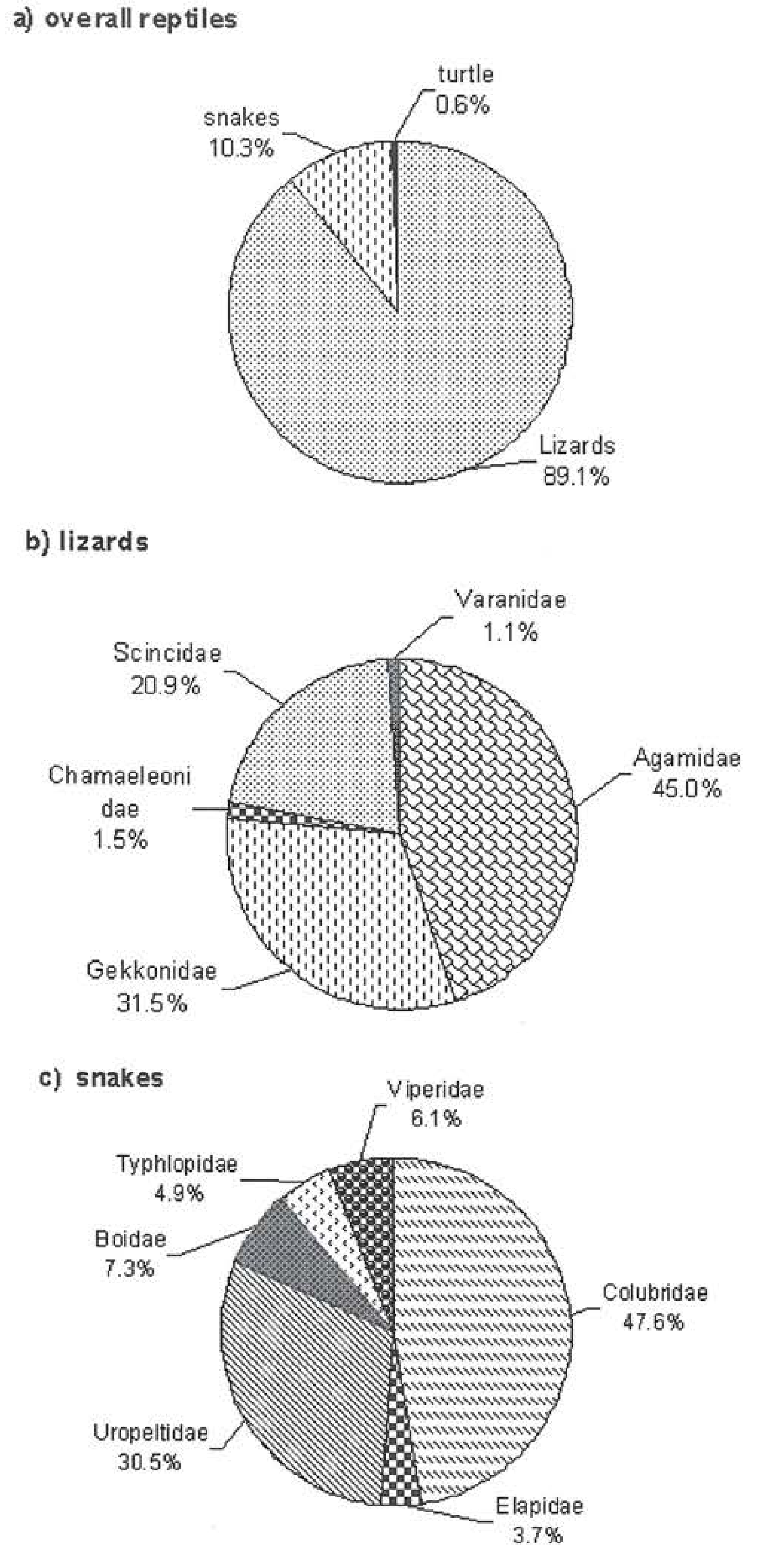


Figure 4.3. Relative abundance of various reptiles in Anaikatty Hills.

Among 26 species of snakes observed in the Anaikatty Hills, relative abundance of *Uropeltis ellioti* was the highest (30.4%), whereas as many as 10 species had the lowest value (1.2%). Other than *Uropeltis ellioti* only one species, *Liopeltis calamaria*, had relative abundance over 5% (Table 4.4). Relative abundances of many species of snakes were low compared to lizards. Photographs of some common snakes and lizards are given in Plate 2, 3 and 4.

Table 4.3. Relative abundance of lizard species observed in Anaikatty Hills during 2002-05 (n= 718).

Sl No	Family	Species	Frequency	% Relative abundance
1	Agamidae	*Sitana ponticeriana*	27	3.76
2		*Calotes calotes*	2	0.28
3		*Calotes versicolor*	287	39.97
4		*Psammophilus blanfordanus*	7	0.97
5	Scincidae	*Mabuya carinata*	123	17.13
6		*Mabuya bibronii*	18	2.51
7		*Mabuya beddomei*	1	0.14
8		*Mabuya macularia*	5	0.70
9		*Lygosoma punctata*	3	0.42
10	Gekkonidae	*Cnemaspis mysoriensis*	119	16.57
11		*Geckoella collegalensis*	9	1.25
12		*Hemidactylus triedrus*	20	2.79
13		*Hemidactylus maculatus*	10	1.39
14		*Hemidactylus Leschenaultia*	2	0.28
15		*Hemidactylus frenatus*	45	6.27
16		*Hemiphyllodactylus Aurantiacus*	21	2.92
17	Chamaeleonidae	*Chamaeleo zeylanicus*	11	1.53
18	Varanidae	*Varanus bengalensis*	8	1.11
Total			718	100

Table 4.4. Relative abundance of the snake species observed in Anaikatty Hills during 2003-2004 (n= 82).

No	Family	Species	Frequency	% Relative abundance
1	Typhlopidae	*Ramphotyphlops braminus*	4	4.87
2	Uropeltidae	*Uropeltis ellioti*	25	30.48
3	Boidae	*Python molurus*	4	4.87
4		*Eryx johnii*	2	2.43
5	Colubridae	*Ahaetulla nasuta*	4	4.87
6		*Ahaetulla pulverulenta*	1	1.21
7		*Argyrogena fasciolatus*	2	2.43
8		*Coelognathus helena*	4	4.87
9		*Boiga trigonata*	1	1.21
10		*Boiga nuchalis*	1	1.21
11		*Boiga forsteni*	1	1.21
12		*Boiga beddomei*	1	1.21
13		*Dendrelaphis tristis*	2	2.43
14		*Dryocalamus nympha*	2	2.43
15		*Lycodon flavicollis*	2	2.43
16		*Lycodon aulicus*	3	3.65
17		*Lycodon travancoricum*	1	1.21
18		*Liopeltis calamaria*	6	7.31
19		*Oligodon taeniolatus*	2	2.43
20		*Ptyas mucosus*	4	4.87
21		*Xenochrophis piscator*	2	2.43
22	Elapidae	*Naja naja*	1	1.21
23		*Bungarus caeruleus*	2	2.43
24	Viperidae	*Daboia russelii*	1	1.21
25		*Echis carinatus*	3	3.65
26		*Hypnale hypnale*	1	1.21
Total			82	100

4.3.5. Size Structure

Maximum, minimum and mean SVL of all reptile species observed in Anaikatty Hills is given in Appendix II and III. Measurements of black turtle *Melanochelys trijuga* were excluded from analysis. Among lizards the smallest species was *Cnemaspis mysoriensis* and the largest was *Varanus bengalensis*, and in snakes it was *Ramphotyphlops braminus* and *Python molurus* respectively.

Three patterns of size structures were observed; (1) Unimodal, right skewed/bell shaped/left skewed (2) Bimodal (two peaks) and (3) No pattern, uniform distribution.

Various patterns of size structure were observed in lizards. Lizard species largely showed unimodal (Figure 4.4-4.5) and bimodal patterns (Figure 4.6a). Species such as *Calotes versicolor*, *Chamaeleo zeylanicus*, *Cnemaspis mysoriensis*, *Geckoella collegalensis* and *Hemidactylus triedrus* showed unimodal distribution pattern. The unimodal right skewed pattern was found in *Calotes versicolor*, *Chamaeleo zeylanicus* and *Geckoella collegalensis*. *Hemidactylus triedrus* showed unimodal left skewed pattern and *Cnemaspis mysoriensis* showed typical (bell shaped) unimodel. However, species such as *Mabuya carinata* showed a bimodal pattern and *Varanus bengalensis* showed no pattern (Figure 4.4-4.6).

Most of the common snake species in the Anaikatty Hills showed unimodal pattern. *Echis carinatus* showed a typical (bell shaped) unimodal pattern. *Ahaetulla nasuta* and *Uropeltis ellioti* showed unimodal left skewed pattern and *Oligodon taeniolatus* the right skewed pattern (Figure 4.7). *Dendrelaphis tristis* showed bimodal pattern.

The graphical representation of all the above-mentioned species is given below.

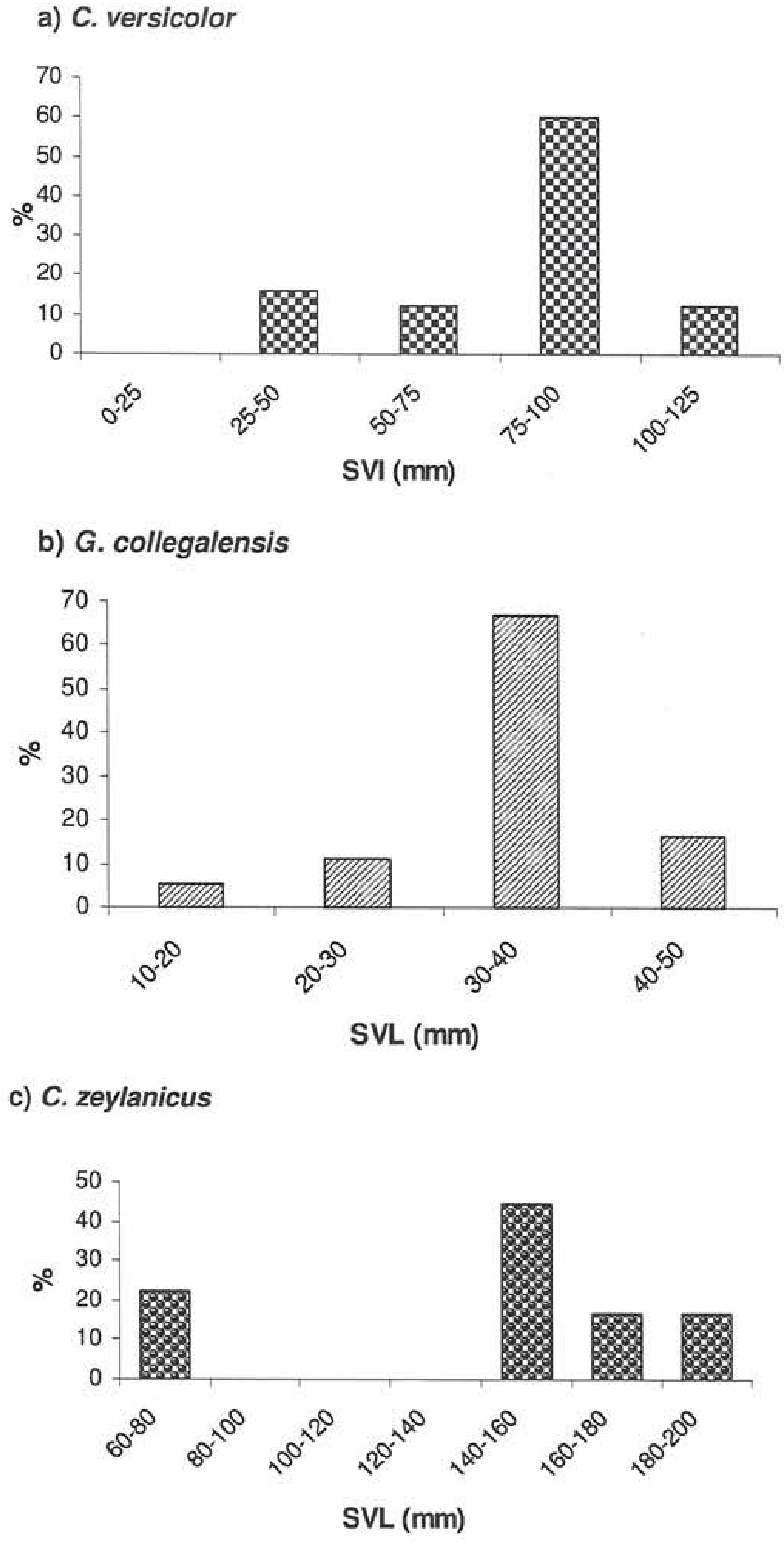
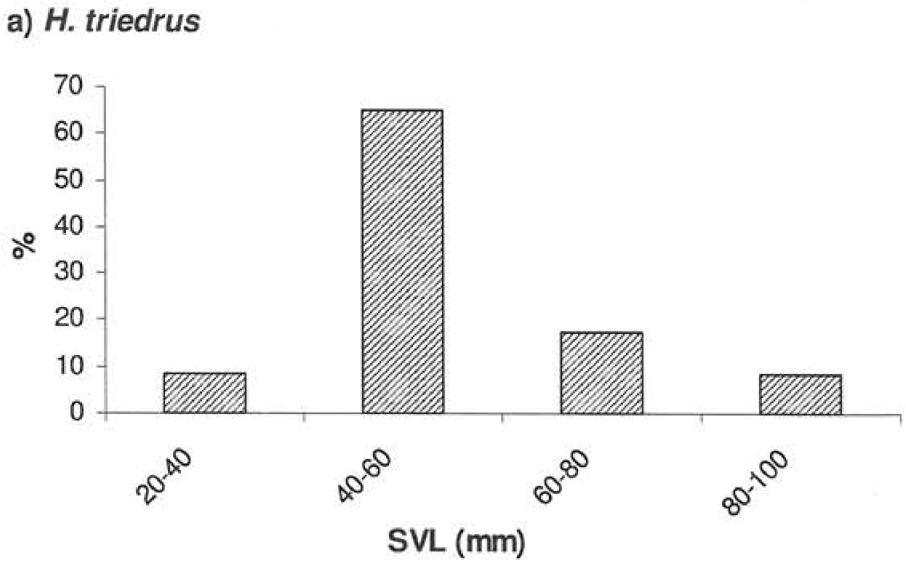


Figure 4.4. Size structure of lizards; (a,c) unimodel right skewed, (b) typical (bell shaped) unimodel patterns in Anaikatty Hills.



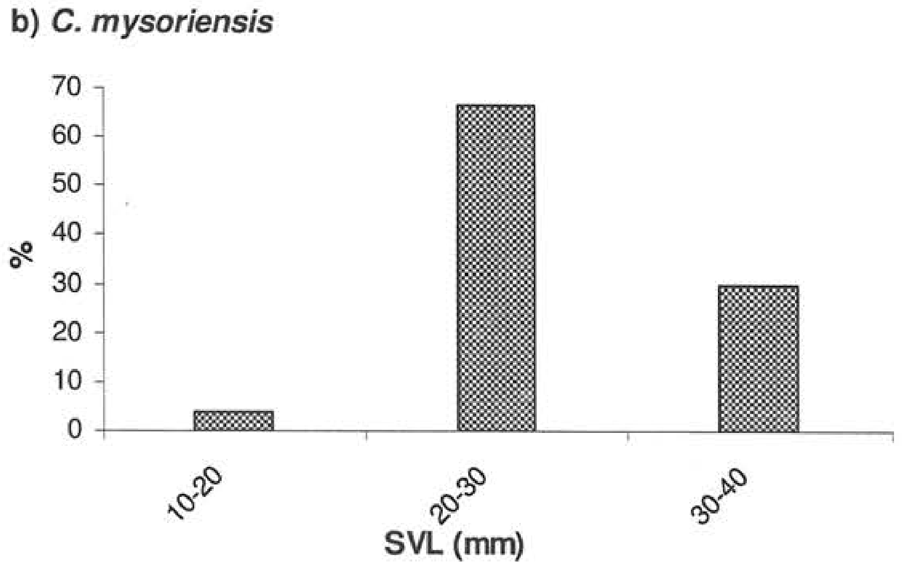
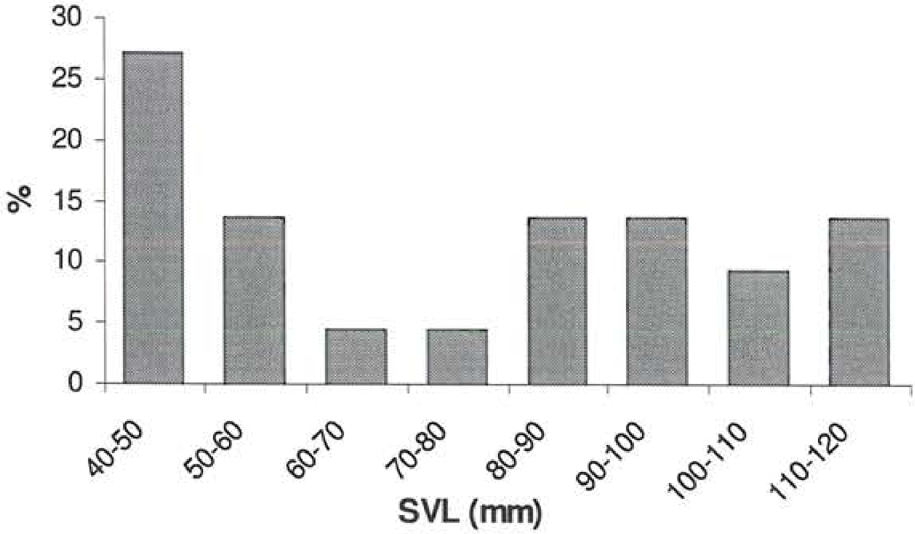


Figure 4.5. Size structure of lizards; (a) unimodel left skewed and (b) typical unimodel pattern.

a) *M. carinata*



b) *V. bengalensis*

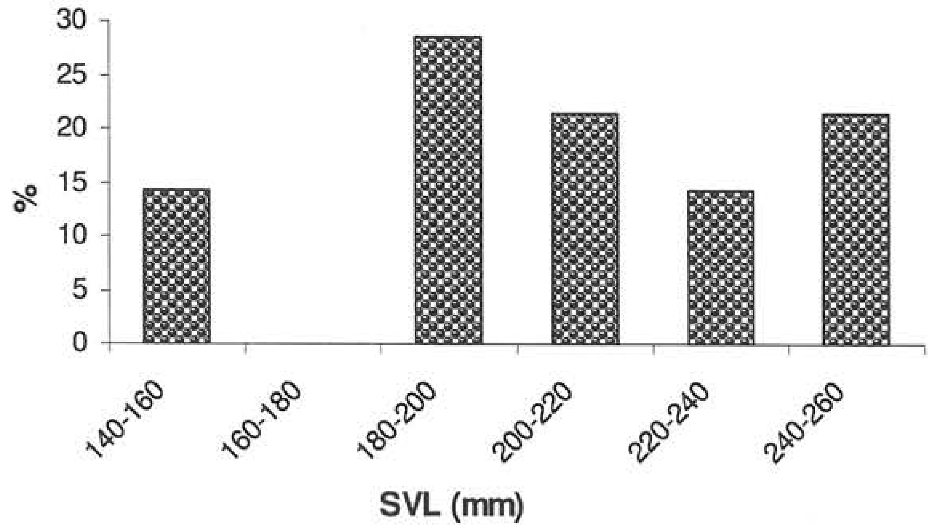


Figure 4.6. Size structure of lizards; (a) bimodal left skewed and (b) no distinct pattern.

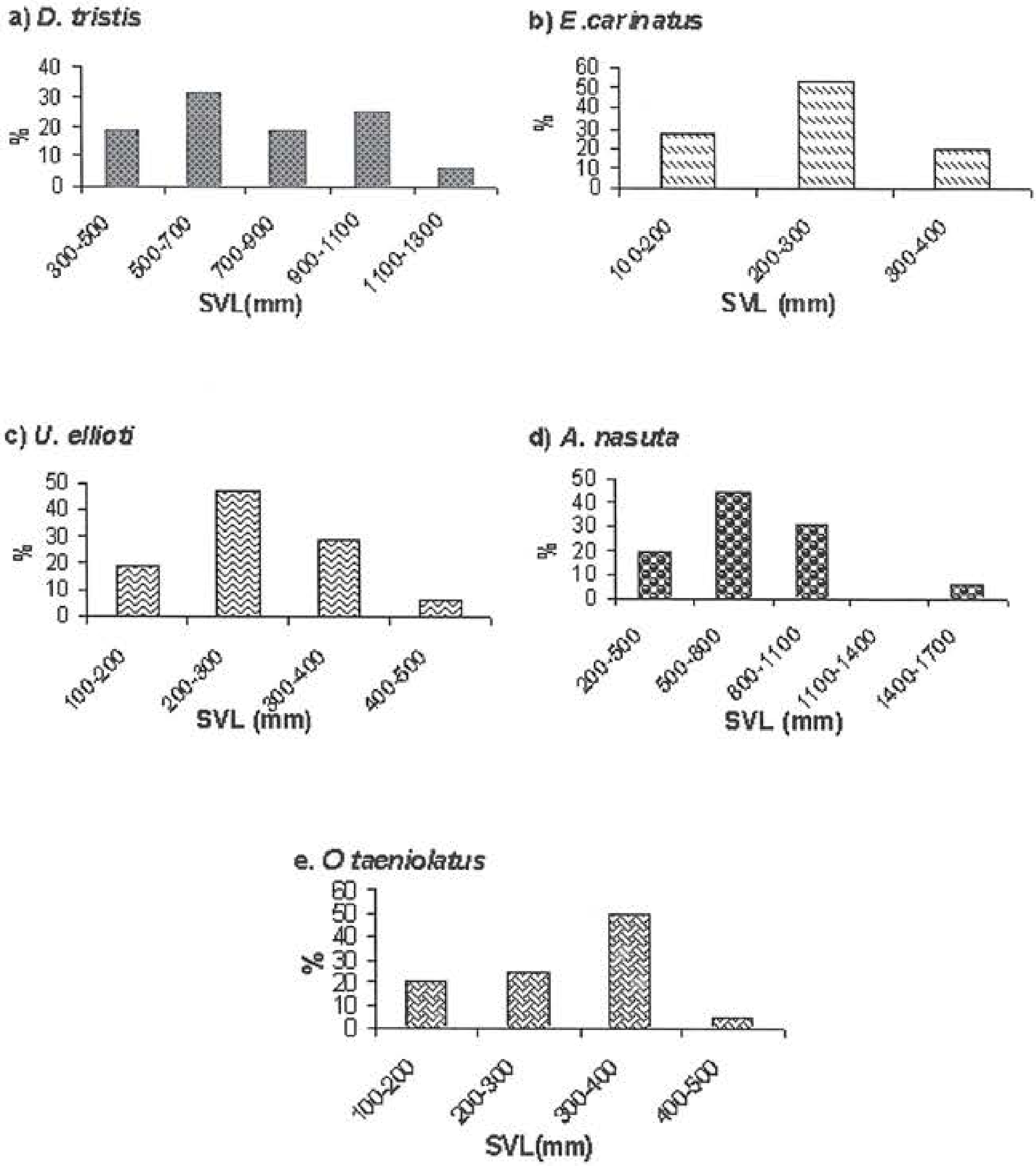


Figure 4.7. Size structure of snakes; (a) bimodel, (b) typical unimodel, (c) unimodel skewed, (d) unimodel left and (e) unimodel right skewed pattern.

4.4. DISCUSSION

A total of 506 species of reptiles were reported to occur within the political boundary of India (Das, 2003). In the Western Ghats 165 species were recorded (Das, 1996), which is about 32.6% of the Indian reptile fauna. This is high when the area of this hill range is considered (also see Study Area; Chapter II).

The higher diversity of the reptiles in the Western Ghats is due to its unique location, heterogeneous habitats and allopatric isolation. The geographic separation among the isolated hills with deep valleys in several places of Western Ghats has increased the diversity and rate of speciation among amphibians and reptiles (Inger *et al.* 1987). Regional endemism in the montane islands may be another important aspect of the high level of diversity in the Western Ghats. Das (1996) reported that 53.3% reptile species of the Western Ghats showed endemism.

During the present study, 58 species of reptiles were observed (Appendix I), which is 9% of Indian and 21.6% Western Ghats reptile fauna. Habitat heterogeneity, availability of various microhabitats, local climatic variation and location of the study area in close vicinity to the Eastern Ghats could be reasons for the higher species diversity. The present study is the first authentic study available on the reptiles of dry forests of the Western Ghats, which has long been ignored in research and management.

In the Eastern Ghats 90 species of reptiles were reported (Murthy, 1990; Daniels, 1994), which is about 18% reptile species reported from India. Among them, 30 species (33.3%) occur in the Anaikatty Hills. The high species overlap between the present study area and Eastern Ghats is probably because of the closeness in geographic location, similarity in climatic conditions and topography. The Anaikatty Hills are located between the eastern slope of the Western and Eastern Ghats.

Excluding marine taxa, 150 species of reptiles were reported from Tamil Nadu state (containing parts of Eastern Ghats and Western Ghats). Reptile species that occur in the Anaikatty Hills comprises 39% of the fauna found in Tamil Nadu (Bhupathy, 2004). Reptile species richness of Anaikatty is much higher than the reported figure that occurred in the Kerala part of Nilgiri Biosphere Reserve mainly Wayanad, Nilambur Reserve Forest, Muthikkulam and Silent valley National Park (Easa, 1998; Whitaker and Martin 1998). The lower number of species reported there could be due to incomplete surveys in the above areas. Moreover most of these areas have different habitats as well.

Study on the population ecology of the reptiles in the Upper Nilgiris, Western Ghats (elevation 2556 m, Southern Montane Wet Temperate Forest) by Nixon (2005) revealed only eleven species (four species of lizards and seven species of snakes). Among them, eight species (73%) were endemic to Western Ghats. In comparison, Anaikatty Hills harbours only two endemic newly described taxa *Cnemaspis anaikattiensis* and *Lycodon flavicollis* (Mukherjee *et al.* 2005; Mukherjee and Bhupathy, 2007). Dry eastern slope connecting the plains and Eastern Ghats could be reasons for this poor number of endemic species.

The most important factor regarding variation of species richness in the Upper Nilgiris (11 species) and the Anaikatty Hills (58 species) was probably because of difference in altitude in these study areas (2000-2500 m in Upper Nilgiris and 600 m in Anaikatty Hills) and resultant cimatic difference. It has been reported that the number of reptile species tends to decrease with increasing altitude (Dobzhansky, 1950). Factors such as colder climatic condition, poor availability of the microhabitats and geometric constraints might have restricted reptile species richness in the Upper Nilgiris (Nixon, 2005). Lower number of reptile species in the colder and higher altitude regions has been reported (Raxworthy *et al.* 1997; Vazquez and Girnish, 1998).

Palmer (1991) evaluated the first and second order Jackknife and the Bootstrap estimators and reported that Jackknife estimators performed better than Bootstrap. In the present study a total of 45 species were observed from the regular sampling, while maximum 59 species were estimated by using Jackknife-2 estimator. Records including various opportunistic observations contributed 58 species from the Anaikatty Hills and which invariably confirm the efficacy of second order Jackknife estimator.

First and second order Jackknife resulted in better estimate compared to other estimators such as Bootstrap, first and second order Chao or rarefaction. This may be because of higher species richness in the present study area. In comparison Nixon (2005) stated that Bootstrap, rarefaction and Chao gave better results in Upper Bhavani than Jackknife, and reported that it is due to low number of species in the community of the Upper Bhavani.

It is generally assumed that high species diversity in the tropics is associated with habitat complexity (Das and De Silva, 1998). Different diversity indices can provide information about species number, relative abundance and evenness in various ways. Magurran (1988) stated that although various diversity indices may be of limited use but it may be helpful in comparing two communities or the same community over time. In the present study Shannon-Wiener and Hill's indices yielded 2.32 and 10.26 respectively compared to 1.24 and 3.5 in Upper Nilgiris (Nixon, 2005). The higher diversity values by both the indices show that Anaikatty Hills have higher reptile diversity compared to the Upper Bhavani, Western Ghats.

Higher diversity Index yielded for snakes may be because of several reasons such as snakes were comparatively more diverse compared to lizards in the present study area. Among lizards, a few species were common and contributed more to the community. In the case of snakes, many species were rare, which resulted in unequal contribution by many species. This could have resulted in higher diversity value in snakes compared to lizards.

An understanding of the abundance of organisms is important to understand their ecology. Many studies regarding population density estimates are unrepresentative since they were obtained from study areas chosen for the high abundance of the target species (Rodda *et al.* 2001). Among snakes, Colubridae contributed the highest (47.5%) relative abundance. In the case of lizards, Agamids contributed the most (45%). Highest overall relative abundance in the case of Colubrids is largely because of the speciose nature of this taxon. Parker and Plummer (1987) reported that suitable habitat may yield higher abundance of some species, whereas in snakes relative abundance is mainly associated with rapid habitat succession (Fitch, 1982; Plummer, 1997). Both the factors may cause higher relative abundance in taxon such as Agamids (Pough *et al.* 1998).

The study on the population ecology of reptiles in the Upper Nilgiris, Western Ghats by Nixon (2005) showed that relative abundance of snakes was low compared to lizards. A similar result was obtained in the present study, where lizards contributed higher proportion of relative abundance. The rarity of the snake species can be attributed to low population density and relatively extensive and irregular movements of some species (Parker and Plummer, 1987). Reynolds (1982) reported that activity of snakes largely depend on the rainfall patterns, which can affect their relative abundance. Findings pertaining to *Uropeltis ellioti* in the present study augment this view. Lillywhite and Henderson (1993) reported that arboreal snakes might be relatively more abundant than terrestrial species. However, the present study yielded contradictory result, and this could be mainly because of scanty tree cover in the Anaikatty Hills, as the area is largely covered with degraded forests.

Smaller body size and secretive behaviour of many reptiles made the study on population ecology difficult (Turner, 1977). Reproductive maturity and fecundity are probably related to size rather than age in many reptile species (Andrews, 1982). Size structure (SVL) gives important information on the reproduction rate, mortality and the rate of generation replacement (Vitt, 1987; Shine 1994; Shine *et al.* 1999).

In the present study, in general the proportion of smaller sized individuals (juveniles) was low in almost all common species. Odum (1971) further reported that a declining population might show a large proportion of old individuals. It is not clear whether the unimodel right skewed size structure of *Chamaeleo zeylanicus* and *Geckoella collegalensis* indicates this. Poor representation of juveniles could be due to higher predation on them and camouflaging body colours and size, which might have escaped from observation.

Most studies reported unimodal right skewed size structure; however, reasons for middle peak (unimodal pattern) in some species could be largely due to higher predation in both juveniles and adults (Brown, 1995; Dixon *et al.* 1995; Bakker and Kelt, 2000; Etienne and Olft, 2004).

Lillywhite and Henderson (1993) suggested that relative to the terrestrial species arboreal snakes may be limited largely by access to sites providing refuge and therefore, may be more exposed to potential hazards such as predation and fire. Rarity of large (older) individuals of *Ahaetulla nasuta* and *Dendrelaphis tristis* in the present study may be due to the scarcity of refuge in the ecosystem. Houston and Shine (1994) reported a high proportion of immature file snake (*Acrochordus arafurae*) in Australia, which showed a high reproductive output. In the present study bimodal size structure in *Dendrelaphis tristis* and unimodal structure (left sqkeued) in *Echis carinatus* had higher number of young individuals, which is similar to the observation by Houston and Shine (1994). *Protobothrops strigatus* showed bimodal distribution of individuals (Nixon, 2005). The unimodel right skewed pattern favouring adults was observed in *Oligodon taeniolatus*. This may be due to the high predation or dispersal of juveniles. A similar trend was observed by Chettri (Pers. Comm.) in case of a fossorial Colubrid *Trachischium guentheri* in Sikkim. Pough *et al.* (1998) reported that juveniles tend to disperse often immediately after hatching, which may be due to competition for limited resources. Colbert *et al.* (1994) reported that cost of dispersal includes increased expenditure of energy and high predation.

4.5. SUMMARY

- Including opportunistic observations, a total of 58 reptile species (one species of freshwater turtle, 24 lizards and 33 snakes) were recorded from the Anaikatty Hills. However, only 45 species were recorded during January 2003 – December 2004 during regular sampling.
- Jackknife 2 yielded the highest estimated number of species (59). This estimator may be suitable for assessing number of species present in the area or a similar habitat with higher number species in the community.
- Various diversity indices showed almost similar trend. Snakes were more diverse compared to lizards.
- Agamids contributed the maximum relative abundance with respect to lizards and Colubrids with respect to snakes.
- Many patterns of size structure in reptiles were observed in the Anaikatty Hills, and reasons for the same are discussed.
- The discovery of two new species from the Anaikatty Hills adds on to the conservation value of this area.

CHAPTER - V
SPATIO-TEMPORAL RELATIONS

5.1. INTRODUCTION

Habitat can be defined as the locality, site or particular type of local environment occupied by an organism (MacArthur, 1972). Studies on the habitat utilization give an idea how organisms use an area, preference and role of the habitat in species survival and interrelationships. These informations are useful for preparing species conservation and management plans (Bright and Morris, 1990; Beauchamp *et al.* 1998). The concept of habitat is independent of species. It is an environment, with its spatial and temporal patterns of varying factors, while microhabitat is the immediate environment of an organism.

The use of space varies widely among species, the differences in microhabitat use are often pronounced. Through microhabitat specificity, various reptile species have specialized in their habitat use (Pianka, 1973). Changes in the microhabitats of an ecosystem influence variation in distribution, abundance and diversity of reptiles (Jones, 1986). The spatial distribution of resource influence patterns in habitat use by a species, as resources are spatially and temporally heterogeneous (Mills *et al.* 1995). Toft (1985) reported that most herpetofauna first partition habitats as primary resource, and as ectotherms much of their ecology and behaviour is limited by physical environments (Brattstrom, 1974).

Reinert (1993) reported that thermoregulation could be one of the most proximate factors, which influences habitat selection in terrestrial Squamates; although Shine and Madsen (1996) stated that it could be applicable only in temperate conditions. Differential habitat selection by various species allows them to coexist (MacArthur and Pianka, 1966; Rosenzweig, 1981). Microclimates, food, shelter and predators all vary spatially and provide opportunities for resource partitioning and hence, niche differentiation between potentially competing species (Schoener, 1974).

Temporal segregation in activities among various species of reptiles can be explained as being active at different times, which may lead to exploitation of different resources and reduce competition among sympatric species. This presumably allows more species to coexist in a community (Pianka, 1973). Variation in feeding and breeding time may help avoiding competition in resource partitioning. By changing the time of emergence of hatchlings, various species may save their offspring from predation, competition with other species for food and shelter.

The most conspicuous temporal segregation is perhaps dichotomy of daily activity patterns (diurnal and nocturnal) in various species (Pianka, 1973). Pianka (1973) further reported a gradual sequential replacement of lizard species during day hours in various lizard communities of American, Australian and African deserts. Another more subtle temporal use can be explained as seasonal patterns of activity or emergence of hatchling among various species. Cowles and Bogert (1944) reported that thermal relations of active lizards vary widely among species and are profoundly influenced by their temporal and spatial patterns of activity.

This Chapter deals with the spatio-temporal use by various reptiles in Anaikatty Hills. Among various parameters, only a few aspects such as microhabitat and vertical distribution (in spatial) and monthly activity based on number of observations (temporal) were considered in the present study.

5.2. METHODOLOGY

Data collected based on monthly sampling from June 2002 to December 2005, data from Transect, Visual Encounter Survey (VES) and Quadrat were considered for analysis. In the case of Road cruising and opportunistic observations, information on microhabitats and vertical distribution of only live reptiles were considered. A description of sampling techniques is given in Chapter III.

On locating a reptile, description on the microhabitat and vertical position were recorded. The descriptive microhabitat information was later clumped into the following nine categories; (1) Boulder (2) Rock (3) Crevice (4) Forest floor, ground (5) Termite hill (6) Tree (7) Shrub (8) Artificial structure and (9) Water. The artificial structures included man-made structures such as buildings and electric posts.

Location of the reptile from ground, when first sighted was considered as its vertical position. The recorded vertical positions of the reptiles were grouped into various categories; 0, 0-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm and > 300 cm. Observations on monthly basis was considered for analysis pertaining to temporal pattern among various reptile species.

5.2.1. Data Analyses

i) Microhabitat associations of various lizard and snake families were explored using One-way analysis of variance (ANOVA) (Zar, 1999). Since data set for most of the species ranged within 0-5; data was transformed into square roots.

ii) Kolmogorov-Smirnov test for goodness of fit was performed to test the hypothesis that both lizards and snakes were distributed uniformly on the Vertical strata (Zar, 1999).

iii) Mann-Whitney U test was carried out to statistically test the difference in monthly activity of lizards and snakes.

iv) Pearson correlations were performed to determine the relationship between different reptile species and various continuous independent variables such as climatic factors (temperature, humidity and rainfall).

5.3. RESULTS

5.3.1. Microhabitat Use

Including opportunistic observations, a total of 1,455 reptiles (1113 lizards, 300 snakes and 42 turtles) were observed. Since turtles were largely associated with a single microhabitat (water body), lizards and snakes were considered for microhabitat analysis. As mentioned earlier (in methods), microhabitats were classified into nine categories.

In the Anaikatty Hills, reptiles largely used forest floor (ground). Maximum number of reptiles (39%) was recorded on forest floor (ground), and minimum (3.2%) under boulders. Trees, rocks and crevices were moderately utilized (Figure 5.1). Water bodies were largely used by the Indian black turtle *Melanochelys trijuga* and Checkered keelback water snake *Xenochrophis piscator*.

Among all lizard Families, Agamids used all eight microhabitats barring puddles followed by Gekkonids (7). Scincids and Chamaeleonids used only a few of them (3).

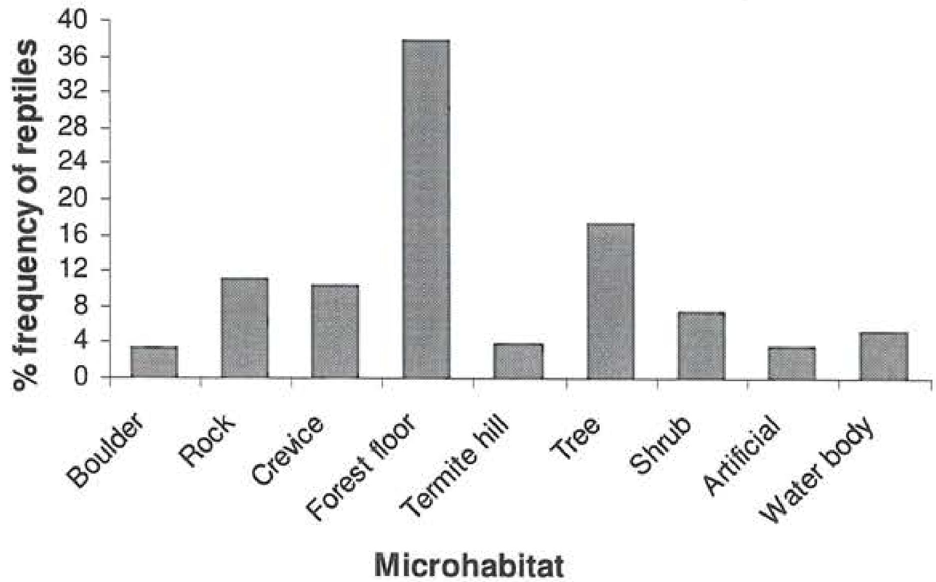


Figure 5.1. Relative abundance (%) of reptiles observed from various microhabitats in Anaikatty Hills.

Lizards at Family level also showed that almost all of them primarily used forest floor. Scincidae, Varanidae and Agamidae predominantly used forest floor boulders, shrubs and artificial structures were occasionally used by lizards (Figure 5.2a, b & c).

Gekkonids predominantly utilized rock crevices (32%) and trees (29%). Geckoes were not found in shrubs and puddle (Figure 5.2a). Scincids largely used forest floor (70.2%), and none inhabited shrubs or puddles (Figure 5.2a). Agamids used almost all microhabitats (Figure 5.2b). Overall, most of them used forest floor (37.4%) followed by tree (26%). Chamaeleonids used only three microhabitats (shrubs 47%, trees 26.7%, forest floor 27%), members of Varanids used four microhabitats; forest floor and termite hills were often used (Figure 5.2c).

Utilization of various microhabitats by lizards showed that forest floor was used by highest number of lizard species (12), followed by tree (11 species). Only two species were found in shrubs and none (barring turtles) in puddles. Among the 12 species of lizards, three exclusively used forest floor. In lizards, at species level, *Calotes versicolor* used the maximum, eight microhabitats. The order of use of microhabitats with respect to number of lizard species is as follows; Forest floor > Tree > Rock> Rock crevices > Under boulder and Artificial > Termite hill > Shrub (Table 5.1).

One way ANOVA showed that only geckoes had partial significance with respect to trees (F= 4.555; df= 9; P = 0.06) (Table 5.2). Other families such as Agamids, Scincids, Chamaeleonids and Varanids did not show any significant relations with any microhabitats. This shows that most of the lizard taxa in the present study were generalist with respect to microhabitat utilization.

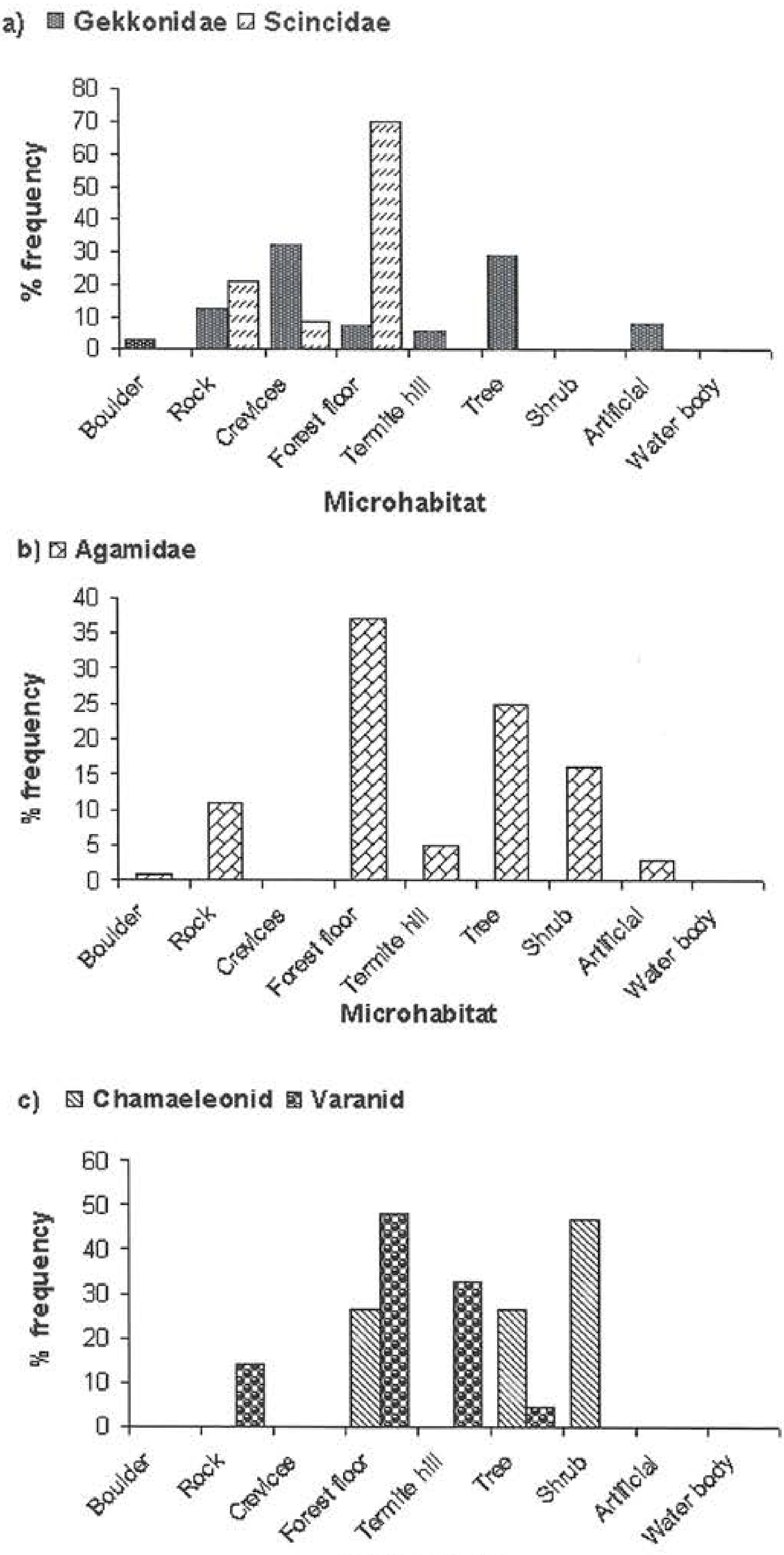


Figure 5.2. Microhabitat use by various lizard taxa, in Anaikatty Hills.

Table 5.1. Microhabitat use (%) by different lizard species in Anaikatty Hills.

Species	Boulder	Rock	Crevices	Forest floor	Termite hill	Tree	Shrub	Artificial structure
GEKKONIDAE								
G. collegalensis	21.4	0	0	78.5	0	0	0	0
C. mysoriensis	3	28	63.1	0	0	6	0	0
H. aurantiacus	20	0	0	33.3	0	46.6	0	0
H. frenatus	0	4.3	6.4	4.3	0	52.6	0	32.2
H. brookii	0	0	0	0	0	100	0	0
H. leschenaultii	0	0	0	0	0	96.5	0	3.4
H. maculates	0	7.1	86	0	0	7.1	0	0
H. triedrus	0	0	0	20	66	8.5	0	6
SCINCIDAE								
M. carinata	0	23.5	10	66.3	0	0	0	0
M. macularia	0	0	0	100	0	0	0	0
M. bibronii	0	0	0	100	0	0	0	0
AGAMIDAE								
C. versicolor	1.4	11.8	0.2	33.2	5	27	18.1	3.3
C. calotes	0	0	0	16.6	0	83.3	0	0
S. ponticeriana	0	0	0	100	0	0	0	0
CHAMAELEONIDAE								
C. zeylanicus	0	0	0	26.6	0	26.6	46.6	0
VARANIDAE								
V. bengalensis	0	14.2	0	47.6	33.3	5	0	0

Table 5.2. Oneway ANOVA showing difference in Microhabitat use by geckoes in Anaikatty Hills.

S. No	Microhabitats	F	P-value
1	Boulder	0.07	0.79
2	Rock	0.63	0.45
3	Forest floor	0.82	0.39
4	Termite hill	0.23	0.64
5	Crevices	0.91	0.37
6	Tree	4.56	0.06
7	Artificial	0.41	0.54

The microhabitat use by snakes showed that members of almost all families were found in open ground (forest floor) such as Uropeltidae, Boidae, Colubridae, Elapidae and Viperidae (Figure 5.3a, b & c). Whereas, Rocks, man-made structures, trees and water bodies harboured a few snake taxa. The Typhlopids were mostly observed under boulder (64.2%) followed by forest floor (35.7%). No study was done opening the forest floor, and hence their subterranean habit is not known in the present area. Boids mostly used forest floor (66.7%) and under boulder 20.8%. Colubrids used 65.5% forest floor (Figure 5.3 a, b). In the present study, Colubrids were relatively less abundant in the microhabitats such as termite hills and artificial structures (2.1%).

One way ANOVA with respect to the microhabitat utilization by snakes showed families such as Typhlopids, Uropeltids and Boids were mostly associated with rocky microhabitats (F= 7.714; df= 7; P= 0.03), whereas Colubrids showed significant values with respect to forest floor (F = 4.473; df= 17; P= 0.05), rocks (F= 20.393; df= 17; P= 0.00), termite mounds (F= 21.441; df= 17; P = 0.00) and trees (F= 18.314; df= 17; P = 0.00) (Table 5.3). Among all Colubrids only *Xenochrophis piscator* showed high significance with respect to puddles (F =17.976; df =17; P= 0.00). The result indicates that most of the snake taxa in Anaikatty were microhabitat specific (Table 5.4).

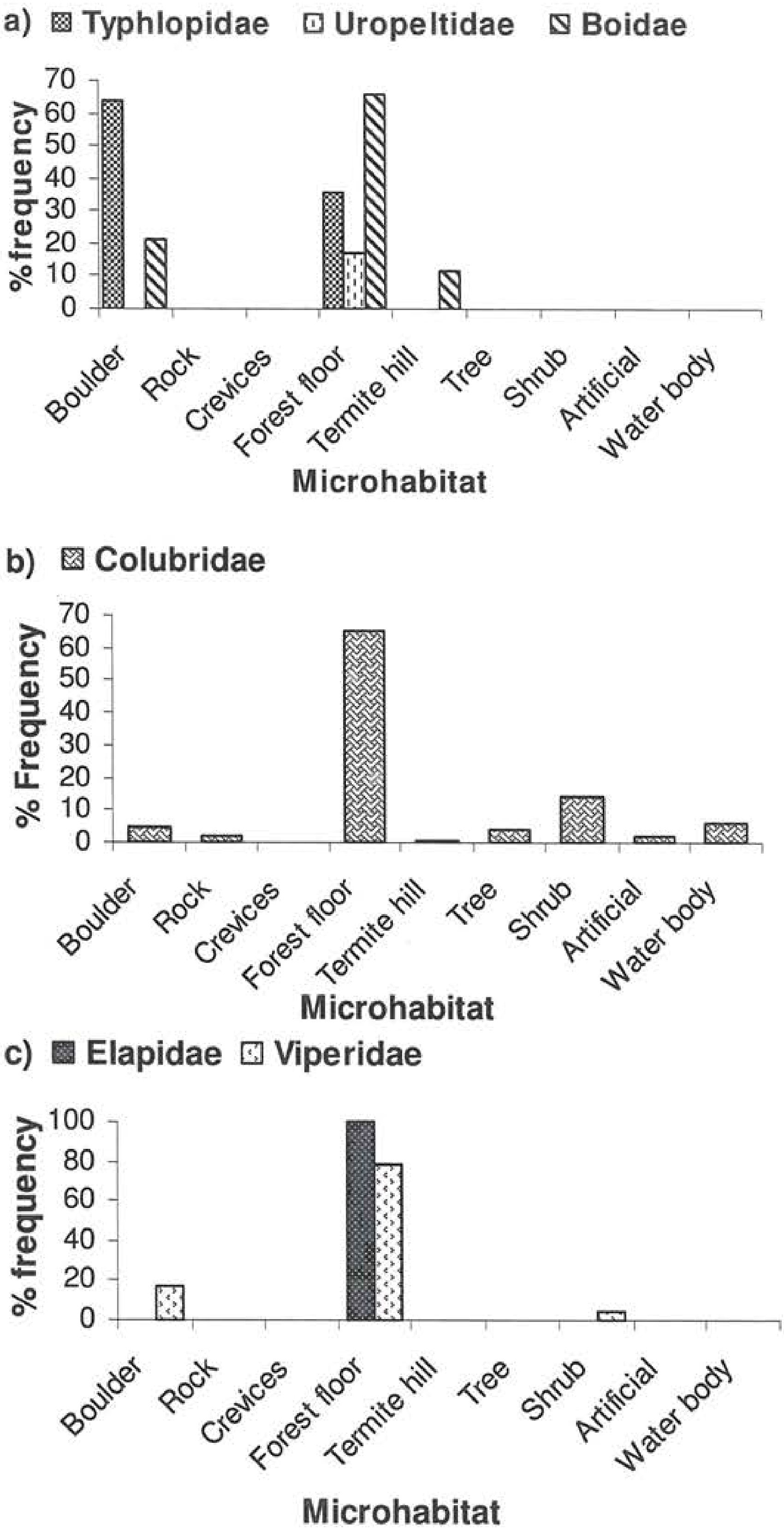


Figure 5.3. Microhabitat use by various snake taxa in Anaikatty Hills.

Table 5.3. Oneway ANOVA showing difference in Microhabitat variables use by Typhlopids, Uropeltids and Boids in Anaikatty Hills.

Microhabitats	F	P-value
Boulder	0.09	0.77
Rock	7.71	0.03
Forest floor	4.92	0.06
Termite hill	4.51	0.07

Table 5.4. Oneway ANOVA showing difference in Microhabitat variables use by Colubrids in Anaikatty Hills.

Microhabitats	F	P-value
Rock	20.39	0.00
Forest floor	4.47	0.05
Termite hill	21.44	0.00
Tree	18.31	0.00
Shrub	3.90	0.06
Puddle	17.98	0.00

Forest floor was used by highest number of snake species (18) followed by boulder (6). No species were found in rock crevices, and one species each was observed on rocks and puddles.

Total of eighteen species of snakes used forest floor, seven of them were exclusively forest floor dwellers. Among all snake species, *Dendrelaphis tristis* used maximum four microhabitats followed by *Ahaetulla nasuta, Boiga trigonata, Lycodon aulicus,* and *Python molurus.* On the other hand, *Xenochrophis piscator* was exclusively found in puddles. The sequence of microhabitat use by snakes is as follows: Forest floor > Boulder > Tree and Shrub > Termite hill > Artificial structure>Rock and Water body (Table 5.5).

Table 5.5. Microhabitat use (in %) by different snake species in Anaikatty Hills.

Species	Boulder	Rock	Crevices	Forest floor	Termite hill	Tree	Shrub	Artificial	Puddle
TYPHLOPIDAE									
R. braminus	64.2	0	0	36	0	0	0	0	0
UROPELTIDAE									
U. ellioti	0	0	0	100	0	0	0	0	0
BOIDAE									
E. johnii	36.3	0	0	45.4	18.1	0	0	0	0
P. molurus	0	0	0	91.6	8.3	0	0	0	0
COLUBRIDAE									
A. nasuta	0	0	0	43	0	7.1	50	0	0
B. forsteni	0	0	0	60	0	0	40	0	0
B. trigonata	0	0	0	50	0	20	30	0	0
D. nympha	80	0	0	0	0	20	0	0	0
D. tristis	0	15	0	35	0	0	40	10	0
C. helena	0	0	0	100	0	0	0	0	0
L. aulicus	20	0	0	60	0	0	0	20	0
L. calamaria	0	0	0	100	0	0	0	0	0
M. plumbicolor	0	0	0	100	0	0	0	0	0
O. taeniolatus	0	0	0	100	0	0	0	0	0
P. molurus	0	0	0	78.5	7.1	14.2	0	0	0
S. subpunctata	50	0	0	50	0	0	0	0	0
X. piscator	0	0	0	0	0	0	0	0	100
ELAPIDAE									
N. naja	0	0	0	100	0	0	0	0	0
VIPERIDAE									
D. russelii	0	0	0	100	0	0	0	0	0
E. carinatus	40	0	0	60	0	0	0	0	0

5.3.2. Vertical Distribution

A total of 1,413 observations were considered for analysis with respect to vertical distribution of reptiles (which includes 1,113 lizards and 300 snakes). The majority (44%) of reptiles in Anaikatty Hills used ground layer (0 cm). As the height increased number of reptiles decreased, minimum 3% individuals were observed over 300 cm above ground (Figure 5.4). Considerable number of reptiles was also observed above ground (1-200 cm).

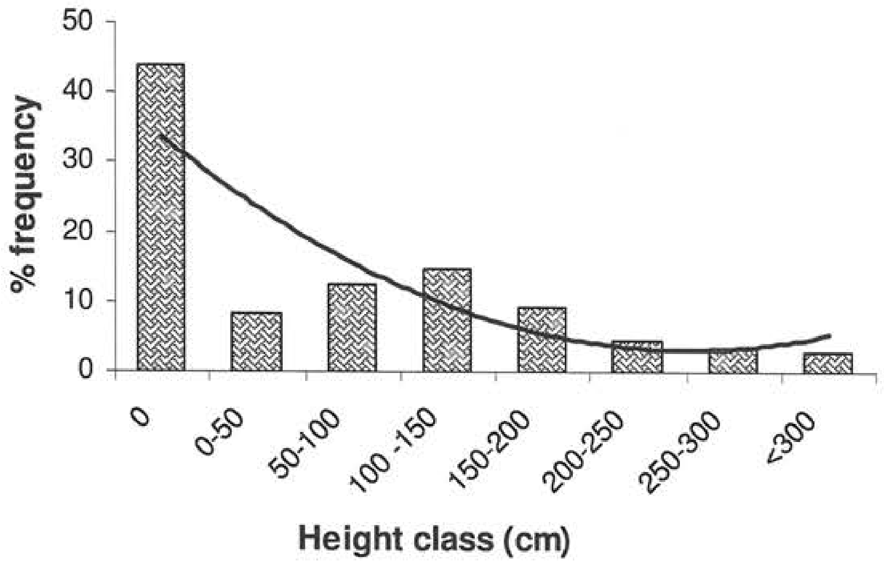
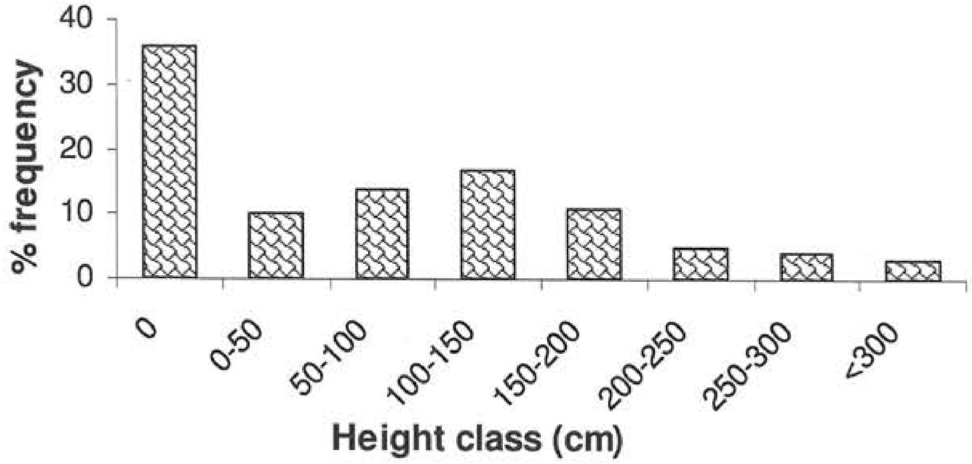


Figure 5.4. Distribution of reptiles at various vertical positions in Anaikatty Hills.

Eventhough highest percent (36%) of lizards were found on the ground (layer), maximum (64%) lizards were observed above ground (1-300cm; Figure 5.5a). The usage of lizards decreased, when the vertical position (layer) increased. Snakes were predominantly seen on the forest floor, and only 16% of them were found above ground (>0 cm, Figure 5.5b).

a) lizards



b) snakes

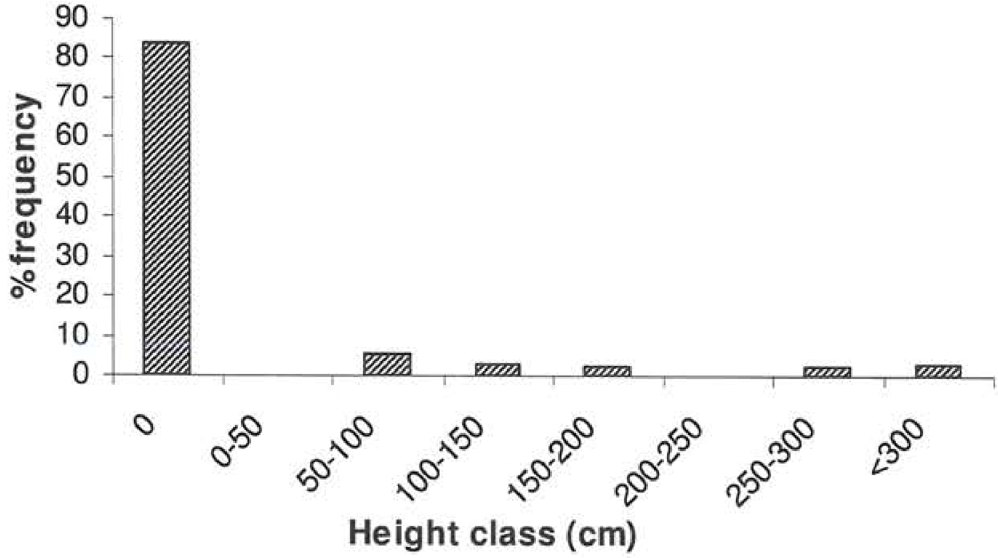


Figure 5.5. Distribution of lizards and snakes at various vertical positions in Anaikatty Hills.

Among all species of lizards, *Calotes versicolor* and *Hemidactylus frenatus* used broader spectrum of vertical strata (Figure 5.6a). Other species such as *Mabuya bibronii*, *Geckoella collegalensis* and *Sitana ponticeriana* used only ground showing narrow band of vertical distribution. In all, five species of lizards exclusively used ground (0 cm). *Mabuya carinata* showed intermediate in vertical strata use (0–200 cm). *Chamaeleo zeylanicus* and *Varanus bengalensis* occupied highest positions, eventhough a few of them found on forest floor (Figure 5.6a).

A few Colubrid species such as *Ahaetulla nasuta*, *Dendrelaphis tristis* and *Boiga trigonata* utilized many vertical strata, which ranged from 0 to over 300 cm. (Figure 5.6b). In all, 20 species exclusively used ground layer (0 cm), which includes *Ramphotyphlops braminus*, *Uropeltis ellioti* and *Python molurus*.

a) lizards

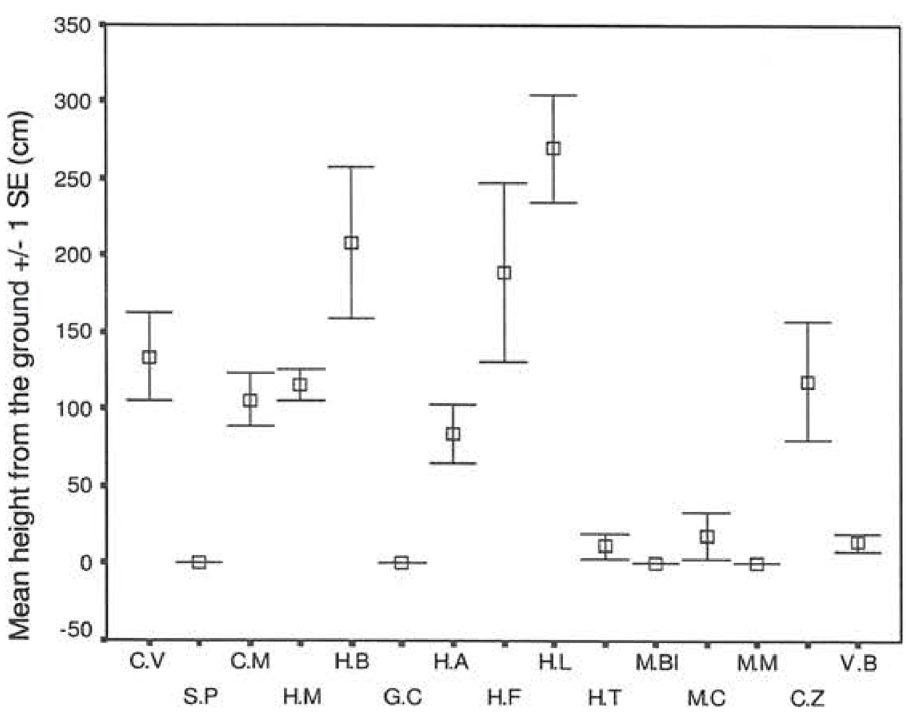


Figure 5.6. Utilization of various vertical positions by lizards in Anaikatty Hills.

b) snakes

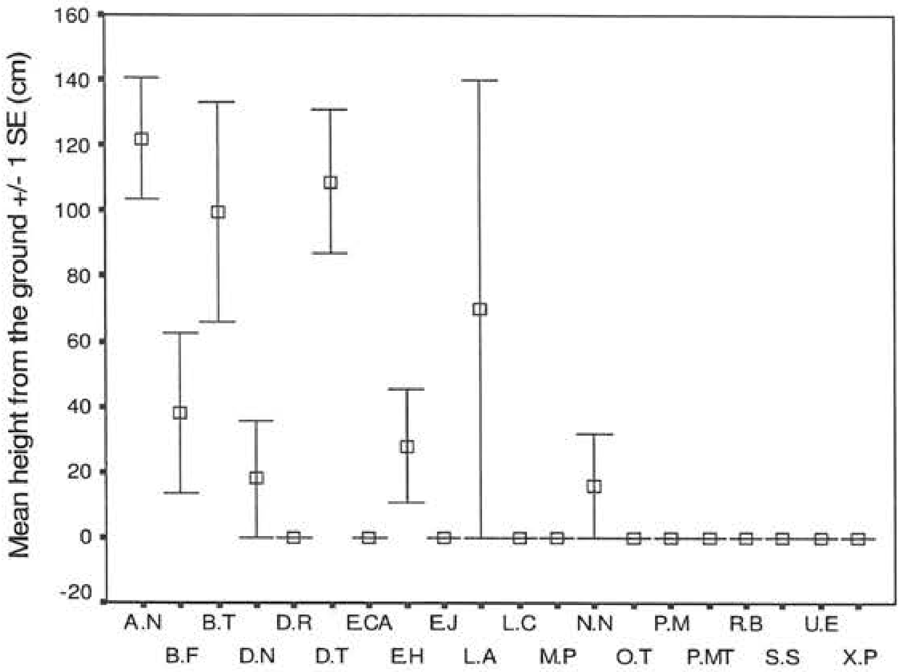


Figure 5.6. Utilization of various vertical positions by snakes in Anaikatty Hills.

Among lizards, the Kolmogorov-Smirnov test showed that lizards are not distributed uniformly with respect to the vertical strata ($Z = 2.121$; $P < 0.05$). Amongst snakes, the Kolmogorov-Smirnov test gave similar results ($Z = 3.00$; $P < 0.05$).

5.3.3. Temporal Pattern

In the temporal (time) use, only monthly pattern was considered due to paucity of data on daily activity, breeding seasonality and hatchling emergence. Maximum of 149 and minimum of 32 reptiles (individuals) were observed during July and May respectively (Figure 5.7 a, b). Considerable number of reptiles was found during other months barring August. It is further observed that lizards and snakes were active year round, whereas turtles showed seasonality being active largely during September to February (Figure 5.7 a, b). Relatively higher number of snakes was observed during October and November.

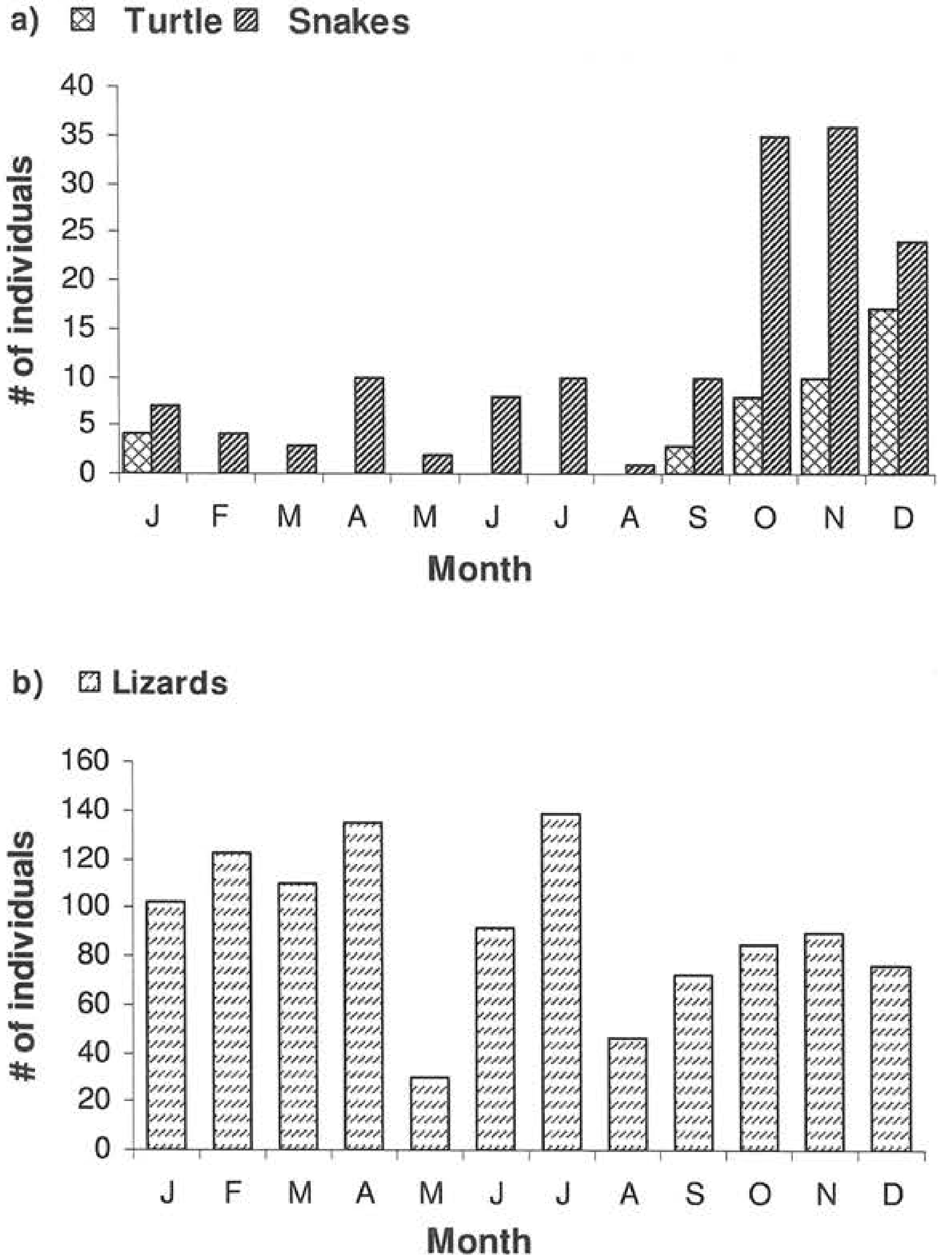


Figure 5.7. Monthly distribution of reptiles in Anaikatty Hills.

Mann-Whitney U test showed that overall monthly observation of lizards and snakes were significantly different ($U = 2.000$, $Z = -4.045$, $P < 0.01$).

Highest and lowest number of Gekkonids was observed during July and May respectively. Relatively higher number of geckoes was observed during January–April compared to August–December. The later months lie within the major monsoon season of the area (Figure 5.8a). Highest of seven species of geckoes were observed during January and lowest (three) during September, November–December.

The majority of Scincids (Figure 5.8b) were observed in November and minimum during May. Maximum four species of Scincids were observed during February and minimum (one) species during April–October. Gekkonids, Scincids and Agamids were observed round the year (Figure 5.8c). However, maximum of them were observed during April and minimum during May. Regarding number of species, maximum four species were observed during January and minimum (one) species during May–August.

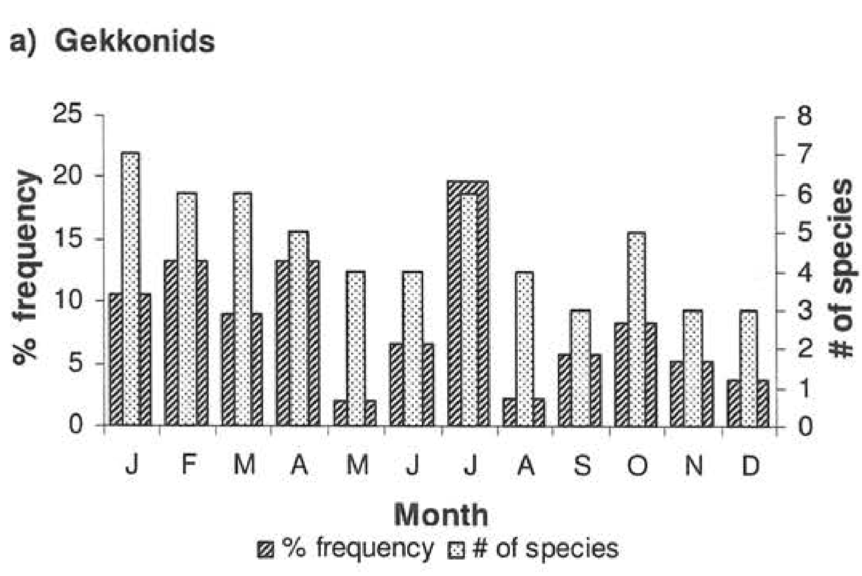
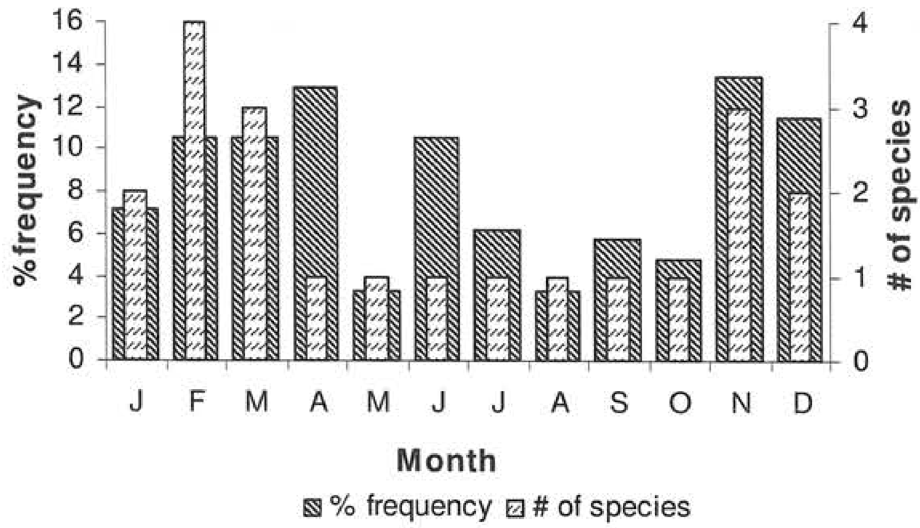


Figure 5.8. Monthly observation of various lizards in Anaikatty Hills.

b) Scincids



c) Agamids

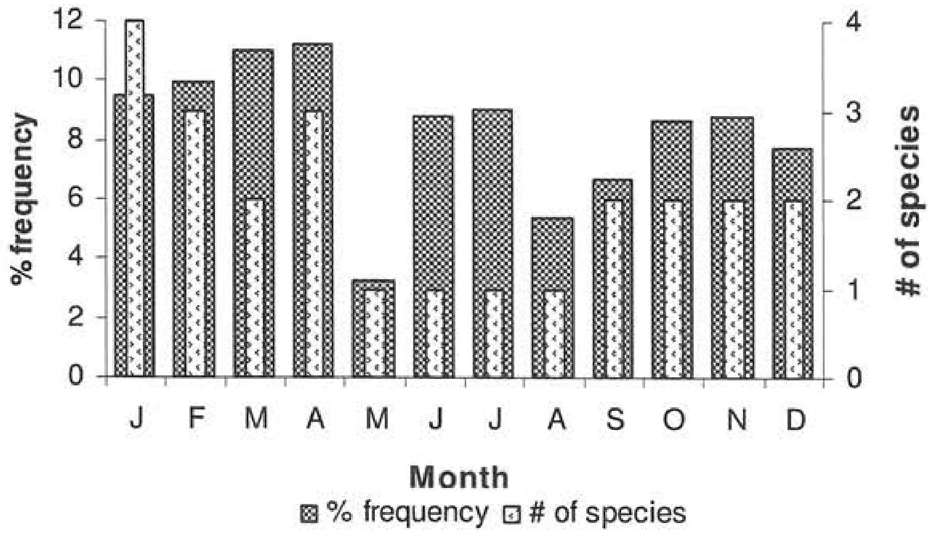


Figure 5.8. Monthly observation of various lizards in Anaikatty Hills.

Species active round the year

Species such as *Calotes versicolor*, *Mabuya carinata* and *Hemidactylus frenatus* were observed round the year (Figure 5.9a, b & c).

Seasonally active species

Species such as *Sitana ponticeriana, Hemiphyllodactylus aurantiacus* and *Geckoella collegalensis* showed strong seasonality in their activity. Among them, *Sitana ponticeriana* avoided rainy months (Figure 5.10a, b, & c).

There was no significant correlation between the environmental parameters (temperature, humidity, rainfall) and observation (considered as activity) of lizards during various months in the present study. Pearson correlation between different lizard species and various climatic factors (temperature, humidity and rainfall) showed that very few species had significant correlation. *Mabuya bibronii* showed negative correlation (r = -0.61) with temperature, whereas temperature had positive effect (r = 0.64) on the activity of *Geckoella collegalensis* (Table 5.6).

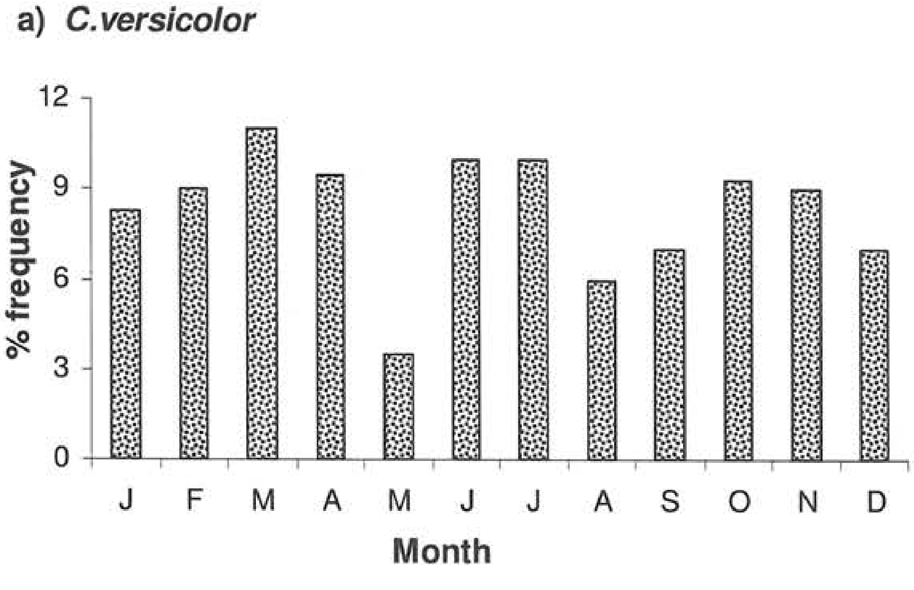
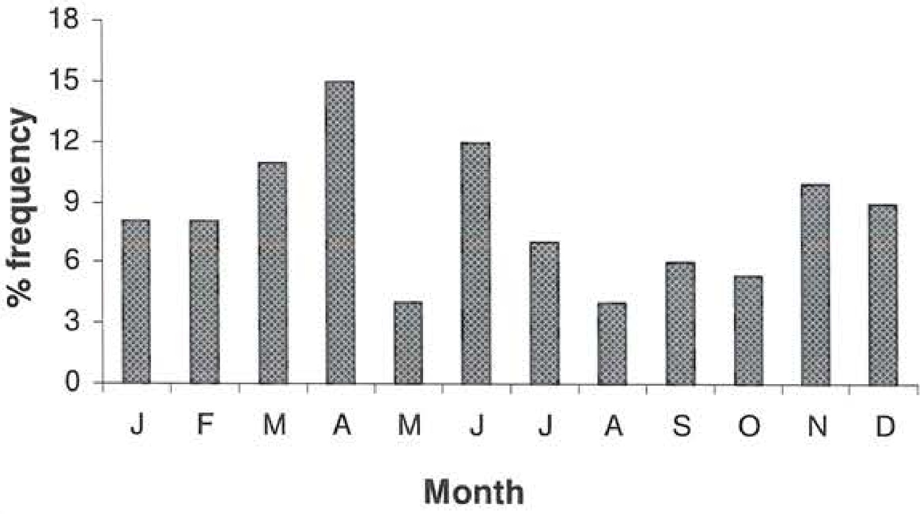


Figure 5.9. Occurrence of selected species of lizards in Anaikatty Hills.

b) *M.carinata*



c) *H.frenatus*

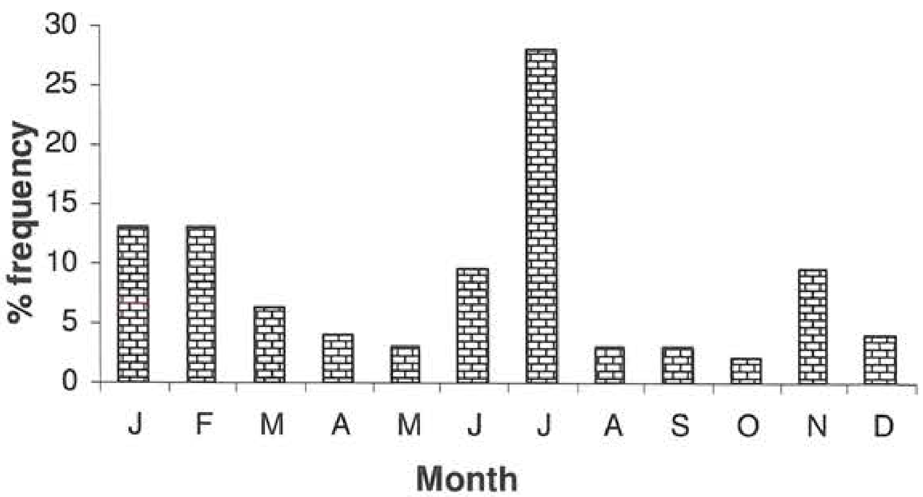


Figure 5.9. Occurrence of selected species of lizards in Anaikatty Hills.

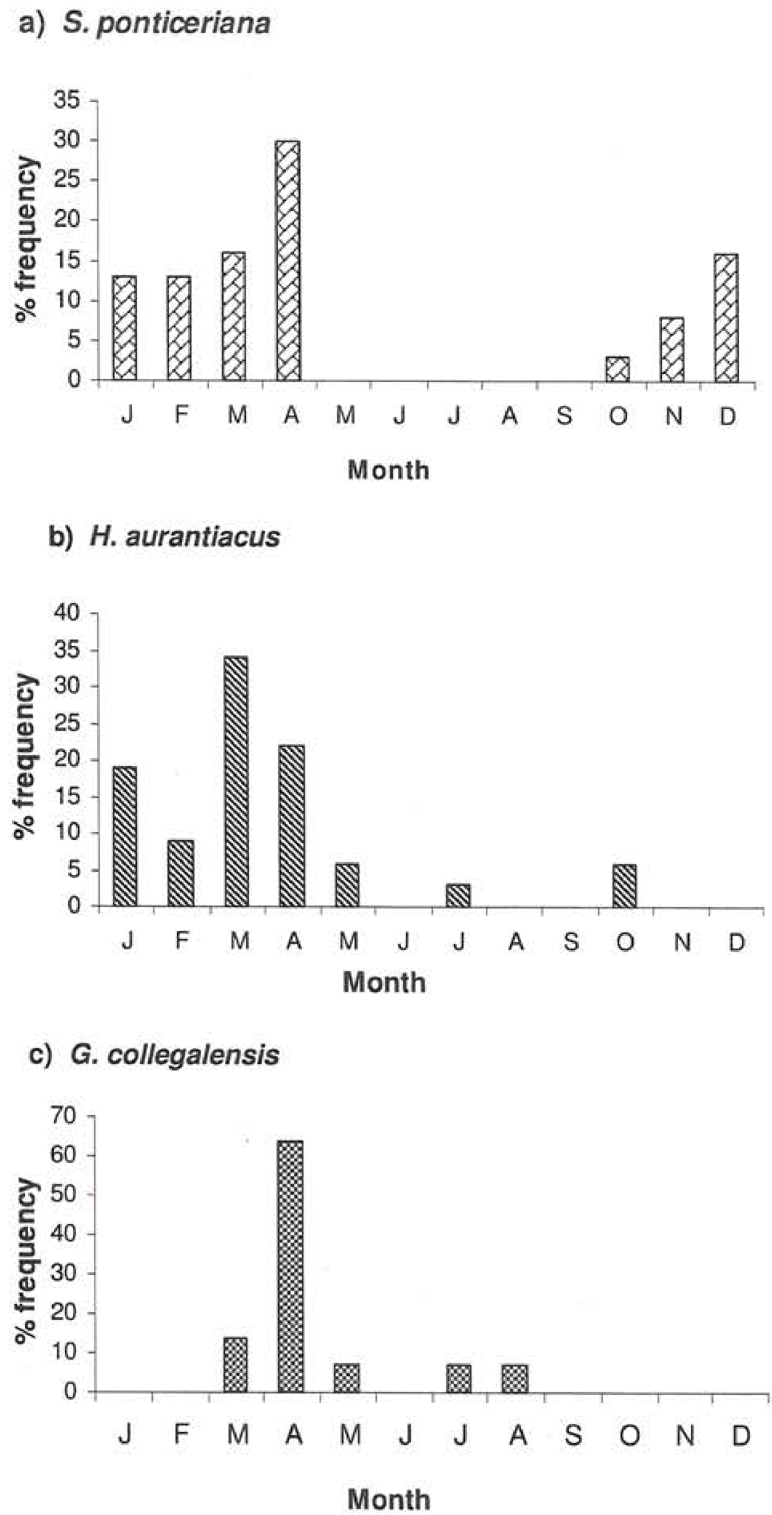


Figure 5.10. Occurrence of selected species of lizards during various months in Anaikatty Hills.

Table 5.6. Pearson Correlation among various species of lizards and environmental factors (* significance at 0.1).

Lizards	Temperature	Humidity	Rainfall
C. versicolor	-0.04	-0.21	-0.05
S. ponticeriana	0.23	0.09	-0.20
H. aurantiacus	0.55	-0.07	0.09
H. frenatus	-0.15	-0.49	-0.44
H. brookii	-0.07	-0.38	-0.24
H. maculates	0.42	-0.25	-0.19
G. collegalensis	0.64*	-0.06	0.09
C. mysoriensis	0.13	-0.23	0.04
H. triedrus	-0.44	0.21	-0.05
M. bibronii	-0.61*	0.55	-0.25
M. carinata	0.20	-0.11	-0.24
M. macularia	0.02	-0.24	-0.25
C. zeylanicus	0.00	-0.55	-0.19
V. bengalensis	0.35	0.19	0.18

Monthly observations on Typhlopids showed availability of the members of this family during certain months only (January, July, November, December; Figure 5.11a). Higher number of Typhlopids was observed during rainy seasons (July, December). Uropeltids were highly seasonal being active only during Northeast monsoons (September-November). Maximum Uropeltids were observed during October and no observation in non-monsoon months (Figure 5.11b). Boids were mainly observed during monsoons (November-January). However, June and August also yielded a few of them (Figure 5.11c). Maximum two (of three) species of Boids were observed during January. Highest numbers of Colubrid species (11) were observed during November and lowest a single species during August. Elapids and Viperids observed during the present study were very few to determine any seasonal pattern. However, Elapids were sporadically encountered during March, June, September and December, and Viperids during January, July and October (Figure 5.11d).

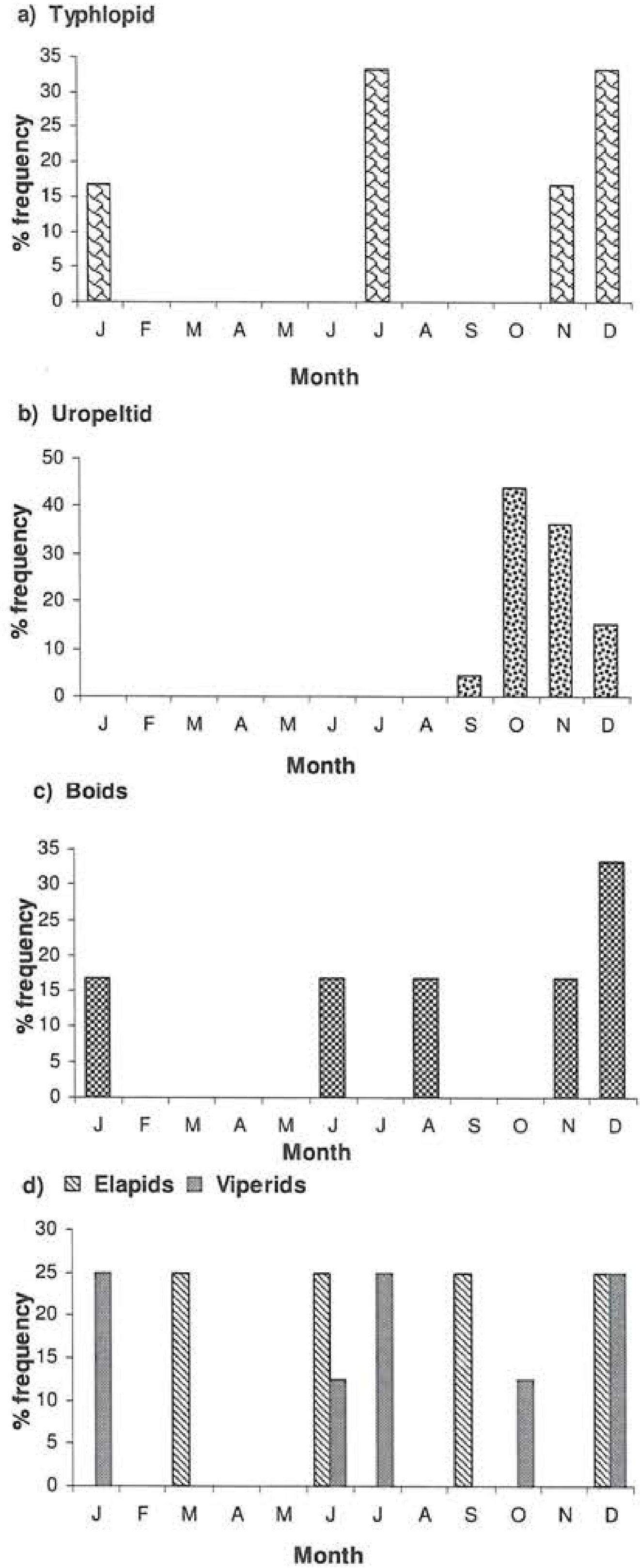


Figure 5.11. Snake families observed during various months in Anaikatty Hills.

Colubridae was the only family observed round the year (Figure 5.12) and the maximum individuals was found during November followed by April. Minimum number of them was observed during August. Relatively fewer individuals were observed during January–March and during May and August. Maximum number of species of Colubrids was observed in April and minimum in May.

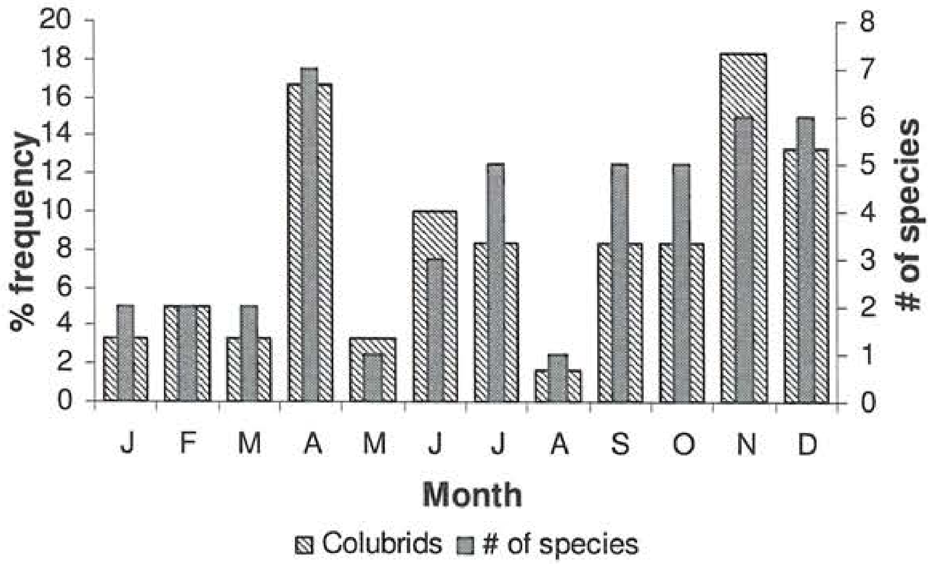


Figure 5.12. Observation of Colubrids during various months in Anaikatty Hills.

Pearson correlation between different snake species and climatic factors showed negative correlation with temperature (r = -0.67) and positive correlation with humidity (r = 0.76). Analysis with respect to each species showed *Uropeltis ellioti* had positive correlation with humidity (r = 0.79) and rainfall (r = 0.58) and negative with temperature (r = -0.61). Other species such as *Dryocalamus nympha* and *Ptyas mucosa* showed positive and negative correlation with rainfall (r = 0.67) and temperature (r = -0.59) respectively (Table 5.7).

Table 5.7. Pearson Correlation values among snakes and various environmental factors (* significance at 0.1; ** significance at 0.05 levels).

Snakes	Temperature	Humidity	Rainfall
R. braminus	-0.54	0.04	-0.46
U. ellioti	-0.61*	0.79**	0.58*
E. johnii	-0.49	0.05	-0.48
P. molurus	-0.12	-0.37	-0.42
A. nasuta	-0.13	0.21	-0.13
B. forsteni	0.42	0.05	0.07
B. trigonata	-0.26	-0.19	-0.36
D. nympha	0.13	0.31	0.67*
D. tristis	-0.21	0.29	-0.20
C. Helena	-0.04	-0.00	-0.39
L. aulicus	0.08	0.16	-0.21
L. calamaria	0.18	-0.43	-0.03
M. plumbicolor	-0.00	-0.36	-0.17
O. taeniolatus	0.30	0.07	0.21
P. mucosa	-0.59*	0.38	-0.27
X. piscator	-0.51	0.56	0.19
N. naja	0.43	-0.01	0.11
D. russelii	-0.37	0.20	-0.33
E. carinatus	-0.43	-0.18	-0.50

Species active round the year

Oligodon taeniolatus, *Coelognathus helena* and *Macropisthodon plumbicolor* were active during many months (Figure 5.13 a, b & c).

Seasonally active species

Apart from Uropeltids, single species *Uropeltis ellioti* (Figure 5.11b), Colubrid, *Liopeltis calamaria* showed seasonality in their monthly activity. This species was largely active during Southwest monsoon (May–July; Figure 5.13d).

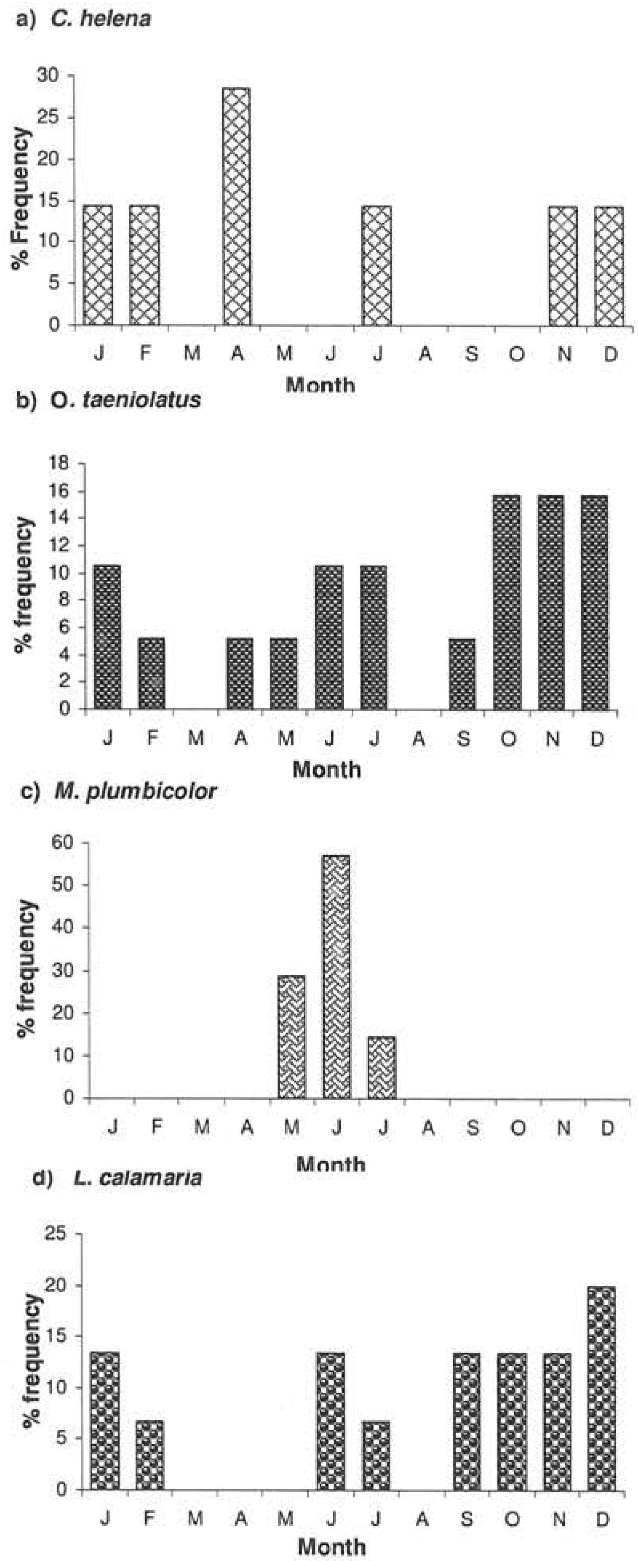


Figure 5.13. Occurrence of Colubrid species in various months in Anaikatty Hills.

5.4. DISCUSSION

Most of the reptiles partition the habitat as the primary resource, but snakes are notable exception (Toft, 1985). Henderson (1974) and Toft (1985) reported food and prey types most probably regulate habitat selection in snakes. The selection of suitable microhabitat by a species can protect itself from adverse weather and predators (Boykin and Zucker, 1993). Huey *et al.* (1989) reported that thermoregulation influence selection of retreat sites in various reptiles. It is also reported that lizards can maintain their optimal body temperature by selecting appropriate microhabitats (Greenberg, 1976).

In the present study, Agamid lizards used wide range of microhabitats. The versatile microhabitat use by Agamids has been reported in various studies (Bhupathy and Kannan, 1997; Daniel, 2002; Ishwar *et al.* 2003; Bhupathy and Nixon, 2004). Higher number of Agamid species and their abundance was observed on trees and shrubs (16%) and the forest floor (16%). *Calotes versicolor* utilized most types of microhabitats in the Anaikatty Hills. A wide range of microhabitat usage by this species has been reported earlier by Smith (1935) and Daniel (2002), and is reported as habitat generalist. Brown (1992b) reported that barring ground holes and burrows *Calotes versicolor* utilized almost all microhabitats. However, in the study area, *Calotes versicolor* often inhabited termite mounds. Termite mounds may have abundant prey species such as termites and other insects as well as temporary retreat sites for this species (Daniel, 2002). As the Anaikatty Hills is covered by dry forest, to beat the heat this species might have used this microhabitat more often than in other areas. Nixon (2005) found that *Salea horsfieldii* (Agamid) utilized a wide range of microhabitats. On the other hand *Sitana ponticeriana* used largely open ground (floor). The microhabitat specificity by this species has already been reported by Smith (1935) and Daniel (2002).

Scincids are the microhabitat specialists in the Anaikatty Hills and largely used exposed grounds. Similar types of reports on the microhabitat use by a few species of Scincids are available from other parts of the Western Ghats

(Inger *et al.* 1987; Daniel 2002; Ishwar *et al.* 2003). Turner (1977) and Morrison *et al.* (1992) reported that open and scattered vegetation covered areas in California as microhabitats of sympatric skink species *Eumeces gilberti* and *E. skiltonianus*. In comparison to the other taxa, gekkonids used more rocks and trees as microhabitats. The cryptic nature and body colours of certain gecko species helped them camouflage with the microhabitats, which may protect them from predators (Weintraub, 1968; Joshi, 1991; Boykin and Zucker, 1993; Pough *et al.* 1998; Cloudsley-Thompson, 1999). Utilization of rock crevices by geckoes was already reported (Smith, 1935); Daniel, 2002; Ishwar *et al.* 2001). Almost all geckoes were specialists with respect to microhabitat use in Anaikatty, with the exception of *Hemidactylus frenatus*. Apart from the observations on all natural microhabitats, artificial structures such as buildings and electric posts were occupied by this species. Das (1996) reported about human commensal Gekkonids such as *Hemidactylus frenatus*, *Hemidactylus leschenaultii* and *Hemidactylus brookii* from Indian subcontinent.

Chameleons were observed largely in the arboreal microhabitats. Moreover, this species seldom used open grounds. *Varanus bengalensis* was more terrestrial in Anaikatty Hills, which augment the observations of Auffenberg (1986). Dent and Spellerberg (1987) and Paulissen (1988) reported that in lower altitudinal areas both larger and smaller bodied lizards used open microhabitats. The results of the present study confirm the above view.

Use of open ground (forest floor) by most of the snakes was already reported (Smith, 1935; Inger *et al.* 1987; Das, 2002; Daniel 2002; Ishwar *et al.* 2003; Whitaker and Captain, 2004) as found in the Anaikatty Hills. Although terrestrial movements may expose snakes to the various risks such as predation and even accidental killing by vehicular traffic, it is essential for foraging, as food is mostly available on the ground (Bonnet *et al.* 1999; Reinert and Rupert, 1999). Studies on the microhabitat use by Boid snake *Epicrates monensis* in Cayo Diablo, Puerto Rico, showed that it highly depended on the prey species availability (Chandler and Tolson, 1990). The abundance of higher number of snake species on the open ground microhabitats in the present study may be related to more availability of prey species such as rodents on the ground, but this could not be investigated during this study.

The obligatory subterranean nature of the *Ramphotyphlops braminus* and *Uropeltis ellioti* has been reported in earlier (Smith, 1943; Rajendran, 1985; Daniel, 2002; Whitaker and Captain, 2004). Nixon (2005) reported the use of (under) boulder as microhabitats in case of Uropeltid species *Plectrurus perroteti* and Colubrid *Xylophis perroteti*. Boid species *Eryx johnii* or *Eryx conica* showed a facultative subterranean mode of life (Daniel, 2002; Whitaker and Captain, 2004). The above ground microhabitats (trees and shrubs) were largely used by arboreal or semi arboreal species such as *Ahaetulla nasuta*, *Dendrelaphis tristis* and *Boiga trigonata*. In comparison Fitzgerald *et al.* (2002) observed that *Hoplocephalus stephensii* in Eastern Australia used trees and tree hollows more than any other microhabitats. Lillywhite and Henderson (1993) reported that morphology of a species (longer and thinner body, with elongated tail) may reflect its arboreal behaviour. Almost all the venomous taxa such as Elapids and Viperids were adapted to terrestrial mode of life. Smith (1943) and Daniel (2002) broadly reported microhabitat use by most of the venomous Indian snakes.

Among the Agamid lizards, *Calotes versicolor* showed versatility in using various vertical positions (from 0 to over 300 cm). However, juvenile *Calotes versicolor* was more associated with the ground (0) and lower level bushes (within 100 cm above ground) compared to adults in Anaikatty Hills. Bhupathy and Kannan (1997) reported that *Calotes versicolor* along with *Draco dussumieri* used trees more than 10 m high from the ground. Brown (1992b) reported that juvenile *Calotes versicolor* used more ground level microhabitats, while adults were more arboreal. Similar results were found on the teiid lizard *Cnemidophorus lemniscatus* and *Anolis cookii* (Genet, 2002). Nixon (2005) reported versatile use of various vertical layers by Agamid lizard, *Salea horsfieldi* in the Upper Nilgiris. Utilization of different heights by various species is not only depended on thermoregulation, but also on prey species availability.

Among geckoes *Hemidactylus frenatus* used wide range of vertical layers from 0 to > 300 cm. Nixon (2005) reported that in Upper Nilgiris *Cnemaspis indica* largely used ground and under boulder; it is assumed that the prevailing colder climate in that area might have driven some species to use these microhabitats. In contrast, *Cnemaspis mysoriensis* in the Anaikatty Hills used relatively wide range of vertical strata. Scincids utilized only ground layer. The only exception was *Mabuya carinata*, which used a quite wider range of vertical positions than others. In comparison Nixon (2005) reported that skink *Scincella bilineatum* used ground layer. From the above data it appears that selection of microhabitats by a species is driven by local climate.

Inger *et al.* (1987) stated that smaller sample size hinder the analyses with respect to spatial use pattern in any ecological studies. Lillywhite and Henderson (1993) pointed out that foliage structure, microclimate and prey availability may interact to affect in the selection of vertical positions for arboreal snakes. Observations of fewer species of arboreal snake species in the area and occurrence of them in the ground layer may be due to the degraded nature and poor tree cover in the area.

Data on seasonality of Indian reptiles is largely unknown, barring anecdotal notes on breeding and emergence of juveniles (Duda and Koul, 1977; Kannan and Bhupathy, 1996; Daniel 2002; Shanbhag, 2003; Nixon, 2005). As ectotherms, thermoregulation of reptiles often depends on environmental factors, which affect their monthly or daily activity (Pough *et al.* 1998). Pianka (1970) reported long-term average warm and winter season precipitation having no correlation with lizard abundance. Pianka (1970) further reported that monthly emergence and duration of activity depend upon the season and local climatic conditions among various lizards. The body temperature of active lizards may often reflect time of activity such as seasonality (Pianka, 1973).

Huey and Slatkin (1976) and Huey *et al.* (1977) reported that generally most reptiles may avoid their activity at the hottest summer and even the coldest time during winter. Encounter of lowest numbers of reptiles during May and August in Anaikatty Hills may be because of this avoidance of higher temperature during these months. Summer inactivity or aestivation is reported in many species of reptiles and amphibians (Pough *et al.* 1998; Daniel 2002).

Huey *et al.* (1977) reported that the ability of year round activity in some reptiles is probably because these species may maintain a low optimal body temperature. This may be true for certain species of Agamids, Scincids and Gekkonids in the present study. However, Huey *et al.* (1977) further reported that only adult individuals may show this behavior. Vrcibradic and Rocha (1998) reported that *Mabuya frenata* in Southern Brazil showed a uniform seasonal activity pattern. An almost similar pattern was found in *Mabuya carinata* in the Anaikatty Hills. As in the present study, Daniel (2002) reported round the year activity in *Calotes versicolor.* Observations of higher number of reptiles during June–July and September–November (South-West and North-East monsoons) in the Anaikatty Hills may be due to higher productivity of their prey (insects) and increased reproductive activities of reptiles. It is reported that reproduction of most vertebrates starts with the onset of rains (Fitch, 1982; Pough *et al.* 1998).

Seasonality of a few species of Gekkonids during November–January in the present study may be associated with partial hibernation, during this period the atmospheric temperature falls around 18 -21º C. As in the present study, year round activity of *Hemidactylus frenatus* has been reported (Smith 1943; Daniel 2002; Das, 2002). As mentioned earlier higher observations of Gekkonids during June–July might be due to the onset of rain and reproductive activities of these species.

The activity patterns of tropical snakes have been poorly understood and this could be due to their rarity (Henderson and Hoevers, 1977; Henderson *et al.* 1978; Gibbons and Semlistsch, 1987; Parker and Plummer, 1987).

Henderson *et al.* (1978) predicted that in tropics a clear understanding regarding seasonality of snakes may only come through detailed species specific studies.

As reptiles are ectotherms, much of their ecology and behaviour are driven by physical environments (Seigel *et al.* 1995; Pough *et al.* 1998). In the present study, most species were observed active from September to December, which coincide with the Northeast monsoon. A clear seasonality was observed in Uropeltid, *Uropeltis ellioti* active during heavy Northeast monsoon in the Anaikatty Hills. This unimodal seasonal emergence pattern in this species could be due to the breeding season and abundance of prey species such as earthworms in this season. Smith (1943) and Rajendran (1985) discussed the seasonality of various Uropeltids in the Western Ghats. *Liopeltis calamaria* was restricted only during Southwest monsoons in the present study area, which may be the breeding season for them. Colubrids showed year round activity with higher peaks in April, June and November in the present study. Seigel and Ford (1987) and Pough *et al.* (1998) pointed out that most of the snakes breed during rainy seasons, which may be largely associated with prey species availability for the juveniles. Hirth *et al.* (1969), Brown and Parker (1982) and Macartney (1985) reported enhanced activity of the *Pituophis melanoleucus* during rainy seasons. Round the year activities of *Coelognathus helena*, *Oligodon taeniolatus* and *Macropisthodon plumbicolor* may be largely associated with mating, foraging and dispersal as reported in other species (Oliver, 1955; Fukada, 1958; Jackson and Franz, 1981).

Round the year activity in lizards compared to snakes may be correlated to the variation in optimal or preferred body temperature in these two taxa. Avery (1982) reported that compared to heliothermic lizards, snakes may be imprecise thermoregulators. Many of the saurian species may maintain a body temperature above 38 °C, whereas in snakes it varies within the range of 28–34 °C and frequently very near to 30 °C (Lillywhite, 1980; Peterson, 1987). Limited thermophily in snakes probably enhanced them to become more seasonal than lizards. Thus, in hotter and cooler climatic conditions most of the snakes may not be active compared to lizards. Various factors such as climate, vegetation structure of the area and reproductive habits of the species may limit the spatio- temporal use by reptiles in the Anaikatty Hills, Western Ghats.

5.5. SUMMARY

- The analyses of spatio-temporal use pattern of reptiles were based on 1,455 observations in Anaikatty Hills during 2002-2005.
- Lizards and snakes largely used terrestrial microhabitats. Among terrestrial microhabitats, forest floor was used by higher number of reptiles.
- Almost all vertical strata were used by lizards, while snakes largely used ground layer. *Calotes versicolor* and *Hemidactylus frenatus* used various vertical strata, while many skinks, geckoes and snakes used only forest floor (ground).
- Activity of various reptile species based on monthly observations showed that maximum and minimum number of them was found during July and May respectively. This may be mostly related to climatic conditions of the study area and breeding seasonality of the species.
- Overall temoral pattern showed that most of the lizards and a few species of snakes were active round the year, whereas turtle showed seasonality (active only during rainy months).
- *Calotes versicolor*, *Mabuya carinata* and *Oligodon taeniolatus* were observed round the year in Anaikatty Hills, whereas species such as *Geckoella collegalensis*, *Sitana ponticeriana*, *Uropeltis ellioti* and *Liopeltis calamaria* showed seasonality.
- Various factors such as climate (temperature, rainfall, humidity), vegetation structure of the area and reproductive habits of the species may limit their spatio- temporal use.

CHAPTER -VI
COMMUNITY ECOLOGY

6.1. INTRODUCTION

One of the major goals of the community ecology is to understand how various species coexist in a biotic community. It is essential to quantify resource use among members of the animal community to determine organization. Resources may be defined as environmental factors that are used by an organism and may potentially influence individual fitness (Ricklefs, 1979). Ways in which species within an ecological community partition available resources among themselves, probably form a major determinant of the diversity of coexisting species (Ricklefs, 1979). According to Pianka (1973) animals partition environmental resources in three basic ways, temporal, spatial and trophic. The difference in resource use may help reducing competition and presumably allow the coexistence of a variety of species. Factors structuring biotic communities are complex (Cody, 1974; Schoener, 1974; Schoener, 1977; Vitt *et al.* 2003). It is reported that the structure of an animal community is determined by the habitat structure and competition among species (MacArthur, 1972; Cody, 1974; Pianka, 1975; Pianka, 1976; Pöysä, 1983; Melville and Swain, 1997; Shenbrot and Krasnov, 1997).

The concept of ecological niche is an important aspect with respect to resource utilization patterns among various communities (Grinnell, 1928). It is the functional role and position of an organism in the community. Elton (1927) defined niche as its place in the biotic environment. Hutchinson (1957) considered niche as the total range of environmental variables to which a species must be adapted (physical, chemical and biotic) and under which a species population lives and replaces itself independently. Niche utilization may be based on the distribution of organisms within a set of resource states. Niche breadth may be defined as the sum total of the variety of different resources exploited by a species population (Pianka, 1988). Niche overlap may be defined as the degree to which two species share various resources (Pianka, 1988). This would provide information on interspecific competition. However, relationships between niche overlap and competition is poorly defined in the literature (Schoener, 1977). Abrams (1977 and 1980) pointed out that niche overlap should be used as a descriptive measure of community. It is reported that a community with more resource sharing or greater niche overlap may support more species than that with less niche overlap (Rusterholz, 1981).

According to Root (1967), guilds may be defined as a group of species that exploit similar type of resources in a similar way, but this concept was highly criticized by Hairston (1981). Schoener (1974) reported that habitat is the most common spatial resource generally partitioned by various animals followed by food and time. It is also reported that temporal specialization should occur only if the risk of predation is high relative to the need for food energy.

It has long been appreciated that an animal's morphology reflects its ecology and variation in the same play a major role in resource partitioning. The prevalence of size dimorphism among vertebrates has provoked several hypotheses concerning food size selection (Pianka, 1974; Slatkin, 1984; Camilleri and Shine, 1990). Differences in body size may promote coexistence allowing associated differences in food size selection and there by reduce niche overlap and competition (Colwell and Futuyma, 1971; Schoener, 1974).

Niche overlap among various species may indicate their competition for various resources. Morphometry of various species may also show niche segregation or avoidance of competition among coexisting species. Hutchinson (1959) proposed that the ratio of mouth part size (mainly jaw length) of sympatric and syntopic species would have minimum critical value 1.3, if the jaw length ratio of the two closely related species reaches below 1.3, both species may not coexist ecologically. On the other hand, while the ratio is 1.3 or over 1.3 both species can easily coexist without serious competition. Brown and Wilson (1956) stated this as ecological character displacement, which is largely based on morphometric variation among sympatric species. However, many workers have questioned the applicability of this ratio (Hespenheide 1971; Grant 1972; Hespenheide, 1973; Peters, 1976; Horn and May, 1977; Fagerstrom, 1978; Strong *et al.* 1979; Grant and Abbott, 1980; Roth, 1981; Pöysä, 1983). This concept was supported by Dayan *et al.* (1990) and Farlow and Pianka (2002).

The present Chapter deals with aspects of community ecology such as niche breadth, overlap and species grouping. Also, an attempt was made to use morphometry to describe variation in resource use among the reptiles of Anaikatty Hills, Western Ghats.

6.2. METHODOLOGY

Detailed methodology with respect to data collection regarding microhabitat, vertical position occupied by a species and monthly activities are given in previous Chapters (Sampling techniques and Spatio-temporal relations). In the case of *Melanochelys trijuga*, only niche breadth was calculated as this species was observed in a very distinct microhabitat (water bodies), highly seasonal in its activity and hence, niche overlap of this species with respect to other species was not calculated. Macro-morphometric measurements (in mm) such as ratio of the tail length (TL) and snout vent length (SVL) were considered for size structure and analysis pertaining to arboreality in certain species. The ratio between TL and SVL is considered to be indication of the degree of arboreality.

6.2.1. Data Analyses

The following data analyses were performed.

(1) Niche breadth is known as niche width or niche size and is calculated following Levins (1968) index, which is analogous to Simpson (1949) index.

$$\beta = \frac{1}{\Sigma P_{ij}^2}$$

where,

β = Levin's measure of niche breadth,

P_{ij} = proportion of individuals of species

i = occupying food resource state j.

The niche breadth value (β) varied from 1 (exclusive use of single resource) to n (number of resource categories). Hence, minimum niche breadth is 1 and the maximum value is number of resource categories.

The niche breadth (β) value was classified into: (i) low (<50% of the number of resource category) (ii) medium (50-75%) and high (>75%) of the maximum value (n= number of resource category).

(2) Niche overlap of a species pair was calculated using Pianka (1973) overlap index (ϕ).

$$(\phi)_{in} = \frac{\Sigma P_{ij} P_{ik}}{\sqrt{\Sigma P_{ij}^2 \Sigma P_{ik}^2}}$$

where,

P_{ij}, P_{ik} = proportion of individual of species j and k occupying the i^{th} resource category,

n = number of resource category.

The niche overlap (ϕ) values vary from zero (0) to one (1), where zero indicates no overlap and one complete overlap. The niche overlap (ϕ) value is classified into five categories; (i) Zero (0) = no overlap (ii) > 0–0.5 = low overlap (iii) > 0.5–0.75 = medium overlap (iv) > 0.75–0.99 = high overlap and (v) 1= complete overlap.

(3) Hierarchical Cluster Analysis was done (SPSS, version 10.0, 2000) to know species packing of lizards and snakes at microhabitat, vertical position and temporal levels. The above mentioned analysis was carried out by selecting single linkage (nearest neighbour) method which can give an idea of closely related species utilizing similar resources.

6.3. RESULTS

6.3.1. Niche Breadth

Nine microhabitat categories were considered for niche breadth analysis and the resultant value range from 1 to 9. Niche breadth value 4.5-6.8 (50%) was considered as moderate, >6.8 to 9 (>75%) as high and <4.5 (< 50%) as low.

Thirteen vertical categories were considered, and since maximum niche breadth value would be 11. Niche breadth value 6.5-9.5 (50-75%) was considered as moderate, > 9.5-11 (> 75%) as high and below <6.5 (< 50%) as low value.

Twelve categories were considered with respect to temporal scale. Niche breadth value 6-9 (50-75%) was considered as moderate, >9-12 (> 75%) as high and <6 (< 50%) as low.

Niche breadth of lizards and snakes with respect to both spatial and temporal parameters are given in Table 6.1 and 6.2.

Lizards

With respect to microhabitat, *Calotes versicolor* scored the highest value (β =4.35) and species such as *Sitana ponticeriana* and *Mabuya bibronii* obtained the minimum value (1.00). No lizards obtained higher niche breadth value with respect to this resource use (Table 6.1), and all species scored low niche breadth (Table 6.3). This indicates that all lizards of the Anaikatty Hills require specific microhabitat, and hence specialists in microhabitat use.

Table 6.1. Niche breadth of lizard species observed in Anaikatty Hills; N= number of observations

No.	Species	N	Micro habitat	Height	Temporal	Average
1	*G. collegalensis*	14	1.52	1.00	2.22	1.58
2	*C. mysoriensis*	171	2.08	5.56	7.69	5.11
3	*H. aurantiacus*	30	2.70	4.00	4.55	3.75
4	*H. frenatus*	93	2.56	9.09	7.14	6.27
5	*H. triedrus*	35	2.08	2.27	8.33	4.23
6	*M. bibronii*	16	1.00	1.00	1.00	1.00
7	*M. carinata*	187	1.96	2.17	10.00	4.71
8	*C. versicolor*	424	4.35	6.25	11.11	7.24
9	*S. ponticeriana*	32	1.00	1.00	5.56	2.52
10	*V. bengalensis*	21	2.78	2.13	5.26	3.39

Table 6.2. Niche breadth of snake species observed in Anaikatty Hills; N= number of observations.

No.	Species	N	Micro habitat	Height	Temporal	Average
1	*R. braminus*	14	1.85	1.00	3.57	2.14
2	*U. ellioti*	17	1.00	1.00	2.86	1.62
3	*E. johnii*	11	2.70	1.00	2.00	1.90
4	*P. molurus*	12	1.18	1.00	4.00	2.06
5	*A. nasuta*	14	2.27	3.13	2.78	2.73
6	*B. trigonata*	10	2.63	5.00	2.00	3.21
7	*D. tristis*	20	3.13	4.55	4.00	3.89
8	*C. helena*	14	1.00	1.32	5.56	2.62
9	*L. calamaria*	10	1.00	1.00	2.33	1.44
10	*M. plumbicolor*	10	1.00	1.00	1.00	1.00
11	*O. taeniolatus*	14	1.00	1.00	2.27	1.42
12	*P. mucosa*	14	1.56	1.32	2.78	1.89
13	*X. piscator*	9	1.00	1.00	2.00	1.33
14	*N. naja*	7	1.00	1.32	1.00	1.11
15	*D. russelii*	9	1.00	1.00	1.00	1.00
16	*E. carinatus*	10	1.92	1.00	2.63	1.85

The vertical distribution of reptiles was divided into 13 categories, at 25 cm interval (0 to 350 cm). Hence, niche breadth value would range from 1 to 13. The highest niche breadth (β = 9.09) was obtained by *Hemidactylus frenatus*, and the only lizard that obtained closer to moderate value (β =6.25) was *Calotes versicolor* (Table 6.1), and rest of them obtained lower value (β = below 6.5). *Geckoella collegalensis*, *Mabuya bibronii* and *Sitana ponticeriana* obtained lowest value (β = 1.00) indicating that they are specialists in vertical strata use (Table 6.1). Of the ten lizards analysed for the vertical strata, only one species got high niche breadth value and the rest (9 species) obtained low value (Table 6.3).

Table 6.3. Summary of niche breadth value obtained for various species of lizards and snakes in Anaikatty Hills.

Niche breadth Category	Resource level		
	Microhabitat (n = 9)	Vertical (n = 13)	Temporal (n = 12)
Lizards			
Low	10	9	5
Moderate	0	0	3
High	0	1	2
Snakes			
Low	16	16	16
Moderate	0	0	0
High	0	0	0

Niche breadth in temporal use was based on 12 categories (i.e. 12 months). The highest value (β = 11.11) was obtained by *Calotes versicolor* followed by *Mabuya carinata* (β = 10.00). Moderate niche breadth value was obtained by *Hemidactylus triedrus*, *Cnemaspis mysoriensis* and *Hemidactylus frenatus* (Table 6.1). Remaining five species had low values. Among all species, *Mabuya bibronii* obtained lowest (1.00) niche breadth value.

Snakes

Out of nine microhabitat categories, *Dendrelaphis tristis* obtained maximum (β = 3.13) and several species obtained the minimum (β = 1.00) niche breadth value (Table 6.2). No snakes obtained higher or even moderate niche breadth value in the present study (Table 6.3).

With respect to the vertical position, out of 13 categories maximum (β = 4.55) niche breadth was obtained by *Dendrelaphis tristis* and minimum (1.00) by several species (Table 6.2). No snakes obtained higher or even moderate niche breadth value with respect to the utilization of vertical positions (Table 6.3). Out of 12 temporal categories, the highest niche breadth (β = 5.56) was obtained by *Coelognathus helena* and lowest (β = 1.00) by several species (Table 6.2). None of the (16) snake species studied during this study had higher or moderate values with respect to their activities in various months (Table 6.3).

Among 10 species of lizards considered for analysis, a few of them obtained high to moderate niche breadth values. Out of 16 species of snakes studied, none of the snake species obtained moderate and high niche breadth values (Table 6.3). The results show that snakes are more specialists compared to lizards.

6.3.2. Niche Overlap

Lizards

Overlap was calculated in pairs among 10 lizard species in microhabitat, vertical position and temporal categories. Niche overlap was low in many species pairs in microhabitat use (ϕ = 0 - 0.5, Table 6.4), whereas complete overlap (ϕ =1.00) was found only between *Sitana ponticeriana* and *Mabuya bibronii.* No overlap (ϕ = 0.00) was found between *Mabuya bibronii* and *Cnemaspis mysoriensis* and Sitana ponticeriana with *Cnemaspis mysoriensis* (Table 6.5a).

Niche overlap was high in many species pairs with respect to the utilization of vertical positions (Table 6.4 and 6.5b). No complete non-overlap (ϕ =0.00) was found between any species pair, while complete overlap (ϕ =1.00) was found in 10 pairs (Table 6.4 and 6.5b).

Table 6.4. Summary of niche overlap in various lizard and snake species pairs observed in Anaikatty Hills.

Overlap Category	Micro habitat	Vertical position	Temporal Level
Lizards			
0 (no overlap)	2	0	3
< 0 – 0.5 low overlap	19	16	14
< 0.5 – 0.75 moderate overlap	12	0	18
< 0.75 – 0.99 high overlap	11	19	10
1 complete overlap	1	10	0
Snakes			
0 (no overlap)	15	0	45
< 0 – 0.5 (low overlap)	14	0	51
< 0.5 – 0.75 (moderate overlap)	29	14	21
< 0.75 – 0.99 (high overlap)	34	60	3
1 (complete overlap)	28	46	0

Table 6.5. Niche overlap of various lizard species pairs observed in Anaikatty Hills.

a) Microhabitat

Species	Gc	Cm	Ha	Hf	Ht	Mbi	Mc	Cv	Sp	Vb
G. collegalensis	-	0.01	0.62	0.07	0.28	0.96	0.90	0.67	0.96	0.77
C. mysoriensis			0.08	0.19	0.01	0.00	0.26	0.15	0.00	0.10
H. aurantiacus				0.69	0.25	0.55	0.51	0.81	0.55	0.50
H. frenatus					0.17	0.07	0.10	0.57	0.07	0.14
H. triedrus						0.29	0.27	0.37	0.29	0.76
M. bibronii							0.93	0.69	1.00	0.79
M. carinata								0.72	0.93	0.82
C. versicolor									0.69	0.70
S. ponticeriana										0.79
V. bengalensis										-

Table 6.5. Niche overlap of various lizard species pairs observed in Anaikatty Hills.

b). Vertical positions

Species	Gc	Cm	Ha	Hf	Ht	Mb	Mc	Cv	Sp	Vb
G. collegalensis	-	0.03	0.85	0.13	1.00	1.00	0.98	0.89	1.00	1.00
C. mysoriensis			0.40	0.77	0.10	0.03	0.21	0.39	0.03	0.10
H. aurantiacus				0.43	0.88	0.85	0.91	0.97	0.85	0.89
H. frenatus					0.20	0.13	0.24	0.46	0.13	0.18
H. triedrus						1.00	0.99	0.93	1.00	1.00
M. bibronii							0.98	0.89	1.00	1.00
M. carinata								0.95	0.98	0.99
C. versicolor									0.89	0.92
S. ponticeriana										1.00
V. bengalensis										-

c). Temporal level

Species	Gc	Cm	Ha	Hf	Ht	Mb	Mc	Cv	Sp	Vb
G. collegalensis	-	0.57	0.63	0.24	0.12	0.00	0.58	0.46	0.74	0.62
C. mysoriensis			0.58	0.82	0.59	0.06	0.80	0.86	0.65	0.71
H. aurantiacus				0.45	0.38	0.00	0.69	0.67	0.80	0.58
H. frenatus					0.76	0.26	0.73	0.81	0.45	0.31
H. triedrus						0.66	0.78	0.84	0.39	0.38
M. bibronii							0.34	0.31	0.19	0.00
M. carinata								0.96	0.81	0.71
C. versicolor									0.71	0.68
S. ponticeriana										0.73
V. bengalensis										-

Niche overlap was moderate (>0.5 – 0.75) in many species pairs with respect to monthly activity. Complete overlap (ϕ =1.00) in lizard pairs was not found during the present category (Table 6.4 and 6.5c).

Snakes

Niche overlap was high in many pairs of snakes with respect to microhabitat use (< 0.75 – 0.99) (Table 6.4) and twenty-eight species pairs had complete overlap (ϕ =1.00). Complete non-overlap (ϕ =0.00) was found in 15 pairs (Table 6.4 and 6.6a).

Niche overlap was high in many pairs of snake species (< 0.75 – 0.99), in the utilization of vertical positions, whereas 46 pairs of species showed complete overlap (ϕ =1.00). Complete non-overlap (ϕ =0.00) and low overlap (<0 – 0.5) was not found in any species pairs during this study (Table 6.4 and 6.6b).

Niche overlap was low in many pairs of species (0 – 0.5) with respect to monthly activities, whereas lowest three species pairs showed high overlap (> 0.75 – 0.99). No complete overlap (ϕ =1.00) was found, but complete non-overlap (ϕ =0.00) was found in 45 species pairs (Table 6.4 and 6.6c).

Table 6.6. Niche overlap in various species pairs of snake species observed in Anaikatty Hills.

a) Microhabitat

Species	Rb	Ue	Ej	Pm	An	Bt	Dt	Ch	Lc	Mp	Ot	Pmu	Xp	Nn	Dr	Eca
R. braminus	-	0.49	0.88	0.48	0.31	0.39	0.30	0.49	0.49	0.49	0.49	0.48	0.00	0.49	0.49	0.89
U. ellioti			0.75	1.00	0.65	0.81	0.62	1.00	1.00	1.00	1.00	0.98	0.00	1.00	1.00	0.83
E. johnii				0.77	0.48	0.60	0.46	0.75	0.75	0.75	0.75	0.76	0.00	0.75	0.75	0.95
P. molurus					0.64	0.81	0.62	1.00	1.00	1.00	1.00	0.98	0.00	1.00	1.00	0.83
A. nasuta						0.93	0.94	0.65	0.65	0.65	0.65	0.65	0.00	0.65	0.65	0.54
B. trigonata							0.85	0.81	0.81	0.81	0.81	0.85	0.00	0.81	0.81	0.67
D. tristis								0.62	0.62	0.62	0.62	0.61	0.00	0.62	0.62	0.52
C. helena									1.00	1.00	1.00	0.98	0.00	1.00	1.00	0.83
L. calamaria										1.00	1.00	0.98	0.00	1.00	1.00	0.83
M. plumbicolor											1.00	0.98	0.00	1.00	1.00	0.83
O. taeniolatus												0.98	0.00	1.00	1.00	0.83
P. mucosa													0.00	0.98	0.98	0.82
X. piscator														0.00	0.00	0.00
N. naja															1.00	0.83
D. russelii																0.83
E. carinatus																-

Table 6.6. Niche overlap in various species pairs of snake species observed in Anaikatty Hills.

b) Vertical positions

Species	Rb	Ue	Ej	Pm	An	Bt	Dt	Ch	Lc	Mp	Ot	Pmu	Xp	Nn	Dr	Eca
R. braminus	-	1.00	1.00	1.00	0.89	0.67	0.86	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
U. ellioti			1.00	1.00	0.89	0.67	0.86	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
E. johnii				1.00	0.89	0.67	0.86	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
P. molurus					0.89	0.67	0.86	0.99	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00
A. nasuta						0.91	0.85	0.94	0.89	0.89	0.89	0.90	0.89	0.94	0.89	0.89
B. trigonata							0.72	0.74	0.67	0.67	0.67	0.70	0.67	0.74	0.67	0.67
D. tristis								0.87	0.86	0.86	0.86	0.85	0.86	0.87	0.86	0.86
C. helena									0.99	0.99	0.99	0.97	0.99	1.00	0.99	0.99
L. calamaria										1.00	1.00	0.99	1.00	0.99	1.00	1.00
M. plumbicolor											1.00	0.99	1.00	0.99	1.00	1.00
O. taeniolatus												0.99	1.00	0.99	1.00	1.00
P. mucosa													0.99	0.97	0.99	0.99
X. piscator														0.99	1.00	1.00
N. naja															0.99	0.99
D. russelii																1.00
E. carinatus																-

Table 6.6. Niche overlap in various species pairs of snake species observed in Anaikatty Hills.

c). Temporal

Species	Rb	Ue	Ej	Pm	An	Bt	Dn	Dt	Ch	Lc	Mp	Ot	Pmu	Xp	Nn	Dr	Eca
R. braminus	-	0.36	0.67	0.47	0.21	0.45	0.00	0.47	0.63	0.14	0.63	0.10	0.63	0.45	0.00	0.63	0.90
U. ellioti			0.18	0.04	0.41	0.18	0.52	0.44	0.29	0.00	0.00	0.22	0.58	0.75	0.00	0.26	0.46
E. johnii				0.35	0.00	0.50	0.00	0.35	0.47	0.00	0.00	0.21	0.47	0.00	0.00	0.71	0.58
P. molurus					0.04	0.28	0.35	0.50	0.00	0.00	0.21	0.38	0.12	0.00	0.00	0.08	0.82
A. nasuta						0.00	0.00	0.50	0.67	0.00	0.00	0.30	0.44	0.63	0.00	0.00	0.27
B. trigonata							0.00	0.35	0.24	0.62	0.00	0.00	0.71	0.00	0.00	0.71	0.58
D. tristis									0.67	0.00	0.00	0.45	0.67	0.47	0.00	0.50	0.61
C. helena										0.07	0.33	0.70	0.44	0.39	0.00	0.33	0.54
L. calamaria											0.22	0.00	0.29	0.05	0.00	0.00	0.09
M. plumbicolor												0.00	0.00	0.24	0.00	0.00	0.41
O. taeniolatus													0.00	0.07	0.00	0.00	0.00
P. mucosa														0.63	0.00	0.67	0.82
X. piscator															0.00	0.00	0.48
N. naja																0.00	0.00
D. russelii																	0.82
E. carinatus																	-

6.3.3. Size Structure in Reptile Community

Size structure of a species or community is important for understanding its population characteristics. In the present study, lizard species had snout-vent length (SVL) varying from 29 mm to 211 mm. The results showed that lizard community in Anaikatty Hills was largely represented by smaller bodied species and the number of species decreased when the body size (SVL) increased (Figure 6.1a). In the present study, out of 17 lizard species analysed, it was found that the maximum of 50% had SVL within 27–60 mm and 40% had SVL within 61–100 mm. Only a few lizard species had large body size (Figure 6.1a).

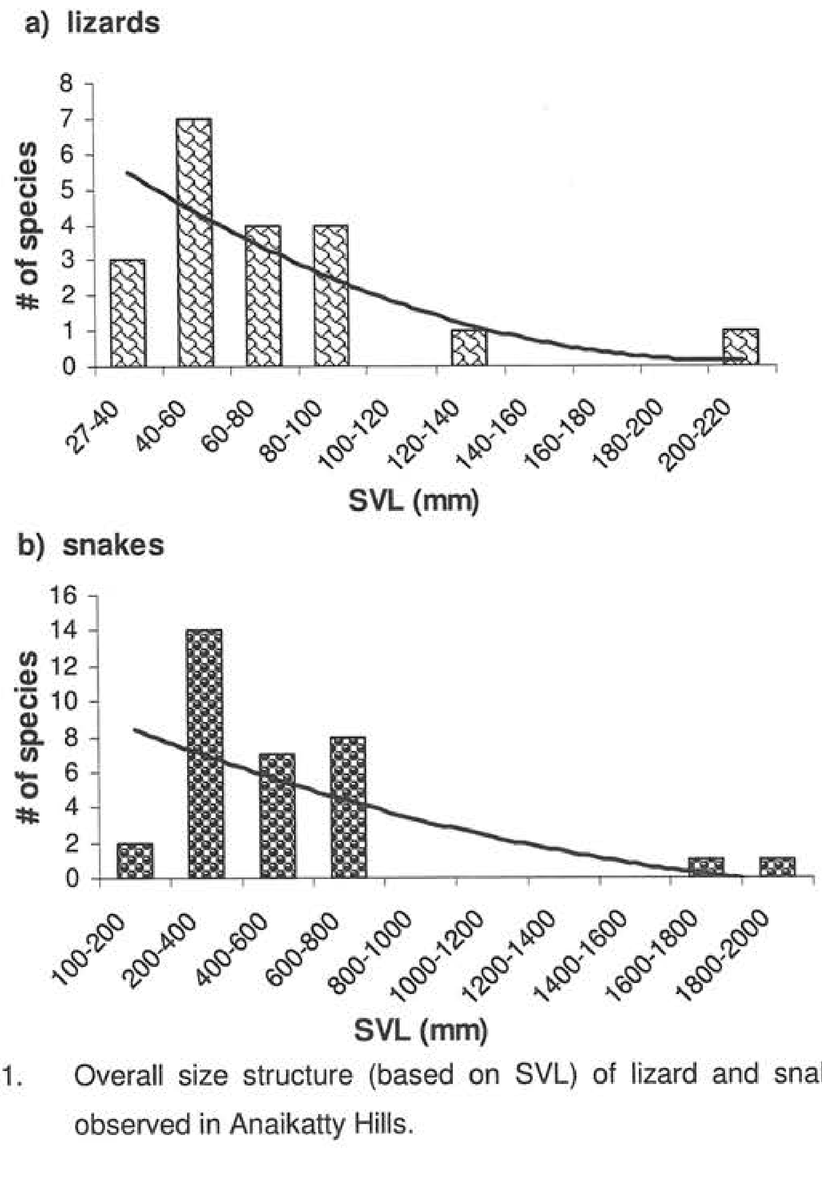


Figure 6.1. Overall size structure (based on SVL) of lizard and snake species observed in Anaikatty Hills.

In snakes, the size structure (SVL) varied from 100 to 2000 mm. The pattern was almost similar to that of lizards. Snake community is largely represented by smaller bodied species. The number of species decreased when the body size (SVL) increased (Figure 6.1b). Out of 33 snake species considered, maximum 48% (number of species) had SVL within 100 – 400 mm and 45% had SVL within 401– 800 mm. A few species of snakes had large body size (Figure 6.1b). Size structure shows that both lizard and snake species had higher number of smaller bodied species. This indicates that theoretically these species would have high competition for various resources.

6.3.4. Arboreality

Arboreality of an animal may be assumed based on various criteria. Among them ratio between tail length and body length in snakes and nature of the digits, claws and body shape in lizards may be important factors. The ratio of tail length and snout-vent length may indicate arboreality of a reptile. Among 33 snake species analysed, this ratio showed wide variation, ranging from 0.33 – 0.66. Species with ratio (>0.40) may be considered as arboreal species (*Ahaetulla pulverulenta*, *Ahaetulla nasuta* and *Dendrelaphis tristis*). In majority of snakes, this ratio varied from 0.10 to 0.40 (Figure 6.2a), which comprised of various semi-arboreal and terrestrial species. Ground dwelling species such as *Oligodon taeniolatus*, *Macropisthodon plumbicolor*, *Python molurus*, *Echis carinatus* and *Daboia russelii* though obtained low ratio, may be found above ground at least in juvenile stage. On the other hand the subterranean or semi-fossorial species, such as *Ramphotyphlops braminus*, *Uropeltis ellioti* and *Eryx johnii* had 0.03 to 0.09 ratio (Figure 6.2a).

Among the 17 species of lizards considered for analysis, the ratio of TL/SVL ranged from 0.32–3.09. *Calotes calotes*, *Sitana ponticeriana*, *Calotes versicolor* and *Varanus bengalensis* obtained high value (Figure 6.2b.). On the other hand, lower value (0.32–0.84) was obtained by *Hemidactylus triedrus*, *Geckoella collegalensis*, *Hemiphyllodactylus aurantiacus* and *Hemidactylus maculatus*. Overall lizards obtained much higher TL/SVL ratio than snakes which indicates lizards attained proportionately longer tail length than snakes.

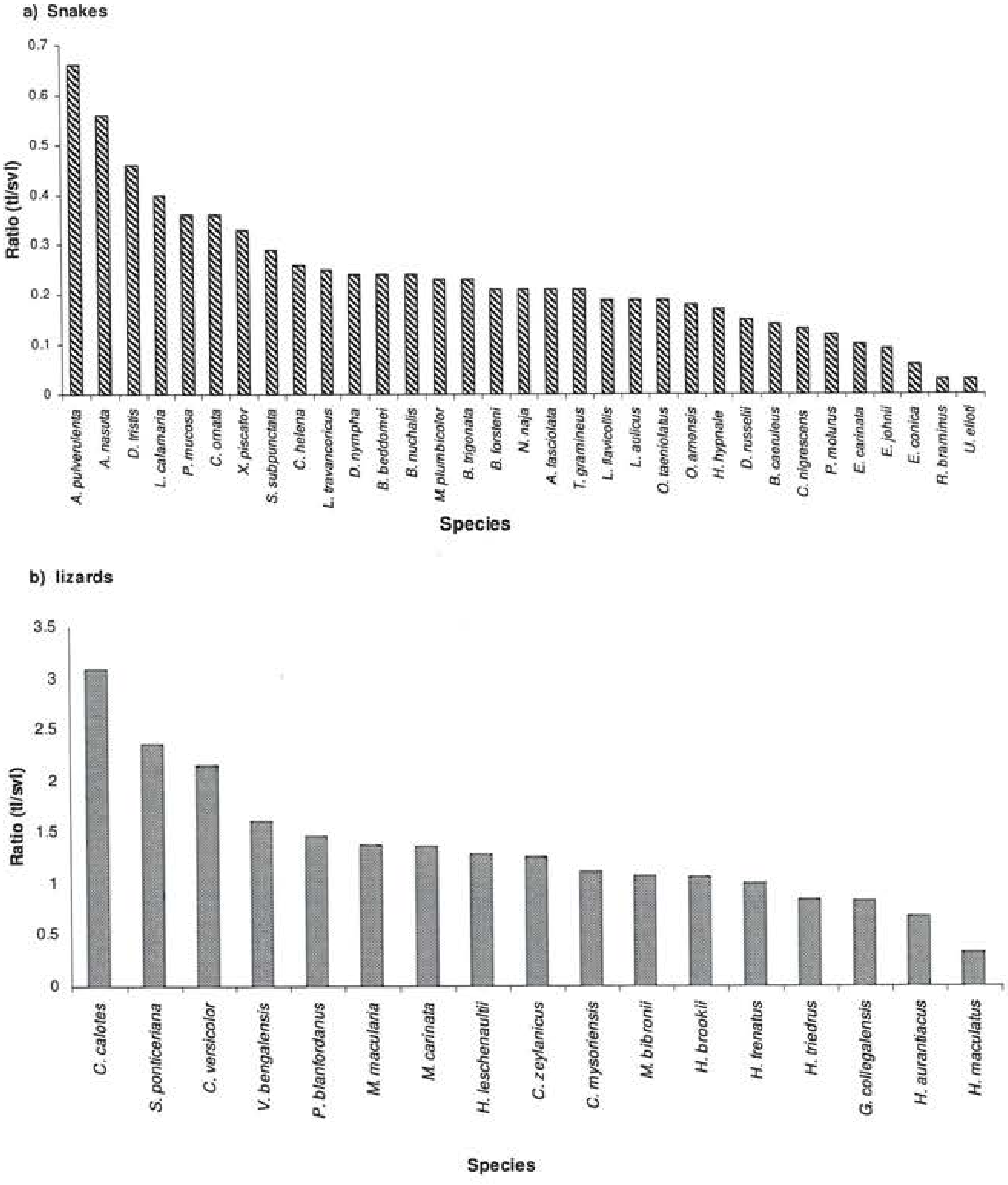


Figure 6.2 Ratio of tail length and snout-vent length in various snakes (a) and lizards (b) observed in Anaikatty Hills.

6.3.5. Species Assemblage

Spatial

Assemblage based on the microhabitat use by various species of lizards showed two distinct groupings as *Calotes versicolor* and the other by remaining species. The second group was divided into two subgroups. *Geckoella collegalensis, Sitana ponticeriana, Hemidactylus triedrus, Mabuya bibronii* and *Varanus bengalensis* formed close packing (Figure 6.3a). This indicated the similarity in the usage of microhabitats of these species.

Based on vertical layers used, lizards showed three distinct groups. These are (i) *Mabuya carinata* (ii) *Calotes versicolor* and (iii) remaining species. The third group was divided into two subgroups comprising *Varanus bengalensis, Hemidactylus frenatus* and a more highly compact group with ground dwelling species such as *Geckoella collegalensis, Sitana ponticeriana, Mabuya bibronii* and *Hemidactylus triedrus* (Figure 6.4a).

Snake species assemblage based on microhabitat use showed two groups, *Xenochrophis piscator* and all other terrestrial species (Figure 6.3b). The second group was divided into various loosely and closely packed groups. Species such as *Ramphotyphlops braminus, Uropeltis ellioti* and *Eryx johnii* showed loose species packing. Compact packing was shown by *Ahaetulla nasuta, Boiga trigonata* and *Dendrelaphis tristis.* Other species pairs such as *Naja naja* and *Daboia russelii, Liopeltis calamaria* and *Macropisthodon plumbicolor* showed close (tight) packing.

With respect to vertical position, snakes formed two major groups; (i) with arboreal species *Ahaetulla nasuta, Boiga trigonata* and *Dendrelaphis tristis* and (ii) the remaining species. The later group was subdivided into two groups (Figure 6.4b). Both these groups had tightly packed cluster of species. The tightly packed group includes *Coelognathus helena, Echis carinatus, Naja naja* and *Daboia russelii.*

Comparison of the species packing with respect to microhabitat use between lizards and snakes revealed the later taxon shown comparatively tight species packing with more subdivision than the former. This indicates that snake species used similar microhabitats compared to lizards. Comparison with respect to utilization of the vertical position among lizards and snakes revealed that species packing was more compact in snakes compared to lizards.

Temporal

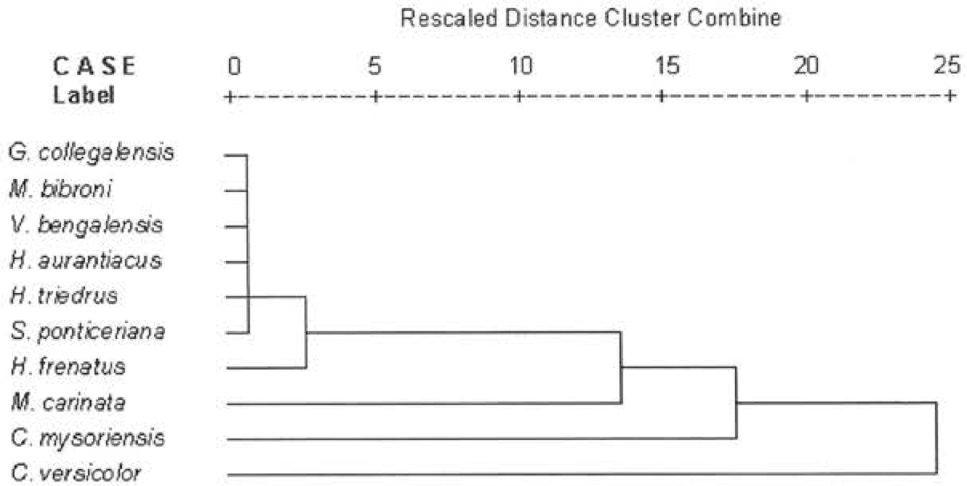
Species grouping based on monthly observations of lizards showed two groups (i) *Calotes versicolor* and (ii) the remaining species. The second group is subdivided into loose group of *Mabuya carinata* and *Cnemaspis mysoriensis*. Other group formed compact pack with many species such as *Geckoella collegalensis*, *Hemiphyllodactylus aurantiacus* and *Hemidactylus triedrus* (Figure 6.5a).

Analysis with respect to temporal level, snake species had two groups; one by *Uropeltis ellioti*, activity restricted to very specific months and the other by rest of the species. The group with rest of the species formed compact cluster indicating their similarity in monthly activity (Figure 6. 5b).

Comparison of the species packing with respect to temporal level showed that snakes had highly compact grouping compared to lizards.

Considering all the three dimensions together (6.6a,b), it was found that in lizard community could be grouped into one closely linked guild and two loosely packed groups. *Calotes versiolor* formed a separate guild (6.6a). In the snakes most of the species (13) formed a closely linked guild while *Uropeltis ellioti* formed a separate guild (6.6b).

a) **lizards**



b) **snakes**

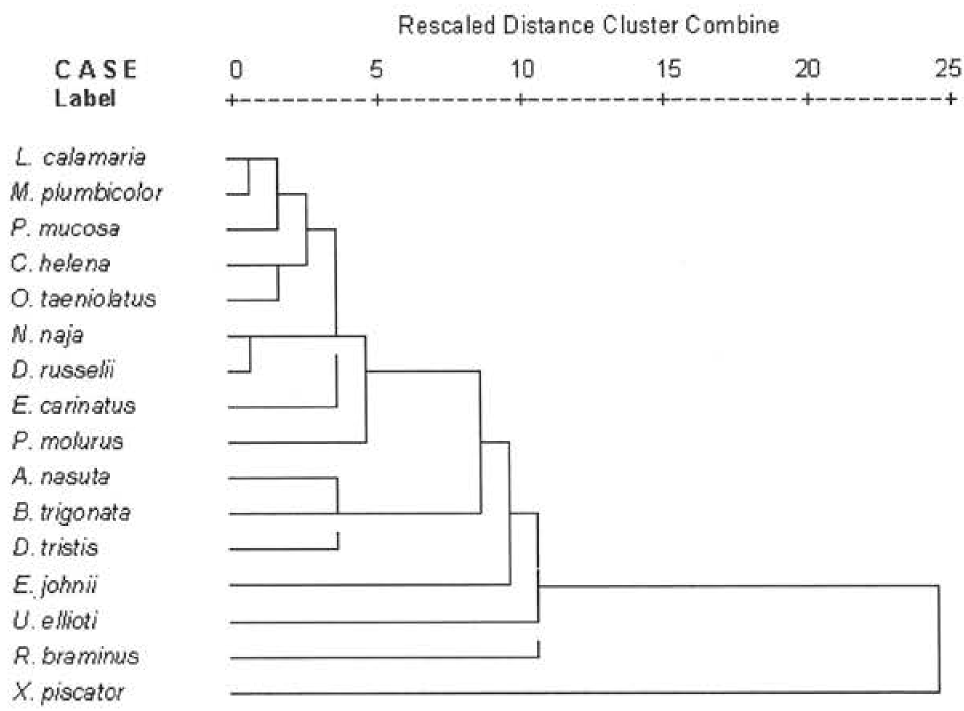


Figure 6.3. Dendrogram based on hierarchical cluster analysis using Single Linkage (nearest neighbour): microhabitats used by lizards and snakes of Anaikatty Hills.

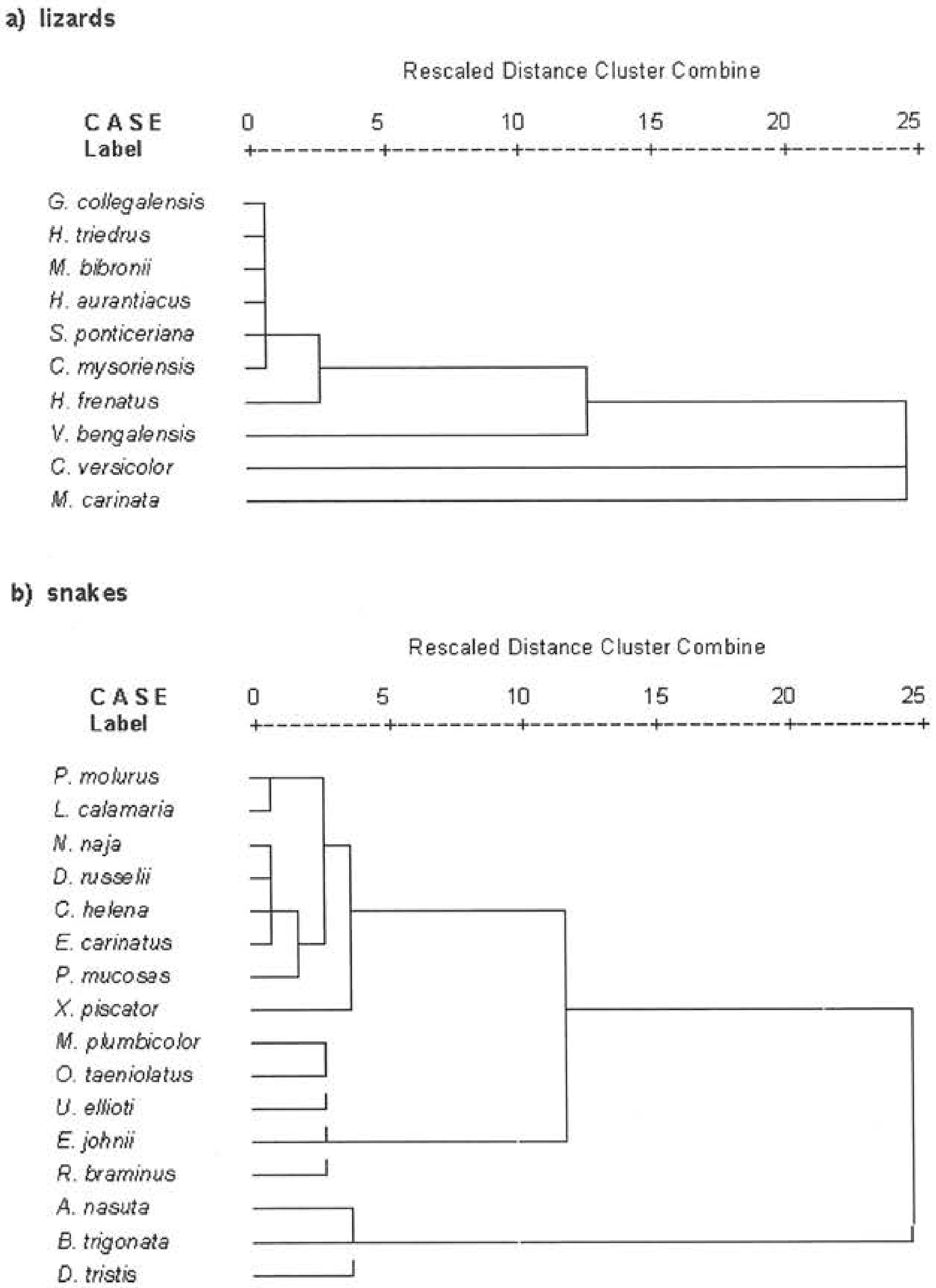
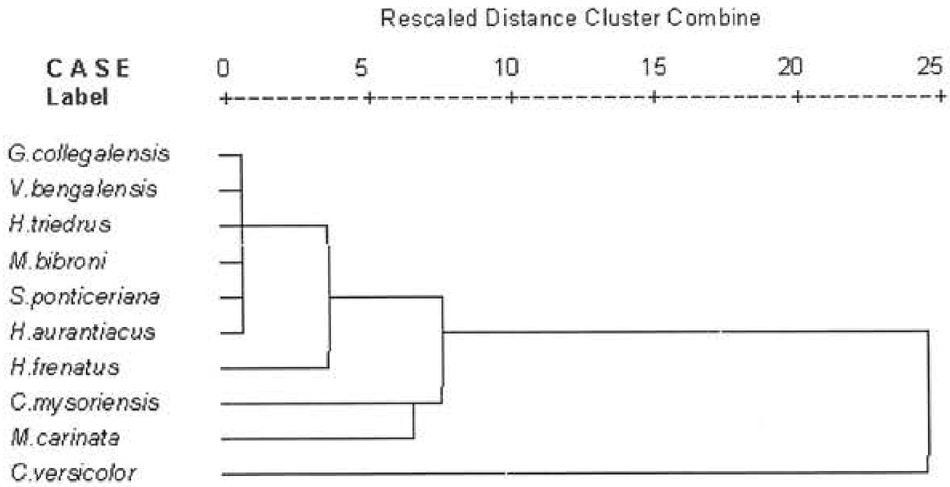


Figure 6.4. Dendrogram based on hierarchical cluster analysis using Single Linkage (nearest neighbour): vertical positions used by lizards and snakes of Anaikatty Hills.

a) **lizards**



b) **snakes**

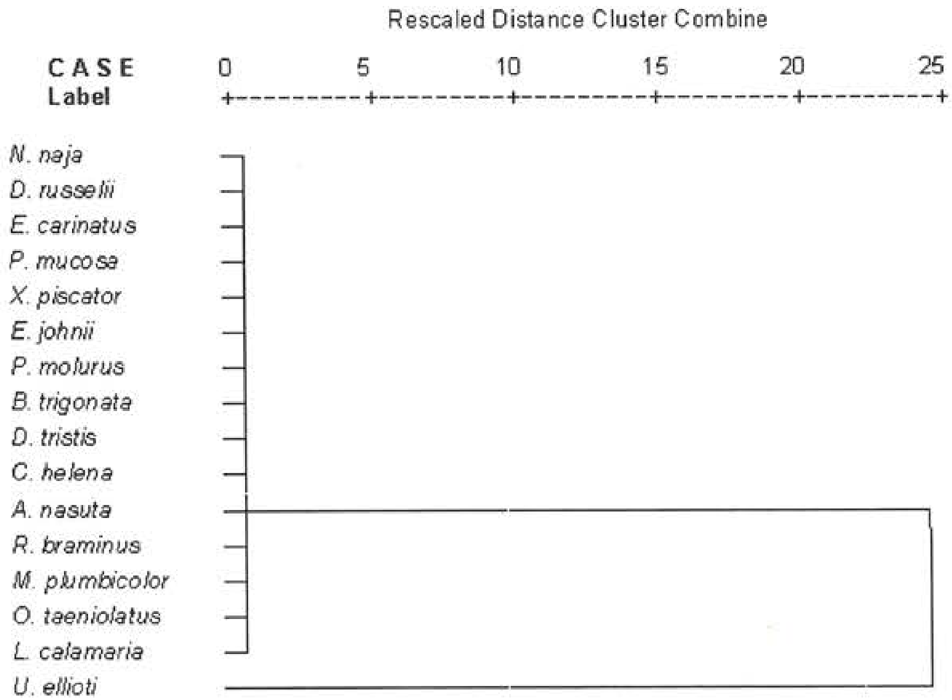
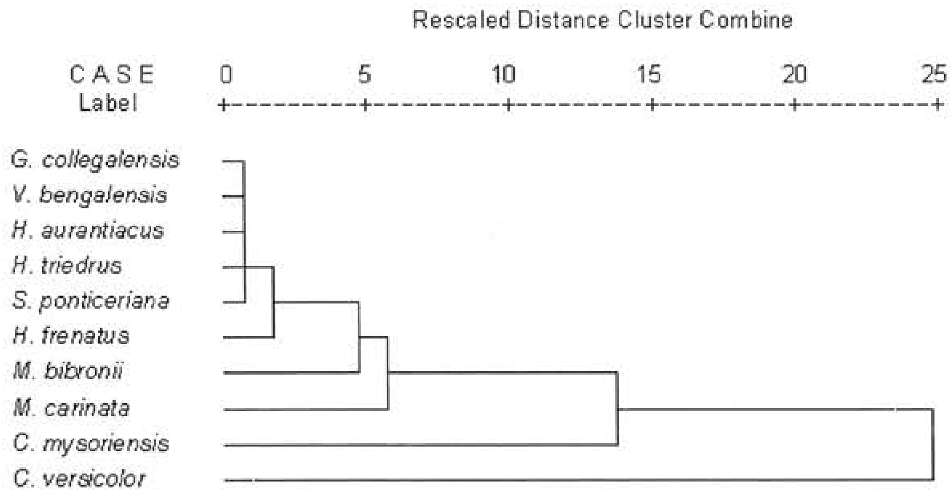


Figure 6.5. Dendrogram based on hierarchical cluster analysis using Single Linkage (nearest neighbour): temporal variations among lizard and snake species of Anaikatty Hills.

a) lizards



b) snakes

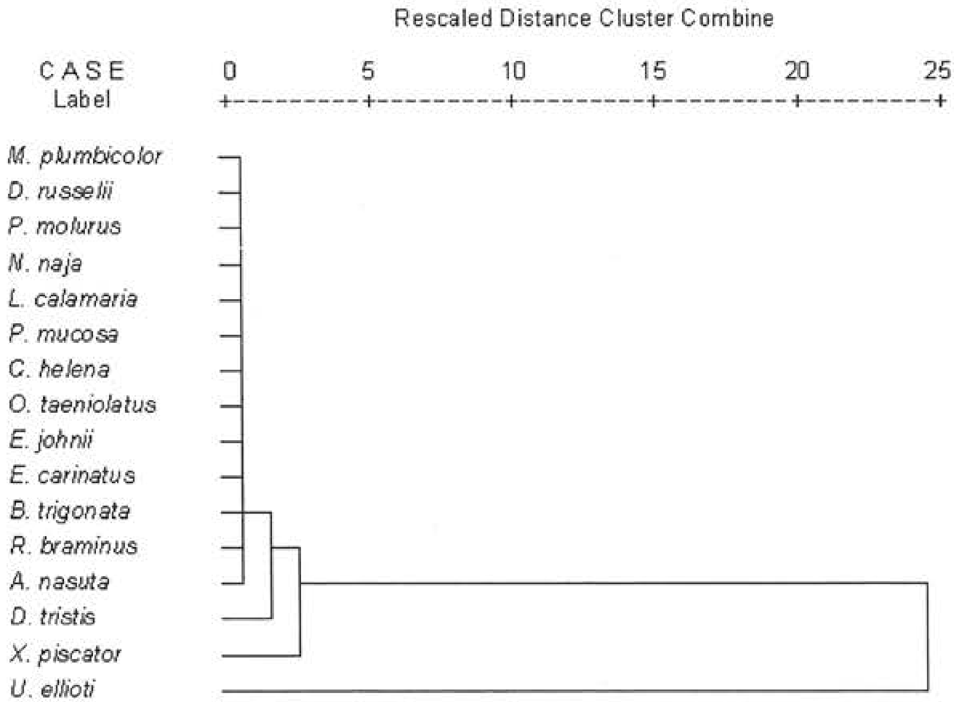


Figure 6.6. Dendrogram based on hierarchical cluster analysis using Single Linkage (nearest neighbour): overall resource utilization of lizard and snake species of Anaikatty Hills.

6.4. DISCUSSION

It is reported that competition is relatively more important in determining the structure of various communities (Menge and Sutherland, 1976; Nudds, 1983). In the present study, a large number of reptile species were recorded, and hence competition among them is expected to be high. Competition may be avoided by variation in resource use at various spatio-temporal levels. Variations in morphometry may also help in reducing competition for similar resource. Variations in morphometry among members of the community may also be helpful in avoiding competition (Pöysä, 1983).

Among all lizards, maximum average niche breadth was obtained by Agamid, *Calotes versicolor*, which indicated that this species is a generalist with respect to the utilization of various resources. Inger *et al.* (1987) reported maximum niche breadth value (2.75) in case of *Calotes rouxii* and *Cnemaspis tropidogaster*. Nixon (2005) reported highest average niche breadth value (4.38) for *Salea horsfieldii* (Agamid) in the Upper Nilgiris. Minimum average niche breadth value (1.00) was obtained by *Mabuya bibronii* which is similar to the observation by Inger *et al.* (1987), where the lowest niche breadth (1.59) was obtained by this species. Low niche breadth in microhabitat and vertical distribution by many species of lizards compared indicates that they are very specific in spatial use compared to temporal use.

The rarity and small sample size with respect to snakes in the field make it difficult to analyze their niche breadth in a given resource category (Inger *et al.* 1987). Among snakes, *Dendrelaphis tristis* obtained the maximum average niche breadth. The broader niche breadth of *Dendrelaphis tristis* indicates utilization of a relatively wider range of resources compared to other species. Minimum average niche breadth value (1.00) of species such as *Macropisthodon plumbicolor* and *Daboia russelii* in the Anaikatty Hills indicate higher specialization of these species. The lowest (1.00) value obtained by several species of snakes (*Uropeltis ellioti*, *Naja naja* and *Daboia russelii*) indicate their specialized utilization of a particular resource such as forest floor. Study pertaining to food habits of reptiles was not covered in the present study. Large number of subterranean species may be seen over ground during high rainfall due to inundation of their burrows. For instance, in the present study, higher number of *Uropeltis ellioti* was observed during October-November (the peak rainfall months). Niche breadth values showed that snakes are relatively more specialists compared to lizards with respect to spatial and temporal resource use in the Anaikatty Hills.

Pianka (1974) reported that when demand for resources is low relative to supply, potential competitors may tolerate a relatively high degree of overlap in resource use. When the demand to supply ratio is high, overlap between species could be low (Rusterholz, 1981). A complete overlap (1.00) with respect to microhabitat and temporal parameters among lizards were not found during this study. This indicates that lizard community in this study area is partially segregated in the utilization of these resources. Only one species pair *Mabuya bibronii and Sitana ponticeriana* had complete overlap with respect to microhabitat. Both species utilized similar microhabitats (i.e. forest floor or open ground). Similar to the present study, Inger *et al.* (1987) reported complete overlap between *Otocryptis beddomii* (Agamid) and *Mabuya macularia* (Scincid) in the Ponmudi Hills, Western Ghats.

Compared to microhabitat and temporal segregation, at vertical layer as many as 29 species pairs had very high overlap ($\phi = 1$, 10 pairs complete overlap; $\phi = 0.75 - 0.99$, 19 with high overlap). This indicates that many species used similar vertical layers. It appears availability of various vertical layers is high compared to use, hence relatively high overlap was found among this layer. It is also found that relatively high overlap was found in one category compared to others.

More lizards showed complete and higher niche overlap with respect to vertical distribution. This is due to similar vertical strata used by several species (ground layer by many species).

Niche overlap pertaining to the temporal level found no complete overlap between any species pairs. This showed distinct seasonal activities among species. Higher temporal overlap between *Calotes versicolor* and *Mabuya carinata* was due to the reason that these species were active year round. Creusere and Whitford (1982) reported that temporal separation of activity reduces intra-specific competition and increases carrying capacity in species for which food is not a limiting resource such as in lizards. The present study augments this view. Eventhough trophic component was not covered in this study; it appears that this may be applicable for the lizards of the Anaikatty Hills. Pianka (1973) remarked that overall niche overlap varied inversely with the lizard species diversity. The higher lizard species diversity in the Anaikatty Hills may be because of most species pairs avoided complete niche overlap value with respect to various spatio-temporal resource axes.

Very few attempts have been made to examine niche relationships among tropical snakes. This is presumably because of a lack of data on habitat and prey. Brown and Parker (1984) reported that in snakes trophic dimension is more important in resource partitioning than the spatial dimension. In the present study, a total of 28 pairs of snakes showed complete niche overlap with respect to various microhabitat used. This is probably because most snakes utilized forest floor or open ground as their main spatial resource. The study on food habits of snakes would have provided further insights in this regard.

Informations on temporal segregation among snakes of tropics (at least in Indian context) are largely unknown because of several reasons associated with their ecology and behaviour (Inger *et al.* 1987; Daniel, 2002). Brown and Parker (1984) reported considerable variation in the emergence of aestivating snakes in Great Basin desert, but this temporal difference in their emergence has largely been attributed to reproductive behaviour and dispersal pattern.

Pianka (1974) reported that species pairs with high overlap in one dimension often show relatively lower overlap in another, which can reduce competition among species. Similar pattern was observed in the present study that, if a species pair having higher or complete overlap on one resource dimension, the same pair showed complete non-overlap or low overlap in other resource dimension. This might have facilitated reptiles of the Anaikatty Hills in segregating varieties of resources that can further enhance coexistence among various species and avoidance of stiff competition for various resources. In contrary to Pianka's (1974) view, Colwell and Futuyma (1971) stated that a high degree of overlap in resource utilization might not prove the existence or non-existence of competition. This is evident when the resource is plenty and not limiting as in the case of using ground by many species in the Anaikatty Hills. Higher overlap values may indicate convergence among species in the use of resources and small values may indicate divergence (Pianka, 1974; Nunez *et al.* 1989). The present study provides baseline informations on niche overlaps among various reptiles of dry forests. Future research on this aspect including trophic component would provide further insights in this regard.

Hutchinson and MacArthur (1959) reported that larger bodied species may require more space compared to smaller bodied ones. As resources are always limited natural selection may support fewer larger bodied species in an animal community. An individual's living space generally increases with increasing body mass. Hence, nature might have favoured many smaller species. Occurrences of a large number of smaller sized species both in snakes and lizards in the Anaikatty Hills augment this view. May (1986) and Griffiths (1986) reported that most of the communities contain smaller bodied species than large ones. May (1978) compiled a rough estimate of the overall number of species of terrestrial animals as per function of their physical size, the result showed a very large number of small arthropods and remarkable rarity of large animals. Fowler and Mac Mahon (1982) stated that extinction rate will be higher among species with low evolutionary plasticity, which may be true for species with long generation times. Since body size positively correlated with generation time, large bodied species will tend to have higher extinction rates than smaller bodied species, while greater evolutionary plasticity is a property of smaller species; with shorter generation rate even speciation will be higher in smaller bodied species Begon *et al.* (1996a and b). Warren and Lawton (1987) and Dixon *et al.* (1995) suggested that size difference among various species explain spatial as well as trophic niche partitioning among them.

Morphometry of a species often provide reasonably accurate information regarding its habits, microhabitat use and even prey size preference (Pianka, 1986; Herrel *et al.* 2002). A long prehensile tail, thin (reduction of body mass) long body, cryptic colouration and even visual acuity may be helpful to distinguish a scansorial or arboreal snake from others (Lillywhite and Henderson, 1993; Cloudsley-Cloudsley-Thompson, 1999). In the present study the ratio of TL/SVL in the arboreal snakes ranged from 0.36-0.66, while 0.10-0.33 showed semi-arboreality and0.01–0.09 considered as ground dweller. The spatial resource partitioning by snake species according to their habits might have helped in reduction of intra and inter specific competition among various species in the Anaikatty Hills.

The ratio of TL/SVL may show some indication of arboreality in the case of snakes. In the case of lizards, this ratio may be misleading, as other modifications such as development of lamellae, sharp claws and dorsolaterally compressed body are available. Longer tail may be useful for balancing in fast moving terrestrial as well as arboreal lizards. These features (lamellae, sharp claws) may provide better indication of arboreality among lizards (Cloudsley-Thompson, 1999; Pough *et al.* 1998) compared to tail length – snout length ratio. Higher ratios obtained by *Sitana ponticeriana* and *Calotes calotes* clearly indicate that this ratio is not a proper one to indicate arboreality in lizards. The former species is a ground dweller and the later species largely inhabits arboreal microhabitats. Hence, other than tail length and body length, other factors play major role in deciding arboreality in lizards. However, with snakes having no such morphological features, the TL/SVL ratio may provide better indication of their arboreality.

Species packing is variously defined by different authors in terms of the number of species that can be accommodated per unit volume of the resource space (MacArthur, 1970; Roughgarden, 1974; Roughgarden and Feldman, 1975; Rappoldt and Hogeweg, 1980; Putman and Wratten, 1984; Tokeshi, 1999). The maximum tolerable overlaps among various species in the community have been shown to depend on the number of species in the community and the pattern of species packing (Putman and Wratten, 1984).

A very diverse use of microhabitats by the Agamid lizard *Calotes versicolor* made this species to be separated from the major cluster in the present analysis. Nixon (2005) reported that in the Upper Nilgiris the Agamid species *Salea horsfieldii* used several microhabitats and formed a separate cluster as in the case of *Calotes versicolor* in this study. Formation of such distinct cluster may indicate that species such as *Calotes versicolor* and *Salea horsfieldii* was broader in their resource requirements compared to other species. Distinctness in species packing among *Mabuya carinata*, *Cnemaspis mysoriensis* and *Hemidactylus frenatus* may indicate variation in microhabitat use by these species in the present study. Close species packing among several species such as *Geckoella collegalensis*, *Mabuya bibronii*, *Varanus bengalensis*, *Sitana ponticeriana* and *Hemidactylus triedrus* is because of their similarity in microhabitat requirements.

Separation of Calotes versicolor and *Mabuya carinata* from the main cluster with respect to vertical distribution may reveal utilization of distinct vertical positions by these two taxa in the present study. Brown (1992b) reported variations regarding use of vertical positions by juvenile and adult *Calotes versicolor*, and stated that adults were more arboreal. The distribution of *Calotes versicolor* in wider vertical strata (0 to 350cm) may depend on several factors such as food, thermoregulatory needs and territoriality as reported by Shanbag (2003) and Radder (2006) in lizards. Compact packing among species such as *Mabuya bibronii*, *Geckoella collegalensis*, *Sitana ponticeriana* and *Hemidactylus triedrus* is due to utilization of forest floor or open ground by all these species.

Distinctness of a few species *Calotes versicolor*, *Mabuya carinata* and *Cnemaspis mysoriensis* compared to the remaining species in temporal level may be because of the year round activity of these species in the Anaikatty Hills. While close grouping of the remaining species may indicate their higher activity in same months.

The early separation of *Xenochrophis piscator* from the main cluster with respect to microhabitat use among snakes indicates distinct spatial resource requirement of this species. This species mostly used water bodies, whereas closeness of *Ramphotyphlops braminus*, *Uropeltis ellioti* and *Eryx johnii* could be because of their similar microhabitat usage. On the other hand compact packing of *Ahaetulla nasuta*, *Dendrelaphis tristis* and *Boiga trigonata* is due to their usage of arboreal microhabitats. Brown (1992b) reported tight clustering between *Ahaetulla nasuta* and *Dendrelaphis tristis* since both species were observed to use arboreal microhabitats.

Species packing of various snakes with respect to the utilization of vertical positions mostly showed loose packing, whereas compact packing was found among few species with respect to the utilization of similar vertical positions. Closeness in the clustering of the *Ramphotyphlops braminus*, *Uropeltis ellioti*, *Oligodon taeniolatus* and *Macropisthodon plumbicolor* may be because of the utilization of almost similar vertical strata, all are ground dwelling species. Roughgarden (1974) pointed out that the closeness in species packing with respect to various clustering depends upon the supply or availability of resources. He reported that while the supply of resources is low, species might show close packing, this could be probably due to the competition for a particular resource type. Roughgarden (1974) further stated that if the supplies of resources were far above the utilization, species package would never become compact. In the present study several species showed compact clustering with respect to some resource parameters, but loose with respect to other respect. Overall species assemblage (packing) shows that species packing with respect to all resource categories is compact (Figure 6.6a & b).

Nixon (2005) reported that volatile environment (ex. Upper Nilgiris) tend to prevent the formation of distinct guilds. Inger and Colwell (1977) reported that area with greater species richness in a more predictable environment may show formations of distinct guilds. Nixon (2005) concluded that vacant niches in the Upper Nilgiris may be occupied by the colonization of invading species, but this may not be applicable in the present study as overall clustering (species packing) is tight. Brokaw (1985), Sagar and Singh (2005) and Fernando *et al.* (2006 in Press) reported that due to high anthropogenic pressures during past several decades the dry deciduous forest cover in most part of the central India is being converted into dry scrub lands, which became progressively species poor. However, the higher reptile diversity in the present study area may be because of persisting low anthropogenic activities and contiquity to plains might have offered opportunities for new niches resulting in higher species richness.

6.5. SUMMARY

- Resource utilization by reptiles at spatial (microhabitat and vertical layers) and temporal (monthly activity) level was studied in the Anaikatty Hills, analyzing aspects of morphometry, niche parameters and species packing.
- Among lizards, *Calotes versicolor* and *Hemidactylus frenatus* showed maximum average niche breadth indicating their generalist nature with respect to spatio-temporal utilization. In snakes, *Boiga trigonata* and *Dendrelaphis tristis* were more generalists compared to other species.
- Among lizards, minimum average niche breadth was obtained by most of the skinks indicating their specialist nature. Most of snake species were specialized in their resource use.

- Lizards showed low overlap compared to snakes with respect to microhabitat and vertical position used.
- Ratio between tail length and snout-vent length shows the suitability of this analysis to assign arboreality in snakes, which is not useful in lizards.
- Clustering with respect to microhabitat use and vertical distribution showed compact species packing. In the case of lizards, species packing was more compact than snakes. The clustering with respect to temporal scale showed loose species packing. This indicates that when there is high overlap (similarity) in resource use in one category, the other resource would have low overlap. Overall the species packing in the present study area indicates close (tight) packing.
- Prevailaing low intensity anthropogenic activities and contiquity of the area with adjacent plains might have offered opportunities for new niches, which resulted in high species diversity.

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a

b

Plate 1 (a). A view of Tropical Dry Mixed Deciduous forest in Anaikatty Reserve Forest.
(b) The State Highway (No 63) cutting across Anaikatty forest (Road transect).

Plate 2. Some venomous snakes of Anaikatty Hills,
(a) *Naja naja*, (b) *Calliophis nigrescens*, (c) *Daboia russelii*.

Plate 3. Some common non-venomous snakes of Anaikatty Hills, (a) *Macropisthodon plumbicolor*, (b) *Ptyas mucosa*, (c) *Oligodon taeniolatus*.

a

b

Plate 4. Representatives of Agamid lizard (a) *Calotes calotes* and Geckkonid lizard (b) *Geckoella collegalensis*.

Appendix I: Checklist of the reptiles of the Anaikatty Hills, Western Ghats.

Sl. No.	Family	Species
1	Bataguridae	*Melanochelys trijuga trijuga*
2	Agamidae	*Calotes versicolor*
3		*Calotes calotes*
4		*Calotes ellioti*
5		*Psammophilus blanfordanus* •
6		*Sitana ponticeriana*
7	Gekkonidae	*Cnemaspis anaikattiensis* *
8		*Cnemaspis mysoriensis*
9		*Cnemaspis yercaudensis*
10		*Cnemaspis sp.*
11		*Geckoella collegalensis*
12		*Hemidactylus brookii*
13		*Hemidactylus frenatus*
14		*Hemidactylus leschenaultii*
15		*Hemidactylus maculatus*
16		*Hemidactylus triedrus*
17		*Hemiphyllodactylus aurantiacus*
18	Scincidae	*Lygosoma punctata*
19		*Mabuya beddomei*
20		*Mabuya bibronii*
21		*Mabuya carinata*
22		*Mabuya macularia*
23	Lacertidae	*Ophisops leschenaultii*
24	Chamaeleonidae	*Chamaeleo zeylanicus*
25	Varanidae	*Varanus bengalensis*
26	Typhlopidae	*Ramphotyphlops braminus*
27	Uropeltidae	*Uropeltis ellioti*
28	Boidae	*Eryx conica*
29		*Eryx johnii*
30		*Python molurus molurus*
31	Colubridae	*Ahaetulla nasuta*
32		*Ahaetulla pulverulenta*
33		*Argyrogena fasciolatus*
34		*Boiga beddomei*
35		*Boiga forsteni*
36		*Boiga nuchalis*

37		*Boiga trigonata*
38		*Oligodon arnensis*
39		*Oligodon taeniolatus*
40		*Chrysopelea ornata*
41		*Dendrelaphis tristis*
42		*Dryocalamus nympha*
43		*Coelognathus helena*
44		*Liopeltis calamaria*
45		*Lycodon aulicus*
46		*Lycodon flavicollis* *
47		*Lycodon travancoricus*
48		*Macropisthodon plumbicolor*
49		*Ptyas mucosa*
50		*Sibynophis subpunctatus*
51		*Xenochrophis piscator*
52	Elapidae	*Bungarus caeruleus*
53		*Calliophis nigrescens*
54		*Naja naja*
55	Viperidae	*Daboia russelii*
56		*Echis carinatus*
57		*Trimeresurus gramineus*
58		*Hypnale hypnale*

* New species described from Anaikatty Hills.

Appendix II: Data on snout vent length (SVL in mm) of lizards observed in Anaikatty Hills.

Sl. No.	Species	n	Max	Min	Average
1	*Calotes versicolor*	25	110	32	83.04
2	*Calotes calotes*	5	104	90	96.33
3	*Psammophilus blanfordanus*	15	100	80	91.25
4	*Sitana ponticeriana*	15	45	38	40.83
5	*Cnemaspis anaikattiensis*	2	61	58	80.00
6	*Cnemaspis mysoriensis*	25	34	20	29.16
7	*Geckoella collegalensis*	20	46	28	37.05
8	*Hemidactylus brookii*	15	45	30	40.13
9	*Hemidactylus frenatus*	15	57	40	46.33
10	*Hemidactylus leschenaultii*	5	95	60	73.80
11	*Hemidactylus maculates*	17	115	70	97.29
12	*Hemidactylus triedrus*	23	85	20	53.39
13	*Hemiphyllodactylus aurantiacus*	15	36	24	29.60
14	*Lygosoma punctata*	5	85	70	76.40
15	*Mabuya beddomei*	2	55	50	52.50
16	*Mabuya bibronii*	12	60	40	51.58
17	*Mabuya carinata*	22	112	43	78.04
18	*Mabuya macularia*	18	70	54	61.11
19	*Chamaeleo zeylanicus*	20	200	30	134.15
20	*Varanus bengalensis*	14	260	150	211.07

Appendix III: Data on snout vent length (SVL in mm) of snakes observed in Anaikatty Hills.

Sl. No.	Species	N	Max	Min	Average
1	*Ramphotyphlops braminus*	12	125	60	102.58
2	*Uropeltis ellioti*	32	434	107	271.18
3	*Eryx conica*	1	370	0	---
4	*Eryx johnii*	10	1090	305	758.00
5	*Python molurus*	13	2812	565	1816.40
6	*Ahaetulla nasuta*	16	1523	268	767.06
7	*Ahaetulla pulverulenta*	3	957	645	788.00
8	*Argyrogena fasciolatus*	4	650	197	396.75
9	*Boiga beddomei*	4	640	386	519.00
10	*Boiga forsteni*	5	1170	410	741.00
11	*Boiga nuchalis*	2	325	64	194.50
12	*Boiga trigonata*	4	445	210	315.00
13	*Oligodon arnensis*	3	540	440	480.00
14	*Oligodon taeniolatus*	25	440	120	292.15
15	*Chrysopelea ornate*	3	740	700	723.33
16	*Dendrelaphis tristis*	16	1300	330	748.18
17	*Dryocalamus nympha*	4	343	40	217.00
18	*Coelognathus Helena*	9	900	200	587.00
19	*Liopeltis calamaria*	7	270	158	222.42
20	*Lycodon aulicus*	9	464	180	358.00
21	*Lycodon flavicollis*	5	440	265	348.00
22	*Lycodon travancoricus*	2	400	330	365.00
23	*Macropisthodon plumbicolor*	9	600	140	333.44
24	*Ptyas mucosa*	10	1840	995	1646.50
25	*Sibynophis subpunctatus*	10	420	130	256.30
26	*Xenochrophis piscator*	5	678	280	475.00
27	*Bungarus caeruleus*	3	660	280	490.00
28	*Calliophis nigrescens*	2	680	660	670.00
29	*Naja naja*	10	1010	250	702.80
30	*Daboia russelii*	5	1027	214	524.40
31	*Echis carinatus*	15	316	145	241.33
32	*Trimeresurus gramineus*	4	730	300	465.00
33	*Hypnale hypnale*	3	364	257	294.66

Appendix IV:

A new species of day gecko (Squamata, Gekkonidae, *Cnemaspis*) from the Anaikatti Hills, Western Ghats, Tamil Nadu, India

Cnemaspis Strauch, 1887, one of the major groups of diurnally active gekkonid members was listed under the family Sphaerodactylidae[1,2]. However, it was considered as subfamily Sphaerodactylinae by a section of taxonomists[3]. Currently, 41 species of *Cnemaspis* have been reported from Asia, including 19 from India[4–8], and 16 from the Western Ghats[8]. The Anaikatti Hills (11°05'30.9" N and 76°47'36.2"E), Western Ghats, is a part of the Nilgiri Biosphere Reserve located in Tamil Nadu, South India. This Ghats range is one of the 25 recognized biodiversity hotspots of the world[9]. Being located on the eastern slope (~600 m asl), the climate of Anaikatti Hills is semi-arid with temperature soaring up to 40°C during summer, and the annual rainfall hardly exceeds 650 mm. The forest type of the area is Southern Mixed Dry Deciduous[10]. Ongoing field studies by Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore in the area yielded 11 species of geckoes, including the present new species of *Cnemaspis* gecko. Geckoes were photographed in life and measured[8] and fixed in 6% formaldehyde. Measurements were taken using Mitutoyo vernier callipers (accuracy 0.01 mm) following Bauer[8]. Taxonomic features of the new species are compared with other congeners known from peninsular India[3–6,8,11].

Cnemaspis anaikattiensis sp. nov. Holotype: ZSI 25601, Zoological Survey of India (ZSI), Kolkata. Adult male, snout-vent length (SVL) 61 mm, tail length (TL) 58 mm, Anaikatti Hills (11°05'30.9"N and 76°47'36.2"E), Western Ghats, Coimbatore district, Tamil Nadu, India. Collected by A.M.A. Nixon and Debanik Mukherjee, 17 September 2003. Paratype: ZSI 25602, female, data as above. Measurements of the specimens are given in Table 1.

Diagnosis: *C. anaikattiensis* (Figure 1 *a*, *b*) is diagnosable from its congeners by the following combination of characters: A large day gecko (SVL 61mm) with circular pupil, flanks without spine like tubercles, nostril in contact with the first supralabial, postmentals three pairs – scales of first pair separated by three small interscales, dorsal scales heterogeneous intermixed with enlarged tubercles, both dorsal and ventral scales of the body smooth, midventral scales in 26–27 rows and lamellae under IVth digit is 16.

The holotype (adult male) measured 61 mm in SVL and 58 mm in TL (regenerated) and the paratype (female) measured 58 mm (SVL) and 58 mm (TL), head large and distinct from the neck, rostral broader and partially divided by a cleft or rostral groove, pupil circular, orbits with extra-brillar fringes, scales on the anterior part of fringes longer but fragmented, supraciliaries merge with extra-brillar fringes, two pairs of supranasals, the anterior one longer than wide and in contact with nostril and rostral, anterior supranasals divided by an internasal, 2–3 postnasals-bound nostril, nostril in contact with first supralabial, 6–7 supralabials, 8–9 infralabials, first supralabial broader and longer than the rest, 2–3 rows of scales separate eye from supralabials, granular scales on the snout larger than that present on the dorsum of the head, ear opening oval, mental subtriangular, broad, three pairs of postmentals, first two pairs larger than the third one, first pair divided transversely by three small interscales and postmentals in contact with infralabials.

Body stout, flanks without any projecting spine-like tubercles, dorsal scales heterogeneous – with enlarged, pointed and conical tubercles intermixed with small scales, tubercles on the flanks and hinder part of the body larger than the adjacent ones, dorsal scales increase in size from mid-dorsum to the lateral parts, scales on the dorsum at the mid-body smaller than those of ventrum at same level, ventral scales smooth and imbricate, gular scales granular and smaller than the pectoral scales and anterior pectoral scales smaller than the abdominal ones. Scales on palm and sole smooth, variable in size, inner surface of the limbs with smooth and weakly imbricate scales, scales on dorsal surface of thigh, tibia, upper and fore arms mostly smaller, flattened, smooth and intermixed with a few comparatively larger conical scales, interdigital webbing absent. Base of the first digit of manus and pes with three enlarged entire subdigital scansors, others with two interphalangeal plates not much enlarged. Relative length of the digits in manus IV (6 mm), III (5.5 mm), V (5 mm),

Table 1. Measurements (mm) of holotype* and paratype of *Cnemaspis anaikattiensis* sp. nov.

Measurement (mm)	ZSI 25601*	ZSI 25602
Snout-vent length (SVL)	61	58
Tail length (TL)	58	58
Tibia length (TBL)	11	11
Tail width (TW)	7.5	7
Head length (HL)	11	10
Head width (HW)	9	9
Head depth (HD)	7	6
Ear length (EL)	1.5	1.5
Forearm length (FA)	10	10
Eye diameter (ED)	3.5	3.5
Eye-to-nostril distance (E–N)	5.5	5.5
Eye-to-snout distance (E–S)	7	7
Eye-to-ear distance (E–E)	5	5
Distance between nares (IN)	2	2
Inter orbital snout distance (IO)	5	5
Distance from axilla to groin (A–G)	29	28
HL/SVL	0.18	0.17
HW/SVL	0.15	0.16
HD/HL	0.64	0.60
E–S/HW	0.78	0.78
ED/E–S	0.5	0.5
ED/HL	0.32	0.35
EL/HL	0.14	0.15
E–E/ED	1.43	1.43
A–G/SVL	0.48	0.48
FA/SVL	0.16	0.17
TBL/SVL	0.18	0.19

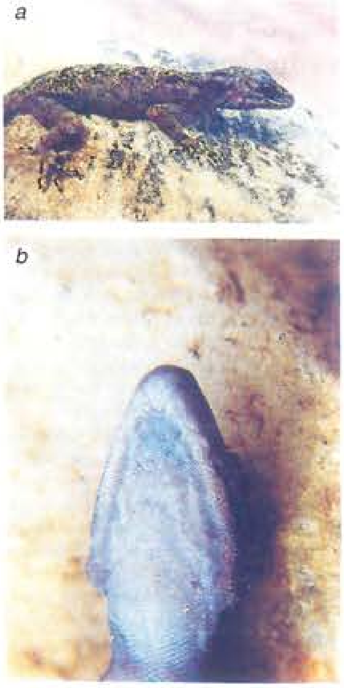

Figure 1. *a*, *Cnemaspis anaikattiensis* in life (ZSI 25601) showing enlarged heterogeneous tubercles and general colouration. *b*, *C. anaikattiensis* showing mental and chin shields arrangements.

II (4.5 mm), I (3.5 mm) and pes IV (7 mm), III (6.5 mm), V (6 mm), II (4.5 mm), I (4 mm). Dorsal scales of the tail flattened, smooth, weakly imbricate, a few mid dorsal scales little enlarged, subcaudals smooth with wide single or paired (divided) plates as in *C. heteropholis*[8] and post-cloacal spur absent. Males differ from females in having 7–8 femoral pores on either side and enlarged preanal scales. Preanal pore or groove is absent in this species.

Colour (in life): Head and dorsum brown with dark spots, vertebral part with yellowish white patches, larger tubercles yellowish, 2–3 black stripes between eye and ear opening, digits with alternating dark and light bands and ventral scales greyish-white.

Etymology: *C. anaikattiensis* is named for the type locality, the Anaikatti Hills, Western Ghats, Coimbatore, Tamil Nadu, southwestern India.

Comparison: Indian *Cnemaspis* geckoes were divided into two groups[11], one having flanks with spine-like projecting tubercles (*C. jerdonii* group) and the rest without spine-like projecting tubercles (*C. indica* group). Of the 19 *Cnemaspis* species reported so far from India, 18 are found in Peninsular India, and among them 10 belong to the latter group. *C. anaikattiensis* belongs to *C. indica* group and differed from other members by possessing smooth (unkeeled) dorsal scales, excepting perhaps *C. yercaudensis* and *C. nairi*. Males of *C. sisparensis*, *C. heteropholis*, *C. wynadensis*, *C. indica* and the new species lack preanal pore or groove, whereas the rest of them have the same.

C. anaikattiensis (superficially) appears similar to *C. sisparensis* and *C. heteropholis* of the Western Ghats. The holotype of *C. sisparensis* (Theobald) [= *Gonatodes bireticulatus*] Annd. collected by F.H.Gravely from 'Kavalai, 1300–3000 ft, Cochin State' ZSI 17970, Zoological Survey of India, Kolkata was examined. Additional taxonomic characters include: no internasal scale in *C. sisparensis* (vs presence in the new species), nostril not in contact with first supralabial (vs in contact in *C. anaikattiensis*), gular and ventral part pigmented, brick-red in preservative in *C. sisparensis* (vs unpigmented). The recently erected *C. heteropholis*[8] differs in supranasals in contact (vs separated by an internasal in *C. anaikattiensis*), nostril not in contact with first supralabial (vs in contact) and keeled scales on the dorsal surface of thigh, tibia, upper and fore arms in *C. heteropholis* (vs smooth). *C. heteropholis* is reportedly most similar to *C. sisparensis*[8].

In addition, *C. sisparensis* and *C. heteropholis* are reported only from high rainfall areas (annually ~ 2000 mm), such as tropical evergreen forest compared to the record of the new species from mixed dry deciduous forest with scanty rainfall (600 mm). Similar to *C. anaikattiensis* and *C. heteropholis*, species with heterogeneous scalation might also be expected from other parts of the Western Ghats (A. M. Bauer, pers. commun.). Till mid 70s, 11 species of *Cnemaspis* have been reported from India[11,12]. Among them distribution data for *Cnemaspis boei* (Gray, 1842)[7] are lacking, and since then five new *Cnemaspis* species have been described from the Western Ghats[4,5,8]. The taxonomy of *Cnemaspis* geckoes is poorly understood[8], and further intensive surveys in the Western Ghats would result in more new species.

C. anaikattiensis is a fast-moving diurnal gecko, largely active during dawn and dusk. It inhabits rocky streambeds in the tropical dry deciduous forest. Fieldwork covering all seasons of the year yielded only four individuals, and it appears that this species is solitary. *Hemidactylus maculatus*, *H. frenatus*, *H. brookii*, *H. triedrus*, *Hemiphyllodactylus aurantiacus* and *Geckoella collegalensis* are common and sympatric with the new species in Anaikatti Hills.

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Appendix V:

VORIS, H. K. 2000. Maps of Pleistocene sea levels in southeast Asia: shorelines, river systems and time durations. *J. Biogeogr*, 27: 1153-1167.

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Uropeltis ellioti in the diet of *Naja naja*

As a part of the biodiversity monitoring of Anaikatty Hills, being undertaken by the Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore, we are conducting investigations on the herpetofauna since 2001. Anaikatty (11° 05′30.9"N; 76° 47′36.2E") is a part of the Western Ghats hill range, and is also in close proximity to the Eastern Ghats. The forest type of this area is tropical dry deciduous (Champion and Seth, 1967), but is largely in a degraded state due to anthropogenic activities such as agriculture and the brick industry. The hills facing east and contiguous to the plains are covered with tropical thorn forest (scrub jungle).

On 29 October 2003, at 1400 h, we were informed of a dead snake adjacent to the SACON campus on the Coimbatore- Anaikatty State Highway Road, which was run over by a vehicle, and was a juvenile *Naja naja*. Closer examination revealed that the cobra had swallowed a *Uropeltis ellioti*, as the tail of the prey was protruding out of the cobra's mouth. *N. naja* is known to feed on a variety of prey species. According to Whitaker (1978), juveniles feed on insects, lizards, amphibians and snakes, while larger individuals prefer rodents, amphibians and birds. This species is also known to feed on the eggs and chicks of birds (Wüster, 1998; Daniel, 2002). Das (2002) reported fish in the diet of *N. kaouthia* and *N. naja* in India.

Ophiophagy is reportedly common in *Ophiophagus hannah*, *Bungarus* and *Maticora*, and occasional in other species such as *Ptyas*, *Ahaetulla*, *Dendrelaphis*, *Elaphe* and *Naja* (Daniel, 2002). This is perhaps the first record of an uropeltid being taken as prey by *Naja naja*. It is impossible to conclude from this single incident how important these snakes are in the diet of a cobra. The present observation indicates that both the predator and prey species were active during the day. Uropeltid snakes are reportedly nocturnal, but may be found active during day hours during the rainy season (Rajendran, 1985).

Total length of the dead cobra and its prey measured 406 mm and 418 mm (snout-vent length 406 mm, tail length 12 mm), respectively. As Smith (1935) recorded the total length of *U. ellioti* as 250 mm and Rajendran (1985) reported 247 mm (snout-vent length 234 mm, tail length 13 mm), the present record is the highest recorded length reported for this species. The impact of road traffic on the herpetofauna is poorly documented in this region. A study on the herpetofaunal mortality due to road traffic in Anamalai Hills, Western Ghats by Vijayakumar et al. (2001) showed that more than 80% of the road kills comprised snakes. Studies on similar lines would provide us further insights in designing roads and traffic that pass through wildlife habitats.

We thank the Tamil Nadu Forest Department and Director, SACON for providing facilities and support our herpetofaunal studies in Anaikatty Hills.

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Duration of meiosis and spermiogenesis in *Euphlyctis cyanophlyctis* (Schneider, 1799)

(with one text-figure)

The duration of meiosis and spermiogenesis in *Euphlyctis cyanophlyctis* as estimated autoradiographically by following the progression of labelled spermatocytes from the onset of meiosis till the formation of radioactive spermatozoa. 34 mature males were collected all at a time in June from Duillya, Howrah, West Bengal. Following a 3 day acclimatization in a glass aquarium of the laboratory each was injected intraperitoneally with 5 μCi of ^{3}H- thymidine (sp.act. 9.00 mCi/mM; Bhaba Atomic Research Centre, Trombay, Mumbai, India). The testes of frogs, killed at intervals covering a period from 0.42 d. to 25.00 d. post injection, were collected. Both histological and squash preparations were made, stained with delafield haematoxylin and 2% aceto-orcein respectively, autoradiographed with Kodak AR-10 stripping film (Ghosal et al., 1993) and most advanced radioactive stages were recorded (Table 1). Specific activity of ^{3}H-thymidine is low enough not to inflict radiation jnjury, nor any alteration in the meiotic cycle. Vertebrate permatocytes, unlike mitotic

Appendix VI:

National Workshop on

Biodiversity Resources Management and Sustainable Use

Edited by :

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2004

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SNAKE DIVERSITY OF THE ANAIKATTI HILLS, WESTERN GHATS, INDIA

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INTRODUCTION

Serpentes, one of the three suborders of the order Squamata, includes only snakes, a widely known and much misunderstood group. Globally over 3300 species, 357 genera, and 12 families of snakes are reported so far, and are found in almost in all regions excepting colder regions such as Arctic. Snakes have adapted to diverse ecological conditions and have predominantly colonized the warmer, densely vegetated areas of the tropics. Herpetofauna of India is one of the most diverse and poorly known in terms of their ecology (Inger et al.1987). The Western Ghats is an important biogeographic zone of India, especially with respect to reptiles as it is one of the richest centers of endemism possessing over 50% of the endemic species. Available information on the Indian reptiles especially the Western Ghats forms are largely on taxonomy and distribution (Smith, 1943; Das, 1997; Daniel, 2002). A total of 274 species of snakes have been reported from India (Das, 2003). They are distributed in 10 families, and Colubridae contributes the maximum (153 species) followed by Uropeltidae (31 species). Information on the distributional patterns of Indian snakes is scanty and studies dealing with monitoring or trend of them are limited. Reptiles are both quantitatively and qualitatively important components of food webs of any given ecosystem. The present paper, we describe the snake species diversity of Anaikatti Hills based field studies on monthly basis from June 2002 to June 2004. Brief notes on survey methods and snake community of the location are also given.

METHODOLOGY

Study Area

The present study was conducted in 44.5 sq km forests of the Anaikatti Hills (11° 05'30.9" N 76° 47'36.2" E), Western Ghats. It is a part of the Nilgiri Biosphere Reserve coming under the Coimbatore Forest Division, Tamil Nadu. Average altitude of the area is about 650 m ASL. Semi-arid climate with soaring temperature up to 40°C during summer, and poor rainfall (650 mm/ year) are the characteristics of this area. Major forest type of the area is Southern Mixed Dry Deciduous (Champion and Seth, 1968). Human settlements and agriculture affect the eastern slope of this hill.

Field Methods

Herpetofaunal sampling protocols are largely untested in the Oriental region. Sampling snakes are difficult as they are secretive, cryptic and are largely active during night. Long period of their inactivity (hibernation or aestivation) and low population densities make the sampling further complicated. Therefore, in the present paper, we used several methods for data collection, including Transect, Quadrat, Visual encounter survey and Road cruising (Heyer et al. 1994). Opportunistic observations of the snakes were also included in the overall analysis.

RESULTS AND DISCUSSION

Suitability of Methods

A total of 180 snakes belonging to 31 species were observed during this study. Of them, 77 individuals were observed opportunistically. Among all methods used, the road cruising yielded the maximum number of species and individuals (Table 1). Data from road cruising largely depend on road traffic density, activity of the snakes and scavenging animals. For instance, fast moving species such as the Indian cobra, *Naja naja* and Indian rat snake, *Ptyas mucosus* are likely to move quickly escaping the vehicle hit compared to slower ones (eg. Shieldtail snake, *Uropeltis ellioti*). Number of sightings of snakes was poor in Transect, Quadrat and Visual encounter sampling, and this could be due to the rarity, sensitivity to disturbance and escape capability of the species. It appears that keeping opportunistic records is essential for making an inventory of snakes, and extensive filed sampling for longer duration using various techniques to make conclusive statement on the snake diversity of an area.

Table 1. Snake species observed in Anaikatti Hills using various sampling methods

Sampling method	Sampling effort	No. of species observed	No. of individuals observed
Transect (km)	192	3	5
Visual encounter survey (hr)	576	3	4
Quadrat (ha)	19.2	0	0
Road Cruising (km)	384	22	94
Opportunistic observations	-	23	77
Total	-	31	180

Table 2. Taxonomic segmentation of snakes recorded in Anaikatti Hills No. in paranthesis is No. of Snakes rom the species reported entire Western Ghats

Family	Genus	Species	No. of individuals observed
Typhlopidae	1 (2)	1(5)	8
Uropeltidae	1(7)	1(31)	42, endemic taxa
Boidae	2 (2)	3 (3)	12
Colubridae	14 (20)	20 (41)	98
Elapidae	2 (4)	2 (6)	6, venomous taxa
Viperidae	4 (5)	4 (8)	14, venomous taxa
Total	24	31	180

Fig. 1. Monthly snake species richness observed in Anaikatti Hills

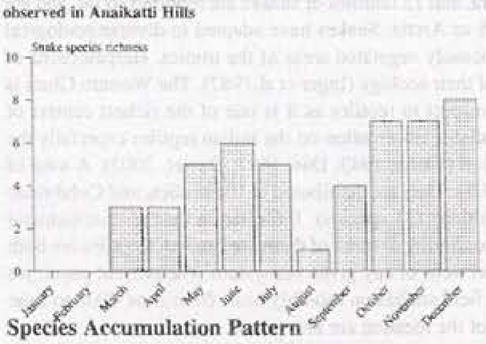
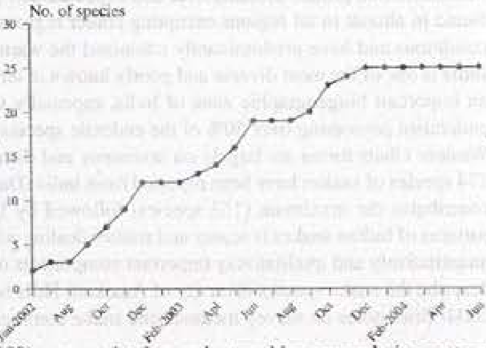


Fig. 2. Snake species accumulation pattern in Anaikatti Hills



Species Accumulation Pattern

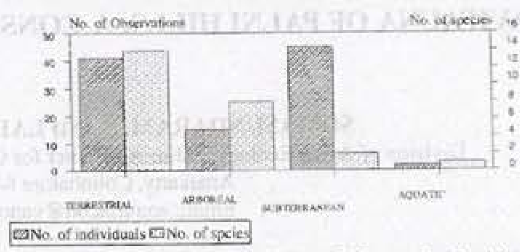
The accumulation rate of new species (Ugland *et al.* 2003) was used to know the trend in accumulation pattern of snakes over sampling effort on monthly basis. Detection of species using various methods (excepting opportunistic observations) revealed a steady accumulation of species over time. No additional species was observed from December 2003 to date, and an asymptote was arrived and maintained (Fig.2). This indicates that only 25 species could be detected using the set of methods followed in the present study. Additional (new) methods may be required to obtain samples other species (at least 6 more species), which were observed opportunistically. It is likely that these missing species may be rare or occupy the habitat marginally (edge species).

Snake Community

A community is composed of all organisms that live together in a particular habitat. The organization of communities and assemblages of tropical vertebrates continue to be poorly understood, although recent studies have shown that various factors including competition and predation play important roles in shaping communities. Number of species and individuals observed during regular surveys was used in the present analysis. The snake community of the Anaikatti Hills may be placed under four broader categories; terrestrial, arboreal, subterranean and aquatic (Fig.3). Most of the snake species (14 species -56% and 41 individuals) observed were terrestrial and were largely ground dwelling. Of the eight (32%) arboreal species, the green vine snake (Ahaetulla nasutus) was most common. Subterranean forms consisted of Shieldtail snake (Uropeltis ellioti) and worm snake (Ramphotyphlops braminus). The water bodies were occupied by only one species (Xenochrophis piscator).

Factors influencing herpetofaunal diversity are largely unknown, which may include differences in litter productivity (Inger, 1980) and moisture regime (Duellman, 1978). The diversity is often regarded as a measure of the richness of the species in a community or biome. Patterns of snake species richness clearly are complex and are influenced by latitude, elevation and moisture and habitat complexity. Vitt (1987) summarized factors that may affect snake diversity. These include historical (age of geographical area, source of snake fauna), biogeographical (nearness to taxon distribution center and to areas of flux), abiotic (latitude, elevation, temperature, moisture, climate stability, habitat structure) and biotic (prey species diversity and abundance, potential predators and habitat productivity). Higher snake species diversity of Anaikatti Hills may be due to (1) availability of diverse microhabitats that provide opportunity for various species (2) its close vicinity to the Eastern Ghats that allows faunal mixture and overlap from adjacent plains and (3) its contiguous range with the Western Ghats, a biodiversity hot spot (Mittermeier *et al.* 1999).

Fig-3 : Snake Community of Anaikatti Hills, Western Ghats



The present study revealed that Anaikatti Hills harbor a high diversity of snakes, but most of them are in low abundance. Evaluation of various sampling techniques in tropical conditions is urgently needed to understand the population ecology of snakes.

Acknowledgements

The present paper is an offshoot of the research project sponsored by the Salim Ali Centre for Ornithology and Natural History R&D funds. We thank the Chief Wildlife Warden, Tamil Nadu and Divisional Forest Officer, Coimbatore for granting necessary permits to conduct field studies. We are grateful to Dr. V.S. Vijayan, Director, SACON for his support and encouragements.

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Appendix VII:

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A NEW SPECIES OF WOLF SNAKE (SERPENTES: COLUBRIDAE: *Lycodon*) FROM ANAIKATTI HILLS, WESTERN GHATS, TAMIL NADU, INDIA

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Submitted February 27, 2006.

A new species of wolf snake is described from the tropical mixed dry deciduous forests of the Anaikatti Hills, Western Ghats, India. This species is distinct from its congeners of the Indian mainland by the following combination of characters: dorsal scales in 17:17:15 rows, scales smooth with single apical pit; anterior nasal shield larger than the posterior, loreal in contact with the internasal, but not with the eye; higher number of ventrals (210 – 224) which do not angulate laterally and hemipenis not forked at the tip and lacks spines. The new species also differs from other *Lycodon* spp. of the Western Ghats in having a prominent yellow collar and dorsum lacking any prominent pattern such as blotches, spots and bands.

Keywords: Wolf snake, *Lycodon flavicollis*, tropical forests, Biodiversity Hotspots, Western Ghats, India.

INTRODUCTION

Lycodon, one of the most widespread Asiatic snake taxa, ranges from the Caspian Sea to the Philippines and Indonesia. Over 25 species have been reported to date (Smith, 1943; Biswas and Sanyal, 1965; Lanza, 1999; Slowinski et al., 2001; Daltry and Wüster, 2002), and 11 of them occur within the Indian subcontinent, including four from the Western Ghats (Whitaker and Captain, 2004). However, Sharma (2003) reported the occurrence of only eight *Lycodon* species from India, and the missed out species are *Lycodon laoensis*, *L. capucinus*, and *L. zawi*. A dorsoventrally depressed head, vertically elliptical pupil, 17 (rarely 15 or 19) rows of smooth or feebly keeled dorsal scales, enlarged anterior maxillary teeth and strongly arched maxillary bone differentiate *Lycodon* from other genera (Smith, 1943).

The Western Ghats of India is one of the 34 Biodiversity Hotspots of the World (Mittermeier et al., 2005). Inger et al. (1987) reported that the herpetofauna of south India is one of the most diverse but poorly known, and is largely due to the lack of intensive studies. In recent years, interest in studying reptiles in this region is growing. Among the 165 species of reptiles reportedly occurring in the Western Ghats, 88 (53.3%) are endemic (Das, 1996). However, since 1996 at least three new species of reptiles (all of them endemic) have been reported from this hill range (Bauer, 2002; Mukherjee et al., 2005) increasing the total number of reptile and endemic species to 168 and 91 (54.2%) respectively.

The Anaikatti Hills (11°05′ N 76°47′ E, Fig. 1), Western Ghats, a part of the Nilgiri Biosphere Reserve, Tamil Nadu state, India, is located in an area of rain shadow on the eastern slopes (~500 – 600 m above sea level). Tropical mixed dry deciduous forest largely covers this area (Champion and Seth, 1968) barring tropical semi-evergreen forest on certain hilltops (1000 – 1500 m a.s.l.). This hill experiences high variation of temperature (17 – 36°C) and scanty rainfall (about 300 mm annually). As a part of the Biodiversity Monitoring of Anaikatti Hills by the Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore, investigation on the herpetofauna was initiated during 2002. Including the present new species, 33 species of snakes have been observed to date from this area.

MATERIAL AND METHODS

The holotype and paratypes were fixed in 6% formaldehyde and then transferred into 80% ethanol. The following measurements were taken prior to preservation; snout-vent length (SVL); tail length (TL); head length (HL): distance between posterior edge of last supralabial and tip of the snout; head width (HW): at angle of jaws; head depth (HD): height at the occipital region; eye diameter (ED): horizontal diameter; eye to nostril distance (E-N): anterior corner of eye to posterior

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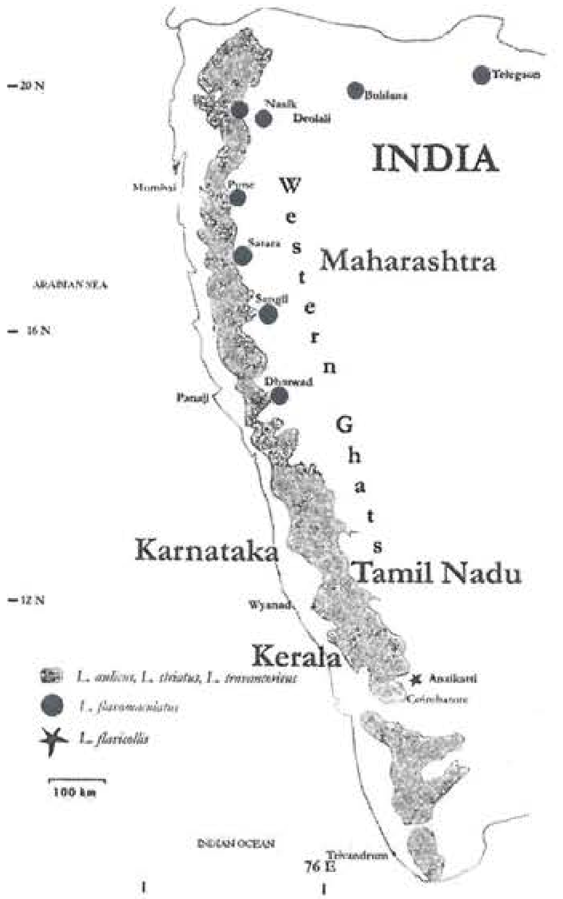

Fig. 1. Map of the Western Ghats, southwestern India showing the distribution of various *Lycodon* species.

edge of nostril; eye to snout distance (E-S): anterior corner of eye to tip of snout; inter orbital distance (IO): measured at the anterior corner of orbit. All linear measurements, excepting SVL and TL were taken using Mitutoyo® dial vernier calipers (accuracy 0.02 mm). SVL and TL were measured using a twine and metal scale. Ventral scute count and hemipeneal description were following Dowling (1951) and Dowling and Savage (1960) respectively.

SYSTEMATICS

Yellow Collared Wolf Snake
Lycodon flavicollis sp. nov.

(Figs. 2 – 4)

Holotype. ZSI 25641, Zoological Survey of India (ZSI), Kolkata, India; male, from Mangarai village located on the periphery of the Anaikatti Reserve Forest

TABLE 1. Aspects of Scutellation and Morphometry of the Holotype and Paratypes of *Lycodon flavicollis* sp. nov., Anaikatti Hills, Western Ghats, India*

Taxonomic/ Morphological character	Holotype ZSI 25641 Male	Paratype ZSI 25642 Female	Paratype ZSI 25643 Male
Ventral	219	224	213
Subcaudal	72	65	73
Temporal	2 + 3	2 + 3	(right) 2 + 2 + 3 (left) 3 + 3
Supralabial and nasal contact	only the 1st supralabial in contact with nasal	1st and 2nd supralabials in contact with nasal (right side). Left only 1st in contact	as in paratype ZSI 25642
Supralabials	9	9	9
Snout-vent length	440	360	265
Tail length	103	66	65
Head length	15.50	11	10
Head width	8.60	6.80	6.10
Head depth	5.70	4.40	4.10
Eye diameter	2.20	2	2
Eye to snout distance	6.30	5	4.04
Eye to nostril distance	4	2.80	2.70
Inter orbital distance	5	3.90	3.30

*All linear characters in mm.

(600 m a.s.l. 11°05′ N 76°47′ E), Western Ghats, Coimbatore District, Tamil Nadu State, southwestern India; collected by Debanik Mukherjee, September 7, 2003.

Paratypes. ZSI 25642, female and ZSI 25643, male; same collector, November 9, 2004 and October 15, 2005 respectively, data as above.

Diagnosis. Snout-vent length up to 440 mm (Table 1); dorsal scales in 17:17:15 rows, scales smooth with single apical pit; anterior nasal shield larger than the posterior one; loreal in contact with internasal, but not with eye; 210 – 224 ventrals, not angulate laterally; anal scute divided, 65 – 72 subcaudals and divided; hemipenis cylindrical, not forked at the tip and lacks spines; head blackish brown, body light brown without bars, blotches and distinct spots, broad yellow collar and a yellow band with black border connecting collar and snout tip (Figs. 2 – 4).

Description of the holotype. Male, snout-vent length 440 mm and tail length 103 mm, rostral longer than wide (length 2.50 mm, width 1.40 mm), partly visible from above, narrowly in contact with the anterior

Fig. 2. Plate showing aspects of head and dorsum of *Lycodon flavicollis*; note the prominent yellow collar and yellow band connecting the collar and snout tip.

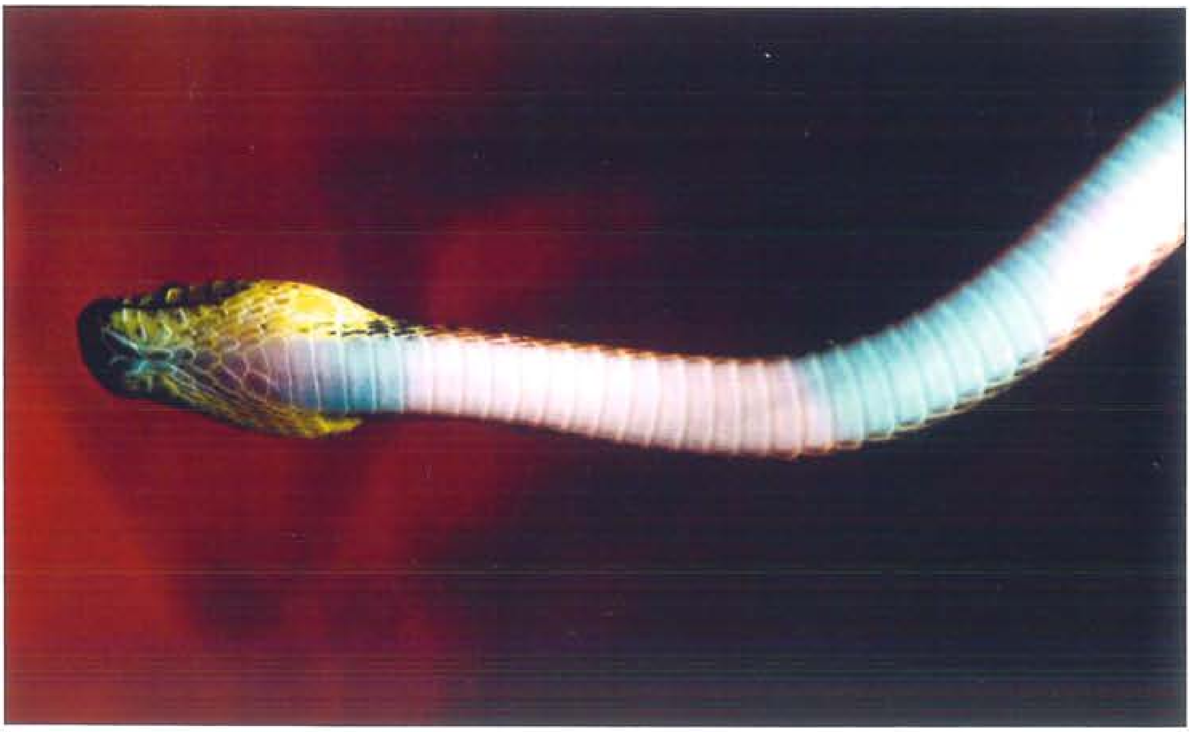

Fig. 3. Plate showing aspects of ventral and throat region of *Lycodon flavicollis*; note the color in the gular region and size of the anterior and posterior genials and shape of the ventral scutes.

Fig. 4. Plate showing head and aspects of dorsal coloration in *Lycodon flavicollis*.

part of internasal; internasals (L 2.14 mm, W 1.50 mm), prefrontals (L 3.30 mm, W 2.10 mm), frontal (L 4.32 mm, W 2.20 mm) and parietal (L 6.20 mm, W 2.90 mm) shields longer than wide; anterior nasal shield larger (L 0.84 mm, 0.70 mm) than the posterior one (L 0.68 mm, W 0.54 mm); single elongated loreal (L 2.90 mm, W 1.34 mm) touching internasal, posterior nasal, prefrontal, preocular and first three (1 – 3) supralabials; one preocular and two postoculars; two anterior and three posterior temporals; nuchals arranged in a semicircle; nine supralabials, first supralabial touches the nasal, 3 to 5 in contact with eye, 11 infralabials; a prominent mental groove present; anterior and posterior genials equal in length but the former one little wider; anterior genials in contact with 1 to 4 infralabials, posterior genials in contact with 5th and 6th infralabials, four pairs of scales between posterior genials and first ventral.

Dorsal scales in 17:17:15 rows, scales smooth with single apical pit, first reduction of the dorsal scale at 154th ventral scute and the next at 161st, reduction occurred on both sides; 219 ventrals, not angulate laterally; anal divided; subcaudals 72 and divided.

Coloration in life. Body light brown with a series of indistinguishable yellow dots; head dark brown; a prominent broad yellow band on the nape, yellow band connecting snout tip and the nape band connecting the eye; sides of the gular region yellow; ventral aspects dirty white and lack notable markings.

Etymology. The specific name (*Lycodon flavicollis*) is derived from the Latin *flavus* (= yellow) and *collare* (collar) and refers to the presence of prominent yellow collar of this species, which is distinct from all other *Lycodon* species reported so far from the Western Ghats. The epithet is formed in the masculine to match the gender of the generic name *Lycodon*.

Comparisons. Smith (1943) placed Indian wolf snakes in two groups based on contact between loreal and eye; (1) loreal in contact with eye (*Lycodon fasciatus*) and (2) loreal not in contact with eye (all other species). The later group may be further divided based on the degree of contact between loreal and internasal shields. In *L. travancoricus*, *L. tiwarii*, and *L. zawi*, loreal do not or slightly in contact with the internasal and the anterior and posterior nasal shields are sub-equal. The members of the other sub group (*L. jara*, *L. striatus*, *L. flavomaculatus*, *L. aulicus*, and the present new species) have extensive contact between loreal and internasal. All these species are also known to occur in Peninsular India. Comparison of them, including *L. travancoricus* and *L. capucinus* with the new species is given below.

The new species (*L. flavicollis*) is distinguishable from *L. travancoricus* based on, loreal in contact with internasal and preocular (vs. no contact in *L. travancoricus*), anterior and posterior pairs of genials equal (vs. larger anterior genials in *L. travancoricus*), ventrals are not angulate laterally in *L. flavicollis* (vs. angulate laterally in *L. travancoricus*), higher number of ventrals (210 – 224) in *L. flavicollis* (vs. 176 – 206), anal divided (vs. undivided in *L. travancoricus*) and hemipenis lacks spines and not forked in *L. flavicollis* (vs. forked at the tip and spinose).

L. flavicollis is distinguishable from *L. aulicus* based on ventral scutes not angulate laterally (vs. angulate in *L. aulicus*), variations in number of ventrals (210 – 224) and subcaudals (65 – 72) in *L. flavicollis* (vs. 172 – 214 ventrals and 57 – 80 subcaudals), hemipenes lacks spines and not forked at the tip (vs. forked and spinose in *L. aulicus*) and *L. flavicollis* lacks bands/blotches or pattern on the dorsum (vs. presence in *L. aulicus*).

L. flavicollis differs from *L. capucinus* in having higher number of ventrals (210 – 224) vs. 187 – 210 in *L. capucinus*, ventral scutes not angulate laterally (vs. angulate in *L. capucinus*), head with distinct yellow collar band in the new species (vs. whitish blotch on the occiput), a narrow yellow band with black border connecting the collar and snout tip in *L. flavicollis* (vs. absence of the same in *L. capucinus*).

The new species, *L. flavicollis* differs from *L. flavomaculatus* in having higher number of ventrals (210 – 224) and subcaudal (65 – 72) vs. 165 – 183 and 53 – 63, hemipenis smooth and not forked at the tip in the new species (vs. spinose and forked in *L. flavomaculatus*), no distinct color pattern (blotches, spots, bands) on the dorsum in *L. flavicollis* (vs. presence of yellow spots in *L. flavomaculatus*).

L. flavicollis differs from *L. striatus* in anterior and posterior pairs of genials equal in the new species (vs. larger anterior genials in *L. striatus*); nine supralabials in *L. flavicollis* (vs. 8); higher number of ventrals (210 – 224) and subcaudals (65 – 72) in the new species (vs. 154 – 195 ventrals and 35 – 58 subcaudals in *L. striatus*); hemipenis with large spines in *L. striatus* (vs. smooth in the new species) and *L. flavicollis* lacks prominent markings on the dorsum (vs. presence of bars or pattern in *L. striatus*).

The new species differs from the other peninsular species, *L. jara* in having higher number of ventrals (210 – 224) vs. 167 – 188 in *L. jara* and hemipenis smooth in *L. flavicollis* (vs. with enlarged spines in *L. jara*).

Natural history notes. The new species appears to be relatively common in the vicinity of Anaikatti Hills, Western Ghats. Of the 13 individuals of *Lycodon* spp. observed in this hill during 2002 – 05, seven belonged to the new species, four (*L. aulicus*) and two (*L. travancoricus*). Mean snout vent length and tail length of seven *L. flavicollis* was 352.28 (265 – 440) and 74.57 (65 – 103) mm respectively. This species was found to be active during both day and night and observed both in human habitations and tropical mixed dry deciduous forest. *Macropisthodon plumbicolor*, *Oligodon taeniolatus*, *Ptyas mucosa*, *Ahaetulla nasuta*, *Dendrelaphis tristis*, and *Boiga trigonata* were found in sympatry with the new species.

DISCUSSION

Eleven species of *Lycodon* have been reported so far from the Indian subcontinent (Whitaker and Captain, 2004). Das (2003) in the synopsis of names of reptile species known from India listed *L. capucinus* as a distinct species, which was considered as a subspecies of *L. aulicus* by Smith (1943). *L. capucinus* is known to occur in Myanmar, Thailand, Malaysia, Hong Kong, Philippines, and Andaman and Nicobar Islands in India (Smith, 1943; Whitaker and Captain, 2004). According to Whitaker and Captain (2004), occurrence of this species in Maldives requires confirmation. Deraniyagala (1955) reported four color varieties of *Lycodon aulicus* from Sri Lanka (*L. a. aulicus*, *L. a. oligozonatus*, *L. a. osmanhilli*, *L. a. unicolor*). The new species (*L. flavicollis*) differs from all the above forms in having yellow collar and a narrow yellow band connecting collar and snout tip (see comparison, Fig. 2).

Including the present new species, five species of *Lycodon* (*L. travancoricus*, *L. striatus*, *L. flavomaculatus*, *L. aulicus*, *L. flavicollis*) have been reported so far from the Western Ghats of southwestern India. Among them, *L. aulicus*, *L. travancoricus*, and *L. striatus* have wide distribution along this hill range (Smith, 1943). The first two species are distributed in the Eastern Ghats as well. According to Captain (1999), *L. flavomaculatus* is restricted to northern Western Ghats particularly in Maharashtra and Karnataka and *L. striatus* could be in sympatry with *L. flavomaculatus* in certain localities.

L. aulicus and *L. travancoricus* are in sympatry with the new species.

Wall (1907) stated that the contact between first supralabial and nasal differentiates *L. flavomaculatus* and *L. striatus*. In *L. flavomaculatus*, the first supralabial is in contact with nasal, whereas in *L. striatus* two supralabials touch the nasal. However, Captain (1999) reported that of the 11 *L. flavomaculatus* and 32 *L. striatus* examined by him, in all *L. flavomaculatus* specimens, the first supralabial was found touching the nasal. However, in 14 (43.75%) of *L. striatus* specimens, only single supralabial had contact with nasal. In *L. flavicollis*, data of five specimens showed that one specimen had only first supralabial in contact with nasal and the remaining (4) specimens had both the first and second supralabials in contact with nasal. Number of temporal shields among specimens examined also varied (2 + 3, 2 + 2 + 3/3 + 3, 1 + 2 + 3) in *L. flavicollis*. Looking at the above data, we suggest that taxonomic characters such as supralabials in contact with nasal and number of temporal shields found in the specimens be dealt cautiously while assigning species at least in the case of Indian wolf snakes. It appears that in the past, *L. flavicollis* had wrongly been identified as *L. flavomaculatus*. We believe that the species involved in the record of *L. flavomaculatus* in Nilgiri Biosphere Reserve by Murthy (1991) is the present species. As this species is relatively common and commensal with humans, and is also found in dry deciduous forest, which has been understudied till recently, further intensive studies in the Western Ghats, would bring more new species to light.

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